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VR Sickness Reduction in Stereoscopic Video Streaming System 'TwinCam' for a Remote Experience

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Abstract

In the present paper, a method to present remote stereoscopic vision with decreased VR sickness is discussed. Our omnidirectional stereoscopic video streaming system (TwinCam) is described introducing the merit of the design. One of the important features is VR sickness reduction which we evaluated by assessing the simulator sickness questionnaire comparing it with conventional parallel cameras design. The result revealed that the TwinCam has significantly suppressed VR sickness from the conventional parallel cameras, at the same level of a fixed monocular camera.

CCS Concepts

• ***Human-centered computing*** → Human computer interaction (HCI) → Interaction paradigms → Virtual reality;
• ***Computing methodologies*** → 3D imaging;

1. Introduction

Telepresence technology that makes you feel as if you are in a remote place in real time is expected to be applied to many fields such as experiential learning, teleworking, remote surveillance, or entertainment for mobility challenged people. In recent years, new telepresence system using an omnidirectional camera or cameras with many lenses arranged on a sphere has been developed [MCE*17] [BBF*03]. However, depth information in all directions based on binocular parallax important for grasping accurate spatial feature may not be obtained accurately. In the present research, we develop a new stereoscopic video streaming camera system that provides omnidirectional depth cue while reduces VR sickness by camera drive mechanisms. We demonstrate the feature by an experiment of a fast changing visual field.

2. Stereoscopic video streaming system (TwinCam)

We developed an omnidirectional stereoscopic telepresence system (TwinCam) that reduces VR sickness and motion blur [TFI*17]. The TwinCam system consists of two omnidirectional video cameras (THETA V, Ricoh Co.Ltd.), a bipolar stepping motor (ST-42BYH1004), a motor controller driver and an HMD (Oculus Rift CV1). The camera head is shown in Figure 1. Each camera takes a 4K size video.

Figure 1: *TwinCam head. Two THETA Vs are mounted on a camera platform that rotates keeping lens direction.*

To maintain correct binocular parallax of the stereo video stream, the rotation angle of the camera base is controlled to be the same as the HMD the user wears while the optical axis of lens remains constant as shown in Figure 2. Owing to this design, the user obtains binocular stereo video with the right parallax corresponding to the head (HMD) direction without motion blur and compensated latency of image.

Although the motion blur does not occur at a detectible level, latency still exists in a sense that there is a delay of communication channel and of mechanical rotation of the camera. However, the latency is not perceivable for the user as long as the image the user sees is updated and follows his/her head turn, which is achieved by possessing a spherical image of the environment and rendering a part of it based on the HMD direction without communication. The perceivable latency is in the binocular parallax that recovers after the camera base rotated to the HMD direction. Before that, the binocular parallax is not correct since the cameras (corresponding to eyeballs) have smaller interval distance (interpupil distance). However, the time to recover parallax is less than 0.5 s that may not introduce very unnatural sensation.

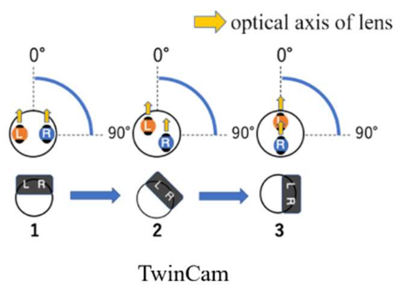

Figure 2: *Head (HMD) turn and camera motion of TwinCam system.*

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3. Evaluation of VR sickness reduction

3.1 Objective and Participants

We demonstrated the effect of VR sickness reduction of the TwinCam. Eight graduate/undergraduate students (mean age of 23.3 years) participated in the experiment. After performed multiple head turns in three visual conditions, the participant filled in the simulator sickness questionnaire (SSQ) [KLB*93].

3.2 Procedure

The TwinCam head was placed at the center of the experimental setup shown in Figure 3. Around the TwinCam, seven boxes numbered 1 to 7 on the side were placed at a 600 mm distance from the center with a 45-deg interval. The experimenter instructed the participant one of the box numbers in a random order verbally every 3 seconds, and the participant turned the head to it to look at the box. After repeating this trial for 30 seconds, the participant responded to the SSQ. We compared three visual conditions: a monocular omnidirectional camera view (no rotation of camera), the TwinCam view (with rotation of camera base), and a conventional parallel cameras view (with rotation of cameras).

3.3 Results

The result of the SSQ total score is shown in Figure 4. The SSQ score of the TwinCam was almost the same as the monocular camera that did not rotate. The conventional parallel cameras that rotated evoked the largest VR sickness. A significant difference between the TwinCam and the conventional parallel cameras was observed ($p < 0.05$), which suggested that the TwinCam system was able to suppress VR sickness at the same level as the fixed monocular camera.

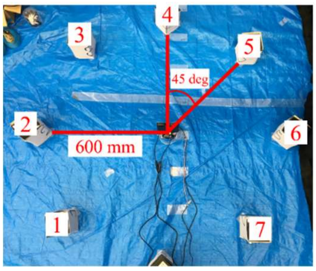

Figure 3: *360-Camera and targets for head rotation.*

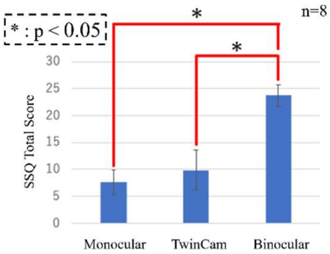

Figure 4: *SSQ total score for three conditions. 'Binocular' means conventional parallel cameras with rotation. (n=8)*

3.4 Discussion

Two factors of image degradation, latency and motion blur in the system of the experiment, are considered related to the SSQ score as an index of VR sickness. The motion blur occurred only in the condition of the parallel cameras. As for the latency, all the conditions involved the latency to the real time event in a strict sense. Video image is captured and compressed, then transmitted and decoded to be displayed on the HMD. These are the same for all conditions. However, the parallel cameras case only degrades the view in the HMD. The latency in question is that the time between the head rotation to displaying the image of right direction. The monocular and TwinCam conditions cover up the latency by presenting the past image in that direction in a very short delay about less than 20 ms. The latency in the parallel cameras was around 400 to 500 ms that will have a severe effect on the SSQ score, however that range of latency is common in current network environment.

4. Conclusion

The TwinCam enabled both the low motion blur and the latency compensation during head rotation of the user. The result on the VR sickness evaluation revealed that the TwinCam could reduce the VR sickness score compared to the conventional parallel cameras. The future work might include to clarify contribution of latency compensation and motion blur suppression to the reduction of the SSQ score.

Acknowledgement

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