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# Architecture and application of integrated spatial information service platform for digital mine

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**Abstract:** Using enterprise GIS platform, spatial databases and modern information technology, building geo-spatial information service platform of digital mine which has the features of the data exchange service, enterprise GIS services, directory services, logging services, is key technology and application infrastructure for digital mine. Based on the support of geospatial information service platform of digital mine, the professional GIS application service adapter can be developed and the application supports related to mining application system can be realized. Using high-resolution satellite remote sensing data, the mine functional partition map and geographic grids can be divided, and the geographic grid parts, status and events of important features of the surface object were investigated and defined. The system architecture and technical characteristics of integrated spatial information service platform were analyzed firstly, which guarantee service ability of digital mine. The methods and applications of functional partition map for integrated management service platform were discussed which are the services scheme of digital mine. The application results indicated that digital mine upgrades and enhances the capability and range of mine surveying and mapping, and is of great significance for guarantee of efficient, green and intensive exploitation of mine.
**Key words:** platform; architecture; web services; application services; digital mine

## 1 Introduction

Currently, the geo-spatial information technology is widely used in the mining industry. The mining industry is changing from the traditional experience-based to quantitative analysis and automatic direction science-based. Digital mine is the whole understanding and digital reproduction for unity and related phenomena of real mine. The core of digital mine is scientific and rational organization of information on various types of mines in a unified spatial and temporal framework, which manages and integrates massive heterogeneous spatial information resources of mine comprehensively, efficiently and orderly [1−2]. Digital mine construction upgrades the level of industrial technology and the innovated forms of industrial technology will play an important role in mining safety production [3] and also are a booster of benefits, the doublers of growth and the converter of development mode.

The management and integration of massive heterogeneous information resources of mine and standard are important contents for digital mine construction. The spatial database for the safety production and management of mine is a multi-source, multi-scale, multi-category and multi-temporal features database. The multi-source spatial information means methods of the spatial data acquisition and different data storage formats [4]. Because spatial database is multi-category and heterogeneous, the ways of data storage management and usage are different, which result in a critical problem of how to integrate and manage mapping, surveying, monitoring databases and etc. The mine spatial database also is a multi-scale spatial database, and mine surveying and mapping is according to the special scale. The temporal spatial database is another characteristic that the spatial data sequences are formed with the exploration of mining resources. The integration of spatial and temporal spatial database is the most basic demands for mine management.

Based on the mine functional partition units databases and integrated information service platform of digital mine, the integration and standardized managements of mine geological and surveying data,

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particularly basic mine surveying data, mine surveying and monitoring datasets are the key technologies and application basis for digital mine construction.

## 2 System architecture and characteristics of integrated spatial information service platform

The integrated spatial information service platform for digital mine should have the technical characteristics of data security protection and standard management of mine spatial data and also can provide the spatial information services according with open geospatial consortium (OGC) [5] and service-oriented architecture (SOA) [6] standards. The mine spatial database includes the basic mine surveying, mine surveying and data monitoring. The mine functional partition map corresponding to the important features of the mine surface objects, which are facilities, buildings, plants, important production areas, land subsidences, slopes and artificial deposits, can be divided and extracted based on high resolution satellite remote sensing data. Then the parts, status and events can be added to the mine functional partition map and integrated with mine spatial database. The spatial information service platform of digital mine can be developed and the data exchange services, special GIS services, directory services, and log services can be realized using enterprise GIS and modern information technology which has strategic significance for management of mine enterprise.

Integrated spatial information service platform architecture is divided into three layers. The bottom layer is mine spatial database whose main contents are basic surveying database, mine surveying database, monitoring database and functional partition database, as well as geology, mining, environmental and ecological spatial database. The middle layer is the core layer whose main contents include enterprise GIS core services, data exchange services, directory services, log services and the application system adapter based on integrated spatial information service platform. The upper layer is application layer which is mainly for mine integrated monitoring and pre-warning services, spatial information query service, the spatial database share and special support and mine safety decision support system etc, as shown in Fig. 1.

The technical characteristics of the platform architecture are as follows.

1) Based on enterprise computer network, users can remotely access the application services of integrated spatial information service platform, and access mine surveying and mapping database, department and decision support information.

2) The mine manager can fully view the status of mining, production facility distribution, query related real-time information and make decisions through the

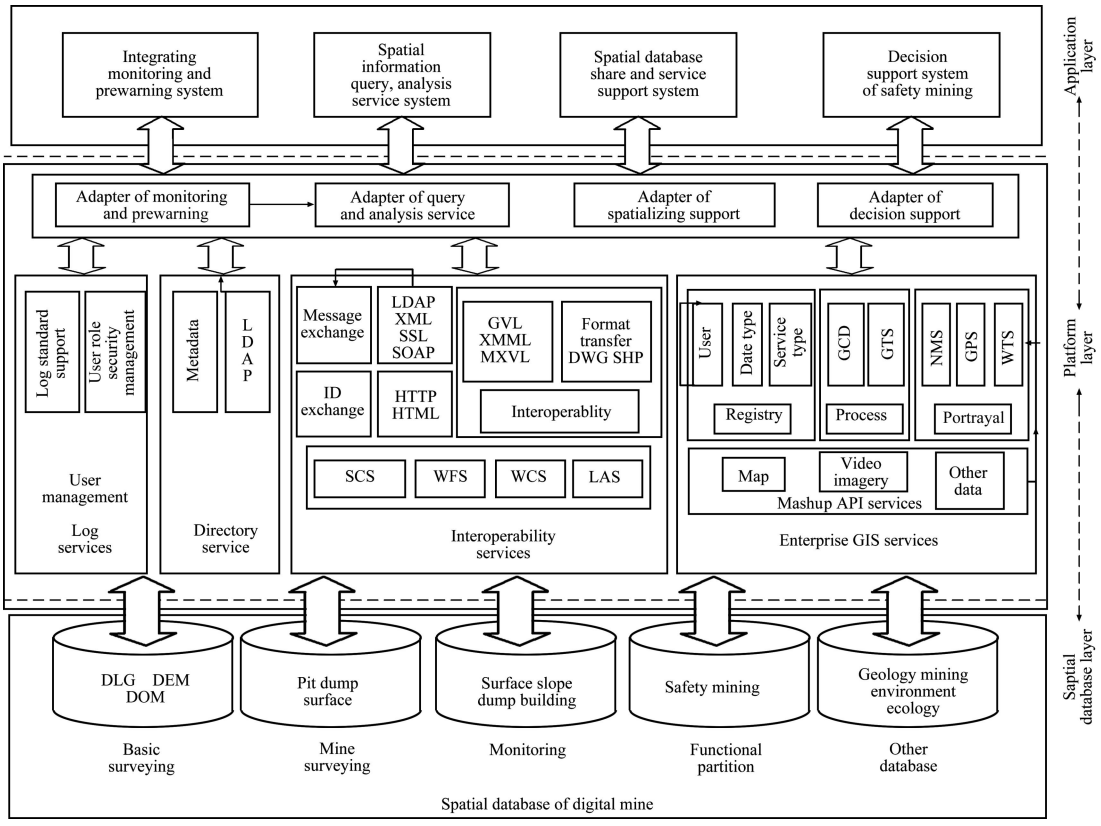


**Fig. 1** Architecture of integrated management services platform for digital mine

platform.

3) In accordance with OGC standards, using the special interface based on spatial information service platform, the exchange protocol and service standards, the registration services, geo-coding services, processing services, portrayal services and data services are available for all users.

4) The database synchronization and backup for the exchange system are built on the basis of data exchange platform for delivery at all levels of data exchange of special process information systems.

5) A mine spatial database directory services system is established in which meta-database and spatial database are available and the directory services-based spatial database management is realized for users.

6) The data security protection management service is also supported by authorized user management system, and users permissions assignment can enhance data security operation.

7) The daily login and operation satisfy log standard and record complete operating details of spatial database and platform.

8) The platform supports geo-coordinate system conversion between mine independent coordinate system and the national coordinate system.

9) The platform also supports a variety of data updating operations, editing, visualizing and management.

## 3 Methods and applications of functional partition units for integrated management service platform

Innovating mine management mechanism and establishing the modernized mine management pattern and the functional partition map of geo-coding with the parts and events for entire mining area are similar to “ten thousands meter grid city management pattern” [7−8]. The real-time monitoring of the entire mining area and the comprehensive management can be realized based on the functional partition map.

Using calibrated high-resolution satellite remote sensing images, the mining functional features can be extracted and the functional partition map can be divided. The feature objects are facilities, buildings, plants, important production areas, land subsidences, slopes and artificial deposits and other components. The feature states and events including corresponding attribute tables can be associated with the functional partition features. The partition type, boundary characteristics, codes, function partitioning clustering methods should be standardized. In accordance with the management demands of spatial database, the functional partition metadata database can be built based on Geodatabase or PostGIS.

Focusing on the surface changes, the surface of open-pit mine will be divided into seven types of functional partition, which are open pit, the pit mining slope and end slope, peeling areas, dump, dump slope, industrial building and roads. Open pit mainly refers to open pit mining area, as coal seams during the mining process exposed to the surface. The remote sensing image appears as concentrated black areas, which is easy to identify. Pit mining slope and end slope are ladder-like slope, distributed along the pit mining direction. Slope and road layers arranged on the performance of the image are very clear. The dump can be divided into internal and external dump field. The former mining site is located within the boundaries, and the latter is located outside the boundaries of the mining field. The internal dump areas are mainly used for materials piling strip. Stripping pit area is the stripped out original surface with lighter color and ladder-like distribution. Roads, including the regional and between regional roads, generally appears pale white. Industrial building means a building area of regional distribution, such as coal washery, crushing station and other industrial construction [9], as shown in Figs. 2 and 3.

**Fig. 2** Functional partition map based on high resolution imagery

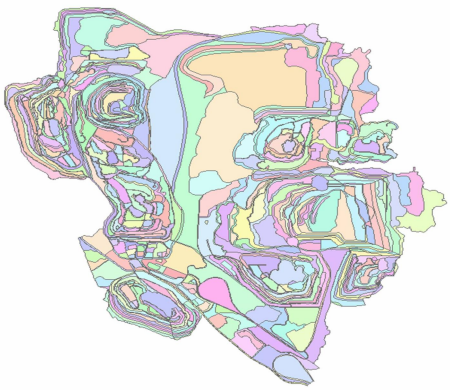

**Fig. 3** Results of surface functional partition and stability evaluation [10]

## 4 Applications of integrated spatial service platform

Based on integrated spatial information service platform, oriented to the demands of mine geology, surveying, safety production and green highly effective mining, many of mine application systems may be constructed and supported.

The users can be authorized access to mine spatial database and develop the application system overlaying the special data through integrated service platform and enterprise computer network.

1) Mine surface subsidence, deformation monitoring and pre-warning systems, main functions include the analysis of surface subsidence based on InSAR and mine functional partitioning map; the integrated monitoring data management and pre-warning of GPS, Geo-Robot and sensor; the collection and analysis of 3D laser scanner monitoring date; field monitoring data management and pre-warning of slope and artificial deposit.

2) Mine spatial information query, analysis and services, including the query of mine ground facilities information, the distribution and progress of engineering projects, mine safety information, and other spatial query services.

3) Spatial database sharing and processing support services system.

4) The GPS, Geo-Robot and the integration monitoring data management of sensor are taken as an example of integration spatial service platform application.

### 4.1 Integrated monitoring data management

Storing monitoring data to database, the multiple source data integrated management should be realized. The traditional way is file management with low efficiency and difficulty of exchanging data. The database is in high efficiency and is convenient in data exchanging and querying by SQL which guarantees its security protection, also it is advantageous for data analysis. Under the digital mine service platform support, GPS and Geo-Robot and the real-time monitoring data of sensor can be imported to the mining monitoring spatial database, and the monitoring data analysis and processing can be carried on efficiently.

### 4.2 Integrated monitoring system

Based on the integrated spatial information service platform support, the general integrated monitoring system can be built, and it realizes the monitoring of mining surface subsidence, slope stability and artificial deposits. A generic class (monitoring adapter) and XML adapter have been implemented to connect the multiple manufacturers of various types of sensors and GPS surveying system.

Users can continuously monitor targets and collect data. The monitoring results can be transmitted to the data center. The data center can display and analyze the displacement of monitoring targets automatically. The main interface of GPS, Geo-Robot and sensor integrated monitoring system is shown in Fig. 4, and the GPS and Geo-Robot automatic monitoring software systems are shown in Figs. 5 and 6 [11].

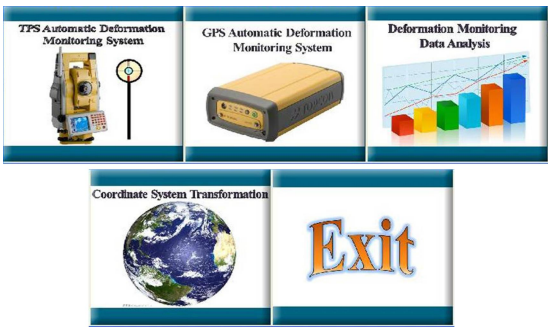


**Fig. 4** Main interface of GPS, Geo-Robot and sensor integrated monitoring software systems

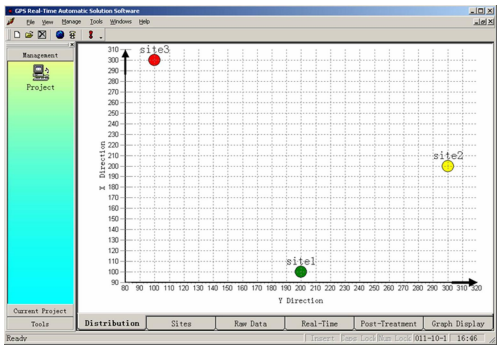


**Fig. 5** GPS automatic monitoring software system

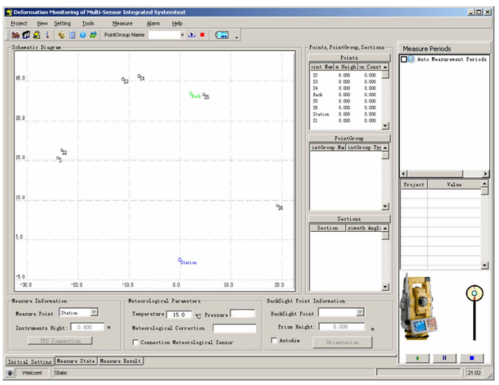

**Fig. 6** Geo-Robot automated monitoring software system

Based on the integration management database of monitoring data, the system can easily access the results of monitoring data. According to a certain method or model, the results of deformation can be analyzed and solved automatically. The two ways for monitoring data

query and analysis have been realized. One is desktop based application, as shown in Fig. 7. The other is WebGIS based application, as shown in Fig. 8. It can also export data from the monitoring database for further analyzing and predicting the stability of monitoring area, as shown in Fig. 9. Once the target of the deformation monitoring or predictive value is higher than the threshold, monitoring system automatically sends alerts to mine manager via SMS or e-mail.

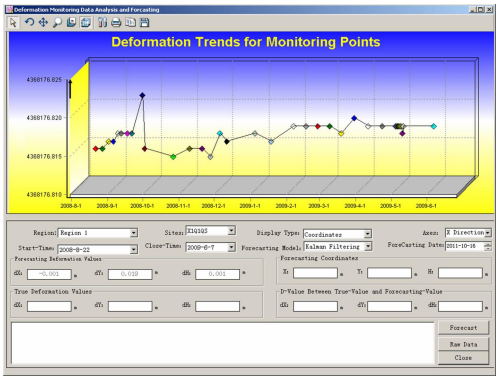


**Fig. 7** Trend changing analysis to monitor target point

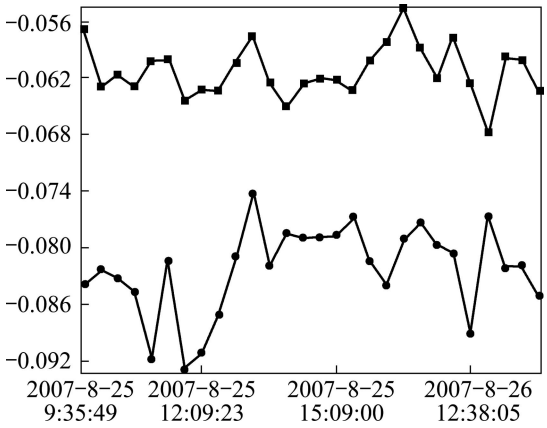


**Fig. 8** Real-time query and analysis based on WebGIS

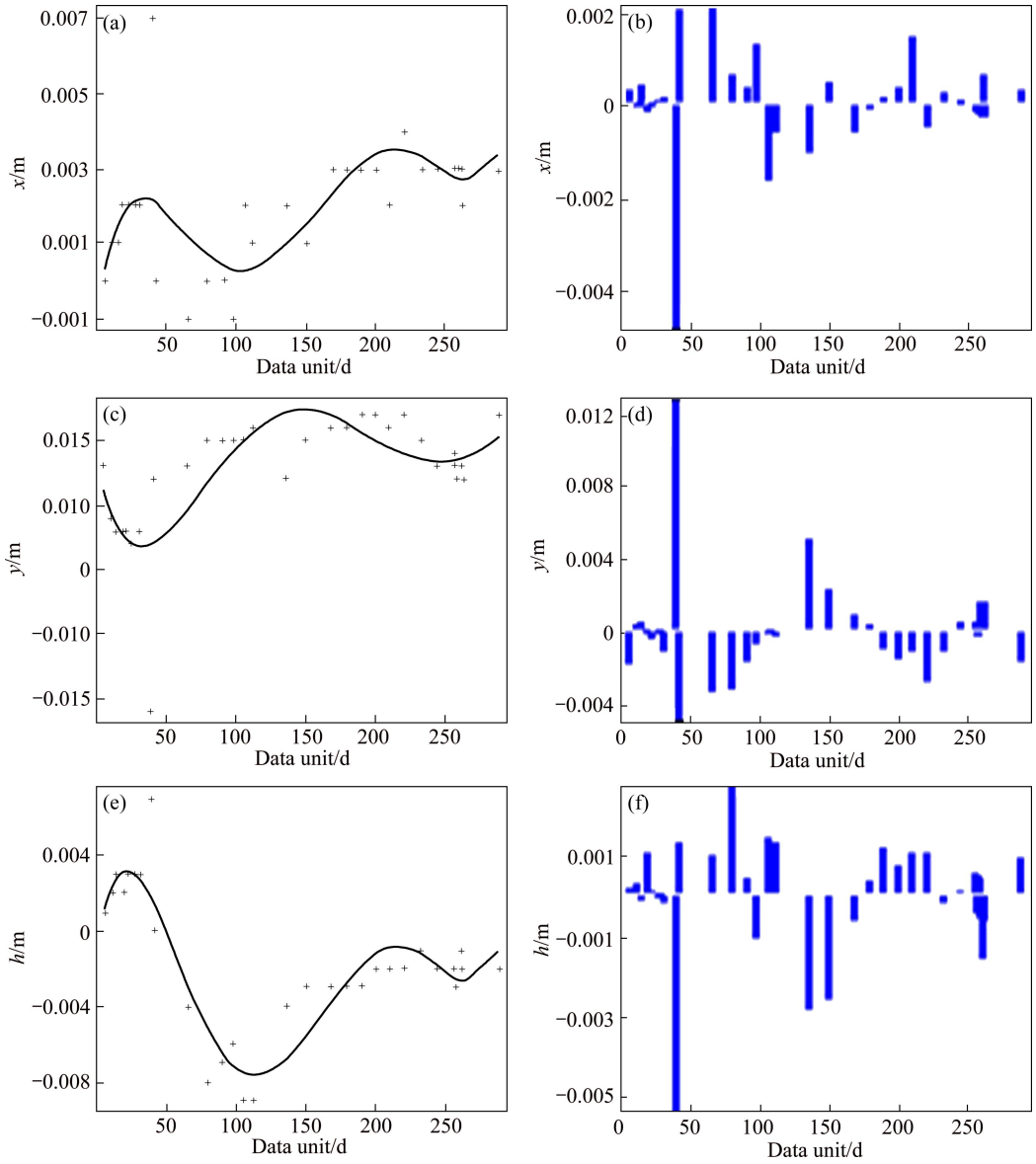


**Fig. 9** Trends model analysis for monitoring target point

## 5 Conclusions

1) The integrated spatial information services platform of digital mine for mine-related production and management provides standardized geospatial data and geographic information services, which achieves data sharing, mining-related applications of spatial-based support services, decision support analysis of mine safety and emergency. Construction and implementation of integrated spatial information service platform can integrate and unify spatial database of mine surveying and mapping, slope and building monitoring data, provide a safe, standardized spatial information service for the mining-related departments, which is of great significance for mine safety, efficiency, green, and intensive exploitation.

2) Based on integrated spatial information service platform, users can remotely access geographical information services and mine surveying and mapping spatial database via computer network. Through the service platform, mine manager can fully understand real-time relevant information of the status of mining production and facility distribution. The data exchange platform and directory services make users access spatial meta-database and realize directory services-based spatial database management.

3) The three-layer architecture of integrated spatial information service platform of digital mine is based on enterprise GIS and spatial database. Based on the support of geospatial information service platform of digital mine, a professional GIS application service adapter is developed and the integrated monitoring application and spatial service supports related to mining application system are realized, and the capability and the range of mine surveying and mapping are upgraded and enhanced. Based on high-resolution satellite remote sensing data, the mine functional map and geographic grids have been divided and extracted. Basic applications indicate that the architecture and platform services are reasonable and efficacious for mine management.

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