DESIGN AND DEVELOPMENT OF FIELD SYNCHRONOUS DATA COLLECTING SYSTEM OF MINING AREA SURFACE DEFORMATION INFORMATION

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ABSTRACT:

In order to grasp the changing situation of ground subsidence and surface collapse caused by underground mining in mining area, and raise the efficiency of field data collecting, this paper's attention is paid to develop Field Collecting System Based on Wireless Communications to acquire spatial data and attribute data. The mobile devices use Web Services to synchronous data with the server. The system can get the required map from server by Map Service, it acquires high precision coordinate by making use of the GPS Differential Technology. The attribute data can be updated to the server by Web Services. The Field Collection System of Surface Deformation Information in Yanzhou Mining Area is developed on the basis of analyzing how the underground mining work affects the ground surface. The System will provide high precision, the lasted data for researching and monitoring the surface subsidence or collapse. It integrates field ascertainment and survey. That simplifies the work of data collecting and entering into the database, and meets the requirement of real-time data.

1 INTRODUCTION

The ground subsidence and surface collapse is common in the mining area. The major cause for surface deformation is a wide range of mined-out space underground caused by coal mining (LIU Guang, 2008). While the surface subsidence, landslides and other geological disasters have a serious impact on mine production activities and people's life, it is very important to know well the changing situation of ground surface for analyzing and predicting the change trends of ground subsidence, helping for adjusting the way of exploitation and planning of land use in the mining area, reducing the hazards of surface deformation. So it is necessary to design a field data collecting system which applies to mining area data acquisition. The system can acquire the position coordinate and the property of the surface, and it will upload the collected data to the server. Then the server will use this data to analyse the surface change trends.

2 SYSTEM DESIGN

2.1 Requirements Analysis

The Field Synchronous Data Collecting System of Mining Area Surface Deformation Information used to collect the planimetric position, elevation, the potion of mined out space, the area, the exploitation date and the picture of mining area where the subsidence has occurred. And these collected data can be uploaded to the server for analysing. There are some fixed monitoring points in the subsidence area. These points are used to analyze the position change, especially the elevation change. We can use the RTK to survey these points for high-precision coordinate. There is a CORS station in the Yanzhou coal mining area, so the GPS receiver can get differential data from the CORS by GPRS.

2.2 System Architecture

On the server, the map spatial data is managed by the ArcSDE. The layers which need to be updated are published as Map Service. And the attribute data is stored in the Oracle. The Web Services are published for access the server by the mobile device. Figure 1 shows the architecture of Field Synchronous Data Collecting System of Mining Area Surface Deformation Information.

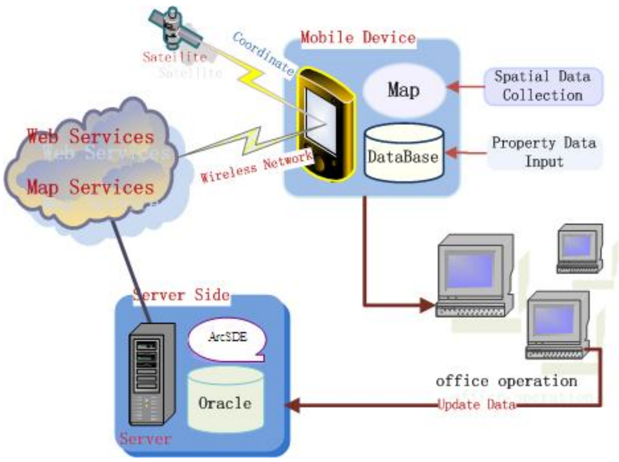

Figure 1. The Architecture of Field Synchronous Data Collecting System.

On the mobile device, the field data collecting system will get the map of the area where need to collect data from the server by the wireless network. Then the collected spatial data will be store in the map. The attribute data are stored in the embedded database-the SQL CE.

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When the work of field data acquisition is finished, the spatial data can be updated to the map layers in the ArcSDE using the published Map Service; and the attribute data can be updated to the Oracle by the Web Services which are published on the server. The second way for uploading the data is to use the C/S mode on PC when processing data in the office. The system will avoid the operator of importing and exporting data, and it is not necessary to convert the data formats. That will raise the efficiency of field data collecting and simplify the data manage.

2.3 System Functional Design

The system is designed for acquiring data in the field. The data collected in the field are managed by a project. Each project contains a map, a database and a coordinate system file etc. One project stores the data of one region or a day's work. The project can be created as it is required.

The system functions include getting coordinate data form the GPS receiver by the port or the Bluetooth, coordinate transformation, storing the spatial data in the map, project creating and managing, attribute data entry and save, getting map from the Map Services, updating the field data by wireless network, embedded database management, GPS control, taking pictures, map operate, such as map zoom, map pan, map query and so on.

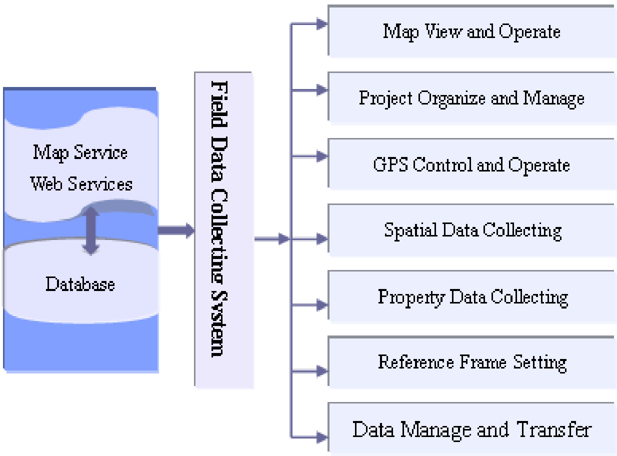

Figure 2. The System Functions Modules

A project is used to manage the collected data. The system can create, open and manage the projects. The reference frame setting module can create or edit a coordinate system file which contains the ellipsoidal parameter, the projection parameter and the parameter for coordinate conversion. A project links to a coordinate system file; the project will use the coordinate system file to convert the spatial data from the WGS 84 geographic coordinate system to the coordinate system as specified in the file when working in field. In the data manage and transfer module can manage the data and transfer the data to server.

2.4 System Project Composition

The system uses projects to manage the data collected at different time. When collecting data in the field, first of all it is to create a project to store the data. After the GPS receiver works smoothly, the system will get coordinates form the receiver. In the project， the spatial data stored in the map, and the property stored in the database. Figure 3 shows the project composition of the system.

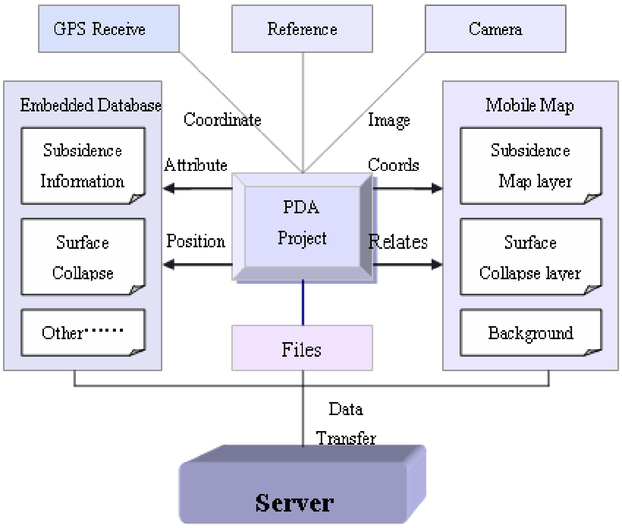

Figure 3. Project composition of the system.

There are several layers in the map. Before collecting spatial data, setting a layer which will be edited, then the coordinates will be saved in the layer. After finish a feature, can entering its property. The attribute data will be saved in the embedded database. When finished the work of data acquisition, the new data can be updated to the server by wireless network or by office operation.

2.5 The Data Organization

The system's data includes map data and attribute data. The mobile map can be acquired from the Map Service on the server or the Map Cache stored in the mobile device.

The Map Cache is created from Map Service by ESRI ArcTools or by ArcGIS Mobile from the wireless network. There are several layers in the map; the layer's type is point, line or polygon. When collecting the coordinate in the field, the coordinate data will be shaped as point, polyline or polygon and stored in one layer. The map can contain image layer. Only the map layer in the Map Service form the ArcSDE can be edited in the ArcGIS Mobile. Another kind of map used in the system is called Base Map. The Base Map created from ESRI map document (MXD file). The layer in the Base Map can not be edited. Both the Map Cache files and the Base Map files have been compressed a great deal; they are much smaller than the layer in the data source. The Map Cache can be get from the Map Service by wireless network while the Base Map can't.

The attribute data is stored in the SQL CE. It's very easy to manage the property by the SQL CE. It is not possible to work with the Oracle directly in the mobile device. So the system calls the Web Service method to query and update data with the server.

2.6 The Hardware Environment of System

The mobile device is Zhonghaida GPS PDA. The Novatel GPS OEM device is built-in in this PDA. And the GPS Receiver can make use of differential data which received from SBAS or the base station to improve the positioning precision. And the PDA includes Bluetooth, so the system can use the built-in Bluetooth to connect to an exterior GPS receiver when need more high precision positioning data. The operating system of the PDA is Windows CE 5.0. That OS is convenience for developing and deploying software. The camera in the PDA can used to take photos for recording the spot in the fields. And this PDA can use the GPRS to connect to the server for requesting or updating data.

3 CRITICAL TECHNOLOGY

3.1 Embedded GIS

Embedded GIS integrate the GIS functions with the mobile technology; it is the expansion of GIS technology from the office into the field (ZHANG Shi-huang, 2001). A mobile GIS enables field-based personnel to capture, store, update, manipulate, analyze, and display geographic information. Mobile GIS integrates one or more of the following technologies: mobile devices, positioning system (GPS, GLONASS etc), and wireless communications for Internet GIS access.

A mobile GIS based on wireless communications can connect to a server through the use of wireless network and Internet. The mobile device sends request and the server return the results what the client needs. For the professional, the mobile GIS can be used to collect field data, and then transfer the data to a server by wireless network. The collected data is stored in GIS data format, and can be updated to the server timely. That will ensure the data can be updated promptly and the real-time of GIS. For the general user, the mobile GIS can get the latest local map from the server and query the place where is interesting. Combined with GPS, the mobile GIS can get the user coordinates and find a path showing how to go to the destinations.

3.2 Web Map Services

A Web Map Service (WMS) is a standard protocol for serving georeferenced map images over the Internet that are generated by a map server using data from a GIS database. A WMS request defines the geographic layer(s) and area of interest to be processed. The response to the request is one or more geo-registered map images that can be displayed in a browser application. The interface also supports the ability to specify whether the returned images should be transparent so that layers from multiple servers can be combined or not (Jeff de la Beaujardiere, 2004). WMS is a widely supported format for maps and GIS data accessed via the Internet and loaded into GIS software, on the client side.

The WMS can provide spatial data for the use form the Internet/Intranet, and can realize the map expression, map query and map positioning (Feng Jin-jun, 2006). The WMS promotes the spatial data switching and resource sharing. ArcGIS Server can provide map services capability which not only support mapping and map viewing, but can also support modelling and geoprocessing, mobile GIS services, and open publishing as OGC WMS and KML. When publishing a map service, it can be set to support mobile GIS services. So the field synchronous data collecting system can access the spatial data which have been published by the map service.

3.3 Global Positioning System

Global positioning system (GPS) provides reliable positioning, navigation, and timing services to worldwide users on a continuous basis in all weather, day and night, anywhere on or near the Earth (Jules G., 2002). GPS has become a widely used aid to navigation worldwide, and a useful tool for map-making, land surveying, commerce, scientific uses, tracking and surveillance.

Space-based augmentation system (SBAS) works on principles similar to DGPS. Correction signals are sent from a network of ground stations to a master ground station that transforms the signals into a grid of correction signals. The grid is sent to one or more geostationary satellites that orbit 36000km above the equator, and is then broadcast to Earth. The SBAS includes the WAAS of the United States, the EGNOS of Europe, and the MSAS of Japan (LIU Wen-tao, 2008). The MSAS signal cover Asia-Pacific Region, and most parts of china can receive MSAS signal. When the positioning precision demand is not high, we can make the GPS receiver get differential data from the MSAS.

The principle of difference GPS is one receiver (Base Station) set at the coordinated point, this receiver will calculate the differential data and send them to other receiver (Roving Station) real time (Kato, 2000). When the roving station is receiving the GPS data, it is also receiving the differential data to improve the positioning precision.

There are two kinds of DGPS: Real Time Differential (RTD) and Real Time Kinematic (RTK). And the positioning precision of RTK is much higher. So when surveying the monitoring point, we can choose the RTK GPS to acquire the coordinates.

3.4 Coordinate Conversion

The reference system of coordinate data received from GPS is WGS 84, but in china the usual coordinate systems are Beijing 54 and Xian 80. So we must convert the coordinate data from the WGS 84 to Beijing 54 or Xian 80. The WGS 84 coordinate system is one of the geographic coordinate systems; and the Beijing 54 or Xian 80 coordinate system is one of the planar coordinate systems.

There are many methods to complete the conversion. It is usually need two steps for the conversion. The following introduces the conversion between WGS 84 and the planar coordinate systems. The first step is convert the rectangular space coordinates of WGS 84 ellipsoid to the rectangular space coordinates of other ellipsoid. The Burse model is a useful method. It is need 7 parameters for the conversion (Zhang Fengju, 1999).

$$
\begin{aligned}
X &= (1+k)X_{84} + \varepsilon_z Y_{84} - \varepsilon_Y Z_{84} + \Delta X \\
Y &= (1+k)Y_{84} - \varepsilon_z X_{84} + \varepsilon_x Z_{84} + \Delta Y \\
Z &= (1+k)Z_{84} + \varepsilon_Y X_{84} - \varepsilon_x Y_{84} + \Delta Z
\end{aligned}
\tag{1}
$$

The second step is Gauss projection, this step convert the coordinate form geographic coordinate system to planar coordinate system (Zhang Fengju, 1999).

$$\begin{aligned} x &= X + \frac{l^2}{2} N \sin B \cos B \\ &+ \frac{l^4}{24} N \sin B \cos^3 B (5 - t^2 + 9\eta^2 + 4\eta^4) \\ &+ \frac{l^6}{720} N \sin B \cos^5 B (61 - 58t^2 + t^4) \\ y &= lN \cos B + \frac{l^3}{6} N \cos^3 B (1 - t^2 + \eta^2) \\ &+ \frac{l^5}{120} N \cos^5 B (5 - 18t^2 + t^4 + 14\eta^2 - 58\eta^2 t^2 \end{aligned} \tag{2}$$

3.5 ArcGIS Mobile

ArcGIS Mobile SDK is provided by ESRI for developing mobile GIS application; it is belong to the ArcGIS Server. The ArcGIS Mobile lets the mobile device like PDA accesses the mobile GIS services published by the server. The map data from the ArcSDE Geodatabase can be edited in the ArcGIS Mobile online or offline. If the data are edited offline, the result will be stored in the map cache, and can be updated to the server when the wireless network is available.

ArcGIS Mobile helps organizations deliver GIS capabilities and data from centralized servers to a range of mobile devices. We can use ArcGIS Mobile to deploy intuitive and productive mobile GIS applications to increase the accuracy and improve the currency of GIS data across your organization. It's easy to use ArcGIS Mobile applications enable field staffs who do not necessarily have any GIS experience to do Mapping, Spatial query, Sketching, GPS integration, GIS editing, Wireless data access to ArcGIS Server Web services (ESRI, 2007a). With the help of ArcGIS Mobile, the staff don't have to go back to update the data that he collected in field to the geodatabase; he can update the data by wireless network.

3.6 Web Services

Web services are self-described software entities which can be advertised, located, and used across the Internet using a set of standards such as SOAP, WSDL, and UDDI. Web services encapsulate application functionality and information resources, and make them available through programmatic interfaces, as opposed to the interfaces typically provided by traditional Web applications which are intended for manual interactions. Web Services connect computers and devices with each other using the Internet to exchange data and combine data in new ways (Sheila A, 2001). Web Services can be defined as software objects that can be assembled over the Internet using standard protocols to perform functions or execute business processes.

With the help of Web Services, the mobile device could do some complex operations that he can't complete itself. It just calls the functions published by the web services to perform tasks to get and update data. It needn't to implement the functions by the software in PDA.

4 SYSTEM IMPLEMENT

4.1 System Software Environment

Figure 4 shows the soft environment of Field Synchronous Data Collecting System of Mining Area Surface Deformation Information. On the server side, the database Oracle manages all the data, and the spatial DB Engine is used to operate the spatial data. The ArcGIS Server publishes map services which support mobile GIS access. On the mobile side, the system gets map data from the map service through the use of ArcGIS Mobile, and the coordinate data collected in field stored in the map layers. The attribute data stored in embedded database. For the PDA's functions are limited, it can't operate the data directly in the Oracle. So the system will call the web services methods published on the server to update data.

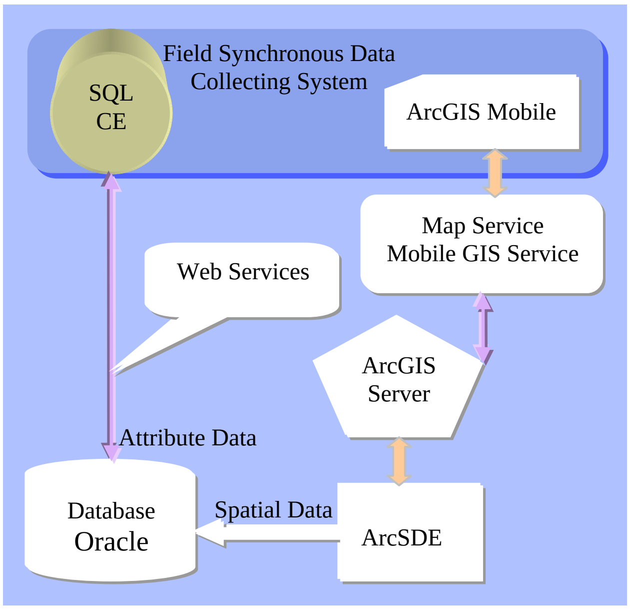

Figure 4. The software environment of System

4.2 Result

The field synchronous data collecting system of mining area surface deformation information based on wireless network supports Windows CE 5.0 and above. It is easy to use the system to collect data of Mining Area Surface Deformation and to update the data instantly to server by map service and web services from the wireless network. The system can get high accuracy positioning data by differential technology. And the system will convert the coordinate data of WGS 84 coordinate system to the coordinate system as specified in the project. Figure 5 shows two interfaces of the system.

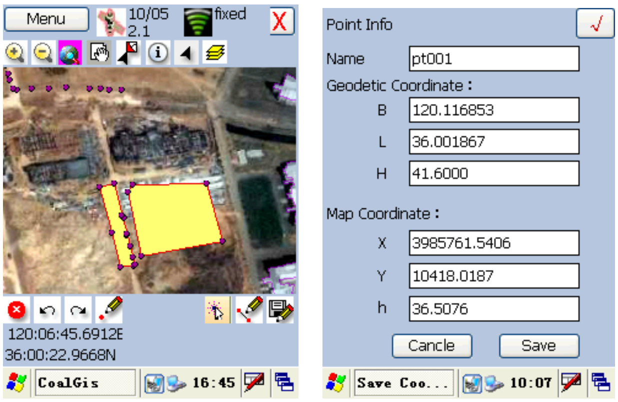

Figure 5. System map interface and the interface of collecting coordinate data.

5 CONCLUSIONS

The article discusses how to use web services and mobile GIS services to update data to the server by wireless network. With the SBAS and RTK technology can improve the positioning accuracy. Using the mobile GIS technique in field data acquisition will improve the efficiency of data updating. Developing a mobile GIS system for synchronous collecting the data of mining area surface deformation information can provide the latest data for analysing the changing situation of ground subsidence.

Reference

ESRI, 2007, ArcGIS Mobile Overview, California, America. http://www.esri.com/software/arcgis/arcgismobile/index.html, (Accessed 12 NOV. 2009)

Feng Jin-jun, Wang Ying, 2006. Research on WebGIS based on Web services. *Journal of North China Electric Power University*, 33(2), pp.101-104.

Jules G. McNeff, 2002. The Global Positioning System. *IEEE Transactions on Microwave Theory and Techniques*, 50(3), pp.645-652.

Jeff de la Beaujardiere, 2004. OGC Web Map Service Interface. *Open GIS Consortium Inc*, OGC 03-109r1, pp.34-36.

Kato T., Y. Terada, M. Kinoshita, H. Kakimoto, H. Isshiki, M. Matsuishi A. Yokoyama, and T. Tanno, 2000. Real-time observation tsunami by RTKGPS, *Earth Planets Space*, 52, pp.841–845.

LIU Wen-tao, XING Lu-lu, LIANG Hong, WANG Wen-hui, 2008. Bit Synchronization Design and Performance Simulation of Satellite Based Augmentation System (SBAS) Receiver, *Telecommunication Engineering*, 48(7), pp.54-56.

LIU Guang, GUO Hua-dong, RAMON Hanssen, 2008. The Application of InSar Technology to Mining Area Subsidence Monitoring, *Remote Sensing For Land & Resources*, 76(2), pp.51-52.

Sheila A, Mcllraith, Tran Cao Son, and Honglei Zeng, 2001. Semantic Web Services. *IEEE Intelligent Systems (Special Issue on Semantic Web)*, 16(2), pp.46-53.

ZHANG Shi-huang, FANG Yu, 2001. Development and Significance of Micro-Embedded GIS Software. *Journal of Image and Graphics*, 6(9), pp.901

Zhang Fengju, Zhang HuaHai, Zhao ChangSheng, Meng Lumin, Lu Xiushan, 1999. *Control Surveying*, China Coal Industry Publishing House, Beijing, pp.235-251.

APPENDIX

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