EVALUATION OF 3D INTERACTION TECHNIQUES FOR GOOGLE EARTH EXPLORATION USING NINTENDO WII DEVICES

Takehiko Yamaguchi, Damien Chamaret and Paul Richard
Laboratoire d'Ingénierie des Systèmes Automatisés (LISA), Université d'Angers, Angers, France

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Abstract: We present a multi-modal virtual reality broadcasting system to support science education. This system is based on a web platform using Adobe Flash and enables users to explore Google Earth using the Nintendo Wii devices. The Google maps Flash API was used to control the user's avatar. The Wii Remote was used for zooming and steering and the Wii Balance Board was used for walking. We tested operation workload for 9 different threshold angle combinations. We found a most low workload threshold angle combination of 45° (for zooming out) /-15° (for zooming in) and of 30° (for steering right) /-30° (for steering left). Moreover, we found overshoot range during actual operation.

1 INTRODUCTION

Virtual reality (VR) technology has become increasingly popular and its applications span a wide variety of different areas that include science education (Johnson et al., 2001), medical training (Basdogan et al., 2001), entertainment (Mignonneauand and Sommerer, 2005).

The wide spread use of this technology has been primarily limited because of the high cost of VR systems (Sines and Das, 2001). With the development of hardware speed, rendering capabilities, and accessible network bandwidth, network-based VR content has become available at lower costs. Thus, most of common web animation and game creating tools such as Adobe Flash (Adobe, 1996), Unity (Unity, 2010) have supported 3D capabilities. In addition, a number of toolkits have been released as open-source software for web applications (Polys, 2007), especially, with the advent of the Nintendo Wii.

In section 2, present the related work. In section 3, we describe the proposed system. Then, we present the experiment that was carried out to investigate the operation workload during a navigation task. In Section 5, the results of the experiment are presented and discussed. Finally, we conclude and give some tracks for future works.

2 RELATED WORK

Wii devices have been adopted by a number of researchers for a wide variety of applications (Schlomer et al., 2008). Generally, in case of using The Wii Remote (WR) for navigation, rotation angles such as pitch, yaw, and roll information are used. For example, Duran (Duran et al., 2009) used the WR for controlling wheelchair using pitch and yaw movements. Fikkert (Fikkert et al., 2009) proposed interaction techniques using the WR and the Wii Balance Board (WB). Both input devices were used for navigating a maze application. If the direction is set using rotation angles, threshold rotation angles are set up on each axis as a trigger. Then, when rotation angle goes over the threshold the direction is changed. In this case, user needs to keep his/her angle position within the threshold. Actually, it is important to consider the threshold from the ergonomic viewpoint because of operation workload of direction input. However, this issue has not been really investigated so far. Before the main experiment, we carried out a pilot study to assess the available operation range (AOR) and analyze the range of zooming and steering operation.

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3 SYSTEM CONFIGURATION

We have been developing Flash based 3D Google Earth navigation system which enables user to explore Google Earth. The navigation / exploration task consists in controlling an avatar. We used Google Maps API for Flash (Google, 2005) for the Google Earth interface, and Nintendo WR and WB as input devices.

3.1 Hardware Framework

Figure 1 shows the hardware configuration of our system. We used a desktop computer, the WR and WB, and a front projected visual display. The WR and WB are connected to the PC through a Bluetooth communication protocol. The WR is equipped with an acceleration sensor that allows to measure both pitch and roll movements. The WB is equipped with 4 force sensors (top left, top right, bottom left, and bottom right).

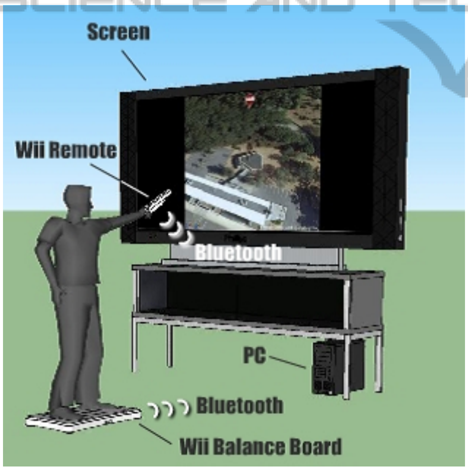

Figure 1: Illustration of the experimental configuration.

3.2 Software Framework

The main interface was developed using Adobe Flash. We used Google Maps API to display Google Earth interface and the Papervision3D library to display and control the avatar. The 3D world developed using Papervision3D was updated at 40Hz. To control the WR and WB, we used Wiiyourself! C++ library. Data from the WR and WB are updated at about 1KHz. To connect between the C++ native application and the Flash application, we developed a C++ server application (TCP/IP protocol).

4 INTERACTION TECHNIQUES

Three different interaction techniques have been proposed to explore the Google Earth effectively. We defined a surfing mode (Fig. 2) to go straight and stop, then we defined a zooming mode (Fig. 3) to scale up and down, and we defined a steering mode (Fig. 4) to turn left and right.

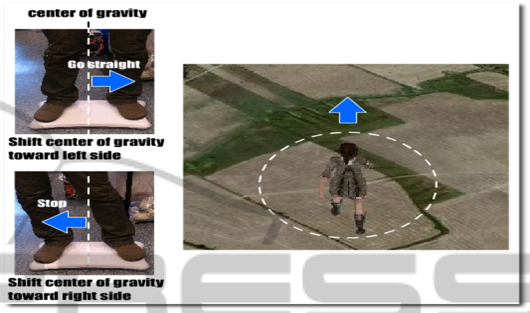

Figure 2: Illustration of the surfing interaction technique.

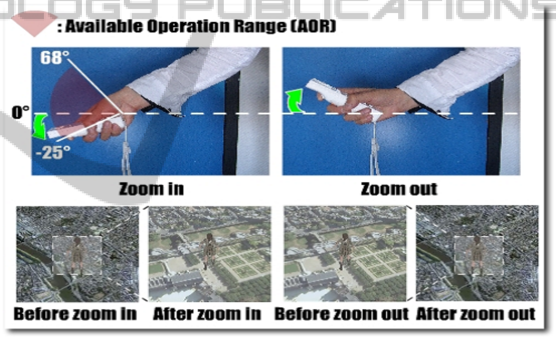

Figure 3: Illustration of the zooming interaction technique.

Figure 4: Illustration of the steering interaction technique.

5 EXPERIMENT

We conducted a pilot testing to determine available operation range (AOR) of zooming and steering operation before the main experiment. The AOR is a operation range which a user can have while zooming and steering without any physical demand. Six subjects tested a simple moving task for 1 minute. We found that zooming operation has an asymmetric pattern ranging from -25°to 68° (Fig. 3), and steering operation has a symmetric pattern ranging from -56°to 66° (Fig. 4). Therefore, we decided to use nine thresholds angle combinations for the experiment.

5.1 Design and Procedure

The aim of this experiment is to find a best threshold combinations for zooming and steering operations to for exploring Google Earth. A total of 14 subjects (between 19 and 24 years old) participated in the experiment. Each session included 9 trials that contained 3 simple subtasks defined below. After each trial, NASA-TLX questionnaires were given to each subject. Subject were instructed to find 3 red goal flags (Fig. 5). When finding a yellow flag on the way, subjects were required to zoom in until the yellow flag become red. When the yellow flag becomes red, the subjects had to reach it.

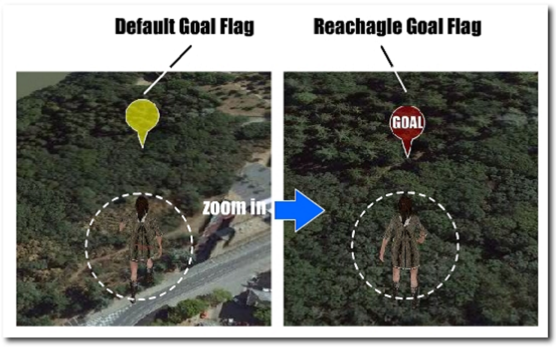

Figure 5: Goal flag status on Google Earth platform.

The subjects had to grab a WR with their dominant hand and stand on the WB. Then they had to do a trial to get acquainted with the zooming, steering, and surfing interaction techniques. Then the subjects were instructed to check the threshold angle for zooming and steering operation , and had to complete the task which contains the 3 subtasks. They had to repeat the task 9 times consecutively (9 threshold combinations). Finally, the subjects had to fill out the questionnaire.

6 RESULTS

6.1 Zooming Interaction Technique

The results of the NASA TLX questionnaires for zooming interaction technique are shown in Fig. 6. The ANOVA showed that there were no main effect for zooming angle/steering angle and no interaction between these interaction techniques. These results show that participants were able to do zooming operation without effect of zooming/steering angle combinations.

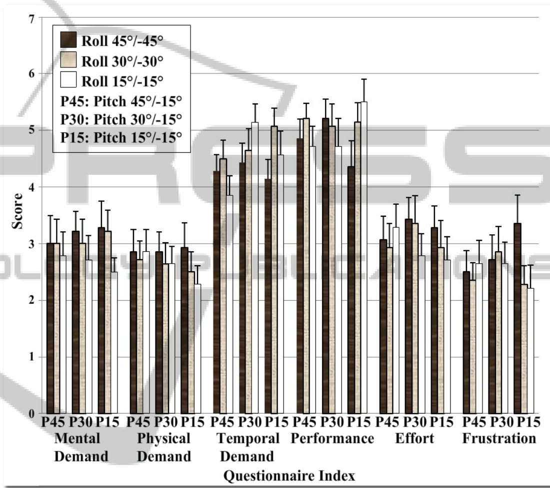

Figure 6: Result of NASA-TLX for zooming interaction technique.

6.2 Steering Interaction Technique

The results of the NASA TLX questionnaires for steering interaction technique are shown in Fig. 7. The ANOVA showed significant main effect on steering angle for physical demand ($F_{(2,26)} = 5.22, p < 0.05$), and for performance ($F_{(2,26)} = 3.74, p < 0.05$). LSD multiple comparison on Physical demand proved that the effect of steering angle on RC1 was higher than that of RC2/RC3, but there was no difference significantly between RC2 and RC3. As for the LSD multiple comparison on performance, the effect of steering angle on RC1 was higher than that of RC2, but there was no difference significantly between RC2/RC3 and between RC1/RC3. These results suggest that participants were able to do steering operation without effect of zooming operation. However, the steering angle combination affected the steering operation.

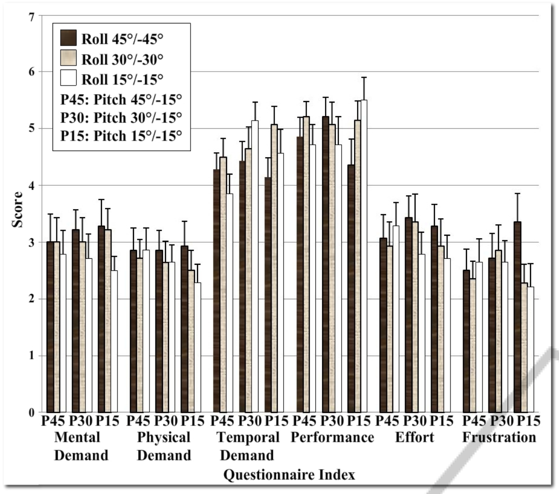

Figure 7: Result of NASA-TLX for steering interaction technique.

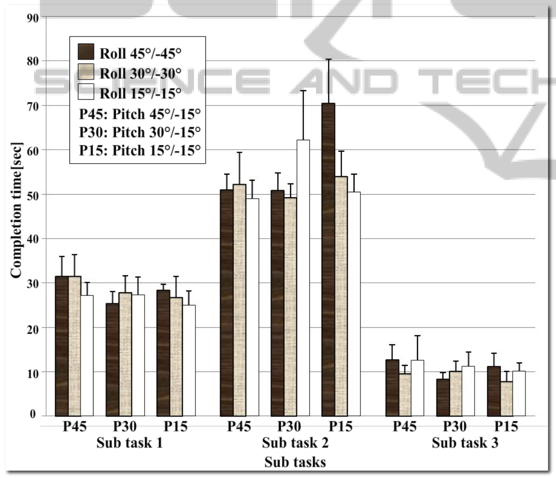

Figure 8: Completion time for each sub tasks.

6.3 Completion Time

Results relative to the completion time are illustrated in Fig. 8 shows the results of the completion time for each. The ANOVA showed no significant main effect on zooming angle, steering angle, and no interaction between these interaction techniques. Since there is significant effect on the subjective results for steering operation as showed in the previous subsection, we expected the completion time supports the significant effect. However, ANOVA showed no significant as above. This result suggest that the subjective data are affected by primitive operation workload more than accomplishment of whole task so that actual operation range during experimental task is considered in the next subsection.

6.4 Overshoot of Operation Range

The results of the distribution of zooming and steering operation range are illustrated in Fig. 9. The mean value was calculated to average over threshold operation angle which is operation angle over the set up threshold angle. We expected that overshoot would happen since it is difficult to stop these operations on the threshold so that the overshoot was happened on overall tasks as shown in Fig. 9.

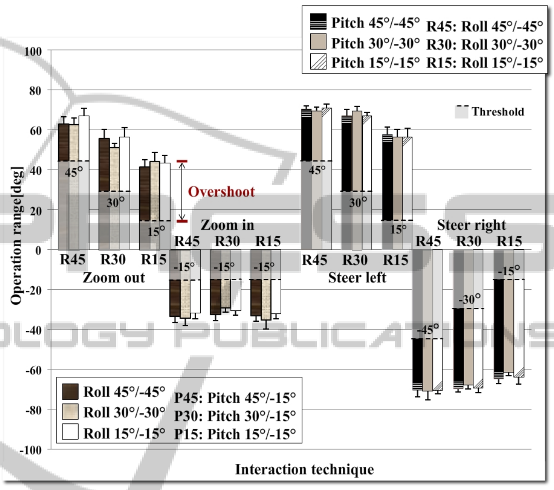

Figure 9: Distribution of operation range for each interaction techniques.

Overshoot Range of Zooming Out Operation. We observed a significant effect on zooming angle ($F_{(2,24)} = 8.474, p < 0.01$). LSD multiple comparison on zooming angle proved that the effect of zooming angle on PC1 was higher than that of PC2 and PC3, and there was no difference significantly between PC2 and PC3. The results show that the overshoot range has expanded as the set up threshold becomes small.

Overshoot Range of Zooming In Operation. The ANOVA showed that there were no main effect for zooming and steering angle and no interaction between these interaction technique. Since the set up threshold was -15°on all of angle combinations, there was no significant difference. According to the minimum operation angle which we measured in the pilot testing as mentioned in the Introduction, it was -25°. Therefore, the effect of overshoot range is limited in about 10°.

Overshoot Range of Steering Left Operation. The ANOVA showed significant main effect on steering angle ($F_{(2,24)} = 32.134, p < 0.01$). LSD multiple comparison on steering angle proved that the effect of steering angle on RC1 was higher than that of RC2 and RC3. The effect on RC2 is higher than that on RC3. The results show that the overshoot range has expanded as the set up threshold becomes small since the overshoot value was higher than that of the zooming operation. We estimate that the ratio of overshoot affected subjective workload.

Overshoot Range of Steering Right Operation. The ANOVA showed significant main effect on steering angle ($F_{(2,24)} = 100.303, p < 0.01$). LSD multiple comparison on steering angle proved that the effect of steering angle on RC1 was higher than that on RC2 and RC3, and the effct on RC2 is higher than that on RC3. The results show that the overshoot range has expanded as the set up threshold becomes small and estimate that the ratio of overshoot affected subjective workload as with the result of overshoot of steering left operation since the steering operation has symmetric operation pattern.

Effect of Overshoot for Operation. Even if the operation range includes the overshoot behavior, we could expect that there are no significant effect on subjective and on objective data as long as the operation range work within available operation range. However actual task includes contiguous action of each interaction technique. For example, when a user action frequently shifts from zooming in operation to zooming out operation, overshoot affects start time of next action as a delay time so that this suggest that the delay time affects subjective view and task performance. Moreover, in case of that the user causes error behavior, the overshoot also affects reaching time which is a time until user reaches target zooming level or steering direction.

7 CONCLUSIONS

The goal of this study is to find available operational range (OOR) for low operation workload associated with zooming and steering action using the Wii Remote. We investigated actual operation pattern and carried out and experiment which mixed zooming and steering operation. We found no effect of zooming angle combinations and steering angle combinations as for the zooming operation. However, steering angle combination affected the result of physical demand and performance. We found no significant effect on the completion time for all conditions. However, we observed overshoot values for steering operation higher than that of the zooming operation. We believe that this result affect the physical demand and performance workload. Moreover, we found that the overshoot range has expanded as the set up threshold becomes small. As a result from the subjective and performance data, we defined the OOR: for zooming operation is between -15°and 45°, and for steering operation is between -30°and 30°. As future work will will try to improve the OOR by considering feedback information.

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