Revisit: Wide Field of View in Visualization

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Abstract: Science museums provide learning opportunities through exhibits using various kinds of media, but they also require providing a space and time environment that differs from that in daily life. Immersive displays have been used to exhibit virtual reality content in such learning facilities, and they can provide users with a sense of presence by incorporating a wide field of view. We created an immersive projection display for visualizing the Yatsu tideland, an area registered under the Ramsar Convention on Wetlands. We conducted an empirical study to compare different fields of view when a user moves around in the virtual world. The results of the subjective evaluation suggested that a field of view of 90 degrees would sufficiently provide a sense of presence in a non-stereoscopic view.

Keywords: Visualization, wide field of view, immersive projection display, subjective evaluation, tideland, science museum

1. Introduction

Learning facilities such as science museums provide visitors with learning opportunities that are enjoyable as well as informative. Exhibits based on real objects are typically displayed in science museums, and multimedia presentations with computers have been used for visualizing various types of content from digital archives (Hawkey, 2004; Clough, 2013). However, simply providing visitors with information on the exhibits is not enough, because museums are considered to be unique places where space and time differ from that in daily life (Bell, 2002). Museums have also tried to make learning compatible with enjoyment by creating learning environments that increase the visitor's interaction with exhibits. Interactive experiments have been found to be particularly effective ways for children to enjoy learning (Falk & Dierking, 2000; Adams, et al., 2004). However, experimental exhibits consisting primarily of play equipment result in environments that are only *fun*. A dilemma exists because such exhibits should not only be fun; they should also convey knowledge to visitors.

Many studies on educational technology have claimed that the learner's performance when using new media or systems is gained in the initial period of time when they were introduced for learning (Clark, 1983). Evidence on the learning effectiveness of new media or systems is typically obtained from a comparison with existing ones, and the opinions on the performance of new media or systems are often biased. Although the novelty effect has been treated as an artifact that should be removed in determining the learning effectiveness of new media or systems, it may work as a factor in increasing visitors' motivation to learn in museums. We believe that large displays such as tiled displays and immersive projection displays are capable of creating space and time environments that differ from those in daily life. Although much work has been done on immersive experiences in large displays, it has not yet been clarified what elements of the large displays affect the user's experiences.

One of the significant factors in achieving a *sense of presence* is considered to be the field of view. It is generally accepted that a wide field of view produces a feeling of immersion in a virtual environment (Patrick, et al., 2000; Lin, et al., 2002). Large displays covering a wide field of view have been introduced in many industries where the objective is to entertain the user, for example, in video arcade games and amusement park rides, so that users get a higher feeling of involvement in the activity they are taking part in. The individual gains on large displays have been measured in terms of task performance, for example, improving multi-window tasks, rich information tasks, and awareness of peripheral applications (Bi & Balakrishnan, 2009). Three-dimensional (3D) navigation experiments showed that a large projection display outperformed a normal-sized desktop monitor in task performance (Tan, et al., 2004). In the experiments, unfortunately, the large projection display had a projection area with a horizontal visual angle of less than 35 degrees, which was insufficient as a large display.

The performance of 3D interaction tasks involving elements such as travel and manipulation was measured by comparing a large display with a desktop monitor (Tyndiuk, et al., 2005). The results indicated that not all users benefited similarly from large displays, and the performance strongly depended on the interaction task. In task performance involving travel, it was found that the travel techniques dominate the task performance according to their appropriateness for the applications and depending on the combinations of techniques that are used (Bowman, et al., 2001). Although much research has focused on task performance, more work needs to be done to determine the individual gains in the sense of presence of large displays, because the sense of presence is not obtained from the task performance.

Since the development of the immersive projection display known as a cave automatic virtual environment (CAVE) (Cruz-Neira, et al., 1993), many systems have been applied as a visualization environment for research work. The typical CAVE system consists of four screens, in which three walls and a floor form a cubic screen. Stereoscopic images are projected onto each screen so as to be seamlessly seen from a user's point of view, achieving a wide viewing angle. In this paper, we describe our subjective evaluation of field of view in an immersive projection display, in which we compared a wide field of view using four screens with a narrow field of view using only the front screen. We developed an original application enabling users to move around in a virtual environment in the Yatsu tideland, an area registered under the Ramsar Convention on Wetlands (Ramsar), so they could learn about various kinds of migratory birds.

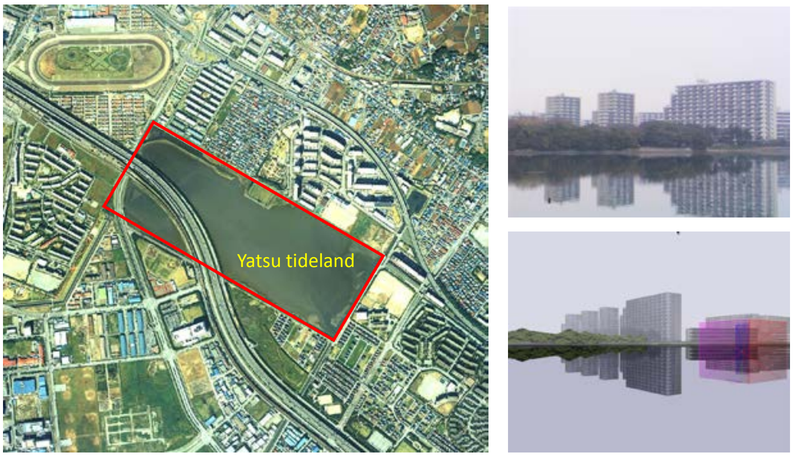
2. System

2.1 Yatsu Tideland

The Yatsu tideland is a 40-ha area located in Chiba, Japan. Chiba is adjacent to Tokyo bay, which had a huge tideland area in the years prior to 1960, when most of the tidelands were reclaimed for development to build industrial and residential districts. The rectangular area, shown in Figure 1 (a), was reserved due to the scarce habitat for migratory birds. The Yatsu tideland was registered under the Ramsar Convention on Wetlands in 1993.

Many kinds of waterfowl such as herons, ducks, and seagulls can be seen throughout the year in the Yatsu tideland. In recent years, large outbreaks of sea lettuce, a kind of green algae, have occurred because of water pollution. After the sea lettuce dies in summer, it decays. The decayed sea lettuce lowers the oxygen concentration of the water and mud, and this kills native animals and plants such as Japanese littleneck clams, hermit crabs, and ragworms. In addition, urbanization around the Yatsu tideland has drastically reduced the number of migratory birds. For example, in 1976, more than 1500 Kentish plovers were observed, whereas the number had plummeted to around 150 in 1996 (Ishikawa, 2001).

We believe that this environment would be useful material for learning about an ecological system. Because the Yatsu tideland still exists, students can actually observe migratory birds and other small creatures. Visualization of the Yatsu tideland in a virtual environment would enable students to learn more about its ecological system. That in turn would lead to deeper insights into the relationships between the food chain, urban development, climate change, and other factors through the virtual environment that could only previously be experienced in the real world. Consequently, we have been developing a virtual reproduction of the Yatsu tideland in recent years to enable observation of migratory birds in a virtual world. Figure 1 (b) shows a photo (upper) and a synthesized model (lower) of some of the buildings around the Yatsu tideland.



(a) Top view of Yatsu tideland* (b) Nearby buildings

Figure 1. Yatsu tideland.

2.2 Configuration

Our immersive projection display was constructed as a CAVE-like system with a four-surface cubic screen (Asai, et al., 2013). Our objective was to build the virtual environment system so that it would not require costly maintenance or advanced technical skills. An overview of the projection screen display is shown in Figure 2.

Figure 2. Overview of projection screen display.

The cubic screen is composed of three walls and a floor. Stereoscopic images are projected by LCD projectors that separate the left-eye and right-eye images through circular polarization. Each screen is 3 m × 3 m, and the projection resolution is 1000 × 1000 pixels. The stereoscopic images are generated by four PCs equipped with a GPU, which form a PC cluster through a gigabit Ethernet LAN.

* Made based on National Land Image Information, Ministry of Land, Infrastructure, Transport and Tourism, Japan

Two input devices are implemented into the immersive virtual environment system. A wired game pad (Sony PlayStation2) is used as a joystick for controlling the viewpoint in the 3D virtual space. A wireless game controller with an accelerometer (Nintendo Wii Remote) is also used as a wand for interacting with 3D virtual objects. These interface devices are controlled by the device PC, and the interaction data are sent to the management PC through the gigabit Ethernet LAN.

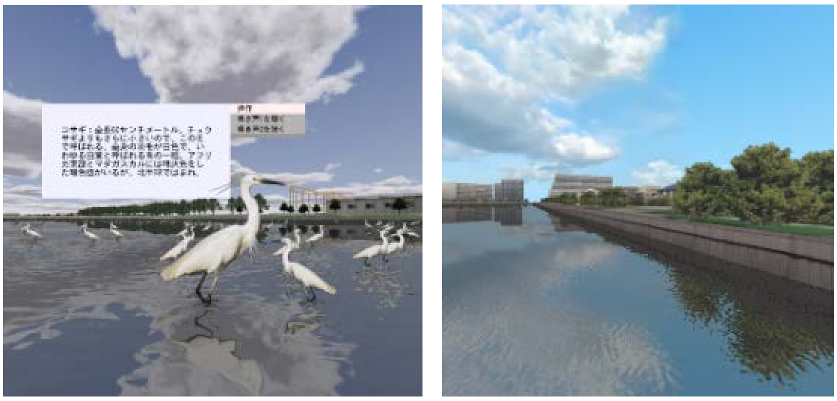
2.3 Software

VR Juggler (Bierbaum, et al., 2001) was installed as a set of libraries for parallel 3D rendering in cluster computing. The VRPN (Virtual Reality Peripheral Network; Taylor, et al., 2001) was used as a set of libraries and servers for implementing various interface devices into virtual reality (VR) applications over a network.

Applications and content data are stored in the management PC. Each rendering PC refers to these data through the network file system (NFS). Although VR Juggler supports a framework to transfer the data from the management PC to the rendering PCs, the NFS enables the programmer to omit the data transfer process in the application development.

We used OpenSceneGraph as an object-oriented framework on OpenGL for describing virtual environments based on scene graphs. That is, the visualization applications were implemented with OpenSceneGraph. Therefore, the Yatsu tideland application and the OSG (OpenSceneGraph) viewer must be used with VR Juggler and OpenSceneGraph. Using OpenSceneGraph makes it easy to install applications in different platforms by setting different parameters.

We developed our own application for demonstration, which involved visualizing the Yatsu tideland. The visualization application enables the user to view the landscape of the tideland and virtually walk through it. Figure 3 shows synthetic images generated by one of the rendering PCs, including (a) an explanation of a kind of egret and (b) the landscape of a shore in the virtual tideland.



(a) Explanation of egret (b) Shore of the tideland

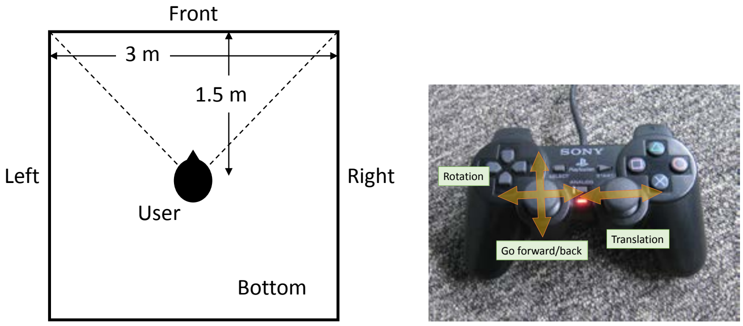
Figure 3. Screenshots of virtual tideland world.

3. Experiment

We conducted an experiment that involved viewing scenes of the virtual tideland. We set the condition to compare a wide field of view and a narrow field of view. No sound was generated during the experiment.

3.1 *Methods*

Nine students (five males and four females) from different universities participated in the experiment. The participants used the system for roughly 10 minutes in both field-of-view conditions. The experimental settings and the input device are shown in Figure 4. The participants were instructed to move around in the virtual tideland world and to find some migratory birds. They were told to read the explanations of at least two migratory birds. When they finished, they were given a preference test.



(a) Top view (b) Joystick

Figure 4. Experimental setting and input device.

The preference test had nine questions items, as listed in Table 1. A five-point Likert scale was used in the preference test. The scale ranged from 1=definitely disagree to 5=definitely agree. The students were also requested to provide open-ended comments about their opinions on using the immersive projection display for viewing the virtual tideland.

Table 1: Questions in preference test.

No.	Question items
1	You could see the surroundings.
2	The objects close to you looked three-dimensional.
3	You were able to distinguish the objects placed near and far.
4	The scenes were viewed with a feeling of depth.
5	You were immersed in the virtual world.
6	The experience of viewing scenes was interesting.
7	You felt uncomfortable when viewing scenes.
8	The setup was suitable for viewing scenes for a long time.
9	You felt tired when viewing scenes.

3.2 *Results and Discussion*

The results of the preference test for the wide field of view and the narrow field of view are shown in Figure 5. The numbers along the horizontal axis correspond to each question item, and the symbols a and b respectively indicate the wide and narrow fields of view. The vertical axis indicates the average scores among participants. The thin bar on each black and white column is the standard deviation. The average scores for questions 3, 4, 5, and 6 exceeded 4 in both conditions, which means that the participants had positive feelings. However, the average scores for questions 2 and 8 were below 3 for both stereoscopic and normal views, which means that the participants did not have positive feelings.

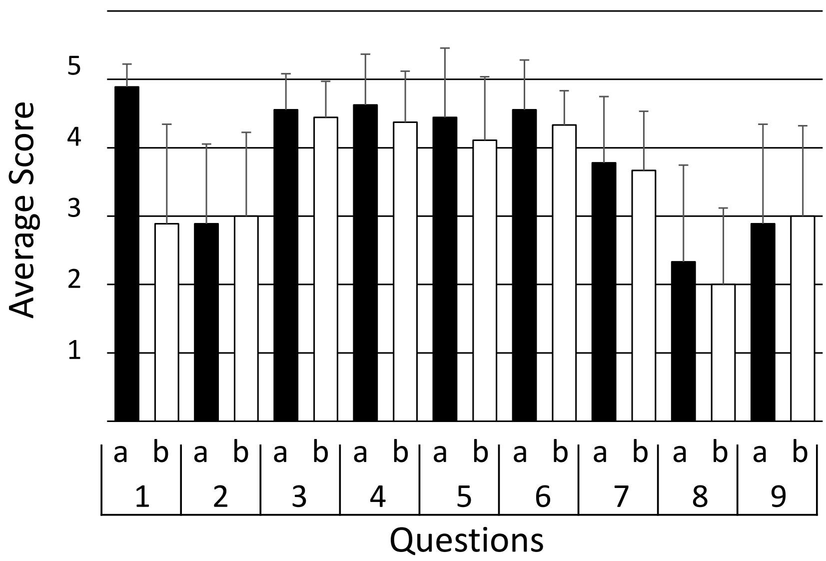


Figure 5. Scores for wide field of view vs. narrow field of view

A large difference was found in the average scores between the conditions for question 1, whereas there was no difference between the conditions for question 5. This result suggests that the field of view of 90 deg. is sufficient for providing a sense of presence because the field of view is considered to be significant to achieving a sense of presence. Although further investigation is needed to clarify the details of the result, it coincides with the earlier studies that visually induced self-motion or vection starts to be perceived at a horizontal field of view over 20 deg. (Allison, et al., 1999). This means that roughly 32 deg. in the horizontal field of view gives us the self-motion perception, but it is not sufficient for achieving a sense of presence, where a normal display with 17 inch (34 cm in horizontal wide) is placed at a distance of 60 cm from a user.

We conducted a subjective evaluation of stereoscopic views in our previous experiments (Asai, 2014). The results showed that virtual objects placed near a user looked more three-dimensional in the stereoscopic views, and a sufficient sense of presence was provided even in the normal views. These results lead us to expect that a field of view of 90 deg. would sufficiently provide a sense of presence in non-stereoscopic views.

4. Conclusion

We performed a subjective evaluation of the field of view in an immersive projection display where the task involved moving around a virtual tideland. The results of comparing a wide field of view with a narrow field of view suggested that a 90-degree field of view is sufficient for providing a sense of presence.

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