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The Progress and Trend of Cartography and Geographic Information Engineering in China （2007-2011）

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Abstract: From traditional cartography to digital and information cartography, the cartography in china has made great development in 62 years since 1949. This report summarized the achievement in cartography and press techniques, automatic generalization of digital map, atlas, GIS software, visualization of geographic information and VGE techniques, spatial data mining and knowledge discovery, uncertainty of spatial data and cartography theory. Based on summarize, the direction of development is put forward by 6 fields: assimilation of spatial data, geo-analysis and spatial data mining, geographic information services based on internet, intelligence of spatial data generalization, integration of GIS and VGE and the theory cartography based on 'multi-pattern', 'space –time', 'integration' cognition model .
Keywords: cartography and GIS, achievement, direction of development

1. Introduction

From traditional cartography to digital and information cartography, China has made great progress in this field since 1949. Digital cartography was developed from traditional, but not limited in traditional cartography; and also, the information cartography was based on and overstepped digital cartography. Resent years, with the rapid development of ground observation and computer net communication techniques, cartography and geographic information engineering is undergoing a more obvious development.

2. The progress of cartography and geographic information engineering in China

(1) Modern integrated digital techniques are completely used in map making and publication

Computer techniques had made great revolution to cartography. China began the cartography devices and software researches since the end of 1980's, and developed the first applied colorful map publication system, which thoroughly instead of the long-time traditional manual map making. Since the 1990's, map making was transformed from manual simulation to digital computer operation. Integrated digital cartography has been the main approach of map making and publication. Especially the integration of geographic information system, geo-database, and remote sensing improved greatly the efficiencies, contents, varieties and currency of digital map. It is a milestone that all of the national serial scale maps, national atlases, province atlases, and the professional atlases adopt the integrated digital cartography and publication techniques now.

(2) The serial scale digital topographic map databases and the geographical databases are being established now for all of the areas of China.

China began the 1:50000 scale topographic survey since 1951, and took the correlative updating work from 1964. Up to 2003, the topographic survey of 1:50000 maps covered 7600000km^2 area of the China. From 2006, a new project termed as "1:50000 scale topographic survey of west vacant" was brought into effected, which filled the rest 2600000km^2 west area of China. In 2010, China produced the 1:50000, 1:250000, 1:500000, 1:1000000 scale topographic maps of the whole land. The 1:10000 scale maps i.e. the basic maps of provinces has also covered all the cities and towns. A larger project that aimed to establish the 1:1000000, 1:500000, 1:250000, and 1:50000 scale geographic spatial databases, ocean surveying and map databases, ortho-image databases, and 1:10000 scale databases of provinces are undergoing, which will make greater progress to the development of digital earth, digital China, digital provinces, digital cities, digital rivers, digital oceans, and take contributions to the national and regional economic programming, disaster-prevention, water conservancy, rebuild after disaster, important project and national defense etc.

(3) Research on automated cartographic generalization has broken through bottleneck and taken in to practical use.

As one of the most creatively research fields and challenges of cartography, cartographic generalization has attracted long attentions of many cartographers in the past decades. In China, the cartographers began the researches of cartographic generalization theories, methods and application since 1950's. From 1970's, the mathematical statistics method was used into cartographic generalization so as to ensure its quantity criteria. In 1990's, more researches put emphasis on cartographic generalization model, algorithms, human-computer interoperability, and the transaction of relationships. Especially since 2000's, China aimed at dealing with the combination process and features with intelligent automated cartographic generalization process control chain and quality assessment techniques, and made a great milestone i.e. transforming the subjective cartographic generalization process into the objective science. The modules of qualitative and quantitative describing, model and algorithm-oriented automated generalization process, usability interaction, integrated intelligent cartographic generalization and process control system, and design for quality forms a new theory and technology system of automated cartographic generalization, which will promote effectively the theories, methods, and techniques of deriving and updating multi-scale spatial databases, multi-representation of GIS, establishment of spatial data warehouse and so on.

(4) The press of state atlases, regional atlases and professional atlases become another milestone of cartography

The atlas publication is another signal project of cartography ad geographic information science. China atlas was one of the state projects authorized by the state department in early 1980's. It constituted of 5 volumes i.e. general, nature, agriculture, economic, and history sub-atlases. The agriculture atlas was firstly pressed in 1990; the economic atlas was published with both Chinese and English languages in 1993, and with CD style in 1995; the general atlas was printed in 1995 and published CD version in 1997; the nature atlas was published with both Chinese and English languages in 1998, and with CD style in 2006; the history atlas was divided into 3 parts and pressed in succession since 2009. All of the 5 volume atlases composed a whole, which summed up roundly the nature, economic, society and history of China. The publication of state atlas offered important supports not only for the programming and determination of state economic construction, development of society, but also for the scientific research, education and

so on. Furthermore, the press of state atlas promoted the development of province and city atlases greatly. For example, the “Atlas of Jiangsu Province”, “Atlas of Zhejiang Province”, “Atlas of Jiangxi Province”, “Atlas of Sinkiang”, “Atlas of Chongqing” were the typical instances, which were more advanced in design conception, content, express method, and print quality than the previous atlases. “Atlas of Shenzhen” achieved the outstanding award of cartography in 19th ICA. And the professional atlases for example “Atlas of State Nature Projection”, “Atlas of State Population”, “Administrative division atlas of China”, “Administrative place name atlas of China”, “Ground Source and Environment Remote Sensing Monitoring Atlas Around Beijing ”, “New Olympic Atlas of Beijing”, “Earthquake Disaster Atlas of Wenchuan”, and many city image atlases were also characteristic. Under this conditions, special application maps for example multimedia map, network map, navigation map of PDA were brought forward, and offered better services for populace. Especially during the 60th anniversary of China, a huge integrated atlas termed “Province division Atlas of China” was published and became one of the breaking projects in China.

(5) Instead of overseas, domestic GIS software systems became the main force in China

GIS was developed from cartography and map database, but exceeded them. It was the extension of cartography. In China, GIS started in 1980’s. At first, we imported oversea GIS software such as ArcInfo. Later, with the rapid development of domestic GIS domain, serial GIS teaching materials were published, and some domestic GIS software were developed and devoted into practical use in 1990’s. Since 2000’s, more GIS software productions were developed, and the function of them was transformed from the basic desktop to the integrated framework and serial professional productions for example MapGIS, SuperMap, GeoStar and other professional GIS software developed by armies. These GIS productions were widely used in resource, environment, traffic, telecom, energy, agriculture, forest, water conservancy, national defense, police, aeronautics and space, digital provinces, digital cites, digital rivers and digital oceans etc, and many GIS literatures and teaching materials were pressed at the same time. Supported with the rapid development of computer network, GIS software was extended from desktop to network and applied widely in every walk of life. Lots of applied GIS productions bore important roles in businesses, governments, companies, and individuals. However, different GIS users established different spatial databases according to their self needs, which led to multi-rebuilds in spatial data sources and produced large wastes because of the unshared and uncooperative distribution. In order to solve these kinds of problems, web service and grid service came into being. Supported with the eleventh five plans, 863 plan, science and technology plan of nation, many new projects were carried into execution so as to establish the cooperation mechanism under network, and build an open service environment to share the spatial geographic resources of different departments. We are glad to see that great progress comes into being these years in China.

(6) Spatial information visualization and virtual geographic environment techniques came into use widely

Spatial information visualization and virtual geographic environment technique is a new extension of cartography. At first, the spatial information visualization was used in terrain visualization. Later, graphic and image software was adopted to make visual geographic productions. For example, we used 3DS software to make geographic animations, lent OpenGL software to develop the real-time interactive 3-dimensional land simulation, and applied Performer and MultiGen software to establish the geo-model and real-time display in SGI workstation.

Developed from spatial information visualization, virtual geographic environment was a high level interactive system, which brought seeing, hearing, feeling, smelling into a cognition environment through 3-dimensional headpiece display, data glove, and dimensional sound earphone etc so as to let users immersed in computer environment. Of course, these kinds of devices were very expensive, only few universities and graduate schools bought some of them, which led to the great limitations to researches and applications. Now, the applications of spatial information visualization and virtual geographic environment are mainly focused on the following three aspects: first application is digital earth browse, and the second is distributed virtual geographic environment desktop, and the third is integrated software such as Google Earth, Worldwind,Skyline, Earthview3D, Arc Globe etc. In China, a similar software termed Geo Globe can attemper and romance large size spatial data in network. It builds a distributed virtual geographic environment with HLA (High Level Architecture). The integration of virtual geographic environment and GIS becomes a new trend because the multi-dimensional animate representation of virtual geographic environment and the data process and spatial analysis of GIS can be combined primely in this case. Now some virtual geographic information systems (VGIS) come into being and also a lot of theories of VGIS are also achieved at the same time.

(7) Spatial data mining and knowledge discovery (SDMKD) is developed from theory research to practical use

Spatial data mining and knowledge discovery means the unordinary process of achieving effective, novel, potential usable, final comprehensible knowledge. During the traditional map analysis and application, the knowledge was obtained through seeing and calculation, which was greatly limited by the experiences and knowledge of cartographers. One of the main functions of GIS is spatial analysis based on graph, and lots of potential usable information hided in large size spatial dataset is hard to be found. So, SDMKD is the extension of traditional map application and GIS analysis under digital cartographic environment. It accords with the development of GIS trend and need i.e. transforming from information collection to elaborate information processing. China began the SDMKD researches since 2000's. However, during the 1980's-1990's, China had started the research work of the cartographic data process model, method and spatial analysis, and put forward primary framework of SDMKD process i.e. "data preprocess---design and build of digital model---data process---design and establishment of map model---decipherment and application of map model". Since 1990's or especially 2000's, SDMKD appears some new characteristics: first, achieves a set of theory research harvests such as the literature "spatial data mining and application", which made in-depth discussion about the data clean, theory usability of spatial data mining, spatial statistic analysis theory of image texture, cloud model, data field, concept grid oriented spatial data mining, concluding learning and rough based spatial data mining, data mining and knowledge discoverer, spatial statistic based image mining etc, and introduced the development of spatial data mining system at the same time; second, the integration of spatial analysis, spatial data mining and knowledge discoverer produced advantages in spatial data management and process; third, SDMKD was developed from theory researches to practical use, and many application cases were achieved such as the SDMKD oriented data combination, analysis, assessment, and optimized decision support of regional glebe using and managing.

(8) Spatial data uncertainty are developed from theory research to producing process control and assessment

Spatial data uncertainty is a wider concept than measurement error, because the later one has a

well-rounded theories and methods. With the rapid development of GIS, the uncertainty of spatial data appeared not only in the process of measurement and cartography, but also in the whole process of information getting, data collection, store, process, analysis and application. So, researching on the reasons, process methods and propagation mechanism of error uncertainty of GIS becomes a widely attentive subject. China began the similar researches since the middle of 1990's and became a hot topic in 2000's. The main research topics were focused in the following three aspects: first, the basic geometry feature's confidence region of spatial data i.e. how to set confidence region of point, arc and region was the pivotal technique, which proceeded with error ellipse, the ellipse confidence region of point, and the ellipse and arc compositive confidence region; second, achieving the position uncertainty of regions by taking the region features of spatial data as a whole, in which the ε-band was confirmed by the average information entropy of the whole arcs' edge distribution, and extended the method into the error entropy model of region by the way; third, achieving the vice rate statistic model of attribute data through samples of data layers. For example in the literature "uncertainty theory of spatial data and spatial analysis", hot topics such as the origin of spatial data, spatial analysis, uncertainty relationship model and modeling of spatial data, visualization of uncertainty, and the application in spatial data mining and quality assessment and controllment were deeply discussed, and a web service oriented spatial data quality service system was brought forward. In another literature named "establishment and application of DEM accuracy model", a content framework of error analysis and accuracy model of DEM was put forward. The terrain oriented DEM accuracy assessment model, linear error transmission model of DEM, LOD error and quality assessment model of detail layers, the fusion model of DEM and spatial features were deeply discussed. And a practical framework about the quality assessment of DEM was designed at last. Especially a lot of research achievements on spatial data uncertainty and quality assessment were brought forward which ensured greatly the quality of spatial data in the past years.

(9) Theory research of cartography and geographic information engineering is transformed from tradition into modem

Cartography has been a broad continual research topic for long time. During the period of traditional cartography, theory researches were focused on three aspects i.e. map projection, cartographic generalization and map symbol. Map projection was the mathematic base of map; cartographic generalization was a immutable research field, which constituted of the basic theories, methods, statistic and applications of generalization; as the most basic representation of map, map symbol was used to show map in a visual type. Map projection, map generalization and map symbol composed the main parts of traditional cartography. Later, with the support of computer, many works that could not be down with slide rule and hand calculator could be finished by computer easily. So many new map projection methods were created, and could be drew or transformed by computer. Two literatures of "theory of digital cartography" and "theory and method of map projection" written by Chinese authors became the world well knew research achievements. Many scientific methods for example statistic, graph theory, ambiguous mathematics, artificial neural network, fractal geometry and so on were applied in automated cartographic generalization, and fused new theories and techniques. The main research topics of map symbol were the seeing effect of symbol design and application. And identifying vector features from image was another research aspect. Based on these, the transformation pattern, model and spatial cognition of map was developed. Since 2000's, information cartography was put

forward, and the transformation theory and method of map projection were ripely used in map making. Intelligent automated cartographic generalization, process control and quality assessment theory, method and technique became hot researches subjects. We also made great processes in the syntax, semantic and rule of map symbol. Supported with digital map, GIS, virtual geographic environment and spatial information transmission, new system info of map model, feeling, geo-ontology, spatial reasoning came into being, which illustrated the outstanding development and progress in cartography and geographic information engineering researches.

3. Trend of cartography and geographic information engineering

(1) Spatial data assimilation attracted more and more attentions

Assimilation means to proceed different things into the same or similar one, and the geographic spatial data assimilation means to transform different spatial datum, scale, temporal, semantic geographic data into a uniform standard entia so as to offer more advanced geographic spatial information servers for regional rules researches, integrated plan and management, and emergent decision and so on.

Now, the ground observation constituted with GIS, RS and GPS has been the primary approach of getting geographic spatial data, which is the main data of GIS. However, different datum, scale, temporal and semantics lead to the inconsistent and discontinue of GIS data, and is hard to be shared and updated. Thus, it is difficult to express unitary effect and domino effect to the grand analysis and decision for national and national defense. So how to uniform the spatial data structure, and build an effective assimilation desktop for geographic spatial data become important approach for human to cognize geographic environment.

(2) The development of cartography has been transformed from geographic information obtaining to geographic information in-depth processing

With the rapid development and wide use of GPS, RS and GIS, it became more and more easy to obtain spatial data. So we should put emphasis the research on in-depth information process so as to strength the functions of spatial analysis, data mining and knowledge discoverer and intelligent data process of GIS. In this kind, we can offer more effective geographic information productions for economic and national defense construction.

(3) The grid and network oriented geographic information service will be the central pattern

The concept, technique measure, production style and service mode of cartography were changing according to the development from traditional cartography to digital cartography, and the information cartography. During the period of traditional cartography, the main work of cartography was to make and offer papery map for users. During the period of digital cartography, its main work was to make and offer papery, digital and electronic map for users. And during the period of information cartography, its primary work was to offer integrated services of geographic spatial information. Information cartography made greater progress compared with traditional and digital cartography.

Lucky, the new techniques of network service and grid offered strength supports to solve the faced problems of cartography and GIS. Geographic information share and cooperation based on gird service becomes the hot research topic, and is being or will being the main pattern of information geographic information services.

(4) Rapid development of intelligent automated cartographic generalization will realize the automated map making

During the period of traditional cartography, cartographic generalization was the primary

theory of cartography. During the period of digital and information cartography, cartographic generalization was also one of the most challengeable and creatable problems. It was because of the needs of multi-representation of GIS, automated spatial database deriver of multi-scale geographic spatial databases, serial scale map making, and integrated spatial data updating of multi-scale geographic spatial databases.

Although cartographic generalization contained lots of creatable thinking, and led to the huge difficulties and complexions of automated cartographic generalization. During the long time development, cartographers made great progresses and produced breaking achievements, which took on wider applications of automated cartographic generalization.

In order to solve all problems of automated cartographic generalization, we should research on the intelligent automated generalization, which includes the basic theories, methods, quantity criteria, generalization model, algorithm and knowledge reasoning and so on, and take the process of automated generalization as a whole to assess and control automatically.

(5) Integration of GIS and virtual geographic environment

GIS and virtual geographic environment was both the extensions of computer technique, graph and image techniques in the field of geographic information engineering. GIS was the extension of cartography. Its functions were developed from simple query and index to spatial analysis, data mining and knowledge discoverer. Its representation approach was also developed from 2-dimensional visualization to 3-dimensional terrain, 3-dimensional city and so on. Combined with 3-dimensional visualization and the function of GIS, a new GIS termed 3DGIS came into being. And many extension applications such as integrated 3-dimensioal overground or underground pipeline GIS, 3-dimensioanl land record GIS etc appeared. With the rapid development of computer technique, integrated 3DGIS services under network environment came into being, which offered a more advanced developing condition for GIS and virtual geographic environment.

(6) Multi-pattern space-time integration cognition oriented cartography and geographic information engineering theory system info will bears more advanced development and be better rounded

Spatial cognition was one of the main parts of cognition subject. Since 1990’s, researchers put emphasized upon its spatial distribution, relationship, and the changing rules etc.

The main characteristics of multi-pattern spatial integrated cognition were “multi-pattern”, “space-time” and “integrated cognition”. Multi-pattern meant the types of research objects for example, map, GIS or virtual geographic environment etc. Space-time meant that the objects of cognition were multi-dimensional, distributable and changed with time. Integrated cognition meant to integrate the map, GIS, virtual geographic environment together so as to form a more comprehensive, systemic, depth, and scientific geographic environment cognition.

Multi-pattern space-time integrated cognition will become the basic theory of cartography and geographic information engineering, because it effects the whole process of cartography and geographic information engineering. The motive of cognition science is to describe the whole proceeding process of people’s cognition. The breaking development of cognition science will lead to the revolutions to education, society, economic development, information technique, and cartography and geographic information engineering at the same time.

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