An Examination of Position Estimation of Virtual Objects Outside a Field of View Using Auditory Stimuli

Kazuki Oikawa
Utsunomiya University
mc206507@cc.utsunomiya-u.ac.jp

Kei Kanari
Utsunomiya University
kanari@is.utsunomiya-u.ac.jp

Mie Sato
Utsunomiya University
mie@is.utsunomiya-u.ac.jp

ABSTRACT

One of the problems in virtual reality (VR) is a natural interaction with a virtual object. In this study, we focus on an interaction with a virtual object outside a user's field of view. The position of the virtual object is estimated without looking at it by using sound pressure change and/or pitch change as auditory stimuli.

CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; **Empirical studies in HCI**; **User studies**.

KEYWORDS

VR, Interaction, Auditory stimuli

ACM Reference Format:

Kazuki Oikawa, Kei Kanari, and Mie Sato. 2020. An Examination of Position Estimation of Virtual Objects Outside a Field of View Using Auditory Stimuli. In *Special Interest Group on Computer Graphics and Interactive Techniques Conference Posters (SIGGRAPH '20 Posters), August 17, 2020*. ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3388770.3407450

1 INTRODUCTION

Recently, research on virtual reality (VR) has been actively conducted. In a related study[Yukang Yan and Iqbal 2018], the comparison of estimating the position of a virtual object with the verbal instruction was conducted between the case without the gazing it and the case with gazing it. The results showed that position estimation of the virtual object without gazing it could estimate the position with sufficient accuracy under the condition of a narrow viewing angle and that the estimation time was shorter than when participants were gazing a virtual object. However, the study on the combined effect with the sense of hearing was insufficient. In addition, our previous study[Kimura and Sato 2020] showed that auditory stimulation improved the operability of virtual objects outside a user's field of view. However, the previous study investigated the virtual objects placed only in a small front range.

In this study, we present auditory stimuli with varying sound pressure and frequency as clues when the user estimates the position of a virtual object without looking at it. The virtual object is placed in all directions around the user. We investigate the effectiveness of auditory stimulation in the position estimation. In an experiment, a participant is presented with auditory stimuli that change depending on the positional relationship between a target transparent virtual object and the participant. The experimenter examines the time and accuracy required for the participant to estimate the position of the virtual object and the subjective impression of the auditory stimuli used as a clue for the position estimation. First, we perform a preliminary experiment to determine the frequency of the auditory stimuli used in this experiment.

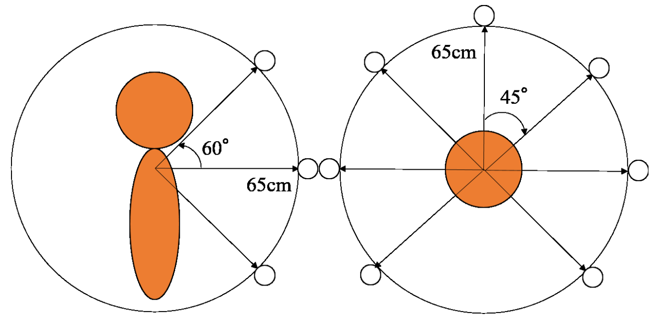

Figure 1: Position of Transparent Virtual Object

Table 1: Auditory Stimuli

Auditory Stimuli	Frequency Change(Hz)	Sound Pressure Change	Three-Dimensional Sound
1	261.750→654.375	×	○
2	654.375→261.750	×	○
3	261.750→654.375	×	×
4	654.375→261.750	×	×
5	×	○	○
6	×	○	×

2 EXPERIMENT

The goal of this experiment is to investigate how auditory stimuli improves the speed and accuracy of the position estimation without looking at a target virtual object.

2.1 Experiment Design and Tasks

We ask the participant to estimate the position of a target transparent virtual object, relying on the auditory stimulus that changes according to the distance between the virtual object and a controller the participant holds. From the error between the estimated position and the actual position, the time until the estimation, and the subjective impression of the auditory stimuli, we analyze the influence of the auditory stimulus on the position estimation of the virtual object outside the visual range.

SIGGRAPH '20 Posters, August 17, 2020, Virtual Event, USA

ACM ISBN 978-1-4503-7973-1/20/08.
https://doi.org/10.1145/3388770.3407450

Figure 1 shows the presentation positions of the transparent virtual object used in the experiment. In the experiment, a target transparent virtual object is randomly presented at one of the 21 positions. The distance between the participant and the virtual object is 65 cm. The horizontal angle is at 45-degree intervals with the front of the participant as 0 degree and the right hand side as positive. The vertical angle is at 60-degree intervals with the forward of the participant as 0 degree and the upward angle as positive with respect to the participant's chest.

In the experiment, we focus on three auditory factors; frequency change, sound pressure change, and three-dimensional sound. Two types of frequency changes were obtained from the preliminary experiment. In the preliminary experiment, we presented eight types of frequency changes and chose the best two types of frequency changes for the position estimation. The sound pressure change was used in a previous research. So, we use the sound pressure change for a comparison with the frequency change regarding their influences on the position estimation. Furthermore, in general, the effect of three-dimensional sound on position estimation is expected. With the combination of the sound pressure change and the three-dimensional sound, the total of six auditory stimuli shown in Table 1 is used in this experiment.

2.2 Procedure

At first, we introduce the goal of the experiment and guide the participant to use the device. The participant is required not to move his or her legs while they wear the head-mounted display. Next, the participant looks at a panel where the instruction is written, for example, "Find a virtual object", "In preparation". When this instruction shows "Find a virtual object", the participant starts to search for a target transparent virtual object by relying on the auditory stimulus, and presses the button on the controller at the estimated position of the virtual object. The participant performs this search for each of all the 21 positions, and then answers the question about the subjective impression of the auditory stimuli.

2.3 Result

The number of error data between the estimated position and the actual position and the time data until the estimation is 2520 (126 trials × 20 participants), and the subjective impression is 20 data points for each question (20 participants).

Figures 2 and 3 show the average error between the estimated position and the actual position for each auditory stimulus and the average time until the estimation for each auditory, respectively. To examine whether there was a significant difference, we performed the one-way ANOVA tests among the auditory stimuli, among the horizontal angles, and among the vertical angles. The results showed that significant differences were found in the error and estimated time among the auditory stimuli, so multiple comparisons by the Tukey HSD test were performed for these data. In addition, there was a significant difference in the estimated time among the horizontal angles. Furthermore, a significant difference was found when the Friedman test was performed for each question regarding the subjective impression.

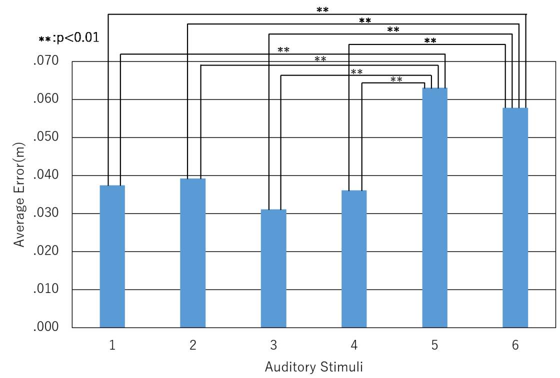

Figure 2: Audio Stimuli and Average Error

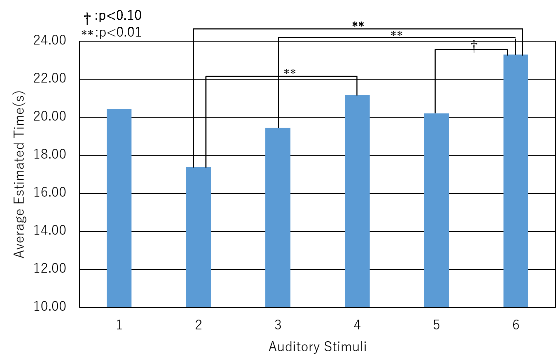

Figure 3: Audio Stimuli and Average Estimated Time

3 DISCUSSION

Looking at Figure 2 and 3, which show the comparisons among the auditory stimuli, the average error for the auditory stimuli 5 and 6 are larger than those for the other auditory stimuli. Since the auditory stimuli 5 and 6 are stimuli due to changes in sound pressure, it can be seen that the average error is smaller in frequency changes than that in sound pressure changes. In addition, the average estimated time is compared between the auditory stimuli with and without the three-dimensional sound, in Figure 3, the auditory stimuli 2 and 5 are three-dimensional sound and those corresponding auditory stimuli without the three-dimensional sound are the auditory stimuli 4 and 6, respectively. So, the three-dimensional sound is effective in terms of the correct position estimation. These results suggest that the combination of the frequency change and the three-dimensional sound works well for the position estimation of the virtual object outside a field of view.

REFERENCES

Zentaro Kimura and Mie Sato. 2020. Auditory Stimulation on Touching a Virtual Object Outside a User's Field of View. *IEEE VR Posters VIdeos 1 & 3* 12 (2020).

Xiaojuan Ma Shuai Huang Yukang Yan, Chun Yu and Hasan Iqbal. 2018. Eyes-Free Target Acquisition in Interaction Space around the Body for Virtual Reality. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* 42 (2018), 1–13.