INTEGRATION OF GIS AND EOS FOR ENVIRONMENTAL SURVEY

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ABSTRACT:

With the implementation of Earth Observation System (EOS), various technologies related to Earth Observation (EO) have been dramatically improved and extensively used. Geographical Information Systems (GIS) has also been developed greatly in recent years. Very few researches, however, have been done to integrate GIS and EO. Through analyzing some problems in the application of existing EOS and GIS, this paper presents a conceptual model on how to integrate GIS with various EO technologies. Based on the model, this paper provides a scheme to integrate GIS, RS, GPS and various airborne survey systems including multi-channel γ spectrometer, airborne magnetometer, and SO_2, O_3, NO_x and aerosol detector. This scheme has been tested on Qinshan nuclear power station and its surrounding areas. From our fieldwork, it has been proven that the survey result is consistent with the scheme. This integrated system can also be applied to investigations of resources and environment, environmental surveys, geological explorations and disaster evaluations.

1. INTRODUCTION

Generally speaking, the traditional applications of GIS and EO in environmental survey can be summarized as follows: 1) Researches in GIS and researches in other fields are separate, and insufficient attention has been paid to their integration; 2) EO studies have mainly been focused on satellite-embarked sensor and the satellite system, but researches on airborne system are fairly limited; and 3) Great progress has been made in improving the instruments for physical geographical observation, very limited work, however, has been done to integrate them with GIS.

Thereby this paper aims at discussing the integration of GIS and various EO instrument. The organization structure of this paper is as follows: In the second section, we analyse the concept of TeleGeomatics and its characteristics. By integrating theories and technologies of GIS, EO, GPS and GSM, we propose an integrated application model of TeleGeomatics. In the third section, the components of the integrated model are examined. The fourth section projects a case study on how to integrate environmental airborne survey with the above model. Finally, the fifth section discusses the application of the integrated TeleGeomatics technology in such fields as disaster management, environment monitoring and urban planning.

2. THE CONCEPT OF TELE-GEOMATICS AND ITS APPLICATION MODEL

The concept of Geomatics has been discussed by numerous scholars (Maguire, D. J., Goodchild, M. F., & Rhind, D., 1991). In many fields, applications require real-time or near real-time data, hence wireless communication technologies are integrated with Geomatics technologies, which gives birth to the concept of “Tele-geomatics”. The applications of Tele-geomatics cover various fields which require real-time or near real-time spatial data. A specific example is field data acquisition, such as environmental survey (temperature, soil humidity, radiation). If real-time data transmission can be realized by using additional facilities when collecting environment data, then we can not only capture teledata, but also perform real-time decision-making. At the same time, it will be helpful in improving the measurement precision (M. Zingler, P. Fischer, J.Lichtenegger，1999).

2.1 The Evolvement of GIS Technology and the Formation of the Concept of "Geomatics"

The 30-year development history of GIS was driven by technology development, including hardware, software, data acquisition, and structure design. At the same time it was guided by the market demand, including demands from individual user, organizations, and millions of Internet users. The development of technologies has remodelled the characteristics of GIS, and affected every corner of our daily life. As Batty argued, GIS technologies have not only greatly impacted the development of other software technologies, but also been integrated with the data infrastructure in a society (Batty, 1999). Internet has been the focus of this process, which has aroused great attention on the real-time input and output of GIS.

Figure 1 demonstrates how GIS has integrated various current technologies and become a part of data infrastructure. Real-time data transmission in GIS has made it the key to related applications, such as traffic management, emergency service, and even real-time mapping. By updating data from handhold facility through wireless communication, it also supports basic daily applications such as urban navigation and information query. In fact, in the future, the new generation GIS will resort to the Internet and the wireless communication technology, and integrate real-time application, shortest-distance routing, and remote control. The connection between different hardwares, such as cable, TV, telephone, and computer, will integrate GIS and other software technologies through input and output （Graham and Marvin,1996）.

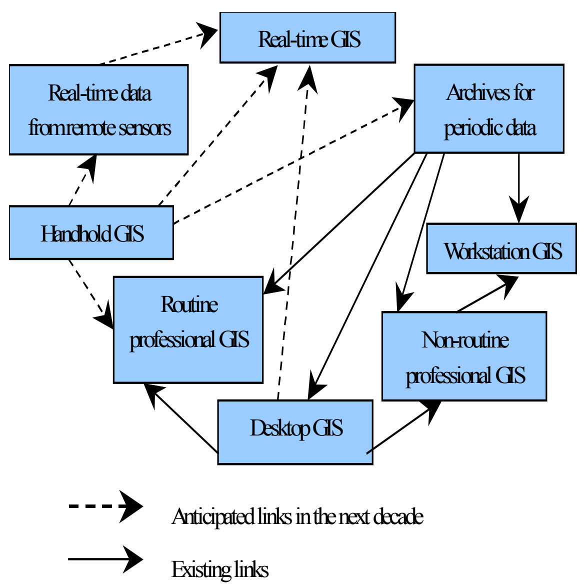

Figure 1. The evolution of GIS technologies (M Batty, 1999)

Nowadays, more and more attention has been paid to Geo-Spatial Information Science (it will be called Geomatics in the following sessions). Geomatics mainly includes Global Positional System (GPS), Geographic Information System (GIS), Remote Sensing (RS), and its key supporting technologies include computer technology and communication technology. It is a comprehensive and integrated information science used to collect, measure, analyse, store, manage, display, and distribute geo-spatial data. Geomatics is a preceding field in earth science and it is a significant element in geographic information science. It is still in its infancy as the development of its theory and its methodology is concerned. An integrated theoretical structure of Geomatics is yet to be constructed. The technology for geo-spatial data acquisition, storage, management, representation, and distribution is yet to be developed.

In the integrated application of 3S, different parts have different functionalities. GPS is mainly used for real-time target searching, including global positioning of various sensors and carriers (automobile, boats, airplanes, satellites, et al); RS is mainly used to supply real-time data about the targets, and its semantic or non-semantic information, detect all kinds of changes in the surface of the earth, and update GIS data; GIS is used for comprehensively processing, integrated management, and dynamic storage of temporal-spatial data from various inputs, it also acts as basic platform of new integrated system, and provides spatial knowledge for data acquisition using AI. In Geomatics, on the one hand it is urgent to solve the theoretical and technical problems related to the integration process; on the other, it is necessary to solve problems related to the application of the integrated system.

2.2 The Concept of TeleGeomatics and Its Characteristics

In the modern application of geography, it is common to integrate field survey data and EO data with some other data (such as data from aerial photos) using data collector. The further application is to bind positioning facilities and related communication technologies. For example, a field survey centre (immobile) can be built by connecting a handhold computer such as a PDA (Personal Digital Assistant) with a wireless communication system within certain distance. Furthermore, a data linkage can be built if several mobile platforms are connected to the field survey centre. More applications can be achieved if additional plug-in sensors are used, such as digital camcorder sensor for temperature and humidity measurement, radiation sensor for radiation measurement.

A high speed data acquisition system without using any paper will save lots of time and money in field survey. In some applications, PDA is used to avoid signal attenuation when the data to be communicated is very important. Sometimes cellular phones are integrated with GPS and connected to mini hand-hold computers to perform computation and display. In modern geographic applications, the demand for real-time communication and the demand for spatial information are usually twins. TeleGeomatics is the integration of spatial information and real-time management. It is not an application focusing on traditional map-making, but an integration of real-time management with spatial information. The characteristics of its application include: 1)the demand for GIS; 2) the demand for modern positional technique (e.g. GPS); 3) exchanging positioning information among various locations; 4) real-time Decision Support System (RTDSS); and 5) remote control.

TeleGeomatics uses GIS and various communication techniques to effectively transmit information and perform spatial analysis. All these spatial analyse are real-time and their ultimate goal is to provide real-time decision support. Here, "real-time", or "near real-time" is the time within the scope of human reaction, and usually lasts from several seconds to several minutes.

A TeleGeomatics system is a real-time geographic information system that strengthens decision support. It has a mechanism to support decision-making, for which purpose it has to have a complete system to transmit commands and information, and to execute commands. It also needs a remote activating mechanism, such as the typical automatic control facility (Boulmakoul,Laurini,1999-2000). It has an important application in dynamic environmental monitoring and remote control.

2.3 The Techniques for TeleGeomatics and Its Application Model

The way to connect field surveyors with the GIS platform is similar to the way central computing facilities are connected with outside users (M. Zingler, P. Fischer, J.Lichtenegger,1999). By connecting them together, it is possible to transmit data timely to users, and at the same time, field surveyors can return collected data.

Considering the limited computing capacity of hand-hold facilities, we can compare the characteristics of C/S linkage with the Internet: most data processing tasks are performed in the server side, and only some simple data processing tasks are done in the client side. They communicate with protocols. The conceptual model of this system is shown in Figure-2.

The field survey module that integrates mini-computer and cellular phone (such as NOKIA9110) should be able to support data input from handhold facility's front end. On the other hand, the immobile central computer uses communication software to process and store the received data. The central computer, which acts as server, as well as its affiliated facilities will send data to clients. Some standard commercial communication companies (such as GSM) or some other companies such as CORDAN will provide specialized wireless transmitters to transmit collected data. As we know, communication through GSM is usually limited by geographic conditions, which usually results in failure or communication blind spot. Only satellite communication system can provide error-proof and permanent connection without suffering from blind spots.

In order to obtain positioning data, the system needs to integrate GPS/DGPS facilities, which will be further discussed in the following sessions. The performance of GPS is determined by the quality of the signals, as well as the methods used (Hof-Wellenhof, Lichtenegger & Collins, 1991). Different field operation methods (dynamic or static) have different impacts on the way the positioning data are obtained, processed, and improved.

An applicable environmental monitoring system should be able to support information service. It is an effective as well as ideal method to increment information by integrating different data sources.

In a word, an important method to fulfil TeleGeomatics is to develop a complete data service system. TeleGeomatics system will guarantee the provision of objective, detailed, and updated data, as well as affiliated data sets. It provides not only standard data, but also detailed data for specific domain, which contain classified data or synthesized data. It not only uses common geographic matching system, but also resorts to topological relationships to build linkages between different data. What's more, it integrates field survey data transmitted from NRT. The fact that all the data (including GPS data and spatial data) can be effectively matched or joined together implies that we only need to concern about different types of data and their reference systems. We need to perform some transformation before transmitting the field survey data to our database if they are of different reference systems.

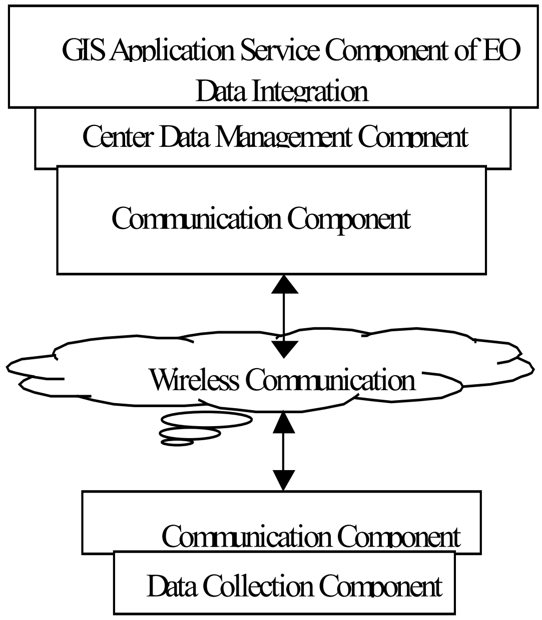

Figure 2. A Conceptual model of Telegeomatics system

3. THE FUNCTIONALITY DESIGN OF MAJOR COMPONENTS

TeleGeomatics may be realized through the development of technology for its components. It has four basic components: 1) field data acquisition component, 2) GPS location component, 3) communication interface component, and 4) GIS-based data integration and application component.

3.1 Field Data Acquisition Component

Field data acquisition component is the front end of the system, performing such tasks as graphic user interface (GUI), data management, device interface, and map display for the end user. Field data acquisition component includes such facilities as PDA with LCD display screen for data input and data formatting. It will provide datasheets that are easy to transmit through wireless communication and easy to use for central database. Due to the limit of the screen size, it is impossible to complete all the mappings by user interface. But we still need to design friendly user interface recognizable by fieldwork personnel.

3.2 Differentiated GPS Location Component

Apart from collecting environmental data, field data acquisition component also includes an important sensor, GPS. The error of an ordinary GPS could be several decameters. Even when SA policy is abolished, its error still could be five to ten meters. Hence, Differentiated GPS technology is needed. The locational precision of differentiated GPS may be about several decimeters. A higher accuracy may be attained if necessary supporting equipment is available.

Differentiated GPS positioning may use Garmin LP25 set. It can work with normal mode or differentiated mode. Combined with Accurate Positioning with Low Frequency service, differentiated positioning can be achieved. The corrected signal is transmitted by long wave transmitter in an interval of three seconds. Recently, quite a few cities are constructing such integrated GPS service networks.

The accuracy lies in the user's location and the distance between the user and the referenced station. Usually the error functions are linear, but sometimes there are random errors from constellations and other interferences. Researches indicate that existing technology can ensure required positioning accuracy（D.Fritsch, D.Klinec, S.Volz, 2001）. The average positioning accuracy in this experimental area is about three meters, and the maximum error of few stations is about ten meters. Such a positioning accuracy is high enough to be used for environmental survey.

3.3 Communication Interface Component

For a TeleGeomatics system, the communication component is very critical. Data collected in the field needs to be transmitted to the central server system timely. At the same time, central computer system also needs to transmit EO, RS or GIS data to the personnel in the field in time. Thereby, not only field data acquisition component but also the central computer system needs the support of the Communication Interface Component. There are many choices on how to physically connect the central computer system with Field Data Acquisition Component. For example, we can choose Internet or wireless communication, depending on our needs. If the communication facility is Wide Area Network (WAN), we may choose mobile telephone GSM, whose speed is higher than 64 KBPS, or potential systems like GPRS or UMTS, whose speed is higher than 2MBPS.

Communication Interface Component may be installed in the central control station. It can also be configured for the handhold computer in the field. When Communication Interface Component runs in the central control station, it can maintain communication connection, ensuring normal data receiving and transmitting between the client and the GIS server. Its foundation is software for Relation Database Management System (RDBMS), which is used for storing and updating received data. It is configured for chronically data storage, data access, and generating reports for field data transmission, so as to prevent the GIS server from being interrupted when transmitting data. GIS Application Service Component and Communication Interface Component are connected for map visualization and visually displaying the attribute information transmitted from Field Data Acquisition Component. When Communication Interface Component is configured for handhold computer. It allows configuring the ranges for accurate data recording, locating anchored points, and defining other input tables.

Field Data Acquisition Component will read GPS information and insert it in the corresponding field of a data template that is defined by the Communication Interface Component. DGPS antenna and receiver are used for accurate positioning. After GPS processes differentiated location information, Communication Interface Component packs the result and other information together and then transmit it to the central control station through communication connection.

3.4 GIS-based Application Components

The function of GIS-based Application Component is the most developed and complicated one comparing with others. GIS acts as a backend server that process information from spatial information communication system (such as DGPS, survey data, text file, and media). At the same time, the component analyzes and forms a variety of thematic maps to meet different users' needs.

4. A CASE STUDY

4.1 The Components of an Airborne Data Acquisition System

The conceptual model of this case study is shown in Figure 3. In this work a new technique is adopted to use various objects in one aircraft. In a γ-5 aircraft we install a Airborne Multi-Channel γ Spectrometer (made in Canada, MCA-2), a Airborne Magnetometer, a SO_2 and Aerosol Detector, a Global Positioning and Navigating System（GPS）, a system for data receiving, recording and control, and some other assistant systems（see Fig.4 The Chart of Airborne Monitoring System.）.

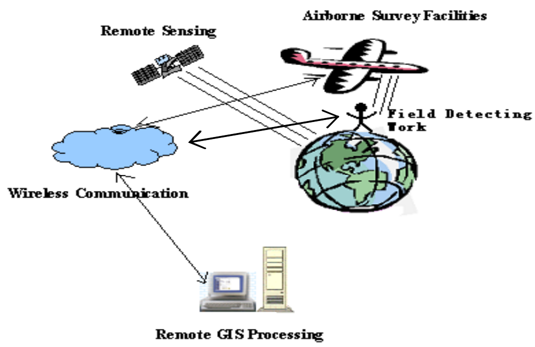

Figure 3. The conceptual model of the system

A γ spectrometer system consists of a NaI（TL）detector which has a lager volume（50L）and higher sensitivity（over 10%, at 662kev， forl37Cs, with spectral counter windows detecting γ ray radioactivity of Cs，Co，K，U，Th，and their total amount. Concentrations of the radioactive elements at ground level, such as K,U and Th, are determined, then the air absorbing dose rate（1m over ground）can be converted. The referenced data for ^{137}Cs and ^{60}Co are obtained by calculation and testing. The calibration factors（F（h）＝0.o165cps/Bq/m2）of ^{137}Cs,at l20m from ground level can be obtained by analogue test of data from point sources.

4.2 The Result

Airborne monitoring of radioactive levels and relevant environmental factors in Shanghai City and Qinshan Nuclear Power Station includes the following contents：

（1）Investigation of nature radioactive levels includes air absorbing dose rate, concentrations of the nature radioactive elements such as K,U and Th and their total amount;

（2）Airborne monitoring and evaluation of radioactive elements；

（3）Airborne monitoring of SO_2 and Aerosol in the atmosphere at chosen points.

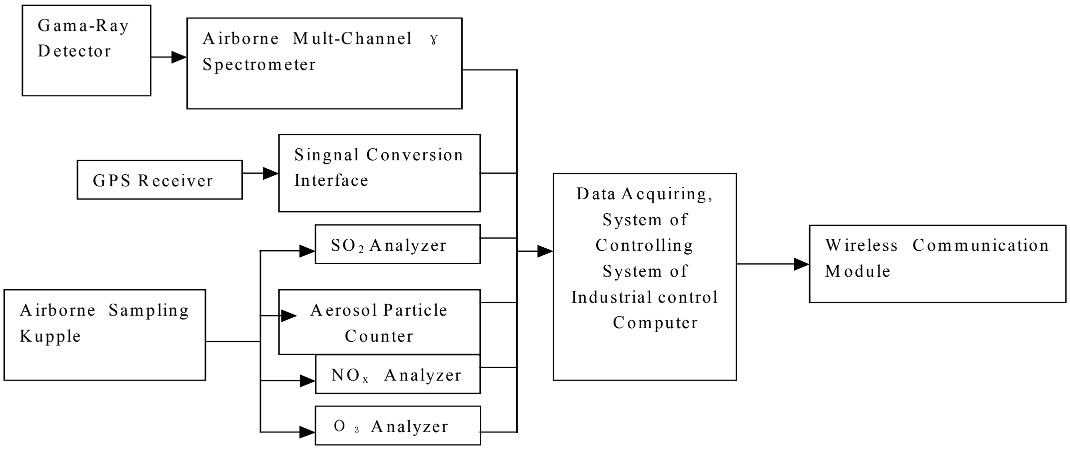

Figure 4. The Chart of Environmental Airborne Monitoring System

Airborne survey plan

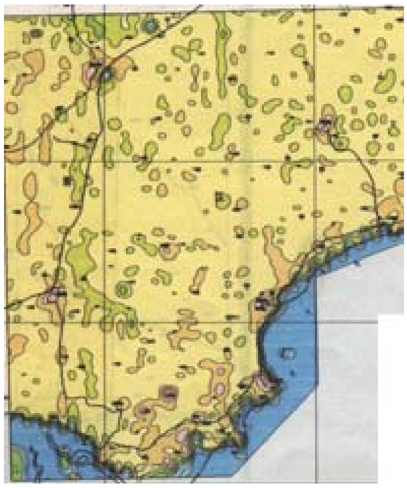

Fig 5b Air Absorbing Dose Rate

Fig 5c Horizontal Distribution of S02 Consistency over the Sample Area

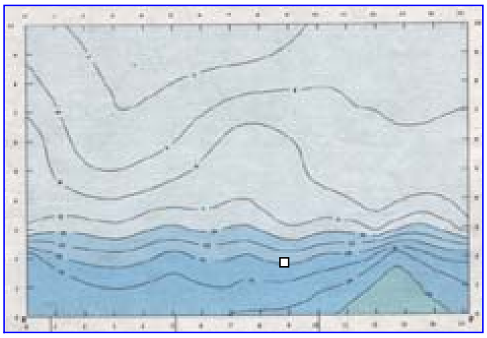

Fig.5d Vertical Distribution of S02 Consistency over the Sample Area

Figure 5. The research result of the example

The main work includes several stages: 1) equipment checking, testing, and calibrating; 2) Pre-exploration over the measured areas; 3) sampling and measuring ground radioactive level; 4) analysing data in the laboratory; 5) data correction in the ground station 6) data processing and analysing with central computers; and 7) mapping and compiling reports.

Simultaneously, remote sensing data from the satellite are used in the investigation of environmental factors in the corresponding areas. The main work includes collecting raw data, analysing data, making colour images, field investigation and verification, model construction, statistical analysis of multi-band image data, image interpretation and report compilation.

This system is designed for the environmental radioactivity survey of nuclear power station and its surrounding areas. At the same time, its conceptual model and method may be used in various surveys of environmental factors. In the future research, we will delve further into the integration of GIS and EO for other applications, such as environmental disaster monitoring.

5. CONCLUSIONS

Different from traditional GIS, the most distinct characteristic of TeleGeomatics is that it integrates wireless communication with geomatics. Wireless communication technology resolves many challenges from spatial information updating and real-time decision-making. The efficient integration of GIS and telecommunication will promote the extensive application of TeleGeomatics, whose key issue is about the development of telecommunication and the survey of relevant environmental factors. TeleGeomatics technology can be applied to construct typical Environmental Monitoring System (EMS). Using high-precision spatial positioning device can save time and costs for updating spatial database. Using TeleGeomatics to monitor and manage environments has great potential. It may be used in such fields as tracking the endangered species, detecting pollution sources, and mapping tourism resources. It can also be used for disaster management, mineral exploration and exploitation, and rescue work, et al. In the future, more efficient sensors for environmental variable detection are needed in order to expand the application areas of TeleGeomatics.

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