Research on the Integration of Data Warehouse, Virtual Reality and Geographical Information System in Water Resources Management

Xian Luo[1], Youpeng Xu[2], Feng Zhou[3]

School of Geographic and Oceanographic Sciences, Nanjing University
Nanjing, China

[1]lx2566@126.com
[2]xuyp305@yahoo.com.cn
[3]zhoufeng_hn@163.com

***Abstract*— As the development of geographical information system (GIS), water resources information systems have been applied in water conservancy management increasingly. However, there are still some problems. Along with the improvement of hydrological telemetering systems, more and more data could be acquired. The inconsistencies in data, as well as bulk information processing would intensify the pressure of clients noticeably. Besides, water resources information systems are usually not intuitionistic enough, and it is difficult for users to recognize underlying surface features comprehensively. This paper explored the integration of data warehouse (DW), virtual reality (VR) and GIS in water resources information system to solve the problems mentioned above, while Yinzhou District, located in Ningbo, Eastern China, was selected as the research area to develop the system. Firstly, DW was built in this system to integrate hydrological data from ultra-short wave (USW) telemetering system with those from general packet radio service (GPRS) telemetering system, providing the system with desirable data without massive calculation in clients. Secondly, remote sensing image was utilized as the base map of the system, which was also used for three-dimensional animations generation so that watershed characteristics could be demonstrated more intuitively. Finally, with the help of GIS, water resources information system was developed which could meet diverse practical requirements of water conservancy management.**

***Keywords*— Water resources information system; data warehouse; virtual reality; geographical information system; integration**

I. INTRODUCTION

Geographical information system (GIS) has been utilized widely in hydrological analysis at present [1]–[4]. Water resources information system, which is a major way for the application of GIS in water resources management [5], [6], plays an increasingly important role in recent years [7]–[9]. With the help of GIS, hydrological data and hydraulic engineering information could be integrated with geospatial data by spatial relationships, which would be beneficial for water resources management [10]–[12].

Though water resources information systems have been applied successfully, there are some meliorations remain to be done. Firstly, hydrological telemetering systems have been improved greatly, hence more and more data need to be analysed which increases processing load greatly [13], [14]. On the other hand, information technologies develop rapidly in recent years, which provide water resources informatization with favourable supports [15], [16].

In this study, we would discuss how to make water resources information system processes faster and corresponds with actual demands better by means of other information technologies. Yinzhou District, located in Ningbo, Eastern China, was selected to develop water resources information system. The landform of Yinzhou is relatively complex. Mountains are located in eastern and western Yinzhou, while plain lies in the middle of the area. On the other hand, influenced by plum rain and typhoon storms, flood disasters occur frequently in Yinzhou. The complexities of underlying surface and climate increases the difficulties of water resources management, and water resources information system could help for analysis and decisions.

There were two major problems in the development of water resources information system for Yinzhou. First of all, two kind of real-time hydrological data could be obtained in the research area, one is transmit by ultra-short wave (USW), while the other is acquired by general packet radio service (GPRS) telemetering system, and there are some difficulties in analyzing these two kinds of data synthetically due to the differences in data format and time interval. Secondly, the terrain in Yinzhou is relatively complex, while it is difficult for users to recognize watershed characteristics comprehensively because topographical map is usually not intuitionistic enough.

To resolve aforementioned problems, we integrated data warehouse (DW), virtual reality (VR) and GIS to develop water resources information system. Firstly, DW was built to process hydrological data from USW and GPRS telemetering systems and organized them into uniform format. Meanwhile, daily precipitation amounts, mean water stages, maximum stages and minimum stages are also computed so that desirable data could be obtained without massive calculation in clients. Secondly, we applied VR technology to generate animations by means of remote sensing images, and these animations could show watershed characteristics comprehensively and intuitively. Finally, with the help of MapX control, water resources information system was

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developed as a client/server application. And the functions of the system mainly include maps operation, hydrologic regimes analysis, reports and hydrographs manufacture, isopluvial and flood risk maps generation, hydraulic engineering and typhoons information enquiry and videos presentation. By integrating DW, VR and GIS, the system is sufficient to meet the actual demands of water resources analysis and management.

II. Data Processing and Organizing

A. Data Architecture of the System

As shown in Fig. 1, water resources information system consists of 4 kinds of data, including hydrological data, water conservancy data, geospatial data and videos, and various data are integrated together by spatial relationships. Hydrological data are processed and stored in DW, and the system sends queries to database server to obtain hydrological regime information. While other data are stored in clients and linked with the system by MapX, database, video and some other controls.

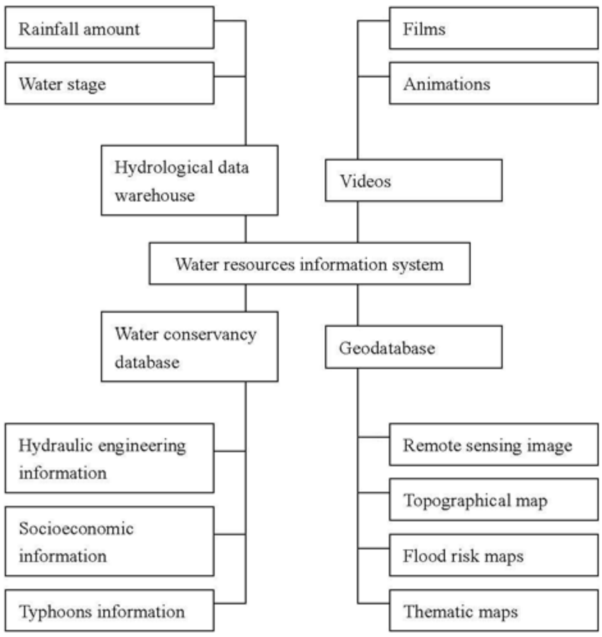

Fig.1 Data architecture of the system

B. Data Warehouse for Hydrological Data

In this study, we built DW to process and organize hydrological data from different telemetering systems. DW is a subject-oriented, integrated and time-variant collection of data, and it mainly provides data for decision analysis. Before storing into DW, required data need to be extracted from source data, and then processed and integrated based on actual needs [17].

Fig. 2 showed the structure of DW for hydrological data. In the process of DW construction, hydrological data were firstly extracted from USW and GPRS telemetering databases, and only hydrological station code, observation time and rainfall amount or water stage were selected to reduce data volume and unify data format. After that, precipitation amount and water level at the intervals of 15 minutes, 1 hour and 24 hours were computed separately. In addition, daily highest, lowest stage and their corresponding occurrence time were also identified. Finally, above-mentioned hydrological information would be stored into database server. When hydrologists need to analyse hydrological regime, water resources information system would get data directly from database server, rather than calculating in clients using original hydrological data, which greatly improve processing speed.

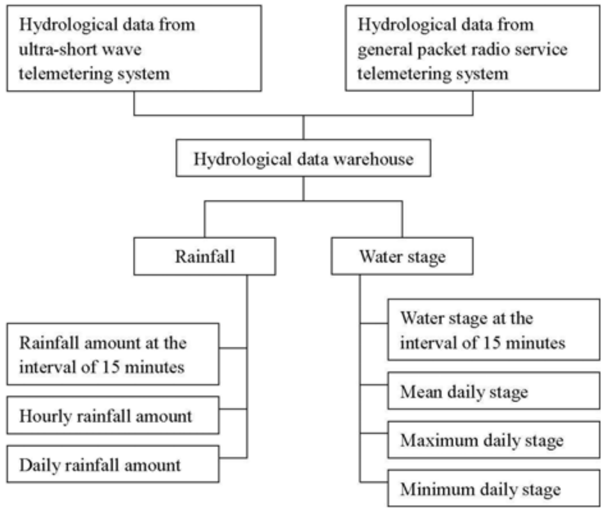

Fig. 2 The structure of data warehouse for hydrological data

C. Geodatabase and Water Conservancy Database

In order to build geodatabase, topographic, traffic and hydraulic engineering maps were collected, and various features, such as administrative boundaries, altimetric points, contour lines, geographic names, stream systems, reservoirs, roads, sea walls, sluices and hydrological stations, were extracted from these maps. On the other hand, flood risk maps and kinds of thematic maps were involved into geodatabase, and remote sensing image with high resolution was also used as base map so that underlying surface information could be reflected better.

In consideration of the performances of geodatabase in data query and update, hydraulic engineering information was stored in water conservancy database but not geodatabase, and geodatabase was linked with water conservancy database and telemetering database by unique identifier attribute assigned for every feature. When a feature in the map was selected, its attribute value would be made as query condition, and detail information could be found in other databases and shown by means of charts, graphs, pictures or other ways.

D. Virtual Reality for Videos

VR produces three-dimensional virtual world by computer simulation, and it has developed rapidly in recent years [18]. By combining VR with GIS, virtual geographic environment could be generated so that users are able to understand watershed characteristics better.

In our research, VR was adopted to manufacture three-dimensional animation. Two kind of remote sensing images were used, one was ALOS image, whose resolution was 2.5 meters, covering whole research area, and the other was QuickBird image, which reached 0.6 meters in spatial resolution, mainly covering urban area of study area. After series processing, both images were able to reflect factual condition of surface features, and then these images were added to the DEM to create a VirtualGIS scene. In addition, spatial information extracted from topographic map, including stream systems, geographic names, and so on, was converted into vector layers and annotation layers respectively. Based on underlying surface features and actual demands, flight paths in virtual environment were created, and animations were generated by filming three-dimension scenes along with these flight paths. Finally, these animations were edited and dubbed so that they could show watershed characteristics more intuitively and systematically, and Fig. 3 showed a picture captured from the animation.

Fig. 3 A picture captured from three-dimension animation

III. System Components

The major objective of the system is to provide systematic and comprehensive means for spatial analysis and data management. For this reason, 8 modules were designed to meet different actual demands of water resources management, and Fig. 4 showed the components of the system.

Maps operation module：This module is the foundation of the system. Except for elementary operating functions, users could query hydrologic regimes, hydraulic engineering information by selecting map features. In addition, kinds of maps could be chosen as base maps, including remote sensing image, topographic map and thematic maps.

Hydrological regimes analysis module： The system would show real-time rainfall amount and water stage of each hydrological station, and the stations exceeding dangerous level or certain precipitation amount would be highlighted to draw attention. On the other hand, the change of precipitation amount, water stage and water storage also could be analysed.

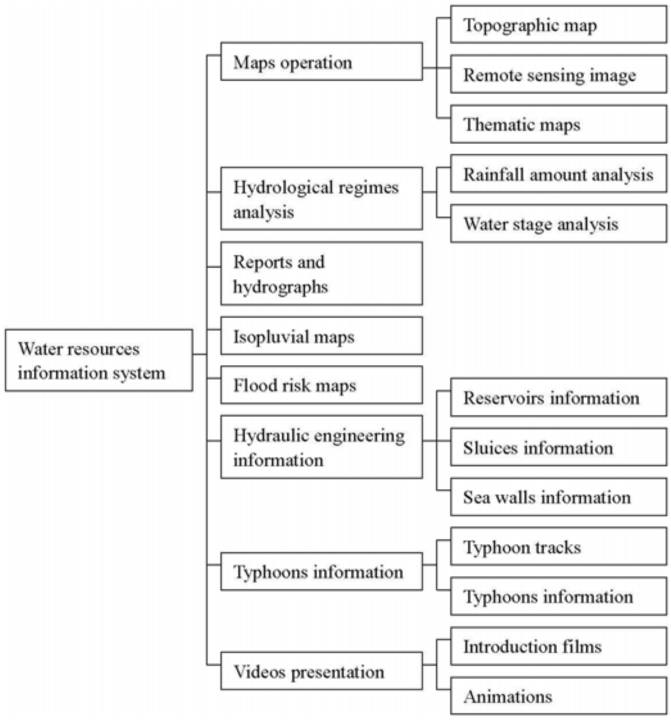

Fig. 4 The components of water resources information system

Reports and hydrographs module. Making use of processed hydrological data queried from DW, this module could generate hydrological regimes reports and hydrographs in different time scales directly, and hydraulic engineering information reports also could be produced as required.

Isopluvial maps module. Using Kriging interpolation method, isopluvial maps for various time intervals could be obtained, and Fig. 5 showed an isopluvial map generated in the system. In order to demonstrate rainfall distribution more clearly, isohyets for different precipitation amounts are drawn in diverse colours.

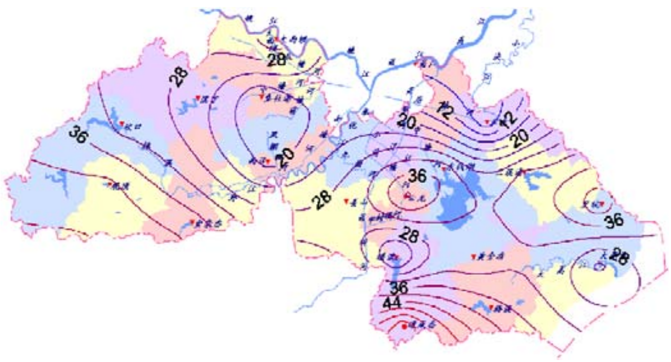

Fig. 5 An isopluvial map generated in water resources information system

Flood risk maps module：By choosing different flood recurrence intervals, probable inundated area and socioeconomic circumstances could be queried in this module.

Hydraulic engineering information module: The information about reservoirs sluices and sea walls could be obtained from water conservancy database, and users also could view and print plane and profile diagrams of water conservancy projects with the help of MapX control.

Typhoons information module：Historical typhoon tracks and other information would be queried in this module, and database administrator could add new typhoons information timely by making use of data updating function.

Videos presentation module：Utilizing a media player control, animations and introduction films which represent hydraulic projects and watershed characteristics could be played directly in the system.

IV. CONCLUSIONS

To meet the demands of massive data processing and intuitionistic demonstration, water resources information system was developed for Yinzhou by integrating DW and VR with GIS, and the system had been proved to be effective in data management and spatial analysis. Nowadays, Water resources information system plays an important role in water conservancy management, and they should be improved continuously to analyze hydrological data and represent complicated watershed characteristics more efficiently by taking advantage of various information technologies.

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