Design and Implementation of Mine Ventilating Safety Information System

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Abstract: Mine ventilation system is one of important factors that affect mining safety. This paper combines GIS with virtual reality and has constructed a mine ventilation safety information system based on 3D modelling technology of ArcGIS Engine and 3ds Max, Google SketchUp. The system has achieved the 3D visual management and auxiliary decision of mine ventilating system, which provides an integrated data management and automatic management platform. The system includes many functions, such as mine data management, ventilation network analysis, air simulation and security evolution, and provides the best refuge and the rescue strategies according to the actual situation of mine accidents. The system has a certain value and significance for mine production safety.

1 INTRODUCTION

Due to the complicated ventilation environment in mining operations, many dangerous gases such as gas and flue gas can easily cause ventilation accidents. Timely monitor and technical measures are the main ways to avoid and prevent mine accidents according to different situations. Roadway system is an important part of mine 3D virtual scene and is the foundation to digital mine (Stothard, 2003; Rossmann, 2003; ZHANG et al., 1998). At present, software system of mine mainly focuses on management and calculation. The expression of three-dimensional laneway is not yet mature and has limited functions in visualization and spatial analysis. There is no MGIS (Mine Geographic Information System) suitable for mine in our country and three-dimensional spatial features of mine are a big factor in limiting their growth (Niu et al., 2007). In the literature (Li et al., 2004), an OpenGL based 3D visual modeling system of underground mine excavations was introduced and key technique for developing the 3D visual modeling system with OpenGL were presented, including entity drawing, geometric transformation, projective transformation, illumination and rendering. GUO (Guo et al., 2005) has developed a 3D simulation system for the mine ventilation network with visual basic6.0, which can show real-time status of the mine ventilation dynamically and veritably, feedback timely, intuitionistic a dependable information of mine ventilation to mine ventilation supervisors. In the literature (Wang and Wang, 2009), under the VC++ development environment, three dimensional tunnel's in computer two-dimensional surface hypothesized demonstration is realized through OpenGL, and the collision examination is implemented when you are roaming in the tunnel three dimensional virtual system. In the literature (Zhang et al., 2010), to solve the problems in mine disaster rescue arising from separate geological model and laneway model, a multilayer 3D model was proposed, which combined the geological model, laneway model and 3D visualization technique. ZHANG (Zhang, 2010) constructed a TIN model of coal seam with grids index algorithm according to drilling data, realized 3D visualization of coal seam by combining solid modeling method and lighting rendering in OpenGL, constructed 3D roadways model with SketchUp and realized 3D visualization of roadway with SceneControl in ArcEngine SDK.The tunnel cross-section modeling method is put forward, and the display of three-dimensional tunnel in two dimensional plane of computer is realized based on

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object-oriented program design and combined with the Skyline (Li et al., 2015).In the literature (Wang and Fu, 2015),the automatic modeling method is put forward, mine roadway 2D representation ,data extracting and organization, mine roadway model 3D building are studied, and two data organization method to extract the mine roadway network data are discussed and realized.

Mine ventilation safety intelligent analysis and disposal decision-making research is in its infancy. In the literature (Li and Li, 2007), evaluation factors of the ventilation system in metal mines were analyzed and selected according to the man-machine-environment system, the member function of the evaluation factors were formulated, and the evaluation system was established. WANG (Wang et al., 2007) proposed a new type of mine disaster early warning and salvage technology system based on GIS to form a complete set of perfect mine safety management assurance system. CHANG (Chang et al., 2018) established three-dimensional mine ventilation system model to simulate ventilation system present situation, the optimizing design, and the roadway expedite and ventilation simulation path, pollutant diffusion and avoid disaster simulation, the 3D ventilation intelligent decision analysis system. An intelligent monitoring and control system for mine ventilation safety was developed, which can real-timely monitor and display ventilation safety parameters, such as air speed, gas concentration, temperature, air pressure and air volume, and the system can also automatically adjust opening and closing state and opening degree of air door when air volume is insufficient or rich (Yang and Hao, 2017). Three-dimensional simulation is an important information technology for mine ventilation safety management and evaluation. However, spatial analysis and emergency decision of ventilation system are bottlenecks in the promotion and application of mine ventilation system in our country. GIS provides an effective tool for the research in this field. Based on actual needs of mine ventilation management, the author uses VB.NET programming language and ArcGIS Engine component GIS and Google SketchUp 3D modeling tools to integrate all kinds of ventilation safety information in the mine to realize 3D visual management and assistance of mine ventilation system. The system provides an integrated data environment and automated management platform.

2 DESIGN OF MINE VENTILATION SAFETY INFORMATION SYSTEM

2.1 Design of Systematic Functions

The system is mainly divided into five modules: ventilation information management, mine three-dimensional modeling, ventilation network analysis, ventilation system safety fuzzy comprehensive evaluation and aided decision-making, as shown in Figure 1. The system has constructed mine three-dimensional scene and topological relations based on measured structure data of mine. With monitors as the real-time data source, dynamic changes of air components such as air speed, air temperature and gas are analyzed. When an indicator exceeds standard value, air speed and air volume are combined to determine the source of gas release. The range of the roadway that is affected by the flow of contaminated gas will be analyzed. After the danger level is assessed, the system will be warned and other intelligent ventilation devices will be intelligently and fuzzily controlled to ensure ventilation safety.

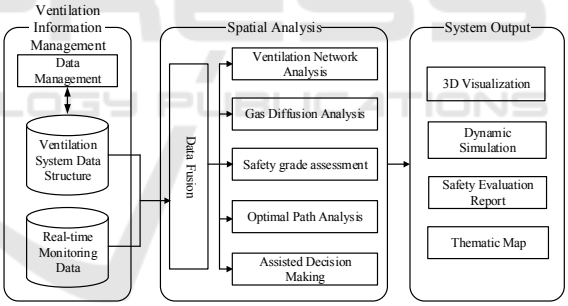

Figure 1: Systematic function diagram.

2.2 Mine Ventilation System Data Organization and Topology

Topological relations are foundation of mine ventilation simulation system, which is directly related to functions and efficiency of mine ventilation system. Through excavation, nodes, structures, ventilation and power devices, flow direction between each other to send messages, topological relationships are built. Branches abstract as a laneway, consists of beginning and end nodes. Branches can be associated with many branches, but the degree of nodes must be greater than or equal to 1. A structure or fan station belongs to only one roadway, and one windward direction graphical

object belongs to one laneway. Nodes are joints that connect laneways in the mine ventilation system. There are no isolated nodes in the mine ventilation system and no isolated laneway exists. Data structure in the system is shown in Table 1.

Table 1: A table with headings spanning two columns and containing notes.

Field Name	Field Type	Description
ID	Integer	branches ID
in_node	Integer	branches beginning node ID
out_node	Integer	branches end node ID
length	Double	branches length
type	Integer	branches type(Horizontal, inclined shaft or shaft)
name	String	branches name

3 THREE-DIMENSIONAL MODELLING OF MINE VENTILATION SYSTEM

Mine ventilation system of three-dimensional modelling includes three parts: three-dimensional automatic ventilation system construction, three-dimensional visual management and air dynamic simulation. The 3D visualization management model is used for ventilation system spatial management and analysis. Based on improved particle algorithm, dynamic airflow simulation module can display ventilation parameters such as direction of airflow, type of airflow and the amount of airflow.

3.1 Ventilation System Topology Relationship Establishment and Management

Managers in management of mine ventilation system can add and remove laneway, structures, ventilation, power devices and direction of air flow, and topological relationship of mine ventilation system can automatically be established and maintained. If a laneway is abolished, its corresponding structures and ventilation units will be removed or abolished. If a structure or ventilation power plant is deleted, the topological relationship between corresponding branches and deleted object is unbound.

The attribute data of mine ventilation system is managed by database. Only four kinds of objects, such as branches, node, structure and fan station, have attribute data in graphic entity of mine ventilation system. The data in the system is distributed storage using spatial graph data and attribute data. Spatial data only contains spatial location and the shape information of the geographical object and is stored in the Geodatabase. Attribute data stores attribute information, stored in SQL Server database. Graph data and attribute data establish real-time association by ID.

3.2 3d Mine Scene Construction

In construction of 3D mine, combined with three-dimensional display of ArcGIS, spatial analysis functions and 3D Max, fast and powerful 3D modeling ability of Google SketchUp software, the existing GIS data can be used to construct large-scale and refined 3D scene quickly and efficiently.

3.2.1 3D Mine Symbol and Storage

In ArcGIS, three-dimensional surfaces are represented in multipatch format, usually expressed as Trianglestrips. This format records three-dimensional coordinates of the points in the model for spatial analysis. However, it is inconvenient to draw 3D model through ArcGIS itself. Google SketchUp can be used to draw beautiful 3D models and convert them to multipatch recognized by ArcGIS, making it quick and easy to work with and beautiful models. Mine ventilation system is divided into four types of graphical entities, namely, branches, node, and structure and fan station. These graphic entities have a lot of similarities. According to the different types of the system, the system draws the model in advance and automatically calls it according to the requirement when drawing, which can generate 3D graphics and 3D scene of ventilation system flexibly and quickly.

3.2.2 Three-Dimensional Automatic Construction of Laneway

Three-dimensional automatic construction of the system is mainly the modeling of the laneway. Spatial data and attribute data of the laneway are stored in a fixed format, including starting point, ending point coordinate of the laneway, and name. When constructing a 3D scene, the system obtains 3D coordinates and attribute information of all the laneways, nodes and structures by accessing property database. After modeling different 3D symbols, they can be transformed flexibly and mine 3D ventilation system can be automatically

constructed. Users can freely browse three-dimensional graphics built to observe and choose to browse. After zooming in, the details of the laneway can be clearly seen. The branches side and the arc-shaped top surface can be seen in the scene of the three-dimensional transportation laneway. Tracks in the alley floor are used to transport equipment and materials.

3.3 Air Dynamic Simulation

The direction of the air flow is indicated by an arrow with a direction, the direction of the arrow indicating the direction of the laneway. The system will read the data of the branches from database according to the user's choice, set direction, type, speed and volume of air flow, and change the state to be air flow dynamic simulation at the same time. In a diffusion simulation of a laneway, the gas model is continuously added along the laneway to be affected in accordance with the direction of diffusion to indicate the diffusion of flue gas. The tunnel is set to be translucent to ensure that the simulated airflow can be seen by the user.

4 MINE VENTILATION SAFETY INFORMATION SYSTEM AND APPLICATION

Taking a mine as an example, this paper uses VB.NET programming language, applies ArcGIS Engine component GIS and 3D Max, and Google SketchUp 3D modelling tools to integrate various mine safety ventilation information and establishes a mining industrial square model and mine tunnel model, a three-dimensional GIS mine ventilation safety information system developed, main interface of the system shown in Figure 2.

The mine has a total of 104 laneway branches, 93 nodes, 4 exits, and a number of structures. The developed system can facilitate the management of mine data conveniently and intuitively, analyze the change of underground ventilation status, simulate the ventilation safety accident and output the report, which can help to improve mine ventilation information management ability and decision level.

4.1 Mine Data Management

The data involved in the system includes two aspects of ventilation system structure data and monitoring data. Ventilation system structure data includes laneway and node data, structure data and ventilation and power unit data, and is managed manually. Ventilation monitoring data (including gas, coal dust, etc.) are collected in real time by gas sensors in mine and workface. The data communication equipment transmits information such as total air pressure of the mine ventilator, air volume and gas concentration to the ground monitoring station. The coal mine monitoring master station displays and manages the data collected by the sensor and sends control instructions to monitoring equipment to realize control functions.

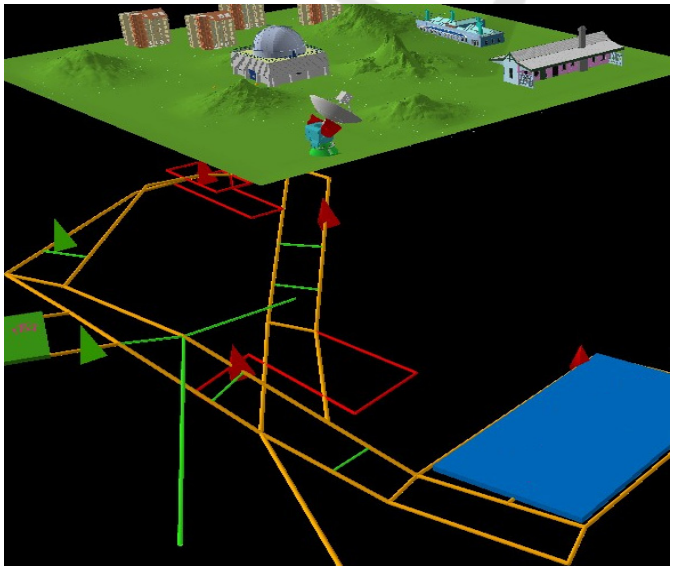

Figure 2: Main interface of ventilation safety information system.

The system has a good human-computer interaction, the combination of spatial data and attribute data, intuitively providing two-way operation of the data to achieve visual management of ventilation system data, three-dimensional spatial attribute query, coordinate query, distance measurement and two-dimensional three-dimensional scene switching.

4.2 Ventilation Safety Analysis and Gas Diffusion Simulation

Ventilation safety information modules mainly include inspection and registration of ventilation, fire prevention, gas emission prevention, and safety inspection and ventilation safety equipment management. Ventilation technical indicators are the amount of air intake, return air volume, effective air flow rate of mine, absolute gas emission, and relative gas emission and so on. Specific to a point, laneway technical indicators are into air speed, air temperature, into air oxygen, gas and other concentrations. At the same time, system can monitor running status and fault of equipment in real time. The system sends information to the man-machine interface, visual display to monitoring staff. The system, realizes simulation analysis of diffusion of contaminated gas, predicts the influence scope, makes decision of hedging and guides mine ventilation safety based on powerful network analysis function of GIS. Mine ventilation real-time monitoring shown in Figure 3.

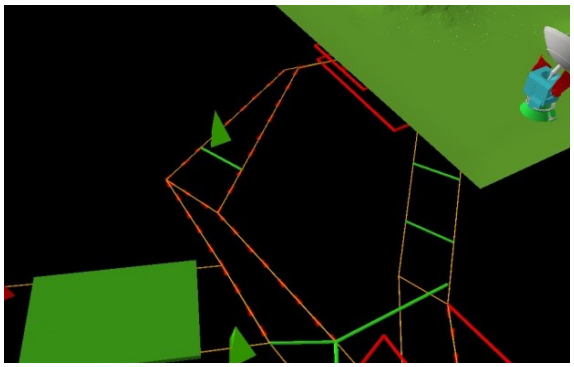

Figure 3: Mine ventilation real-time monitoring.

4.3 Mine Safety Emergency Decision-Making

According to results of analysis of safety status, the system conducts fuzzy comprehensive evaluation and control based on expert knowledge and disposition plan. Gas concentration in the lane changes more frequently, so the design of its boundary line alarm system uses theory of fuzzy mathematics, that is, when the concentration value in a certain range, the number and location of fans to open will be different, the purpose of it is to prevent fan jitter, and second, reduce the number of fans to open and extend the life of the fan. When the fault is not controllable, the system generates the disaster prevention route and guides absenteeism. After the disaster, hedge lines are shown in Figure 4.

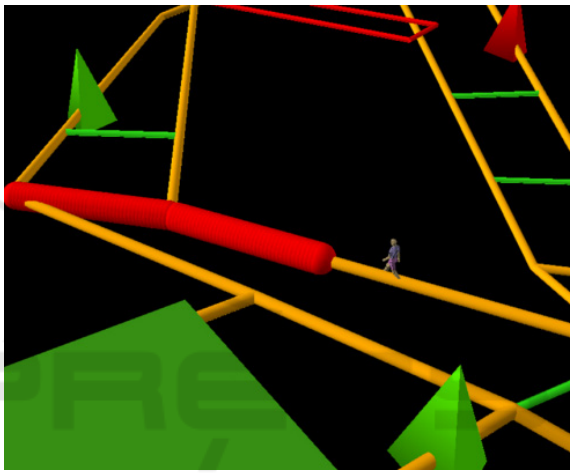

Figure 4: Disaster prevention route planning.

4.4 Report Output and Thematic Map

Report and thematic map output module is the ventilation safety and related data to the report or thematic map output. Thematic map is formed by setting different color, pattern or symbol according to a particular value. Thematic map contain the amount of air flow map, gas concentration map, etc. We can know the monitoring point of the air volume and gas concentration to reflect the safety of underground conditions based on thematic map.

5 CONCLUSIONS

Based on the analysis of the current research status of mine ventilation system, the solution to the spatial analysis and visualization of mine ventilation system is put forward based on GIS technology. Finally, taking a mine as an example, a mine ventilation safety information system based on 3D GIS has

been developed. Based on real-time monitoring data, the system comprehensively analyses and controls ventilation, integrating data monitoring, analysis and evaluation, and provides an integrated data environment and visualization platform for mine ventilation information management. Safe production and mine disaster information to provide intelligent technical support, the system has a certain application value and market prospects in safe production and mine disaster information to provide intelligent technical support. System establishes a comprehensive and stable algorithm, based on flow of gas in the airway to carry out monitoring and early warning. It can be extended to a variety of tubular face ventilation system management and monitoring analysis.

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