

# Application of GIS and 3D Visualization Simulation in Irrigation Management System

An effective solution of visualization and dynamic for water resources management

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**Abstract**—In order to provide scientific and effective analysis tools and decision support platform for the irrigation district management, this paper provides a way using GIS spatial database, visualization simulation(VS) to research on a new way for irrigation management system. During the system, interface of ArcObjects was used by 2D GIS modules to call visual component and water resources modeling. Meanwhile, Lynx software was adopted by 3D visualization simulation modules to implement a 3D model rendering and scene driver. Communication mechanism of design module has achieved dynamic computing canal excavation, flood analysis and simulation of Irrigation, providing an effective solution of visualization and dynamic.

**Keywords**-GIS; 3D visualization simulation; data interaction; irrigation management system

## I. INTRODUCTION

In the national "12th Five-Year Plan" for Water Resources Informatization, Remote Sensing (RS), Geographic Information Systems (GIS), Global Positioning System (GPS), Network and Virtual Reality (VR) will be widely used in water resources management, especially in irrigation management. Irrigation management system integrates information of workflow, RS, GIS and VS, also executes models for hydropower, irrigation and environment evaluating to enhance the level of informatization management roundly.

However Irrigation management system is large and complex. In order to provide scientific and effective analysis tools and decision support platform for the irrigation district management, this paper provides a way using GIS spatial database, scientific visualization simulation(VS)[1] to research on visualization simulation(VS) system of the irrigation management system. A prototype system is implemented for providing an effective solution.

## II. IRRIGATION MANAGEMENT VISUAL SIMULATION SYSTEM

During the design and implementation of Irrigation Management System, GIS technology and simulation

technology [2] are applied to many aspects of the design, and have achieved remarkable results.

In order to make GIS and simulation can effectively be integrated, Irrigation Management System can be logically divided into three modules: 2D GIS module, 3D visualization simulation module [3] and communication module. 2D GIS module and 3D visualization simulation module are two independent modules, by building communication between the two modules to achieve each data exchange and information sharing. That is the original spatial data of 3D visualization simulation module which is obtained by 2D GIS module, which transmits to 3D visualization simulation module through the communication module of data management, then the process and results data of 3D visualization simulation module are generated to enter into 2D GIS module via the communication module (as shown in Figure 1).

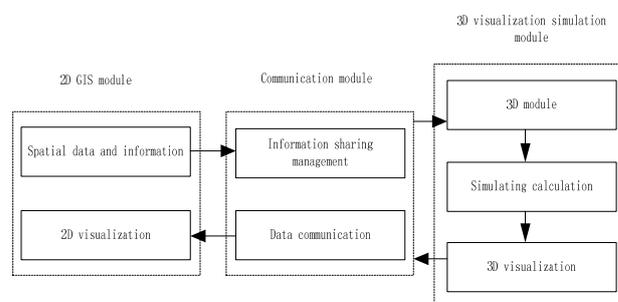


FIGURE I. INTEGRATED APPROACH OF GIS AND SYSTEM SIMULATION

This integration approach[4] exploits simply, and because of the relative independence of 2D GIS module and 3D visualization simulation module and scalability, is easy to system maintenance and further development.

2D GIS module is mainly used for interaction with the users who need to query system data, analyze, and issue a scheduling order. Thus, it requires the operating system to be as simple as possible with the analysis and interpretation of functions to be strong enough.

3D visualization simulation module builds on whole irrigated 3D terrain with rendering of surface features model and scene driver, simulation and visualization. The module is controlled by 2D GIS module, which provides real intuitive decision platform and precise scientific visualization simulation for Irrigation water management and decision-making analysis.

The communication module establishes a communication connection between 2D GIS module and 3D visualization simulation module to achieve data sharing and interaction. This module uses Windows Sockets communication mechanism to communicate through message delivery. 2D GIS module sends the message that must comply with certain format to 3D visualization simulation module, so that 3D visualization simulation module can parse correctly.

### III. DATA STRUCTURE AND DATA ORGANIZATION

Entity objects in the 2D space can be divided into point, line and face. Each of them involves consistent geometries and topology features. In the 3D space, not only does it add special information to the three kinds of entities, but also increases the body entity in a part of the application, forming point, line, face, body four types of spatial entities. Body-based notations are also used to express the surface features of 3D. Due to the amount of space data, the visual efficiency is low in the graphic display, therefore, adopting the face-based notations to describe entity objects by topological relations of face-side-point.

Spatial entity object is divided into two major categories including terrain, surface features in 3D scene [5]. Topographic data is mainly DEM (Digital ElevationModel) data. The surface features are variety, which are consisted of buildings, roads, lawns, water and so on. In this system, both of them are made of TIN data structure that is based on the data structure of face-based and made of profile and top triangulated networks to be better to take into account surface features, having less redundant data and distortions.

In addition, it needs to associate 2D data with 3D data in order to facilitate data exchange between 2D and 3D GIS module visualization simulation module, and make 3D scenes operation fully use of the 2D GIS data resources(as shown in Figure 2).

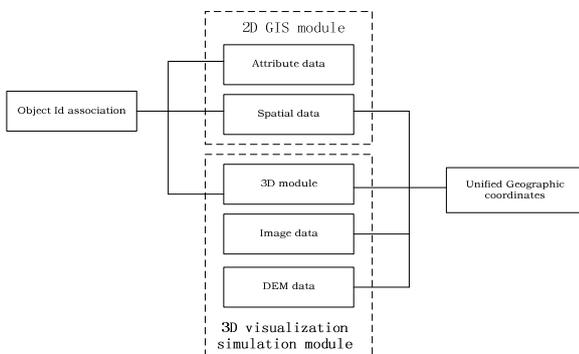


FIGURE II. 2D DATA AND 3D DATA INTEGRATION

The 2D geographic element and spatial information are associated with professional attribute tables in the relational database through the ID (Object ID). Instead, in the 3D scene, the graphic symbols of 2D geographic element may be the objects of 3D model, there are also associated with the same form through the ID (Object ID). Meanwhile 2D and 3D spatial data should have a Unified Geographic coordinates.

### IV. IRRIGATION MANAGEMENT VISUAL SIMULATION SYSTEM

System is established on Irrigation electronic sand table, communication mechanism of design module has achieved dynamic computing canal excavation, flood analysis and simulation of Irrigation. During the system, 2D GIS modules[6] use interface of ArcObjects to interact with geographic database, display map, query and analyze spatial information, and has ability to call visual component and water resources modeling. Meanwhile 3D visualization simulation modules adopt Lynx software to implement a 3D model rendering and scene driver using VEGA and OpenGL to run 3D simulation.

#### A. Construction of Irrigation Electronic Sand Table

3D visualization simulation module through the establishment of Irrigation electronic sand table reflects the changes in the latest planning and construction of irrigation timely. One side shows great scene of whole irrigation, on the other side can also reveal the local details of the key canals or hydraulic engineering, providing a wealth of comprehensive information.

The specific implementation method is based on existing data, collecting altitude data of basin contour lines, to convert into DEM data of terrain modeling used. There is 3D terrain model based on full-irrigated areas by the data processing (as shown in Figure 3).

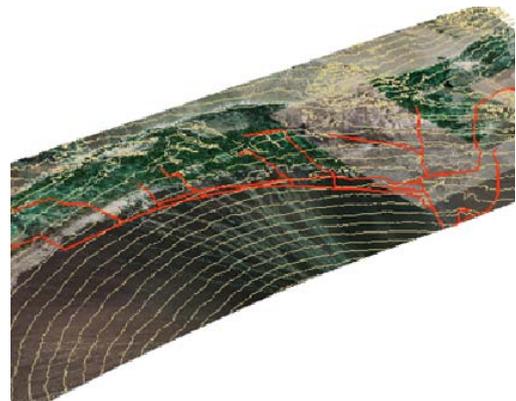


FIGURE III. 3D TERRAIN MODELS OF WHOLE IRRIGATION

The next step is modeling and simulating on Water Control Project. Simulation of Water Control Project is design for water scheduling process to meet requirements of understanding the operational state. It integrates scene, accurate terrain model, vegetation and dynamic surface models to use 3DMAX, Multigen Creator and other modeling tools.

Then, the work has been implemented by editing and mosaicing the satellite imagery as texture of topographic map, collecting thematic maps, all kinds of professional photography library material to generate ground texture mapping. There are relations between the terrain and the image, which are attached to the 3D terrain and surface features to recur irrigated terrain and the Water Control Project (as shown in Figure 4).



FIGURE IV. DETAILED MODEL OF SEDIMENT EJECTION AND SPILLWAY TUNNEL

Moreover, it also needs to match the 2D electron map with the spatial coordinates of 3D irrigation terrain to establish geographic elements on a 2D GIS module and the mapping of 3D scene of Water Control Project in order to interactively query and display.

#### B. The Design of Inner-module Communication Mechanism

System formulates interactive response mechanism which is based on Windows Socket communication technologies, in order to achieve information interactive of the 2D GIS module and 3D visualization simulation module. In this mechanism, socket is based on C/S framework including that the 2D GIS module is seeded as a server-side, 3D visualization simulation module is as a client.

When the communication is linked, the 2D GIS module and 3D visualization simulation module can transmit and receive data in time. Communication contents of inner-modules mainly include:

1) *Geographical coordinates*: It picks up points with the mouse when it clicks on the 2D electronic map to send into the 3D visualization simulation module, which converts coordinates to the 3D map after receiving. This data is mainly used to implement a custom path roaming, 3D scene viewpoint selection and canal system design and other functions.

2) *The command field*: According to the actual needs of the system, the 2D GIS module is necessary to send command to 3D visualization simulation module to complete the spatial analysis and visualization. Therefore, there are a set of command field in this system (as shown in Table 1). 2D GIS

module grimly send a message of Socket to the 3D visualization simulation module on the basis of this command field; 3D visualization simulation module is strict in the format of this message to parse and complete corresponding contents of the 3D display and behavior states controlling [7].

3) *Attribute value and calculation results*: The 3D visualization simulation module will analyze the results of 3D space (such as slope, aspect), flooded area, excavations to send to the socket control module of 2D GIS [8]. While the 2D GIS module will deliver query results to the 3D visualization simulation module.

TABLE I. SELF-DEFINING COMMUNICATIONS COMMAND FIELD

The Command Field	Illustration		
	Valuation	Semantics	Parameters
EXIT	0	Indicates the client exits	null
SET_VIEW_POSITION	1	Set the viewpoint position	double x, double y, double z Respectively indicate X, Y, Z coordinate of the viewpoint
TRAVER_PREDEF	2	Predefined start roaming	null
OPEN_GATE	3	Open the gate and show Drainage effect	null
DIG_DITCH	4	Channel excavation	(int nNumOfVertex, double dDepth, double x1, double y1, double x2, double y2, ... double xn, double yn)
WATER_OVERFLOW	5	Display water-floating and overflowing effects	null

#### C. Calculation and Simulation of Dynamic Canal Excavation

Irrigation canal excavation project is an integral part of the management process. This system is achieved by adding or modifying a canal in the 2D GIS module that the 3D visualization simulation module can dynamically display procedure of the canal which is changed. With estimation of the earthwork function to calculate the amount of earth excavation or landfill, the results can be saved in the 2D map and the 3D terrain model respectively.

Implementations of system must consider not only the terrain excavation, such as canal, open cut on the tunnel's inlet, but also consider the accuracy of buildings and terrain. Terrain excavation performs modification of digital terrain modules. In essence, it is to TIN terrain models' operation. The system uses the following methods: Firstly, receiving a series of point coordinates, excavation depth, width and the lower rear end of the bottom width information, which are transmitted by the 2D GIS module to generate an initial excavation TIN model in which it goes to the target point with time sheet successively. The excavation surface ensures to intersect with the original terrain TIN. Then the new generation of TIN and the original intersect with calculation to generate boundary, cutting excess

excavated slope area of initial body surface and new TIN model from the original intersecting line. Finally, combining the two corrected TIN to constitute a terrain DTM. Each step of heading face to go further, should repeat the above calculation and display simulation results.

By using the API MultiGen CREATOR system provides interface for TIN, it can get the amount of excavation and excavate area during the excavation of the calculation process (as shown in Figure 5).

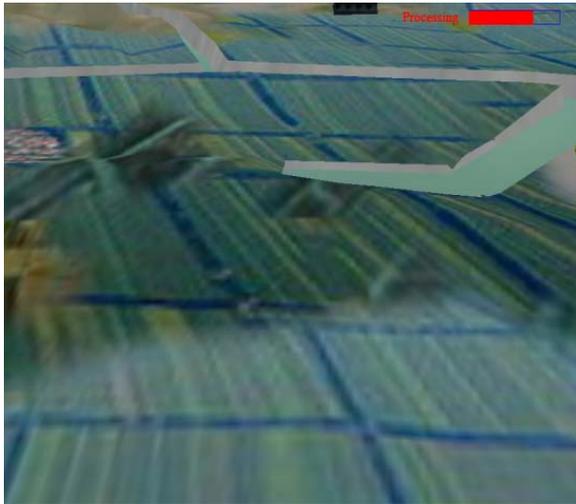


FIGURE V. 3D VISUALIZATION SIMULATION MODULE CANAL EXCAVATION DYNAMIC CALCULATION AND SIMULATION FUNCTION

#### D. Flood Analysis and Simulation

Using 3D visualization simulation technology and GIS spatial analysis technology, it can quickly and accurately simulate the flood area, providing a reference for the size of the evacuation, the estimated affected population and flood damage. The system will achieve the following functions:

1) *The 3D simulation on submerged areas:* According to the results of hydrodynamic model and flood routing model, dynamic presentations in active and passive source flood two cases including different water level, different scale flood inundated farmland, houses and hydraulic construction reproduce or preview the whole process irrigated flood ,and send the results to GIS subsystem for flood analysis.

2) *Flood area calculation:* The system enables to achieve based on the calculation of 3D terrain flooded area in the 3D scene, and send submerged areas and flooded area to the 2D systems, which not only can show the submerged areas and flooded area in 2D map, but also can be superimposed analysis by the flooded area and related electronic map to calculate different land types and farmland flooded types and estimate damage.

#### V. CONCLUSION

This paper presents tendency of using GIS technology to achieve water resource management, flood control decision

supports applications in the construction of Irrigation Management System visual simulation. However, the implements of GIS and 3D visualization simulation are not fully perfect, especially in the 3D spatial analysis, 3D statistical query and database systems aspects. In addition to flood control, GIS and 3D visualization simulation technology will also play a significant role in the soil and water conservation, land and resources management, power management. More efforts are in need to research on GIS and 3D visualization simulation technology and make it more applicable in the future.

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