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Natural disaster hidden danger recognition decision support system for coal mine

Abstract. *Safety accidents caused by pit natural disasters affect operation and economic benefits of coal mine seriously. Against types of Coal mine natural disasters, occur regulation and workflow models of coal mine safety management, the concepts, architecture, construction principles, key theory and methods and techniques of Pit Hidden Danger Recognition Decision Support System model were proposed, based on geography information system, management information system and cooperative work theory and so on.*

Streszczenie. *Incydenty bezpieczeństwa spowodowane przez klęski żywiołowe kopalnii mocno wpływają na bezpieczną produkcję i efektywność ekonomiczną. Uwzględniając rodzaje i prawidłowości występowania klęski żywiołowej w kopalni zaproponowano koncepcję i model systemu wspomagania decyzji. (**System wsparcia decyzji w przypadku klęsk żywiołowych z ukrytym zagrożeniem w kopalniach**)*

Keywords: natural disasters; hidden danger recognition; decision support system
Słowa kluczowe: klęska żywiołowa, dostrzeganie problemów ukrytych, system wspomagania decyzji

Introduction

With the rapid development of Chinese national economy, energy demand increases rapidly, which leads to the imbalance of exploitation intensity of coal resources and the application of safety science and technology. Coal enterprises are traditional resource exploitation enterprises, the safety production affects coal enterprises tremendously, safety work occupies an important position in the coal mine production, and the result of management has a direct bearing on the economic and social benefits of coal mine.

The coal mine safety information is active, dynamic changeable and related to the space position closely. The research about forecasting, preventing and controlling coal mine accident is a systematic project, it involves the whole process from exploiting, producing to selling coal products. Among them, the most serious affect is the natural disaster in the course of the exploiting, such as gas burst and explosion, water spurt, coal dust prominent and so on [1].

Coal industry is one of the most dangerous and the most serious casualty accident industry in China's industrial production. The natural environment such as the gas, the water and fire, the ground pressure and roof, coal dust and so on is the main factor causing coal mine accidents. In recent years, the natural catastrophes like mine gas explosion, underground permeable and so on have kept on striking one after another. Fatal accidents due to the natural environment account for 78.6% of the total accidents and 84% of the total death toll in 2011. Especially severe coal mine accidents which are caused by the natural environment and bring about more than 10 deaths occupy 15% of the total accidents and 60% of the total death toll. Coal mine natural disaster and accident causes huge losses to the people's lives and the property of the State, impacts the production capacity of coal enterprises and image of the coal industry and endangers the social harmony and stability. Based on analysis of all kinds of accidents, the first cause of pit natural disasters is the negligence of safety management, and the second cause of pit natural disasters is the lack of real-time tracking tools of recognition pit safety hidden dangers. For this, the research of Pit Hidden Danger Recognition System and the establishment of decision support models will be of practical significance [2,3].

The pit natural disasters are multiple sources, mainly including the aspects of the water, coal dust, gas, coal self-igniting, exploiting sink and coal pressure and so on, which are the direct reasons that cause the coal-mine natural disasters.

To ensure coal-mine safety production, early warning and forecasting of pit natural disasters must be established, for which the construct of pit natural disasters hidden danger model is very important. At present, how to apply the developing computer technology, spatial information technology, database technology and some related theory and methods to coal mine safety management has become a hot aspect for theorists and enterprises [4].

Considering the rule and characteristic of coal-mine natural disaster and workflow pattern of the coal-mine safety management, the research on pit natural disaster hidden danger recognition decision support system model conform to the practical work of coal-mine safety management, can solve the real-time share of safety information, will provide the effective way and methods of the coal-mine safety business prevention and emergency cooperation processing, which is based on the data of geography information system (containing WebGIS), the integrated geology, the survey, "one ventilation three-defenses", and the correlation information.

The Concept and Architecture of System Model

(1) The concept of system model

Pit natural disaster hidden danger recognition decision support system is an information-sharing platform. Based on workflow pattern, computer, Intranet/Internet and spatial data technology, using related geography information system and management information system, which can achieve many functions such as coal-mine safety data storage, management, analysis, enquiries and so no, and which can offer the service of decision-making in various ways and real-time online processing and decision analysis, based on the data of geodesy, ventilation, safety and so on(Fig.1) [6,7].

(2) Architecture of system model

Because of the differences of pit natural disasters and the information sources of the hidden danger, the solving process for hidden danger is different. But the hidden danger solving processes must depend on the geodesy and the safety production information. Simultaneously, it must use the related knowledge data (for example: expert knowledge, existing regulation, natural disasters' classification index system and so on). So the pit natural disaster hidden danger recognition decision support system model is not an isolated information model, but it is a cooperation-processing model based on the data dynamic changing [8,9].

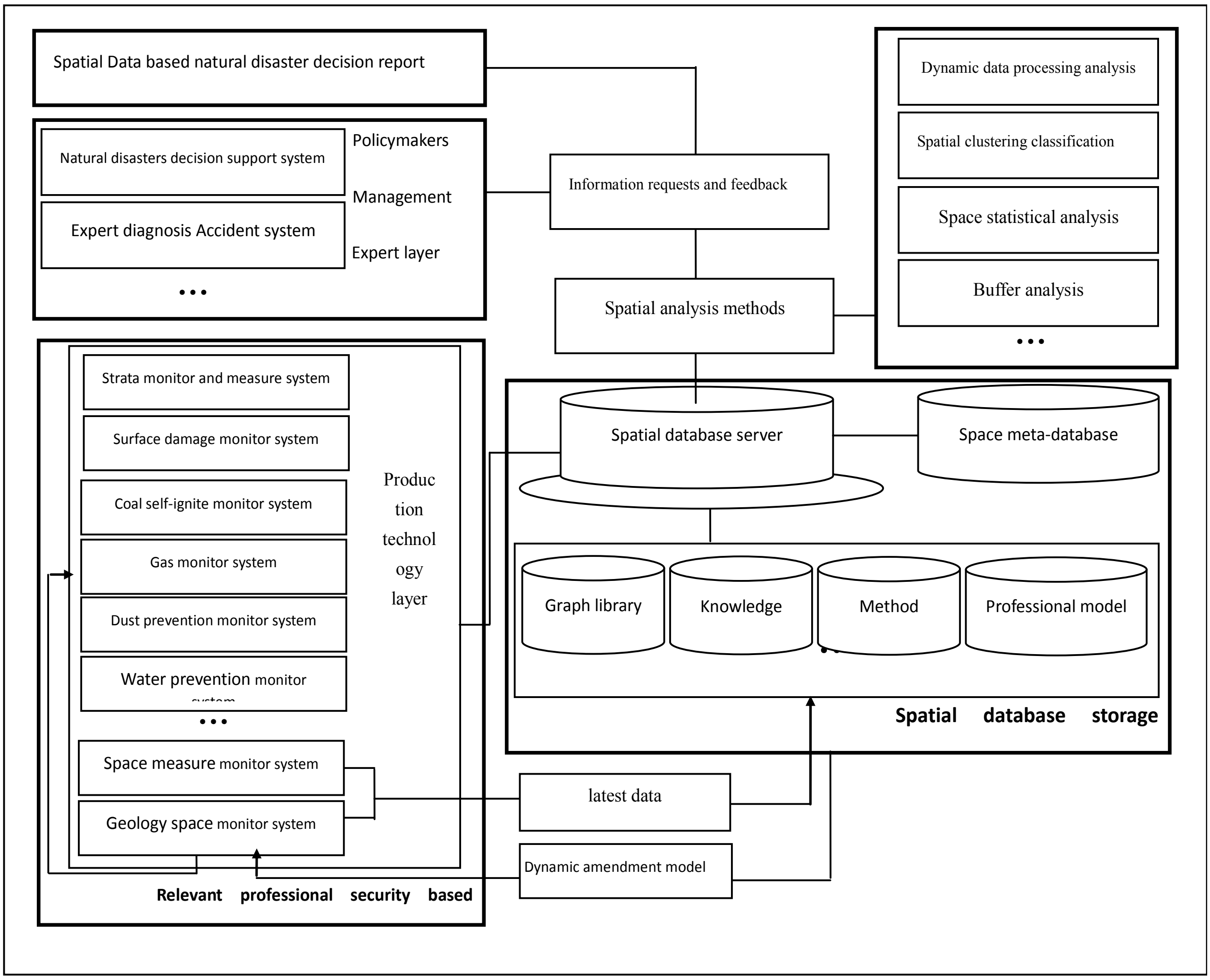

Fig.1. Pit natural disaster hidden danger recognition decision support system model

Principles and Approaches of System Model Construction

The pit natural disasters are mainly caused by the factors such as water, coal dust, gas, the coal self-igniting, exploiting sink, strata and so on. But these factors may not lead to the accidents at any time. They are only caused by some certain parameters when the certain marginal value surpassed in the course of exploiting. For this matter, the foundation which the mine pit natural disaster hidden danger recognition decision support system model construct is the establishment of the natural disaster classification system, the related disaster type knowledge, the model library and the spatial database firstly, the next is the development of the related software system, the method research of accident hidden danger recognition and the establishment of method library[10].

The key principles and methods of model construction:

(1) Construct the appraisal index system library

The appraisal index system library is the concrete parameter knowledge library about the pit natural disaster hidden danger. The model construction must establish corresponding index system according to different index systems of natural disaster hidden danger such as gas, water and its marginal value. The parameter of the hidden danger alarm recognition mainly refers to the dynamic mining of the exploiting horizontal plan and the correlation tunnel. Each kind of gas hidden danger, the flood hidden danger, and the ventilation hidden danger formed the corresponding appraisal index. The gas appraisal index system table shows as the table 1[11,12].

(2) Establish the professional analysis model library based on the geodesy, ventilation and mining and so on

Corresponding professional model library is established according to the types of natural disasters such as gas and water and so on. For example, gas disaster forecasts firstly establish gas geology district chart based on the pit geology conditions and the coal bed (contains gas burst warning area, gas burst threatening area and high gas area and so on), next, it establishes contact and carry on the comparison analysis to make sure whether the mining area or the future mining belongs to the high gas areas or not based on the dynamic mining information of the exploiting horizontal plan and the correlation gas district.

(3) Establish method library based on the GIS space analysis

The GIS space analysis is an important way of the pit natural disaster hidden danger recognition and an important way of the safety accident warning and forecasting. For instance, the district delimit of against the water, is mainly based on the coal column. The determination of coal mine column may obtain through the GIS buffer area analysis.

Table 1. The parameters of the sensor

Sorts of near accident	Evaluated items		Evaluated index	Forecast and alarm	Relieve alarm
Gas probe	Check cycle		7 days	Yellow hint	Filling newly checked information
Taken gas out system （pump station）	Monitor cycle		7 days	Yellow hint	Filling monitored situation
Tunneling surface	Monitor cycle		7 days	Yellow hint	Filling data
	Length to the coal pot		≤50	Red alarm	Taking measures，evaluating it
	Math model		Expected length Ly－picked length Lx≤50		
High-gas and high-stress zone Developing surface	Monitor cycle		One day	Yellow hint	Filling new data
	Lc(m) The shortest length to pump station		Lc-Lx ＜ 6m	Red alarm	Stopping excavation
	Lp(m) Length to gas taken pot		Lp-Lx＜ 15m	Red alarm	Stopping excavation
High-gas area	Lg（m） Length to the High-gas area		≤50	Red alarm	Filling measure and evaluation
Outburst threatening area	（m） Length to the threatening area		≤50	Red alarm	Filling measure and evaluation
Outburst dangerous area	（m） Length to the dangerous area		≤50	Red alarm	Filling measure and evaluation
Gas check point	Evaluated period		7days	Yellow hint	Filling measure and evaluation
	CH_4（%）	Mine section	≥1	Red alarm	After relieving the index
		One flank	≥0.75	Red alarm	After relieving the index
		Mine	≥0.75	Red alarm	After relieving the index
	CO_2(%)		≥0.5	Red alarm	After relieving the index
Penetration	Monitor cycle		1day	Yellow hint	Adding new data
	（m） Full mechanized developing butt		50	Red alarm	Taking measures
	（m） Blast developing butt		30	Red alarm	Taking measures

The spatial statistical analysis, the multiple source information fitting, the data mining and so on are also common GIS space analysis methods in safety hidden danger monitoring of gas and flood and so on, such as the physical prospecting hydrology unusual area determination and the gas prominent warning area determination.

(4) The realization steps of pit natural disaster hidden danger recognition and decision-making

Evaluation index library, model library, method library and graphics library are the base of pit natural disaster hidden danger recognition and decision-making. Realization steps of pit natural disaster hidden danger recognition and decision-making[13]:

① Establish pit natural disaster real-time monitor system, track correlation disaster real-time data dynamically.

②Real-time realize the comparison between pit natural disaster data or information and correlation natural disaster index library, model library, knowledge library as well as spatial database, and use graph library data to determine safety hidden danger category with GIS space analysis method.

③Have the real-time warning and the policy-making analysis of the mine pit natural disaster hidden danger; Submit the report based on the spatial data natural disaster hidden danger recognition and the analysis processing.

In the construction of Pit natural disaster hidden danger recognition decision support system model, detailed research on pit natural disaster classification system and recognition system (guidelines) are principles, which is based on the professional field knowledge. And pit natural disaster hidden recognition on basis of the time and space change and GIS spatial analysis are methods. Related principles and methods construct the Pit natural disaster hidden danger recognition decision support system model.

Critical Theory and Techniques of Supporting System Model

The construction and realization of pit natural disaster hidden danger recognition decision support system model is a complex project with integration of many critical theory and techniques such as GIS, computer, spatial information sharing and so on. The system model is a typical dynamic collaboration platform of multidisciplinary and multi-center management around the geodesy space.

(1) Geography information system

GIS is the computer system of collection, storage, processing, analysis and display of geographic data, and the geographic data has its space characteristic. So the geography information systems are very suitable for organization, management and performing dynamic data or information. Its main advantage is: geography information sources relied on certain spatial data infrastructure, in a certain of user requirements, GIS provide data organization, management, processing, distribution, performance, and GIS spatial analysis with certain spatial data infrastructure to make data and information applications more efficient, more economical, more natural and more coordinated, namely to achieve excellent results. One of main basis of pit natural disaster recognition and decision-making is all kinds of related geological survey graphics, which are typical vector graphics with characteristics of high accuracy, small data amounts, suitable for remote management, browsing and online services of analysis and decision-making. Based on GIS data flow, key technologies and methods of data acquisition, data transmission, data storage, data processing and data sharing, and so on is the base of pit natural hidden danger recognition decision support system model[14].

(2) Cooperative work

The concept of "computer support cooperative work" (Computer Supported Cooperative Work, CSCW) is proposed by the American Irene Greif of MIT and Paul Cashman of the former Dec company in 1984.Subsequently, the academic community had different interpretations of CSCW, such as D.Rosenberg and C.Hutchison (1992) thought CSCW concern in the way people work together and how computer systems can be designed in ways that support collaborative work. CSCW have mainly done a lot of research on cooperative work models, communication protocols, parallel mechanism, and achieving methods of cooperation mechanisms, interfaces between computer and humans and standards, CSCW have applications in the military, medicine, education, and so on[15].

The information of pit natural disaster hidden danger recognition decision support system is multi sources, and sometimes is multi-user. For example, when coal mine geodesy information changed, it leads to a dynamic update of mining protect, triggering a mine safety' real-time collaboration with related information to form the latest ventilation system maps, dust prevention systems maps and gas monitor maps, etc. At the same time, against mine safety accidents and security control, mine decision-makers layer, group decision-makers layer and expert layer realize to solve safety management issues through real-time online collaboration. Asynchronous cooperation model oriented to coal mine work flow and synchronous model oriented to mine decision-makers layer, group decision-makers layer and expert layer are the two main models. Two types of Collaboration model are all constructed with data layer, network layer and web application layer. Network transmission layer uses web collaboration services platform packaging multiple network functions, provide basic communication and data transmission functions for web application services layer. The data layer provide collaborative data for web application services, and web application services layer provide various services for the technical workers, decision-makers and experts. With the cooperation of the three layers, the pit natural disaster hidden danger recognition decision support system will make decision for pit safety accidents.

Conclusion

Pit natural disaster hidden danger recognition decision support system model is an information model oriented to coal mine safety management, and which is based on GIS and cooperative work theory. The basis of construction of the model is pit natural disaster classification and hidden danger recognition index. Using spatial analysis methods of GIS, the model can achieve early warning and forecasting of safety hidden danger and online decision-making analysis. Its research and applications will have an important significance for forecasting and solving coal mine safety accidents caused by natural disasters.

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