Matching Prescription & Visual Acuity: Towards AR for Humans



Figure 1: (top) Display results from our Prescription AR prototype. Without Prescription AR, the myopic viewer sees the nearby real strawberry in focus but the more distant plant and chart are blurry. With Prescription AR both the more distant real objects and the virtual logo are in focus. A freeform image combiner delivers an augmented images while the prescription lens corrects the vision. The image combiner is embedded inside the prescription lens for small form factor; the center thickness is only 5 mm. (bottom) Results from our Foveated AR wearable prototype. By tracking the gaze direction (red cross), the system dynamically provides high-resolution inset images to the foveal region and low-resolution large-FOV images to the periphery.

CCS CONCEPTS

• Human-centered computing \rightarrow Displays and imagers; • Hardware \rightarrow Emerging optical and photonic technologies.

KEYWORDS

Augmented Reality, Foveated Displays, See-through Displays

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INTRODUCTION

An increasingly important part of usuable near-eye displays to allow use by users who use vision correction such as that provided by glasses and contact lenses. Recent research indicates that over 20% of world population is myopic, and this percentage is increasing [Holden et al. 2016]. Commercial prototypes have offered an additional prescription lens pair or a glasses-compatible design, but both of these approaches increase the size and weight of the device. Ideally, a user's prescription should be considered from the optical design stage for the smallest form factor.

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For all viewers, a high-resolution, large field-of-view (FOV) neareye-display has been a goal of the field since Sutherland [1968] laid out his vision of an ultimate display which created artificial graphics in the real world. Although both research literature and commercial prototypes have shown great improvement in the subsequent half century, it is still a difficult challenge to simultaneously satisfy wide FOV, high resolution, variable focus, wide eye box, and small form factor. Furthermore, even if we had a ultimate display, it is still impractical to transmit video data with the today's display interface standards at the bandwidth required. One popular and promising idea that can both improve overall visual quality and reduce required bandwidth is to take advantage of the human foveal architecture where only a small portion of the visual field is seen in high resolution. This is referred to as a foveated display [Rolland et al. 1998] that has a low-resolution image for most of the visual field and a high resolution inset that moves with the gaze.

In this installation, we demonstrate two novel wearable augmented reality (AR) prototypes inspired by the understandings on human visual system: *Prescription AR* and *Foveated AR*. Prescription AR is a 5mm-thick prescription-embedded AR display based on a free-form image combiner. A prescription lens corrects viewer's vision while a half-mirror-coated free-form image combiner located delivers an augmented image located at the fixed focal depth (1 m).

Foveated AR is a near-eye AR display with resolution and focal depth dynamically driven by gaze tracking. The display combines a traveling microdisplay relayed off a concave half-mirror magnifier for the high-resolution foveal region, with a wide FOV peripheral display using a projector-based Maxwellian-view display whose nodal point is translated to follow the viewer's pupil during eye movements using a traveling holographic optical element (HOE). The same optics relay an image of the eye to an infrared camera used for gaze tracking, which in turn drives the foveal display location and peripheral nodal point. Our display supports accommodation cues by varying the focal depth of the microdisplay in the foveal region, and by rendering simulated defocus on the 'always in focus' scanning laser projector used for peripheral display.

Prescription AR is the first vision-correcting, passive, light-weight and customized wearable prototype according to the user's visual acuity. Attendees will simultaneously experience both corrective optics and augmented images. Foveated AR is the first demonstration of see-through AR that is both high-resolution and wide FOV.

THE DEMO

For Prescription AR, several image combiners with different prescriptions will available. We will display several explanatory videos to show our concepts to non-myopic attendees. Foveated AR will have the high-resolution insert in a particular position where the user can look at it as well as to the low-resolution surround. We will move the insert so that the flexibility is demonstrated. Because of our target of five minutes per viewer, we will not include eye tracking (requiring per viewer calibration), but we will have a video in the booth detailing the eye tracking.

THE PRESCRIPTION AR PROTOTYPE

Our prototype delivers an augmented image through a prescription lens. A beam shaping lens and an in-coupling prism is attached to the top surface of the prescription lens, so the light rays from a micro OLED (Sony, ECX339A) goes into the 5-mm thick prescription lens and propagates inside the lens. After two total internal reflections inside the lens, the light rays meet the half-mirror coated free-form surface and reflected to the eye. The free-form surface was calculated based on the 1D myopia human eye model [Atchison 2006], and this calculation can be applied to any prescriptions including any myopia, astigmatism, and hyperopia. All the optical components were manufactured by ILLUCO.

We will demonstrate both a static demo and a dynamic demo. The dynamic version will include the real-time generation of binocular images and the generated images will be transferred through a cable. The display and the driving board will be implemented inside the wearable prototype as shown in Fig. 1. The static prototype will be a non-tethered demo and show printed images on the light valve technology (LVT) films. The backlight module and the battery will be included in the wearable prototype. The angular resolution will be 23 cpd at the center and the horizontal FOV will be 40 degrees. The weight of dynamic and static prototypes will be 164g and 79g.

THE FOVEATED AR PROTOTYPE

Our prototype combines light from two elements: a high-resolution, small FOV *foveal display* and a large FOV, low-resolution *peripheral display*. We designed the foveal optical path with a planar image combiner and also embedded a reverse optical path for on-axis gaze tracking. In the periphery, an HOE refracts light rays from a laser projector to create a Maxwellian viewpoint. These two displays move as with the user's gaze. As a result, our wearable prototype can provide over 30 cycles per degree (cpd) at the fovea and 60 degrees horizontal FOV.

The wearable prototype consists of a modular, 3D printed frame that houses and aligns all of the optical/mechanical components including a compact laser projector (MEGA1, MEGA1-F1), a beam shaping lens (Edmund Optics, 84-281), a right angle prism (Thorlabs, PS908), a micro OLED (SONY, ECX335R), optical front-end from ILLUCO (combiners and half mirrors for the fovea and tracking optical path), and the motion stage used to translate the foveal and peripheral displays in relation to each other. Note that the driving modules of micro OLED and laser projector are embedded in the wearable prototype, and the images were transferred from the graphics card through two micro HDMI cables.

The wearable prototype uses a dual-threaded actuator to carefully control displacement of the foveal display's micro OLED relative to the peripheral display's HOE. This dual-threaded assembly can either be turned by hand or using an electromechanical source such as a DC or stepper motor. The weight of all components building the wearable prototype excluding attached cables is 316g.

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