FaceDisplay: Enabling Multi-User Interaction for Mobile Virtual Reality

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Abstract
We present *FaceDisplay*, a multi-display mobile virtual reality (VR) head mounted display (HMD), designed to enable non-HMD users to perceive and interact with the virtual world of the HMD user. Mobile VR HMDs offer the ability to immerse oneself wherever and whenever the user wishes to. This enables application scenarios in which users can interact with VR in public places. However, this results in excluding all the people in the surrounding without an HMD to become sole bystanders and onlookers. We propose *FaceDisplay*, a multi-display mobile VR HMD, allowing bystanders to see inside the immersed users virtual world and enable them to interact via touch. We built a prototype consisting of three additional screens and present interaction techniques and an example application that leverage the *FaceDisplay* design space.

Author Keywords
FaceDisplay; nomadic virtual reality; mobile virtual reality; multi-user virtual reality

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: User Interfaces - Graphical user interfaces.

Figure 1: Two users interacting with FaceDisplay.

Introduction

Mobile VR describes a type of VR HMDs which have display, optics and processing embedded into one device, allowing users to access VR wherever and whenever they want. This enables a new interaction scenario (Nomadic VR), where a user operates a mobile VR HMD in an instrumented and sometimes public environment [2]. This scenario comes with new challenges such as the exclusion of all the people in the surrounding from the virtual environment of the immersed user. This makes multi-user interaction challenging in asymmetric scenarios in which only one user operates a VR HMD. In stationary scenarios this is often solved using external screens which mirror the immersed user's view or with concepts that introduce additional hardware for the non-HMD user to view and interact inside the virtual world [4]. We present *FaceDisplay*, a mobile VR HMD allowing non-HMD user to see and interact with the virtual world of the immersed user (figure 1).

Prior work on mobile VR already started to extend the capabilities of feedback and interaction inside the nomadic VR scenario by embedding new technology into the HMD itself [3, 8, 7, 5]. This approach allows to keep the amount of additional accessories low and supports the nomadic scenario. Pohl et al. presented in [7] a similar approach to *FaceDisplay*, by attaching one screen to the back of a Google Cardboard that mirrored the immersed users view. The goal of the project was to increase social acceptance of mobile VR HMDs by showing people in the surrounding what the user with the HMD actually does. In *FaceDisplay*, our goal was not only to let the bystander see the virtual environment but also enable them to interact with the HMD user without additional accessories. Another similar hardware setup consisting of a tablet attached to the back of a mobile VR HMD was presented by Misawa et al. [6]. The intention however was to build a remote telepresence system using a human-surrogate and not on enhancing any form of interaction for mobile VR. To the best of our knowledge, *FaceDisplay* is the first approach which presents asymmetric multi-user interaction for mobile VR.

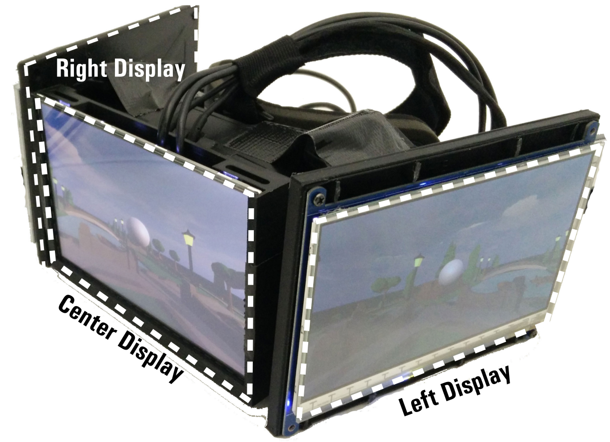

Figure 2: The hardware prototype of FaceDisplay, consisting of three touchscreens attached to the back and the sides of an Oculus Rift DK2.

FaceDisplay

The main goal behind *FaceDisplay* is to push the notion of a mobile VR HMD which is not solely designed for the user who wears it but also includes visualization and interaction concepts for people in the surrounding. We propose to leverage the plastic case of every mobile VR HMD as a touch display for the outside world. The vision for our final prototype would be a curved display which covers the entire back and sides of a HMD.

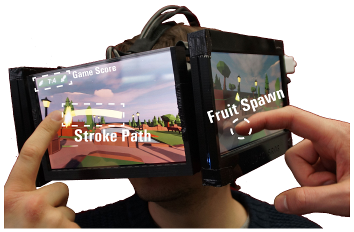

Figure 3: A closeup of two users interacting with FaceDisplay. Highlighted are the slicing path the HMD user created and the spawn location of the next fruit.

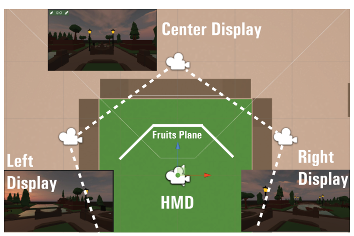

Figure 4: Schematic camera arrangement

Technical Implementation
Our current prototype consists of an Oculus Rift DK2 and three displays attached to the back and sides of the HMD (figure 2). We used two 7 inch Waveshare screens for the sides (resolution: 1024x600) and a 7 inch ChalkBoard Electronics display on the back (resolution: 1280x800). The two screens on the side are attached with an angle of 75 degree to be still partially visible when looking straight onto the HMD. Each display is capable of capacitive multi-touch.

Design Decisions
We made several design decisions during our iterative process which we will explain in the following.

Display Arrangement: We opted for using more then just one screen (in contrast to [7]) since our first prototype that consisted only of one display on the back led to the problem that users outside of the HMD had to follow the head rotations of the immersed user to be able to see the screen. The slightly angled side screens allow the outside user to be able to still see what is happening when the user rotates left and right.

Touch Interaction: Since we wanted to embed the capability for an asymmetric interaction into the HMD we decided to use touch on the screens. Both users interact with the virtual world by using the touch screens. Based on findings of Gugenheimer et al. on touch interactions for mobile VR HMDs, we decided to mainly use the screen on the back as a form of input for the HMD user [3]. The non-HMD user influences the virtual environment by touching the corresponding point on any of the touch displays. In the future we are planing to extend the touch interaction through mid-air gestures using a Leap Motion.

Physical Interaction: A second form of interaction we designed for is the physical rotation of the HMD user by the non-HMD user to guide his view to a certain location. At first glance, this from of physical interaction seems highly intrusive and can potentially lead to discomfort. However, in the preliminary interactions we had inside our research lab, we experienced that when executed moderately and combined with game dynamics, it could potentially benefit the immersion of the HMD user [1].

These two forms of input (touch and rotate) are the basic forms of interaction *FaceDisplay* is designed around. We are currently running a study to explore the social implications of these interaction forms and trying to assess their impact on immersion, enjoyment and mainly comfort.

Demonstration Application

To start an exploration of the design space *FaceDisplay* offers, we implemented a sandbox-like game application, which is a modified Fruit Ninja clone. We implemented two variations, a collaborative and a competitive game. In the competitive variant, the HMD user has to cut all the fruits the non-HMD user throws at him. The user can fruits inside of his field-of-view by swiping on the back display, creating a visual slice animation which indicates his fail or success (figure 3). Gugenheimer et al. showed that when presenting HMD users with a visual indicator where their finger touches the screen, they are able to interact with a screen attached to the back of an HMD with high accuracy [3]. The three displays are virtually positioned inside the scene facing the HMD user (figure 4). Therefore, the non-HMD user looks towards the HMD user and can also see the fruits flying and the slices done by the HMD user. The non-HMD user can throw fruits by touching any position on any of the screens. Every fruit sliced gives a point to the HMD user and every fruit missed a point to the non-HMD user. Whoever gets to ten points first wins. The cooperative mode works similar, only that the fruits now are thrown randomly at the HMD user and the non-HMD user can help him slice by swiping on any of the screens.

After implementing this demo application and using it with colleagues in our lab, we had several observations we are aiming to study in the future. One observation we had was that during the competitive mode, HMD users feel where the non-HMD user touches the screen and can anticipate which direction the next fruit is going to come from. We plan to further study how precisely the HMD user can detect touches on the HMD. A second observation was that the non-HMD user has a higher power level in terms of game play which he could potentially abuse. He could impede the movement, block a slice or even turn the HMD user away from a fruit. However, we did not experience this being exploited in any form yet. Nevertheless, we are eager to explore the social implications *FaceDisplay* has with this imbalance of power.

Conclusion

We presented *FaceDisplay*, a multi-display VR HMD enabling asymmetric interaction for mobile virtual reality. We presented our technical prototype and gave design rational behind each decision we made. We further presented an example application focused on enabling a non-HMD user to interact with the virtual world without having to wear an HMD himself. We finally discussed preliminary observations we had while using the *FaceDisplay* prototype ourselves. We finally want to emphasize, that the goal of *FaceDisplay* is not to create an equivalent VR experience for the non-HMD user but to allow for a whole new form of experiencing VR and interacting with a VR HMD user without having to wear an own HMD.

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