A DEVELOPMENT OF 3D URBAN INFORMATION SYSTEM ON WEB

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ABSTRACT:

The needs for 3D city models are growing rapidly and the applications of those models on computer graphics and virtual reality are appearing in a variety of fields in recent years. In parallel, the speed of the internet communication is being greatly improved by the fast and wide spread of broadband infrastructure. Today, those web3D applications are waited eagerly that make possible interactive fly-through and walk-through manipulations in detailed 3D city models on the internet. For the recent few years the authors have developed techniques for automatic generation of 3D city model using LIDAR data, 2D digital map and aerial photography, as well as a virtual reality (VR) viewer software with high-speed graphic engine which can deal with large areas of 3D city models on VR. The newly developed 3D urban information system on web can provide transmission and reception of a great amount of urban information with interactive manipulation of detailed 3D city models linked with geographic information system (GIS), on ordinary internet infrastructure such as DSL. New techniques have been developed for the system, including; (a) reduction of data, (b) level of detail (LOD) and streaming, and (c) linkage between 3D city model and geographic information system (GIS). Based on those techniques the authors have developed a prototype system that includes the design and construction of a client-server system as well as the development of the client software. After those basic developments the authors conducted an experiment of communication in a local area network (LAN) environment, which resulted in a great success.

1. INTRODUCTION

In recent years, the needs for 3D city models are growing rapidly and the applications of those models on computer graphics and virtual reality are appearing in a variety of fields, including urban design, tourism, commerce, hazard prevention and real estate development. A 3D city model, which consists of a great number of buildings and structures, can offer accurate and realistic images of fly-through and walk-through in a great area of city, and is recognized as a very useful urban information infrastructure. For the recent few years the authors have developed techniques for automatic generation of 3D city model using LIDAR data, 2D digital map and aerial photography (Figure 1), as well as a virtual reality (VR) viewer software with high-speed graphic engine which can deal with large areas of 3D city models on VR.

On the other hand, as broadband communication infrastructure, such as DSL (digital subscriber line), is getting popular, and 3D graphics hardware is rapidly getting cheaper, a variety of Web3D techniques have been developed which make possible display real-time 3D image with associated information through the internet with easy operations. And now some of them are used in the business area, especially in e-commerce for industrial products.

A few Web3D systems even have made possible to communicate and display a wide area of cities on the internet. However, those systems show only terrain model with texture of aerial photography providing only fly-through images. Up to now we cannot find Web3D systems which offer photo-realistic walk-through images of wide area of cities. And we cannot find such systems that are integrated with spatial database of geographic information systems (GIS) either.

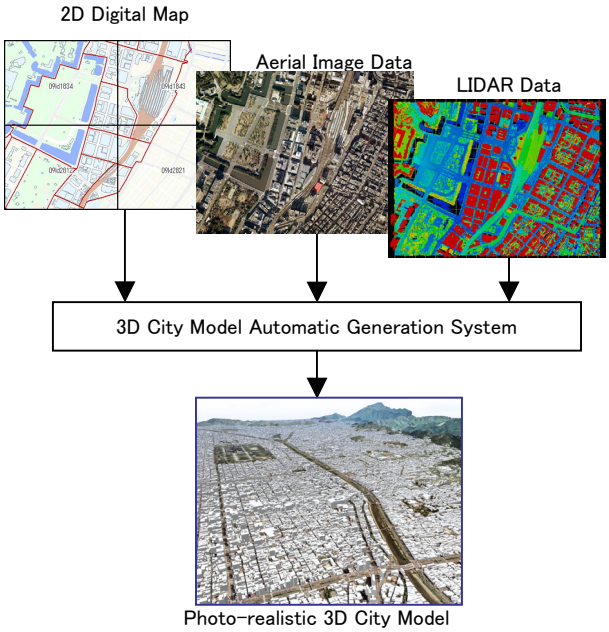

Figure 1. Automatic generation of 3D city model

2. DEVELOPMENT OUTLINE

The research has aimed at the development of an urban information system using new Web3D techniques which make possible walk-through in a wide area of photo-realistic city models in the internet. This paper reports on major technical problems in the development and the ways they are solved.

2.1 Data Structure of 3D City Model for Web

A 3D city model ordinary consists of a great amount of geometry data of buildings/structures and terrain models. When they should be transmitted through the internet, it becomes a critical requirement to reduce the data as well as to divide it into small data parts in order that they can be transmitted efficiently in the ordinary transmission environment.

2.1.1 Geometry Data: When a 3D city model is rendered in real time, those polygons of buildings/structures and terrains defined by 3D coordinates are displayed. Because the buildings' geometry data occupy the largest portion of the whole data, the reduction of their amount is most important. The authors have developed a new way of data reduction by keeping the building's geometry data as the polygon of its bottom shape and its height instead of the polygons of all surfaces. As the result the reduction of data amount reached to 20% of the original (Figure 2).

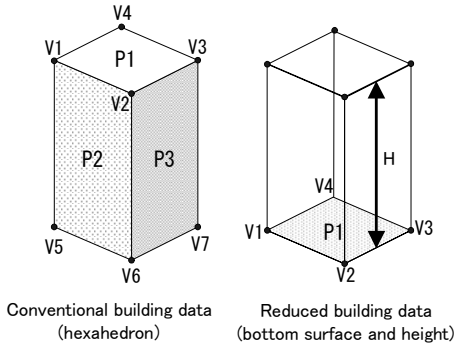

Figure 2. Data structure of the building

2.1.2 Texture Image Data: The texture images for the terrain models are usually made from aerial photography. In order to achieve smooth real-time display, the texture images of different resolutions for terrain models are made and stored in the database server. First, the client PC sends data including the view position and distances to the objects to the web server. The web server orders the database server to extract the image data with the most appropriate resolution for the user's view position. Then the extracted image data are sent to the client PC (Figure 2).

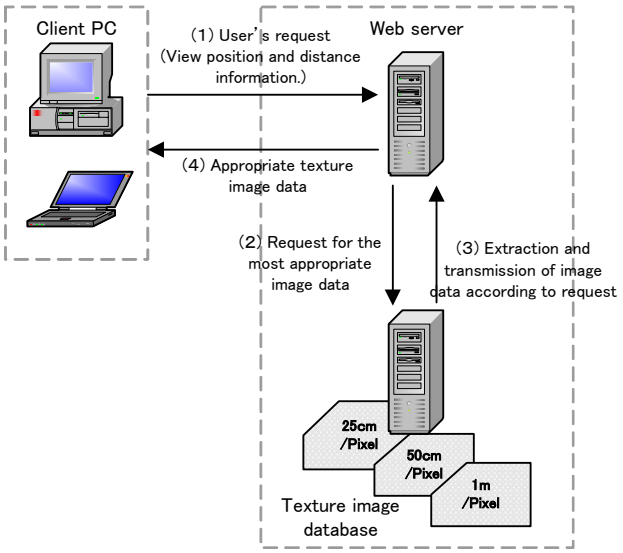

Figure 3. Transmission of texture images

2.2 Seamless Transmission of 3D City Model

When a great amount of data like a 3D city model and related information is communicated between a server and client PCs through the internet, it is very important that the 3D images should be drawn and displayed in real time with good quality in order that the users feel less stress in their operations. Aiming that the authors have developed new techniques for seamless transmission of 3D city model including techniques of the level of detail (LOD) and the streaming of data.

2.2.1 Level of Detail (LOD): Level of detail (LOD) is a technique that is widely used for virtual reality to control in real time the quality of 3D models' display. It automatically changes display/non-display of 3D objects, as well as display of the objects' geometry and texture images with appropriate data amount and resolutions, according to the distances between the viewing positions and viewed objects, and the viewing angles. By employing LOD technique in the development, it has been achieved that a great amount of data of 3D city models can be dealt with in real time in ordinary network environment such as DSL.

In the developed system, the client PC first receives the area management files from the web server. The area management file includes reference addresses, and the position, size, type and display priority of 3D object data. Then the client PC receives appropriate data which is automatically selected by the web server according to the client PC's information such as viewing positions and angles. When the viewing positions and angles change in the client PC, a new request is sent to the web server. Then the web server transmits only the requested data to the client. Figure 4 shows the process of LOD in the transmission.

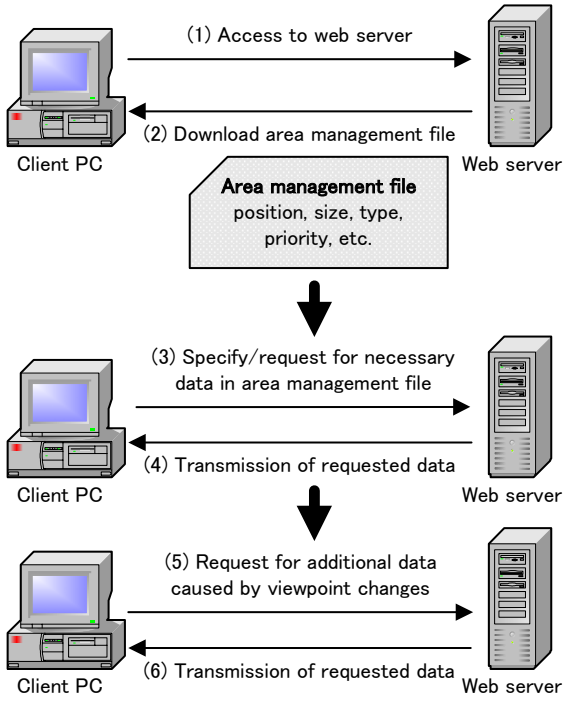

Figure 4. Process of LOD in transmission

2.2.2 Application of Streaming Technique: Streaming is a technique ordinary used for the transmission, reception and real-time playing-back of music or movie content through the internet. With streaming technique the data is continuously

transmitted and displayed little by little through the network. Before the streaming technique could be used in the internet, the users could enjoy the contents only after all data was downloaded in the hard disk of PC. Therefore the PC had to have a considerable amount of hard disc capacity then. Today, the streaming technique is essential for the transmission of great amount of data through the internet such as in the case of internet broadcasting.

Employing the streaming technique the authors have developed an application for the timing control of loading and unloading of 3D city models.

According to the request for LOD received from the client PC, the web server transmits the requested data continuously little by little. The client PC continuously downloads the data and displays the image. On the other hand, the data downloaded before and not used at the time is automatically deleted from the memory so that new data can be downloaded there.

In the case of the streaming of music or movie, the content data is processed in order of time. However in the case of the streaming of 3D city information, the data is transmitted, received and played back with the priority according to the client's viewing points and angles.

As to the communication protocol the authors have employed HTTP protocol, which is widely used in the internet, so that the system can work in all ordinary firewall environments.

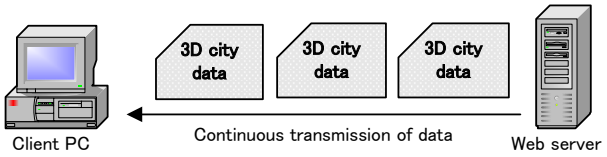

Figure 5. Streaming of 3D city data

2.3 Database Management System

A database management software is necessary for the system for efficient reference and display of 3D-GIS. Through detailed investigation of database management software in the market, the authors have selected and employed Oracle10g Standard Edition because it has the best development environment for indexing, referencing and operation of spatial information.

3. CONSTRUCTION OF PROTOTYPE SYSTEM AND EXPERIMENT

After the development of techniques described aforementioned, the authors have developed a prototype of 3D urban information system on web. The prototype aimed to transmit 3D city model of a whole city area and attribute information in DSL communication environment using ordinary PC, though equipped with a graphics card.

Then by using the prototype system the authors have conducted an experiment of transmission and reception in a local area network (LAN) environment.

3.1 System Structure

As shown in figure 6, the prototype system consists of a web server which transmits 3D city model, a GIS server which controls and manages GIS database, and the client PCs.

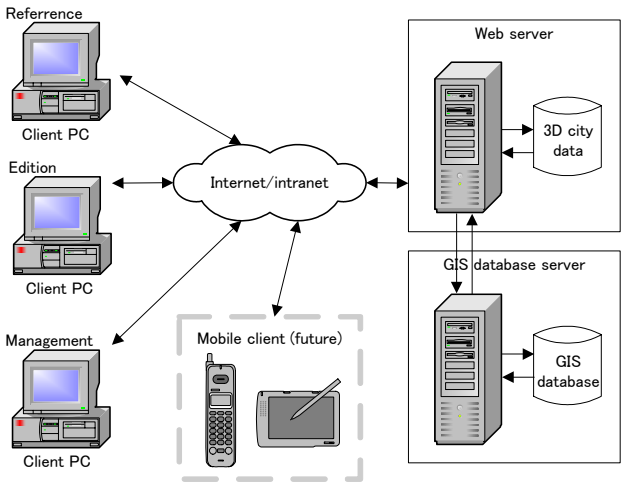

Figure 6. System structure

3.2 System Environment

With the prototype system a transmission experiment was conducted using the 3D city model of all of the 23 wards of Tokyo with the area of 600 square kilometer. The total size of building data reduced by the new technique reached to 600 megabyte. Incidentally, that of conventional building data was 1.8 gigabyte.

The experiment employed Apache for the web server software, a Linux PC with Pentium III 1 gigahert CPU and 1 gigabyte memory for the web server, and 3 Windows PCs with NVIDIA GeForce4 Ati Randeon8500 graphics cards for the client PCs. The experiment was implemented with these 3 PCs all of which were connected to the web server at the same time.

Server PC	Web server: Apache OS: Linux CPU: Pentium III 1 GH z Memory: 1 GB DBMS: Oracle10g
Server Transmission	Optical fiber network 100 Mbps (Efficient speed of 40 Mbps)
Client PC	OS: Windows XP/2000 Bowser: Internet Explorer 6.0 CPU: Pentium III 1 GH z Memory: 1 GB Graphics card: NVIDIA GeForce4200Ti/ATi Radeon8500
Client Transmission	ADSL 4 Mbps (Efficient speed of 80 Kbps with 4 kilometer distance to telephone network station)

Table 1. System environment for the experiment

3.3 Experiment

The result of the experiment was successful. Both user's operation and displaying speed were sufficiently smooth, achieving approximate rate of 30 frames per second. In most cases the amount of data displayed at once in a viewing angle ranging from several kilobyte to several hundred kilobyte. And the data divided into several dozen kilobyte was consequently loaded and displayed. As the result, a sufficient responding speed was achieved even in DSL environment. Figure 7 to 9 show the examples of displayed images at the experiment.

The experiment employed the spatial indexing function of Oracle10g, and it achieved a sufficiently speedy response. It took about 1 second for the extraction of designated building information from the data of 2 million buildings in 23 wards of Tokyo.

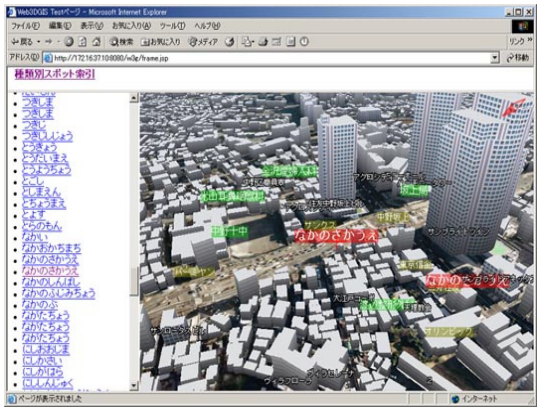

Figure 7. Display of 3D image and the list of areas

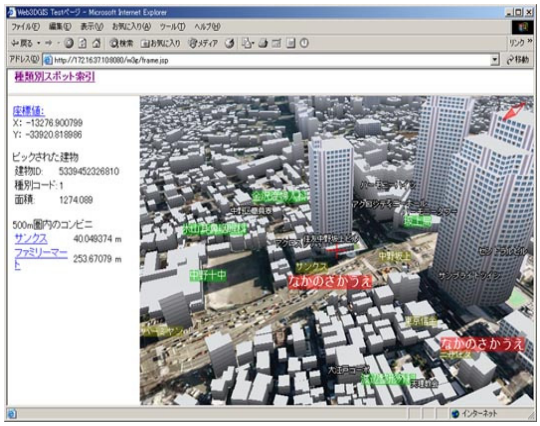

Figure 8. Display of the buildings' information

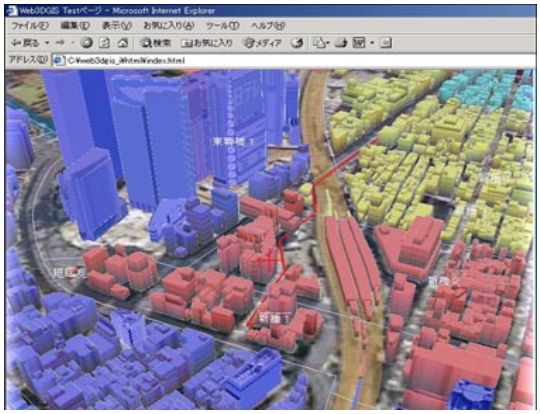

Figure 9. Colouring according to the buildings' attribute

4. CONCLUSION AND FUTURE WORK

In the transmission of 3D city model, the prototype system has achieved a greater response than expected in spite that it should deal with a great amount of data. The most difficult part in the development was to design the structure of data and the database for smooth transmission and reception. The authors believe that the development has been successful in that sense, and has achieved a basis for a variety of systems that will be developed from now on.

Our future works should include easy link with other GIS databases, easy import and disposition of 3D data of different formats, equipment of analytical functions of GIS, and transmission of 3D terrain model.

References from Journals:

Meguro, K., Yoshimura, M., Takase, Y., Goh, B, Sone, A., 2003. Development of Integrated Information System for Disaster Management, 2nd International Symposium: New Technologies for Urban Safety of Mega Cities in Asia, International Center for Urban Safety Engineering, Tokyo, pp.339-344.

Takase, Y., Sho, N., Sone, A., Shimiya, K., 2003. Automatic Generation of 3-D City Models and Related Applications, International Workshop on Visualization and Animation of Reality-based 3D Models, Tarasp-Vulpera, Switzerland, ISPRS Commission V, WG V/6, CD-ROM.

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