Can We Maintain Space Constancy in Virtual Environments?

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ABSTRACT

Users of Virtual Reality (VR) expect to see space-stabilized scenes when they explore virtual environments with combined head and eye movements. Like our experience in real world, users expect space-constancy during head and eye movements. This talk will present a study to demonstrate the break-down of space-constancy during vestibule-ocular reflexes in VR.

1 INTRODUCTION

Virtual Reality (VR), originally developed for pilot training has become an accessible technology for almost every household [1]. There are over 16 million VR installations world-wide in 2021 (statista.com). Due to COVID-19 pandemic, these numbers are growing as VR concerts, conferences and exhibitions are getting popular [2]. One of the main purposes of VR is to immerse users in simulated stable (world-locked) visual surroundings. To achieve this, lenses without distortion are essential for projecting images to their correct angular positions. As the VR users turn their heads, these images should remain spatially stable at their world-locked positions thanks to head tracking functions. This ability to immerse users in a spatially stable VR world is the uniqueness of VR. Unfortunately, lens distortion can disrupt this ability resulting in an unstable and unexpectedly moving VR world.

Space constancy refers to the perception of a stable world despite constant changes of viewpoints [3 – 6]. As we move around this stable world or rotate our eyes, images of the world will shift in the opposite directions on the retina. Instead of perceiving the “moving” images of the world as moving, our brains calibrate these image movements against our head and eye movements. The result is our interpretation that the world remains stable (i.e., space constancy is maintained). As we explore virtual environments by turning our headsets, VR graphic engines will select the correct views to be displayed which will appear that the images on the VR display are shifted in the opposite directions of our head movements. This will usually fool our brains into perceiving that the virtual world is stable. If, however, the directions or magnitudes of the image movements are distorted, space constancy can be disrupted. Normally, lens distortions are mapped and corrected in VR displays. However, the correction process cannot be perfect because lens distortion is a function of eye gaze relative to a lens. If eye gazes are not known, the lens distortion can only be approximate assuming that the eye gazes are towards the center of the lens. This leads to the reported issue of dynamic distortion [7].

This presentation will report studies investigating such disruption and its side-effects caused by imperfect lens distortion correction in VR systems. Solutions to quantify and predict the problems and tools for selecting better lens will also be discussed [7].

2 METHODS

Sides effects of VR has been the subject of many studies [8 – 10]. When space constancy is disrupted, the unexpected movements of the VR scenes can cause conflicts of sensory cues leading to visually induced motion sickness (VIMS) [11 – 14]. In order to verify that imperfect lens distortion correction can cause discomfort among VR users, a user study was conducted. In order to avoid the influence of scene movement induced vection, only static and space-stabled VR scenes were used. As the participants turn their heads, the expected to see a space-stabled VR world. Eight participants were exposed to two VR conditions of uncorrected lens distortion for twenty minutes with at least 7 days apart. Rated discomfort scores were simulator sickness questionnaire (SSQ) scores were collected. A model was also developed to predict reported discomfort scores from lens distortion parameters. Further details can be found in [7].

3 RESULTS

The twenty-minute exposure to the two VR conditions significantly increased the SSQ total scores (p<0.001, [7]). This suggests that even without scene movements, immersion in VR simulation for twenty minutes could cause symptoms of VIMS. Further details of the reported symptoms can be found in [7].

Significant differences in rated discomfort scores were reported after exposure to the two VR conditions. This suggests that the changes of the uncorrected lens distortion can significantly affect the rated discomfort scores [7]. Findings associated with the models will be presented at the conference.

4 CONCLUSIONS

Effects of lens distortion cannot be fully removed in VR displays. The remnant distortion has been shown to cause significant increases in discomfort after twenty minute interactions with a static VR scene. A model has been developed to quantify the effects. Further details can be found in [7].

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