Feedback of Rotational Sensation Experienced by Body for Immersive Telepresence

Vibol Yem
Tokyo Metropolitan University
Hino, Tokyo, Japan
yem@vr.sd.tmu.ac.jp

Tsubasa Morita
Tokyo Metropolitan University
Hino, Tokyo, Japan
morita@vr.sd.tmu.ac.jp

Tomohiro Amemiya
The University of Tokyo
Bunkyo, Tokyo, Japan
amemiya@vr.u-tokyo.ac.jp

Michiteru Kitazaki
Toyohashi University of Technology
Toyohashi, Aichi, Japan
mich@tut.jp

Yasushi Ikei
The University of Tokyo
Bunkyo, Tokyo, Japan
ikei@vr.u-tokyo.ac.jp

ABSTRACT

In our previous study, we proposed a telepresence system that can transfer the riding sensation of a vehicle (Segway) for assisting collaborative task. The system could provide a local expert who remotely attend the task not only the view of a remote environment that is captured by a camera but also the vestibular perception during the movement of the camera. In this study, we examined the rotation feedback by the rotary seat when the camera is rotated. The measured intensity adjustment showed that the angular acceleration of the rotary seat was about half that of the camera rotation. Further, the result of the simulator sickness questionnaire scores showed that the inphase rotation of the seat with the camera is appropriate for suppressing virtual reality sickness, indicating that the requirement of vestibular intensity is quite low compared with the visual cue showed on the head mounted display, which allows a designer to develop a sensation feedback device that has an actuator of low strength.

CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**.

KEYWORDS

Rotational Feedback, VR Sickness, Telepresence, Riding Sensation.

ACM Reference Format:

Vibol Yem, Tsubasa Morita, Tomohiro Amemiya, Michiteru Kitazaki, and Yasushi Ikei. 2021. Feedback of Rotational Sensation Experienced by Body for Immersive Telepresence. In *Special Interest Group on Computer Graphics and Interactive Techniques Conference Posters (SIGGRAPH '21 Posters), August 09-13, 2021.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3450618.3469154

1 INTRODUCTION

Telepresence is a technology that enables a user to remotely perform tasks with highly immersive sensation. This technology has been studied for decades to improve its usability and reduce virtual reality (VR) sickness [Higuchi and Rekimoto 2012]. In our previous study, we proposed and developed a riding telepresence system for remote collaboration in tasks that require a vehicle [Yem et al. 2019]. Our system was shown at *Siggraph Asia 2019*, where approximately hundred attendees took our demo experience, and we received feedback that vestibular sensation feedback is necessary.

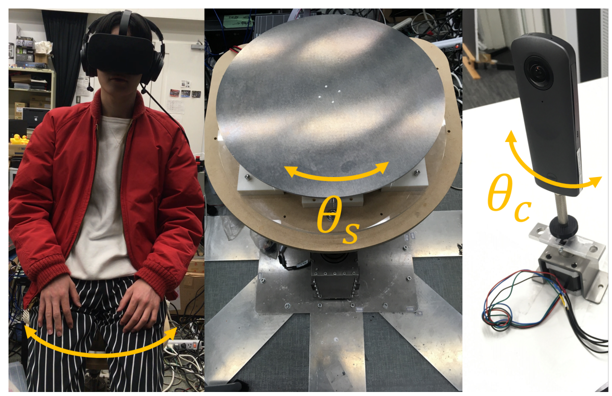

Figure 1: (Left) A participant sitting on the rotary seat. (Middle) Rotary seat for rotation feedback presentation. (Right) A 360-degree camera attached to a stepper motor.

The current study examines the appropriate intensity of vestibular sensations during rotational motion. Because of the sliding of the vehicle (Segway) wheels, we did not use our riding telepresence system but developed an experimental system that consists of a rotary seat that is actuated by a direct current (DC) motor and a 360-degree camera that can be rotated by a stepper motor (Figure 1). With this experimental setup, we could examine sensation feedback with high accuracy. This article reports the optimal intensity of the vestibular and its effectiveness in reducing VR sickness.

2 EXAMINATION METHOD

2.1 System and Stimulation

A 360-degree camera (THETA V, Ricoh) was used to capture live video images of a room and transfer them to a head-mounted display (HMD) (Oculus Rift CV) via WebRTC. As shown in Figure 1, the

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the owner/author(s).

SIGGRAPH '21 Posters, August 09-13, 2021, Virtual Event, USA

© 2021 Copyright held by the owner/author(s).

ACM ISBN 978-1-4503-8371-4/21/08.
https://doi.org/10.1145/3450618.3469154

camera can be rotated in reciprocating motion using a stepper motor (ST-42BYH1004, 400 steps/rev). For vestibular feedback, we developed a rotary seat in which the upper part can be rotated by a DC motor (454797, Maxon). The following functions, respectively, show the angular movements of the 360-degree camera and the seat:

$$\theta_{camera} = \theta_{c_A} \sin(\frac{2\pi}{T} t) \quad (1)$$

$$\theta_{seat} = \theta_{s_A} \sin(\frac{2\pi}{T} t + \alpha) \quad (2)$$

where θ_{c_A} and θ_{s_A} are angular amplitudes, T is a period, and α is the phase between the rotation of the camera and seat. The maximum angular acceleration can be calculated using the following angular amplitude and period values:.

$$\ddot{\theta}_{max} = \theta_{amplitude}(\frac{2\pi}{T})^2 \quad (3)$$

2.2 Adjustment of Vestibular Intensity

The purpose of this experiment is to find the optimal angular acceleration of the rotary seat with respect to the rotation of the camera. Seven males participated in the experiment. The camera was rotated with the amplitude of θ_{c_A}=60 degrees and with the following three angular acceleration conditions: $\ddot{\theta}_{c_{max}}$={6.2,12.3,18.5} deg/s^2. The participants sat on the rotary seat and used a controller to adjust the rotational amplitude of the seat (θ_{s_A}), matching it to the intensity of the rotational images (i.e. visual cue) showed on the HMD for each angular acceleration condition. White noise was introduced using headphones during the experiment. Each participant could stop and restart the seat and camera rotations at any time via the controller.

2.3 VR Sickness Examination

Ten males (average age = 23.1 years old) participated in this experiment. The angular amplitude of the camera was 60 degrees. The angular acceleration of the seat was determined based on the result of this adjustment. The sensation feedback of the seat was set as the following three types: no rotation θ_{s_A}=0), inphase rotation (α=0), and antiphase rotation (α=180 degrees). Inphase rotation is a condition in which the seat rotates in the same direction as the camera, whereas antiphase rotation is a condition in which the seat and camera rotate in opposite directions. After presenting each condition, the participants were asked to answer a simulator sickness questionnaire (SSQ) [Kennedy et al. 1993].

3 RESULTS AND DISCUSSIONS

3.1 Vestibular Intensity of the Seat

Figure 2 (left) shows the adjustment results of the angular acceleration of the seat to that of the camera. It was suggested that the optimal angular acceleration of the seat was approximately half the angular acceleration of the camera, indicating that the rotational vestibular sensation is more sensitive than the rotation of visual cue shown on the HMD. This finding allows a designer to develop a vestibular device having low actuator strength.

3.2 VR Sickness Reduction

Figure 2 (right) shows the result of the SSQ score for each angular acceleration of the camera. Mauchly test confirmed no violation of sphericity, and a one-way repeated measures ANOVA showed the main effect of the seat stimulation condition [$F(2, 18) = 6.2$, $p < 0.001$]. A post-test using the Bonferroni method showed a significant difference between the inphase rotation and other conditions ($p < 0.05$ for each). The result indicated that in the inphase rotation, vestibular feedback was significantly effective to reduce VR sickness, which showed the necessary of the motion feedback. In contrast, the antiphase rotation was ineffective in reducing VR sickness, which might be because the participants could detect the rotation direction of the seat and the perception of sensory mismatch easily occurred.

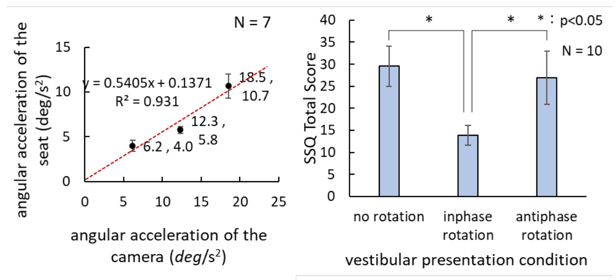

Figure 2: (Left) Adjusted angular acceleration of the seat to that of the camera. (Right) SSQ score representing VR sickness level for each condition of vestibular presentation.

4 CONCLUSION

We examined the optimal angular acceleration of a vestibular chair to the rotation of the visual cue. The results indicated that the angular acceleration of the seat was approximately half that of the camera. Moreover, an SSQ score showed that the rotational motion of the body feedback inphase with the camera rotation reduced VR sickness. In further studies, we will investigate the effect of vestibular stimulation in translation motion and apply the optimal parameter values to experiments on our developed telepresence system.

ACKNOWLEDGMENTS

This work was partially supported by the MIC/SCOPE #191603003, JSPS KAKENHI Grant Number 18H04118 and 18H03283.

REFERENCES

K. Higuchi and J. Rekimoto. 2012. Flying Head: Head-Synchronized Unmanned Aerial Vehicle Control for Flying Telepresence. *SA'12 Emerging Technologies* (2012). https://doi.org/10.1145/2407707.2407719

R.S. Kennedy, N.E. Lane, K.S. Berbaum, and M.G. Lilienthal. 1993. Simulator Sickness Questionnaire: An Enhanced Method for Quantifying Simulator Sickness. *The International Journal of Aviation Psychology* 3:3 (1993), 203–220. https://doi.org/10.1207/s15327108ijap0303_3

V. Yem, R. Nashiki, T. Morita, F. Miyashita, T. Amemiya, and Y. Ikei. 2019. TwinCam Go: Proposal of Vehicle-Ride Sensation Sharing with Stereoscopic 3D Visual Perception and Vibro-Vestibular Feedback for Immersive Remote Collaboration. *SA '19 Emerging Technologies* (2019). https://doi.org/10.1145/3355049.3360540