

# Testbed for Intuitive Magnification in Augmented Reality

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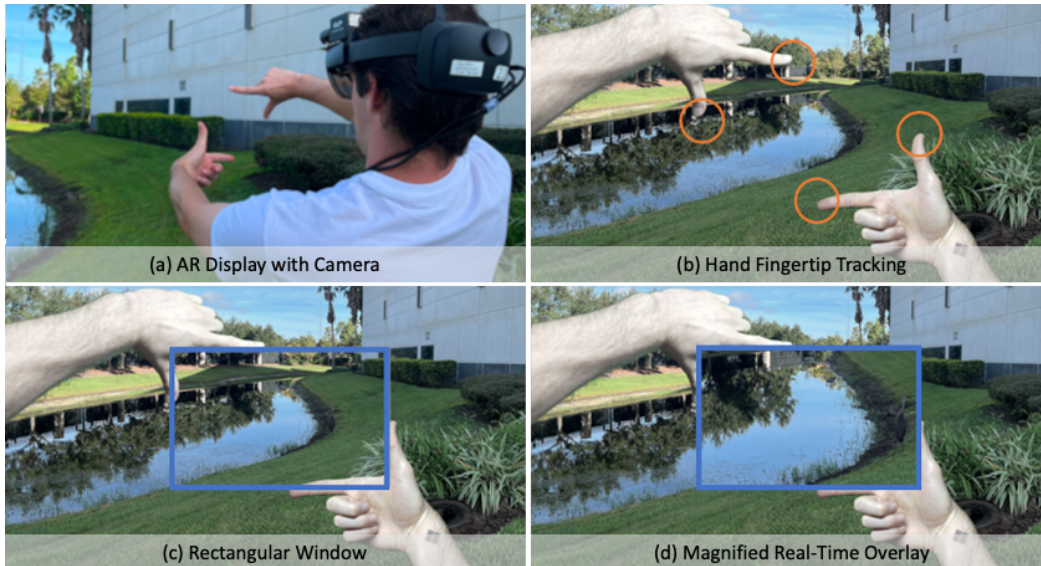


Figure 1: Illustration of augmented reality (AR) magnification with hand gestures: (a) setup with a user wearing an AR head-mounted display (HMD) and an attached high-resolution camera, (b) using the HoloLens' hand tracking to determine two fingertips (index finger and thumb) of the right and/or left hand, (c) forming a rectangular window from the bounds of the tracked fingers, and (d) rendering an AR overlay in the window with the registered portion of the camera mounted on the HMD at a variable scale factor.

## ABSTRACT

Humans strive to magnify portions of our visually perceived surroundings for various reasons, e.g., because they are too far away or too small to see. Different technologies have been introduced for magnification, from monoculars to binoculars, and telescopes to microscopes. A promising technology are modern high-resolution digital cameras, which are capable of optical or digital zoom and very flexible as their imagery can be presented to users in real-time with mobile or head-mounted displays and intuitive 3D user interfaces allowing control over the magnification. In this demo, we present a novel design space and testbed for intuitive augmented reality (AR) magnifications, where an AR optical see-through head-mounted display is used for the presentation of real-time magnified camera imagery. The testbed includes different unimanual and bimanual AR interaction techniques for defining the scale factor and portion of the user's visual field that should be magnified.

**Index Terms:** Human-centered computing—Mixed / augmented reality; Computing methodologies—Computer graphics

## 1 INTRODUCTION

Our vision allows us to see the world around us by detecting light in the visible spectrum. However, the human visual acuity is limited by the density of rods and cones on the retina. These cells convert light into electrical signals that are sent to the brain. If the size of an

object's projection on the retina is too small, we cannot see it or its details. For example, as a car drives away from us, its retinal size decreases. This means that we see fewer and fewer details of the car until it becomes indistinguishable from the background. Magnification is the process of making an object appear larger by increasing the angle it subtends at the eye. Analog binoculars and monocular telescopes have been used for magnification for a long time, but two digital technologies offer new possibilities for human-computer interaction. First, digital cameras now can reach a higher resolution than the human eye. This means that they can capture more details, which can be used to magnify images. Second, augmented reality (AR) head-mounted displays (HMDs) allow us to see digital images overlaid on the real world. This means that we can magnify real-world objects by overlaying a magnified digital image of the object on our view of the world. By integrating a camera and an AR HMD, we can register a captured image in real time and overlay it on the same portion of a user's visual field. This allows us to magnify objects in the real world in real time. In this demo, we present a functional prototype which allows users to explore the design space of real-time AR based magnification (see Figure 1). Our prototype enables several user interface approaches, using a high-resolution digital camera to capture live visuals and an AR HMD to selectively magnify the imagery within the bounds of the user's left and/or right hand or a situated window, while maintaining a natural (unmodified) view in the remainder of the user's visual field.

## 2 RELATED WORK

Devices that can magnify one's view of the real world have been used for a long time to improve visual acuity across a wide range of application fields. These devices include microscopes, magnifying glasses, monoculars, binoculars, and telescopes. For instance, fixed optical zoom lenses have been integrated into or attached to

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AR displays to optically magnify the view of the real world users are seeing. A prime example are “AR loupes” for use in microsurgical procedures, including neurosurgery and dentistry, and other medical applications [5]. Oskiper et al. [4] developed “augmented reality binoculars” that integrate a wide-angle and narrow-angle camera to provide either an unmagnified or zoomed-in view of a real scene. Further, Orlosky et al. [3] attached telescopic lenses to a head-mounted camera pair to enable see-through magnification, and explored different interface mechanisms for controlling the magnification state. Other researchers investigated interfaces that magnified specific objects within the user’s visual field, while leaving the rest of the field unchanged. For example, Narumi et al. [2] developed a system that detected and scaled up food in a video see-through AR HMD’s camera feed, giving the illusion of eating more food than one really consumes. Choudhary et al. [1] used a head-mounted camera and machine learning to detect and magnify people’s heads in a user’s visual field, allowing the user to identify people who are far away. Ueda et al. [6] proposed “IlluminatedZoom,” a system that uses periodically zooming eyeglasses and a high-speed projector to provide dynamic, synchronized lighting that accentuates and enhances a particular region or object at a given magnification.

However, we are not aware of previous work looking at 3D user interfaces (3D UIs) to intuitively control magnified imagery that is overlaid over one’s visual field.

### 3 DESIGN SPACE AND HARDWARE PROTOTYPE

In this section we describe our research demonstration and design space for intuitive real-time AR magnification.

#### 3.1 Design Space

We identified three UI aspects (*window*, *scale*, and *focus*), which together enable a core range of functionality for applications in this domain, with our primary focus being interfaces to control the magnification in real time. In exploring the design space, we assumed a hardware configuration consisting of a high-resolution imaging sensor (integrated into an AR HMD or mounted separately on the user’s head) for capturing real-time imagery of the real world which is then processed and presented to the user via an AR HMD. The processing and rendering of the camera imagery is based on the three UI aspects:

1. A *window* in the user’s visual field is determined, in which the magnified AR imagery from the camera should appear. The image region corresponding to that window is segmented from the full camera stream image.
2. The rendering engine then creates a *scale* transformation that describes the factor by which the augmented imagery should be up-scaled compared to a one-to-one view of the imagery.
3. Lastly, the registered, segmented, and scaled imagery is then used to generate the output for the AR see-through display. The imagery is presented in three-dimensional visual space at a *focus* distance from the user’s eyes.

#### 3.2 Prototype

In developing a prototype for the above design space, we identified and implemented different alternatives for manipulating or presenting the magnified AR imagery for each of the three UI aspects:

1. The *window* size and location can be defined by the index finger and thumb of either one or both of the user’s hands (only visible when the user’s hand or hands are held up; see Figure 1), or can be persistent (always visible, with UI widgets at the corners for changing the size and location).
2. The *scale* factor can be defined by: the distance of the user’s hand(s) from their face (magnifying the imagery by bringing it closer to them); the size of the window (magnifying the imagery by making the window larger); voice commands (e.g.,

“mag five” for 5x magnification); a virtual 3D slider presented in front of the user; or by turning a physical knob device.

3. For manipulating the *focus*, the AR window can be positioned either at a near distance (e.g., within arm’s reach, as if the user is holding a picture in their hands) or at a far distance (to match the physical distance of the objects being magnified)

Users of this testbed are able to explore, test, and compare each combination of the different techniques we realized to map out the design space for intuitive real-time AR magnification, including the three *window* size UIs, the five *scale* factor UIs, and two *focus* UIs.

Our demonstration prototype uses a Microsoft HoloLens 2 optical see-through AR HMD with a  $1,440 \times 936$  resolution per eye, 52 degrees diagonal with 43 degrees vertical and 29 degrees horizontal field of view<sup>1</sup>, about 20 pixels per degree of resolution, and 60 Hz update rate for presenting the AR magnification overlay. On top of the HMD, collimated at a vertical offset of 9 cm, an SVPRO ELP 4K digital camera is mounted, with a Sony IMX317 sensor for low-light environments,  $3,840 \times 2,160$  camera resolution, 2.8–12 mm varifocal lens providing a variable field of view between 50 degrees and 125 degrees (calibrated to 70 degrees for this demonstration, to provide full overlap with the HoloLens’ display field of view), and a 30 Hz frame rate. For rendering and system control we use a Gigabyte Aero 15x v8-BK4 laptop with an Intel Core i7-8750H CPU at 2.2–4.1 GHz, 32 GB of RAM, Nvidia GeForce GTX 1070 graphics card, which runs Windows 10 Pro. The AR imagery is generated by a custom application created in the Unity engine (version 2020.3.13f1) using Microsoft’s Mixed Reality Toolkit<sup>2</sup>. For the magnification control mode using a physical input device (knob), we use a Griffin PowerMate rotating multimedia controller.

### 4 CONCLUSION

In this work, we presented a design space for intuitive real-time AR magnifications along with a demonstration prototype incorporating an AR HMD, a high-resolution camera, and different 3D user interfaces. Future work may focus on addressing limitations of current display and sensor hardware that could lead to a wider adoption of AR magnification in different application fields.

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<sup>1</sup><https://uploadvr.com/hololens-2-field-of-view/>

<sup>2</sup><https://github.com/microsoft/MixedRealityToolkit>