Casual Immersive Viewing with Smartphones

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ABSTRACT

In this paper, we explore how to better integrate virtual reality viewing to a smartphone. We present novel designs for casual (short-term) immersive viewing of spatial and 3D content, such as augmented and virtual reality, with smartphones. Our goal is to create a simple and low-cost casual-viewing design which could be retrofitted and eventually be embedded into smartphones, instead of using larger spatial viewing accessories. We explore different designs and implemented several prototypes. One prototype uses thin and light near-to-eye optics with a smartphone display, thus providing the user with the functionality of a large, high-resolution virtual display.

Our designs also enable 3D user interfaces. Easy interaction through various gestures and other modalities is possible by using the inertial and other sensors and camera of the smartphone. Our preliminary concepts are a starting point for exploring useful constructions and designs for such usage.

CCS Concepts

• **Human-centered computing** → *Displays and imagers* • *Interface design prototyping* • *Gestural input* • **Computing methodologies** → *Mixed / augmented reality* • *Virtual reality* • **Hardware** → *Displays and imagers*

Keywords

Near-to-eye display; mobile computing; virtual reality; augmented reality; 3D interaction.

1. INTRODUCTION

While typical screen sizes of smartphones have recently grown, they still provide little immersion for spatial applications such as 360x180° spherical videos, virtual reality (VR) and augmented reality (AR). The need to view 3D scenes and spatial content casually and easily in a very short-term manner is increasing with the boom of VR, AR and 360x180° videos. If such a lightweight viewing system of reasonable size could be embedded in a smartphone, it might become analogous to a contemporary View-Master stereoscope[1], yet suitable for a much wider range of media. Such an embedded VR viewer would always be available to the user. Along with various sensors it would also bring spatial 3D and immersive user interfaces (UI) closer to mainstream usage.

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Lightweight and high-resolution virtual views can be created with various kinds of hand-held micro-displays or head-mounted displays (HMD), or projected to the environment with pico projectors. Current HMDs are not pocket-sized or suitable for casual use. Even lightweight HMDs are too big to be carried everywhere and may not always be available. They are very immersive and suitable for use at homes and offices for many purposes, but they may be inconvenient for very short tasks and for casual mobile use in arbitrary locations and situations.

Our contribution in this paper is to initially explore designs for casual, immersive viewing of spatial and 3D content with smartphones. For example, we use tiny, foldable, integrated magnifying optics (preferably a Fresnel lens or holographic optical element (HOE)) in front of the smartphone display, thus transforming it into a very compact near-to-eye display. The folding optics can be embedded in the phone itself or in its cover, or it can be used as an auxiliary loupe.

Our novel (though somewhat crude) designs enable near-to-eye displays for smartphones in an easy way with almost no extra cost or weight. After short viewing they can easily be slipped back into pocket, thus enabling more convenient use. They also have trade-offs such as somewhat limited immersion compared to special-purpose HMDs. There are also engineering challenges with personal adjustments, robustness and stable positioning between lenses, screen and eye due to the required small size and light weight. However, we find the idea of embedding the required parts to a smartphone for casual immersive viewing very promising and relevant, and in this paper we establish a starting point for the concept. An integration of such designs would allow immersive viewing at any time and place and might change the ways people use smartphones. We also envision interaction with such devices.

2. PREVIOUS WORK

Dioramas and the invention of stereoscopic viewing [16] and later stereoscopic photography enabled the general public to immerse themselves with stereoscopic image pairs by the late 19th century. The first HMD employing 3D graphics and head tracking was implemented nearly 50 years ago [15]. Casual use of 3D imagery became possible with the emergence of mobile phones as a computational platform [4]. Some phones had embedded near-to-eye micro-displays in the early 2000's [6, 11]. Also, mobile phone prototypes with near-to-eye micro-displays have been introduced [11]. HMDs may be categorized to *immersive HMDs*, *optical see-through glasses* and small, *peripheral displays*.

[1] https://en.wikipedia.org/wiki/View-Master

Immersive HMDs (e.g., Oculus Rift[2]) block out reality and replace it with a synthetic one. Smartphones can be used as the display element [9] for HMDs. Recent products such as Homido[3], Samsung GearVR[4] and Google Cardboard[5] provide a range of cost, image quality and weight factors. A very lightweight version is Goggle Tech's C1-Glass[6]. Employing Fresnel lenses or HOE may diminish the optics size and improve the field-of-view, as demonstrated by the Wearality Sky[7] glasses. Also a head-mounted VR smartphone has been proposed [2].

See-through glasses (e.g., Hololens[8], Meta Pro[9]) have a form factor of eyeglasses, and some of them enable gestural UIs by embedding tracking sensors. They are designed for mobile use, but are usually not worn all the time.

Peripheral near-to-eye displays (e.g., Vuzix M300[10]) are designed to be worn at all times, but they are typically monocular and cover only a small area of the human visual field at its edges.

Some displays use HMD technology but are meant to be hand-held and to be used casually, similarly to binoculars, such as the discontinued n-Vision VB-30. Pulli et al. [10] presented CyPhone, a cell phone-like augmented reality device employing micro-displays.

Easy interaction is useful for spatial viewing. Several previous works employ near-to-eye displays and gestural UIs. For example, Fukushima et al. [3] describe a system employing an HMD with cameras to track the user's finger for input. Mann [8] presents a finger-mouse for wearable computing, which uses an HMD with an attached camera. MIT's AR UI for wearable computing [14] employs finger tracking, allowing the user to steer a mouse pointer this way.

Rakkolainen [11] presented the MobiVR concept, which consists of a near-to-eye micro-display and a tracking system for gestural UI. It derives largely from VR, but has a more suitable form factor for mobile computing. Koskela et al. [5] discussed the usability and user acceptance issues of the concept. The users pointed to problems associated with small displays and clumsy input methods of mobile phones at the time. Most of their focus group was reluctant about HMD form factors and instead preferred the self-contained and more casual MobiVR device.

Loupe [6] is a tiny hand-held micro-display with cylindrical touch pads on its sides. It enables casual viewing of information in a small size and employs inertial sensors and touch panels for interaction.

None of the previous works are both designed for smartphones and enable embedded designs. Currently most AR / VR displays use a built-in display element or a smartphone which is attached to a frame or inserted into a structure. We focus on a different approach, attaching or ultimately embedding the necessary extra parts to a smartphone.

[2] https://oculus.com/
[3] http://www.homido.com/
[4] http://www.samsung.com/global/galaxy/wearables/gear-vr/
[5] http://google.com/cardboard/
[6] http://goggletech.net/
[7] http://www.wearality.com/wearalitysky/
[8] https://www.microsoft.com/microsoft-hololens/en-us
[9] https://www.spaceglasses.com/
[10] https://www.vuzix.com/Products/m300-smart-glasses

3. CASUAL IMMERSIVE VIEWING FOR SMARTPHONES

Our goal is to create a low-cost embedded design for casual (short-term) immersive viewing for smartphones. Several display types can be used for this. In the following we will envision and explore some smartphone-based possibilities for always-available, omnipresent VR.

3.1 Smartphone Screen as a Window to VR

The simplest way to use a smartphone for immersive viewing would be to use the screen as a hand-held window to the virtual world. The image needs to be rendered according to the spatial relation between the eye and the screen. Viewing software is available for finger-browsing VR and 360x180° videos, but this type of viewing on a smartphone is not very immersive or convenient. Also, the field of view is very narrow at typical phone-interaction viewing distances.

3.2 Micro-displays

One way to implement a large virtual view is with a tiny micro-display with optics. This option has already been initially explored [6, 11]. However, current smartphones do not have micro-displays built-in, and adding them would bring additional cost. Wide-angle optics for micro-displays also presents a serious design challenge. On the other hand, such a construction would theoretically enable diminishing the size of a smartphone to something comparable to a pen (or even a die) if the large LCD screen were to be discarded. One such diminished concept was the NEC P-ISM computer pen[11], which actually did not use a micro-display but a pico projector. Another possibility would be pop-up, see-through glass-plate displays for AR with light-guide grating (see, e.g., [7] for inspiration).

3.3 Pico Projector as a Near-to-eye Display

Another option is to employ an already embedded low-power pico projector as image source and suitable optics in the same way as with a micro-display. Some HMDs already use laser- or LCD-based projectors as image sources, such as head-mounted pico projectors[12] to project images to the environment [12]. Some smartphones have embedded pico projectors for image projection, but to our knowledge pico projectors doubling as a near-to-eye display have not been used as a hand-held VR display.

A suitable folding lens for the pico projector would be needed to replace standard optics. Optionally a mirror or waveguide of a head-up display could make the setup more ergonomic. Also brightness adjustment and/or gray filters can be used to prevent any eye damage. Special care is needed with laser-based projectors.

3.4 Smartphone Screen as a Near-to-eye Display

Employing micro-displays or pico projectors as near-to-eye displays for immersive viewing are intriguing future possibilities, but a more near-term and widely available opportunity is to use the installed base of current smartphones and design lightweight retrofitted add-ons or eventually embed them to near-future smartphones. After reviewing many design possibilities, we converged on initially exploring a smartphone screen, its sensors, foldable near-to-eye optics, and software as a very feasible and promising approach to enable casual, immersive viewing.

[11] http://www.slashgear.com/nec%E2%80%99s-p-ism-pens-for-virtual-internet-kiosk-062807/
[12] http://castar.com/news/

If suitable optics are placed in front of a high-resolution smartphone screen, it will effectively become a near-to-eye display. A Fresnel lens or a holographic optical element (HOE) is a thin, light and low-cost option for this. Technically, such a display is fairly similar to devices such as Google Cardboard.

Figure 1 shows eight potential optics holder prototypes. They weigh 10-40 grams (not including the smartphone). With proper design and manufacturing, the weight can be reduced and usability can be improved significantly. The designs could also be adapted for other hand-held devices such as smart watches, cameras, etc. Also 3D printing of holders opens many opportunities.

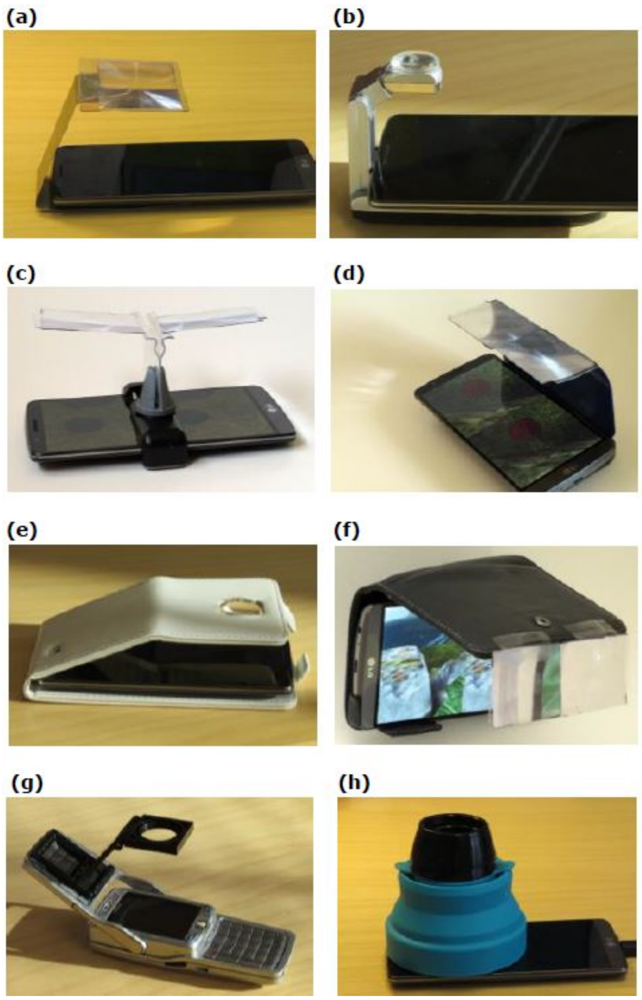

Figure 1. Some potential optics holder designs: a) - f) foldable optics embedded or attached to a smartphone or its cover, g) optics embedded to a clam phone, h) collapsible silicone.

The main contribution of our designs is that they enable easy immersive viewing with a smartphone while being small, easy and low-cost, and with all the parts eventually integrated into the phone. The necessary optics assemblies can be optimized for fast deployment and retraction. This is convenient for real usage situations when casual immersive viewing is needed. A near-to-eye display approach may be more immersive and easier than, for example, a hand-held smartphone or tablet screen held at hand's distance. Our designs can also easily be carried everywhere as they are integrated into the phone or its cover.

Many of our designs are monoscopic, but they can easily be extended to stereoscopic use by adding another lens and thus providing an image for both eyes. The designs have less weight and size than the current HMD add-ons for smartphones, and more importantly, they could always be with the smartphone. Also, a single, large Fresnel lens can provide a stereo collimated display for improved immersion.

We used an LG G3[13] smartphone and constructed a set of lens holders for it. The LG G3 has a 5.5" screen with a resolution of 1440 x 2560 pixels (515 ppi) and it can render smoothly 360x180° videos with a resolution of 3840 x 1920 pixels. We tested flat Fresnel lenses and a lens of a Homido HMD and designed several holders for them. The orientation of the image is based on the inertial sensors of the phone. Vision-based tracking using the camera phone could be used to improve tracking and interaction.

Embedded or retrofitted foldable optics would suffice for short-term, casual viewing. There are numerous ways to construct such holders, which could be turned, slid, rotated, popped up, clipped on, or twisted on when needed and hidden when not needed. Figure 2 shows one of our prototypes in use.

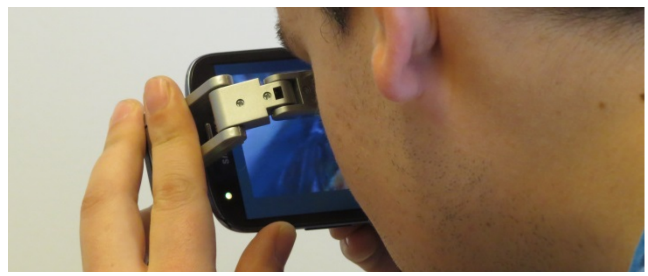

Figure 2. A casual 3D viewing prototype in use.

The designs enable casual viewing of 3D UIs, 3D graphics, AR, VR and immersive 360x180° panoramic content for smartphones. They do not provide as good image quality and immersion as special-purpose HMDs, but such a VR viewer is always with the user, embedded into the smartphone or its cover. Modular smartphones such as Google Ara[14] might also support this goal.

4. USER INTERFACES FOR CASUAL VR VIEWING

Having an adequate-sized display and an easy way of interacting on a pocket-sized device is difficult to obtain. Interaction is an important consideration for the casual, hand-held VR, AR or immersive, spherical videos. We envision some multimodal UI extensions for such smartphones, which may enable easier interaction.

Hand gestures, speech, gaze tracking and other multimodal interaction methods can be used with our prototypes for easy input and interaction. Interaction can also benefit from various inertial and other sensors and the camera of the smartphone. Also many kinds of 3D UIs [1] would be suitable for the concept.

Hand gestures may be one particularly suitable interaction method. The user could point to the items on the virtual view intuitively with a finger in mid-air in front of the smartphone camera. The finger pointing UI concept applied to this context bears some similarity to the work by Song et al. [13], Rakkolainen [11], Google Project Soli[15], Microsoft hand interaction[16] or technologies such as eyeSight[17] in terms of user interaction, and to smartphone-

[13] http://www.lg.com/us/mobile-phones/g3

[14] https://atap.google.com/ara/

[15] https://atap.google.com/soli/

[16] blogs.microsoft.com/next/2016/06/26/talking-hands-microsoft-researchers-moving-beyond-keyboard-mouse/

[17] http://eyesight-tech.com/

based HMDs (e.g., [9] or Google Cardboard) in terms of display. However the finger pointing UI concept has here a new perspective as the designs are meant to be embedded into a smartphone for casual, immersive viewing.

5. FUTURE WORK

Proper implementation of multimodal interaction, comparisons of various designs, user acceptance studies and user testing are part of our future work. User testing is essential in finding out how useful these designs are.

6. CONCLUSION

We initially explored how immersive spatial and 3D viewing add-ons could be conveniently retrofitted to smartphones and eventually embedded to them. We proposed several ways to implement immersive viewing for a smartphone or even for pen-sized or wrist-watch-sized devices. We have presented designs for casual immersive viewing with smartphones, which are very low-cost and light. We built prototypes employing the display and sensors of a smartphone to create an orientation-tracked near-to-eye display.

We also proposed gestural and multimodal interaction with smartphones, as it may be a viable solution to the issue on how to have a decent-sized display and an easy way of interacting on a pocket-sized device [5].

The presented designs seem to be useful and easy to use for viewing 2D and spatial 3D content with smartphones. They are well-suited for short-term use and casual viewing, are always with the smartphone and can be applied to many purposes. We hope that improved designs will become a standard element of future smartphones.

7. ACKNOWLEDGMENTS

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