# Development of Geographic Information Systems (GIS) in China: An Overview

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## Abstract

*Geographic information systems (GISs) were introduced into China (Mainland) in the 1970s. This paper provides an overview of the advances in GISs in Mainland China (not including Taiwan, Hong Kong, and Macau) during the past more than 20 years. It covers the developments of operational application systems, national geospatial databases, and technical systems. It also reviews the advances in research, education, and institutional development.*

## Introduction

Geographic information systems (GISs) were first introduced into China (excluding Taiwan, Hong Kong, and Macau) at the end of the 1970s. The early applications of GISs in the 1980s were either "technology-pushed" or "system-driven." A GIS was treated as a tool for geo-spatial data processing, and was used mainly for the automation of existing manual map-based operations, such as computer-assisted mapping, land suitability evaluation, environmental assessment, map data storage and retrieval, and so on (Yeh, 1985; Chen, 1986; Chen and Sun, 1989). On the whole, the applications of GIS were largely research-oriented pilot studies. Some systems remained in a continual cycle of pilot projects, and many GIS projects failed to deliver their originally anticipated benefits within the predefined time frame. End users could not make effective use of the systems, partly because the organizations involved had not trained sufficient experts (He and Jiang, 1992).

Since the beginning of the 1990s, the open-door policy and modernization process have motivated the development of more specialized and purposeful GIS applications and long-term and productivity-enhancing GIS application programs (Xu, 1998). There was a huge demand for the operational use of GISs in the fields of urban planning, land management, resource survey, and environmental analysis, with the purposes of rationally utilizing various resources, protecting the life-dependent environment, developing the economy, and raising the living standards of the general population. Radical technical advances also made GISs easier to use and more affordable. As a result, numerous GIS activities have been taking place in China. Both the government and private sectors have set up operational GISs for their daily work and strategic

planning, and for public use (Li and Chen, 2000). Quite a number of operational GISs have been set up in recent years.

In the early development, most of the GIS software systems were imported. Since the beginning of 1990s, many home-grown GISs have become available. Quite a number of them were already very advanced, even at that time. Homegrown GISs are normally less expensive than those imported, which drives more and more users to make use of them.

In recent years, the GIS industry in China has been booming. With the rapid growth of the GIS industry, a number of non-technical issues have become critical, i.e., data sharing, training of expertise, and basic research. The government has paid much attention to the development of a national spatial data infrastructure. Many universities have opened GIS programs. Scholars have paid more attention to basic research in GISs.

Indeed, a lot has happened to GISs in China in the last 20 years, so it is now the time to provide an overview of that development. The next section describes the development of operational application systems. This is followed by an examination of the development of multi-scale geospatial databases. Then the advances in technical system development are reported. This is followed by reviews of the advances in basic research. The next section then focuses on institutional and policy issues. Finally, an overview on education is provided.

## Development of Operational Application Systems

The operational use of GISs in China can be classified into three categories according to the nature of their utilization. The first is GISs used for day-to-day routine work, such as many urban GIS applications. The second is characterized by the strategic or senior management operation of government departments or major businesses, such as those used by local and central governments. Social GISs for use by the general public belong to the third category.

### Urban GIS for Day-to-Day Routine Work

As an increasing number of urban organizations are becoming proficient in the use of GIS tools for spatial data storage and mapping, interest in the past ten years has been moving towards handling routine tasks. *Computer Supported Collaborative Work* (CSCW) systems for urban planning and land management have been developed by integrating GISs with office automation in more than 30 large- and middle-sized cities, such as Changzhou, Guangzhou, Haikou, Liuzhou, Shanghai, Shenzhen, Tianjin, Xiamen, Yantai, and Zhongshan (Chen *et al.*, 1998a). Easy access to the data by contents is available and promotes information sharing within organizations.

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Specific desktop spatial data handling tools are provided for delineating land lots or building layouts on large-scale digital maps. The office automation functions consist of client applications registering, reasonableness checking, opinions giving and exchanging, permits printing, and documents filing. With the help of these operational CSCW systems, planning staff and land managers and their administrators perform building reviewing steps in a logical order instead of in artificial sequences. It is easier now for administrators to supervise the reviewing process, resolve conflicts, and settle negotiations through better control of information and the networked staff. The efficiency of collaborative decision making for building reviewing has been largely improved by reducing duplication of effort, minimizing redundant data collection and analysis, and maximizing the sharing of information (Chen *et al.*, 1998b).

Many other operational GISs can be found in city power network management, mobile phone network planning, real estate management, emergency response systems, bus navigation systems, etc.

It is now common for automated geographic information processing capabilities to be used to aid in the direct and immediate solution of location-related problems in urban business and operations. For example, an overlay analysis of large-scale digital maps and orthophotos has been used regularly by the Tianjin Construction Committee for planning road-widening projects.

### Strategic or Senior Management Operations in State and Provincial Departments
The applications of GISs in state and provincial governmental departments are more central to strategic or senior management operations. A GIS-based Comprehensive Situation Information System has been established in the State Council and in more than 20 provincial government headquarters (Zhang, 2001). A variety of socio-economic, environmental, and resources data has been integrated on the basis of the multi-scale geo-spatial data. Such systems have been playing an important role in strategic planning and spatial decision making. For instance, such a system served as a flood management (control) information system during the flood-control campaigns from 1997 to 2000. Real-time rainfall data as well as water levels at large reservoirs and hydrographic stations were transmitted and automatically added to the system. Figure 1 shows the flood area displayed in such a system. The loss caused by the flood has also been estimated. This network-based quick reporting system for flooding risk helped government officers to monitor and evaluate the floods so as to make prompt decisions (Sun, 1999).
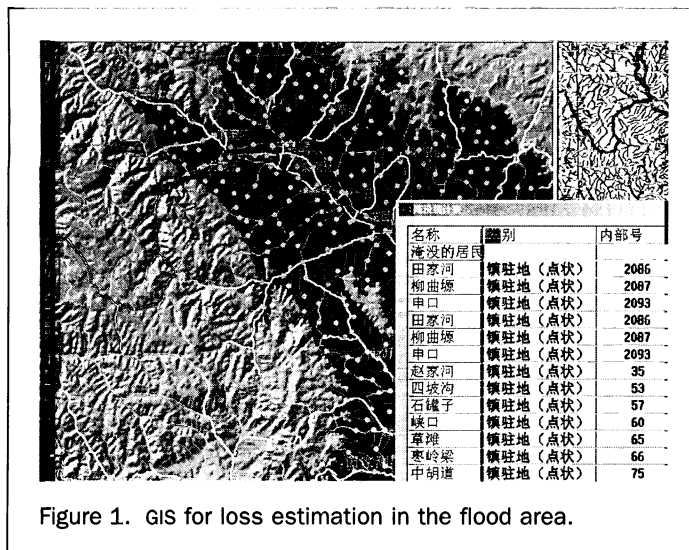

Figure 1. GIS for loss estimation in the flood area.


Figure 2. GIS to facilitate the negotiation of the international bounbary between China and Vietnam.

Operational applications of GISs have taken place in many other ministries and agencies, such as the Ministry of Foreign Affairs, the State Commission on Development and Planning, the Ministry of Finance, the State Bureau of Statistics, and the State Bureau of Environmental Protection. For example, a multi-media frontier GIS was developed for the Ministry of Foreign Affairs and it had been used to assist officers in the state boundary negotiation with Vietnam during the period of 1996–1999 (Figure 2).

There have been many successful applications of GISs in various engineering projects (such as hydraulic engineering for transporting water from the south to the north of the country, and road engineering for the planning and design of railways and highways) and resource surveys (such as the exploration for petrolium and other resources, and crop yield estimation for rice, corn, cotton, etc.). In most such applications, GISs have been integrated with spatial analysis models developed in other disciplines. For instance, crop growth models have been integrated with GIS spatial analysis capabilities for the yield estimation of rice, corn, and cotton (Chen, 2000).

### Social GIS for General Public Use
In recent years, many electronic mapping products have been published by the China Cartographic Publishing House and others. Examples of such products are the national general atlas of China, the history of China's Anti-Japanese War, the electronic map of Beijing 2000, and the tourist attractions of Beijing on CD-ROM. At the same time, web on-line based GIS services have been developed. For instance, the *Go__to Map* provides the public with the latest information about 34 large cities. The content includes transportation, tourism, shopping, dining, real estate, recreation, finance, education and training, and so on. The *Every Thing You Want to Know about Beijing on Line* provides information in both pictures and text regarding 3,400 place names, 1,400 blocks, 300 tourist attractions, 10,000 organizations, 1,000 real estate projects, and 400 bus lines in Beijing.

The website of the Bureau of Planning and Lands of City Shenzhen (*Du et al.*, 2000) also provides users with various types of spatial information (Figure 3).

Another example is the Networking Center for China Sustainable Development (http://www.sdinfo.net.cn), developed under China's Agenda 21. This serves as the gateway for general information on the country's sustainable development, and as a clearinghouse for information sharing. There are a total of 14 distributed sub-centers, covering the areas of land use, biodiversity, forests, marine, minerals, agriculture, climate change, disasters, environmental protection, etc. Free access to 122 databases is provided, including population, natural resources, environmental protection, and social-economic and natural disaster information.

## Development of Multi-Scale Geospatial Databases

As in many other developing countries, the availability of data was a bottleneck in earlier GIS development in China. The development of multi-scale core (fundamental) geospatial databases became the top priority of the central government since the late 1980s. Substantial human and financial resources were invested to establish national basic geographic databases and various thematic databases. The state, provincial, and municipal governments continue to be the biggest providers of geospatial data for GIS applications. Figure 4 illustrates the structure of the geospatial data production in China.

### National Geospatial Databases

At the national level, China's 1:1,000,000- and 1:250,000-scale topographic databases were completed in 1994 and 1998, respectively, by the State Bureau of Surveying and Mapping (SBSM). The 1:250,000-scale database is composed of topographic, geographic name, and DEM data sets. The topographic database consists of 816 map sheets and 14 feature layers. The geographic name database consists of 805,431 place names. The DEM database consists of data sets with two different grid sizes, one being 100m by 100m and the other 3″ by 3″.

In 1999, the SBSM started to develop its 1:50,000-scale database, which consists of seven datasets. The DRG (digital raster graph) dataset was completed at the end of 2000 and the 25- by 25-m DEM data set was completed at the end of 2001. Landsat 7 and SPOT images covering Mainland China were collected and used to produce 1:50,000-scale digital orthoimage maps
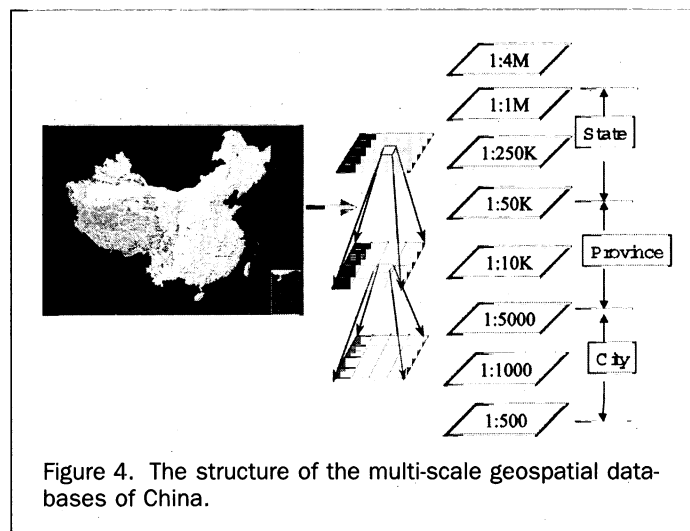


Figure 4. The structure of the multi-scale geospatial databases of China.

(DOMs). The 1:50,000-scale database is scheduled to be completed by the end of 2005.

Quite a number of projects have also been undertaken by other ministries and agencies to develop their thematic geospatial databases. For instance, the Ministry of Land Resources has digitized the 1:500,000-scale land-use and geological maps. It initiated a national project for digitizing the larger scale land-use maps and geological maps in 1999. Furthermore, some natural resources and environment databases at scales of 1:500,000, 1:1,000,000, and 1:4,000,000 were also set up by the Chinese Academy of Sciences (CAS) and other agencies. The main contents of these data sets include soil, vegetation, forests, geology, mines, earthquakes, etc.

### Provincial and Local Databases

The provincial surveying and mapping authorities are responsible for the development of the 1:10,000-scale topographic database. More than 35,439 sheets of maps at 1:10,000 scale had been updated and 21,340 sheets had been digitized by the end of the year 2000. The provincial land administrators are in the process of digitizing 1:10,000-scale land-use maps.

Larger scale digital datasets are produced by municipalities. For instance, in addition to the 322 map sheets of 1:10,000-scale data sets, the Shanghai municipality has produced 7,511 sheets of 1:2,000-scale digital maps covering the whole municipality; 5,060 sheets at 1:1,000 scale for the urban fringe area; 7,758 sheets at 1:500 scale for the downtown area; and 2,463 sheets of DOM at 1:2,000 scale. Shanghai has also established its GIS for real estate tenure management and land-use planning.

The Guangzhou Municipal Bureau of Planning has established databases with 1:500-scale digital topographic maps covering its 700 km² developing area, 1:500-scale digital maps of underground pipelines covering its built-up area, and 1:2,000-scale digital topographic and digital orthoimage maps covering the whole city.

Websites have been set up for these GIS data sources. A website for the National Fundamental GIS (nfgis.nsdi.gov.cn) has been set up and been in operational use since 2000. The catalogue information for map sheets at scales from 1:50,000 to 1:1,000,000 can be retrieved. The 1:4,000,000-scale vector data can be read and downloaded.

## Advances in Technical Systems

As more and more long-term and productivity-enhancing GIS application programs become operational, advanced technical
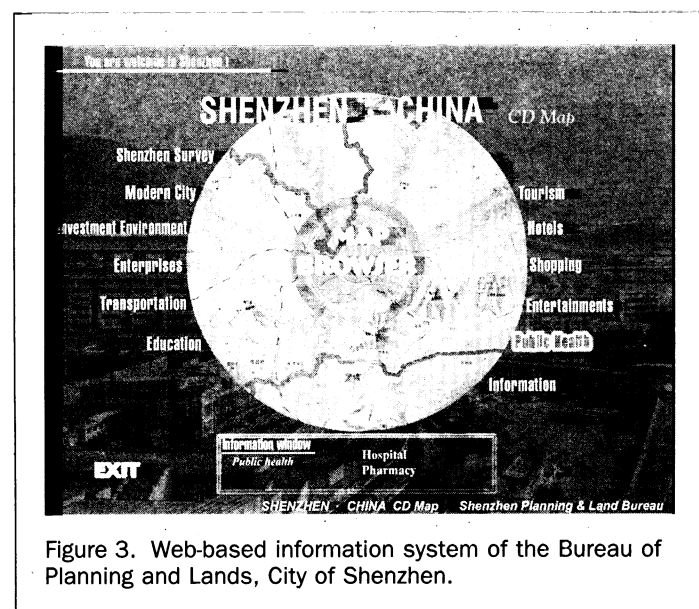


Figure 3. Web-based information system of the Bureau of Planning and Lands, City of Shenzhen.

systems and standardized products or services are required for increasing system performance and reducing the relative cost of computing (Strand, 2000). In China, many software systems have been developed for digital surveying and mapping, and geographic information handling.

### Development of Digital Surveying and Mapping Systems

In order to improve the ability of geospatial data acquisition, processing, analysis, management, and dissemination, the SBSM has developed digital surveying and mapping systems (DSMSs) by integrating GISs with remote sensing, the Global Positioning System (GPS), and digital data communication (DDC) technology. Figure 5 shows the digital production system employed by the SBSM. The homegrown digital photogrammetric workstations, raster-to-vector conversion packages, laser scanners, and other digital surveying and mapping systems have become the mainstream technology in the surveying and mapping community.

The VirtuOzo and JX4 are the two major digital photogrammetric workstations in use. They have not only acquired 90 percent of the domestic market but have also entered the international market for competition. Popular software products for field data collection, data conversion, and image processing include EPSW2000, EPSCAN 2000, Geoway, Photomapper, LT VRMap, etc.

### Development of GIS Software Systems

In the early stage of development, most GIS software was imported. Since the late 1980s, efforts have been made to develop homegrown GIS software systems. The initial efforts came from university laboratories and research institutes. Several GIS software packages were developed as the result of research projects. Since the mid 1990s, attention has been paid to the commercialization of such software.

In order to promote the industrialization and commercialization of homegrown GIS software products, an annual evaluation of such products has been organized by the State Science and Technology Commission (SSTC) and China Association for GIS since 1997. In such an evaluation, major GIS software packages are assessed against a set of nominated parameters (standards). The main items for assessment include software

functions, operational speeds, efficiency, user groups, user feedback, etc. As a result, the best products are recommended to users after the evaluation. Technical innovation has also been encouraged to improve the performance, applicability, and usability of GIS software products. A number of software companies have also been set up for marketing GIS products (Xu, 1998).

There are now a dozen commercial homegrown GIS software products. MAPGIS, GEOSTAR, CITYSTAR, MapEngine, and Supermap are among the popular commercial GIS platform software. AF Internet GIS, CD WebGIS, Geobeans, and Geosurf are popular website GIS software. Based on statistical data in 2000, homegrown GIS software has occupied about 30 percent of the domestic market (National GIS Software Evaluation Committee, 2000).

## Advances in Scientific Research in GIS

While the applications of GISs in China have been shifted from technology-driven to application-driven, it is now becoming more and more important to gain a better understanding of a set of fundamental scientific issues arising from, stimulated by, or surrounding the applications (Goodchild, 1995). Many of these issues came from the practice of handling geographical information, and many others were raised by pursuing scientific or application goals using GIS technology (Worboy, 1995). This has stimulated intensive research activities in geo-information science in China, and has broken down many of the old boundaries between disciplines.

### Research Groups

As early as 1986, a state key Laboratory on Resources and Environmental Information Systems (LREIS) was set up at the Institute of Geography of the Chinese Academy of Sciences (CAS). Another state key Laboratory on Information Engineering for Surveying, Mapping and Remote Sensing (LIESMARS) was established at the former Wuhan Technical University of Surveying and Mapping (WTUSM) in 1990.

With a background in geo sciences, the LREIS concentrates on the basic problems related to spatial analysis and geo-applications. Geo-information graphic analysis (*Tupu*) was proposed by the LREIS as a new research direction for enhancing



Figure 5. The digital production system employed by the State Bureau for Surveying and Mapping.
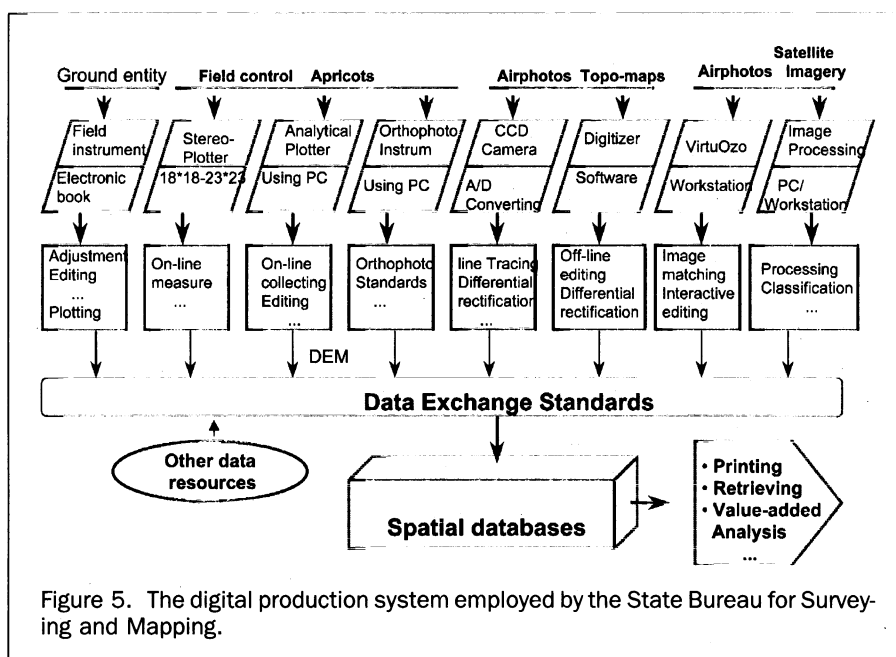
spatio-temporal analysis capabilities (Chen, 2000). The theory was used to design dynamic models according to the natural process or social economic development rules to simulate the past, to express the present, and to forecast the future. Some preliminary experiments have shown that applications of *Tupu* are encouraging in research on ocean tides, transportation routes, and resource evaluation along seashores and riverbanks.

The LIESMARS, on the other hand, focuses on the development of the basic theories and key technologies of remotely sensed data processing, GIS spatial data modeling and high precision positioning, and integrated systems and applications (Chen, 1994).

There are also more than 20 GIS research groups at other universities or research institutes.

### Funding Bodies and Research Areas

The basic study on geo-information sciences is funded mainly by the National Nature Science Foundation of China (NNSFC). Funding for 50 GIS-related research projects was granted to researchers by the Division of Geographical Science of the NNSFC during the period of 1991–2000. Seventy-five percent (75%) of the principal investigators come from universities. Spatial data modeling, spatial analysis models, spatial decision support systems, and system integration are among the hot topics of basic research in the past five years. For example, Voronoi spatial data models, spatial-temporal data modeling, 3D data modeling, and dynamic and multi-dimensional GISs were the major research areas.

It should be noted that more attention has also been devoted to the study of non-technical factors in the implementation of operational GISs. New concepts and methodologies have been developed or proposed, such as re-engineering the networked organization under the computer-supported collaborative work (CSCW) environment, shifting the organizational structure and the workflow, policies and regulations for assuring the operational use of the systems, education and training strategies, updating and budgeting mechanisms for fundamental geographical information, and data sharing.

### Publication of Research Results

From 1994 through 2000, 2562 papers with GIS as a keyword were published in domestic journals. The *Acta Geodetica et Cartographica Sinica, Journal of WTUSM, Journal of Remote Sensing, Journal of Geography*, and *Journal of Image and Graphics* are the top five Chinese journals that publish research papers on GIS. A journal in English, *Geospatial Information Science*, appeared in 1999, published by the Wuhan Technical University for Surveying and Mapping (now Wuhan University).

As a result of funding by the NNSFC for basic research, Chinese scholars have started to publish research results in international journals on GIS, such as the *International Journal of Geographical Information Science* (Li *et al.*, 1999; Chen *et al.*, 2001), *GeoInformatica* (Chen and Jiang, 2000; Chen *et al.*, 2000), and *Photogrammetric Engineering & Remote Sensing* (Gong and Li, 2000; Gong *et al.*, 2000).

In recent years, Chinese scholars have been very active in participation in international conferences on GIS and related areas. They have also presented many papers at such conferences.

### Scholarly Activities on the International Stage

In recent years, Chinese scholars have actively participated in scholarly activities on the international stage. For example, China is a participating member (P-member) of ISO/TC211. Chinese scholars have also played important roles in a number of geographic-information-related international organizations,

for example, as the President of Commission II of the International Society for Photogrammetry and Remote Sensing, as Vice-President of the International Cartographic Association, and so on.

Very encouragingly, a number of international conferences on GIS and related areas have recently been organized by Chinese scholars. Examples of such conferences include the first International Conference on Digital Earth (1999), the 9th International Symposium on Spatial Data Handling (2000), the International Conference on Cartography (2001), the first and second International Workshop on Dynamic and Multi-dimensional GIS (1997, 1999), etc.

### Institutional and Policy Development

Apart from the traditional geographic information organizations, some new organizations and companies have emerged during the last few years. For example, a number of geomatics or GIS centers have been set up at national, provincial, and city levels as geospatial data custodians in the context of the spatial data infrastructure. On the other hand, a variety of companies have been created or are emerging in GIS-related businesses. This section outlines some organizations at the national level.

### The GIS Association at the National Level

In order to promote the development of GIS professionals in China, an association was set up at the national level in 1994. It is called the China Association for GIS (CAGIS). Its main objectives are to foster exchanges between users, manufactures, and academics; to promote the operational use of GIS; and to disseminate new technology and experience (www.cagis.org.cn).

The CAGIS has ten commissions, as follows:

- Commission I: Theory and Methodology;
- Commission II: Standardization and Quality Control;
- Commission III: Geo-spatial Data;
- Commission IV: Education and Popularization;
- Commission V: Resources and Environment Application;
- Commission VI: Urban Information Systems;
- Commission VII: Government GIS;
- Commission VIII: Engineering Applications;
- Commission IX: Software Industry; and
- Commission X: Market Promotion.

The CAGIS now has over 3000 individual members and about 300 corporate members. It also publishes a professional journal— *Geomatics World* (in Chinese). CAGIS also organizes biennial GIS conferences.

### Geospatial Information Coordination at the National Level

A State Committee for Geospatial Information Coordination was established in 1999. This inter-department (ministry) organization consists of representatives from more than ten government departments (ministries) that have GIS-related business or activities. It aims to promote the national cooperative framework on geospatial information and to develop strategies and policies at the national level.

One of the policy developments is on geospatial data sharing. An Administrative Regulation on Licenses for Using National Fundamental Geographic Data was formulated and executed by the SBSM at the end of 1999. This regulation classifies users into three categories: i.e.,

- Central government agencies and provincial governments;
- Non-commercial organizations or individuals; and
- Commercial users, or non-commercial organizations using the data for commercial purposes.

The first category of users can obtain national fundamental geographic data free of charge for the purposes of decision making and social welfare. Users of the second category can obtain the data at favorable prices for internal or individual use in education, academic research, planning, and management,

or to provide research results to central government agencies and provincial governments for macro decision making and social welfare. Users of the third category can obtain the data at market prices. This has promoted the social services of national fundamental geographic information and the geospatial data sharing process in China.

In order to provide timely geospatial data, an updating and budgeting mechanism was established in 1997 for fundamental geographical information. The central government has set up a special budget for fundamental surveying and mapping. In fact, the amount of the funds has increased significantly.

### Standards at the National Level

During the establishment of the 1:250,000-scale national database, which was completed in 1998, several types of guidelines for standards were developed. They are, for instance (Jiang and Liu, 1999):

- Regulations for 1:250,000-scale topographic databases (general and data acquisition),
- Specifications for the collection of geographic name databases,
- Guidelines for the interfaces between the topographic databases and geographic name databases,
- Guidelines for quality control for the 1:250,000-scale databases, and
- Metadata for the 1:250,000-scale databases.

Since 1991, several national standards have been worked out and published as follows (Liu and Jiang, 1997):

- *Geographic grid* (GB 12409-90),
- *Classification and codes for national fundamental geographic information* (GB 13923-92),
- *Classification and codes for forest resources*,
- *Coding system of river names of China*,
- *Classification and codes for features on topographic maps at the scale 1:500, 1:1000, and 1:2000* (GB 14804-93),
- *Guide to standardization for Urban GIS, Coding structure and rules for urban geographic features—city roads, road intersections, blocks and municipal piping systems* (GB 14395-93),
- *National standard for spatial data transfer (GB/T 17798-1999)*;

It is worth noting here that it has taken only a few years for China to develop its national standard for spatial data transfer. The standard is a compromise between the SDTS of the United States and data file formats used by major GIS vendors in China. It takes features from various standards such as the SDTS, ISO 8211, DIGEST, NTF, GLD, DEM, DOQ, and DRG. Indeed, some concepts used in SDTS and ISO 8211 have been adopted directly or adopted with modification.

Some other standards are under development, such as data quality control and estimation, symbol systems for digital mapping at scales from 1:500 to 1:1,000,000, navigational maps, metadata standards, standards for data products and distribution, etc. (Liu and Jiang, 1999). The use of these standards lays out the basis for geospatial data sharing in China.

As a P-member of ISO/TC211, China has been actively involved in the activities of its working group, and some Chinese experts have taken part in the formulation of international geomatic standards. The National Technical Commission of Geographic Information Standardization (NTCGIS) was founded in 1997, and aims at promoting the standardization of geographic information at the national level. The NTCGIS continues to organize the formulation and revision of national geographic information standards; to coordinate, examine, and approve geomatic standards; to promote activities related to geomatic standards; and to give publicity to geomatic standards.

## Educational Development

The development of GIS applications and the GIS industry has had a tremendous impact on geospatial information education at universities and on-the-job training (Li and Hu, 1994; Li and Chen, 2000). There is a huge demand for GIS professionals (especially high-level professionals) in the market. As a result, about 100 universities and/or colleges offer GIS-related seminars or lectures at various departments (include surveying and mapping, geography, geology, earth science, environmental science, forest, hydraulic engineering, agriculture, urban planning, and so on).

### Degree Programs in GIS

In 1988 the first GIS program (geo-information engineering) at the under graduate level was established at the Wuhan Technical University for Surveying and Mapping (WTUSM) (now Wuhan University). Since then, more universities have started to offer GIS programs. It has been estimated that 50 universities are now offering four-year GIS programs, with an intake of about 1,500 students each year. Moreover, more and more universities are starting to offer courses at the M.Sc. level, and some universities have been granted the authority to offer Ph.D. degrees in GIS. About 100 M.Sc. and/or Ph.D. graduates per year have left universities for GIS enterprises or user communities since 1995.

Most undergraduate level GIS programs have been developed by geography, geology, or surveying departments, i.e., the spatially oriented disciplines. It is now encouraged to combine courses on spatial sciences with basic computer science courses in programming and data structures, leading to more advanced course work on spatial data structures, database design, and the development of various applications of interest to GIS trainees (Gold, 2000). On the other hand, many current GIS programs are more technology-oriented, and the career prospects of GIS graduates are constrained by this perception. Efforts are needed to include business-relevant and other non-technical topics (legal, personnel and managerial) in these GIS programs, to facilitate the strategic use of GIS (Rhind, 2000).

### On-the-Job Training in GIS

On-the-job training is another aspect of GIS education. A survey conducted by the SBSM in 1998 showed that 51.3 percent of professionals in the GIS area have only one to two years' experience and 55.1 percent are under 30 years of age. This means that more than half are young people who have just left university or college and recently begun to work. They are the main force now and will also be the main force in the future in GIS. However, they lack experience and multi-disciplinary knowledge. A three-level training program has been proposed and implemented by the SBSM for its employees for on-the-job GIS training.

Training courses are also run by GIS vendors, but only for training in the use of their own GIS software.

### Textbooks on GIS

In China, the publication of a book as a textbook is a complicated process. It needs approval from authorities at the Ministry of Education. Currently, there are around ten GIS and related textbooks. The textbooks are also classified into two types, one for undergraduates (e.g., Guo *et al.*, 1997; Wu *et al.*, 2001) and the other for postgraduates (e.g., Chen *et al.*, 1999).

However, there are quite a number of GIS books available on the market. An incomplete survey indicates that over 30 GIS books have been published in the past ten years. Some of them are non-officially used as popular textbook (e.g., Bian, 1996; Gong, 2001).

Recently, more specialized books related to GIS have also been authored and non-officially used as textbooks, such as *Virtual Geographic Environment* (Gong and Lin, 2001) and *Digital Elevation Models* (Li and Zhu, 2000).

Although a number of good GIS books have been published in China, a variety of important topics related to GIS education

are still waiting to be covered. The Education Commission of China Association for GIS is devoting its efforts to the publication of quality textbooks.

## Concluding Remarks

In this paper, an overview of the advances in GIS in China has been provided. It covers the developments of operational application systems, national geospatial databases, and technical systems. It also reviews the advances in research, education, and institutional development. However, this paper is confined to Mainland China and doesn't cover Taiwan, Hong Kong, and Macau.

From this review, it can be seen that, after the development over the last more than 20 years, more and more GISs are in operational use in China. These systems can deliver the originally anticipated benefits. It has also been found that spatial data infrastructure is underway and some components have already been completed. The central government is paying much attention to it. The GIS industry is booming, which has led many universities to open degree programs in GIS. The National Natural Science Foundation of China has funded more projects in GIS and related areas in recent years. Basic research is picking up quickly, and one could expect more papers authored by Chinese scholars to appear in reputable international journals.

However, there are still many issues to be tackled in the development of long-term and productivity-enhancing GIS application programs. Much attention has been paid to the development of dynamic and multi-dimensional GIS, and the development and maintenance of multi-level spatial data infrastructure.

## Acknowledgment

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# Call for Papers
## PE&RS Special Issue, April 2003

# Linear Feature Extraction From Remote Sensing Data For Road Centerline Delineation And Revision

This special issue will focus on linear feature extraction methods for highway and road centerline from remote sensing data. With recent advances in remote sensing technologies, the extraction of road centerline and other linear features from satellite and aerial imagery has gained a substantial interest in recent years. The primary goal is to offer a viable approach for accurate and cost-effective methods for road centerline delineation and revision of spatial databases using automated and semi-automated extraction techniques. The introduction of satellite imagery with high spectral and spatial resolutions is one enabling factor towards this goal. Yet even with significant advances in extraction techniques, the human operator still plays the principal role in extracting meaningful linear features and integrating them in GIS or other spatial databases. As with other human based feature collection tasks, accuracy, efficiency, and cost-effectiveness are the main variables in a production environment. At present, road centerline spatial databases still lack currency, and geometric as well as attribute accuracy. This affects many transportation infrastructure and other applications, particularly from an economical standpoint.

This special issue will address the state-of-the-art technology, research, and the challenges in automated linear feature extraction specifically designed for highway and road centerline databases from remote sensing imagery. In this specific context, the Special Issue encourages submission on topics that may include, but are not limited to, the following:

- Comprehensive survey, comparison, and evaluation of production-oriented linear feature extraction technologies,
- New visions and concepts in modeling the human capability of delineating linear features and recognizing associated attributes,
- The role of enabling technologies, such as hyperspectral and high-resolution imagery, and GIS interface,
- New techniques and the underlying theories for automated and semi-automated extraction methods, and
- Integration with GIS and other spatial databases and road networks.

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