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Research on the Design of a Mine Gas Warning System Based on Cloud Computation

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In order to improve gas disaster warning capability, this paper has further studied the theory and method of mine gas warning analysis based on cloud computation data integration model by analyzing mine gas inspection/monitoring data characteristics and its integrated control model. Based on the principle of cloud computation, the physical architecture of cloud computation model and its cloud computation platform model applying to mine gas warning analysis are built, mine gas inspection/monitoring data processing and prediction and warning algorithms are encapsulated, and a cloud computation model is built for the programmed service of gas warning computation, achieving effective warning analysis. According to experimental results, the theory and method of gas warning analysis under the cloud computation data integration model studied in this paper applies to gas warning analysis at coal mine sites, providing a new digital platform construction method and means for coal mine gas disaster prevention and control.

1. Introduction

For a long time, coal is a dominating energy source in China, which has been accounting and will account for a high percentage in primary energy production and total consumption in China. In recent year, the coal percentage in primary energy production and consumption structure in China is always around 70%, which is expected to more than 50% by 2050. The coal industry has played and will continue to play an important role in the national economy. In recent years, the total coal in China has been increasing from 1.299 billion tons in 2000 to 2.19 billion tons in 2005. The national coal production reached 3.24 billion tons in 2010 and 3.7 billion tons in 2013 (Awange, 2018). However, it is worth noting that China is among the countries with the most serious coal mine accidents. At present, coal enterprises are generally equipped with security monitoring systems and some even with auxiliary safety decision system for different coal mine disasters in coal mine (Bilbao-Terol et al., 2017). But since there is a lack of data sharing mechanism between different application systems, application systems are difficult to integrate so as to support safety data fusion, in-depth data analysis and mining, decision analysis for the whole coal mine at a higher level, which restricts the improvement of safety management of coal enterprises to some extent (Christensen et al., 2017).

Cloud computation data processing can gather multiple server resources distributed in different places and process data by network-distributed computation resource model, allowing shared software & hardware resources and information to be provided to computers and other devices on demand to greatly facilitate resource sharing and improve data processing efficiency (Finogeev et al., 2017). Therefore, studying coal mine safety inspection/monitoring data analysis based on cloud computation model can not only realize unified integration of multi-source coal mine data to provide reliable data sources and efficient data processing mechanism for the in-depth analysis and exploration of safety data, but also provide technical support for realizing highly effective ventilation gas risk analysis and safety pre-control (Goyal et al., 2017). It will definitely become an effective means to improve coal mine safety management information. Although the warning theory and technology starts relatively late in the field of coal mine safety, various coal mine disaster warning analysis issues has drawn great attention as coal mine safety production problems are becoming increasingly prominent (Jabbarpour et al., 2017). With the development of information technology and the continuous improvement of coal mine information technology to provide efficient safety management means since the 1990s, the construction of coal mine safety management information systems and applications are well

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developed (Liu et al., 2017). Then, with the continuous development of coal mine automation and artificial intelligence technology, the coal mine safety management information technology is oriented to the intelligence, having promoted the development of coal mine risk warning technology (Mishra et al., 2017).

2. Gas inspection/monitoring data integration and control model

Despite difference in data structure of inspection/monitoring data, manual data and real-time monitoring data are both important to gas warning analysis. The correlation analysis of both is an important means to realize effective gas warning analysis. From a gas emission mechanism perspective, both are the external manifestation of gas emission. Therefore, there is relevance between them, which is mainly reflected on the data structure, data characteristics and analysis efficiency. The monitoring data preprocessing process is shown in Figure 1.

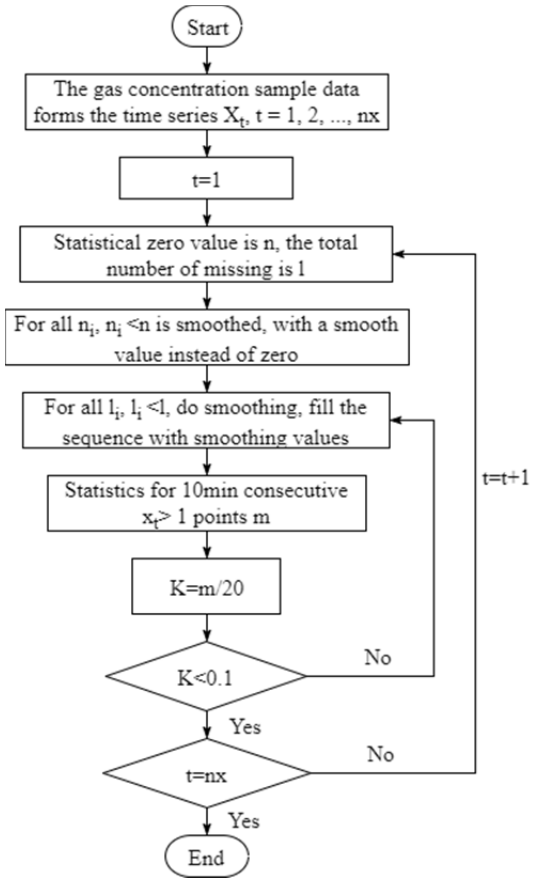

Figure 1: Monitoring Data Preprocessing Process

Cloud computation technology architecture is adopted for integrated control of inspection/monitoring data on coal mine sites. The architecture is shown in Figure 2.

The functions of each part are described as follows:

Data collection program: manual inspection data are imported to the database through the data uploading program after preprocessing or according to various report formats (xls files). For real-time monitoring data from the monitor host, the monitoring data files can be transferred in advance to the data server, and then imported to the database through the real-time data collection program developed or directly scheduled for warning analysis.

Data analysis services: To build cloud computation data analysis, a dynamic trend prediction and warning model of mine gas concentration and a gas outburst hazard prediction and warning model are to be first established and programmed. Then, the application service components are to be developed and a PaaS cloud computation system based on cloud computation principles is to be built.

Infrastructure services: For inspection/monitoring data integration control, the infrastructure services provide the storage virtualization management for bulk data integration. The infrastructure services consist of a

physical facility resource layer and a virtualization platform layer. The physical facility resource layer includes servers, storage devices and network devices and other infrastructure provided by the cloud data center, and virtualization platform layer is to make use of server virtualization, storage virtualization, network virtualization technology to generate a virtual resource pool based on these physical devices.

Data storage: The data stored is derived from two aspects. One is the original inspection/monitoring data, which can be imported to the database by data uploading or data collection program. The other is the computed results and intermediate data processed by the analysis service (processed gas inspection/monitoring data).

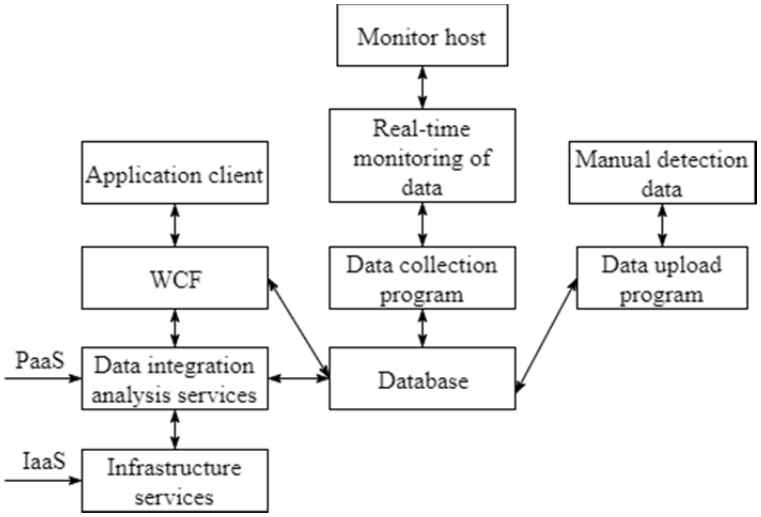

Figure 2: Data Integration Architecture

3. Prediction model and process

For the prediction and warning of gas concentration for the monitoring points of compound mining face, the real-time gas monitoring data of a single monitoring point is taken as the analysis object to build a single monitoring point gas concentration prediction model through preprocessing real-time gas monitoring data based on the computation principle and method of ARMA model, to calculate prediction interval prediction results for warning analysis. The detailed process of the prediction and warning method is shown in Figure 3.

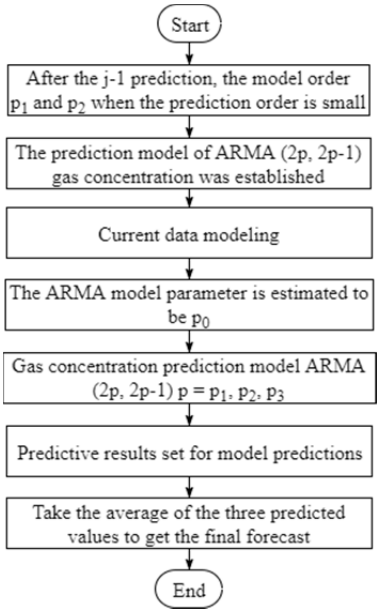

Figure 3: Dynamic Revision Process of ARMA Prediction

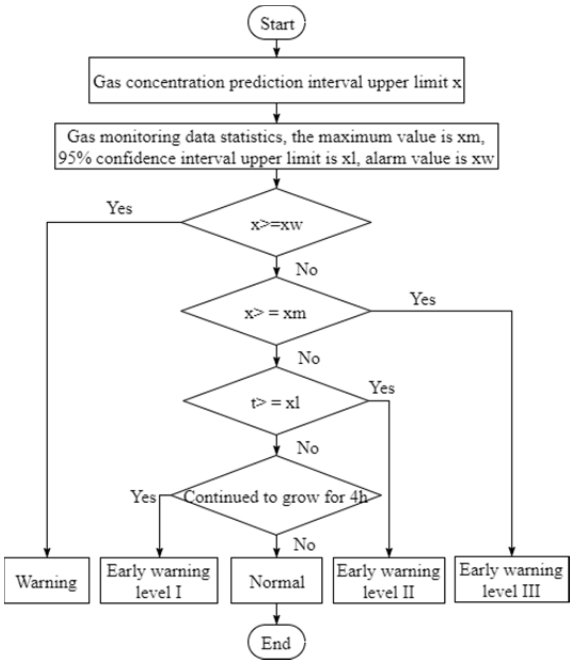

Figure 4: Warning Analysis Process

4. Gas concentration warning analysis

The gas concentrations warning of a specific location or important area in underground coal mine is based on the alarm values of different underground locations specified in the Coal Mine Safety Regulations. The gas concentration warning analysis value shall not exceed the alarm value, which serve as the boundary of warning and alarm to divide the warning results into 4 levels. The gas concentration warning analysis process is shown in Figure 4. The warning levels are shown in Table 1.

Table 1: Warning Levels

Prewarning Grade	Warning sign	Prevention and control recommendations
pre-warning level III	Red	Set the alert time and control the rectification
pre-warning level II	Yellow	Need special attention and take measures
pre-warning level I	Blue	Focus on the trend of gas concentration and identify the cause

5. Cloud computation model for inspection/monitoring data analysis

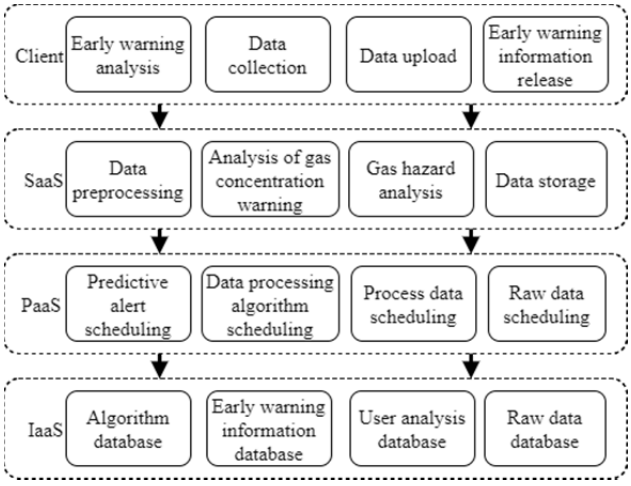

Figure 5: Internal Model Structure Diagram of Cloud Computation Platform

The internal management model structure of cloud computation based on the cloud computation platform architecture design of mine gas inspection/monitoring data is shown in Figure 5.

6. Gas prediction and analysis process under cloud computation model

Based on the basic principle of cloud computation and the cloud computation platform for inspection/monitoring data analysis, the gas prediction and warning analysis process characterized by data integration control analysis under the cloud computation model is shown in Figure 6.

Data integration control: Data integration control is to import on-site gas inspection/monitoring data to the database through the data collection procedure. Computed in prediction processing and intermediate process of prediction and warning, the data can be called in gas warning tracking and analysis to guarantee real-time prediction and warning as well as improving the computational analysis performance.

Algorithm integration scheduling: The gas warning analysis computation under the cloud computation model mainly involves the algorithms of gas monitoring data preprocessing, gas concentration prediction, dynamic correction of prediction model, gas outburst hazard prediction, statistical analysis of gas inspection/monitoring data, gas concentration and gas outburst hazard warning. Algorithms can be encapsulated as integrated elements under the cloud computation model. Integrated control and scheduling enhance the reliability and flexibility of the algorithms, applicable for the data fusion analysis in the case of huge amounts of data.

Prediction and warning refinement: Under the cloud computation model, gas concentration trend prediction and gas outburst hazard prediction based on the statistical analysis of inspection/monitoring data and model construction and optimization can be completed through integrated control of data and uniform scheduling of algorithms. With the prediction results as the object, refined and real-time warning can be achieved according to statistical analysis results of inspection/monitoring data to effectively support coal mine sites. Advanced alarm and warning can be achieved by means of routine inspection/monitoring data analysis preprocessing.

High computation and analysis efficiency: Unified scheduling and integration control of resources can be realized under the cloud computation model, achieving high efficiency in warning analysis, ensuring the reliability of on-site application, and providing an effective means to analyze inspection/monitoring data of coal mine sites to expand the existing safety prevention and control facility functions for mines and realize the mine disaster prevention and control methods and means.

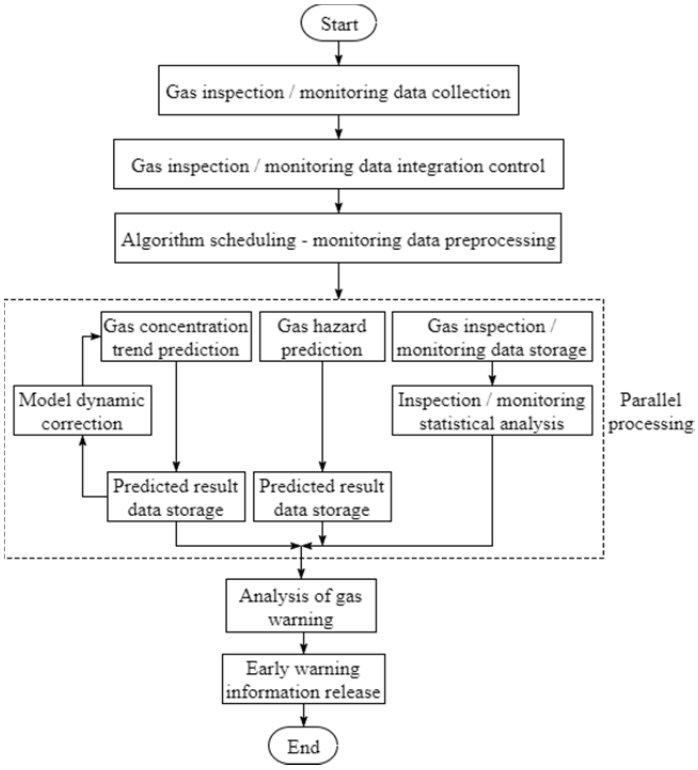

Figure 6: Gas Prediction and Warning Analysis Process under Cloud Computation Model

7. Conclusion

This paper analyzes systematic research on gas prediction and warning methods under the cloud computation model based on coal mine inspection/monitoring data processing and applications at home and abroad, gas concentration prediction and warning methods, gas outburst prediction and warning method and its application, with expanding coal mine daily gas inspection/monitoring data as the analysis object and expanding coal mine safety monitoring system functions as the purpose. According to the characteristics of mine gas inspection/monitoring data, the gas inspection/monitoring data preprocessing method under the cloud computation model, gas concentration prediction and warning method, and gas outburst hazard prediction and warning method were proposed based on the basic principle of cloud computation; By building a cloud computation mode for gas inspection/monitoring data processing, designing system functions and system development architecture and developing application software, the validity and applicability was verified in site application.

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