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Research on the construction of mine safety production emergency rescue information system under the background of Internet of things and big data

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Abstract
Emergency rescue and impact control of coal mine accidents are crucial for coal safety production and societal stability. Under the context of the Internet of Things (IoT) and big data, establishing a new type of mining safety production emergency rescue information system will offer effective means for accident emergency rescue and impact control. This paper, based on the characteristics of mining IoT and big data, constructs a system for the safety production emergency rescue information system according to the IoT architecture. By using the emergency rescue time series division method, it explores the fundamental framework of big data application in emergency rescue, including aspects such as pre-event preparation, monitoring and warning, emergency response, and post-event recovery. The emergence of IoT has led to the proliferation of big data, and the integration of IoT with big data in mining safety production emergency rescue information systems will ensure safety in mining operations.

Keywords: *Internet of Things; Big Data; Emergency Rescue; Information Systems*

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I. INTRODUCTION

In recent years, from the national level to local authorities, the work of safety production has revolved around the concept of safety development, implementing responsibilities comprehensively, strengthening the investigation and treatment of hidden dangers. The overall situation of safety production has been running steadily, and the emergency rescue system for safety production has been gradually improved [1]. Despite notable progress in China's safety production in coal mines, the overall level is relatively low compared horizontally. There remains a significant gap with the advanced international standards in safety production, particularly in the occurrence of major and severe coal mine safety accidents [2]. Therefore, emergency rescue and impact control in coal mine accidents are crucial for coal safety production and social stability. With the development of mining IoT systems, the integration of production and safety information and the generation of massive data have been promoted. In the context of the Internet of Things and big data [3-4], how to use information technology products to ensure coal mine safety production, prevent accidents, rapidly and accurately locate incidents, allocate rescue materials, carry out emergency rescue, and control public opinion impact has become an urgent and significant subject requiring further research.

II. MINING IOT AND BIG DATA

The 'Internet of Things' (IoT) refers to the deployment of embedded chips and software with certain perception, computing, and execution capabilities in physical entities, making them 'smart objects.' These objects communicate with each other and with humans through network infrastructure, achieving information transmission, collaboration, and processing [5]. When this technology is applied in mines, it forms the Mining IoT. It visualizes, digitizes, and makes mining smart through various perception, information transmission, information processing technologies, and multidisciplinary mining technologies. The operation process of IoT involves identifying object attributes, where static attributes can be directly stored in tags, and dynamic attributes are detected in real-time by sensors. Identification devices then read the object attributes, convert information into data suitable for network transmission, and finally transmit object information to the information processing center through the network for relevant computations and processing.

The application of Mining IoT will integrate various production and safety monitoring systems in underground coal mines into a unified information platform, eliminating 'information silos' and enabling data sharing, thereby promoting the generation of coal mining Big Data. Regarding 'Big Data,' research institution Gartner provides this definition: 'Big Data' is massive, high-growth, and diverse information assets that require new processing modes to have stronger decision-making, insight discovery, and process optimization capabilities. It exhibits the 4V characteristics: Volume (large amount), Velocity (high speed), Variety (diversity), and Value (value) [6]. According to statistics, there are as many as fifty to sixty production subsystems in general state-owned coal mines, and the consolidation of information from these systems exhibits Big Data characteristics. Big Data will drive mining safety monitoring, warning, safety supervision, and accident emergency rescue from causal relationships towards associative relationships, enabling the fusion of technology and disciplines."

III. CONSTRUCTION OF EMERGENCY RESCUE INFORMATION SYSTEM BASED ON MINING IoT

3.1 Problems in the current stage of mine safety monitoring [7]

Although the digitalization of mines has facilitated the establishment of various production and monitoring systems, there are still several prevailing issues:

(i) Traditional and singular on-site perception means

Gas sensors predominantly rely on traditional bulky catalytic components, lacking integration with MEMS (Micro-Electro-Mechanical Systems) sensors.

(ii) Lack of ubiquitous perception networks

The absence of a unified underground wireless perception layer network results in most existing sensors and monitoring systems being based on wired networks. They can monitor the state of fixed equipment and environments but are not suitable for mobile operations in mines or for situations where the positions, distribution, and movement patterns of hazards are uncertain. This limitation creates significant perception blind spots, failing to achieve ubiquitous coverage and ensuring full coverage of safety perception.

(iii) Insufficient information fusion at the application level

While comprehensive mine automation has achieved network integration of application systems, the linkage and information fusion between application systems and decision integration have not been adequately implemented.

(iv) Insufficient interdisciplinary research

The mechanisms behind major disasters, coal mine equipment failure diagnosis, integration of multidisciplinary research in geology, measurement, hydrology, monitoring, intelligent information processing technologies, among others, are not comprehensive enough.

The construction of Mining IoT systems is conducive to addressing these issues. Its core construction involves perceiving information on underground production equipment conditions, personnel and environmental safety information, dynamic personnel information, and application development based on big data analysis.

3.2 Requirements of Mining IoT Emergency Rescue Information System [8,9]

Following the emergency management timeline, the system should be able to capture various safety status and warning information beforehand. It should manage emergency supplies and an expert database effectively. During the emergency response process, utilizing Mining IoT should enable the timely detection of the status and location of endangered personnel. It should dynamically respond to real-time underground disaster situations, providing real-time information for rescue command, accurately predicting the development of accidents, and offering precise and effective information for emergency measures, thus reducing search and rescue time. Meanwhile, leveraging surface IoT can swiftly locate and mobilize surrounding resources for emergency operations. During emergency rescue operations, the system should fully tap into available rescue forces in the vicinity. It should efficiently manage road traffic to ensure that firefighting and medical rescue teams swiftly and smoothly reach the scene, providing a basis for rescue command decisions. Establishing a public opinion influence control system is necessary to promptly release accurate information and guide public opinion correctly, thereby reducing the social impact of accidents.

3.3 Structure of Emergency Rescue Information System Based on Mining IoT

The classical architecture of IoT consists of three layers: the perception layer, the transmission layer, and the application layer [10]. Mining information systems are diverse and relatively independent, resulting in different data structures among systems, hindering efficient interconnection and communication between them. To establish a unified data structure, a data service interface is designed before the application layer, allowing more efficient interconnection between the perception layer and various systems in the application layer [11]. The structure of the mining IoT emergency rescue system is divided into four layers: perception layer, transmission layer, processing layer, and application layer.

(i) Perception Layer

Its primary function is information perception and collection, achieved through devices like RFID tag readers, sensors (temperature, humidity, pressure sensors, gas sensors), and video cameras. These devices accomplish data collection and equipment control tasks for IoT applications. Various sensors access the backbone network wirelessly through gateways or directly via sub-stations.

(ii) Transmission Layer

This layer includes data access and network transmission. Data access controls the networking of application terminal nodes and information aggregation. Various communication networks, such as 2G, 3G, 4G, the internet, mobile communication networks, and LANs, form the transport network, facilitating information communication between IoT layers. The sensor network primarily assumes the functionality of the transmission layer.

(iii) Processing Layer

This layer carries out the analysis, classification, storage, retrieval, and upload of large volumes of data. Only useful information for a specific system in the application layer is transmitted.

(iv) Application Layer

Comprised of various application servers, this layer performs data aggregation, conversion, and analysis. It oversees the acquisition, analysis, and processing of information from the entire IoT system regarding terminal nodes. Cloud computing and big data analysis techniques are applied during this process. The application layer not only aggregates mining information but also deals with various ground-based IoT information, such as gathering network data, conducting accident-related public opinion analysis, and establishing a public opinion control system [12].

3.4 Disaster Warning and Accident Information Gathering and Processing

When disasters occur, the primary focus is on disseminating rescue information to the outside world and analyzing it comprehensively. The application of IoT technology in disaster relief enables rapid and accurate information retrieval and comprehensive processing. This establishes an efficient information processing platform.

(i) The emergency rescue system based on mining IoT encompasses the following functions

Equipping various production and environmental monitoring devices in coal mines with RFID tags.Employing various sensors to conduct large-scale, distributed information acquisition and status identification of material attributes, environmental states, behavioral patterns, both static and dynamic.Utilizing collaborative processing to conduct online calculations and control over a variety of information, angles, and scales.Sharing and interacting resources among networked units via access devices based on the gathered information.Facilitating real-time tracking of equipment operation status.

Tracking the work situations of workers at various job positions and the dynamic distribution of personnel underground through precise personnel positioning and dynamic management within the mine.Facilitating prompt identification of working conditions compliance and issuing evacuation orders and escape routes in the event of disasters.Offering supervision during specialized operations and detecting potential violations.Enabling prompt identification of compliance with work regulations, preventing accidents resulting from violations.

Leveraging cloud computing techniques to conduct associated analysis and computations on the vast amounts of unstructured and semi-structured data generated by the system.Forming various application systems by combining data from mine gas sensors, wind speed sensors, and mine ventilation systems for real-time dynamic analysis of mine airflow and gas concentration distribution, even during disasters.Integrating seismic monitoring, electromagnetic radiation monitoring, and acoustic emission systems for real-time perception of abnormal characteristics and precursor information during the genesis, evolution, and induction of coal and rock dynamic disasters.

This amalgamation enhances the effectiveness of disaster management and emergency response within mining environments by leveraging IoT's capabilities in data collection, analysis, and comprehensive system integration.

(ii) Using IoT Technology for Comprehensive Disaster Relief Deployment

Building an information processing platform based on IoT technology enables comprehensive deployment of disaster relief actions, enhancing the efficiency of rescue efforts and optimizing response times.

After a disaster strikes, rapid emergency response and the relocation of individuals are paramount. Deploying RFID wireless sensors extensively allows real-time monitoring of temperature, hydrology, wind speed, and other parameters in affected areas. This provides accurate warning information for rescue personnel, aiding in precise personnel localization and relocation.

Utilizing an information platform established on IoT technology facilitates seamless communication between on-site dispatchers and organizational personnel in command centers. Timely transmission of crucial information from disaster zones to command centers aids in making informed decisions, ensuring an organized rescue operation.

Swift and accurate transportation and distribution of rescue equipment, food, drinking water, medical apparatus, and other relief materials to affected areas are crucial. Employing electronic tags with unique codes for various items and using Radio-Frequency Identification (RFID) technology allows for swift identification of item categories, shelf life, and other vital data, ensuring efficient allocation of abundant and diverse relief materials. Additionally, GPS navigation and monitoring of rescue vehicles facilitate precise monitoring and deployment.

IV. APPLICATION OF BIG DATA IN MINING EMERGENCY RESCUE

The construction of a mining emergency rescue information system under the context of the Internet of Things (IoT) and Big Data is based on the architecture of mining IoT systems. However, it transcends the mining IoT by incorporating ground-level IoT, involving both underground and surface mining environments as well as the temporal dimensions of mining and society. IoT facilitates the generation of Big Data, but it's only through the effective application of Big Data that the value of IoT can be maximized. Big Data technology and thinking constitute two aspects of the application mode of Big Data in emergency management[14].

Big Data technology encompasses not only traditional techniques like data warehouses, data marts, and data visualization but also newer technologies like cloud storage and cloud computing. Meanwhile, Big Data thinking involves identifying problems from vast amounts of data and approaching problems with a mindset that considers the entire dataset, embracing notions of fuzziness, correlation, and holistic consideration. The fusion of Big Data technology and thinking will exert a profound impact on emergency management in the IoT era.

The application of Big Data in emergency rescue management spans all stages—pre-accident, during the accident, and post-accident—encompassing stages such as preventive preparation, monitoring and warning, emergency response, and post-disaster recovery. As current Big Data applications in emergency management mostly lie in the technical application phase and have not been strictly categorized for emergency management, this paper constructs a basic framework for the application of Big Data in emergency management before, during, and after an incident, based on the simplest time-series division method in emergency management[15].

V. CONCLUSION

The Internet of Things (IoT) and Big Data represent emerging phenomena with extensive applications. Their implementation in the realm of safety can effectively elevate the level of safety production in our country, providing robust technological support for the stable development of the economy and society. The construction of a mining safety emergency management information system under the architecture of the IoT necessitates not only the improvement of underlying wireless sensor networks, intelligent sensors, and hardware devices but also a paradigm shift in emergency management approaches and mindsets from the perspective of Big Data applications. Only through this transformation can a modern mining safety emergency management system be genuinely and effectively constructed and utilized.

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