AR Eyewear and mobile devices: the challenges ahead

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Abstract**—** Mobile AR growth will be limited by the use of built-in screens on mobile devices. Eyewear-based AR displays will be necessary for a wide variety of applications. We explain the benefits of eyewear-based AR displays, then examine the obstacles to their widespread use. We conclude that some of the obstacles can be overcome through standards in AR display interfaces. The first area that we believe could be standardized is the hardware interface between the mobile device and the eyewear. We discuss some key concepts on which the entire ecosystem must agree before standards development can begin. We briefly identify other challenges that will emerge once a standard hardware interface for eyewear-based AR displays has been defined.

I. INTRODUCTION

While the mobile telephone platform has largely contributed to the adoption of AR among consumers by enabling such applications to run on a relatively cheap and well-accepted form factor, mobile Augmented Reality (AR) using the built in screen of the device can be limiting and awkward.

It is the opinion of the authors of this paper and of others in the community that eyewear designed for AR experiences will become popular and enable use cases which are otherwise unlikely. The purpose of this position paper is frame the discussion of eyewear for mobile AR in such a fashion that the issues which can be addressed through standards are easily identified. We make the case that having an open API that defines how eyewear for AR and mobile phone platforms communicate will greatly accelerate the development, lower costs and increase popularity of eyewear for mobile AR.

II. THE PHONE PLATFORM

Although it is currently the most popular platform for mobile AR, smartphones have a number of issues that make them less-than-optimal as AR viewing systems for many compelling applications. For the purpose of this paper, we will focus only on:

- Screen size
- Resolution of the real world and augmentation
- Field of View
- Arm position

Screen Size. The screen of most smartphones does not exceed 3.5 inches. This is the size of the Apple iPhone4 display. The HTC Desire is 3.7 inches. There is a limit to how large the screen can be and still be easily stored in a pocket or bag. Even at the upper limits found in the latest mobile devices, a smarphone accommodates less information than a larger screen could.

Resolution. The resolution of most smartphone screens does not exceed 960 x 640 pixel resolution (this is the resolution of iPhone4). Increasing the display resolution to increase the amount of information can help but only until the user is no longer able to read the information at the typical working distance or is unable to see the real world on the display because the size of augmentations is too large.

Resolution issues are also caused by the fact that the quality of the camera is far lower than that which is supported by the display. In fact, smartphone cameras are not designed for AR applications and, consequently, perform poorly in diverse lighting conditions and do not mimic the human eye. As a result, the user must learn to map what is shown on the screen with their view of the real world.

Field of View. The field of view provided using a smartphone screen is in the order of a few degrees, far less than that provided by nature. Fortunately, the field of view of the camera showing the background view is much larger, but consequently, there is a distortion between the view of the world that is augmented (as seen on the small screen) and the real world that can been seen around the phone. This creates a non-intuitive mapping that the user must adjust for due to the difference in angular resolution. The result of this mapping challenge is a slower user response time.

Arm Position. Finally, and perhaps most importantly, phone-based AR requires that the user hold their phones at eye-level to position the phone between their eyes and the real world they are augmenting, a position which is tiring and interferes with other activities (e.g., driving). This, along with the response time of an AR application, is arguably the largest problem preventing the mass market adoption of AR technology as a preferred information awareness tool.

III. AN EYEWEAR-BASED AR DISPLAY

An intuitive extension of the phone platform for AR is the eyewear-based AR display. Eyewear-based AR displays are worn on the user's head, and resembles sunglasses, covering both eyes, using a transparent screen through which the use can see for visualizing digital information on top of the real world. We do not consider video see-through eyewear to be an option for mobile AR because the video camera system does not produce the same field of view as the unaided eye, making its use unsafe for certain applications.

Eyewear-based AR displays must permit the user to see, as do sunglasses and correction eyeglasses, most of the real world so that the user can safely move around. This means that occlusions due to the frame of the display should be minimal and the field of view through which the user can see the real world, also sometime called field of regard, should be close to the field of view of the human eye. This does not necessarily mean that the field of augmentation, or the field of view where the user can see overlays, has to match the field of regard, as this is still a big challenge to achieve with today's optical technology. A small field of augmentation can still allow a user to move in the real world effectively; it will just constrain the user to center its line of sight directly on objects by turning the head rather than only the eyes.

The eyewear-based AR display solves many of the issues enumerated above with the mobile phone platform for AR. Indeed, with suitable eyewear AR can be used hands-free thereby letting the user do other tasks than holding the phone. Because it overlays graphics on an undistorted view of the real world, the user can then move safely instead of having to stop to consult a small display with a lot of information in high resolution. This ability to move around is further improved by letting the user see the real world in the full resolution and brightness range that the eye can perceive. Finally, it offers a field of augmentation that is comparable to the one of the phone (not the field of view of the screen at the working distance but the field of view of the camera). Due to distortion factors, difficulties with matching the angular resolution of the augmentation and of the real world the user will intuitively associate the overlays with the real world while still having a good view of the real world.

While there is the perception that eyewear-based AR displays are too far away to be considered seriously, we argue that they are less than a decade to large scale adoption. There are two main reasons for this. First, the eyewear companies have been focusing on creating monocular opaque displays because reaching the level of brightness that was necessary was an issue in the past. Unfortunately the mainstream introduction of such displays, mainly in the military, has caused problems due to occlusion of the operating environment and the interface has been judged as intrusive by most users. When brightness issues were solved with the introduction of retinal scanning, for example, eyewear companies were keeping the one eye design, even if see-through, potentially due to their main customer being the military, but also because of the nonexistence of any commercial market and the lack of demand for a binocular display.

The market is now ready for binocular displays and some companies have started to produce binocular offerings. Since early 2010, several eyewear companies have come to an identical breakthrough while relying on different designs: the ability to produce eyewear displays that are close to the form factor of eyeglasses.

The technologies used to achieve those levels of miniaturization is out of the scope of this paper but all the largest companies have already produced prototypes. Some are close to production level. Unfortunately, eyewear companies work primarily on optics and micro displays rather than AR and today only a few are starting to offer a connection to mobile phones. These are only designed to watch media content generated by the phone and most will be inappropriate for mobile AR applications.

IV. NEED FOR A STANDARD AR HARDWARE INTERFACE

Manufacturers of mobile devices have adopted a wide variety of standards to lower the overall cost of production and to permit users to change handsets easily, or to use handset features with vendor-neutral devices. For example, virtually all smartphones have the 3.5mm headset minijack, permitting users to plug any manufacturer’s audio accessory into the mobile. Further, all mobile phones use a standard-compliant hardware interface for the SIM card.

In early 2009 the GSM Association launched an initiative to standardize the physical interface for power chargers. In the final days of 2010, the community of mobile device manufacturers and the European Union announced that the micro-USB interface would be the standard interface beginning as early as February 2011.

In order to capitalize on the emerging commercial market for AR on smartphones and, further, to expand it dramatically, a standard interface between eyewear-based AR displays and smartphones must be developed. Such an interface will drive the AR content market by providing an optional, and we feel superior, display mode to users. Second, as the number of low cost high quality eyewear-based displays and smartphones able to power and work with eyewear for AR experiences grows, a standard interface will ensure healthy competition. By permitting users to choose among many models of phone-compatible AR eyewear, there will be greater diversity and offers for many different budgets and use cases.

A standard interface for eyewear-based AR displays and smartphones should be developed by hardware providers, in collaboration with content companies and experts in the field of AR. This will assure that many current and future use cases and complex issues are being taken into account and increase the future impact of mobile AR.

Some argue that there will be a point when phones and other processing platforms will merge into eyewear. Early concept prototypes have been introduced illustrating how this could function. While such highly integrated devices would potentially void the utility for the envisioned interface, it is unlikely to happen before it is proven that users will adopt eyewear displays. Moreover, there are additional miniaturization challenges to making the smartphone disappear into the frame of eyewear and medical issues pertaining to using a cellular radio close to the brain to be resolved before such a design concept can become a reality.

Instead, a standard interface between eyewear designed for AR and a class of AR-ready mobile devices can be achieved with today's existing technology. Early prototypes have been achieved by one of the authors and possibly by others. We believe that it is time to begin working on a standard interface to avoid future problems with proprietary solutions and so AR can expand to its full potential.

V. CHALLENGES OF CONNECTING EYEWEAR TO PHONES

Optical see-through eyewear superimposes a video feed on the user’s field of view. Without taking into account the technology used for the optics and for the display, one can think of this as providing the user with a large transparent screen. The screen is placed at some distance from the user, depending on the focal distance of the display, but typically several meters away. The video fed into the eyewear is shown on the transparent screen and the user can see the digital information superimposed on the real world.

In order for the eyewear to show a view identical to that shown on the phone screen when the phone runs an AR application, the AR application on the phone will need to:

- Use the pose of the eyewear rather than the pose of the camera of the phone
- Display the generated graphics on the eyewear rather than on the phone's screen

These two apparently simple things already present many challenges calling for the specification and adoption of a standard. For starters, let's examine how the data from the eyewear about the user's pose will be communicated to the application running on the handset/mobile device or in the cloud. The raw video input could be transmitted to the mobile device, or could be pre-processed in the eyewear. What are the pros and cons of the different options? The community of vendors developing eyewear for AR and the manufacturers of mobile device hardware interfaces might explore possible collaborations with the developers of other types of hardware that capture very large real time data throughput via an accessory device, such as those being commercialized by InterAxon and NeuroSky..

Separately, current eyewear designs do not include, as part of their standard build, a sensor to measure the pose of the eyewear or of the user's field of view. Sensors will need to be added at least to produce an orientation measurement as reliable as the phone's own positioning hardware is, given the expected accuracy of the GPS or other modalities used for positioning. However, sensor formats and interfaces are all proprietary and, unless there is a standard, AR applications will be unable to connect to and receive data from eyewear-based AR display sensors.

What about the output of real time data from the AR application back to the eyewear? To date, handset manufacturers limit the ability of some phones to output video except for seeing movies and slide shows. Video generated by an AR application is unavailable for viewing except on the device screen. Even if their internal processors can do it, the connector is not always available and no connector has emerged as standard yet, although WHDI, recently featured by several manufacturers at CES 2011, seems to be promising.

Another issue lies in providing an interface or driver to the phone-based AR application developer. A software standard that works with minor or no rewrite of existing applications would be optimal. Unfortunately, current applications are written without testing or even knowing how to test for eyewear-based AR display compatibility. The problem is more complex than just mirroring or changing a display. The AR application must take into account the orientation of the user's head rather than of the phone as a parameter.

Existing schema, such as patching the system calls related to pose determination and video display, can be used to solve these problems but they are highly dependent on the platform and cannot be achieved across the whole industry without handset manufacturers and distributors all working in the same direction.

There are many other considerations that should be taken into account beyond this first look at the problem. Once the hardware interface standards is defined and on the way to successful mass adoption of AR with the assistance of eyewear-based AR displays, the industry will be confronted with other display-related questions such as:

- Will stereoscopic imagery, i.e., one different image for each eye, be needed, and how will it be produced from the mobile platform?
- How can such a standard interface be made wireless while still keeping the power budget under control and providing low latency?
- Is there an opportunity to send primitive drawing commands rather than all pixels from a video frame and how does the hardware or software determine when one might be better than the other?
- Future eyewear will need to capture the view of the user to analyze it and determine where and how to place information. How much analysis will be performed on the eyewear and how much will be on the phone? If on the eyewear, how will the video or relevant data be sent to the mobile device?

VI. CONCLUSION

In this paper we make the case that the built-in display of most mobile devices is not well suited to mobile AR and we introduced the need and market implications of a standard interface which defines connections between mobile devices running AR user agents and eyewear-based AR displays. We consider implementation options and then discuss some of the challenges associated with developing such an interface without a standard being created.

We hope that this paper will start an open discussion between handset, chip, and eyewear manufacturers as well as AR experts and those in nearby communities of interest to assess current and future use cases and to develop a robust, extensible interface that will permit the AR industry to expand into everyday life.

ABOUT AUTHORS

Yohan Baillot specializes in interactive visualization systems and eyewear-based AR displays. He is a pioneer in the Augmented Reality research community with 13 years experience working in all aspects of AR through building many prototypes for the medical and military fields. He is currently working on a standard interface to connect any digital eyewear to smart phones running AR. Yohan has a MS in EE from Polytech' Montpellier in France and a MS in CS from UCF in Orlando FL. He is the author of more than 30 academic papers and 6 patents. He is also a member of the Computer Society and the founder of the ARForum, a mailing list on AR with more than 600 members.

Christine Perey has been working in the domain of rich media communications for 20 years, initially in the area of dynamic media technologies on personal computers; she founded, was the editor and publisher of the QuickTime Forum, a publication for QuickTime developers 1991-1993.

When enterprise and wide area networks emerged as a means of distributing rich media created and consumed on personal computing devices, she expanded to provide a variety of services to the companies in the rich media communications industry, and accelerated adoption of videoconferencing and streaming media.

Since 2006, Perey studies and assists companies to better understand their opportunities in the domains of Mobile Social Networking and Augmented Reality. Perey is an active leader of new industry initiatives, organizing thought-leadership meetings and think tanks about mobile AR topics.