Transparent Reality: Using Eye Gaze Focus Depth as Interaction Modality

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Figure 1. (a) Focus depth of the user where left is close and right is far, (b) Custom hardware, integrating a pupil labs tracker into Oculus, and (c) Experimental setup

ABSTRACT

We present a novel, eye gaze based interaction technique, using focus depth as an input modality for virtual reality (VR) applications. We also show custom hardware prototype implementation. Comparing the focus depth based interaction to a scroll wheel interface, we find no statistically significant difference in performance (the focus depth works slightly better) and a subjective preference of the users in a user study with 10 participants playing a simple VR game. This indicates that it is a suitable interface modality that should be further explored. Finally, we give some application scenarios and guidelines for using focus depth interactions in VR applications.

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INTRODUCTION

Eye tracking and eye movement analysis is often used in psychology experiments, marketing etc. to better understand user's intentions [1], as implicit input in gaming or as automatic tagging and context recognition tool during everyday life [5]. So far, there are only few researchers exploring explicit eye- gaze based interactions, as users often feel eye fatigue [2]. The best approaches seem to use some stimulus (e.g. smooth pursuit) for less stressful gaze interactions [4]. This paper presents an initial prototype of focus depth implementation in a standard VR headset. Although a couple of researchers already implemented binocular eye tracking systems in VR [3], so far we are not aware of any research using focus depth tracking as an interaction modality. Our contributions are as follows: (1) We implemented a custom prototype to use eye gaze focus depth as novel input modality for VR applications. (2) We show a sample application using focus as a switching mechanism and show that interactions using focus depth information are comparable to explicit input of a scroll wheel. (3) We present guidelines and application cases for using eye gaze depth in VR systems.

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IMPLEMENTATION

We modified an Oculus Rift DK2 HMD for the initial prototype of the system. It consists of two infrared (IR) eye trackers by Pupil Labs that are placed in the cavity of the HMD just below the lenses to capture the user's eyes. The HMD's lenses were modified to provide more space for the cameras without interfering with the user's comfort. The lenses were cut about one third of its total height at the bottom to achieve this. The result are shown in Figure 1(b). Since the Pupil trackers do not support VR environments by default, a custom plugin was written for the tracking software with Python that enables the raw data from the trackers to directly stream into Unity via open sound control (OSC). Unity then reads these values directly into the VR environment. We are using the two normal vectors of the iris for both eyes (provided by the pupil software) to perform the depth calculation, detecting the intersection point or the vector that represents the shortest distance between the two vectors. The focus depth is accurate for distances between 5 - 25 meters in VR space. For the user study, we use a calibration system based on the K- nearest neighbor (KNN) algorithm that teaches the system to recognize two layers of depth in the VR world. By selecting K= 3, KNN calculates the Euclidean distances of the current eye gaze with the trained values to determine the two closes values of K that contains the information of the layer currently being observed. This allows a robust user dependent recognition.

EXPERIMENTAL EVALUATION

We conducted a case study to determine the usability of the proposed system by comparing two methods: scroll-based and gaze-based. The scroll-based method utilizes a more conventional approach where the user is required to obtain scores by touching a sphere, which is controlled with a mouse, to a 2D square placed in front of the user. However, the squares' position also change in the z-axis (depth). The scroll wheel allows the sphere to move in the z-axis. For the gaze-based method, the scroll wheel's function of depth control is substituted with eye gaze. After the calibration phase, the task is no different than the scroll-based method, except that the user is now able to control the sphere's depth simply by focusing near or far. A total of 10 participants, consisting of 6 males and 4 females aged between 20 and 25 and have variable degree of eye sight clarity were given a score-based task in the VR environment. At the end of the session, each participant is then required to complete the System Usability Scale (SUS) score questionnaire to determine the gaze-based method's intuitiveness.

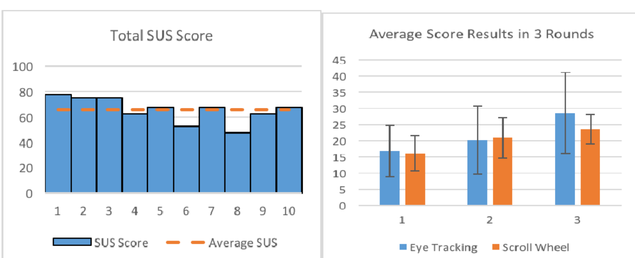

Figure 2. SUS Score of 65.5 of the proposed method and the average scores for both scroll-based and gaze-based method for the first, second and third trial

The achieved scores are rather comparable overall with gaze-based method marginally higher in all three rounds, proving that its precision is also comparable to mouse movement. Two of the participants wore spectacles and had no previous experience with eye tracking and VR. One of the participant needed to remove it while wearing the HMD, whereas the other was able to fit the spectacles in it. Participant 6 and participant 8 suffers from both short sightedness, while participant 8 suffers from minor diplopia. This leads to difficulty in focusing at objects. If the results for both of these participants were excluded, the new SUS score would be 69, which is above the average SUS score that is deemed as a favorable system. Applying a T-Test on the score results show that for the first session, a p-value of 0.804 was obtained. For the following second and third session, the value steadily decreases from 0.4266 to 0.295 respectively. There is no statistical significance between the scroll-wheel and focus-depth based method. Indicating that our method is at least comparable to the scroll- wheel implementation.

APPLICATION CASES AND GUIDELINES

Since the proposed system offers a new layer of interaction in VR, it has the potential to provide a hands-free experience in VR that preserves the immersion. For example, this method of selection would be useful for heads-up-display (HUD) based interaction where the user just focuses close to see the HUD, and focuses far to see the main content. This is particularly useful in spectating sports.

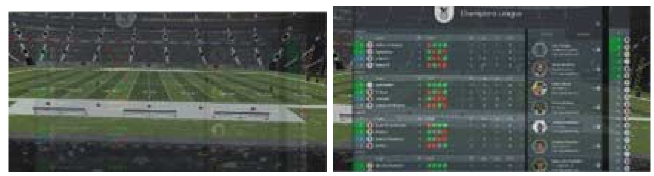

Figure 3. The scoreboard changes in transparency depending on the user's focus depth.

Along the lines of the transparent HUD, focus depth can also be used for menu selection tasks, where different focus depths are associated with different menus. Another application in VR is that it can provide a user with a window to the physical world by mounting a camera on the HMD. By focusing close, the user may switch back to the physical world, while focusing far causes the physical world layer to fade away.

CONCLUSION AND FUTURE WORK

We presented a novel interaction technique based on eye gaze focus depth for virtual environments. Our prototype imple- mentation are comparable in performance to scroll wheel interactions with the advantage of being hands-free. In the future, we will determine the presence of eye fatigue.

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