

ON DEVELOPING SPATIAL DATA INFRASTRUCTURE OF CHINA

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ABSTRACT:

From Information Highway, Spatial Information Infrastructure (SDI) to Digital Earth, the requirement from the user raised new chances and challenges to GIS software. As a part of Digital Earth, the core of Digital China is SDI of the country and that of all levels of administrative regions. This paper discusses the requirement of GIS software system for the construction of SDIs of China in detail. As an initial solution for creating various levels of SDIs in China, GeoStar, a GIS software system capable of providing a powerful platform for integrating multi-source massive spatial data in distributed computing environment is introduced. Based on our successful experiences of GeoStar applied in a series of pilot projects of SDIs in China, it is concluded that GeoStar is a feasible solution of software environment for creating the country level and regional levels of SDIs in China.

1. INTRODUCTION

Despite the nature of globalization of the information revolution, most policies for information and telecommunications infrastructure are developed and working at the national level. These national policies reflect regional economic, social, historical, and political circumstances. Based on a dozen case studies analyzing how national-level policy initiatives address the challenge of information technology, interactive content, and new applications, the former US President, Bill Clinton, proposed the concept of "Information Highway" and issued the National Information Infrastructure (NII) Initiative in 1993. This Initiative clearly concluded that an advanced communications and information infrastructure should be a national priority of the US. This is the first proposed national information infrastructure in the world.

However, the economic, social and environmental development of the world is based on the use of land, water and other natural resources. Major activities of human being such as mining, farming, forestry, transport, tourism, coastal zone management and community services are directly operating on earth surface. It is well accepted that more than 80 percent of the information we concerned is spatial and geographical related. So, the National Spatial Data Infrastructure (National SDI, NSDI) is the core and foundation of NII. Consequently, in 1994 the Executive Order 12906 was issued for creating the US NSDI in order to further accelerate spatial data sharing and standardization. The concept of NSDI was in later years further extended to Global SDI (GSDI) and regional SDI. All these SDIs will provide a unified way to access geographic information at various levels by developing an online directory and distributed clearinghouse with consistent standards and policies for data sharing.

A conceptual breakthrough related to GSDI is Digital Earth (DE) proposed by the former US Vice President Al Gore in 1998. Al Gore described the DE as virtual representation of our planet that enables a person to explore and interact with the vast

amounts of natural and cultural information gathered about the Earth. It's obvious that GSDI is the mathematical base and spatial information framework of DE. As the first step of creating the DE, a lot of countries have started to develop NSDI and/or regional SDIs in recent years. China has also worked on all aspects to create a country level SDI and different levels of regional SDIs. Based on these National SDI and SDIs, all related information including natural, cultural, social, economical and historical information is integrated, fused and utilized through this platform to form digital city, digital province and Digital China.

This paper introduces our research on creating national and regional SDIs of China using distributed GIS platform GeoStar, a COM-based enterprise GIS software developed by Wuhan University. Section 2 discusses the technical requirements of GIS software as platform of SDI. Section 3 introduces the distributed GIS GeoStar that we applied to create SDIs in China. Section 4 introduces our experimental studies on creating Digital Shenzhen, SDI of Guangdong Province and the national SDI of China on GeoStar platform. Some conclusion remarks are given in section 5.

2. TECHNOLOGICAL REQUIREMENTS FOR SDI

2.1 The ability of integrating multi-source massive data into a seamless database

With the development of earth observation and data collection technologies, geo-spatial data has been in intensive explosion. Terabytes of data are generated from different programs everyday. A national SDI is required to carry massive multi-source data in a distributed computing environment. And, SDI is also required to take in the growing dataset and have the ability to updating data.

2.2 Object-Oriented and Flexible Architecture

Object-Oriented theory and programming provide a powerful way of modelling the structure of information in SDI. The mechanism of abstraction, inheritance and polymorphism makes an object-oriented GIS capable of protecting private information as well as opening public methods of geographical objects in SDI. More over, by object-oriented modelling, it is very easy to map the digital object to the real object of the world and to understand the behaviours of queries and analysis for various users. A GIS platform for SDI development should be in flexible architecture, extensible and easy for customisation.

2.3 Dynamic, multidimensional and real-time 3D visualization

SDI is a platform providing geographical information. It also has to provide "user interface" for various users to view the information. As DEM and 3D models are fundamental information in SDI, ready-to-use 2D display or 3D rendering tools are essential for GIS software for SDI. As is described in Al Gore's speech, users can view the earth from the space and zoom into a city, even a building. If the network bandwidth is broad enough in future, some real-time information such as running cars can be also viewed through the platform. So, SDI should have the capacity of integrating dynamic information.

2.4 Multi-scale representation

For applications, the collection and/or integration of spatial data at a wide variety of scales are very fundamental. The land use management in national, provincial and local level needs different accuracy. The multi-scaling representation with LOD technique in GIS software is a necessity.

2.5 Data fusion and information fusion

High level of data fusion technology has played an important role in utilization and development of increasingly complicated data like multi-source image. For instance, the relatively high resolution of SPOT panchromatic images is suitable for 1:50,000 land cover investigation, however, they have no spectral information at all. On the other hand, Landsat TM images possess rich spectral information and have been used for land cover classification for a long history, but their low spatial resolution limit their usage for 1:50,000 landcover investigation. Information fusion technology fuses these two kinds of images and the image fused is of spatial resolution as the SPOT image while keeps the spectral information as TM image.

2.6 Data mining and knowledge discovering from spatial DB

An SDI should provide a mechanism for users to navigate and search for geospatial information. Especially, the automatic interpretation of image and the extraction of semantic and non-semantic information from images need the intelligent decision-making support of GIS. Fortunately most of the knowledge needed for expert system (ES) just exists in GIS database implicitly, and which provide a mutual facilitative and interactively integrated environment for ES's development and applications.

2.7 Data mining and knowledge discovering from spatial

Interoperability is the capacity to access multiple resources through common approaches to allow interaction of the wide variety of information technologies. Interoperability is defined in standards, through agreement on terminology; adoption of defined protocols, and through distributed services on the Internet. Interoperability allows simultaneous use of multiple geo-spatial data sets without needing to change the underlying digital resources. As users request data from multiple digital resources the interoperability is apparent as the responses from each of the various digital resources can be combined in a standard Web Browser. This allows a user to request land, water and political boundary data from different sources and overlay the data with geographic accuracy, producing a product specific to the user's application.

2.8 Federated spatial databases

SDI is not an isolated system, but a distributed system with huge volume spatial data and related attributes data on wire and wireless computer networks. It is necessary to develop a distributed, heterogeneous and autonomous federated spatial database management system and to solve the data accessing of distributed heterogeneous component databases transparently, the data handling in collaboration in the aspect of spatial data operation, analysis and representation as well as the data delivering from data providers to end-users by web and mobile.

3. GEOSTAR: A GIS SOFTWARE FOR DEVELOPING SDIS

3.1 Main Features

GeoStar is a GIS software which is developed by Wuhan University, the former Wuhan Technical University of Surveying and Mapping (WTUSM) in China since 1992. The latest version was 4.0 released at the end of 2002. The object-oriented technology has been widely applied in the design and implementation of this software. There are seven major aims of GeoStar version 4.0 when designed. They also form the major features of this version of GeoStar. These features reflect the latest achievements of IT and object-relational database management system. These features are:

- Able to provide solutions for enterprises with image, vector, DEM and 3D models integrated into a single application
- Supporting object-relational database management system to manage massive spatial and attributes data,
- With flexible architecture supporting both B/S and/or C/S applications,
- Can be run in both Windows and Unix operation systems,
- Based on COM technology and easy for customization,
- With built-in 3D modeling and visualization tools,
- Compatible with old versions

3.2 Architecture

GeoStar v4.0 is 4-tier architecture as shown in Fig 1. The first layer is database SDC/ODBC layer. Both spatial and attributes are stored and managed in commercial relational database. For compatible purpose, data can also be in file format of lower version of GeoStar. The second layer is spatial COM/DCOM layer that contains kernel components of this system. The rationale of spatial semantics and primitive operations are implemented in this level. An extended OGC simple feature

object model is supported at this level. The third layer is user's interface ActiveX layer. Some major interface for building applications are provided as ActiveX controls. The fourth layer is application layer. Five standard application systems are provided here. The end user can directly use these systems by importing the application data. Experienced users can stay in this layer to build their personalized systems other than these standard application systems. They can use any programming language that capable of calling ActiveX controls and COM/DCOM. A lot of examples are provided to help the use to customize their own systems based on these example systems.

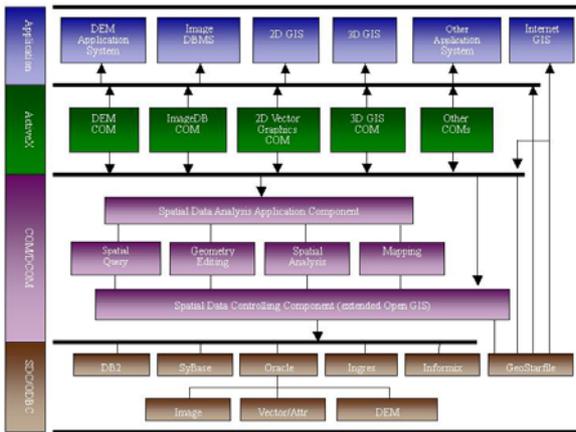


Fig 1. Component Architecture of GeoStar v4.0

Fig. 2 is the module architecture of GeoStar v4.0. The five standard application systems are 2D GIS GeoStar (note: this is the same name of the whole system), Internet GIS GeoSurf, image database management system GeoImageDB, DEM application system GeoDEM and 3D city GIS CCGIS. Customized systems can be B/S Internet GIS, C/S Intranet GIS or hybrid system integrating both Internet and Intranet applications.

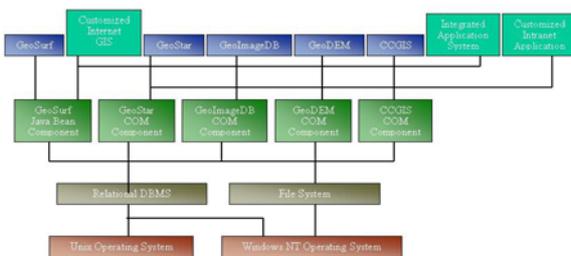


Fig 2. Module Architecture of GeoStar v4.0

3.3 Data Model

OGC proposed a simple feature specification in which 2D geographical objects are modeled in a hierarchical object system. However 3D models are not specified in this document. As GeoStar deals with 2D vector objects as well as 3D models, images and DEM, an extended object model, refer to Fig 3, is developed to address all these geographical information. This model is compatible with OGC proposed simple feature specification.

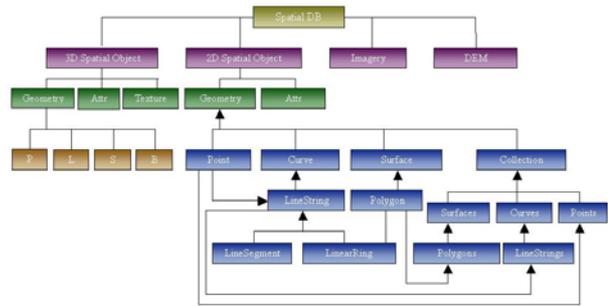


Fig 3. Data model of GeoStar v4.0

3.4 Data management

Data can be stored in any object-relational database system or even user-defined file system. The system provides a common data controlling components. Some standard interfaces are defined and any classes implemented these interfaces can access extended data storage system. For data store in Oracle, SQL Server and file format of lower version of GeoStar, a group of standard COMs are provided and can be directly applied. Users can also define their own data storage strategy in Oracle, SQL Server and any other RDBMS and file system provided that they implements common data access interfaces by themselves. This provides a mechanism to extend the system on user's decision.

3.5 Integrated platform

GeoStar is an integrated platform. It supports the integration of image, vector, DEM and 3D models within a window or a system. It supports B/S application, C/S application and integrated B/S and C/S applications. The GeoStar server implemented OGC WMS, OGC WFS and OGC WCS. It also supports GML for geographical data to transfer over the Internet. Fig 4 is a snapshot of WMS client with 2 layers of geographic data from two different servers that one is GeoStar server.

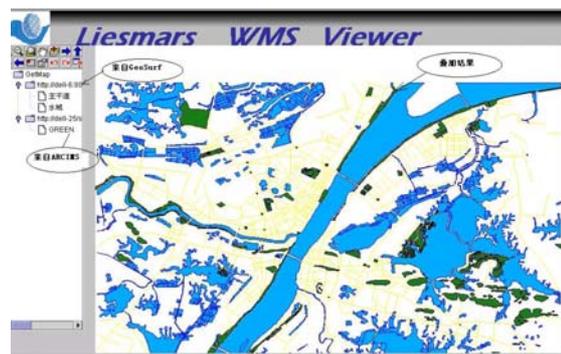


Fig 4. WMS client with two overlaid layers from two different WMS servers

4. EXPERIMENTAL STUDIES OF CREATING SDIS IN CHINA WITH GEOSTAR AND ORACLE

Some experimental studies of creating SDIs in China with GeoStar and Oracle are conducted, including three levels of SDIs in a hierarchical architecture. The lowest level is large-scale Digital Shenzhen, the second largest city in Guangdong province. The intermediate level is a mid-scale SDI of Guangdong Province, a typical province in south China. The

highest level is the small-scale national SDI of China, the kernel of Digital China.

4.1 Digital Shenzhen

Use the SI (Systeme Digital Shenzhen is an integrated intranet system for 3D city visualization and analysis system implemented by GeoStar. The data is stored in Oracle and managed by GeoStar Spatial Data Controlling Components. The client-side includes CCGIS modeling tool and 3D browser. It supports real-time model creating and updating to the database. The 3D browser can be deployed in any machine of the intranet. It manages 1:500~1:5000 multi-scale image, vector, DEM and 3D models. The total data size is near 100GB. Fig 5 is a snapshot of flying through a partially finished urban area in Digital Shenzhen.

4.2 SDI of Guangdong Province

The dominating scale of provincial level SDI is 1:10000. In the project of creating SDI of Guangdong Province, we imported several-hundred GB image data, graphic data and DEMs at scales from 1:10,000 through 1:250,000. The images are joined into seamless database at several scales. In some most active areas, even 1:500 images are included. All these data are stored in Oracle and managed by GeoStar Spatial Data Controlling Components. A lot of applications have been developed based on GeoStar COMs and ActiveX controls for various purposes. Fig 6 is a snapshot from the view tool of the system.



Fig 6. Integrated view of image, DEM and vector data in SDI of Guangdong Province

4.3 National SDI of China

The national level SDI of China includes image, vector and DEM in three scales: 1:1,000,000, 1:250,000 and 1:50,000. Table 1 shows the number of layers and data size of 1:50,000 scale in this system. The total size in this scale is 10TB and 671GB of this dataset is online over the Internet.

Data name	Data type	Size (GB)	Online Size(GB)	Note
DRG	Image	186	162	With 4m resolution
DEM	Vector, raster	1700	78	25m*25m grid
DOM-API	Image	6250	218	1m resolution ortho-image
DOM-TM30	Image	600	42	6 bands of 30m resolution, 1band of 15m resolution
DOM-S10	Raster	456	25	Panchromatic, 10m
CP	Text, raster	127	50	0.422 million points
DLG	Vector	122	56	Key elements, no contour
PN	Text	4	4	4 million items
LC	Raster, vector	30	10	30m resolution
MD	Text	10	10	
Other data		524	16	
Summery		10TB	671GB	

Table 1. 1:50,000 databases for National SDI of China

Fig. 7 shows that there are eleven 6° projection zones. GeoStar solved this problem and the end user can seamlessly roams across neighbour 6° zones.

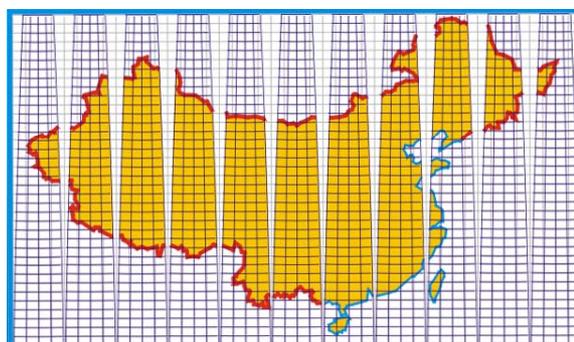


Fig 7. The 6° projection zones of China

All the spatial and attribute data are stored in Oracle and managed through the GeoStar Spatial Data Controlling Components. The project is expected to be finished in 2004. The DEM and DRG databases have been completed while DOQ and DLG database are on the way of creating.

5. CONCLUSIONS

The achievements in the technology of fast collecting GIS data and the demands to explore more from geographic information bring new chances and challenges to the R&D of GIS software. The history of conceptual evolution from NII, NSDI to Digital Earth also implies the future of GIS software. A lot more efforts are expected in how to address multi-scale, multi-resolution, multi-source, multi-temporal, multi-media, and multi-dimensional geographic information in a distributed computing environment.

For creating Digital Earth and NSDI, it is critical to integrating multiple huge databases. To meet various types of users, the GIS software should be customizable and of flexible architecture. From the experiences of creating Digital Shenzhen, SDI of Guangdong province and the country level SDI of China, GeoStar, a domestic enterprise version of GIS platform, provides a feasible solution as the GIS software for creating SDI of China at various levels.

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