International Conference on Artificial Reality and Telexistence
Eurographics Symposium on Virtual Environments (2022)
R. Kondo and T. Teo (Editors)

Demo

Boomshin: Evaluation of VR Game Experiences with Switching the Presence of Haptic Feedback

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Abstract

We proposed a VR game named "Boomshin" using an encountered-type haptic display and investigated the effects of switching the presence of haptic feedback for objects in the VR space over time. We named objects with and without haptic feedback as "real entities" and "clones" respectively, and evaluated the impression of the VR game experience under the various temporal presentation patterns of them. The results showed that the players' surprise and satisfaction were higher when real entities and clones were mixed than when only real entities or clones appeared. In addition, a sudden change in the frequency of appearance of real entities brought an impression impact.

CCS Concepts

• ***Human-centered computing*** → ***Human computer interaction(HCI);*** *Virtual reality;* • ***Computer systems organization*** → *Robotics;*

1. Introduction

Haptic feedback plays an important role to enhance the sense of presence and immersion in Virtual Reality (VR) space, and various haptic displays have been proposed, including an encountered-type haptic display using a mobile robot [SHZ*20]. Such a haptic display works as an obstacle at the moment physical contact occurs between the user and the virtual object at that location. However it can present natural haptic sensations because it utilizes actual physical contact, it is difficult to deliver all haptic sensations in time due to the limitations of the speed and range of its movement.

On the other hand, in the fields of game design and behavior analysis, it has been suggested that the intermittent compensation (partial reinforcement) has a strong impact on behavior and attracts strong interest than the continuous compensation (continuous reinforcement) [Hod17] [MMT99] [Sch12]. In this research, we propose mixing objects with and without haptic presentation in the VR space by using an encountered-type haptic display. It could enhance impressions and behaviors of the user by generating intermittent compensation of haptic sensations. This paper introduces a VR game, named "Boomshin" that switches the presence of haptic feedback, including an encountered-type tactile display using a differential two-wheeled mobile robot. We named objects with and without haptic feedback as "real entities" and "clones", respectively, and had a user study to investigate how the temporal patterns of real entities and clones changed impressions of Boomshin game experience.

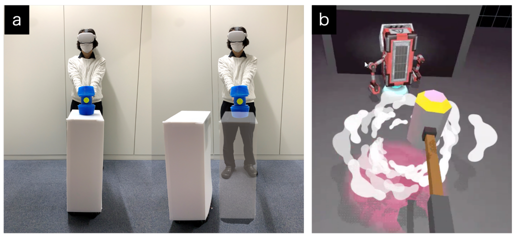

Figure 1: *a) Switching between haptic presentation and non-haptic presentation: striking a real entity (left), striking a clone (right), b) HMD wearer's view*

2. System

Our VR game, Boomshin, utilizes an encountered-type haptic display with a differential two-wheeled mobile robot. It consists of a contact unit that presents haptic sensation made of cardboard box which size is 300*300*700[mm] and a drive unit. The drive unit is Turtlebot3 waffle pi, and ROS2 (Robot Operation System 2) on a Raspberry pi 4 is running in the unit. Unity 2020.3.17f1 was used to construct the VR space and a VR HMD (Meta Quest 2) was used to show the VR space.

In our game, a player strikes targets approaching from the front with a toy hammer one after another. The targets are generated in every 3-seconds and move straight toward the player at the speed of 0.15[m/s]. The size and position of the target in the VR space is synchronized with those of the haptic display when it is a real

DOI: 10.2312/egve.20221311

entity. When the target is a real entity, the haptic display moves to a point 30[cm] in front of the player, and when it is a clone, it moves to a point 50[cm] to the left from point of the real entity (Figure 1a).

By fixing the Meta Quest 2 controller to the toy hammer, the posture of the hammer in VR space is synchronized with that in physical space. The player swings the hammer down when a new target enters in the VR space into the spotlighted area in front of him/her (Figure 1b). When the target is a real entity, the haptic sensation is generated by hitting the haptic display. When the target is a clone, no haptic sensation is generated because the haptic display is located off to the side. A visual effect and a sound effect are shown at the moment of hitting both when the target is a real entity and a clone in order to avoid differences other than tactile sensations.

3. User Study

We had a user study to investigate the effect of temporal presentation patterns of entities and clones on the impression of the VR game experience. We defined "entity rate" as the percentage of the number of real entities among the striking targets and used it as an independent variable in the user study. When the rate is 0.0, all targets were clones. When it is 1.0 when all targets were real entities. When the entity rate was 0.3, of the nine targets, three were real entities and six were clones. The number of the study participants were seven (male=6 and female=1; between 19–51 years old). The number of striking targets in the study was nine per trial, and we compared five entity rates (0.0, 0.3, 0.5, 0.7 and 1.0 : Figure 2). Each participant tried five entity rate games in random order, and after each trial, he or she answered on a 7-point Likert scale regarding the magnitude of surprise, tension, and satisfaction.

The results indicated that the intermittent haptic presentation mixing of real entities and clones enhanced the level of surprise and satisfaction in the VR game experience (Figure 3). There were significant differences between the entity rate of 0.3 and 1.0 for surprise response values and between 0.0 and 0.7 for satisfaction response values (Mann-Whitney U Test U=47.5, $p<0.05$ and U=30, $p<0.05$ respectively). Particularly, a difference in surprise response values was confirmed between the entity rate of 0.3 and the entity rate of 0.5, with the latter tending to be less surprised. This could be due to the difference in the frequency of occurrence of real entities and clones. It could suggest that a surprise is generated especially

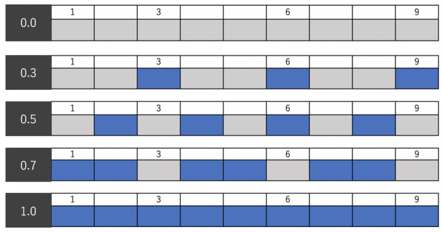

Figure 2: *The order in which real entities and clones appear for each entity rate. Blue: real entity, Gray: clone.*

when the numbers of real entities and clones are not equal, as in the case of the entity rate of 0.3 and 0.7.

4. Conclusion

In this paper, we introduced a VR game that switches presence of haptic feedback over time with an encountered-type haptic display. The results of our user study indicated that switching the presence of haptic enhanced the surprise and satisfaction of the game, and changing the frequency of the appearance of the real entity deliver impressions. We will also study switching spatial presence of our haptic display as a future work.

5. Acknowledgments

This work was supported by JST, CREST Grant Number JP-MJCR19A4, Japan.

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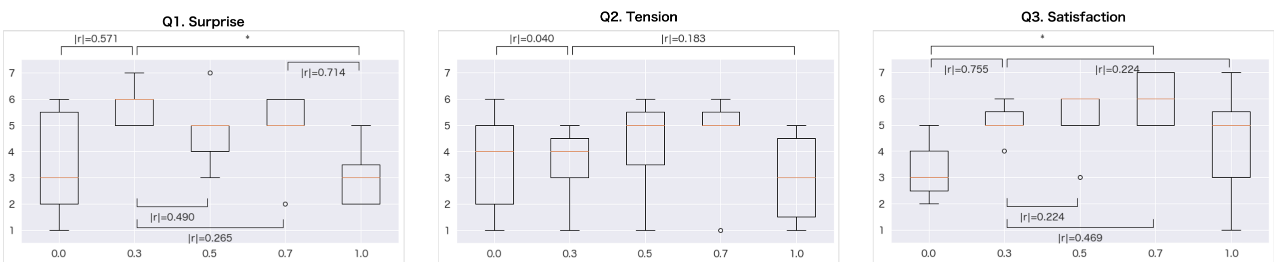

Figure 3: *Response values for "surprise", "tension", and "satisfaction" in the user study. The horizontal axis shows entity rates. Marked with an asterisk significant differences.*