

# See what I see: concepts to improve the social acceptance of HMDs

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## ABSTRACT

Virtual Reality is reaching into the consumer space. Mobile virtual reality solutions are nowadays widely available and affordable for many smartphones, by adding a case with attached lenses around the phone to create a head-mounted display. While using these in public places or at social gatherings where the head-mounted display is given around to others, it can lead to problems regarding social acceptance, as the surrounding people are not aware of what the virtual reality user is seeing and doing. We address this problem by adding a second, front-facing screen to the head-mounted display. We build and evaluate two prototypes for this usage.

**Index Terms:** I.3.3 [Computer Graphics]: Picture / Image Generation—

## 1 INTRODUCTION

The availability of compact, inexpensive, and high-quality displays for mobile devices has motivated interest in consumer-oriented head-mounted displays (HMDs) for virtual reality experiences. These display panels can be combined with inexpensive optics and accurate sensors (gyroscope, accelerometer) for head tracking to achieve immersivity with low cost [5, 6].

With the increased availability of consumer HMDs, they are not only used at home with powerful computers, but mobile versions [8, 1] are used outdoors like on long-distance trips or social gatherings where the HMD is being given around to share the virtual reality experience. While on the home computer setup the rendered image is often shown duplicated on the monitor and the HMD, the mobile virtual reality solution is just visible for the user wearing the HMD. For other observers, this can cause problems with social acceptance or feeling discomfort not knowing what the virtual reality user next to them is seeing and doing. Our contribution is, to address these issues by adding a second, front-facing screen onto the HMD (mock-up shown in Figure 1), which either duplicates the image or shows a more informative view of the virtual reality experience. We first build a mobile HMD prototype with an extra screen that duplicates the image. We continue with a second prototype for a PC-based platform which shows content rendered from a variety of different perspectives on the outside screen, which can be switched through gesture input from the outside spectator.

## 2 RELATED WORK

The option to use more than one display has been becoming common for work spaces and high-end gamers. It can be easily achieved through support from the operating system and graphics card drivers. However, in the mobile space, second screen support started only in 2008 with early specifications of Mobile High Definition Link (MHL) and first products in 2011. Today, together with the Mobility DisplayPort [10] (SlimPort) standard and wireless solutions like MiraCast [11], second screen support is available in a wide variety of smartphones and tablets. However, mobile operating systems currently mostly support only duplicating and not extending the screen. Custom apps like Intel WiDi Social Cast [2]

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Figure 1: Image-edited mockup of the Samsung Gear VR head-mounted display with an additional front-facing screen.

have been shown to use an extended second screen on Android, but these apps focus on specific tasks, restricting the possibility to use two different applications at once in different displays. To drive new content on the second screen in the mobile environment, another source needs to be taken, like another computer streaming pixels wired or wireless [7]. In the following, we will develop two virtual reality HMD prototypes with an additional front-facing screen.

## 3 PROTOTYPE 1: CARDBOARD + SECOND SCREEN

In this section, we describe our first mobile HMD prototype which duplicates the content of the smartphone inside a Google Cardboard HMD [1] and shows it on the outside.

### 3.1 Setup

The new HMD consists of two main components. First, it uses the regular Google Cardboard with the LG G3 smartphone inside. Second, we mounted on top of the Google Cardboard another small box made out of cardboard, in which we put an additional 5 inch display (Adafruit,  $800 \times 480$  pixels, HDMI, controller board PCB800099-V 9). The display is powered by an external battery (EasyAcc PB 12000A) and connected to the smartphone over a SlimPort to HDMI adapter (DeLock, model 65468). Adding these components increases the weight of Google Cardboard from 203 g to 426 g plus the external battery with 328 g, which can be put into trouser pockets. The HMD can be seen in Figure 2.

### 3.2 Experimental Results

The screen duplication has been accomplished easily and with good results. We did not discover any issues in terms of additional latency or performance impact. Similar frame rates were achieved using GFXBench 3.1 [4] with only one display and both displays connected. Despite the different screen resolutions and aspect ratios between the inside and outside screen, the image has been automatically resized properly through the SlimPort adapter. Over longer usage, we discovered that the smartphone was heating up more than usual, due to the lower air flow with the extra screen on top, which also generates heat. Starting at  $25^{\circ}\text{C}$ , measured with a thermometer



Figure 2: HMD prototype 1. Google Cardboard extended with a front-facing screen that duplicates the internal image.

at the back plate of the phone, the phone took about thirty minutes until it shutdown automatically due to overheating at 43°C.

#### 4 PROTOTYPE 2: RIFT + SECOND SCREEN + REALSENSE

In this section, we describe our second, PC-based HMD prototype which shows different images on the inside and outside with additional gesture input control for the outside spectator.

##### 4.1 Setup

To be able to easily drive different content on the inside and outside, we used a PC-based setup to design this HMD prototype. We mounted the same outside-facing screen as in prototype 1 onto the Oculus Rift DK2 [5] (1920 × 1080 pixels). To avoid blocking the underlying infrared lights on the Rift that are used for positional tracking, we decided to put the screen on top of the HMD. Additionally, an Intel RealSense [3] camera has been mounted to allow gesture control input. We created an Unity 3D [9] (version 4.6.8) app with a client/server model, running on the same system, where different camera positions and orientations of the Oculus Rift Tuscany demo scene can be displayed. Gesture input captured from the outside spectator, like waving or thumbs up, can switch between different perspectives to be displayed on the outside screen. The rendered images can be seen in Figure 3 (left and center). The HMD is displayed in Figure 3 (right).



Figure 3: Left: image created for the outside screen. Center: lens distortion compensated stereo image for the inside viewer. Right: photo of the HMD prototype 2.

##### 4.2 Experimental Results

As we ran both the client and server, each responsible for generating the pixels for one of the screens, from the same machine, we

did not encounter any issues with network latency. Despite rendering two different perspectives, we still achieved on our test system (Intel Core i7-6700K, Nvidia GeForce 970, 16 GB DDR4 memory) a smooth frame rate of 75 fps for the Rift and 60 fps for the outside facing screen. However, in more complex scenes, rendering this might become a bottleneck. For sending updates of the camera orientation from the server to the client, we got smooth results with a 10 ms interval. Through adding the second screen and the depth camera, the weight of the HMD increased from 440 g to 790 g. This made the prototype rather uncomfortable to wear, but with depth sensors getting smaller and integrated into future mobile devices, this might become less of an issue.

#### 5 DISCUSSION

We have shown working prototypes with the benefits of other people being able to see what the virtual reality user experiences. The setups are easy to rebuild. To save on the cost of producing such an HMD, cheaper and lower resolution displays can be used on the outside. In the current prototype state, the extensions add noticeable additional weight and cables to the HMD. From the hardware and software side, the technology to implement this into a potential professional product solution would be ready. For that, it would be ideal if support for the front-facing screen would be planned in from the beginning, allowing a lean and ideally wireless setup. The front-facing screen extension could be in the form of a clip-on solution which only gets added when needed. During a social gathering where an HMD is used, a wireless clip-on solution could also be placed at a table for others to see instead of being mounted to the head of the virtual reality user.

#### 6 CONCLUSION

We have shown a potential solution to the social discomfort that can happen when virtual reality HMDs are used in public or at social gatherings, where the surrounding people cannot perceive what the virtual reality user is doing, by adding a front-facing screen to the head-mounted display. We built two prototypes to demonstrate this and evaluated the setups. We extended this by letting outside users interact with the displayed information through gesture control.

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