Loupe: A Handheld Near-Eye Display

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ABSTRACT
Loupe is a novel interactive device with a near-eye virtual display similar to head-up display glasses that retains a handheld form factor. We present our hardware implementation and discuss our user interface that leverages Loupe's unique combination of properties. In particular, we present our input capabilities, spatial metaphor, opportunities for using the round aspect of Loupe, and our use of focal depth. We demonstrate how those capabilities come together in an example application designed to allow quick access to information feeds.

Author Keywords
virtual displays; near-eye display; handheld

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

INTRODUCTION
Near-eye displays use small high resolution micro-displays placed in close proximity to the eye. Given the closeness to the eye and small size of the pixels, the user can not focus directly on the display. Instead, optics are used to create a virtual image at a distance that the user can see. These displays are used in the electronic view finders of digital cameras to show the picture and emulate an optical view finder. Near-eye displays are also used in devices such as Google Glass and the Epson Moverio where the display and optics are incorporated into a device worn somewhat like glasses. While head-up displays offer their users some unique capabilities such as providing a virtual display, they also suffer from some limitations. For example, creating compact high quality optics is technically challenging leading to larger form-factors [7]. These devices are worn on the user's face and can have negative social implications which are critical to consider [9].

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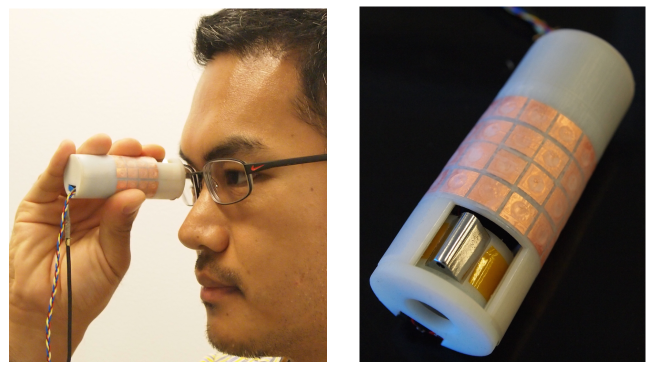

(a) (b)

Figure 1: a) The user looks into the end of Loupe to see a virtual image. b) Our prototype showing touch electrodes and focus mechanism.

We conducted this work seeking to gain some of the unique advantages associated with head-mounted displays, but not their associated drawbacks. In particular, Loupe is a handheld near-eye display (Figure 1). The user brings the device in front of the eye and looks into it much like a jeweler's loupe, spyglass, or medical scope to see a virtual image. The handheld form enables the user to manipulate the device in numerous ways. When not in use, Loupe can be worn like a pendant or placed in a shirt pocket for easy access. In this paper, we situate Loupe in the context of other mobile devices and discuss its unique combination of features as a novel platform. Next, we present our use of sensing and the interaction opportunities afforded by this device. Finally, we present an example application demonstrating the capabilities of Loupe.

RELATED WORK
While there has not been much research into handheld near-eye displays, it is not completely without precedent. A decade ago, Nokia released the short lived Kaleidoscope pocket image viewer[1]. It had a 266x225 pixel display and the user looked into the end of the device to view an image. This device offered very minimal interaction allowing a user to

[1] **http://nds1.nokia.com/phones/files/guides/Nokia_Kaleidoscope_I_UG_en.pdf**

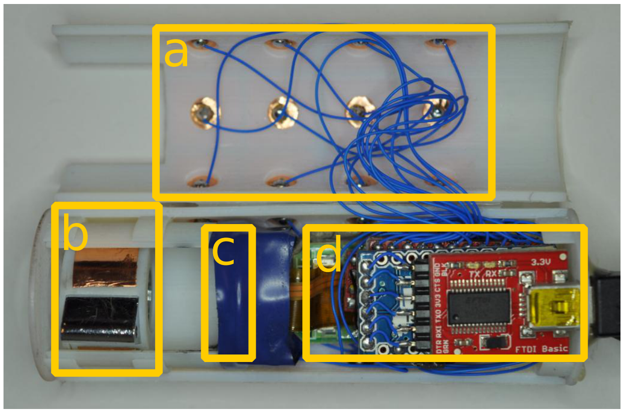

Figure 2: Inside Loupe: a) inside of capacitive pads. b) optics from jeweler's loupe, c) Epson micro-display (under tape), and d) circuit broads for sensing, Arduino & display driver. The optic's microswitch & IR sensor are not visible.

press buttons to switch between pictures. In the intervening decade, we have seen tremendous advancements in technology. Micro-displays have much higher resolutions and we see fully integrated solutions with display, on-board computation and sensing in compact forms. Given these advancements, we are revisiting a handheld form factor and explore how it might be used in an interactive device.

More broadly, it is useful to situate Loupe as a platform relative to other mobile devices. Head-mounted displays have a lot of technical similarity using micro-displays and optics to create a virtual image at a distance from a user [7]. The ability to create such an image means these devices are unaffected by presbyopia (becoming farsighted with age), a common source of frustration with smartphones [6]. Another advantage is that one can engineer the perceived field of view and create a compact device with a display that appears large. In contrast, if one wants a larger field of view with a phone or a watch, the display must be made physically larger or the user needs to bring it closer to their eyes. Near-eye displays are also very personal and private because the optics make it so the virtual image is only viewable when the device is in exactly the right relationship to the eye [7]. Finally, there is a social signaling component of using wearable displays [9]. Determining if a user is looking at or looking through a head-up display can be more nuanced than understanding use of a phone or watch. While Loupe has a virtual display, the handheld nature provides the benefit of a strong indication of use to onlookers.

Input is an important consideration for near-eye displays. There is no way to directly manipulate the visual content like on a phone or smartwatch since there is no physical display to touch. Devices like Google Glass, for example, offer a relatively small surface for touch input. The handheld cylindrical nature of Loupe provides a convenient location for touch sensing similar to [11] and other work using touch off the device's display [4, 12]. We also incorporated a variety of sensors for user input [3, 5].

We also surveyed the form factor of existing (non-computing) ocular devices as we considered the shape of Loupe. There are many devices in this space including kaleidoscopes, handheld telescopes, binoculars, medical scopes, range finders, opera glasses, Stan Hope rings, and our namesake, jeweler's loupes. We decided to implement a long cylindrical shape with a monocular display. This form relates to many of the objects surveyed, provides an opportunity to explore a round design, and affords a surface for input. Finally, we designed Loupe to be worn and quickly moved into position for rapid access and to enable micro-interactions [1, 2].

DEVICE IMPLEMENTATION

Our Loupe prototype is composed of several components and Figure 2 shows the device opened into two halves. At the heart of Loupe is the micro-display obtained from an Epson Moverio BT-100 binocular head-up display. We disassembled the Epson glasses, discarded the glasses' optics and housing, and extracted one of the LCDs and associated LED backlight. The LCD is a 0.52 inch color display with a resolution of 960x540. We also retained the electronics so the display is still driven by the Epson Android computer.

In front of the display, we use simple magnifying optics. Here, we use a jeweler's loupe to provide the needed magnification. This loupe has a diameter of 13mm and a nominal magnification of 20x[2]. These are not ideal optics as they create visible aberrations in the displayed image; however, for our prototype, the image quality was sufficient and allowed us to explore different magnifications and physical forms.

We provide a mechanism allowing the optics to move and change the perceived distance to the virtual display. This movement changes the focal depth from approximately one meter to tens of meters. The focal depth determines where in space the user must focus to see the virtual content. When the focus is set to the close state, the user must refocus their eyes and look near. Likewise, when it is set to far, the user must look far away. Focal depth is a property of most near-eye displays, however many choose a single focal depth (typically far). We added a microswitch inside Loupe so it is depressed when set to the far focal depth. In this work, we leverage the ability to sense the focal depth state (near or far) as part of the user interface. In a different prototype, we explored setting focal depth programmatically by displacing the LCD with a shape memory alloy wire. This approach showed promise but we did not use it in Loupe to reduce mechanical complexity.

Loupe has numerous sensors for input. We use an Arduino Pro Mini to collect and preprocess sensor data which is then forwarded to the Android control box of the Epson Moverio. We have 9 DOF motion sensing with a 3-axis accelerometer, magnetometer, and gyroscope (Sparkfun SEN-10724). Using a sensor fusion algorithm, this data provides the orientation of the device and we use relative changes for continuous input. An infrared proximity sensor (Vishay VCNL4000) is placed on the end next to the optics to determine when the device is placed in front of the user's eye.

[2] `http://www.amazon.com/gp/product/B001C9LG60`

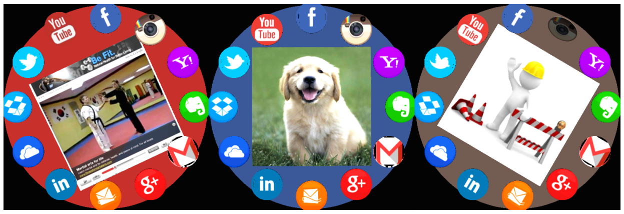

Figure 3: As the user rotates the device, both icons and central content reorient to counteract the user's movement. The background color changes to match the selected icon.

Figure 4: Pivoting down transitions from a 2D rendering of a single piece of content, to a 3D array of multiple elements.

Loupe has four Freescale MPR121 capacitive touch sensor controllers to sense an array of 48 touch points. We use pieces of copper foil as electrodes in a circular array around the circumference of Loupe. Each electrode has an area of 7.9x7.9 mm and has an adhesive back we used to attach them to the outer shell of Loupe. The shell has small holes where we solder on leads to the electrodes and connected them to the touch controller (Figure 2). We configured the touch controllers to report binary touch points. We also perform simple gesture detection to determine when the user swipes their thumb or a finger against the device in one of four cardinal directions. Loupe has provisions for bimanual use. The user can apply their second hand to twist on the surface of the device similar to using the focus ring on an SLR camera. After detecting a region being held, we look for two new touch points which we assume to be a pinch by the second hand. We then track movement around the circumference and emit clockwise or counterclockwise movement events as appropriate. Finally, we track the touch points and determine when the user is rolling the Loupe in their hand.

All of these electronics are assembled into a custom 3D printed shell to house the optics and electronics. We built multiple generations of Loupe each time shrinking the device and adding more capabilities. Our final version is 3 cm in diameter and 8 cm long, and a set of cables exits the rear of device tethering it to the Epson computer and Arduino.

LOUPE INTERACTIONS AND APPLICATION

Based on the form factor and input capabilities, we created a set of interactions for Loupe and an example application to demonstrate how all of these concepts come together as part of an overall platform. Our prototype was built using Unity3D and runs on the original Epson Android device.

The general model of this application is to allow quick access to notifications and numerous feeds of information the user might be interested in throughout the day. This could be updates from various social media sites, news, or updates from friends and family. The user interface provides a central detailed area surrounded by icons representing different applications with different feeds (Figure 3). To indicate the active application, its icon spins in place. The three-dimensional motion helps the user distinguish it from the central content and reinforces our use of depth throughout the user interface.

We assume one would wear Loupe around the neck or store it in a shirt pocket. In this storage position, the display is within view if the user looks down but it is not legible because of the nature of the optics. When a new piece of content comes into Loupe while not in use, the display starts blinking as a notification. This is implemented by rendering two contrasting solid colors (e.g., red and cyan) alternatively on the entire micro-display. The user can notice this visual indication by glancing through the optical opening. If desired, they pick up the device which is sensed by the IMU and IR proximity sensor and in turn launches the related application feed. Additionally, the eye proximity sensor allows us to detect more subtle changes in pose. If the user rapidly moves the device away and returns it, we can use that as a signal to advance in the application. In contrast, if the device is in the non-use state for awhile, we reset to the home screen.

We accentuate the roundness of Loupe with the physical form and user interface. To overcome the lack of a natural upright orientation, we use the inertial sensors to determine the gravity vector and rotate the user interface so it appears upright to the user. We also use this rotation for explicit user input. As the user rotates the device around its main axis, Loupe switches between applications and the background color gradually changes to match the color of the next application thus notifying the user of the new selection. Figure 3 shows images from the computer's perspective as the user physically rotates the display.

We also take advantage of the inertial sensors to enable two-dimensional panning. The small size, the way the device is held, and its proximity to the eye, all combine to allow the user to make movements to pan through a two-dimensional environment by pivoting the device in front of the eye. In each application, a number of pieces of content are laid out in a one-dimensional array away from the user toward the screen depth. The user can see additional content by gradually making a downward panning motion (Figure 4) and then swiping on the touch area moves through the content array.

Finally, our device has the ability to change the focal depth of the virtual image. We leverage this ability to incorporate additional depth cues in the user interface. As discussed above, we are using two states: near and far. The user has to focus their eyes at the appropriate focal depth to see the image, otherwise it is out of focus and blurry. We use the two focal depths in the user interface to render two different but related views of content. The near focal distance is used as a metaphor for personalized content, whereas generic content is displayed at the far focal depth. For example, when viewing Twitter posts in the default far mode, the system

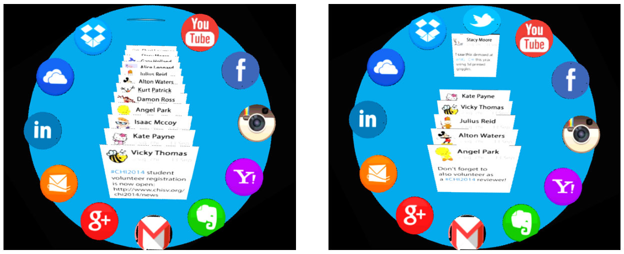

Figure 5: We use the shift in focal depth as a metaphor. The left is far focus showing all Twitter feeds and the right is the near focal depth showing close friends' feeds.

shows feeds from all users (Figure 5, left). When the focus is switched to the close mode, the user needs to look nearby and the interface only shows feeds from the user's close friends (Figure 5, right). Thus, as part of our interaction design, we change depths both physically with focal length and semantically with different information.

DISCUSSION AND FUTURE WORK

A novel aspect of Loupe is the ability to detect the focal depth state and to incorporate this information in the user interface. In this work, we tied together the focal depth to the semantics of content. Exploring other design options for focal depth is a clear area for future work. Also, we explicitly picked only two different focal depths as re-accommodating to the virtual image can be a challenge for novice users. Selecting which and how many focal depths the device could support should be informed by additional near-eye display research.

We believe the interaction elements we proposed are well supported by Loupe and its form, but other design choices can be made. For instance, we embraced roundness in Loupe using it in the form, touch array, and user interface. Alternatively, it would be straightforward to design a rectangular device to match the display aspect ratio. For a different prototype, we used a half-silvered mirror to create an optical see through device that could be used for an augmented reality interface. It had a vertical orientation and more closely resembles a medical scope. We also briefly explored much flatter, and wider shapes using optics similar to the waveguide in the Epson Moverio glasses, Saarikko's exit-pupil expander [10], or Light Field Displays [8]. This shape would enable forms similar to a pocket watch or magnifying lens. Loupe's current form was chosen for its relative simplicity as a starting point for exploring this design space. However, all of these forms show promise and could offer different affodances.

Our demonstration application enables quick access to notifications and information feeds similar to some applications on Google Glass or smartwatches. Loupe's resolution (even with a 540 pixel diameter) compares favorably relative to these devices. And while this type of use is plausible, there needs to be research to uncover possible applications similar to other explorations being conducted on smartwatches and glasses.

Many current near-eye displays are always worn and can confuse onlookers as to if one is looking at the virtual content or the physical world. We believe this is an artifact of the form factor and not of near-eye display technology. Loupe provides an alternative in a handheld form. It would be interesting to explore the social implications of near-eye displays and Loupe might serve as a foil to glasses-based approaches.

CONCLUSION

We presented Loupe, a novel near-eye display in a handheld form factor. It offers a wearable form that can be quickly moved into position like a smartwatch and uses a virtual image presented at a distance like a head-up display. Using these capabilities, we presented our Loupe application showing how to use this device to gain access to information feeds. We also discuss how our set of sensing capabilities, virtual image, and two focal depths combine to form an interesting and novel mobile computer.

REFERENCES

1. Ashbrook, D. *Supporting Mobile Microinteractions*. PhD thesis, Georgia Institute of Technology, 2010.
2. Ashbrook, D. L., Clawson, J. R., Lyons, K., Starner, T. E., and Patel, N. Quickdraw: the impact of mobility and on-body placement on device access time. In *Proceedings of CHI* (2008), 219–222.
3. Bartlett, J. F. Rock'n'scroll is here to stay. *Computer Graphics and Applications, IEEE 20*, 3 (2000), 40–45.
4. Baudisch, P., and Chu, G. Back-of-device interaction allows creating very small touch devices. In *Proceedings of CHI* (2009), 1923–1932.
5. Harrison, B. L., Fishkin, K. P., Gujar, A., Mochon, C., and Want, R. Squeeze me, hold me, tilt me! an exploration of manipulative user interfaces. In *Proceedings of CHI* (1998), 17–24.
6. Hasegawa, S., Fujikake, K., Omori, M., and Miyao, M. Readability of characters on mobile phone liquid crystal displays. *International Journal of Occupational Safety and Ergonomics (JOSE) 14*, 3 (2008), 293–304.
7. Kress, B., and Starner, T. A review of head-mounted displays (hmd) technologies and applications for consumer electronics. In *SPIE Defense, Security, and Sensing*, International Society for Optics and Photonics (2013), 87200A–87200A.
8. Lanman, D., and Luebke, D. Near-eye light field displays. *ACM Trans. Graph. 32*, 6 (Nov. 2013), 220:1–220:10.
9. McAtamney, G., and Parker, C. An examination of the effects of a wearable display on informal face-to-face communication. In *Proceedings of CHI* (2006), 45–54.
10. Saarikko, P. Diffractive exit-pupil expander with a large field of view. In *Proceedings of SPIE*, vol. 7001 (2008).
11. Song, H., Benko, H., Guimbretiere, F., Izadi, S., Cao, X., and Hinckley, K. Grips and gestures on a multi-touch pen. In *Proceedings of CHI '11* (2011), 1323–1332.
12. Sugimoto, M., and Hiroki, K. Hybridtouch: an intuitive manipulation technique for pdas using their front and rear surfaces. In *Proc. of Mobile HCI* (2006), 137–140.