EyeHacker: Gaze-Based Automatic Reality Manipulation

Daichi Ito
The University of Tokyo
ito@star.rcast.u-tokyo.ac.jp

Sohei Wakisaka
The University of Tokyo
wakisaka@star.rcast.u-tokyo.ac.jp

Atsushi Izumihara
The University of Tokyo
izumihara@star.rcast.u-tokyo.ac.jp

Tomoya Yamaguchi
National Institute of Technology,
Ishikawa College
i151340@gm.ishikawa-nct.ac.jp

Atsushi Hiyama*
The University of Tokyo
hiyama@star.rcast.u-tokyo.ac.jp

Masahiko Inami
The University of Tokyo
inami@star.rcast.u-tokyo.ac.jp

Figure 1: (left) A user experiencing our system. The user wears a HMD with an eye tracker and an omnidirectional camera is placed in front of the user's eye for capturing the live scene. Scene transition is allowed when the user gazes at motionless area in both current and next scenes. (right) System diagram. The transition algorithm will be explained in Figure 2.

ABSTRACT

In this study, we introduce EyeHacker, which is an immersive virtual reality (VR) system that spatiotemporally mixes the live and recorded/edited scenes based on the measurement of the users' gaze. This system updates the transition risk in real time by utilizing the gaze information of the users (i.e., the locus of attention) and the optical flow of scenes. Scene transitions are allowed when the risk is less than the threshold, which is modulated by the head movement data of the users (i.e., the faster their head movement, the higher will be the threshold). Using this algorithm and experience scenario prepared in advance, visual reality can be manipulated without being noticed by users (i.e., eye hacking). For example, consider a situation in which the objects around the users perpetually disappear and appear. The users would often have a strange feeling that something was wrong and, sometimes, would even find what happened but only later; they cannot visually perceive the changes in real time. Further, with the other variant of risk algorithms, the

system can implement a variety of experience scenarios, resulting in reality confusion.

CCS CONCEPTS

• Human-centered computing → Virtual reality.

KEYWORDS

substitutional reality, change blindness, inattention blindness, gaze measurement

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1 INTRODUCTION

Virtual reality (VR) does not have to follow physical laws. In a previous study that investigated reality cognition, an experiment was conducted in which the live and recorded scenes were alternately presented without the users noticing the scene transition at the very moment of the transition [Suzuki et al. 2012]. The experimental platform introduced in the research is referred to as the substitutional reality (SR) system. In the study, however, when a noticeable visual gap was expected at the transition of the scenes (i.e., when the configuration of objects and persons in the users' subjective view were spatially or temporally discontinuous), experimenters

*Also with RIKEN Center for Advanced Intelligence Project.

needed to determine the switch timing manually, observing the users' behavior and conjecturing their attention.

Here we introduce EyeHacker, an VR system that enables flexible, stable, and automatic trigger of the scene transition, making optimal use of perceptual phenomena, change blindness (CB) and inattention blindness (IB); CB and IB are phenomena concerning the failure of detecting visual change, or temporal discontinuity in visual information [Rensink 2009]. More specifically, CB is a phenomenon that humans fail to detect visual changes during temporal loss of vision like a saccade or a blink, while IB is a phenomenon that they fail to recognize visual changes when their attention is being drawn to other events or tasks. Previous studies adopted CB or IB in an immersive computer graphics system [Triesch et al. 2003], reduction in rendering time [Cater et al. 2002], and subtle redirected walking [Suma et al. 2011]. EyeHacker also monitors the gaze of the users with an integrated eye tracker in a head-mounted display (HMD). Combining with real-time image analysis of the scenes, the system manages CB and IB at the scene transition. Thus, this system enables automated experience scenarios otherwise manual triggers are required, and even enables scenarios that are difficult to implement with manual triggers.

2 SYSTEM OVERVIEW

An omnidirectional camera (Ricoh Theta S) placed in front of the user's eye captures a live stream of the surrounding scene in an equirectangular format. Further, the surrounding scenes are recorded by the same camera in advance at the same recording site. The custom-made software (TouchDesigner, Unity, Python, etc.) in a computer (CPU: Intel core i9-8950HK, GPU: Nvidia RTX2080) mixes the live and recorded scenes and transfers them to a HMD (HTC Vive). The HMD is equipped with an eye tracker (Pupil Labs) (see Figure 1 right). When the user wears the HMD, our system begins a calibration procedure for measuring the accurate gaze position. The software spatiotemporally mixes the live and recorded scenes in an equirectangular format. Further, it converts the mixed equirectangular image into the sphere image, extracts the subjective view based on the head orientation information, and presents it to the HMD.

The scene transitions are triggered by the following procedure (see Figure 2). The images of the two scenes are reduced with respect to the resolution and are transmitted from the main software to the Python program for obtaining the optical flow images. Every pixel in the images represents the degree of motion. To covertly switch between scenes, the system switches scenes when the user looks at the motionless region. By utilizing two optical flow images and gaze information, our system detects that the user gazes at the motionless region. In particular, it calculates the transition risk by referring to the pixel intensity of two optical flow images around the gaze point. Our system allows scene transition when the transition risk is less than the threshold determined by the head rotation speed for a given length of time. Depending on experience scenarios, quality and accuracy of camera setting, the other variations of the risk algorithms are applied.

The experience examples that generate reality confusion are as follows: 1) removing and adding the moving objects or persons in the room that the user is not looking at (see Figure 1 left);

Figure 2: The transition algorithm. Our system calculates the transition risk by verifying that the area that the user gazes at is motionless. It is utilized for deciding to trigger the scene transition.

2) letting the user count the number of balls on the floor, which becomes difficult because the balls appear or disappear covertly; and 3) conversely, moving the objects that the user is gazing at (i.e., psychokinesis-like phenomena). Note that, in all of the three examples, objects and persons in the live scene are subjectively indistinguishable from those in the recorded scenes.

3 CONCLUSION AND FUTURE WORK

We introduce EyeHacker, a VR system that spatiotemporally mixes the live and recorded/edited scenes. Utilizing the optical flow of the scenes and the gaze information of the users, a variety of experience scenario can be implemented without the users noticing the scene transition at the very moment of the transition. Because there is plenty of room for improvement of the risk algorithm, the algorithm modification and the individual parameter optimization should be investigated as future work. We believe our approach of "hacking eye" gives deeper insight into the mechanism of reality cognition.

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