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Development of Urban Geology Information System Based on MapGIS

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ABSTRACT

The main objective of this study is to develop an implemented system based on MapGIS for managing and visualizing urban geology information, such as borehole, remote sensing (RS) data, geophysical and geochemical data-in Shanghai City. More than 20,000 boreholes, 80G byte RS data and other geological data were managed with three levels in the system. For the convenience of sharing information and building 3D geological model, standard forms of borehole and other geological data, such as cross-sections, were proposed. The design of urban geological datacenter is to ensure the possibility of geology information share. With B/S (browse/server) and C/S (client/server) architectures, the software architecture of the system is composed by three subsystems: (1) The data management subsystem supported by the data center; (2) The geological data analysis and appraisal subsystem running on the intranet with C/S architecture. Most functions of the developed system were integrated in this subsystem; (3) The urban geological data share and information issue subsystem running on the internet. It is built on the basis of Web GIS and provides functions, such as information search, statistical summaries and 3D geological model browsing, which are stored in the data center for the public. As a result, the system makes the efficient management for urban geology information possible and provides a 3D virtual visualization of underground geological environment with 3D geological modeling function.

INTRODUCTION

Analyzing the geological data is common and critical for geological investigations to acquire subsurface information. The geological data can be used to provide useful information for both surface and subsurface conditions. In the recent past, these datasets have widely been used in numerous fields, for example, civil works, exploration of natural resources, environmental problems, and transportation.

The geological data consist of borehole data, fracture data, and joint data. The magnitude and diversity of the geological data do not allow us to easily handle them without using any database or information system. The management of geological data has been one of the important research fields in engineering geology, geotechnical engineering, and Geographic Information

System (GIS). Chang and Park developed a system on the basis of a web-based GIS for onward management of boreholes and geological data. Qu et al. designed a geological data management and service system for the data cases of urban geological investigations. Several management and processing systems on the basis of GIS, Geotouch and Bore Is, were designed as a tool to store, manipulate, and put queries of data. Commercial software packages, for example, VIEWLOG, are also developed to manage the geologic data; this software can be used to handle the data from a range of popular databases, such as Microsoft Access, SQL Server, and Oracle. It is pertinent to highlight that despite many powerful features of VIEWLOG, it may not be feasible to use it on small-scale, that is, in small companies and within little research groups and so forth.

Geological maps—borehole histograms, rose diagrams, and joint isointensity diagrams—are widely being used in geology and they can intuitively express the important information of the subsurface, that is, the structure of the strata, sedimentary rules, and so forth. In the past, while constructing those maps, the engineers used to draw, modify, and fill the maps and patterns by hands, which was both time consuming and inaccurate. Due to rapid development of computer hardware and software, many researchers and experts have started to study the construction of geological maps by using the automated techniques. To model and visualize the borehole information and histograms, several boring and logging software [e.g., wellCAD, WinLOG, and Borehole tools in ArcScene have been developed. Many programs, for the automatic generations of the borehole diagrams, had been developed. Zhang and Luo devised a procedure to realize the drilling sections for automatic generation of logs, which was based on DpenGL 3D Platform combined with MFC second development method. Many other programs were based on MapGIS, which had been developed for borehole histogram for onward automatic mapping.

Once all the desired data have been entered into a GIS system, they can be combined to produce a wide variety of individual maps, depending on which data layers are included. One of the most common uses of GIS technology involves comparing natural features with human activity.

The Pre-1980 remote sensing technology in China was traditionally driven by downloading and storing data in computer. The fieldwork data was seldom delivered and transformed, which can hardly be traced by the data producer and end-users. The geosciences information had been collected with no geospatial reference and did not match with any standard data sets then. There was no connection between the geosciences data and end-users. From 1980 to 2000, China began to carry out the digital transformation of the traditional geosciences data including the construction of the National Fundamental GIS (NFGIS) databases, research on geo-information standards and digital survey of geomapping. These different geo-information databases were established on the basis of demand driven, application oriented and problem solving. However, the data was not well classified and the end-users were not clearly identified. There was a clear gap between the produced information and the absorbing of end-users. From 2000 to present, the expansion of GIS has changed the traditional survey methods and has increased the storage capacity in the use of this kind of technology by various geo-survey institutes in China. Numerous geo-information and databases were available to the growing number of related public and national institutions for their research and decision making. The developing technology of Earth orbiting and observing provides a better resolution of the geospatial data to normal end-users who are interested in the geo-information for their own usage. The computer training helps both the researchers and citizens to gather local and international geo-information for their own needs.

For instance, GIS maps can display what man-made features are near certain natural features, such as which homes and businesses are in areas prone to flooding. GIS technology also allows users to “dig deep” in a specific area with many kinds of information. Maps of a single city or neighborhood can relate such information as average income, book sales, or voting patterns. Any GIS data layer can be added or subtracted to the same map.

GIS maps can be used to show information about numbers and density. For example, GIS can show how many doctors there are in a neighborhood compared with the area’s population.

With GIS technology, researchers can also look at change over time. They can use satellite data to study topics such as the advance and retreat of ice cover in Polar Regions, and how that coverage has changed through time. A police precinct might study changes in crime data to help determine where to assign officers.

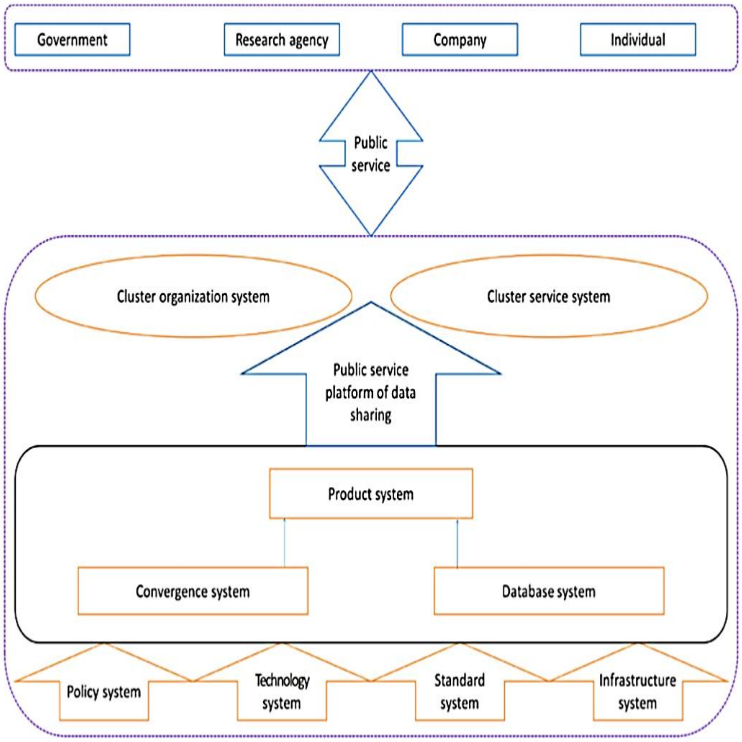
Once the actual fieldwork begins, the treatment plan and related data are downloaded to field computers for use by NYPA inspectors. These inspectors track the actual treatment in the field and then upload the data to the central server for future use. When a ROW field visit is repeated, NYPA uses the as-treated data to analyze how well the previous treatment cycle worked. John Wingfield, GIS/survey manager, reports, “On the first line where we had a repeated cycle, we saw a 60 percent non-compatible vegetation reduction. Presumably, on the next cycle we will see another significant reduction. Eventually, because of our IVM program, we will be using only a fraction of the herbicides and manual effort we had used in the first cycle. We have already saved a significant amount of money in the first cycle; ultimately, we will have saved money and had an ecologically positive result.”

Temporal Analysis: Observing environmental change over time indicates trends and patterns. ArcGIS Tracking Analyst provides tools for display and analysis of time series data. It is useful for playing back historical data, integrating temporal data within the GIS, and charting and analyzing change in historical or real-time data.

Three-Dimensional Analysis: GIS constructs three-dimensional composites that can be interactively visualized. Information such as lithological, geologic structure, and water-level data is represented in three-dimensional space by creating spatially continuous surfaces or grids using industry-accepted algorithms to interpolate between data points. This makes it possible to interpret three-dimensional data in two-dimensional space.

Data storage is one of the most important issues, while handling the vast amount of data for the geological survey. In the past, these datasets have been stored manually. However, it is not possible to deposit such large volumes of subsurface data manually. Some researchers developed tools; for example, Hou et al. developed and implemented system on the basis of MapGIS for onward managing the information of urban geology. Although their works were meaningful, it is not user-friendly because it had no user interfaces. Thus, the corresponding interfaces were designed to make the data stored easily and efficiently.

The storage of geological information is treated as very important step in the new geological system. To make the storage convenient, the interfaces for data input have been designed. There are two ways to input the data into the database of geological information by using the input module of the interface. First way is to enter it into an Excel template and thereafter enter it into the database. Next way is to enter the data into the database directly from the interface. Both of them are convenient for the most of users.



The basic framework of clustering and industrialization of geo-data information services

EXISTING METHOD

On a scientific level, GIS for environmental analysis is used to explore the spatial relationships, patterns, and processes of geographic, biological, and physical phenomena. The two primary methods of geospatial analysis include quantitative mapping and thematic mapping. A quantitative map shows how much of something is in a selected area. It is a spatial representation of numeric values such as temperatures, population density, elevation, pollution levels, and so forth. A thematic map demonstrates a specific feature or concept such as judicial boundaries, soil types, or flood zones. The combinations of data for environmental geospatial analysis are endless.

METHODOLOGY

The actual drilling process is complex, often with different diameters of drill, which leads to the sizes of boreholes to be changed. In many situations, borehole diameters may be changed many times within the same strata. The times are uncertain, so it is very difficult to put forward an algorithm of automatic generation method for different borehole diameters. Aiming at solving the problems, a new algorithm for variable boreholes was designed, the corresponding programs were written in code, and the corresponding interfaces were designed as well.

The basic principle of algorithm of automatic generation method for different boreholes can be plotted as follows:

$$[X] = [x(1), x(2), \ldots, x(n)]^T_{1\times n},$$

where [X] is an array that is used to record the thickness of strata, represents the number of the strata, and x(i) represents the thickness of the i_{th} rock stratum

$$[C] = [c(1), c(2), \ldots, c(m)]^T_{1\times m},$$

where [C] is an array that is used to record the depths, where the diameters of drill hole is changed, m represents the times of change in diameter of borehole, and c(i) represents the depth of the th change.

The equation can be expressed as follows:

$$[\text{Sum}] = [A] \times [X],$$

where $[A]$ is

$$[A] = \begin{bmatrix} 1 & 0 & \cdots & \cdots & \cdots & 0 \\ 1 & 1 & 0 & \cdots & 0 & 0 \\ 1 & 1 & 1 & 0 & \vdots & 0 \\ 1 & 1 & \cdots & 1 & 0 & \vdots \\ \vdots & 1 & \cdots & \cdots & 1 & 0 \\ 1 & 1 & \cdots & \cdots & 1 & 1 \end{bmatrix}_{n\times n},$$

$$[SX]_{m\times n} = [1, 1, \ldots, 1]^T_{1\times m} \times [\text{Sum}]^T_{n\times 1},$$

$$[SC]_{m\times n} = [C] \times [1, 1, \ldots, 1]_{1\times n},$$

$$[G]_{m\times n} = [SX]_{m\times n} - [SC]_{m\times n}$$

DATA CONTENTS

1. The cluster organization system is mainly composed of governmental, industrial and business entities. The governmental organizations are responsible for the land and resources administrative management; the collection and public services of the geological data are managed by the national, provincial and commissioned organizations. The success of producing an efficient and reliable metadata depends on different entities, which are creating and using data and information. The Development Research Center (DRC) and six regional centers of

the CGS are the main work forces for database development, regeneration and maintenance, computer network construction, and finally provide the professional services to the public. The data intermediary organizations and all levels of the geological prospecting organizations are in charge of commercial information services and constitute the organization systems of the business services. Now, there are 32 governmental administration organizations, 33 national and provincial data storage organizations, 35 data commissioned storage organizations and 6 professional servicing organizations in China. These organizations are responsible for collecting the geological data and providing public services. 35 commissioned storage organizations were commissioned by the MLR for storing oil and natural gas data in 2012.

2. The cluster service system is a 3-D network servicing pattern in conceptual design. Combining the conventional windowing with the modern networked servicing systems, the cluster service system is vertically consisted of integrated data services, regional data services, professional data services and primary data services, while horizontally of administrative public services, library public services, professional public services and commercial public services. Five geo-information servicing platforms are established in 2012 by the NGAC and provide more than 400 000 data catalogues for the public.
3. The product system involves a series of inter-connected servicing products including demand survey, data processing and system services. The product system research developed the basic theory of geological data production, the characteristics, factors and procedures of servicing products. The national and provincial geological data archives developed geological data searching, inquiring and browsing products. This helps the end-users find the products satisfying their needs. The NGAC compiled and provided the reliable, accurate and up-to-date geological survey maps for the governmental strategic planning and researches. The nationwide geological data integrated products supported the city construction and environmental protection, such as Shanghai 3-D city construction, Beijing ground subsidence monitoring, Anhui geological park planning and underground railway construction, 3-D digitalization of geological samples.
4. The convergence system is a standard mechanism for better submission and collection of the geological data. The MLR strengthened the geological data

management through the departmental regulations. The primary data, final report and geological samples are entirely collected and centralized stored in national and provincial geological data archives. The MLR established a monitoring platform for the national geological data submission in 2012. This platform improved the quality of geological data submitting and accomplished the unified supervision of geological data.

5. The database system is a geological data integration and regeneration process. It includes the construction of regional geological survey, regional hydro-geological survey, marine geological survey, professional geological survey, exploration of mineral resources, water and environmental exploration, geophysical and geochemical survey, remote sensing imaging, thematic geological maps and other different types of databases. Now, the NGAC established 11 graphic and text databases, and set up a service-oriented database for promoting the integration of geological data. 35th International Symposium on Remote Sensing of Environment (ISRSE35) IOP Publishing IOP Conf. Series: Earth and Environmental Science 17 (2014) 012259 doi:10.1088/1755-1315/17/1/012259 5
6. The policy system is the roles for each participating organization in the establishing and subsequent maintenance of the metadata requires. To work in harmony and use effectively, users and coordinating entities in the governments and private individuals need a stable policy system. As the increasing needs for metadata, the MLR has established and released a series of policies for data collecting, sharing and publishing of geological data, right of the users, and data services.
7. The technology system refers to the facilities of data interpreting, processing, publishing and the methodologies of geological data surveying. The NGAC integrated and exploited the number of geological information and developed a standard technology system for data collecting, mining, exchanging, processing and sharing processes. The users can obtain their information from the NGAC by the traditional, online and newly developed mobile services.
8. The standard system is a framework of providing common sets of terminology and definition for documentation of spatial data. As the standards of different nations must be consistent with those in related fields, standardization of data is a very serious problem. There need to be a common working ground to

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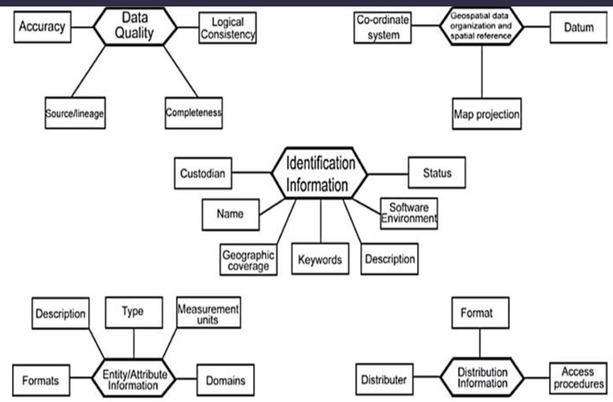
stand on for different users to cooperate and achieve their objectives. The standards of China geological data informationalization include fundamental standards, database standards and specifications of software system development. To support the databases development and informationalization, a series of standards have been issued since 1999. For spatial databases, CGS adopts uniform national geographic space reference coordinates system. Nowadays, China has established a servicing standard for geological information system framework, especially for the servicing description and searching protocol in NGAC.

9. The infrastructure system concerns the networked geospatial databases and data handling facilities. . A proper metadata requires a solid infrastructure of policy, administrative arrangement, technical standards, and fundamental databases. As the cauterization and industrialization of information services processing, national and provincial geological data centers have been constructed since 2010. In the meanwhile, the infrastructure system construction was written in the national geosciences data servicing project



CARRIER KEY ASSUMPTION

Geographic databases are no longer stand-alone commodities. Government and private organizations recognize the need for sharing geographic information and are working together to develop GIS-based small- and large-scale data products that will provide the foundation for national and regional spatial data infrastructures. ESRI has worked in cooperation with international GIS and information technology standards organizations and business partners such as Safe Software. ArcGIS is based on key interoperability and Web computing concepts and is used by tens of thousands of organizations that rely on GIS and information technology interoperability.

During the past decade, a network of organizations from around the world has begun to collaborate on a Global Spatial Data Infrastructure that supports the publishing of an open global library of digital geographic information. Internet portals allow people to publish, share, and use geographic data and services on the Web. These geospatial portals are made available to private, public, and commercial users; data publishers; service providers; and developers. The ESRI Portal Toolkit

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provides both the technology and professional support for building and managing data and applications and for deploying them in a service-oriented architecture using Internet and intranet environments.

CONCLUSION AND FUTURE WORK

In this study, 2D and 3D GIS technology were adopted to visualize those vast and diverse geological data, and the virtual geological environment underground in Shanghai City. An implemented system for urban geology information management, 3D geological modeling and web-issue was successfully designed and put in practice by using the MapGIS SDE, MapGIS TDE and MapGIS IMS software package. The various and vast amount of urban geological data were managed as three logical levels: original data, basic data and production data. Each level can be divided into several sub-classes by the professions. The standard forms for urban geological data were proposed and utilized in the implemented system. According to the real requirement of Shanghai City, an urban geological data center with 3D display center was designed for managing those large-scale data efficiently. The architecture and classification of functions in the system was proposed. All of the functions and data are linked with data flow in the system. The system architecture combined software, data, data standards and hardware and can be used as an infrastructure as data for other related applications, such as environmental project, urban plan.

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