A KNOWLEDGE BASED SYSTEM FOR MINE FIRE HAZARD ASSESSMENT

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ABSTRACT

Most of the major mine disasters have been caused by explosion and fires throughout the history of mining and both causes remain among the greatest potential hazards in mining. The major hazards associated with a mine fire are the ventilation disturbance, the heat and toxic effects of the combustion products. So it is very important to quantify these hazards in order for the layout of the sensors and the safe escape routes to be determined. In view of this, a knowledge-based system has been developed for this purpose. With this system, the fire induced ventilation disturbance. and the resultant concentration and temperature can be predicted.

1.INTRODUCTION

A knowledge-based system, which is also called knowledge, based expert system or simply expert system, is a computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solutions [1]. As shown in Figure 1, a typical knowledge based system comprises three basic components, that is knowledge base, inference engine and user interface.

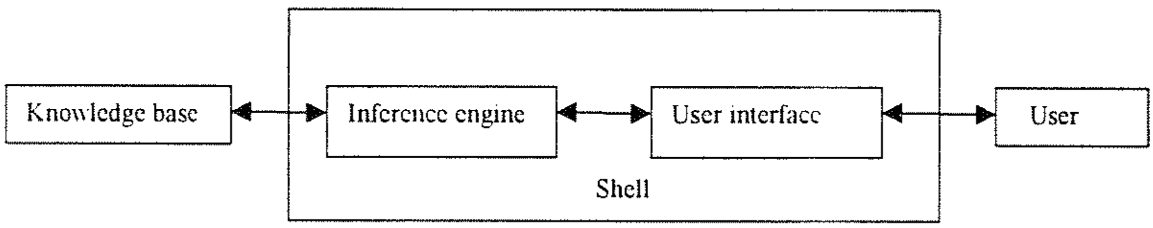

Fig. 1 Components of Knowledge Based System

Knowledge base comprises the knowledge that is specific to the domain of application, including the things such as simple facts about the domain, rules that describe relations or phenomena in the domain, and possibly also methods, heuristics and ideas for solving problems in this domain. In order to make use of the knowledge that is contained in the knowledge base, the expert system must possess a component, which can scan facts and rules, and provide answers to the queries from user. This component is known as the inference engine. The user interface is the means by which the user communicates with the expert system. It provides a mechanism for the input of information concerning a problem, the examination and modification of the knowledge base and the output of recommendations and reasoning by the system.

Because of the advantages of expert systems, they have got widely applications in many areas such as business, science and engineering. This paper demonstrates the implementation of an

Table 1

Airway Number	Start Junction	Finish Junction	Airflow Rate(ft^3)	Airway Length(ft)	cross-sectional Area(ft^2)	Alarm Times (13.22.14)	Alarm Pattern [22-13.14-22]
1	2	1	2355	2000	54	[159.15.140.03.50.81]	[-19.12.-89.22]
2	3	2	5615	2000	54	[98.51.87.22.70.04]	[-11.29.-17.18]
3	4	3	13783	2000	54	[45.33.34.05.77.89]	[-11.29.43.83]
4	5	4	43488	5000	54	[18.62.19.73.84.09]	[1.11.64.36]
5	1	6	2355	200	36	[113.29.94.17.4.95]	[-19.12.-89.22]
6	2	7	3259	200	36	[79.27.68.00.78.27]	[-11.29.10.27]
7	3	8	8168	200	36	[37.50.26.22.110.81]	[-11.28.84.59]
8	4	9	29706	200	36	[12.42.13.52.96.67]	[1.10.83.15]
9	10	5	43488	200	36	[18.79.19.90.84.26]	[1.11.64.36]
10	7	6	1456	2000	54	[184.41.165.29.76.06]	[-19.12.-89.22]
11	7	8	2670	2000	54	[77.06.65.79.150.37]	[-11.27.84.58]
12	8	9	4418	2000	54	[36.62.37.72.120.88]	[1.11.83.16]
13	9	10	22186	5000	54	[12.17.32.07.96.43]	[19.90.64.36]
14	6	11	3812	200	36	[110.24.91.11.1.89]	[-19.12.-89.22]
15	12	7	867	200	36	[85.37.74.09.84.37]	[-11.28.10.28]
16	8	13	6420	200	36	[44.45.25.33.109.93]	[-19.12.84.60]
17	9	14	11937	200	36	[32.40.13.28.97.88]	[-19.12.84.60]
18	15	10	21302	200	36	[19.12.20.24.84.60]	[1.12.64.36]
19	11	12	3812	2000	54	[108.35.89.23.112.7]	[-19.12.23.47]
20	12	13	2944	2000	54	[80.03.60.89.145.48]	[-19.14.84.59]
21	13	14	9365	2000	54	[43.33.24.21.108.81]	[-19.12.84.60]
22	14	15	21302	5000	54	[31.80.12.67.97.27]	[-19.12.84.60]

4. CONCLUSIONS

An analytical method and the associated computer program for determining the mine fire location have been developed. An example has also given to demonstrate the applicability of the method. Compared with the Bureau of mines' method, the calculated alarming times and the resultant alarming time patterns are more accurate because the fire characteristics, ventilation dilution effect and the sensors' properties have been taken into account in the process of determining the alarming time patterns. The major limitation of the method is that the fire location may not be unique if the corresponding fire zone contains more than one airway.

5. REFERENCES

[1] John C. Edwards, Fire Location Model, US Bureau of Mines, Information Circular, pp1-8.

[2] Tan Zhenxiang, A.R.Green &Jean Cross, April 1999, a Prolog Program for Predicating the Concentration of Combustion Products in Mine Ventilation Network, the First international Conference on the Practical Application of Constraint Technology and Logic Programming, London, pp399-413.

expert system for mine fire hazard assessment. With this expert system, the mine fire hazards can be assessed by predicting the airflow flow changes induced by the fire and the resultant the distributions of the contaminant concentration and temperature in the mine airways and junctions.

2. IMPLEMENTATION

The implementation of an expert system is to develop the three components of the system. Prolog(Programming in Logic) has been selected as the developing tool. Prolog contains both a built-in inference engine and a user interface, therefore the task left is to build the knowledge base needed by the inference engine. The knowledge base for the mine fire hazard assessment system consists of two kinds of information, that is the mine database and the algorithm for predicting the ventilation disturbance, and the resultant concentration and temperature distribution.

2.1 Mine database

The mine database is equivalent to the input data in a conventional computer program. For predicting the ventilation disturbance induced by a mine fire and the resultant concentration and temperature distribution in the mine ventilation network, the mine database should contain the physical configuration data (the identification of each airway, the start junction and finish junction in terms of the direction of the airflow), the geometry of an airway (airway length, airway cross sectional area, the aerodynamic data (the initial airflow rate, airway wall friction factor and airway resistance) , the rock thermal properties(the rock temperature, thermal diffusivity and conductivity), and the mine junction properties(the junction identification, junction temperature and junction elevation). Besides these data, for the airways containing fans or fires, the characteristic of the fans and fires must be specified. The junctions with the known temperature and concentrations also need to be specified.

To represent these data, predicate airway/11, rock_thermal_property/4, junction/3, fan_data/2 ,fire/4 , and surface_j/1 are defined.

2.2 Algorithm and its representation

2.2.1 Algorithm

In order for the Prolog inference engine to predict the fire induced ventilation change and the resultant concentration and temperature distribution, besides the mine database, the algorithm for the problem must be represented in the knowledge base too. The algorithm represented in the knowledge base is the one developed by Michigan Technology University[2]. The principle of the algorithm is shown in Figure 2. As shown in Figure 2, the first step of the method is to carry out a ventilation simulation to get the airflow distribution. Based on the calculated airflow distribution, the concentration and temperature distribution resulting from the specified fire sources are determined. The fire induced thermal forces are then calculated according to the temperature calculation results. Repeat the ventilation simulation, the concentration and temperature calculations until the ventilation network reaches a balance state.

(1) Ventilation Simulation

The governing equations for the mine ventilation simulation problem are two Kirchhoff's laws. The first law is that the quantity of air leaving a junction must be equal to the quantity of air entering a junction. The second law is that the algebraic sum of the head losses in the branches in a mesh is zero. A number of solution methods have been developed to solve the system equations. Among them, Hardy Cross iteration method has been proved to be the most effective method with respect to the calculation time needed. The major procedures involved in the algorithm are forming the basic meshes (the closed airway paths), then satisfying the junction equations, and then apply Hardy Cross correction to the mesh containing no fix quantity airways. Repeat this procedure until the differences between two successively updated airflow rates fall within the specified accuracy. During the correction, fan pressure is determined by Lagrange interpolation method and the natural ventilation pressure for a given mesh is determined by the given temperatures and elevations of the junctions contained in a mesh.

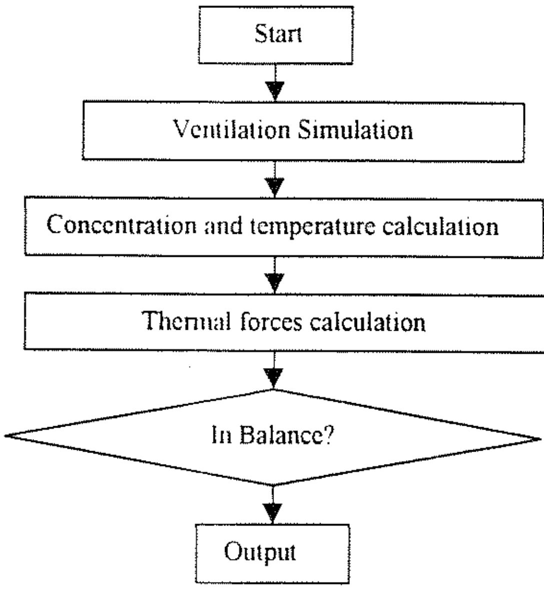

Figure 2 Algorithm of the mine fire hazard assessment

(2) Concentration and temperature calculation

The nature of the concentration and temperature calculation is an alternative calculation process between the airway calculation and the junction calculation. Initially, the airway calculation starts with the surface junctions whose concentrations and temperatures are deem to be known. After the airway calculation, the junction calculation will be carried out for the junctions whose entering airways' concentrations and temperatures are known from the previous airway concentration calculation. For a network without re-circulation path, this alternative calculation process will continue until the concentrations and temperatures of all junctions and airways are determined. However, for the network with re-circulation paths, the alternative junction and roadway calculations will not be able to be continued when the junctions affected by the re-circulation are encountered. In this case, these affected junctions and airways are assigned to some initial concentrations and temperatures then apply the alternative calculation process repeatedly until the differences between the two successively calculated values are close enough.

(3) Thermal forces calculation

The influence of a mine fire on the ventilation network is twofold, that is a throttling effect caused by the volume increase of the air passing through the fire zone, and a natural draft effect caused by the conversion of heat into mechanical energy. The throtelling effect from a mine fire can be accounted by multiplying airway resistance R by a factor $(T_2/T_1)^2$, where the subscrips 1 and 2 denote the post fire and prefire temperatures. The natural draft effect is determined by DR /5.2 $\int (T/T_m)dz$. When one assumes airway with constant slopes, $\int T\,dz$ can be replaced by $\sum t_m DZRD(t_m = 1/LA\int t\,dL)$.

2.2.2 Algorithm Representation

A general strategy used for representing the algorithm in Prolog is to reprent each procecdure involed in the whole calculation with a corresponding Prolog predicate. Each procedure can be further broken down into the simper procedures. The procedure is repeated until the Prolog facts (the mine database) defined in the knowledge base are reached. For example, the procedure for ventilation simulation can be broken down into the following sub-procedures: set up spanning tree, determine chords, form meshes, carry out Hardy Cross iteration. In Prolog, this can be simply represented as the following Prolog rule:

```
ventilation_simulation:-
        spanning_tree(SpanTree).
        determine_chords(SpanTree,Chords),
        form_meshes(Chords,SpanTree,Meshes),
        hardy_cross_iteration(Meshes,Chords,Nvpl,IterNum).
```

3. CONCLUSIONS

Based on an existing mine fire hazard assessment algorithm, a knowledge based mine fire hazard assessment system has been developed in Prolog. Compared with the conventional computer simulation method, the knowledge-based system has the following features:

- Friendlier user interface. Prolog console window allows the user to query the system by issuing goals defined as the Prolog predicates and the system responds by giving true or false or numerical results to the queries.
- Better readability. The data and each procedure involved in the problem have been represented by Prolog predicates. Therefore the meanings of the predicates can be easily recognized from the definitions of them.
- Easier and quicker implementation. Because of the intrinsic power of Prolog, the input formation and the algorithm of the problem can be mapped into Prolog facts and rules more quickly and easily.
- Intelligent feature. The solution process to a query in the system is an inference process of the built-in inference engine. This simulates the human's reasoning process.
- Better modularity. Each predicate in the system can be tested independently and the position exchange of the different predicates will not effect the function of the system.

4. REFERENCES

[1]B.Denby, T.Akinson , 1988. Expert System Applications in the Mining Industry. The Mining Engineer, No 5, pp505.

[2]Greuer,R.E.1977. Study of Mine Fires and Mine Ventilation. Part I. Computer Simulation of Ventilation Systems under the Influence of Mine Fires. US Bureau of Mines, NTIS PB-288 231.