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DESIGN AND IMPLEMENT OF 3D ELECTRONIC CHART DISPLAY AND INFORMATION SYSTEM

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ABSTRACT

Two-dimensional electronic chart system can’t intuitively express the various information of 3D navigation environment, and the existing 3D electronic chart system lacks comprehensive display and scientific quantitative analysis. In that context, designed a 3D electronic chart system framework based on GIS and virtual reality technology (VR technology) and studied the key technologies such as visualization of 3D navigation environment, numerical simulation of water current and dynamic ship information display. Consequently, a 3D electronic chart system has been developed for Sutong Bridge section of Yangtze River waterway and it is verified to be feasible and reliable for ensuring safety of navigation.

KEYWORDS: GIS, Three-Dimensional Electronic Chart, Three-Dimensional Simulation, Virtual Reality

INTRODUCTION

With the development of GPS/GIS/GSM technologies, Automatic Identification System (AIS), Electronic Chart Display System and Information System (ECDIS), more and more research institutions and companies have focused on design and realization of the 3D electronic chart all over the world and achieved some results. However, the current development of three-dimensional electronic chart systems are inadequate. Such as: i. The simulations of underwater topography, flow field numerical and navigation marks distribution are carried separately, which leads to weaknesses in comprehensive display, and most of them stay in the demonstration phase; ii. Focusing on simulation blindly causing the failure in integration of GIS models effectively and this causes the lack of spatial analysis function and scientific quantitative analysis function; iii. Majority of the current three-dimensional electronic chart systems is developed based on the relevant systems, so there are some problems in maintenance and upgrade systems[1]-[3].

In this context, this research focuses on how to integrate GIS technology and virtual reality technology to construct a 3D electronic chart which can be adapted into shipping practically. With illustrating the information of underwater terrain, waters situation, beacon distribution, waterway scale and other kinds of information related to navigation safety, this system provides an intuitive and realistic decision-making environment for crew and improve maritime safety efficiently.

SYSTEM FRAMEWORK

Figure 1 shows a system framework of 3D electronic chart system, which based on bathymetric data, flow field data, terrain elevation data and other basic information. At the same time, topical information such as buoy information, AIS information, iconic building information, hydrological and meteorological information are considered. In this framework, the GIS technology and virtual reality technology are adopted. Outstanding advantages of the system as follows: i. Illustrating the information of geographical environment, water flow and water level visually with the simulation and numerical calculation of geography and hydrology; ii. Providing safe distance early warning and decision-making with the model analysis and spatial analysis abilities for crew. In this framework, the simulation of three-dimensional geographic scene, the numerical simulation of flow field and the ship dynamic data is the basic for decision-making, traffic management and channel analysis.

In the framework, three-dimensional terrain module's function is to create underwater topography and coastal terrain holistically with the method of the irregular grid model based on DEM data, electronic chart depth data, orthophotos and texture data. Topic database module would implement fast storage, remove, query and matching operations for the three-dimensional solid model, element models and textures with effective management. Numerical simulation of flow module is constructed based on CAD drawings, measured discharge, water level, gradient and other channel information with the equations of mass conservation and momentum conservation. AIS message parsing module takes AIS serial data as input to parse ship dynamic and static information[4], in succession, ship model database module queries and matches ship models based on actual demands. visualization& visualization module integrates three-dimensional terrain model, topic database model, numerical simulation of flow model, AIS message parsing module and ship model database together, and display all kinds of data comprehensively.3D display and query platform superimposes related attribute, control information and decision-making information into the associated visual results, and provides display and query service.3D Roam module could provide three roaming modes(i.e. manual roaming, automatic roaming and hawkeye navigation). 3D interactive module could provide terrain information and feature attribute query. Channel analysis module provides shipping activities analysis[5], project analysis, shallow point automatic recognition and early alarming function.

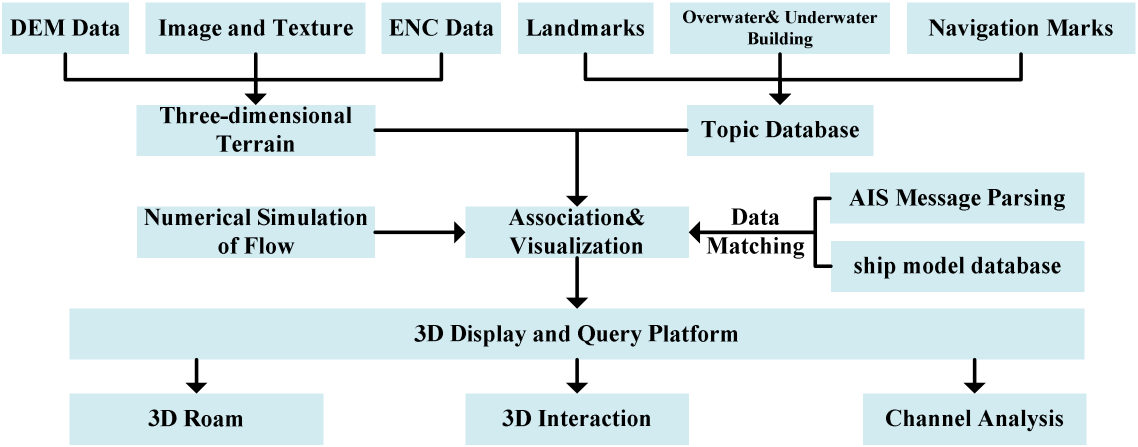

Figure 1: The Framework of three Dimensional Electronic Chart System Based on GIS and VR Technology

KEY TECHNOLOGIES

Building 3D Geographic Scene Based on GIS and 3ds Max Technologies

Three-dimensional electronic chart system is based on highly realistic three-dimensional geography scene[6]. Firstly, this paper establishes sea (river) bed DEM with irregular grid models; then, combines sea (river) bed DEM and land DEM together; finally, builds view models according to researched data, reproduce topography, beacons and artificial buildings.

The key factor in the integration of the underwater topography and coastal topography is to coordinate a unified framework for the terrain data. Under the unified framework, the general terrain model construction method can be applied. Underwater and coastal topography integrative building process is shown in Figure 2. In order to achieve uniformity of terrain data, coordinate transformation module changes every coordinate systems into a unified global coordinate system WGS84.

Unified coordinate frame module takes reference datum WGS84 as a unified vertical datum to achieve the unity of the data. Creating TIN triangulation module constructs DEM models based on irregular grid with the Bowyer-Watson algorithm. The integration of land and underwater terrain is shown in Figure 3.

In order to improve the real-time viewing without affect the visual realism significantly, this paper uses the layered strategy to build solid models, and then integrates each level solid models together. The model simulation for the waters are divided into three levels: i. For beacons and representative ship models, both geometric modeling and textures are made in the most fine manner; ii. For bridges, docks and coastal landmark buildings, just their geometric pattern and texture features are maintained; iii. For other land surface features, their outline and geometrical pattern is expressed. Simulation scenario with features and effects is shown in Figure 4.

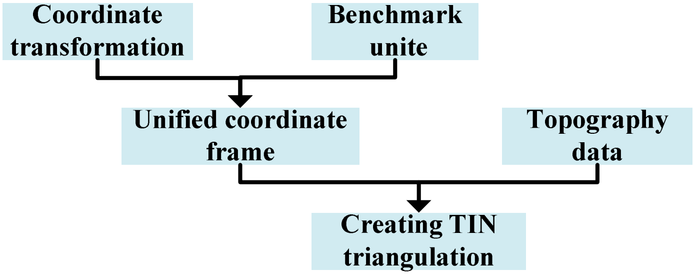

Figure 2: The Integrative Building Process of Underwater and Coastal Topography

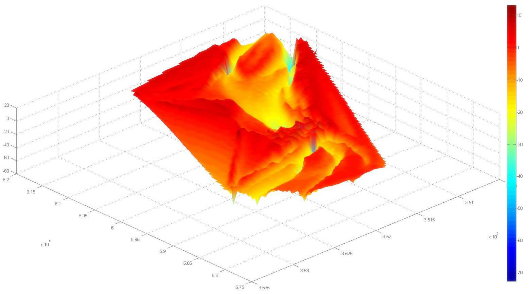

Figure 3: The Integration of Land and Underwater Terrain Figure 4: Simulation Scenario with Features and Effects

The Numerical Simulation of Flow

Currently, water level, flow rate and flow field morphology are calculated mainly with the 2D mathematical model[7], which includes water flow continuity equation and water dynamic equations.

Water flow continuity equation:

$$\frac{\partial z}{\partial t}+\frac{\partial[u(z+h)]}{\partial x}+\frac{\partial[v(z+h)]}{\partial y}=0 \tag{1}$$

Water dynamic equations:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=fv-g\frac{\partial z}{\partial x}-g\frac{u\sqrt{u^2+v^2}}{c^2(z+h)}+\xi_x\nabla^2 u+\frac{\tau_x}{(z+h)\rho} \tag{2}$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-fu-g\frac{\partial z}{\partial y}-g\frac{v\sqrt{u^2+v^2}}{c^2(z+h)}+\xi_y\nabla^2 v+\frac{\tau_y}{(z+h)\rho} \tag{3}$$

In which, u, v- flow rate in the x, y directions; z- water level; h- depth of water; g- gravitational acceleration; ξ_x, ξ_y -turbulence viscosity coefficient; f-bathymetry coefficient.

Numerical simulation of channel flow is based on the fairway CAD drawings, measured flow, water level, slope and other related data. This research imports the simulation results into the three-dimensional simulation scene of the determined area to support real-time interactive queries. Which can help the crew accurately determine the mainstream and slow flow, as well as push flow, suction flow, swirling water and other risk of ship navigation, timely develop safe navigation policy and.

In this paper, the calculation result of the flow which near Sutong Bridge is compared with the measured flow rate, and the comparison shows that this numerical model of flow is accurate and meets practical needs well. The simulation results of flow rate and flow pattern are shown in Figure 5.

Display of the Dynamic Ship Information

The dynamic ship information display system is based on underwater topography, hydro meteorology, ship motion posture information and other related data and provide the crew with early warning with model analysis and spatial calculation, and effectively ensure the navigation safety of the ship.

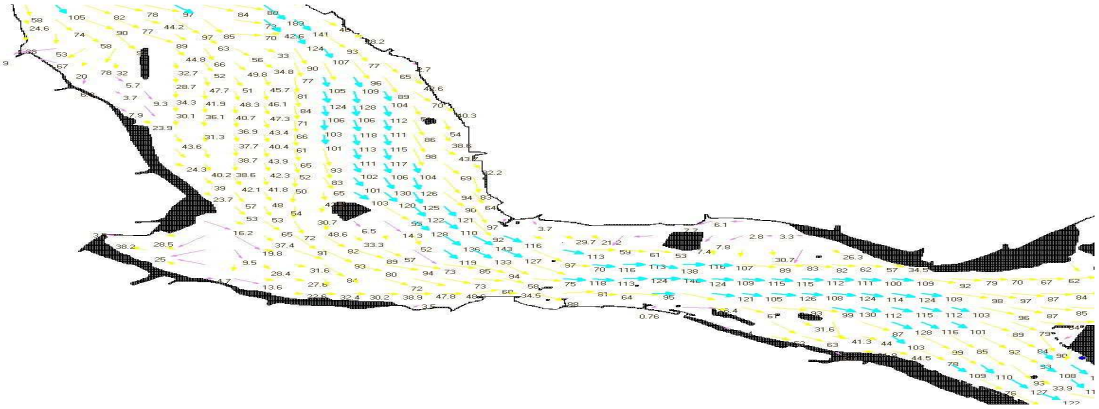

Figure 5: The Simulation Results of Flow Rate and Flow Pattern Near Sutong Bridge

With parsing original AIS messages, the 3D electronic chart system gets static and dynamic information of the nearby ships and display the ship's moving situation in the virtual 3D navigation environment[8]. With the original message parsing, AIS input system gets the safety information of the ships around, and the ships' motion is displayed in a virtual three-dimensional simulation environment. Dynamic 3D simulation display module of the ship motion is shown in Figure 6.

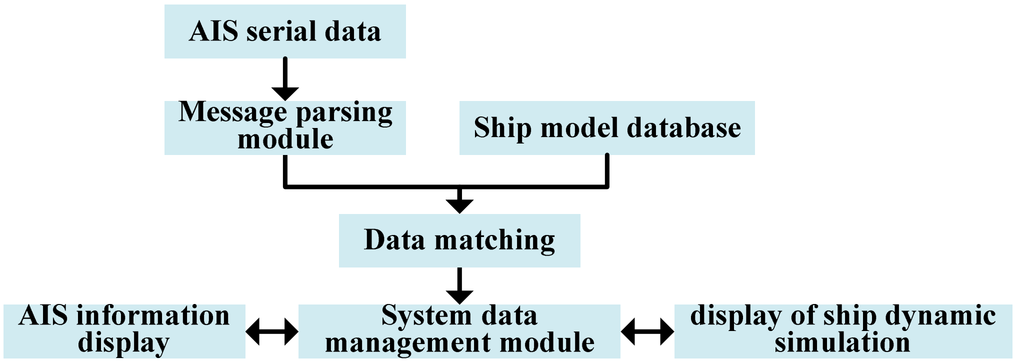

Figure 6: Dynamic 3D Simulation Display Module of the Ship Motion

CASE APPLICATION

With the above methods and techniques and the practical requirements, a preliminary 3D electronic chart system has been designed. The trial includes five stages, i.e. system initialization, plug-in initialization, interface calls, data processing and data output, which involves four levels such as communication service layer, data support layer, application support layer and represent layer.

The 3D electronic chart system based on GIS and virtual reality technology provides a full range of features and services based on the 3D simulation environment, which includes navigational aids, characteristic features of landscape, safe distance early warning, different scene modes (sunny, cloudy, rain and snow) switch, analysis of the underwater terrain in front of the ship, passage plan display, sailing trajectory backup, etc. Figure 7 shows a 3D electronic chart of Sutong Bridge waterway, which includes wharfs, bridges, numerical flow field, ships, landmarks and navigation aids, etc.

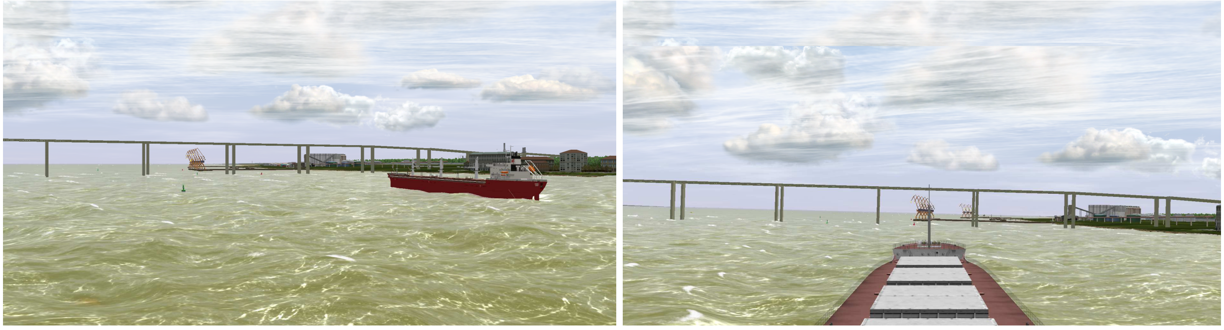

Figure 7: The Three-Dimensional Electronic Charts of Sutong Bridge Waterway

CONCLUSIONS

In view of the prominent problems in the development of three-dimensional electronic chart system, this paper has studied the key technologies to reach the main functions. Based on the design of the system framework and researched methods, this paper has developed a three-dimensional electronic chart system, which integrated GIS and VR technology organically. Due to the current conditions, the system needs to be improved in the future in terms of the dynamic organization of large scenes.

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