Research and application of three-dimension electronic sand table for water resource in Three River Source Region

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Abstract. In order to improve the water management, decision-making and water efficiency in Three River Source region, 3D-GIS technique was used in water management. At first it confirmed overall design of the structure, and then according to the user specific requirements, to design and expand function of the system. Thus, the secondary development based on World Wind is performed to construct the three-dimensional electronic sand table system of water resources. The results show that the system can provide a comprehensive and intuitive display of topography, morphology and basic geographical information in 3D virtual environment. It demonstrated potential visualization and spatial analysis in combination with different requirements. Therefore it is useful and significant to improve the management, decision-making, sustainable utilization and development of the water resource in the Three Rivers Source region.

1. Introduction

Sand Table is a solid model, which is made of sand or other material according to real terrain. However, the traditional sand table has the shortages such as large area occupation, inconvenience of carrying, lack of performance richness. Moreover, it has not been able to fulfill the current demands of planning and administration. The rapid development of the computer network communication technology and graphics application makes it possible for three-dimension scenery simulation. Traditional sand table is going to the digital direction, which has produced the three-dimensional electronic sand table system (3D-EST). The 3D-EST, also known as Three-dimensional Geographic Information System (3D-GIS), is the combination of Remote Sensing, Geographic Information Systems and three-dimensional simulation technology. The 3D-EST has the advantages such as rapidness, simplicity and accuracy compared with the traditional sand table. In addition, it can display dynamic information, and provide interactive operation of the virtual reality environment. Thus, the 3D-EST has been widely used in the field of military, education, tourism, water conservancy, etc [1,2].

With the continuous development of water resources information, the 3D-EST has been well applied to water conservancy. It can provide a comprehensive and intuitive display of watershed topography, river morphology and distribution of water projects, so as to provide more direct and comprehensive characteristics for policymakers to understand the watershed. It also improves the efficiency and water management level, and realizes the optimal allocation and sustainable development of regional water resources. In recent years, China's Ministry of Water Resources has paid more attention to 3D-EST construction. Beijing, Ningxia, Shandong, Hebei and Guangdong provinces successively have established respective 3D-EST. Therefore, in this study, a 3D-EST has

been designed and developed for water resource in Three River Source region based on NASA World Wind. The virtual reality technology, vivid three-dimensional virtual scenery was used to build a simulation system. It provides spatial analysis tool and efficient assistant support platform for the decision-makers.

2. Technology and methodology

2.1. Study area

Three River Source Region is taken as an example in this study (figure 1). It is the origin of Yangtze River, Yellow River and Lancang-Mekong River, with the name of river source and water tower of China. Three River Source region lies in the center of Tibetan Plateau, and it is the water conservation and plateau biodiversity protection area in the west of China. Approximately, Three River Source region provides 49% of the runoff of Yellow River annually, and the annual outflow of Yajiang, Lancang and Nujiang is about 500 billion m^3, making it the strategic reserve area of China's water resources. The issue of water resources and ecology has become more and more serious, owing to the dual effects of climate change and human activity. With the sharp decrease of iceberg, lakes and wetland, the desertification of grasslands and the rise of snow line, the problem is even worse in Three River Source region, which limits the sustainable development.

Figure 1. Location of the study region (Three River Source region).

2.2. Research technologies

2.2.1. Virtual reality and 3D-GIS. Virtual reality generates a simulated reality environment with the use of computer. It provides users with a realistic man-machine interaction system by using multi-source information fusion. The combination of 3D-GIS and virtual reality can provide visual spatial geographic information services [3]. In the 3D-EST system, a dynamic three-dimensional visual simulation environment is constructed by means of virtual reality and three-dimensional visualization technology. It makes the information and scientific research more practical [4]. This proposed methodology would help the decision maker to get more accurate and efficient research data, further to provide visualization services for water resources and ecological environment management, monitoring and evaluation. Nowadays, various open source platforms of 3D GIS, such as Google earth, Skyline, World Wind and SuperMap, have widely application in all the world [5,6].

2.2.2. Massive data processing and cloud storage. Various data, including high precision digital elevation model (DEM), high definition satellite and aerial image, vector data and so on, is required in the construction of electronic sand table, and these required data often need terabyte or even bigger storage space [7]. Therefore, more efficient and open data processing technology is needed to the organization and management of mass data. Herein, the system constructed in our research used multi-source data fusion, distributed storage and management, tile pyramid technology to realize the layering memory of mass data. With the technical background of big data, the fragmented data can be stored in the corresponding cloud service cluster using distributed storage and processing technology of cloud computing. When the map server receives the user's request, the stored map image and the element information of the geographic location would be returned to the user to realize the cloud storage and call of the massive data [8].

2.2.3. Image processing and pyramid technique. Remote sensing image, one of the main data sources of the 3D-EST, is acquired at different time and resolution, so many image data processing techniques should be used to treat it by multiple steps. In order to intense the veracity and reliability of the type recognition, interpretation and decision-making of surface feature, various processing methods including format conversion, color enhancement, logic processing, image correction, image registration and image fusion were applied in the study [9,10]. Image pyramid refers to a pyramid structure in the same space for users to store and display in different resolution, and it is formed with data amount and the resolution from coarse to fine resolution. The pyramid hierarchy contains multiple data layers, the bottom has the storage for original data with the highest resolution, and from the bottom to top layers, the resolution of the data in turn reduces [11]. If the image pyramid can be seen as abstract iterative transformation of filtering and sampling process, the iteration process could decompose the original image data into different image tiles with different resolution, as is shown in figure 2.

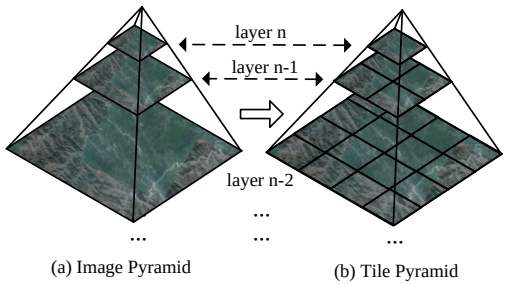

Figure 2. Image pyramid model.

3. Results and discussion

3.1. Design of 3D-EST

Based on the theory of virtual reality technology and GIS, a practical 3D-EST system was established. Primarily, the 3D terrain data of the region was collected to establish the digital elevation model. Then, the functional characteristics of the GIS were analyzed, and the remote sensing image data and basic geographic vector data were loaded on DEM data to establish the 3D-EST system. Based on the World Wind, it provided a powerful interactive terrain visualization environment and the three-dimensional space scene was rapidly generated using DEM data and remote sensing image data. The technological design of 3D-EST is shown in figure 3.

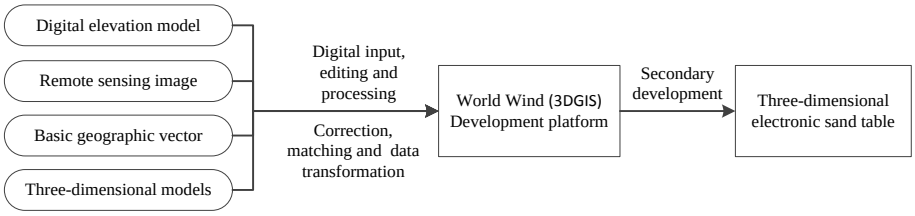

Figure 3. Design of three-dimension electronic sand table.

3.2. System framework

The 3D-EST system framework was partition four layers, including the client layer, service layer, core layer and data layer. This framework is illustrated in figure 4. The client layer was composed of 3D-EST and computer operating system for assistant support platform. The data layer established spatial, hydrologic and terrain database for basic data management. The core layer of the system was integration and application GIS, RS, GPS, servers and databases for 3D visualization environment. The service layer provided an interoperability interface of virtual reality, whose main implementation functions are as follows:

- Platform interoperability service interface, mainly including amplification, reduction, translation and visual angle changes;
- System extension and control interface, mainly including flight and positioning function;
- Spatial information maintenance interface, mainly including the update and replace of spatial data;
- Application service interface, mainly including the integration and display of water conservancy data.

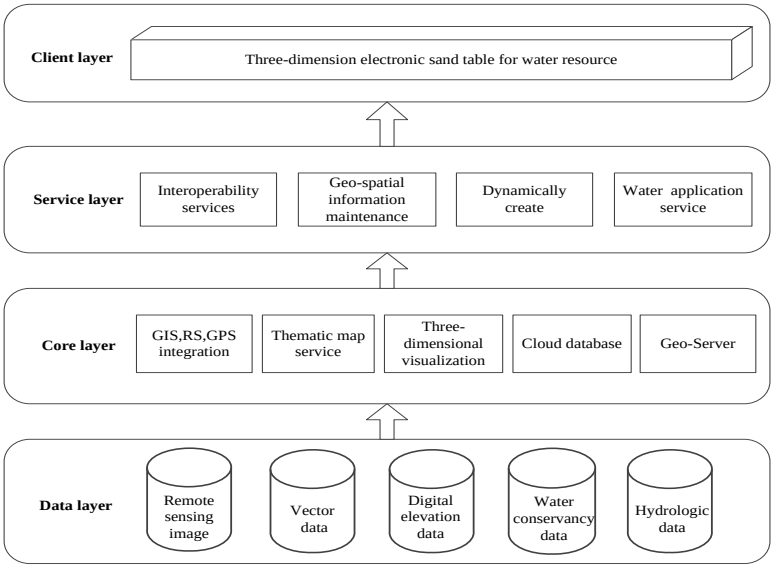

Figure 4. System framework.

3.3. Result of application

The present study was firstly aimed to develop a 3D-EST of water resources and build a three-dimensional geography scene in Three River Source region. In 3D scene, it had elementarily realized functions of spatial data release for water conservancy, interactive operation on Internet, query and display of thematic information, statistical analysis, online monitoring, spatial analysis and assistance decision.

3.3.1. Spatial and thematic data query. The spatial and thematic data used the national water resources census data and the projects data provided by the water conservancy administration of this area. In the 3D-EST, the system used a display model that features content hierarchy and progressive refinement. Starting from topography and geomorphology of this region, it hierarchically presented spatial and thematic data such as river, sources, glaciers, Snow Mountains, geographic data and water conservancy projects. The basic geographic data included provinces and cities boundary, road, railway and administrative division. Water conservancy project data included reservoirs, hydropower stations, pump wells, floodgates and hydrological stations. With this Panel control, users can call and display the kinds of entity in the distributed virtual environment. The spatial distribution of river and sources in Three River Source is shown in figure 5.

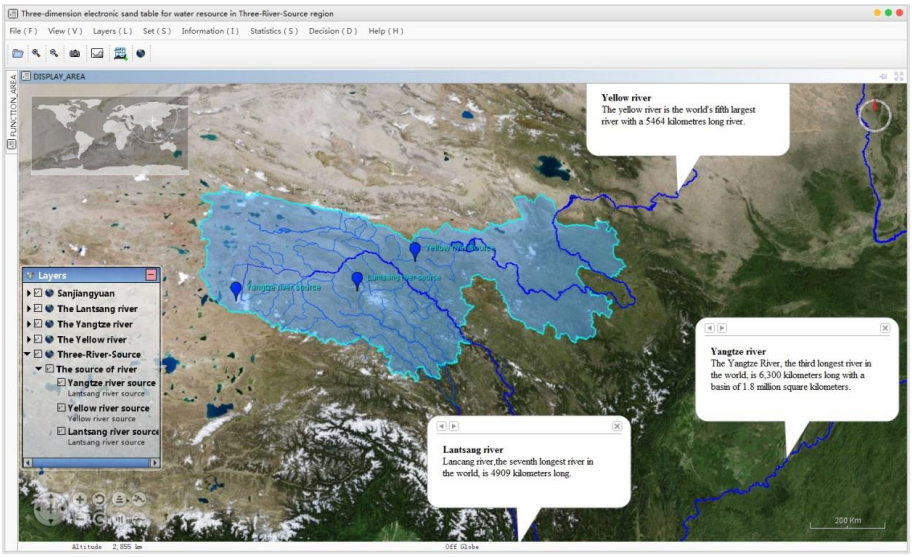

Figure 5. The spatial distribution of river and sources in Three River Source.

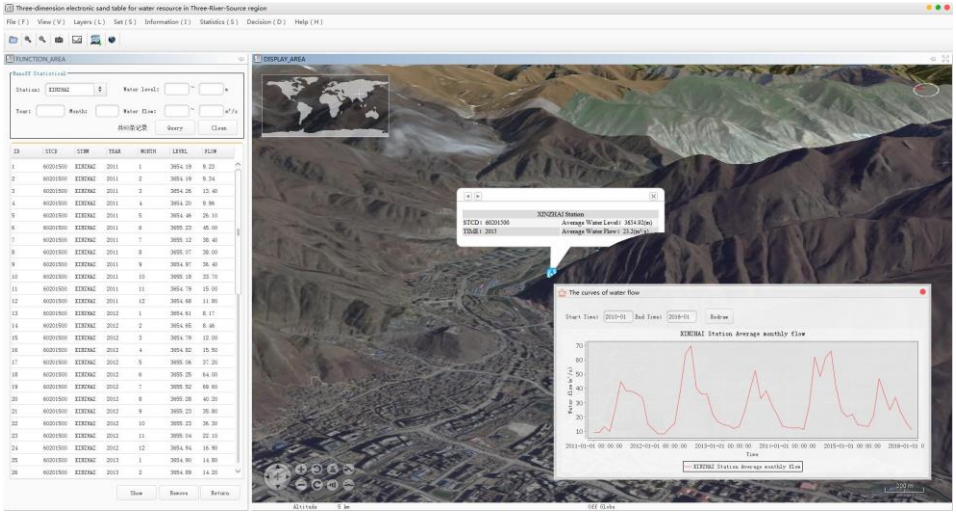

Figure 6. The statistical analysis of water resource quantity in the study area.

3.3.2. Online monitoring and statistical analysis. Online monitoring was an application of information technique in meteorological and hydrologic regime. The 3D-EST obtained data from existing automatic meteorological and hydrologic stations, including temperature, precipitation, evaporation, sunshine duration, water level, water flow and sediment discharge. Meanwhile, based on the

monitoring data, the value of runoff and precipitation can be predicted by time series. It also included water quality and water source area monitoring. This provided technical support for water resource management and assessment of this region. The runoff monitoring and statistical analysis of the hydrological station is shown in figure 6.

3.3.3. Spatial analysis and assistance decision. The spatial analysis and assistance decision function were based on the spatial geographic analysis, including coordinates and elevation query, cross-section analysis, visibility analysis, area measuring, distance measuring and cruise flight. In the 3D-EST, users can query the coordinates and elevation of a water conservancy project site, conduct length and cross-section analyses of the river, and measure the disaster area. In addition, cruise flight can be intuitive to observe project distribution and water resource conditions according with the planned flight path.

4. Conclusions

The 3D-EST is an important direction development of GIS application. It also plays a more and more important role water resources management in the future. This research developed a 3D-EST system of water resources based on the 3D-GIS. It provided a 3D virtual platform for the water management and decision-makers, and made users to obtain overall and visual water projects and water resources distribution information. Based on 3D-EST, it enables spatial and thematic information display and query, online monitoring, statistical and spatial analysis. In a word, it can provide technical and decision-making support for water resource management of the Three Rivers Source region.

However, there are some limitations to the present study and suggestions for further study. Firstly, the 3D virtual scene is the basis of 3D-EST system. One of the further research directions is how to make the best use of massive data and to create large-scale and high-precision virtual environment. Secondly, with the fast development of cloud computing and Big Data technology, the application of new technologies will promote 3D-EST development, which is one of the most important research fields. Finally, the development of 3D-EST is for application, and it achieves more function, according to the demand of water conservancy management and decision-makers, so as to improve the capability of intelligence decision-making.

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