C. M. Herr, N. Gu, S. Roudavski, M. A. Schnabel, *Circuit Bending, Breaking and Mending: Proceedings of the 16th International Conference on Computer-Aided Architectural Design Research in Asia,* 261-270.

SIMULATING 3D ARCHITECTURE AND URBAN LANDSCAPES IN REAL SPACE

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Abstract. In the present research, we have developed a system by which to simulate three-dimensional architecture and urban landscapes in any outdoor space. As the basic AR environment, we used Vizard running on a laptop PC, where the urban model component, location tracking component, and image display component work together using original Python scripts. For the urban model component, digital maps data were converted. For the location tracking component, portable DGPS and a high-precision gyroscope were introduced in order to minimize the locational error. For the image display component, optical see-through HMD was used. Stereovision was also realized with the functions of GPU on the PC. A walking experiment was performed to test the proposed system on a redevelopment plan for our university campus.

Keywords. AR; GIS; DGPS; Optical see-through HMD; Stereovision

1. Introduction

At present, landscape simulation using CG is widely used in the field of architecture and urban planning in order to produce photorealistic images of proposed plans. Most of these images must be viewed on printed materials or on a screen presentation in a room. However, spatial recognition by planar picture expression can be at variance with the spatial recognition of real space.

For example, most architectural regulations (e.g., volume control) are designated based on numeric criteria. However, the experiment of the present study reveals that even experts cannot accurately estimate architectural volume from a three-dimensional image presented on a screen. In order to understand the construction project exactly, visual pseudo-recognition at the actual location can be effective for both experts and general citizens.

However, augmented reality (AR) technology is growing rapidly, and advanced applications are beginning to be used. Systems to supply text-based information within the view of actual places have attracted the attention of the public*1, whereas the use of systems to supply three-dimensional images remains limited to indoor experiments or trials in a confined space.

In the field of information technology, the experimental system using RTK-GPS and HMD was proposed in the late 1990s (Feiner et al, 1997). Then, in the field of architecture and urban planning, various studies have also been performed by the advanced researchers in the world (Wang and Schnabel, 2010). In Japan, Onohara and Kishimoto (2004) used the immersive HMD in the experimental room to evaluate street landscapes virtually. Kakuta et al (2008) imaginarily reconstructed the ancient capital "Asuka-Kyo" landscape on the site by using RTK-GPS and video see-through HMD. Recently, many studies using ARTookit can be found to overlay virtual models on the video images based on the makers located in real space (Yamada et al, 2008; Kunori and Watanabe, 2010). Similar to the evolution of CG technology, these farsighted researches are committed to the overlay of photorealistic images for exact and natural video images and do not enable users to walk around freely. Kawaguchi et al (2006) studied the movable system using Tablet PC and DGPS, nevertheless he pointed out the problem of taking time to modify locational errors of overlaying images.

2. Objectives

The purpose of the present study is to develop an AR system that can simulate three-dimensional architecture and urban landscapes at any location in outdoor spaces, not only depending on high-precision sensing devices, but also introducing a manual function to interactively correct locational errors with reference to the existing facilities. Specifically, the proposed system is implemented using three components, namely, the urban model component (GIS / CG), the location tracking component (GPS / gyroscope / game controller), and the image display component (HMD / stereovision), which work together using computer code developed for this project.

3. System configuration

The proposed system is shown in Figure 1, and the elements of the three components of the system are shown in Figure 2. The laptop PC and peripheral devices are installed on a backpack frame, which enables the system to be carried by the operator. The system weights 8.4 kilograms.

In terms of software, Windows XP is used because old and new elemental technologies must be combined, and Vizard is used as the AR development environment. The computer code consists of scripts written in Python as an object-oriented programming language.

Figure 1. Proposed system

3.1. URBAN MODEL COMPONENT

For the case in which position markers or magnetic sensors installed in the local area are used to obtain locational information of viewpoint for displaying the specific three-dimensional model, it is sufficient to use the relative coordinate system. However, for the case in which GPS is used to obtain locational information over an extensive area, three-dimensional models should use the official coordinate system.

In the present study, we used the official digital map data developed by GSI (the urban foundation, e.g., roads, railways, and public facilities) and the commercial digital map data (additional information, e.g., office buildings, apartments, and private houses) together as the fundamental locational information. However, these data sets use individual data formats and cannot be loaded directly into the AR environment. The geographic information system (ArcGIS) is used to convert the data to the proper format, and the data are also modified and complemented to fill in incomplete areas from ArcGIS by using orthographic high-accuracy aerial photo (resolution: 8 cm).

Since digital maps are basically two-dimensional data, the digital elevation data (DSM/DTM) obtained by airborne LIDAR are used as height data. The DSM are the three-dimensional coordinate data of the surface of the ground, including the effects of construction, according to the recording density with a horizontal resolution of 2.5 m. The DTM also include three-dimensional coordinate data of the terrain in which the effects of construction are removed based on a mesh density of 5 m. Architectural volumes are estimated by assigning differences in average *z* values of the DSM and DTM included within each polygon of architectural components in the two-dimensional map.

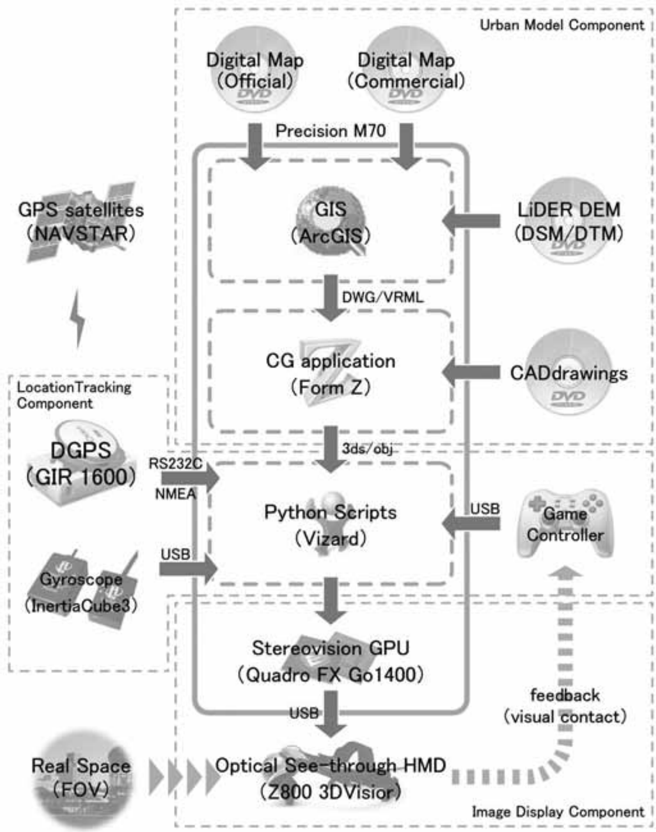

Figure 2. Elements of the proposed system.

In order to complete the three-dimensional urban model, the versatile DWG/VRML files exported from ArcGIS are imported into the CG application (Form Z). After the DWG/VRML files are combined with the data of the newly planned buildings designed based on CAD drawings, all of the files are converted to the 3Ds/obj format, which can be loaded into the AR environment.

3.2. LOCATION TRACKING COMPONENT

High accuracies are required in order to measure the viewpoint and eye direction of the system wearer so that three-dimensional urban models of images can be overlaid on the real space. For viewpoints, popular GPSs are not sufficiently accurate. A portable Differential GPS device (SOKKIA GIR 1600) is introduced in order to minimize the locational error. The GIR1600 realizes the locational accuracies within 1 m and exports longitude and latitude information based on the standard NMEA format via a legacy RS232C interface. The original script is prepared in order to open the RS232C port, read NMEA records, translate these records to the official coordinate system[*2], and pass the records to the viewpoints of the three-dimensional urban model.

For the detection of eye directions, the gyroscope initially attached to the HMD (described later herein) has poor sensitivity and does not provide sufficient accuracy. As with the case of locational information, a dedicated gyroscope (Intersense InertiaCube3) is introduced in order to minimize the directional error. InertiaCube3 realizes an RMS accuracy of 1 degree in the yaw direction and 0.25 degrees in the pitch and roll directions and exports this information via a USB interface. In the developed script, although the correction of declination according to the results of geomagnetic measurement[*3] is taken into account, the results are also passed to the eye direction at the viewpoint.

However, there are limitations to the accuracies of sensing devices. In addition, the errors are also included to some extent in the constructed three-dimensional urban model, even though the model is made from the official data. Therefore, it is impossible to closely match visual images to the real space at any time. In order to address this problem, a manual function to interactively correct the viewpoint and eye direction, a game controller is incorporated into the system.

3.3. IMAGE DISPLAY COMPONENT

Video see-through HMDs are widely used in the recent studies on AR in attempts to effectively combine the physical field of vision and the generated virtual images. However, using video see-through HMDs for the purpose of walking freely in outdoor spaces is dangerous because video see-through HMDs completely obstruct the physical view of the operator. Therefore, an optical see-through HMD (eMagin Z800 3DVisor ST) is used in the present study. The resolution of the 3DVisor is 800 × 600 pixels, and the generated virtual images are overlapped transparently through half-mirror glasses. That is, the physical view required for walking is ensured, while the background, which should be hidden by generated images in nature, can be seen at any time. Therefore, there is no sense of processing contextual occlusion between real substances and virtual objects. In addition, at present, it is impossible to provide a sense of high immersion because the viewing angle of the optical see-through HMD is not of sufficient width as compared to the viewing angle of the human eye. These characteristics are unsuitable for achieving high-quality images, but are acceptable for assisting in the spatial recognition of real space.

In order to take full advantage of the binocular HMD, stereovision is also investigated in order to provide depth perception to the three-dimensional urban model. Stereovision technology has been used in the field of computer games, but these games are only used on the desktop computer systems. Few laptop PCs realize stereovision using the GPU function on a PC. After several trials, the ability to use a specific stereovision driver on the GPU (nVIDIA Quadro FX Go1400) installed in a legacy PC laptop (DELL Precision M70) is confirmed.

4. Walking experiment

A walking experiment was performed to test the proposed system on a redevelopment plan for our university campus. The 2.6-km^2 site is almost flat and contains more than 200 buildings. A bird's-eye view of the site is shown in Figure 3, which shows the three-dimensional urban model prepared for the experiment.

A participant wore the system and walked freely about the campus. Based on the experimental record, the current landscape view of his eye direction at location P, the display images of binocular vision produced by the system, and the participant's actual field of view through the optical see-through HMD are shown in Figures 4 through 6. As shown in Figure 4, a new research building is currently under construction, and the landscape view after the completion of construction can be confirmed through the HMD.

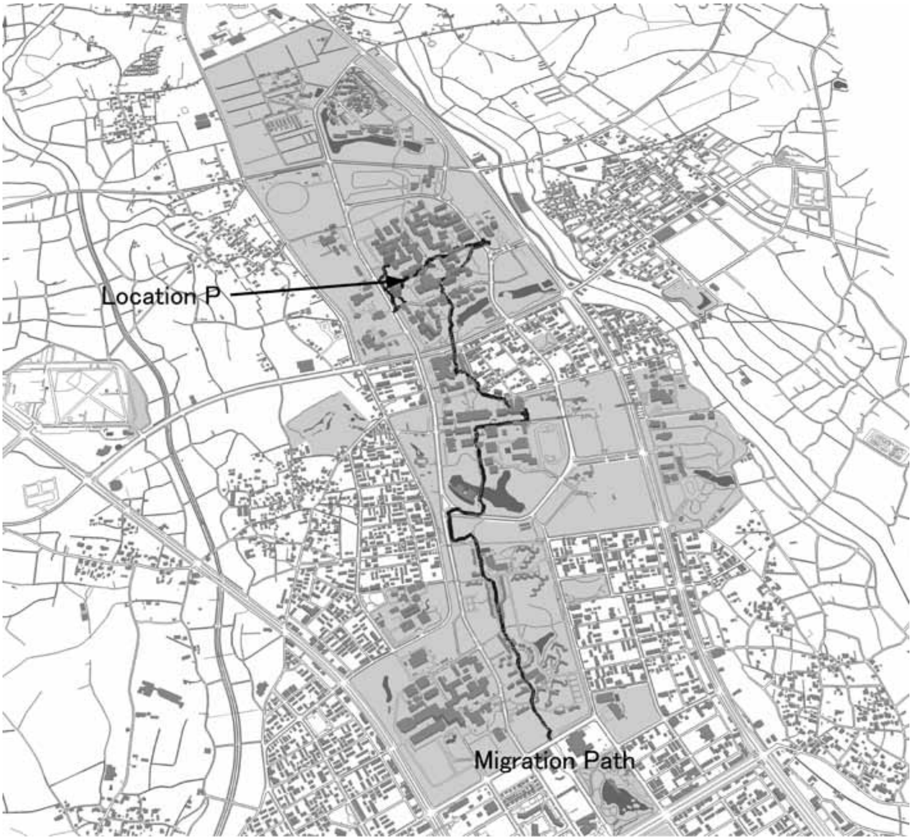

Figure 3. The three-dimensional urban model.

The record of the operation of the game controller by the participant associated with walking is shown in Figure 7. The viewpoints were generally measured in the correct positions, which verifies the accuracy of the proposed system. However, GIR1600 returns 0.0 for the longitude and latitude values when the signals cannot be properly received, for example because of being in the shadow of a building. As a result, the display images were momentarily jumbled. The participant more frequently adjusted the yaw/pitch/roll, as compared to the position. That is, with respect to spatial recognition, errors in eye direction are more bothersome than errors in viewpoint.

Figure 4. Current landscape view at location P.

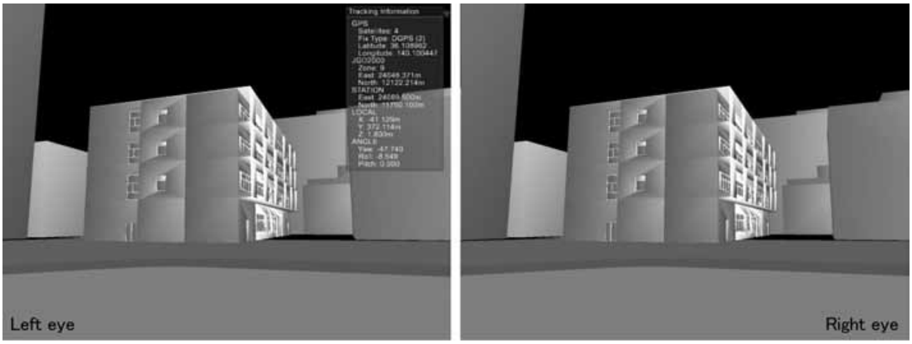

Figure 5. Display images produced by the proposed system.

Figure 6. Actual field of view through the optical see-through HMD.

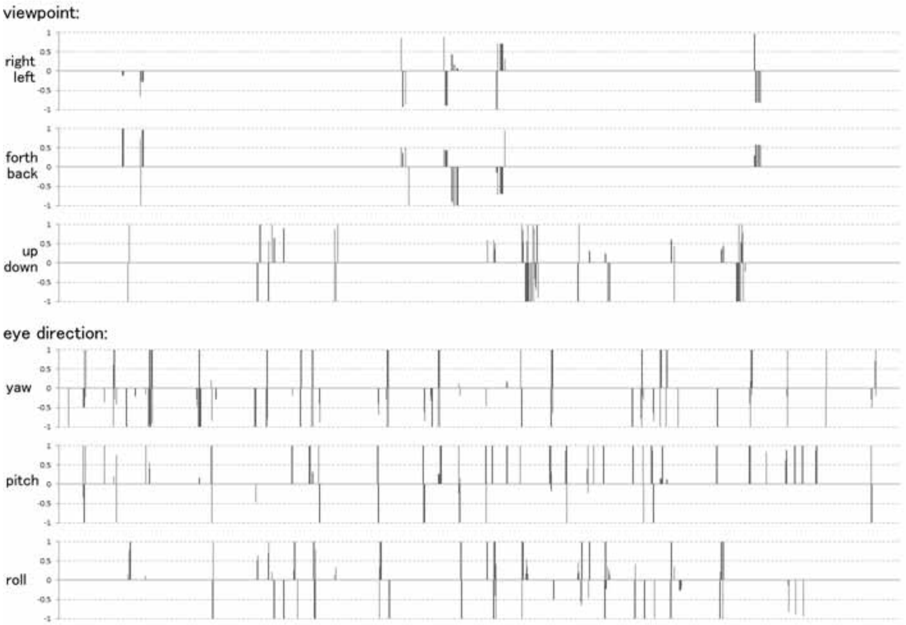

Figure 7. Record of operation of the game controller.

5. Conclusion

Unlike CG and VR, AR requires position adjustment between real space and virtual space. In the present study, we developed a system that can be used extensively in outdoor spaces by integrating advanced devices and manual functionality to correct locational errors according to an existing three-dimensional urban model. A university campus with spaces that are under development was selected as the subject of a walking experiment. However, landscape simulations using this system can be used not only for currently nonexistent features, but also for existent features that can't be seen. It may be used to confirm the old-time view of city landmarks (e.g., church steeples or distant mountains) recently hidden by tall buildings.

The prototype system is heavy, primarily because of the use of a DGPS device and a legacy laptop PC that supports stereovision. The size and weight of these components are expected to be reduced as advanced GPS and 3D technologies become more commonplace. However, the stereovision of the prepared three-dimensional urban model provides little information regarding depth perception, and much more detail is required in order to improve the system. Since the optical see-through HMD does not have high luminance, it is difficult to see in sunlight, but the HMD was adequate for use in the evening and on cloudy days.

With respect to the necessary computer scripts, an automatic function to correction viewpoints according to the adjacent data is required to prevent display images from jumbling when the GPS device cannot pick up a signal. In addition, at present, the system loads all of the data of the three-dimensional urban model upon start-up. In the future, a mechanism to separate and load data individually as needed is expected.

Endnotes

1. For example, “Sekai Camera”, which was introduced in 2009, attracted a great deal of attention as a practicable AR application that can be used on the iPhone.
2. http://vldb.gsi.go.jp/sokuchi/surveycalc/algorithm/bl2xy/bl2xy.htm
3. http://vldb.gsi.go.jp/sokuchi/geomag/

Acknowledgements

We would like to acknowledge the contribution of Mr. Yoshitaka Kunori, a graduate student at University of Tsukuba. The present study was supported by the “New Developments of Spatial Analysis Methods Combining Geographic Information Science and Urban Engineering” Grants-in-Aid for Scientific Research (KAKENHI) in Japan.

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