Development and Application of a Three-Dimensional GIS-Based Data and Information Visualization Environment

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Abstract

A GIS (geographic information system) based database visualization environment, GIS-based DBVE, was developed for exploration and presentation of the geo-referred data and information, such as data, text, image, audio/video, animation, as well as other multimedia, in a three-dimensional virtual world. The GIS-based DBVE shed light on the potential of applications of computer graphics in both GIS and databases. The system was applied to explore and present various types of geo-referred data and information of the study of population ecology of Formosan landlocked salmon [1]. This innovation has demonstrated to be very useful and effective to present and visualize the geo-referred data and information comparing with the classical GIS and database tools. It could also be used as a CAI (computer-assisted instruction) for promoting applications of computer graphics and environmental education.

Keywords: geographic information system, database, data and information visualization, computer graphics, computer-assisted instruction

1. Introduction

Classical GIS (Geographic Information Systems) are tools for manipulating and analyzing spatial data such as maps, aerial photographs, and satellite images. It generally supports the query and analysis of data, and simple graphic as well as table presentations [2~5]. GIS has been widely used in natural resources management, urban and rural development, and natural management [6]. In recent years, due to the fast-changing Internet technology and advancements of computer graphics, computer technologies, such as distributed database, visualization and VR (virtual reality) have brought GIS to new realm of researches and applications [7, 8].

The purpose of the study is to develop a three-dimensional GIS-based DBVE (data and information visualization environment). Contrary to classical GIS and databases, DBVE

uses the DTM (digital terrain model) as an infrastructure to present and visualize the geo-referred data and information, such as data, text, image, audio/video, animation, and other multimedia, in a three-dimensional virtual world. We used the data and information of the study of population ecology of Formosan landlocked salmon [1] to demonstrate the functions and features of the DBVE.

Introduction and application of DIVE (Distributed and Interactive Visualization Environment), which designed for visualization in the three-dimensional virtual world and distributed collaboration, is introduced in Section 2. The GIS-based DBVE (Database Visualization Environment), which is a module of DIVE, and its implementation are given in Section 3. The applications of DBVE are illustrated in Section 4. Based on the demonstrations, some concluding remarks are made in the final Section.

2. Distributed and Interactive Visualization Environment

DBVE is a module of the DIVE (Distributed and Interactive Visualization Environment) for presentation and visualization of the geo-referred data and information in the three-dimensional virtual world via remote DBMS (database management system). DIVE (Distributed and Interactive Visualization Environment) is an in-house developed, Windows-based networked visualization system [9, 10]. The early version of DIVE does not support the access of DBMS. It supports the visualization and navigation of terrain model and associated geo-referred data in the three-dimensional virtual world, and supports

distributed collaboration as well as interactions. The system has been applied to the study and visualization of tidal flows of Tamshui River, Taiwan [11]. DIVE basically consists of two components: the *display* module and *net* module, as illustrated in Figure 1. We employed OpenGL for rendering and navigating the three-dimensional terrain model as well as the associated physical behavior of the system in the *display* module, and CORBA (Common Object Request Broker Architecture) for distributed communications between the clients and server in the *net* module.
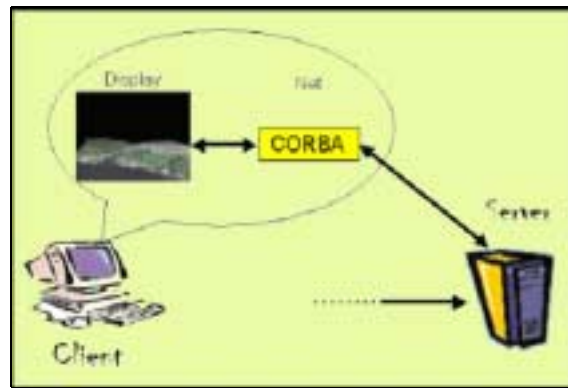

Figure 1. Architecture of Distributed and Interactive Visualization Environment.

The DTM (digital terrain model) data and SPOT satellite image were processed to generate the three-dimensional terrain model of the study area, Chichiawan Stream basin, as depicted in Figure 2. Application of DIVE for Chichiawan Stream basin was presented in Figure 3. Interface of DIVE showed that it contains of logging in, file managing, exchanging of the token, generating 3D object from 2D image, chatting, zooming and navigation functionalities, two views (*local* and *global*) of the current scene, and a list of the session participants. Local window denoted the state of view for the local user, and global window the updated state

of view for all users. Users could visualize, explore, gain insight, interact and collaborate with remote colleagues, and communicate their insights to others via the Internet. Such approach has great potential for visualization and collaboration, and therefore, can be widely applied to modern distributed science and engineering projects. This innovative GIS-based visualization system leads to the development of DBVE to explore and present the geo-referred data and information in a three-dimensional virtual world.
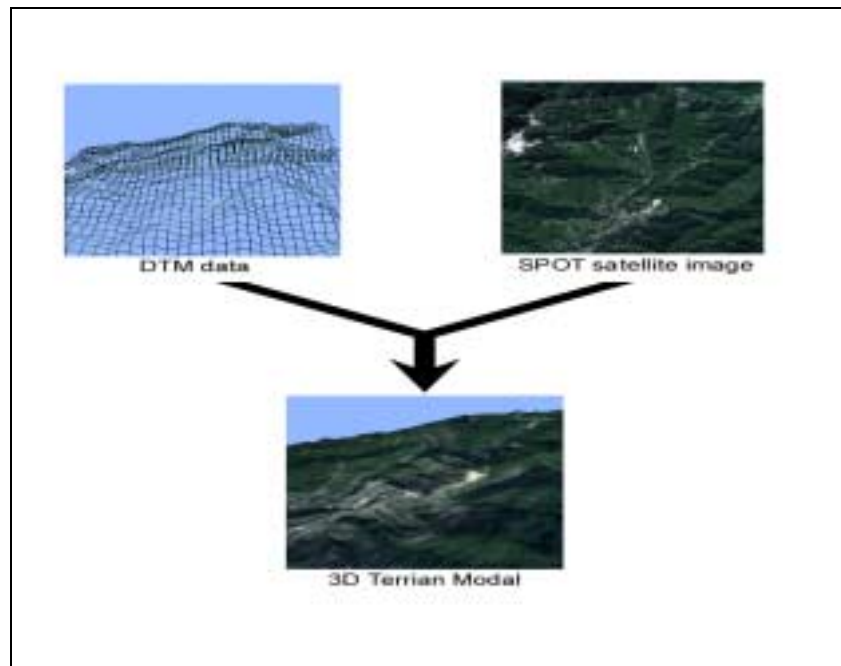

Figure 2.   Terrain model of the study area - Chichiawan Stream basin.
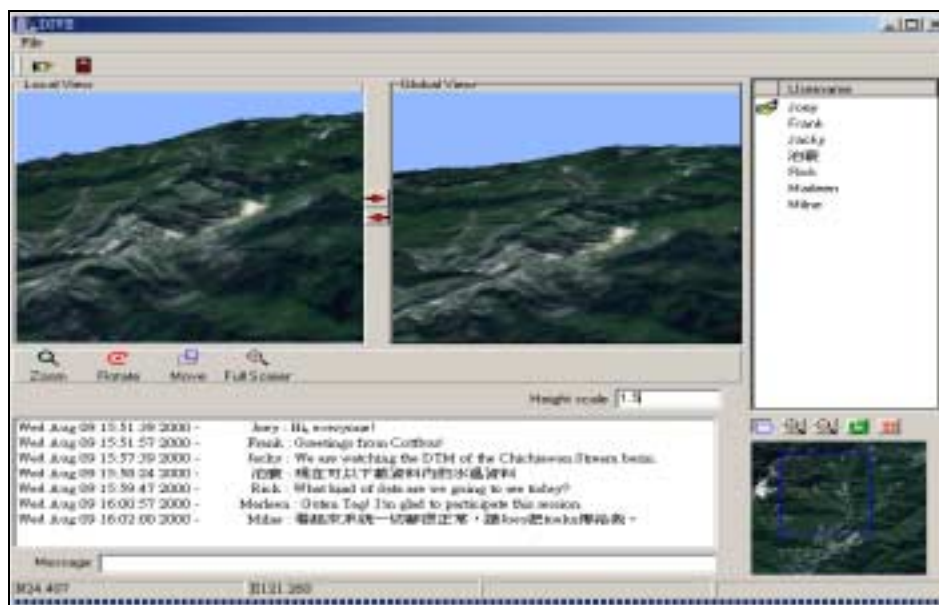

Figure 3.   Application of DIVE for the terrain model of the study area – Chichiawan Stream basin.

3. Database Visualization Environment

Traditional GIS supports the query and analysis of geo-referred data and information, and presents the data in simple formats such as charts and tables in a passive way. The presentation of data and information is, in general, less attractive and lack of diversities as well as interactivities. Due to the fast-changing network and multimedia technologies and advancement of computer graphics, the exploration of data and presentation of information of GIS have therefore improved and become one of an active research subjects [7]. In this study, we developed a GIS-based data and information visualization environment, a GIS-based DBVE. Contrary to classical GIS which emphasize on data query and analysis, DBVE used the DTM (digital terrain model) as an infrastructure to present and visualize the geo-referred data and information, such as data, text, image, audio/video, animation, and other multimedia, in a three-dimensional virtual world. Figure 4 shows the architecture of DIVE and its relationship with DBVE. DBVE is an independent module of the DIVE system. The DBMS is a standard server-client architecture where server holds and manages the actual database, and clients hold software to work with database [12]. It was designed to access the target data of the database system, and present the geo-referred data and information in a three-dimensional virtual world.

We used Microsoft SQL Server as our back-end DBMS and developed the kernel of DBVE using the BCB (Borland C++ Builder). DBMS is used to store and manage the large amount of data. We used DBE (Borland Database Engine) and ODBC (Object Database Connection) to link the DBMS. Any DBMS that meets the standard of ODBC can be processed by DBVE. Figure 5 illustrates the architecture of DBVE. DBVE connects to the standard interfaces, BDE and ODBC, to access SQL Sever. Users can remotely access the data and information via the SQL server, and present/visualize the data and information with the functions and formats of the *display* module of DIVE support. The data and information, such as data, text, image, audio/video, animation, and other multimedia, are presented in a table or chart or multimedia in the three-dimensional virtual world.

4. Application of Database Visualization Environment

The Formosan landlocked salmon is one of the legally-protected endangered animals of Taiwan. The small population can be found only in the Chichiawan Stream basin of the Shei-Pa National Park which locates in the upstream of Daichia Stream. The authorities of Shei-Pa National Park have persisted in population census of this precious species to effectively supervise and protect the relic natural treasure. Water temperature of the creek which is one of the important indicators of the living condition for the Formosan landlocked salmon has been recorded in the past years. We used the database of the study [1] as an example to demonstrate the functions and features of the GIS-based DBVE.

Figure 6 depicts the interface of database connection and diagram setting of DBVE. DBVE connects the target DBMS via DBE and ODBC. Users can navigate around the study

area in the 3D virtual environment as illustrated in Figure 3, and choose the locations and associated data and information, and present them in a table or diagram format. Figure 7 shows the time history of the water temperature of one of the measurement site.
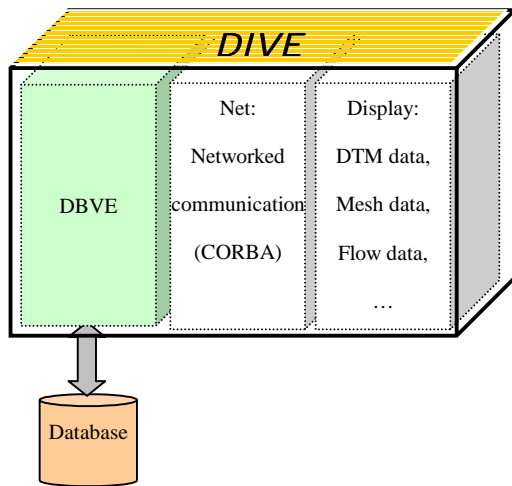

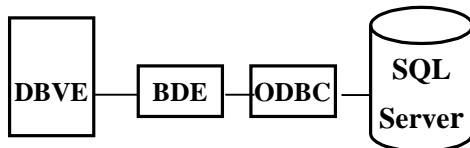Figure 4. Architecture of DIVE and its relationship with DBVE.

Figure 5. Architecture of DBVE.

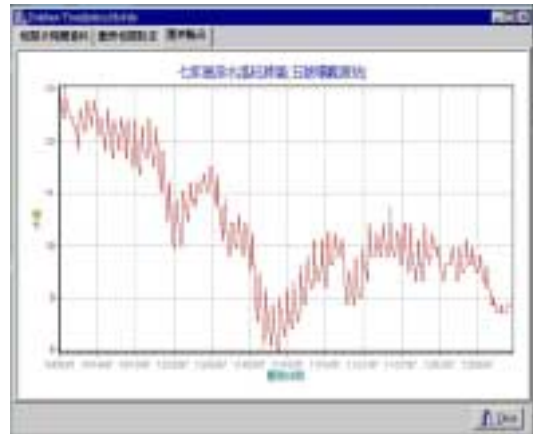Figure 6. Interface of database connection and diagram setting.

Figure 7. Illustration of the chart presentation of data: The time series of water temperature at one of the measurement site.

DBVE also supports the functions of multimedia playing which is done with the TMediaPlayer component of the BCB. Figure 8 illustrates the playing of an MPEG (Motion Picture Experts Group) file that records the activities of Formosan landlocked salmon. Users can choose the button to control the multimedia device such as CD-ROM drive, MIDI sequencer, or VCR.
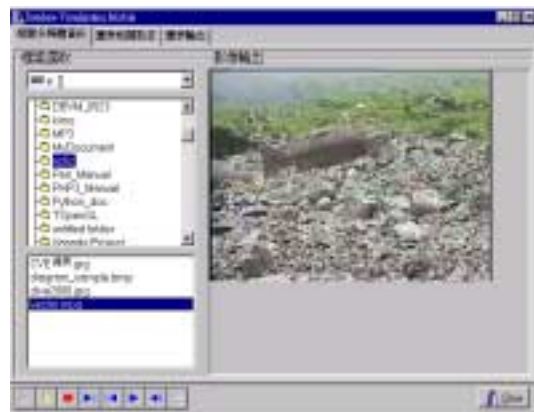

Figure 8. Illustration of the multimedia functions of DBVE.

Figure 9 illustrates the dynamic linkage of DBVE to other organizational websites. Users can save the relevant websites in the database for references. By double clicking the URL of the websites listed on the text grid of the left panel of the window, users can automatically access to the hyper-linked URL, and launch the default browser to view the organizational database as shown on the right panel of the window.
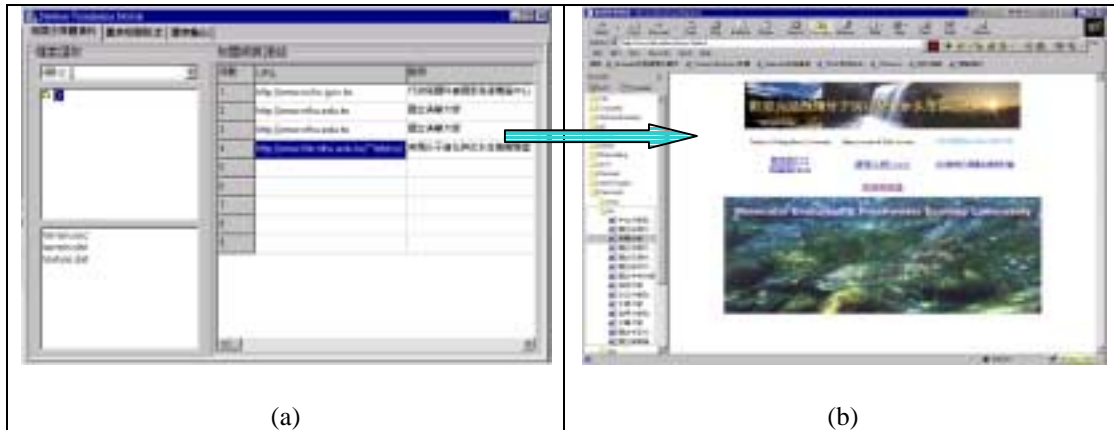

(a)	(b)

Figure 9.   Illustration of dynamic linking to other relevant websites: (a) The listing of the organizational websites of the database, and (b) direct linkage and web view to the target website.

5.   Conclusion

Traditional GIS (geographic information system) integrates the technologies of topography, terrain features and databases. It supports query and analysis of geo-referred data and information as well as the visualization of two-dimensional topographies in a passive way. The presentation of data and information is less attractive and lack of diversities as well as interactivities in general. Due to the fast-changing network and multimedia technologies, and advancement of computer graphics, the exploration of data and presentation of information of GIS have hence improved. A GIS-based data and information visualization environment, a GIS-based DBVE, was developed. Contrary to classical databases which emphasize on data query and analysis, DBVE used the DTM (digital terrain model) as an infrastructure to present and visualize the geo-referred data and information, such as data, text, image, audio/video, animation, and other multimedia, in a three-dimensional virtual world. The system was applied to explore and present various types of geo-referred data and information of the study of population ecology of Formosan landlocked salmon [1]. This innovation was found very useful and effective to present and visualize the geo-referred data and information, and could be used as a CAI (computer-assisted instruction) for promoting computer graphics and environmental education. General public can grasp the advancements and applications of computer technologies, and use this system to learn the growing environment and habitual behavior of Formosan landlocked salmon.

6. Acknowledgements

7. LIST OF ABBREVIATIONS

BCB: Borland C++ Builder

CAI: Computer-Assisted Instruction

CD-ROM: Compact Disk Read-Only Memory

CORBA: Common Object Request Broker Architecture

DBE: Borland Database Engine

DBMS: Database Management System

DBVE: Database Visualization Environment

DIVE: Distributed and Interactive Visualization Environment

DTM: Digital Terrain Model

GIS: Geographic Information System

MIDI: Musical Instrument Digital Interface

MPEG: Motion Picture Experts Group

ODBC: Object Database Connection

SQL: Structure Query Language

URL: Uniform Resource Locator

VCR: Video Cassettes Record

VR: Virtual Reality

8. References

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