EyeMR - Low-cost Eye-Tracking for Rapid-prototyping in Head-mounted Mixed Reality

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ABSTRACT

Mixed Reality devices can either augment reality (AR) or create completely virtual realities (VR). Combined with head-mounted devices and eye-tracking, they enable users to interact with these systems in novel ways. However, current eye-tracking systems are expensive and limited in the interaction with virtual content. In this paper, we present EyeMR, a low-cost system (below 100$) that enables researchers to rapidly prototype new techniques for eye and gaze interactions. Our system supports mono- and binocular tracking (using Pupil Capture) and includes a Unity framework to support the fast development of new interaction techniques. We argue for the usefulness of EyeMR based on results of a user evaluation with HCI experts.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; **Virtual reality**; *Interaction techniques*; *Interactive systems and tools*; • **Computing methodologies** → **Mixed / augmented reality**;

KEYWORDS

Eye-tracking, rapid prototyping, mixed reality, head-mounted, virtual reality, augmented reality

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1 INTRODUCTION

In the past years Augmented and Virtual Reality were becoming more relevant to the consumer market. Especially head-mounted devices allow users to navigate virtual scenes in a natural way. Combined with eye-tracking sensors novel ways of interactions are possible (e.g. Gaze+Pinch [Pfeuffer et al. 2017]) and the use of gaze is on a constant upswing [Jacko 2009]. However, current solutions for eye-tracking in these head-mounted devices are rather expensive. Further, the interaction with virtual content is missing. Especially for HCI researchers, these disadvantages do not allow rapid prototype approaches to develop and evaluate new interaction concepts. However, eye-tracking solutions need to fulfill at least three key elements: precision, calibration and avoid of "Midas Touch" [Bulling and Gellersen 2010].

In this paper we present EyeMR, a low-cost (below 100$) system to enable rapid prototyping for novel eye-tracking methods. To raise requirements we interviewed two HCI researchers. Based on these requirements we built EyeMR upon the Google Cardboard [Google 2014] platform (see Figure 1a) and a conventional USB-camera extended with an IR-LEDs circuit board (see Figure 1b). Our approach allows monocular and binocular tracking [Duchowski 2007]. For software we used Pupil Capture [Pupil Labs 2014] by Kassner et al. [2014] (see Figure 1c) and extended it with our plugin (see Figure 1d) to connect to our developed Unity [Unity Technologies 2014] framework. In the end we evaluated EyeMR with ten HCI experts.

2 REQUIREMENTS

Since our eye-tracking solution focuses on rapid prototyping for HCI researchers we conducted two expert interviews to raise requirements for the development. Both experts had more than five years of experience in the HCI domain. Each interview was semi-structured and took about 45 minutes. The results showed that the system had to be low-cost, first solutions should be feasible within one workday, a Unity integration is required and it should be possible to observe the system during studies as well as analyze the data afterward with replay options.

3 DEVELOPMENT

We built EyeMR based on existing hardware and software components. For the hardware, we built upon the Google Cardboard platform. This comes with several advantages like support for Virtual and video-see-through Augmented Reality and the platform itself is low-cost itself (below 10$). The most expensive part of current eye-tracking systems are the cameras. To reduce these costs we used conventional USB-cameras (ELP 960P HD 1.3 MP) and placed them into a modified Google Cardboard. To improve the camera feed, we developed a circuit board consisting of six radial placed IR-LEDs with a beam angle of 20 degrees and a wavelength

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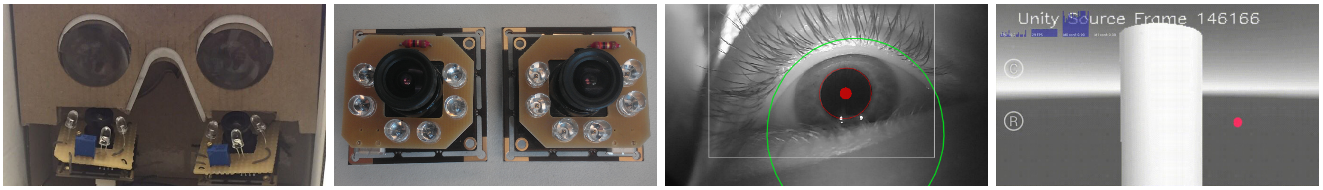

(a) *EyeMR with Google Cardboard.* (b) Camera IR-LEDs extensions. (c) Pupil eye detection. (d) Unity framework with Pupil integration.

Figure 1: Hardware and software implementation of EyeMR. *Best seen in color.*

of 850nm. For the software side, we built upon Pupil Capture. To combine the eye-tracking data with the view of the user we wrote a Pupil plugin that imports a Unity video stream. Further, to enable interaction of gaze data with virtual objects we developed a Unity framework that uses the eye-tracking data from Pupil. This framework is extendable and has built-in support for basic gaze operations (e.g., fixations, saccades and pursuits [Vidal et al. 2013]). Further, the framework allows to record and replay gaze interactions in Unity. The framework and Pupil plugin are published as Open Source software on Github [Project Group Bull's Eye 2017b]. Additional information about showcases and technical documents such as the modified Cardboard template and schematics can be found on the project homepage [Project Group Bull's Eye 2017a]. For the placement of virtual objects in Augmented Reality we use the marker tracking of the Vuforia framework [PTC Inc. 2015].

4 EVALUATION

To evaluate if EyeMR is useful for rapid prototyping we invited ten HCI experts (six female) to implement proof-of-concept scenes while "thinking aloud". Further, participants were asked to evaluate the wearing comfort and the helpfulness of the written instructions. The experts were aged between 26 and 36 (M=29.10, SD=2.81) and all members of the HCI group at the University of Oldenburg. All of them had at least three years of experience in human-computer interaction.

Overall the evaluation showed that all experts were able to implement the proof-of-concept scenes with EyeMR. However, it became clear that good programming skills are required to implement interaction techniques with EyeMR. This is due to the fact that the framework is designed for the use in Unity and requires the user to implement new interaction techniques in C#. Further, two experts stated that an installer application would further simplify the setup of all required components (e.g., Pupil Capture, Unity, etc.). All remarks regarding the written instructions were directly improved in these documents.

5 CONCLUSION

In this paper, we presented our rapid prototyping tool for gaze-based interactions in Mixed Reality. We built EyeMR based on Google Cardboard and Pupil Capture. In an evaluation with HCI experts, we could show the usefulness of our system. In the future, we want to further improve the framework to support more existing interaction techniques from scratch.

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