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Poster

Vehicle-Ride Sensation Sharing for Immersive Remote Collaboration with Vestibular Haptic Chair to reduce VR Sickness

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Abstract

We proposed a telepresence system presenting vehicle-ride sensation in real time for remote collaborative tasks. We used a Segway, a personal vehicle for a local driver, and a rotary chair with vestibular haptic feedback for an expert who remotely attends the task. The telepresence system will enable an expert to collaborate remotely with a local driver regarding a highly professional local surveillance task. We conducted a preliminary test on the feedback system design using a rotary seat built for the evaluation. The result showed that the participants adjusted the angular acceleration of the rotary seat at about a half of the angular acceleration of the camera in motion. The seat rotation needed to be in-phase with the rotation of the camera to reduce VR sickness.

CCS Concepts

• ***Human-centered computing*** → Human computer interaction (HCI) → Interaction paradigms → Virtual reality;

1. Introduction

Various telepresence technologies which make the user feel as if being in a remote location in real-time, have been widely studies [FFK*12][KR15]. These technologies will allow an expert to perform a task remotely by using the avatar robot sent to various places. However, the latency of network communication has decreased the quality of the current telepresence system so that the user may not control the robot effectively to achieve the task. At the same time, VR sickness usually occurs when the camera attached to the robot head is rotated quickly, which is a common issue for telepresence. These problems need to be solved in order for anyone to be able to experience or operate the remote environment with high perceptual quality.

2. Vehicle-ride sensation sharing system

As a solution to the issue of telepresence, we proposed a *TwinCam Go*, a vehicle-ride sensation sharing system, for a remote collaboration task that required a vehicle deployed to the long distance work place such as building or construction surveillance. In our previous study, we proposed TwinCam system that used two 360-degree cameras (THETA V) for reducing motion blur and VR sickness during head rotation by fixing the direction of each camera lens constant in the world coordinate [TFI*17]. This can transmit stereoscopic 3D images in low apparent latency and low motion blur even during quick head rotation.

In the present study, we attached this camera system (TwinCam) to a Segway vehicle via a motion stabilizer. Figure 1 shows our system (TwinCam Go) that can provide both visual and vestibular haptic feedback to an expert observer

Figure 1: *Overview of proposed telepresence system. (TwinCam Go) Left: driver on a Segway with TwinCam system, right: viewer on a rotary seat.*

who sits on a chair and receives the sensation of remote site as the Segway driver. Not only being provided with an omnidirectional view, but the observer receives the sensation of vehicle rotation the driver made, that corresponds to his/her *remote body* orientation change. We modified an office chair by attaching a DC motor to evoke the sensation of body rotation. We considered that a body motion feedback reduces VR sickness during the visual field rotation. This paper preliminarily reports the relation between rotation of the 360-degree camera and a rotary seat built for the experiment, and shows the effectiveness of rotational motion sensation in reducing VR sickness.

3. Preliminary test for feedback design

3.1. Optimal rotation acceleration for vestibular feedback

The purpose of the test was to investigate the relation between angular acceleration of the camera and optimal angu-

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lar acceleration of the rotary seat shown in Fig. 2. Seven male students participated in the test. Participants were presented the live view from a single 360-degree camera (RICOH, THETA V) through the head mounted display (HMD, Oculus Rift CV). The camera was rotated by a stepping motor in a sine-wave trajectory with the amplitude of 60 degrees (Fig. 2, right). Participants sat on the rotary seat and adjusted the amplitude of rotation of the seat by using a controller. The optimal amplitude of the seat was selected in terms of three levels of angular acceleration of camera rotation. White noise was presented over the headphones during the test. The rotation of the seat and the camera could be stopped and restarted at any time.

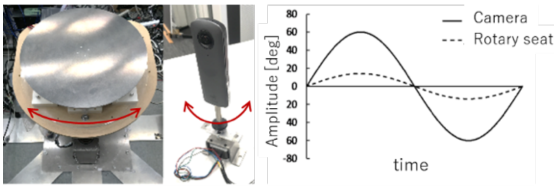

Figure 2: *Rotary seat (left), 360-degree camera (center), and waveforms of camera and seat rotation (right).*

Figure 3 shows the optimal angular acceleration of the seat to the camera. The result suggested that the appropriate value of the angular acceleration of the rotary seat was about a haft of the camera. Since the vision and vestibular sensation are closely related and processed in an acceptable sensory integration, the equation is expected not to conform to a simple linear mapping. Further research is needed for this value and the feedback design. Based on this result, power

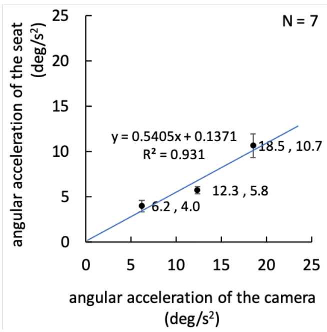

Figure 3: *Relation between the angular acceleration of the camera and the seat.*

to rotate the seat may be less than required for equivalent motion of the vehicle.

3.2. Suppression effect of VR sickness

The trajectory profile required for vestibular haptic feedback to reduce VR sickness was examined. Ten male students participated in the test. The amplitude of camera rotation was 60 degrees and the angular accelerations of the rotary seat were determined based on the result of previous section. The vestibular haptic feedback was three levels: no rotation, in-phase rotation to the camera, and antiphase rotation to the camera. The in-phase rotation has the same direction of rotation to the camera rotation, and the antiphase the opposite direction of rotation. After each trial, the participant was asked to fill in the questionnaire of SSQ evaluation [KLB*93].

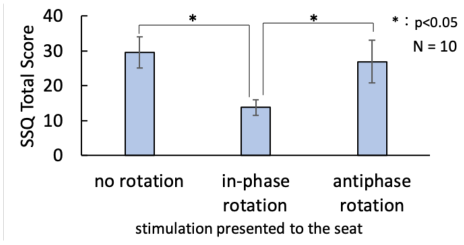

Figure 4: *VR sickness level for each condition of vestibular haptic feedback.*

Figure 4 shows the result. The one-way ANOVA revealed that the seat stimulus was highly significant [$F(2, 18) = 6.2$, $p < .001$]. Bonferroni post-hoc test indicated the significant difference between *in-phase rotation* condition and other conditions ($ps < .05$). The in-phase rotation of the rotary seat indicated significant reduction of the SSQ total score, which means the vestibular stimulus was effective to reduce VR sickness induced by image rotation if the direction of the seat was the same as the camera. The antiphase had no effect, and did not increase the SSQ score, the reason of which is unknown.

4. Conclusion

We proposed a telepresence system with providing a vehicle riding sensation for remote collaboration. Our preliminary test revealed that about a half of angular acceleration of the camera rotation was necessary in providing the vestibular haptic feedback to reduce VR sickness. Our future work includes clarification of the effect of vestibular stimulus on VR sickness reduction, and to increase the degree of freedom of motion of the seat. In addition, the effectiveness of our ride sensation system in remote collaboration task needs validation.

Acknowledgement

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