Journal of Geographical Sciences 15, 1 (2005) 87–96 ISSN: 1009–637X www.geog.cn

Visualization issues in the development of electronic atlas in China

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Abstract: In this paper, we discuss the development of electronic atlas in China, with focus on the issues of visualization. We particularly categorise this development into four periods, and then analyse the characters in each period and discuss the visualization issues. The four periods are highlighted: 1) Infant period (<1990) characterized as computer assisted mapping with products of screen maps; 2) Starting period (1991-1995) characterized as object-oriented mapping with products of interactive maps/atlases; 3) Advancing period (1996-2000) characterized as integrated mapping with products of multimedia cartographic maps; 4) New era (> 2001) characterized as web mapping and adaptive map design with products of Internet maps and atlas as well as adaptive maps. It is obvious that the development follows the logical way from static to dynamic, and even real time visualization, from single user to multiple users, from presentation to exploration for effective communication and knowledge construction. Current research and development projects are focused on customisation of atlas information systems for real-time tasks, Internet operability, small displays and mobile environments. The major challenges involved in each of such customisation processes are identified and commented in relation to the further development of visualization.

Key words: computer-assisted mapping; interactive maps; multimedia maps; Internet maps; adaptive maps; electronic atlas
doi: 10.1360/gs050111

1 Introduction

Spatial data can be visualized and explored in various ways. Developments in hardware and software have led to and will surely continue to stimulate novel methods for visualizing spatial data and creation of electronic atlas information system. This has been witnessed world-widely over the last two decades (Changdi Computer Company, 1997; Institute of Geographic Sciences and Natural Resources Research, i.e., IGSNRR, 1996-2001; 2003; Liao *et al*., 1990; Lin and Loftin, 1998). Since the late 1980s, electronic atlas information system has been growing rapidly in many countries, esp. in USA, Canada, UK, Sweden, The Netherlands, Switzerland and so on (Biochip K *et al*., 1999; Liao *et al*., 1990; 2001). Instead of traditional map design and production, it has fundamentally changed the way of theoretical thinking and methodology of paper maps or paper atlas. With the development of computer mapping, geographic information system (GIS), computer graphics, WWW technology, artificial intelligence, virtual reality and cognitive science, user-adaptive interaction is being/has been brought into electronic atlas information system design, development and implementation (Liu and Jin, 1988).

In China, electronic atlas information system had its start in the late 1980s, paralleled to the GIS development, and was further developed in the early 1990s and gained a great leap after 1995. By reviewing its characteristics of development, we have highlighted four development periods as: 1) Infant period (<1990) characterized as computer assisted mapping with products of screen maps; 2) Starting period (1991-1995) characterized as object-oriented mapping with

Received: 2004-06-30 **Accepted:** 2004-11-19
Foundation: National Research Program of China, No.2003BA808A14
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products of interactive maps/atlases; 3) Advancing period (1996-2000) characterized as integrated mapping with products of multimedia cartographic maps; 4) New era (>2001) characterized as web mapping, real time visualization and adaptive map design with products of internet, mobile and adaptive maps. In the following sections, the paper will review the characteristics of each period, emphasize the key advances and highlight the future prospects.

2 Four periods of development

2.1 Infant period (prior to 1990)

Electronic atlas research and production in China may be traced back to the late 1970s and 1980s. It, at that time, can be characterized as a computer-aided mapping stage with overwhelming products of screen maps and many achievements in the research have laid the basis for electronic atlas information system development in the coming years. Researches and experiments have been conducted by a few institutions, such as Department of Cartography of Institute of Geography, Chinese Academy of Sciences (CAS), China University of Surveying and Mapping, etc., working in the area of cartographic automation, computer-aided mapping, mapping database design and software prototype development. The main hardware was based on personal computer 286, 386 or microcomputer. Computer graphics were limited to wire-frame representation of geographic objects and the screen display or refreshing rate of maps was rather slow. At that period, it was noted that the Institute of Geography, CAS (former IGSNRR) has pioneered its research and application in thematic computer mapping, and focused on thematic map design and initiated statistical mapping database and system. It was featured with the monograph of Thematic Map Automation by Liu and Liang (1981) in 1979 and other notable publications (Liu and Jin, 1988), and the Population Atlas of China were graphically designed and produced with the aid of personal computer and microcomputer in 1987, although it was printed in paper version.

This stage was paralleled to the commencing of Geographical Information System (GIS) in China. GIS advance was witnessed in hardware importing and software application. Unlikely, however, researchers in cartographical domain have focused on their original development, including many researches and experiments on the computer-aided mapping system design and intelligent mapping system development.

The sharp characteristic in this stage in China was that the cartographers in China were divided into two groups. One group followed GIS directions and used GIS mapping functions as a tool for mapping, less attention was paid to its own cartographical information system development and consequentially made a gap to GIS in the visualization system. And later some of those people were transferred to GIS domain and the rest remained in cartography has still used GIS functions for mapping but mainly presented in hardcopy. The other group in cartographic domain, especially in IGSNRR, started to study and design cartographical information system with emphasis on visualization and became the pioneers in the development of electronic atlas information system.

During 1980-1990, there were rarely any vector-based electronic atlases but a few raster-based electronic atlases or screen maps due to the limitation of hardware and software, although achievements have been made in computer-aided mapping database and system, such as geographical mapping database and statistical cartographic expert system. A few screen maps or atlases produced simply served for visual presentation of spatial data, and short of user interaction. At IGSNRR, the automated computer aided mapping research team was established and many research projects related to the topic were carried out.

2.2 Starting period (1991–1995)

World-widely during this period, scientists have made progress in improving GIS and visualization systems, in order to deal with time visualization of the real world and spatial data exploration (DiBiase *et al.*, 1992; Dorling D, 1992; MacEachren A M, 1994; Shepherd I D H, 1995). While in China, electronic maps have been developed with more interaction based on object-oriented to allow exploration of spatial data and production of atlas. The publishing of the National Economic Atlas of China in electronic version has marked the new era of electronic atlas information system with interactivity in China (IGSNRR, 1996), which was the first interactive electronic atlas information system in China produced by the Institute of Geography, CAS. The atlas system was created using self-developed software called EA-world (on Window platform and later transferred into the Windows 95 with improvement) with object-oriented design and programming approaches (Chu and Liu, 1996). EA-world system was composed of 5 modules named Mapmagic, SymbolMagic, ColorMagic, EA-Power and EA-Viewer. MapMagic modular is a mapping system and EA-Viewer modular is a viewing sub-system, and has user-friendly interface and allows users to self-design and self-produce maps or atlas using cartographic models and map colour and symbol library (including dot, line, square, circle, triangle, bar, pie, pyramid and other flexible combinations of them) according to data value and mapping rules. Maps can be viewed by category based on the functions of map view, zoom in/out, roam, query, statistical and spatial summarizing by region or property. This was the typical reflection of statistical mapping achievements in electronic atlas development and cartographic visualization. In terms of statistical mapping functions at that time, EA-World had many advantages over ArcView package. However, there was much space for improvements, such as flexibility for ordinary users and interactivity. During this period, other cartographical research and application organizations have initiated projects for the production of electronic atlas. However, only a few bore fruit and had inherited thinking models for paper map production.

The notable products in this stage included the National Economic Atlas of China and the National Population Atlas of China made by EA-World system.

2.3 Advancing period (1995–2000)

This was the period of interactive, analytical and three dimensional representation. Highly interactive exploration of spatial data was developed to allow users a complete control of the representation procedure (Andrienko G and Andrienko N, 1999). Researchers at the University of California, Los Angeles have developed an Urban Simulator which links a real-time 3D visual simulation system with traditional 2D GIS and databases to facilitate the modelling, display and evaluation of physical environments (Jepson, Liggett and Friedman, 2001). Recently, VR-techniques are used more and more frequently to create a simulated reality representing the real world in a very direct way (Lin and Loftin, 1998).

The production of electronic atlas information system in China boomed during this period with characters of 1) more institutions involved; 2) more products published; 3) more areas touched, 4) more functions included and 5) more domains extended. Additional to IGSNRR, the main institutions involved extended to map production institutions and computer companies, which included cartographic research institutes such as Wuhan Surveying & Mapping University of Science and Technology, Chinese Academy of Surveying & Mapping, map production institution such as China Cartographic Publishing House and mapping companies such as Beijing Changdi Mapping Company, Shanghai Motian Company, Beijing Great Wall Computer Company, Beijing Supermap Company and so on.

In this period, more electronic atlases were published (Changdi Computer Company, 1997; Chinese Academy of Surveying and Mapping, 1999; Ding and Liu, 2001; IGSNRR, 1996-2000), concerning many professional and public applications. The typical products by IGSNRR included Hong Kong Electronic Atlas (English and Chinese version), Comprehensive Economic Data Atlas of China (English version), Tibet Multimedia Electronic Atlas (English and Chinese version), Electronic Enterprises Atlas of China, Electronic Industrial Atlas of China, Yunnan Multimedia Electronic Atlas for Tourism. Besides, other well-known products included General Electronic Atlas of China, Beijing City Tour Guide, Shanghai City Tour Guide, Beijing Electronic Atlas, The Digital Atlas of China, The Digital Historical Atlas of China, Electronic

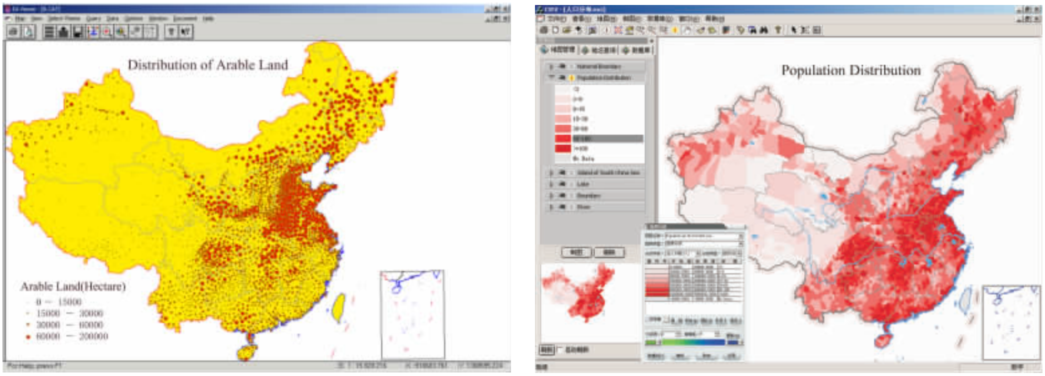

Figure 1 User interface in EA-World and Chinese Regional Development Atlas

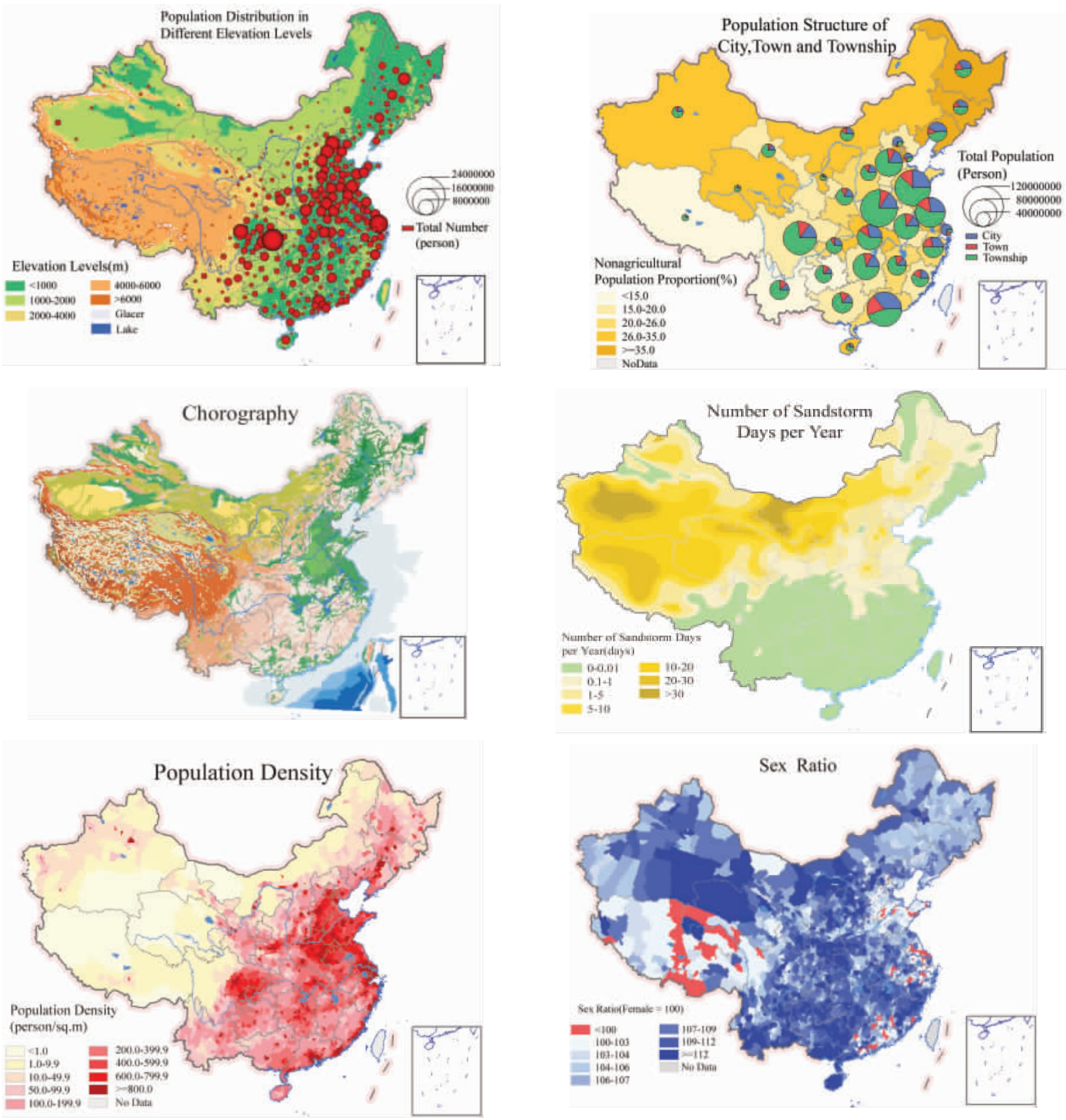

Figure 2 Sample maps made by spatial statistical mapping system

Atlas of Chinese Cities and the Fifth Census Atlas. They were produced as CD-ROM by the above-mentioned institutions.

Several mapping systems, based on object-oriented design and programming with multi-functions of data input/output, data format transfer, processing and management, map view, browse and query, statistical and spatial analysis as well as multimedia integration, were developed and popularised by IGSNRR and other institutions. They were more users friendly with more powerful interactive functions. Additionally, they integrated multimedia functions by linking programming and multimedia techniques to visually explore and mining data. The typical atlas information systems developed in the Institute of Geography are listed as follows: the integrated multimedia spatial information system (as the supportive platform for Tibetan Multimedia Electronic Atlas, Yuxi Multimedia Electronic Atlas for Tourism, Chinese Geo-name Atlas etc.), which now has developed as geo-name management system and tourism management system; digital city mapping system (as the supportive platform for Hong Kong Electronic Atlas, Beijing Electronic Atlas, Xi'an Electronic Atlas, etc.), which now has developed as spatial navigation system by linking GPS and telecommunication protocol installed on normal PC and PDA; the spatial statistical mapping system (see Figure 2, as the supportive platform for the Electronic Atlas of Population, Environmental and Sustainable Development, National Enterprise Electronic Atlas, National Economic Electronic Atlas, National Industrial Electronic Atlas, The Fifth Census Atlas, etc. See Figures 1 and 2), Supermap mapping system developed by Supermap GIS Company under IGSNRR (as the supportive platform for Guangzhou Electronic City Atlas, National Physical Atlas of China, etc.).

Notably in this period, three dimensional and dynamic visualization techniques in desktop and Internet systems have been addressed in cartographic research and applied in electronic atlas production (Liu and Zhang, 2001; Wang *et al*., 2001; Yu *et al*., 2001). In IGSNRR, multi-perspective, three dimensional and spatial-temporal cartographic model and visualization, screen map design and generalization, etc, have drawn much attention. The application has been extended from the social-economic statistics to tourism, urban planning and management, regional planning, sustainable development, telecommunication, transportation and natural resources management.

The web-based map system developed by Java in IGSNRR began to work in 1999, which has the cross-platform functions in map display, fast roaming, fuzzy and logic query (Liao, 2001). Three-dimensional system developed in cartographical domain in IGSNRR has multi-functions in quick roam, overlay and other 3D analysis tools.

2.4 New period (> 2001)

The new development stage, on one hand, is characterized by the trends of incorporating modern techniques such as mobile computing, telecommunications, Internet and GPS with geo-visualization, and more applications are market-oriented. On the other hand, a user-centred methodology has increasingly received attention, which aims at preventing new techniques from misleading map users, creating an adaptive environment for information representation, analysis and exploration, and narrowing the gap between designers/producers and users (Chen, 2000; Wang *et al*., 2001; Yu *et al*., 2001).

Recently, many presses or publishing institutions have been involved in publishing electronic atlas, including Chinese Cartographic Publishing House, Science Press, Xingqiu Cartographic Publishing House, Chinese Electronic Publishing House, China Wanfang Electronic Publishing House and other provincial presses.

The prosperity of electronic atlases in IGSNRR has experienced over ten-year pre-stage of computer-aided mapping and nearly ten-year rapid stage of geo-visualization and electronic atlas development. So far, more than six National Atlases have been completed using computer mapping technique and integrated mapping publishing system, and over 10 electronic atlases have been created using self-developed mapping software from scratch. The focused areas have included social-economy, natural resources, physical and urban environments for information communication, analysis and exploration. Particularly, IGSNRR has reached the top level in statistical data collection, indicator selection, geo-visualization-oriented data processing, representation, analysis, exploration as well as self-developed statistical visualization system. Recently, mini-screen and Internet visualization have been targeted, and mobile map production linking dynamic spatial information such as GPS data is being specially attended.

However, the traditional "one-size -fits-all" and less user-centred methodology has been dominating the electronic atlas research and production for years (Wang *et al.*, 2001). Due to insufficient understanding of user demands and user behaviours, many existing geo-visualization systems are far from being satisfactory. User interfaces of these systems are equipped with poorly structured and unnecessarily intricate operations that can only be mastered by expert users. By keeping pace with the progress of modern visualization techniques, IGSNRR is cooperating closely with internationally recognized institutes, targeting the adaptive geo-visualization system. Models of the goals, preferences and knowledge of each individual user are being established. Built-in user models will be used throughout the interaction with the user in order to adapt to the needs of that particular user, thus enhancing the usability of geo-visualization systems. This reveals the actual trend of new era toward a new generation of electronic atlases information system.

The newly proposed adaptive mapping system is ongoing in IGSNRR. It includes user modelling, intelligent GUI design, adaptive database restructuring, adaptive symbol library, etc.

Adaptive GUI design: With rapid advancement of computer technology, digital maps, GIS and geographic data gathering techniques, more and more geo-visualization systems such as electronic atlases system, web maps have been developed. The systems have become more powerful, tremendous and complicated, but the use of them has been more and more difficult, as the user interfaces in these systems are designed only according to the designer's instead of user's preference and understanding and takes less characteristics of geographic information into account (Fuhrmann and Kuhn, 1999; Peterson, 1994). Due to insufficient understanding of user demands and user behaviours, most existing geo-visualization systems are rich in interactive functions but poor in performance. Theoretical guide and standardized methods to design graphic user interface are in urgently needed for the development and implementation of cartographic information visualization. An ideal user interface must be an adaptive one, allowing the user to choose the interactions according to his knowledge, skill and liking, and depending on his particular task. IGSNRR has started to explore the GUI adaptation based on the GUI problems exiting in current systems. The results will guide the adaptive user interface design and the development of GUI design methodology for geo-visualization systems (Figure 3).

Adaptive symbol design: Due to insufficient research and understanding of user demands and user behaviours map symbolization in existing cartographic systems is far from being satisfactory. Every country is developing and using its own map symbolization system in which even the regional differentiation is sometimes considered. Such diversified country-wise symbolization systems may be well accepted by their native users. Beyond the country border, however, their usability decreases dramatically and misinterpretations of map symbols become

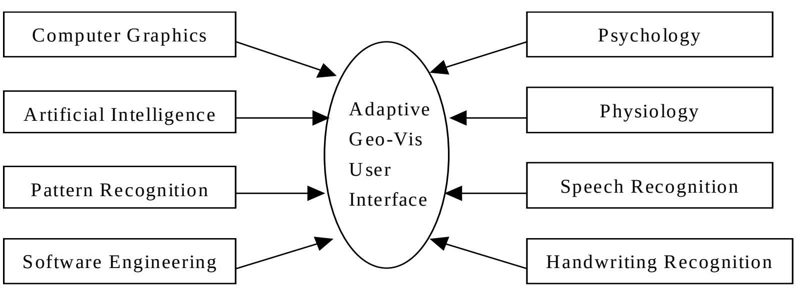

Figure 3 Relevant technologies with adaptive geo-visualization user interface

inevitable. On the other hand, standardization of map symbols either has become a more or less forgotten issue in spite of relentless endeavours of cartographers since many generations or tends to be largely overshadowed by the seemingly more urgent tasks concerned with standardization of geo-data.

In order to tackle this problem and develop a globally usable map symbolization system, IGSNRR proposes a symbol adaptation approach that embraces both components of interactive adaptation and autonomous adaptation (self-adaptation). The initial design stage has focused on point symbols. Standardization and individualization are integrated in detail as two poles spanning over the user modelling procedure. A dynamic trade-off between them is regarded as an essential requirement for a successful symbol adaptation that has a broad user acceptance and meanwhile preserves the necessary diversity.

The approach starts with a worldwide symbol collection. After an initial organization, certain symbols are selected as test base to acquire information acquisition for user modelling. Before any interaction takes place, the system provides a set of default symbols (S_1). As soon as a user activates an application, the default set will be replaced by a location-sensitive symbol set S_2 which is in principle at the highest possible standardization level, e.g. globally, regionally or locally accepted level. With more and more additional information on user characteristics and usage scenario accumulated in the system, S_2 gives way to the symbol set S_3 at the highest necessary standardization level. From this stage on, the individually preferred symbols can be integrated. In addition to this successive adaptation procedure, users have the freedom to choose alternatives from the symbol library or create their own symbols with an appropriate design tool. An important part of symbol adaptation is represented by an evaluation module which defines the prerequisites for user preferences being recorded and is embedded into the adaptation procedure. With the help of such an evaluation mechanism, interactivity decreases step by step during an application session while the self-adaptation increases. Since users can interactively control what is going on whenever they feel like to, their freedom will never be entirely robbed away by the self-adaptation.

User modelling for geo-database adaptation: In the context of research cooperation between the Institute of Geographic Sciences and Natural Resources Research, CAS and the Technical University of Munich, Germany, the fundamentals on the concept of geo-database adaptation is investigated as a prior stage of adaptive geo-visualization. Two concurring implementation approaches of geo-database adaptation are compared and evaluated in detail.

The need for adaptive geo-visualization is mainly triggered by the usability issue. Efforts in the realm of web cartography have resulted in numerous working tools. However, these tools are often too complex to learn and handle for average Internet users. Being aware of the importance of usability, the research addresses the issues involved in the design of a geo-database for the purpose of adaptive geo-visualization. A geo-database is structured along three dimensions: geographic area, content categories, and level of details. Different users are often interested in different subsets of the same geo-database, depending on their demographic parameters (e.g. age, gender, skills and language) and tasks. Each of such subsets corresponds to a cluster described by a unique triple. The recorded "visiting" points and frequencies during the access of the geo-database as indicators of user behaviors are statistically analyzed. As a result, various individual user models are established. A further categorization of these seemingly diversified user models helps to identify usage patterns, hence determine the subsequent adaptation strategies for the retrieval and presentation of geo-data.

Based on the findings of user modeling, the authors have proposed two different implementation approaches. The first one aims at adapting the geo-database itself, the second at developing a geo-visualization (web) service with adaptive functionality. Adapting geo-database itself helps to find more intelligent data-structuring mechanisms in accordance with usage patterns that are built up beforehand. A smart indexing method can, above all, speed up the data retrieval and enhance the response performance of any system that has to handle enormous amount of geo-data. Geo-visualization (web) service on the other hand provides its adaptive functionality on-demand and in real time. Since a more dynamic mechanism is embedded in the service, more flexible solutions to highly volatile user behaviors in constantly changing usage situations are possible.

Adaptive system design: An adaptive geo-visualization system includes modules such as spatial data collection, spatial data structuring, geo-visualization, user interface, map-based spatial cognition, user behaviour monitoring and adaptive map display (Figure 4).

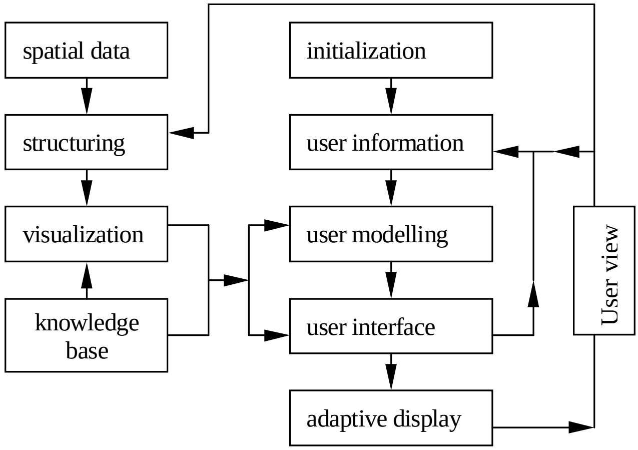

Figure 4 The composition of an adaptive geo-visualization system

3 Existing problems

Although many achievements in electronic atlas development have been made at IGSNRR as well as in many other institutions in China, difficult situations and challenges still remain. The advances in visualization in China have kept pace with the rapid development in technology and their extensive applications in the world pretty well, yet there is still a gap. Because insufficient budget support constantly keeps research and development in advanced areas, researchers must pursuit small fund from various sources to maintain the research and development team, this has considerably constrained the level of development. Due to predetermined goals of the various fund sources, the research had to focus on the diverse research directions. Consequently, neither the central task could be maintained nor significant results could be achieved, apart from the waster of human resources and development time. Secondly, the gap still exists between research and application areas or market, consequently, the economic return from applications or market is insufficient to maintain the sustainable development, provided there is not enough fund from organization or foundation councils. Thirdly, the knowledge divide between cartographers and computer scientists causes the atlas more paper map oriented or more technical oriented. Fourthly, the communications between map designer and atlas users needs to be strengthened, in order to improve the design and meet users' demand.

4 Conclusions

After reviewing the progress in cartographic research and atlas information system development in China, we give a summation of the achievements in China.

(1) It started from computer aided mapping in 1980, and then stepped to interactive statistical mapping system in the early 1990s, and in the late 1990s, developed into an integrated system with interactive, analytical and multimedia representation. Recently the trend of coupling interaction, analysis, multimedia, Internet and telecommunication technology has been suggested to provide a real time and mobile platform, tending to an adaptive system in the coming years.

(2) The research on visualization in IGSNRR focuses on multi-perspective modelling, spatial and temporal data modelling, screen map design for desktop, Internet and PDA or mobile telecommunications, cartographic spatial cognition and subject evaluation. The adaptive system design initiates from user data acquisition, analysis, user modelling, knowledge base creation and mathematic modelling. These bring the development foci into the desktop, Internet and

mini-screen visualization system, incorporating spatial-temporal cartographical modelling and visualization system, general statistical mapping system, urban and tourism-oriented mapping system and multi-perspective visualization system. The new adaptive visualization system is under conceptual design based on usability study and user modelling. The adaptive models, interfaces, intelligent navigation and knowledge databases will be developed.

(3) The software development is another notable achievement, which is based on objected-oriented system design and programming with multi-functions of data acquisition, transferring, import/export, display, roam, zoom in/out, query, statistical and spatial analysis, and multimedia data integration. Among these, the function of quick roam, linear dynamic annotating, data sort and statistical mapping has reached the high level in China.

(4) The main applications include social-economy, physical resources and environment, industry, tourism, sustainable and regional development, urban planning and management, population, etc. So far, IGSNRR has completed the following mapping database with various years and indicators at county and provincial level and containing basic map elements at scale of 1:4,000,000, including national economic database, national industrial database, national enterprises database, national population database, national resource, environment and sustainable development database, national regional development database, national historic database, national administrative division database, national physical environment database and several other provincial tourist and urban database and so on.

(5) The electronic atlases under planning and development will have Chinese atlas for city tourist guide, Chinese geo-name atlas for cities, National economic, population and regional development atlas, National historic atlas, National relics atlas, etc. Much attention of research and development will be oriented to multi-perspective spatial-temporal visualization system, real time visualization system, adaptive cartographic visualization system, mini-screen visualization system, Internet visualization system and mobile cartographic visualization system, which will link to GPS and telecommunication protocols of GSM, CDMA, CDPD, Blue tooth and develop into adaptive visualization system incorporating Internet with adjustable display resolution/scale screens, especially the mini-screen application.

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