Research on mobile intelligent mine platform based on risk control

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Abstract. It is a challenge to effectively solve the "bottleneck problem" of the information management and safety evaluation of coal mine. In case of unexpected events, it is hard for miners to rapidly know the status of environment and find solutions. On the basis of the concept of mobile work, we design a mobile intelligent mining platform aiming for an early warning. That platform is a comprehensive application of the Internet of Things, mobile Internet, intelligent control theory and other technologies. It is mainly composed of four parts: underground sensor, underground subsystem, mobile intelligent mine platform and mobile terminal. An early warning combination model is proposed and described to address this issue. The fuzzy AHP is combined with neural network because of fault-tolerant ability, parallel processing ability, processing non-linear problem ability. The paper adopts the neural network model and the fuzzy AHP model to construct a coal mine safety early warning model. With modern wireless 4G network and geographic information technology, mobile terminal allows staff to know not only the specific risk level but also the status of the scene nearby. The intelligent terminal user interface provides real-time queries and handles processes coal mine production, safety and management. It achieves comprehensive monitoring and integration management both on the automation system and security system.

1. Introduction

1.1. Background

The overall status of coal mine safety of China is on the rise. However, it is inevitable that serious accidents still occur now and then. If the staff can’t know the information about their surroundings, or know little, they could not realize danger in time and would lose the best time for rescue or self-rescue when they are in danger, for example, when the concentration of toxic gas is abnormal. The highly-reliable underground communication network which can ensure normal communication when a disaster occurs is not available. At present, the underground operators lack effective mobile communication terminals by which they can report their location and surrounding environment to the rescue personnel. These problems bring great difficulties to the disaster emergency rescue.

As can be seen from the above, underground operators need an individual mobile security monitoring system and mobile communication equipment. The following characteristics of mobile security monitoring system must be considered: (1) Always keeping the underground operators informed of the
surrounding environment for them to know the surrounding status, and automatically recording and sending information of gas concentration, location, time, and inspector to the ground monitoring centre; (2) Performing mobile monitoring to perceive underground surrounding and eliminate monitoring blind spots caused by the arrangement of fixed gas sensors; (3) Transmitting the situation and work instructions to front-line underground workers and the ground monitoring centre in time, administrator on duty; (4) helping rescue work for the trapped person and the rescuers by broadcasting the disaster situation, location and surrounding conditions of trapped people.

1.2. Research status at home and abroad.
In the field of mine monitoring information systems and platforms, the introduction and promotion of Geographic Information Systems (GIS) have greatly changed the traditional operation and management mode of mine monitoring in China, which has drawn the attention both of the domestic geologists and the mining enterprises and related management departments.

Li Xiangong[1] designed the risk pre-control management to meet identifying, evaluating, managing standards and measurements for hazard sources in coal mines, and studied the feedback closed-loop management and the process management for three violations and hidden dangers. Ding Baochong[2] designed a two-level neural network structure including "influencing factor level-comprehensive evaluation level" by comprehensive evaluation of early warning indicators, single indicator early warning and system comprehensive warning based on warning indicator values and limits. Wang Yang[3] studied the method of combining AHP comprehensive evaluation with BP neural network through a combination of subjective and objective evaluation model in the coal mine safety risk assessment, then designed the network structure of coal mine safety risk assessment model.

Zheng Lingxiao[4] applied the Java language, Eclipse development platform, Tomcat server, and MySQL database to build a C/S-based visual danger source risk pre-control mobile phone management information system, and introduced the implementation method. Yao Min[5] established a risk assessment model for coal mine gas explosion hazards based on fuzzy mathematics, verified the feasibility and applicability of the model by calculation analysis. The paper introduced the qualitative analysis of the risk factors of gas explosion in coal mining face, and established a pre-control index system of risk of gas explosion danger source in working face. Li Xinchun [6] studied the management evaluation system of comprehensive expert evaluation weights, BP network weights and comprehensive weights. Wu Yuliang [7] studied coal mine gas extraction system based on wireless sensor network. The wireless central node handled complex data processing such as access control, data forwarding and transmission, routing maintenance and other tasks.

1.3. Problems.
The research and application of remote sensing and GIS at home and abroad in mine environmental monitoring have developed rapidly with great social attention. However, these researches mainly focused on remote sensing or monitoring of the current status of mineral resource development and environmental status, and these studies didn’t provide much attention to the dynamic monitoring of remote sensing. Even if there are relevant researches, it is limited to simple statistical analysis based on the current status information during each recording period. Research on the dynamic monitoring of geological environment mines is insufficient. Some could reflect the dynamic monitoring of mines, but they focus on simple text reports of reflecting the changes of their mine development or environment. And the real dynamic monitoring system of the geographical environment of the mine is not enough. The above issues can be summarized as follows:

(1) Mine risk evaluations are mostly qualitative descriptions without quantitative indicators. The selection of evaluation indicators is not appropriate so there is no suitable mine geological environment assessment system for mining.

(2) Massive monitoring data lacks centralized, effective, systematic, scientific and effective management. Few mine information systems involve the dynamic monitoring of the geological environment of the mine and dynamic results.
(3) An effective mobile geographic information and risk pre-control tool is not available for front line workers.

1.4. Mobile intelligent mine

The data sources are scattered in traditional coal mine automation and information systems and intelligent analysis of data are insufficient. The dispatcher's business is mostly "relay messages", but these messages cannot be sent to all the workers in the mine in real time.

After the research of the practical application requirements of underground mobile security monitoring systems and mobile communication systems, we integrate mobile security monitoring systems and mobile communication systems and install their functions into mobile terminals.

Based on the Internet of Things (IoT) of the mine, we develop a set of IoT applications suitable for mine workers. The application scenarios of mobile Internet technology in mining enterprises mainly include security monitoring, positioning, and scheduling management. The supervisory pictures and data of each monitoring system can be displayed on the smart terminal in real time.

Besides, the mine environment could change (such as gas outburst) at any time, the leaders could be informed in time in case of an emergency. Keeping abreast of changes in the mine environment and the operation of the equipment, the leaders in charge can take effective measures based on actual conditions.

Combined with the application of smart terminals with locating systems, it is convenient to display personnel (or vehicle) location information on smart terminals, so we can know the number and distribution of underground personnel anywhere and anytime. And it can detail the coal mining face, each head, the specific number of people at the equipment area and personnel identification information. In the traditional way to locate people, the control room needs to first send notice to the underground communication station before searching for people. That is really a waste of time and energy. The smart terminal changes that situation, now it is easy and fast enough for target location of people.

2. Design of mobile intelligent mine system

In order to achieve the objective of coal mine management, safety production, we propose a solution of intelligent mine information system. Through integrated information construction, coal mine informatization is carried out for construction management and enterprise business. By means of sensing staff, equipment and surroundings, the ultimate goal of the mobile intelligent mine system is to allow the staff member to utilize the up-to-date technology, and to provide intelligent, computer-aided instruction for the risk control in coal mine. Figure 1 presents the block diagram expression of mobile intelligent mine system.

![Figure 1. Mobile intelligent mine system](image-url)
The seamless connection was established between the existing monitoring system of the coal mine and the intelligent mobile terminal by background application service center which we called network management system platform. At the same time, the platform is responsible for interacting with the ground station and the mobile terminal. The information platform collects real-time data from the coal mine monitoring system, and stores the data into a background database. The smart mobile terminal connects to the Internet through a 4G mobile communication network or WIFI, so the background database of the information platform could be available for mobile application. The firewall works as a security isolation device to realize the security separation between the existing information network of the coal mine and the industrial control network.

On the special situations of mobile application scenarios in coal mines, the mobile information platform consists of 3 modules, as shown in Figure 2.

| Ground Mobile Application Support Platform |
|-------------------------------------------|
| Personnel Authority Management             |
| Unified Data Transmission Interface        |
| Underground Module Version Management      |

| Mobile Communication Module                |
|-------------------------------------------|
| 3G/4G Transmission Module                  |
| WIFI Transmission Module                   |

| Underground Mobile Application Platform    |
|-------------------------------------------|
| Mobile Configuration Module               |
| Mobile Main Module                        |
| Mobile Service Module                      |
| System Operation Configuration             |
| Unified Data Transmission Interface        |
| Terminal Module Version Management         |
| Storage Module                            |
| Camera Module                             |
| Hidden Trouble Investigation              |
| Environmental Data                        |
| Equipment Management                      |
| Risk Control Push                         |
| Integrated Automation                     |
| Extended Business Module                   |
| Human Computer Interface                   |

![Figure 2. Mobile application system platform composition risk pre-control](image)

(1) Ground mobile application support platform. Data support and configuration management for the normal operation of underground mobile applications is achieved on application support platform.

(2) Mobile communication module. It is mainly for the discontinuity and instability of underground wireless signals.

(3) Underground mobile application platform. It consists of a mobile configuration module, the main module and a business module.

① Mobile configuration module. The relevant data is downloaded from the server to the mobile configuration module to configure the initial application environment. Device basic function test (such as camera call) and APP download management is also included.

② Mobile main module. It provides a tested hardware module driver of universal application. The user can manage different business modules and subroutines according to configuration. The module provides a universal program login entry, a message mechanism, a common data access interface, and a network communication interface. This module improves the reliability of application apps, so mobile application developers only need to pay attention to the development of professional business functions.

③ Mobile business module. The module provides a series of development protocols for underground professional application APP modules developed by different development companies or developers. For example, company A developed a gas inspection and equipment inspection module, and company B developed a remote video surveillance APP. Despite relatively independent with business, database and data interaction, these sub-modules should be designed by following a common platform development protocol.
3. Coal mine safety early warning combination model

3.1. Coal mine risk early control management.
Coal mine risk early control management consists of identification of hazard sources, risk assessment of hazard sources, formulation and implementation of management standards and measures, and inspection feedback. The task analysis method is chosen for the hazard source identification and the risk matrix method for the risk assessment. After performing a risk assessment on a hazard source, different risk levels will be determined based on the results of the assessment. Management standards, control measures, and supervision measures are formulated based on the identified hazard sources and their risks. Each identified hazard source has a corresponding risk level, management standard, and management measures to ensure the control of the hazard source and ensure the safe production of the coal mine. The entire operation process is shown in Figure 3.

![Figure 3. Diagram of risk pre-control management](image)

3.2. Construction of coal mine safety early warning combination model.
The basic idea of the model and application is shown in Figure 4.

![Figure 4. The basic idea of the model and application](image)

This algorithm to compute the early warning by combination model can be described step by step as follows: The early warning period \( T \) of the network model is less than that \( L \) of the fuzzy AHP(Analytical Hierarchy Process) model, which guarantees the technicians sufficient time to determine the accurate weights and membership functions to ensure the overall validity and model reliability. The early warning process is completed by neural network\[8\], and the fuzzy AHP model plays a role of auxiliary verification to provide timely and effective early warning of the coal mine safety status.

The neural network early warning model runs and works with the fuzzy AHP model all the time during a specific time to confirm each other. If the two evaluation results are the same, the network model is valid and continues to work without modification. Otherwise, the weights of the output of the
two models would be reset and the early warning value would be adjusted. Then the original sample is expanded with the adjusted data, and the network training is executed to refresh network model. In the changed environment, the new network structure will learn "new knowledge" so as to improve the reliability of the early warning results in subsequent stages. The trained neural network structure works as an updated model and compares it with the fuzzy AHP model in the follow-up cycle and would be adjusted again.

When the platform obtains values of monitoring indicators \( x_1, x_2, \ldots, x_n \), the early warning values \( y_1 \) and \( y_2 \), monitoring indicators are substituted into the network model and the fuzzy AHP model. As the corresponding alarm level is already determined by the early warning criteria, the network model would be considered to be effective if the warning values \( y_1 \) and \( y_2 \) are the same. If different, the calculation formula of the early warning value would be adjusted. Assuming the weight of the network model result is \( \alpha \), the weight of the fuzzy AHP model is \( 1 - \alpha \). The adjusted early warning value is \( \alpha y_1 + (1 - \alpha) y_2 \), where the value of \( \alpha \) is \([0,1]\) specified by on-site technicians.

4. Conclusion
The mobile intelligent mine system is based on the database technique, mobile information platform, cross-platform web services, 4G network, and AJAX technology. That intelligent platform aims to integrate various types of system and multi-level networking and comprehensive supervision. Running on IOS or Android platform with application in smartphones and tablet PCs by 4G network, 5G in the future, that platform is powerful since all mining scheduling subsystem and network data are seamlessly connected with it. So, it is convenient and effective for storage and query, analysis with it.

The intelligent platform provides the function of data statistic analysis, such as approval, query for historical data, reports exporting as basic features. It will fulfill the need for more formal data sources, management processes, graphical data analysis and graphing which will provide accurate data and vivid charts for enterprise management and decision-making.

Based on the combining of fuzzy AHP and compensation fuzzy neural network we propose a coal mine safety early warning model which improves the scientific reliability of pre-warning.

The platform adopts the advanced Ethernet communication technology and runs on PC and mobile terminals. It successfully established the connection between the data and the frontline workers. Its advantage is not only the remote approval, dynamic information reminder, statistical information sharing, management automation but also seamless docking and low cost for personal mobile office. Hopefully, this system can serve as the reference framework for developing a mine platform, and helping staff members in enterprise production management.

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