Augmented Reality Magnification for Low Vision Users with the Microsoft Hololens and a Finger-Worn Camera

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ABSTRACT
Recent technical advances have enabled new wearable augmented reality (AR) solutions that can aid people with visual impairments (VI) in their everyday lives. Here, we investigate an AR-based magnification solution that combines a small finger-worn camera with a transparent augmented reality display (the Microsoft Hololens). The image from the camera is processed and projected on the Hololens to magnify visible content below the user's finger such as text and images. Our approach offers: (i) a close-up camera view (similar to a CCTV system) with the portability and processing power of a smartphone magnifier app, (ii) access to content through direct touch, and (iii) flexible placement of the magnified image within the wearer's field of view. We present three proof-of-concept interfaces and plans for a user evaluation.

CCS Concepts
• Human-centered computing → Accessibility technologies • Computing methodologies → Mixed / augmented reality

Keywords
Visually impaired; wearable computing; assistive technology; augmented reality; reading printed text; magnification

1. INTRODUCTION
Augmented reality (AR) has the potential to enhance the accessibility of the physical world for people with visual impairments (VI). One important emerging application area is the magnification and enhancement of visual information. Traditional methods such as closed-circuit television (CCTV) systems and other desktop video magnifiers [2] allow users with some residual vision to magnify and display content on a large screen. Many users also rely on magnifying glasses or smartphone-based magnifiers [1], which are more portable but offer a limited visual area and require the user to hold a device while reading. In contrast, a wearable AR system is portable and always available, provides a perceptually large display, and can allow for magnified output that is visually co-located with or even overlaid on top of the original content within the wearer's field of view.

In this poster paper, we introduce a novel AR magnification approach that combines a finger-worn camera to capture visual content with a transparent head-worn display for displaying a magnified and/or adjusted view of that content—in our case, using a *Microsoft Hololens* device [5]. Two previous approaches to magnifying information on a head-worn display have used video see-through displays where a video feed from a head-worn camera is displayed on screens in front of the user's eyes along with computer-generated content [3, 8]. In contrast, our approach does not restrict the user's field of view to only the camera view, allows for small finger movements to select the content to magnify (as opposed to head movements), and allows for 3D virtual content to be overlaid within the physical world. This lattermost characteristic is enabled by the Hololens API, which provides robust 3D mapping and motion tracking to make AR content appear as if it is fixed in place in the physical world.

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Figure 1. Prototype Hololens and finger-camera system: (a) reading a magazine article; (b) close-up view of the camera.

To date, we have implemented a proof-of-concept system with three interface variants for sensing, processing, and displaying magnified and/or adjusted images (*e.g.*, pictures, text). We describe these interfaces and associated design considerations, discuss plans for future user evaluations, and enumerate open questions for assistive AR applications. Our contributions include: (i) a preliminary investigation of a finger-mounted camera with an AR display for viewing printed or other non-tactile information and (ii) a proof-of-concept AR system with three distinct interface options for displaying magnified visual content.

2. PROTOTYPE HARDWARE
Our prototype system (Figure 1) includes a head-worn Microsoft Hololens unit and an Awaiba NanEye Idule camera worn on the index finger via a custom ring. Similar cameras have been applied for automated reading of printed text [6, 7] but here we use it solely as a digital magnifier. Currently, the camera connects to a laptop, which processes the video feed and communicates with the Hololens over Wi-Fi. While the Hololens is bulky and relatively heavy, its advanced capabilities and high-resolution display allowed us to quickly prototype and explore novel AR interfaces. In the future, we envision a fully wearable, lightweight system.

3. INTERFACE DESIGNS
To explore the magnification design space afforded by the combination of a head-worn display and finger-worn camera, we designed three interface options that vary in how the magnified AR view is displayed (Figure 2). Similar to *ForeSee* [8], we also implemented and explored real-time image processing techniques

(a) Fixed position on 2D AR display (*i.e.*, fixed within the wearer's field of view). **(b) Fixed position on 3D surface or midair, in this case rendered flat on the magazine page.** **(c) Dynamic finger tracking, where magnified view follows and hovers above the finger.**

Figure 2. The three viewport positions in our prototype system, which vary in how they present the magnified view to the user.

such as color and contrast changes to enhance legibility for low-vision users.

Design 1: Fixed Position on 2D AR Display. Our first design places the AR content at a fixed position within the user's field of vision, no matter how they move their head. We envision this design working similarly to other wearable heads-up displays such as Google Glass [4] but allowing for greater customization of the size and position of the magnified information. These parameters can be adjusted to account for user preference or vision level (*e.g.*, at the periphery for users with macular degeneration). This design is simple to implement and easy to understand but also partially obstructs a portion of the user's vision at all times.

Design 2: Fixed Position on 3D Surface. A second design places the display at a fixed position in 3D space, creating a virtual screen (the magnified image) on any surface the user chooses (*e.g.*, on a table or wall or on the document that the user is reading) or floating in midair. This design has the advantage of not occupying a part of the user's vision, instead staying at a fixed location in the world no matter how the user moves. This type of display may also more seamlessly integrate the virtual and physical worlds with content overlaid alongside or even in place of the original text in the physical world. However, this design requires more complex processing and user interactions, and since the virtual display is partially transparent, it may not work well for all locations.

Design 3: Dynamic Finger Tracking. In our third design, the display is positioned floating above the finger as it glides along the page. This design helps prevent disorientation by keeping the display as close as possible to the touched location so that the user can more easily view both. The interaction is similar to holding a physical magnifying glass or smartphone magnifier except that the user can do so at a greater distance and does not need to hold a physical device in hand, leaving the fingers free to touch the page. This design is the most complex, requiring reliable finger tracking and continual updating as the user moves, and it is possible that the motion of the display may distract from the content.

4. DISCUSSION AND OPEN QUESTIONS

Below we discuss open questions related to our system's design, plans for user evaluations, and our long-term vision for AR-based assistance for low-vision users.

The Hololens allowed us to easily prototype and experiment with novel AR designs; however, it has limitations that should be addressed for future versions of the system—specifically its size and relatively narrow display area centered in the user's field of view. Similarly, our finger-worn camera hardware is somewhat large fore regular use, and more importantly is not fully wearable—it currently relies on a separate computer for power and streaming images to the display.

While we have focused primarily on how and where to display the magnified content, designing appropriate user interactions is also important. For each of our interface designs, the user should be able to customize the magnification level, position, text processing, and other settings. Interacting with the system could be done via hand gestures or speech recognition (both are common with the Hololens). Future usability testing here is necessary to determine an appropriate interaction model.

To assess our three AR designs, we plan to conduct an evaluation with low-vision participants comparing the designs in terms of usability and comprehension. We will also compare finger-worn and head-worn cameras to explore the tradeoffs of each and compare our AR-based magnification approach against the current status quo—a handheld smartphone magnifier.

We also envision a future AR system that goes beyond simple magnification. For example, if combined with optical character recognition, the system could change fonts (*e.g.*, [8]) or read the text aloud as needed using text-to-speech. Content could be dynamically enhanced and placed over the original, although for legibility, the AR overlays would need to be opaque rather than the semi-transparent holograms that are currently possible with the Hololens. Future systems could also include touchscreen text and image manipulation features such as highlighting or copy and paste, potentially broadening the appeal to users with any level of vision.

5. ACKNOWLEDGMENTS

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