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A high-speed response linkage model for integrated monitoring system at coal mine based on intellectualized data analysis

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Abstract

With the construction of integrated automated mining monitoring system and its platform, the monitoring data of great capacity from different subsystems were converged in the dispatching room. A high-speed response linkage model for integrated automated monitoring system at coal mine was proposed. In this model, the monitoring data from different subsystems were analyzed intelligently by building the data storage and linkage rules. Also, the uniform data exchanging formats and data processing mechanism were defined to share monitoring data between different subsystems for united alarms, which provide coal mine with an efficient intelligent dispatching and decision-making method. The simulation results show that this model can meet the demand of high-speed response linkage for integrated monitoring system at coal mine.

Keywords: data analysis; linkage model; monitoring system

1. Introduction

The main problems faced to safe and efficient mining are to improve the levels of mine production management and system automation, which require a variety of automation control system equipment, such as hoister automation systems, drainage control system, ventilation systems, power automation systems, mineral separation system and so on. The purposes of building various fields of automation are to improve the safety level of coal production and efficiency, to reduce the number of underground miners with improving efficiency. Furthermore, in order to realize a comprehensive monitoring of mine, an integrated automation and monitoring system should be built by integrating each automation subsystem mentioned above. The integrated automation and monitoring system provides with a large-scale opening control platform. How to fully interchange and share heterogeneous monitoring information between hybrid automation subsystems is the problem faced by the integrated automated monitoring system of coal mine. In view of those, a high-speed response linkage model for integrated automated monitoring system of coal mine is proposed. In this model, the monitoring data from different subsystems are analyzed intelligently by building the data storage and linkage rules. Also, the uniform data exchanging formats and data processing

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mechanism are defined to share monitoring data between different subsystems for united alarms, which provide coal mine with an efficient intelligent dispatching and decision-making method.

2. High-speed response linkage model

2.1. Physical model

Researchers have carried on a large number of studies for integrated mine monitoring and automation systems [1-3], and pointed out that the integrated automation of mine should have a unified data-transmitting network platform. So, according with the structure of the integrated automation system, for the reliable transmission of integrated multimedia streams, a high-speed response linkage physical model for integrated automated monitoring system of coal mine is built, which is shown in Fig. 1.

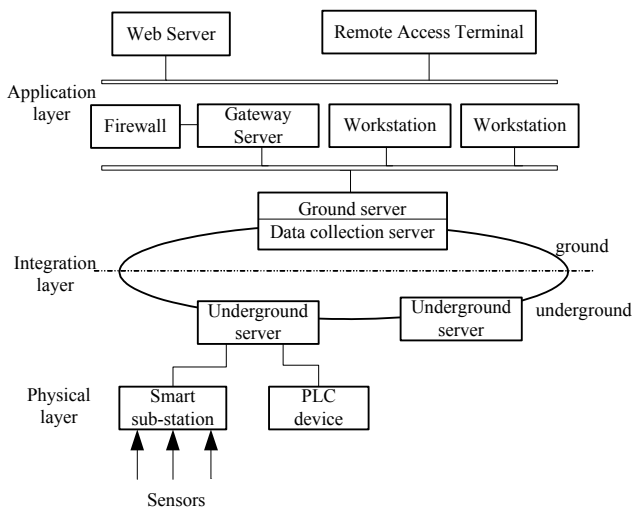


Fig. 1. The high-speed response linkage physical model for integrated monitoring system

According to the characteristics of data streams of the integrated monitoring system and the three-layer model theory of control network [4], the physical model is divided into three layers: physical layer, integration layer and application layer. The devices of physical layer mainly include various intelligent sub-stations and the PLC control equipments. With different data-transmitting agreements, the monitoring data packets are converted into IP packets that can be transmitted by Ethernet platform of mine to exchange information among different monitoring devices. The devices of integrated layer mainly include ring network platforms of mine, the ground switches, the underground switches and data collection server. In order to meet the requirements of reliable and congestion-free transmission of data, the redundant ring network topology is adapted. The underground switches and ground switches are connected each other to establish a fiber ring network as the integrated monitoring message transmission platform. Data collection server collects the various bottom data from different physical layers, and then converts the data packets to a unified format. So, a database is built to provide with a software platform for sharing data packets among different monitoring devices. The devices in application layer mainly include local workstations, web servers and remote access terminals. The local authorized workstation works as a client of the data collection server under C/S structure. By requesting the data in the database of collection server with the linkage rules, the integrated monitoring data is processed and outputted. The model is based on thin-client mechanism, under which the remote terminal can browse data through IE. Also, in order to ensure the security of data in integrated monitoring system, the external information network and the local monitoring network are connected through the firewall and gateway servers.

2.2. Logical model

The physical model is analyzed from the perspective of the mine monitoring equipment and physical structure. The logical model is built from the view of comprehensive monitoring data processing and conversion, as shown in Fig. 2.

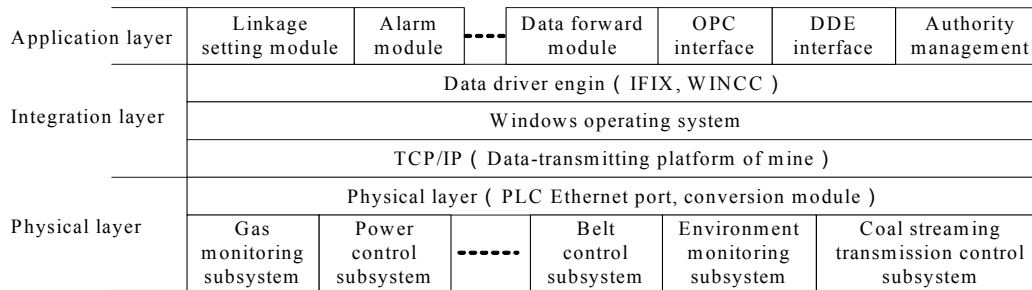


Fig. 2. The logical model of integrated monitoring system

In accordance with the characteristics of monitoring data communication, the physical layer is aimed at achieving the unified definition of the packet with different accessing modes and transmitting protocols from different subsystems. By this way, the data packets are compatible and convenient to be exchanged between different systems for data sharing. At the same time, the PLC Ethernet modules and sub-stations have independent IP addresses based on the opening TCP/IP protocol to build the vertical communication tunnel between the IP packets of integration layer and the monitoring data of physical layer for high-speed data transmission. The monitoring data packets are analyzed in integration layer to build a database of different monitoring systems. The monitoring packets of physical layer are received through the data transmission platform and analyzed according to communication protocols. The real-time /non-real-time data and control information is marked by different priority to meet the reliability and real-time requirements at the same time. The integration layer provides the application layer with a data-transmitting interfaces through data linkage engine. The application layer completes the definition of linkage rules and output the analyzed results. Furthermore, it can provide with opening interface (such as OPC, DDE) for other systems.

3. Linkage rules of heterogeneous monitoring data

In integrated monitoring system of coal mine, data linkage engine of integration layer provides a visualization control interface to process monitoring data uploaded from the physical layer in real time and outputs the results of various automatic processing forms in accordance with alarm-thresholds set in the application layer. Because the working environment of mine is complex and the workplace and resources conditions vary continuously, there are many factors which can result in alarming. It is necessary to analyze the relation of integrated monitoring, and then the relationship is provided to the linkage modules or technical staffs in order to achieve accurate and scientific decision-making and command. In addition, because of the specificities of the mining industry, an integrated monitoring system must not only process the collected real-time data, but also analyze the historical data of a period of time. Thus for different aspects of production, multi-dimensional data analysis is done to show the producing history in the form of curve, bar graph and pie chart, which provides a decision-making aided method to analyze existing failures and predict the development trend of production. Therefore, linkage rules of heterogeneous monitoring data with multi-source must be researched.

3.1. Characteristics of heterogeneous monitoring data with multi-source in mine

A wealth of monitoring data resources is collected by sub-stations and PLC control equipments. Because the different transmitting protocols and the acquisition methods, they are heterogeneous data packets. In the integration layer, a lot of heterogeneous monitoring data are collected into the database of the collection server, and then are processed and stored in the real-time relational database with the unified form. The physical sharing problems of heterogeneous data are solved by database, but semantic conflicts of sharing data become barriers of exchanging

caused by different software platforms and data model of monitoring devices.

Heterogeneity includes three aspects: systems heterogeneity, data models heterogeneity and logical heterogeneity [5-6]. The last one is the main heterogeneity appearing in integrated mine monitoring data. That is, when the monitoring data from different subsystems are stored in the relational database, the same data may indicate different semantics or the same semantic exists in different forms.

3.2. XML-based data linkage method

When building a data warehouse, the heterogeneous integrated monitoring data are stored in the general relationship database. The basic unit of database model is the attribute of data, and the attribute itself contains semantic information. So the linkage of the multi-source heterogeneous data in this database model is based on the attribute. By this means, without changing the local data structures, storage manners and management methods of the original data, the heterogeneity is shielded among the platform between the data source, the system environment, the data structures and so on to solve a series of semantic conflicts of database models in the pattern matching process and data sharing.

In this paper, the semi-structured XML data model is used in the global unified description of data form to maintain data integrity of integrated mine monitoring system and querying [5-7]. Heterogeneous multi-source differences in the underlying data sources is shielded to build the unification of heterogeneous data sources, and to eliminate semantic heterogeneity and pattern heterogeneity. So, the consistent and real-time access capacity is provided to the linkage modules to realize the sharing and correlation of different sub-systems data completely. XML-based multi-source heterogeneous data linkage structure is shown in Fig. 3.

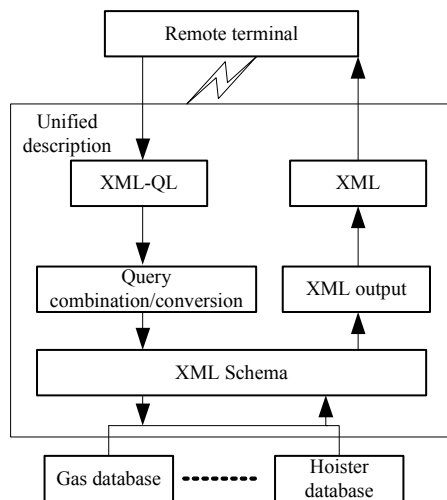


Fig. 3. XML-based multi-source heterogeneous data linkage structure

The data from subsystems is stored in the data warehouse in the collection server located at integration layer. In order to overcome the autonomy and heterogeneity of monitoring data form the subsystems, the XML schema is used to describe the data model. The data from different source modules are collected in real-time mode, and expressed by a unified form XML documents, thus the interacting and mapping between XML and the underlying relational database is completed.

In the integrated monitoring system, the multi-source heterogeneous data are stored and updated in the relational database. Therefore, it is necessary to switch the semi-structured XML data into a structured data stored in the two-dimensional table to make use of the relational database to store and manage the XML data. In Fig. 3, the remote terminal use XML-QL in the XML Schema to create querying sentences, and collect the view data fragments to make query combination, and then the XML query format will be converted to SQL language to realize the query on the underlying heterogeneous multi-source relational database. Finally, the querying results will be provided to the remote terminal in the way of XML format. By this way, the sharing and linkage of the multi-source heterogeneous

data is realized in the data warehouse of the integration layer.

However, due to the distinct differences of data model between XML document and relational database, in order to exchange data between XML documents and databases, a template-driven approach is used to map XML document model (XML Schema) to the relational database model. In the integrated monitoring system, only the conversion from relational database to XML document is used; and compared with the model-driven mapping methods, the template-driven mapping methods do not need to define the mapping relationship ahead between XML documents and other data. So, the template-driven mapping method is used in this paper. The embedded SQL commands in the XML document are identified and implemented automatically by the system and output the results. It is simple and can exchange information in real time.

4. Experiment and discussion

Based on the proposed high-speed response linkage model for integrated monitoring system of coal mine in this paper, a ring industrial Ethernet platform is built to simulate coal production environment. The integrated monitoring system integrates gas detection subsystem, underground drainage subsystem and belt monitoring subsystem. The statistics of core parameters of ring industrial Ethernet network are shown in Table 1, and linkage statistics of parameters of the monitoring sub-system are shown in Table 2.

Table 1. Statistics of core parameters of ring industrial Ethernet network

| Core parameters | Value |
|----------------------------|--|
| Data transmitting protocol | TCP/IP |
| Transmission medium | Single-mode optical fiber, five-type cable lines of mine |
| Maximum transmitting rate | 1000Mbps |
| Transmission distance | $\leq 30\text{Km}$ (Single-mode optical fiber) $\leq 100\text{m}$ (five-type cable lines of mine) |
| Bit error rate | $<10^{-9}$ |

Table 2. Statistics of parameters of the monitoring sub-system

| Gas detection subsystem | Underground drainage subsystem | Belt monitoring subsystem |
|------------------------------|--------------------------------|---------------------------|
| Gas concentration | Motor temperature | Motor temperature |
| Wind speed | Flow | Belt temperature |
| Tunnel pressure | Water level | Cord switch |
| Tunnel temperature | Motor voltage | Deviation Sensor |
| Carbon monoxide concentratio | Electric current | Speed Sensor |
| Throttle switch state | Pump outlet pressure | Valve state |
| The state of fan | Pump outlet | Smoke sensor |

In the physical layer, the gas detection subsystem obtains real-time monitoring information by using the smart

sub-station. The underground drainage subsystem and the belt subsystem obtain real-time monitoring information by using PLC. In the integration layer, the data collection server makes use of SQL Server relational database to access and share data in real-time. IFix4.0 is used as linkage engine to achieve the data linkage and alarm output in the application layer. Results of experiment show that the model meets the demand of the integrated monitoring system for high-speed response linkage.

5. Conclusions

1) The integrated monitoring platform of mine for data integration is built from the aspect of high-speed response linkage physical model and logical model.

2) XML Schema data model can complete the unified description and management of the mine monitoring heterogeneous multi-source data, and share the multi-source heterogeneous data by linking them in the data warehouse of integrated layer.

3) Experimental results show that the model meets the demand of the integrated monitoring system for high-speed response linkage.

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