Exploring the Interaction Design Space for Interactive Glasses

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Abstract
In this paper, we explore the interaction design space for interactive glasses. We discuss general issues with interactive glasses (i.e., optics, technology, social, form factors), and then concentrate on the topic of the nature of interaction with glasses and its implications to provide a delightful user experience with the *NotifEye*.

Author Keywords
Wearable Computing; Head-Mounted Displays

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
Computers are getting smaller, more powerful, and closer to our bodies. Computers have transitioned from being in a large room (e.g., ENIAC), to our desks (e.g., PCs), to a bag (e.g., laptops), and to our pockets (e.g., mobile phones). A common question these days is where will this trend towards miniaturization take us next. On one hand, tablets (e.g., Surface or iPad) seem to have favored a larger and more comfortable format that allows complex tasks such as typing, while still providing the freedom and availability of a portable device. On the other hand, wearable computers (e.g., the WIMM watch or iPod Nano) have continued the

Figure 1. A person wearing the Epson Moverio see-through binocular head-mounted display.

[1] www.epson.com/Moverio/

[2] plus.google.com/+projectglass/

trend towards ever-smaller computers, ones that can be worn on our wrists or other parts of the body. In addition to physically small computing devices placed on the body, some wearable computers utilize head-mounted displays (HMDs). These displays use optics and decouple the physical size of the device from what a user perceives. In particular, a small piece of optics placed in front of the eye can create a large virtual image for the user.

The improvement in optics, computing hardware, battery efficiency, lighter and stronger materials, form factors, and overall social acceptance of see-through HMDs is bringing interactive glasses closer to reality. Products such as the Epson Moverio[1] (Figure 1) or Google's Project Glass[2] are exploring the possibilities that interactive glasses could soon offer to the general public. However, one topic that still remains unsolved is the nature of interaction with glasses. What things would interactive glasses allow us to do that we cannot currently do? How would people provide input to interactive glasses? Is there accompanying hardware to do this? What conceptual model and interaction paradigms make sense for virtual displays (e.g., does a WIMP interface make sense for these devices)? Perhaps more generally, what is the overall user experience (UX) that we are trying to design for and what are the fundamental design aspects of that experience?

In this paper, we explore the interaction design space for interactive glasses. Based on a rich work history looking at optics, form factor, and social acceptance issues with HMDs, our aim is to provide answers to some of the questions presented earlier and discuss its implications towards providing a delightful user experience with interactive glasses.

The paper is structured as follows. First, we review relevant related work. We then discuss the main interaction issues that remain unsolved, followed by a detailed description of the *NotifEye* prototype, which embodies and explores example interaction techniques. Finally, we present conclusions and future work.

Related Work

There has been a variety of work exploring different interaction aspects of wearable computers. One key aspect is the nature of the visual display. Many current wearable products have small conventional displays like smart watches. Turning to HMDs, we can broadly classify two different styles of interaction. Augmented Reality [1] uses tracking of the real world and registers virtual objects so that they appear overlaid with the user's view of the world (world-fixed [4]). In contrast, we are considering displays where the information is fixed with respect to the user's frame of reference (display-fixed [4]). These systems do not rely upon tracking and act more like a conventional display that stays in the same location in the user's field of view.

Input is another key consideration for wearable interaction. Speech is one obvious solution, but might come with unwanted social overhead (e.g., speaking to one's computer in social situations could be awkward). One approach for addressing this issue was Dual Purpose Speech by Lyons et al. [8]. Pointing is fundamental to most interactions and there has been some work evaluating the effectiveness of different devices [13] as well as gesture and physical props [12]. Various keyboards have also been evaluated including mini-qwerty keyboards [3] and even gloves [2]. Others have been looking at deeper integration between computing and clothing [5][9].

Figure 2. A fisheye representation of the user's field of view: a) the binocular visual field, b) the Epson glasses' frames, and c) the virtual image of the HMD at 23 degrees diagonally, covering only ~1/10 of the horizontal binocular visual field.

In contrast to this research looking at different components of wearable interactions, there has been less work examining the use of wearables outside of specific vertical markets. This is likely due to the unwieldy nature of most wearables and the correspondingly few wearable users. However, this is likely a ripe area of investigation as we are seeing the next wave of wearable hardware being developed. A few early adopters leveraged their ability to rapidly touch type on the Twiddler keyboard, and as power computer users, adopted the Emacs text editor as an environment for much of their use [7]. The Remembrance Agent is built on top of Emacs to provide the user a proactive memory aid [10].

General Issues with Interactive Glasses

A series of general issues must be dealt with in order for interactive glasses to become widely accepted:

- **Optics** – Large field-of-view (Figure 2c), high resolution, high brightness and contrast, opaque objects that can be perceived on a transparent background are typical expectations for see-through HMDs. Due to many limitations however (size, weight, etc.) practical solutions tend to have only a subset of these characteristics [6]. Furthermore, the focus distance and convergence are usually fixed in infinity.
- **Technology** – The continued progress of Moore's Law now means that what would have been considered a super computer in 1997 at the dawn of much wearable computing work can now fit into a few dozen cubic centimeters or less. While computation, storage density and radio connectivity improved tremendously, raw battery capacity has not seen such progress. However, as demonstrated by Google's Glass it is now feasible to integrate a fully functional computer into a device with eyeglasses-like form factor.
- **Social** – This issue relates to people's perception of interactive glasses. What is the meaning of wearing and using interactive glasses both for those who wear them and the people around them? How awkward is it for people who do not normally wear glasses to have to wear them? How important is it to be able to make eye contact with the person that is wearing the glasses? How do we design for the coevolution of glasses technology and corresponding social perceptions?
- **Form factors** – Once we establish that people are fine with the general idea of wearing interactive glasses, we must identify the size, weight, and ergonomics of such interactive glasses so that people feel comfortable wearing them. Would people prefer monocular (i.e., one eye) or biocular (i.e., both eyes) designs? What type of design is better suited for social communication?

Figure 3. Context of use: using interactive glasses while walking on a busy street.

[3] en.wikipedia.org/wiki/Xybernaut

[4] research.nokia.com/page/4861

[5] youtube.com/watch?v=CGwvZWyLiBU

- **Interaction** – The questions that we are mostly interested in relate to the nature of the interaction. What are the conceptual models and interaction metaphors for interactive glasses? How should those pixels be used? How is a user going to provide input (e.g., for pointing, typing, navigation)? What apps are uniquely suited for glasses? In this paper, we concentrate on interaction issues.

Prototype: *NotifEye*

Based on the first author's first hand experience wearing an Epson Moverio binocular and Xybernaut Poma[3] monocular devices, our rich history working with HMDs[4,5], and the relevant literature described earlier, we have designed and implemented *NotifEye*. The goal is to explore some of these open UX questions in the context of a simple notification application. This application allows a person to receive and take action on incoming notifications from social networks while moving (e.g., walking on a busy street).

Context of Use

We decided to focus on situations where interactive glasses could be at an advantage over other mobile technologies (e.g., phones, tablets). One such situation is using mobile technologies while walking on a busy street (Figure 3). Bumping into street signs and other people while walking on a busy sidewalk is a common problem when people are also trying to check their email or update their Facebook status. Ideally, interactive glasses should be able to provide timely information (e.g., notifications, simple navigation cues) while still allowing people to pay attention to and keep an eye on other pedestrians on the sidewalk.

Discreet Interaction

Once we had identified a context of use, we then decided to look into ways of interacting with the glasses that would allow people to act as naturally as possible in a public situation. More specifically, we wanted to avoid highly visible hand gestures that imply waving, touching the glasses, or looking at one's own hands through the display [11]. To provide user input to the glasses, we believe that people should be able to make small, subtle movements with their fingers (e.g., finger-snapping, counting coins, or rolling a marble). Therefore, we have placed a rub pad on the user's index finger as the main means of input (Figure 7).

In order to keep the interaction simple, we have limited the options available to a person from the interactive glasses to receiving, opening, or ignoring incoming notifications. We do not deal with replying at this point, as typing would require heavy user input. We are also aware that people might prefer to stop walking and take their mobile phone out to take further action on the incoming message. Therefore, we chose not to allow replying to an email from the glasses, at least not for now. Once we have properly understood the implications of handling notifications with interactive glasses, we will then explore more complex ways of providing input to the glasses.

User Experience

With our chosen context of use and interaction style in mind, we set out to create a delightful user experience with interactive glasses. We wanted to create ways that allow people to subtly and beautifully see virtual notifications overlaid on top of the physical reality. It should be something that feels refreshing and almost inviting people to take a break, while still being

Figure 4. A sample flight trajectory of a butterfly carrying a notification.

Figure 5. Butterflies for incoming Twitter (left) and Facebook (right) notifications.

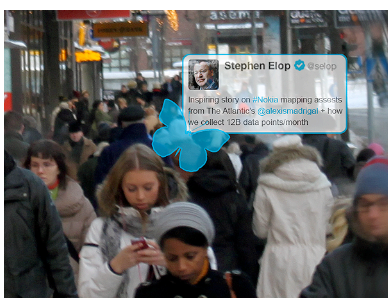

Figure 6. A Twitter message is shown on the glasses' display.

something that can simply be ignored. Instead of filling the display of the glasses, we aimed at providing as few UI elements as possible. These elements should also not be placed by default along the edges of the display, as these would bring the edges of the display (and thus its limitations) to the user's attention (Figure 2). Therefore, we explored small butterflies flying across the user's view, carrying incoming notifications content.

Interaction Techniques

- **Receive Notification** – To receive a new notification, a person must be wearing the interactive glasses and must have shared their social network credentials (e.g., Twitter or Facebook). When a new notification arrives, a butterfly carrying the incoming message starts flying from one part of the screen to another, gently flapping its wings (simulated view in Figure 4). The butterfly slowly increases in size as it moves across the display, and then does the opposite until it fades away if the person has decided to not act upon the notification. The butterflies vary in color to provide visual cues as to which social network the incoming notification belongs to. Light and dark blue butterflies announce incoming Twitter and Facebook notifications respectively (simulated view in Figure 5).
- **Open Notification** – To open an incoming notification, the person must use the finger rub pad (Figure 7) to match the direction of the butterfly's flight, which results in displaying the message or contents of the notification. If the butterfly is flying from left to right on the glasses' display, then the person must rub the finger pad with their thumb in that same direction to see the message. In the current implementation, up to two incoming notifications can be displayed and acted upon at a given time (i.e., one flying from left to right and the other one in the opposite direction). In the future, we plan to match the speed of flight to the input that the person provides on the finger rub pad, thus allowing people to handle a few more simultaneous incoming notifications.
- **Read Message** – Once the person has opened the notification (simulated view in Figure 6), they must hold the message (or butterfly) in their hand by holding their finger down on the rub pad.
- **Close message** – To close a message, the person lets the butterfly go by removing their finger from the finger rub pad. The butterfly will gracefully fly away and continue along its previous flight path. This gives a chance for the user to reopen the message if needed.

Implementation

The Epson Moverio we used is an Android device that communicates with the outside world via Wi-Fi. With application portability in mind, the code for the visualization and animation of the notifications running on the Moverio was implemented as a web application (HTML+JavaScript). The custom capacitive finger rubpad was mounted on a cylinder made of a low melting temperature plastic, and connected to a PC via an Arduino. The touch and slide events, as well as social network updates to the Moverio, were communicated through a server using HTTP requests.

Initial Observations

During a short internal evaluation of the prototype, we found that people were able to deal with incoming notifications while keeping an eye on their surroundings. People also reported that the (edges of the) display disappeared as they were walking and the digital butterflies nicely coexisted with the real world.

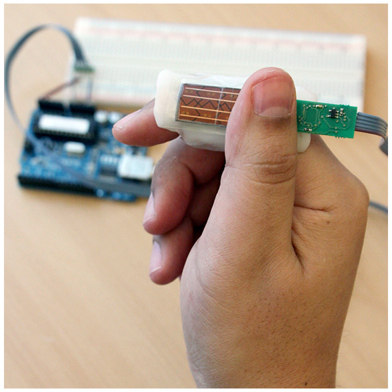

Figure 7. A capacitive finger rub pad placed on the person's index finger.

Conclusions and Future Work

In this paper we have described the interaction design space for interactive glasses. Based on a rich work history looking at optics, form factor, and social acceptance issues with HMDs, we have designed and implemented the *NotifEye*, which allows a person to receive and take action on incoming notifications from social networks while walking e.g. in a busy street.

Our initial observations from this work-in-progress are encouraging. In the future, we plan to evaluate hedonic and pragmatic aspects of the interaction with *NotifEye* in context. Participants will be asked to deal with incoming notifications from their social networks (e.g., Twitter and Facebook) while walking in a busy street. Among other things, such a context will allow us to study how a person's movement and the background information influence the task. We also plan to study other situations where people would benefit from using interactive glasses compared to other existing technologies. More generally, we want to explore both the design space and the broader questions related to the wearable computing experience. *NotifEye* touches on some of the basic issues associated with wearable computing interactions; however, there are still many fundamental questions to be addressed.

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