Development of the Environmental Design Tool "Tablet MR" on-site by Mobile Mixed Reality Technology

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As a tool for carrying out environmental design study on planned construction site (on-site), the "Tablet MR" system adapting MR (Mixed Reality) technology is designed and a prototype system is developed. Tablet PC, RTK-GPS, 3D motion sensor and a live camera are unified; VR image is compounded on live video image. A use scene is assumed after performing system design, mounting, and accuracy verification.

Keywords: *Mixed Reality; Mobile Computing; Environmental Design; On-site Design Tool; GPS*

Introduction

In a planned construction site (on-site), design review meetings of specialists, such as architects and clients, or presentation scenes among professionals and local residents or citizens are usually held. Although drawings and perspective drawings are now used in such situations, since these are not intuitive images, it is hard to recollect them after completion. This research develops the mobile type design tool "Tablet MR" which compounds a video image displaying the present condition of a planned construction site, and a 3DCG (3-Dimensional Computer Graphics) image displaying a design proposal in real time. VR (Virtual Reality) technology and its systems have so far been developed as an effective means of design simulation or presentation in the environmental design field (Fukuda, 2003). However, these are systems that assume use inside a building or a meeting room. Mobility is required to use such a system on-site. On the other hand, MR (Mixed Reality) is a technology which mixes and displays a video image and VR image. Kuo (2004) is developing a mobile mixed reality system for an outdoor sustainable education tool in a university campus as an example of research in the environmental design field. In this paper, development of a "Tablet MR" system, accuracy verification of the system and consideration of system use are carried out.

Concept of MR and system design

When onsite use is required, the integration of a plan proposal rendered in a VR system and of real world visual stimuli may be of use. Two methods of integrating real world visual stimuli and real-time CG models in a contiguous real-time representation are available: AR (Augmented Reality), which extends real space, and AV

Figure 1
Definition of MR concept.

Figure 2
System Sketch

(Augmented Virtuality) which extends virtual space. The method, which encompasses both of these methods and provides an integrated real-time representation, is mixed reality (MR) (Figure 1).

In the MR system, the pattern matching technique and sensor embedding technique are used in a method which compounds a video image and a VR image. Although these techniques are effective in the interior of a room or a narrow space, for a wide area, such as in an environmental design, they are not suitable. To attain the purpose of this research, it is necessary to extend the present VR system (Yeo, 2005) and to develop the following: GPS sensor which adopts the network type RTK-GPS (Real Time Kinematic-Global Positioning System) survey system by VRS (Virtual Reference Station) with the high accuracy of 2-3 cm of plane errors and 4-6 cm of height errors as a system which acquires the position data of the user in real time, 3D motion sensor as a system which acquires the angle of the display unit in real time, and web camera (300,000 pixels) as a system which compounds a video image of the surrounding environment and a CG image of the design proposal on real time (Figure 2).

System implementation

First, the models for the design are created using 3DCG software (3DStudioMAX), and data are imported to VirtoolsDev3.5 of Virtools™. The video image captured with a web camera is defined as a live movie texture on VirtoolsDev. Moreover, the position and angle data of a virtual camera which draws a 3-dimensional virtual space on VirtoolsDev are calculated based on the user's position data obtained from GPS, and the rotation angle and the elevation angle data of the tablet PC which are obtained by a 3D motion sensor. An MR image is generated by mixing the VR image rendered from the virtual camera position with the live movie texture of a video image in real time (Figure 3, Figure 4).

Furthermore, neither a mouse nor a keyboard is used for this system as an input device. Instead, a stylus is used, operated by tapping. Therefore, a user interface design that can perform all operations on a display was created. Functions such as the virtual camera operation, a 2Dmap which displays the user's position, a compass, and an error tuning program were developed. A user's system use image is shown in Figure 5, and a user interface is shown in Figure 6.

System evaluation

Accuracy verification of the developed system was performed. As the method of verification, according

Figure 3
MR system flow.

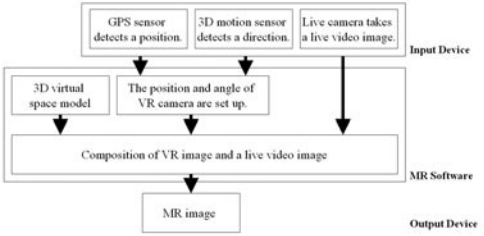
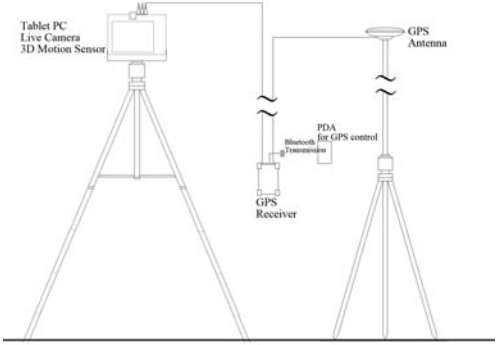


Figure 4
System configuration.



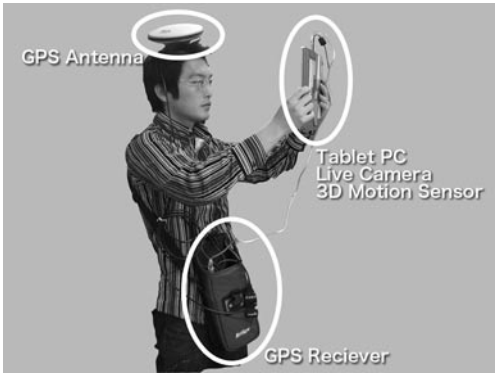


Figure 5
System use image.

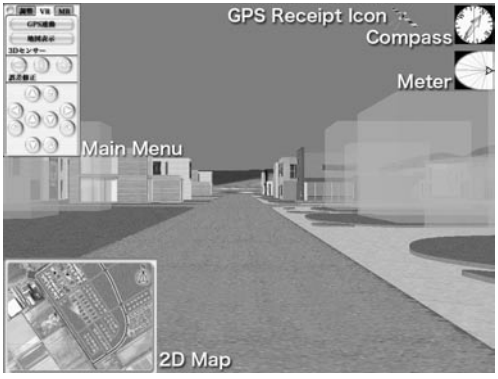


Figure 6
User Interface.

Figure 7
Hand-drawn sketch on Tablet MR.

to the distance to the design object, the view was classified into a close-range view, a middle view, and a distant view. In each landscape, the gap of a live video image and VR image was measured with the pixel value. Consequently, although adjustment of the view angle of a live camera and VR camera was realized, the 3D sensor had many errors so an error correction program was developed.

Realization possibilities are considered supposing application in actual environmental design projects. In the developed system, the rendering of the VR image is carried out in front of a live camera image. Therefore, since the situation occurs in which the object which should be in front of the VR image is not rendered, the design scope is limited. However, with a project involving a site that is currently an undeveloped land lot, it is thought that the problem of imaging the design proposal actually being realized in the location is solved effectively. For example, the Kobunaki Eco Village project, in which the authors participate, will develop farmland of 15ha, and is planned to include an environmental symbiosis type village including 300 residences, roads, and a park (Fukuda, 2006). The present condition is farmland, and when stakeholders visited the site, they made remarks such as, "It cannot be imagined that a village will actually be made" or "It is unimaginable what kind of buildings will be built where". It is thought that by showing an MR image on site to people making such remarks it will become easier to carry out image sharing of a design proposal. By using a Tablet PC, the capture of the MR image can be carried out and a hand-drawn sketch can also be added with picture editing software (Figure 7). The present environmental grasp and study of a design concept are expectable on site with use of the developed system.

Moreover, two design studies were performed using the developed system, reconstruction simulation of the building in the authors' campus and the square renewal design in downtown Takamatsu-city (Figure 8, Figure 9). A questionnaire survey was conducted using this system. There were many favorable opinions such as, "Since design study can be performed while actually looking at the present building, it is more intuitive and easy to understand than a design study in a meeting room.", "It is good to be able to carry out a comparison study, changing two

Figure 8.
Design study by "Tablet MR" system.

or more buildings in real time", and "It is effective for those who do not know a site so well". On the other hand, there were also some negative opinions such as, "It is worrying that a frame rate falls and an MR image advances frame-by-frame", "Since the surrounding scene is reflected and crowded on the liquid crystal screen, it is hard to see the screen", and "The hardware is large and it is hard to move around".

Conclusions and future work

In this research, the on-site type "Tablet MR" system was designed as a new environmental design tool, and a prototype system was developed. Future work, would include solution of the problem by which the rendering of the VR image is always carried out in front of a live camera image, and improvement in the accuracy of each device. Moreover, since the objects and functions needed are different for each environmental design project, it is necessary to apply this system or a future upgraded system to various projects and to improve the guidelines of effective on-site design study.

Figure 9
MR capture images of square design study in Takamatsu-city.

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