Construction of Emergency Services Platform for Coal Mining Accidents by Integrating Multi Source Datasets

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Abstract — Along with the massive mining of coal resources in China, different kinds of coal mining accidents have been frequently caused, so more information supports for emergency rescue are being paid more attention. In this paper, we study the basic issues in the framework of emergency service platform for coal mining accidents, including basic data sources of coal mine emergency service and data integration technologies and the combination forecast model for coal mine gas accidents based on the grey system theory and neural networks theory. A 3D landscape system of coal mines was built. We obtained the prototype of basic data overall platform for coal mine emergency service by integrating the basic data on the ground, stratum data and measured data in the pit, and proposed suggestions for future technical studies on the construction of coal mine emergency services. The results show that it is necessary to monitor and forecast a coal mining accident by rapidly obtaining and integrating different kinds of basic information within a coal mine area in the process of both observations before disaster occurrence and rescue afterward. The emergency service platform can present a real-time relevant information through visualized figures and images for administrators and decision-making persons. Also, these basic data can be used for accident forecast and development trend of accidents, which should greatly improve the emergency rescue efficiency of accidents for the safe, efficient and sustainable development of modern coal enterprises.

Keywords - coal mine accident; emergency service; gas forecast; platform construction

I. INTRODUCTION

China has numerous coal enterprises, however, different kinds of safety accidents continue to occur along with the fast exploitation of coal resources in recent ten years, which has put much high pressure on the emergency work of coal mines. Relevant studies show that effective emergency rescues can reduce the loss down to 6% comparing with that without any emergency measurements [1]. It is necessary and urgent to introduce new methods and technologies to promote the level and efficiency of emergency management in Chinese coal mines. The keys to coal emergency service are to make sure the correct information of coal mines and accident areas can be obtained in time, to integrate and analyze all kinds of information comprehensively, forecast the development trend and influence range of accidents and rapidly make the emergency plan and measurements. Therefore, timely acquisition of all kinds of basic information of coal mines and rapid integration of these kinds of information together are the base of emergency service, and also play significant roles in the process of emergency service. However, these kinds of information distribute in different departments of coal enterprises, running independently and lack of effective coordination and interoperation. This means that the real difficulty of the emergency service is not the lack of information sources, but the rapid acquisition and convenient sharing of necessary information in a very limited time [2].

The main type of accidents in coal mines is the gas accident, on which specific studies of emergency rescue system have been carried out from two aspects of emergency mechanism and emergency plan [3, 4], and the corresponding design plan for gas accident early-warning system have been finished [5]. However, the study on the mode of emergency rescue organization structure is still in the initial stage [6]. In order to provide the decision-making support for disposal of coal mine accidents, the design plans of coal mine emergency rescue command and management information system [7] and data integration based coal mine emergency management system [8] were proposed, respectively. However, for gas accident forecast, most traditional methods only have consideration from a single point of view and their proposed forecast models are just deterministic mathematic models or empirical models, containing two or three factors that may cause an accident, which is hard to meet the requirements of forecast and early warning in reality. Therefore, we introduced the grey system theory [9] and neural network model [10] in our forecast model, and explored in which way the wireless emergency communication system [11], the theory and key technologies of the Internet of Things (IoTs) [12], etc. work for coal mine emergency service.

In this paper, we focused on the integration strategy of multi-source dataset and the accident forecast model by constructing an accident emergency service platform. Furthermore, to some relevant problems are also analyzed and discussed in the construction of accident emergency service platform by an in-situ example.

II. MATERIALS AND METHODS

A. Data Resources for Coal Mine Emergency Service

1) Huge data from various sources and different organizations: From the view of coal mine data sources, the data involve many aspects, such as the production, life, economy, ecology and environment etc. Just the aspect of technology among them, it will relate to the many fields again, e.g., the mining, geology, measuring, mechanics,
management. It should satisfy the following requirements:
- network data servers and realize the real data distributed network service, WFS and WMS, to widely connect international standard protocol of OPEN GIS spatial data with coal enterprises by Ethernet and using the coal mine emergency service. This platform can connect and makes them into the basic data integration platform of underground of coal mines.

The basic geographical information (GI) data for emergency service in coal mines mainly include: high-resolution remote sensing data, high-resolution digital elevation model data, vector data of basic elements, 3D model of buildings on the ground and plane graphs of underground coal mines.

2) Data correlation: The geological bodies in coal mines have interaction in between, e.g., between ore body and surrounding rocks, two adjacent and nonadjacent strata, tectonics and ore beds, etc. Besides, the connection of information between different departments in coal mines is also very close. For instance, the departments related to geology, measuring, mining, electro-mechanics and ventilation should use the same spatial coordinate data in mining areas, and these data have close relationship.

To integrate all the information and construct the basic data integration platform for emergency service of a coal mine, it is necessary to have an overall and clear visual grasp about the source situation its surrounding areas, the situation of real time production, the running situation of equipment and facilities and the situation of hidden danger, etc.

B. Data Integration for Coal Mine Emergency Service

Data integration generally has two different modes. One is to transplant the original data into the new database management system by using the federative database or data warehouse, and the other is to use the middleware technology to realize the integration of heterogeneous data [8]. But the distributed and heterogeneous types are the current situation of spatial data of emergency service. To solve the problem of data integration and sharing, the network environment is needed eventually, and the development of wireless network technology makes the network communication possible in disaster conditions. Therefore, we think that the semantic web is the most promising solution of integration and interoperation of emergency service spatial data, which are urgent to be solved at present [2].

The basic data integration of coal mine emergency service is an effective combination of information from traditional measuring, geology, mining, coal mine dispatching, TV monitoring, staff management, equipment management, electromechanical repair, production management, production control, safety management, etc., and makes them into the basic data integration platform of coal mine emergency service. This platform can connect with coal enterprises by Ethernet and using the international standard protocol of OPEN GIS spatial data network service, WFS and WMS, to widely connect network data servers and realize the real data distributed management. It should satisfy the following requirements:
- Displaying and inquiry of basic geography maps, documents and information of coal mines.
- Inquiry of basic technology information such as geology situation, mining situation, resource situation, etc. of coal mines.
- Checking of running situation and relevant parameters of underground electromechanical equipment.
- Early warning of gas accidents and provide the best escape route.
- Tracing of miners, bogies, mining machines, belts and other underground persons and equipment.
- TV monitoring of key sites on the ground and underground.
- Accident statistical analysis for selected areas, also valid by different types of accidents and different classes.

![Figure 1. Flowchart of basic data integration technology of coal mine emergency service.](image)

The flowchart of basic data integration technology of coal mine emergency service is shown in Fig. 1.

C. Combination Forecast Model of Coal Mine Gas Accidents

Gas accident is the main type of coal mine accidents. The common approach to emergency early warning of gas accidents is to monitor the real time variation of gas data. By setting the up and down limitation of gas warning range, the warning will be triggered automatically once the underground gas density reaches the certain value, which ensures the safe production and emergency warning for mining areas.

However, many factors can cause the gas accident and gas density is only one of them. Assuming that there are x different factors which can cause gas accidents, then the assembly of all factors can be expressed by \(x = \{X_1, X_2, ..., X_x\}\). Similarly, we assume that the coal mine gas accidents have m different types, then expressed by \(y = \{Y_1, Y_2, ..., Y_m\}\). There should be some internal relations between x and y. According to the basic law of gas accident occurrence, we can judge that these relations are multi-factors and nonlinear. So, the gas accident influence factors and gas accidents form a typical nonlinear system.

For this nonlinear system, which at the same time is
influenced by the work environment, human factors and other many factors, with some information known and some unknown or uncertain, the grey system theory and BP nerve net model have been applied on gas accident early warning [9, 10].

Based on current research results we believe that the grey system theory and BP nerve net model are both effective for gas accident forecast even though they are used separately. But the gas accident often happens suddenly, the more accurate of the prediction, the higher the prediction ability, which will greatly reduce the loss and casualties. Consequently, we can carry it out by two steps, firstly forecasting the gas accident by the grey system theory and BP nerve net model, respectively, and then building the combination forecast model. This way can combine and highlight their advantages of the two methods and enhance forecast accuracy. The flowchart of the combination forecast model is shown in Fig. 2.

III. RESULTS AND DISCUSSION

A. Results

In view of the basic GI data on the ground by aerial photogrammetry, stratum data by drilling and measured data of underground roadway, we reconstructed the 3D landscape model for the ground surface, strata and the underground of the coal mine. Then, combining the extracted texture data, and applying the 3D GIS technology, computer virtual reality technology, simulation and database technology, the prototype system of basic data integration platform for coal mine emergency service –3D landscape system of coal mines was built preliminarily (Fig. 3). The geographic locations of the buildings, equipment, facilities and other things on the ground of coal mines and the distribution of major hazard sources underground can be drawn in detail in the system. Additionally, the geographic locations and fundamental attributes of surrounding administrative divisions, residential areas, rives, roads, emergency resources (e.g. rescue equipment, emergency rescue team, police stations, fire stations and hospitals), etc. can also be easily labeled.

![Figure 3. 3D landscape system of coal mines. A: 3D landscape of mining area; B: 3D map of coal stratum data.](image)

This system can provide the information of underground roadways and chambers with accurate geographic coordination data, materials and others for emergency rescue. Based on these kinds of information, we can analyze all elevations and coordination underground rapidly and determine the non-inundated areas and possible evacuation areas after water inrush accidents. Besides, the system can locate the places where gas or coal dust exploded, analyze the influence areas of the accident and guide underground personnel to take a
correct escape route and plan. By loading the gas accident combination forecast model in the basic data integration platform of coal mine emergency service, the model training can be done, making a forecast based on the factor data that will influence the occurrence of gas accidents to determine the accident influence area, death radius, serious injury radius and so on. The 3D holographic display and visualization of the future development trend of the whole accident can help commanding officers and experts grasp the key points rapidly and accurately and control the further deterioration of accidents, aid the decision making and enhance the efficiency and accuracy of emergency rescue work.

B. Discussion

1) Acquisition of basic geographic data on the ground: There are many ways to obtain the basic geographic data on the ground of coal mines, including traditional measuring, aerial photogrammetry and remote sensing. At present, UAV digital aerial survey is mostly carried out for small areas, to map 1:2000 topographic maps [13, 14], which is particularly suitable for coal mines to rapidly get the large scale basic geographic data within such small areas. Its main products include panoramic images of survey areas, digital elevation model, digital ortho-photos, digital line graphs, image topographic maps, comparison diagrams of image on the ground and underground, 3D image maps, 3D landscape maps etc. Therefore, we can get the basic geographic data on the ground of coal mines rapidly with the aid low altitude UAV digital aerial survey system, including the topographic maps covering coal mines and surrounding areas, digital elevation model, ortho-photos and 3D landscape maps (some of digital basic geographic data are shown in Figs. 4A, 4B, 4C). The acquisition of plane graph data underground can adopt the traditional measurement methods, by using the correlation between spatial coordination and ground basic data, generating the new data expression form for emergency service (Fig. 4D).

2) Basic data integration platform of coal mine emergency service: We realized the 3D landscape system of coal mines only in this study, which is a prototype system and can be integrated with the industrial TV monitoring system, gas monitoring system, personnel location system, ventilation control system, belt monitoring system, power monitoring system, lift monitoring system and rescue system after accidents together, to realize the construction of basic data integration platform of coal mine emergency service and then form a uniform visualized 3D emergency service platform for coal mines. This platform can help the commanding officers in the field rapidly and intuitively learn the real situation on the ground and underground, greatly convenient to carry out rescue work. This improves the coal mine capability of disaster monitoring, discovery and detection before accidents, greatly avoiding the occurrence of coal mine disasters.

Figure 4. Digital basic geographic data. A: DOM; B: DLG; C: DEM; D: Combination map of comparison image on the ground and underground and lines.

3) Combination forecast model: In the gas accident combination forecast model build in this paper, it is important to note that the computer time of BP nerve net model has little to do with the numbers of neurons, but obviously depends on the study samples. Therefore, it is necessary to detect and remove the abnormal values from selected training data before using them, in order to get the high resolution forecast results. Additionally, we selected the weight coefficient combination method for this work, but the other nonlinear combination forecast method will be tried in the future study, to compare the usability of the two methods and expect to get the more perfect forecast model.

IV. CONCLUSION

The construction of coal mine accident emergency service platform can provide comprehensive visual service for safety risks in daily production of coal enterprises. The key technologies for the platform construction are basic data integration of the coal mines and accident forecast model. The study was focused on theses aspects in this paper, proposed the technology plans and preliminarily constructed the 3D landscape system for coal mines, providing the theoretical and practical base for construction of coal mine accident emergency service platform.

Currently, constructing the platform based on coal mine emergency service is still a new field and little experience can be refereed. Therefore, the study on the following technologies in the process of platform construction and improvement is needed paying close attention to:

1) Quick access to the reliable information once disaster happens and its effective integration with existing data: Because of the specific environment when disasters
and other emergency happen, the integration and sharing of all spatial information must have the aid of network to achieve. The technology of wireless network, internet of things and sensor network provide the support for network communication in the disaster environment. However, the issues of how to quickly obtain reliable emergency service information, efficiently integrate them with the existing data and provide the integrated support for coal mine emergency rescue still need to explore continuously.

2) Disaster situation analysis and rapid reconstruction of 3D scene: At present, the solution of this problem mainly is concentrated in the model simulation and numerical simulation. The research on the rapid reconstruction of 3D scene under the limited environment and suitable for coal mine disaster dynamics is still very immature and it is needed to enhance the strength of relevant studies and practice.

3) Visualization of emergency plan: Traditional coal mine emergency plans are mainly paper-based, with low efficiency of updating and maintaining. To visualize the emergency plans and field disposal plans, we can set the information and scenarios for accident situation, personnel behaviors, personnel evacuation, equipment used situation, emergency disposal etc., and then compile and make the plan and action plan under the virtual 3D scene. Based on all kinds of specific information in the 3D scene, the visual display of emergency plans and field disposal plans can be realized by using professional script editing tools to digitize these plans.

The coal mine emergency service platform can improve the emergency service of coal enterprises into a higher level, with practical and considerable economic benefits and social benefits for coal enterprises. At the same time, it has theoretical and practical significance for adopting Information Technology, digitization and intelligence of coal mines in China.

REFERENCES