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Research on 3D Digital Map System and Key Technology

Zhao Zhongyuan

*School of Remote Sensing Information Engineering
Wuhan University, Wuhan 430072, China, zhaozy@wpl.gov.cn*

Abstract

3D digital map is the further development of digital city, and 3D space foundation in city detailed management. First, the concept, character, main content and applications about 3D digital map are described. And then some key issues, such as management of tremendous data, 3D modeling, visualization and analysis technology are discussed, the end, the achievement of Wuhan 3D digital map system is introduced.

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1. Concepts and characteristics

With the further development of digital city and urgent need of city informational management, city spatial informational management has become increasingly demanding. The traditional 2D digital map has been unable to meet the needs of 3D space city management. The establishment of 3D digital city has become the common goal of science community, business world and the government city management department.

1.1. The concepts

3D digital map is a continuous 3D digital model of the city, which is the core of 3D digital city construction. Natural topography, geomorphology, environment, roads, buildings and major infrastructure together with natural and human elements of urban and rural areas are digitized in plane, elevation, structure as well as texture through dividing the model units and management object, and then make a seamless mosaic under unified coordinate system. 3D digital map comprehensively use of GIS, RS, network, multimedia and VR technologies. To form a multi-dimensional network-based digital city

information platform based on expressing the true 3D space elements of urban and rural areas integrated financial space, time and socio-economic information at the same time.

1.2. The characteristics

3D digital map system is an important part of the city spatial data infrastructure, which with the following characteristics:

- Virtual space environment of the real city. 3D digital map system uses the advanced technologies of 3D GIS, VR, data compression, computer and network technologies and other high-tech. The multi-source, multi-scale and multi-temporal information are integrated under a unified space to achieve a dynamic interactive browsing, spatial analysis and simulation of the huge amounts of data. That is a virtual space environment of the real city.
- Support the geographic synergies of network environment. 3D digital map system based on 3D GIS technology and network technology provides seamless management of urban space, it will also support multi-user concurrent using under the private network environment, and support the general public internet users access. It is an open and collaborative space information system.
- 3D space basic platform for city management. According to statistics, more than 80% urban activities are relative to space. The 3D digital map system can provide citywide macro information such as topography and river system, provide space frame and urban morphology information of city proper and key areas, also provides the detail of blocks, single constructions, urban facilities, and landscape facilities. 3D digital map system is the 3D digital space platform for all kinds of city management activities.
- City public services. 3D digital map has the characteristics of multi-dimensional information processing, expression and analysis. It has very widely applications in virtual tour, grid-based management, intelligent transportation, emergency command, disaster prevention and mitigation, e-commerce management and district, especially the social services of spatial information. The application of 3D digital map has more and more obvious advantage and irreplaceability.

2. System architecture and function design

2.1. System architecture

3D digital map system uses multi-level technology systems. As shown in Figure 1. It can be divided into four levels such as hardware support layer, the data layer, service layer and application layer level.

Hardware layer is the basis of communication among all levels in the 3D digital map systems, which is responsible for the computing resources and computing resources among applications and user's communication.

Data layer is the center of 3D digital map for information management, maintenance, collecting and distributing and transmission, which is responsible for the preservation of massive DEM data, DOM data, topographic maps of various scales and other basic data. It also contains 3D model data, texture information and planning special information. The security, timeliness and accuracy of data can be protected through data management and maintenance.

Service layer is the core of 3D digital map, which is the bridge to connect the underlying data resources and high-level application function. It provides generic and basic functions for all applications. It is also responsible for providing a variety of data services and function services for local area network and wide area network. It extracts data from the database, completes the assigned function according to

the need, and then upward to the application layer so as to service for all types of business systems and public systems.

Application layer is based on service layer. Combined with expertise in different fields and aimed at different needs of different users, it provides applications for a variety of areas and industries which include the planning and management agencies, other businesses, clubs and the public research and so on.

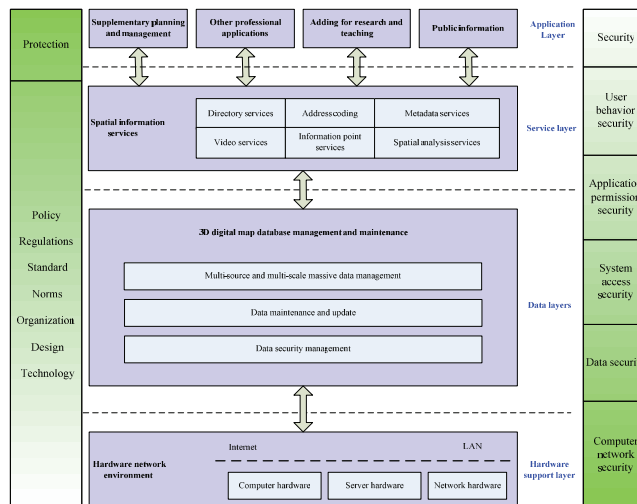


Figure 1 System architecture of 3D digital map

2.2. The function of 3D digital map system for client

The client software of 3D digital map system can provide 3D GIS environment for routine work of users. Its main functions are included :

- Layers show. The system data is managed and controlled by hierarchical layers according to topography, block models, status quo models, planning establishment information, fundamental geographic information, approval information and 3D model of planning project.
- Navigation view. It provides view mode such as walking mode, driving mode, flying mode, and so on. It also provides the functions of route custom view, 2D and 3D map navigation matching location view, viewport snapshot of view and so on. At the same time we can adjust view parameters, set view path, make the system fly along pre-determined path or fixed target and output AVI format file.
- Information query. It provides functions like name search location, fuzzy seeking location and building information query. Building attribute is displayed by clicking the 3D model, inversely, if we input building attributes, we can search building model. It also provides planning information query, planning attribute is displayed if we click the planning information, and the same as the inverse situation.
- Statistics functions. It provides computing functions in the light of the amount, area and volume of the regions and thematic information.
- Data maintenance tools. It provides the tools like model check, model format transformation and data production, updating and maintenance.

- Assisted planning tools. It provides the tools like spatial query, visibility analysis, indicators calculation, demolition estimation, inundation analysis, intelligent site selection and traffic flow simulation.

2.3. The function of 3D digital map for server

The server software of 3D digital map system provides the functions of data storage management and data scheduling and safety management. Main functions include:

- Data organization and management. Data are unified stored in server-side to integrate the massive data conveniently. Data mainly include DEM, DOM, block model, fundamental geographic data, planning establishment thematic information and management thematic information, 3D model (including status quo model and planning project model) and attribute information.
- Data management version. Time property is added to DEM/DOM and 3D model data. Updating data needs to reserve historical data.
- Data security management. Data backup program and server security management program is adopted to avoid data loss caused by hardware and software faults and operation environmental disaster.
- System user management and log service. It provides user right management and identity validation to ensure legitimate access to data; And it provides system log service to record and monitor the state of system operation and user visit.
- System configuration and services balance. Server-side software can deploy and migrate conveniently in the standard configuration or higher than the standard configuration of the hardware environment, and provides balanced scheduling server.

3. Key technologies

3.1. Multi-source and multi-scale model fusion and massive data management

Compared with conventional 2D data, 3D GIS data has characteristics of complex and large amount, how to organize the large amount data and construct database is a very important technological and strategic problem. It includes:

- The methods of data organization

The fundamental starting point of GIS data organization has three strategies including sub-site organization, sub-regional organization and sub-element organization. Sub-site organization as well as sub-regional organization is to divide the studied regions into different blocks in the horizontal direction and then organize them. Sub-element organization is to divide the geographical space in the vertical direction.

During the construction of 3D digital map database, irregular grid is adopted to organize the model data, and combined the above three methods to give full play to the data organization advantage. The correspondence between 3D model database and 2D database is taken into account to realize the unified management.

- The methods of data compression

According to data organization principle of 2D information database, pyramid data structure is established for raster data of regular grid (such as DEM data, DOM data) and LOD model data of irregular grid to achieve compression..

- The establishment of spatial index

Spatial index is a spatial data structure according to a certain order. It can improve the effectiveness of space operation and exclude those spatial data having nothing to do with the space operation quickly. Proper spatial index must be developed for 3D scene of massive data to accelerate position and access of 3D model data and improve the efficiency of data access and storage.

3.2.3D modeling techniques

3D digital map modeling is to reconstruct real urban geographic conditions, which means to re-create urban landscape (including topography, urban construction and road facilities) by real geographic spatial location. If real world is simulated in the computer, object model must be built, it resembles real object in shape, illumination, texture under multi-dimensional scale. The following questions need to address:

- Modeling region division

The city includes built-up areas, suburban districts and so on. Built-up areas include new-built areas and to-be-modified areas. Before modeling, the first step is to plan and divide region by grid or block and to set levels for every sub-section.

- Integration and use of multi-source data

3D city modeling construction refers to kinds of data sources including DEM data, DOM data, topographic map, real pictures and planning drawings, and so on. Those data sources need to be integrated effectively and streamline according to the applications requirements to satisfy the requirements of 3D model in geometry and detail.

- Rapid establishment of large-scale 3D scene model

There must be a quick modeling technology and method for large-scale 3D scene model to improve automation and ensure model quality.

- Establishment of modeling technical specification and standard

Because 3D digital map system is widely range and model diversity, it is very important to establish unified model standard and specification, which not only can ensure modeling quality, effect and smooth execution but also can promote and realize the sharing of 3D data.

3.3.Large-scale scene 3D visualization techniques

The information of geographical things and scenic objects is very complicated. In the usual hardware condition, it is practically impossible to realize massive data real-time visualization in the light of conventional visualization technique, so disposal strategies must be studied concerning characteristics of the project itself. Those strategies include:

- Effective scene management

3D scene data organization model based on node, layered, sub-block is adopted to simplify scene management. Simultaneously, efficient data organization and efficient index methods (such as linear quadtree, R-tree) are used to improve the efficiency of space operation.

- Efficient scene simplification

Data compression storage technology, multi-resolution model techniques and simplification techniques based on LOD scene are used comprehensively to accelerate 3D scene drawing.

- Efficient visibility techniques

Quick and efficient visibility judgment techniques are adopted to improve data loading and hit rate of rendering. At the same time, efficient loading techniques are combined to achieve real-time browsing and data loading simultaneously.

3.4. Inquiry, analysis and computing of 3D space data

Inquiry, analysis and operation of 3D space data is the basis to assist daily planning management. It includes:

- The space relationships operations are realized on the basis of data organization and relationship between 3D space objects and their correlation.
- 3D algorithm model (such as sunlight analysis, visibility analysis) is used and optimized in space analysis and algorithm.
- GEO-SQL is adopted to inquire and search 3D space data and provide space computing function of measurement and transformation.

4.3D digital map system construction practice of wuhan city

3D digital map system construction of Wuhan city begins in 2006, and it was listed as demonstration project by Ministry of Housing and Urban-Rural Development in 2007. Main achievements include:

- City 3D model technical specifications and implementation details have been studied and established. The technical document and guiding the city model construction are completed. The technical document includes City 3D Modeling Technical Standard, City 3D Terrains and Framework Model Making Requirement, City 3D Model Data Organization and Acquisition Program, City 3D Modeling Range Zoning Principle, City 3D model Making Implementation Detail and City 3D Model Data Inspection and Acceptance Method. On this basis, Wuhan City Planning Bureau takes the responsibility of national industry standards composition — City Modeling Technical Specification .
- City framework model of 8649 square kilometers has been established. In the unified coordinate system, DEM, DOM and the aerial image matching and corrective work of 8649 square kilometers have been completed; 3D model of topographic and physiognomic has been developed; Block model of 1100 thousands buildings and 3D modeling of critical infrastructure and landmarks such as Yellow Crane Tower, Guishan TV tower and 9 bridges over Yangtze Hanshui have been completed; based on topographic and physiognomic, block, critical infrastructure, landmarks and geographical name data, 3D framework model is developed and unified 3D space framework has been developed for urban and rural planning.
- 3D model of 450 square kilometers of Center City has been established. 3D model of different precision about 450 square kilometers of Wuhan Center City has been established by exploring kinds of experimental region from small-scale operation to large-scale 3D data throughput(see Figure2).



Figure2 delicate model of MARSHLAND Hankou



Figure 3 3D digital map management platform

- 3D digital map management platform is initially established. Based on Oracle database system, 3D digital map database is set up, DEM, RS image and geographical name information of 8649 square kilometers are integrated; critical infrastructure such as aerial remote sensing image of Main City, building block, Yellow Crane Tower and Yangtze River Bridge are integrated; realistic city framework model is set up; planning information such as delicate 3D model, planning roads and Urban Services Line of Control are integrated; many functions such as large-scale 3D terrain scene web browser, delicate 3D model superposition, 2D vector data superposition and geographical name inquiry are achieved; The unified management of massive data of multi-source, multi-dimension and multi-scale is realized (see Figure 3).

5. Conclusion and outlook

3D digital map is a digital simulation of the real urban space environment. It is proved that 3D digital map system has played a great role in the city planning, improved the technological level and haven a great development in other industries. At present, 3D digital map system construction is a very complex project, there are still lots of studies should been done in data fusion, modeling, network transmission, data management and analysis of 3D space and geographic coordination. With the further development of related technique and project construction, 3D digital map will head for ageing and play a greater role in national economy and social development.

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