ANALYSIS OF A MIXED REALITY DISPLAY FOR OUTDOOR AND MULTI-USER IMPLEMENTATION

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Abstract. This research describes a tool which can be used outdoors instead of a paper medium by a group of people to facilitate city tour guiding or design studies. First, the problems of the device and software which constitute the developed outdoor type MR (Mixed Reality) system were considered. Problems regarding the display, sensor, and composition with video and 3DCG images were clarified. In addition, taking account of the problem that the display is dark outdoors, the luminosity of a number of displays was measured in a dark room and outdoors. In addition to the dark room contrast ratio, the importance of ambient contrast was highlighted through the experiment.

1. Introduction

There are many opportunities for people to share information outdoors. The expectation is growing for development of a digital tool for sharing such information. For example, a digital tool is needed to allow city tour guides to present old photographs, old drawings or background information such as population, area, wind direction, water quality and so on. As other examples, such a tool is needed on plan sites or construction sites in order to study or to present design proposals. Figure 1 shows photographs of a city tour guide and a design study. At present, it is still common to use media such as paper in these situations.
In this research, digital tools used outside by individuals, such as cellular phones, PDAs or HMDs (Head Mounted Display), were not the targets of this study. Rather, a digital tool with which about ten people can share information was the focus of the research. Many studies have reported on digital tools used outdoors (Feiner, 1997; Behringer 2000; Julier 2000; Baillot 2001; Kuo, 2004; Onohara, 2005). However, many of these tools have been for individual use, and are thus outside the scope of this research.

The author has developed an MR (Mixed Reality) system which includes a video image displaying an existent image, and a real-time 3DCG image displaying images of objects or scenes that do not yet exist, such as design proposals or demolished buildings in real time (Fukuda, 2006; Kaga, 2007). This system for outdoor, multi-user and mobile use is set up with a tablet PC, MR software, live camera, RTK-GPS (Real Time Kinematic - Global Positioning System), and a 3D motion sensor. This system is expected to be applied for city tours or field design studies in areas of education, research and practice. However, some problems in its use have appeared.

Thus, the first purpose of this research was to identify the problems which became clear through real employment of the MR system. The second purpose was to propose a method of evaluation of the display outdoors, since this display issue was one of the most important problems identified.

Chapter 2 describes the outdoor type MR system that has been developed. Chapter 3 describes the problems of each device which constitute the system. One of the problems which become clear in Chapter 3 was the low luminosity of the display. Therefore, Chapter 4 describes the method of evaluation of the display used outdoors in order to select the optimal display. Chapter 5 gives the conclusion and describes future work.
2. Developed Outdoor Type MR System

The developed MR system consists of the following devices. First, a GPS sensor which adopts the network type RTK-GPS survey system by VRS (Virtual Reference Station) with a high accuracy of 2-3 cm of plane errors and 4-6 cm of height errors as a system for acquiring the position data of the user in real time. Second, a 3D motion sensor as a system for acquiring the angle of the display unit in real time. Third, a live camera as a system for obtaining a live image of the surrounding environment in real time.

Next, system implementation is described. First, the models for the design are created using 3DCG software (3ds MAX), and data is imported to Virtools Dev (ver. 3.5) of Virtools™. The video image captured with a live camera is defined as a live movie texture on Virtools Dev. Moreover, the position and angle data of a virtual camera which draws a 3D virtual space on Virtools Dev 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 the 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 (see Figure 2).

![Figure 2. MR system: System flow (upper left); System configuration (upper right); Appearance (lower left); Usage (lower right).]
3. Problems of each device constituting the MR system

Some problems of the developed outdoor MR system appeared during actual use. They are described in this chapter.

3.1. DISPLAY

The developed MR system is designed to allow about ten people to look at a display simultaneously. However, when this display is used outdoors, since its luminosity is low, there is a problem that the display image cannot be seen. The problem occurs not only for MR content but also with other content, such as pictures and animations. It is thought that the luminosity is inadequate for outdoor use since the display of the tablet PC in this system is of a design generally intended for use indoors.

3.2. SENSOR

The problems of sensors, such as the RTK-GPS and 3D type, are described below.

1. In order to acquire high accuracy (2 - 3 cm), RTK-GPS transmits the GPS observation data from an observation point to a data processing center. In this center, RTK analysis of this data and the standard office data generated from the electronic datum point network is performed every second. The coordinate data of the computed observation point is sent to a user's RTK-GPS. In this process, the communication interval with the data processing center is 1 second. That is, the updating interval of the position information on the 3DCG camera used in the MR system is 1 second. This means that the frame rate of the MR system is set to 1 fps or less, which is low.

2. In order to measure with high accuracy (2 - 3 cm) using RTK-GPS, it is necessary for a GPS receiver to recognize at least three GPS satellites. The many buildings in a city act as obstructions so it is common for the system to be unable to lock on to more than one GPS satellite.

3. Considering the intended mobile use of the MR system, the antenna and receiver of the RTK-GPS sensor are large. Generally, the RTK-GPS is a design used in survey platforms that involve little movement.

4. Stable data is not obtained by the 3D sensor due to various types of noise. Therefore, it is necessary to give a compensation value.
3.3. COMPOSITION WITH A VIDEO IMAGE AND 3DCG IMAGE

1. The judgment method of the CG image and the video image order position is a problem. In the present system, the video image obtained by the live camera is drawn on the background, and the 3DCG image is always drawn at the front. This is satisfactory when the subject obtained by the live camera is not in front of the subject drawn with the 3DCG image. For example, the construction plan in a land lot without a construction could be a suitable application. However, in many cases the subject obtained by the live camera actually exists in front of the subject drawn with a 3DCG image. That is, technology is required for drawing the 3DCG image onto the video image drawn on the background, and the video image should always be drawn at the front.

2. In order to obtain a realistic image, there is a problem of removing the difference of representation of the video image and the CG image. In the case of 3DCG obtained by the pre-rendering method, there is little difference in representation of CG and the video image by the highly precise simulation of light and shadow. However, representation of 3DCG obtained by the real-time rendering method and the video image shows a difference.

3. The live camera which obtains the video image uses 300,000 pixels, and the screen resolution of this camera is 640 by 480 pixels. On the other hand, the resolution of 3DCG generated by MR software is 1024 by 768 pixels or 1280 by 960 pixels in actual use. That is, the quality of the video image is lower than that of 3DCG. However, the live camera is 2 million pixels (1600 by 1200 pixel), and this problem will be solved by the new system.

4. Evaluation of the display used outdoors

4.1. MEASUREMENT OF LUMINOSITY OF DISPLAY

The brightness of a number of displays, including the display of the developed MR system, was measured. Usually, the brightness of a display is expressed with a luminosity value and a contrast ratio. The contrast ratio is the luminosity ratio of the white (the maximum luminosity) and black (the minimum luminosity) on a display. Display makers provide the dark room contrast ratio, which is a contrast ratio usually measured in a dark room (illumination 0). The dark room contrast ratio is the numerical value of a standard. However, since it is significantly influenced by outdoor daylight,
just the dark room contrast ratio of evaluation of an outdoor display is inadequate. Therefore, it is necessary to measure the ambient contrast ratio, which is a contrast ratio which adds and measures the conditions of fixed outdoor daylight.

The author carried out three experiments. Experiment 1 was the measurement of the display luminance in a dark room and dark room contrast ratio. Experiment 2 was the measurement of the display luminance in outdoor daylight. The display was subjected to direct sunlight. Experiment 3 was the measurement of the display luminance in outdoor daylight. The display was not subjected to direct sunlight. The detailed methods of the following experiments are shown (see Figure 3).

- **Experiment 1**: In a dark room (illumination 0), a picture of two patterns of white \((R, G, B) = (255, 255, 255)\) and black \((R, G, B) = (0, 0, 0)\) was displayed by turns on a display. The measuring point was the center of the display. The luminosities from the display front and from an angle of 45 degrees to the display were measured.
- **Experiment 2**: Outdoors in daytime, the same measurements under the same conditions as experiment 1 were carried out. The display was positioned to face south.
- **Experiment 3**: Outdoors in daytime, the same measurements under the same conditions as experiment 1 were carried out. The display was positioned to face north.

The measurement conditions are shown in table 1. The specifications of the used display are shown in table 2. Figure 3 shows the plans of each experiment and a photo.

### TABLE 1. Measurement conditions.

<table>
<thead>
<tr>
<th></th>
<th>Experiment 1 (dark room)</th>
<th>Experiment 2 (outdoors in daytime)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Illumination on the ground (lx)</strong></td>
<td>0</td>
<td>59,000 - 69,000</td>
</tr>
<tr>
<td><strong>Weather</strong></td>
<td>Fine weather</td>
<td>Fine weather</td>
</tr>
<tr>
<td><strong>Latitude, Longitude</strong></td>
<td>34.822623, 135.522781</td>
<td>34.822623, 135.522781</td>
</tr>
</tbody>
</table>
TABLE 2. Specifications of display.

<table>
<thead>
<tr>
<th></th>
<th>Tablet PC 1 (NEC VersaPro VY11F/GL-R)</th>
<th>Tablet PC 2 (Lenovo X41 Tablet)</th>
<th>Notebook PC 1 (Sony VAIO VGN-SZ94PS)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CPU</strong></td>
<td>Intel® Pentium® M 1.1GHz</td>
<td>Intel® Pentium® M 1.6GHz</td>
<td>Intel® Core™2 Duo T7800 2.6GHz</td>
</tr>
<tr>
<td><strong>RAM</strong></td>
<td>512MB</td>
<td>1.49GB</td>
<td>2GB</td>
</tr>
<tr>
<td><strong>Graphic Memory</strong></td>
<td>ATI MOBILITY RADEON 7500 (32MB)</td>
<td>Intel 915GM Express (96 MB)</td>
<td>NVIDIA GeForce 8400M GS (256MB)</td>
</tr>
<tr>
<td><strong>Weight (kg)</strong></td>
<td>0.855</td>
<td>1.88</td>
<td>1.75</td>
</tr>
<tr>
<td><strong>Resolution (pixels)</strong></td>
<td>1024 by 768</td>
<td>1024 by 768</td>
<td>1280 by 800</td>
</tr>
<tr>
<td><strong>Display size (inch)</strong></td>
<td>10.4</td>
<td>12.1</td>
<td>13.3</td>
</tr>
</tbody>
</table>

Figure 3. Plan of experiment 1 (upper left); Plan of experiment 2 (upper right); Plan of experiment 3 (lower left); Photo of experiment 2 (lower right).
4.2. RESULT

Photos of the displays in experiment 3 are shown in Figure 4. The experiment results are shown in Figures 5 and 6.

Figure 5 shows the luminance and contrast ratio in a dark room. This ratio is the numerical value of a standard. In all displays, the measurement result from the front obtained a higher luminosity value \(L_{1wf}\) and a higher contrast ratio \(L_{1wf}/L_{1kf}\) than the measurement result from a 45-degree angle. Moreover, Tablet PC 1, which is the display of the existing MR system, had the lowest luminosity value \(L_{1wf}\) and the lowest contrast ratio \(L_{1wf}/L_{1kf}\) of all the displays.

Figure 6 compares the luminosity value and contrast ratio measured in front of the displays, as obtained from the three experiments. The fact that \(L_{2kf}\) and \(L_{3kf}\) show high luminosity values means there was a strong influence of sunlight or reflected light. That is, it turned out that Tablet PC 1 was the one most influenced by outdoor daylight. The ambient contrast ratio of all displays was 5.1 or less. Compared with the dark room contrast ratio, this is a very low value. This value was low because it was considerably influenced by outdoor daylight, and most images on the display were not seen.

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Figure 4. Display of experiment 3: Tablet PC 1 (left); Tablet PC 2 (middle); Notebook PC 1 (right).
Figure 5. Luminance and contrast ratio in a dark room (L1: luminance of experiment 1; k: black image; w: white image; f: front position; s1, s2: angle of 45 degrees to display).

Figure 6. Comparison of front luminance and contrast ratio in the three experiments (L1: luminance of experiment 1; L2: luminance of experiment 2; L3: luminance of experiment 3; k: black image; w: white image; f: front position).

4.3. DISCUSSION

Figure 5 shows that the luminosity values of the displays differ greatly in the dark room and outdoors in the sunlight. As Section 4.1 described, when evaluating the display used outdoors, measurement of the ambient contrast ratio is important. However, this experiment was measured in a certain specific time. That is, since sunshine conditions constantly change, it is
difficult to reproduce the result of experiments 2 and 3. Therefore, it is necessary to build an ambient contrast ratio evaluation system which can reproduce and measure certain outdoor daylight conditions. For example, VESA (1998) has proposed an experimental device which uses an integrating sphere. In that study, the relation between the illumination of the outdoor daylight in an integration sphere, and the ambient contrast of a display is shown. In order to evaluate quantitatively a display used outdoors, it is necessary to build an experimental device which can duplicate such fixed outdoor daylight.

5. Conclusion and Future Work

This research considered the problems of the device and software which constitute the developed outdoor type MR system for use by city tour guides and in design studies. Consequently, the problems of the display, sensor, and composition with a video image and 3DCG image were clarified. Moreover, to address the problem that the display is dark outdoors, the researchers measured the luminosity of a number of displays in a dark room and outdoors. Consequently, in addition to the dark room contrast ratio, the importance of ambient contrast was highlighted through the experiment.

A future problem was described. In regard to the display, it is necessary to build an ambient contrast evaluation system as described in Chapter 4, and to conduct a quantitative evaluation experiment. Moreover, it is necessary to understand the characteristics of the display through a comparison of liquid crystal displays of high luminosity and organic electroluminescence displays etc. It is necessary to aim at finding a solution for the problems of the devices and software which were considered in Chapter 3.

References


