# Membrane AR: Varifocal, Wide Field of View Augmented Reality Display from Deformable Membranes

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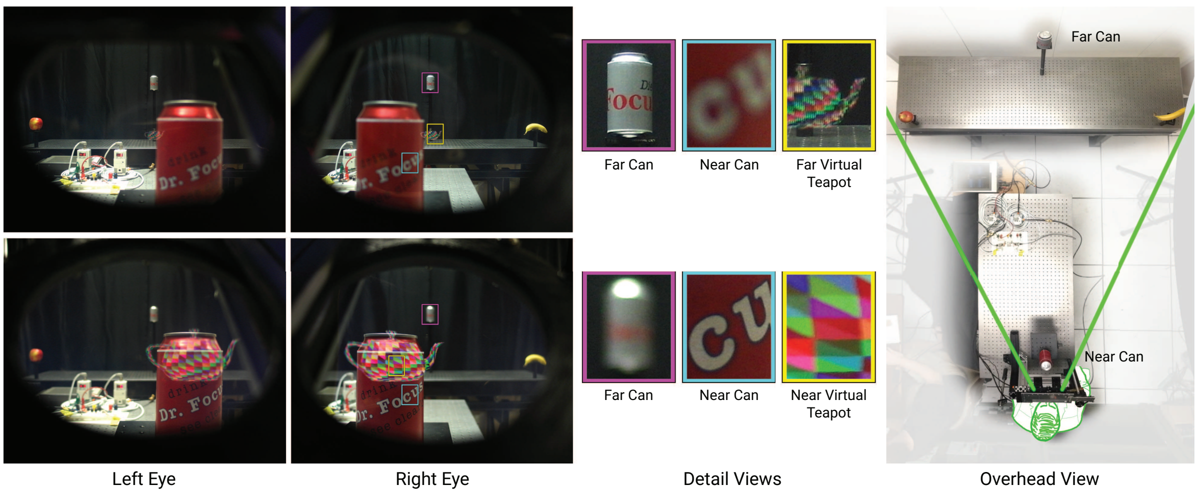


**Figure 1: Wide field of view augmented reality display showing virtual teapot at far and near distance together with real objects, soda cans, at near and far. Photos through display system left and right eyes with focus at far (top row), focus near (bottom row), and overhead view (right) of the system. Details from right eye views showing focus of near and far soda cans and virtual teapot (middle).**

## ABSTRACT

Accommodative depth cues, a wide field of view, and ever-higher resolutions present major design challenges for near-eye displays. Optimizing a design to overcome one of them typically leads to a trade-off in the others. We tackle this problem by introducing an all-in-one solution – a novel display for augmented reality. The key components of our solution are two see-through, varifocal deformable membrane mirrors reflecting a display. They are controlled by airtight cavities and change the effective focal power to present a virtual image at a target depth plane. The benefits of the membranes include a wide field of view and fast depth switching.

## CCS CONCEPTS

**•Hardware → Displays and imagers; •Computing methodologies → Mixed / augmented reality;**

## KEYWORDS

head-mounted displays, near-eye displays, see-through displays, varifocal displays, augmented reality

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## 1 INTRODUCTION

Augmented Reality (AR) [Carmigniani et al. 2011] overlays computer-generated visuals onto the real world in real time. Near-Eye Displays (NEDs) for AR applications have recently been proposed for widespread public use, such as Meta[1], and Microsoft Hololens[2]. Some of the fundamental limitations of existing NEDs for AR are limited field of view (FOV), low angular resolution, and fixed accommodative state. We tackle the problem of providing wide FOV


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[1]https://www.metavision.com/
[2]http://www.microsoft.com/microsoft-hololens/en-us

and accommodative cues together in the context of see-through and varifocal systems. By bringing the idea of hyperbolic half-silvered mirrors and deformable membrane mirrors together for NEDs in AR applications, we demonstrate a new hybrid hardware design for NEDs that uses see-through deformable membrane mirrors. These deformable beamsplitters are incorporated in a complete prototype [Dunn et al. 2017] that promises to address Vergence-Accommodation Conflict (VAC) [Hoffman et al. 2008] caused by lack of accommodative cues together with wide field of view capabilities.

## 2 RELATED WORK

Integral imaging deals with the reproduction of light fields which with enough angular resolution can provide correct accommodative cues. Recent computational methodologies [Huang et al. 2015] can additionally provide a wide FOV. However, light field displays are computationally intensive and limited in angular resolution. Always-in-focus methodologies [Akşit et al. 2015; Maimone et al. 2014] can imitate accommodative cues in computational means, while providing large FOV with a small form factor, but are limited in angular resolution. Varifocal techniques [Konrad et al. 2016] provide high angular resolution and accommodative cues, but none of these systems have achieved a wide FOV up until now. Recent studies show evidence that supporting accommodative cues through a varifocal mechanism improves visual comfort [Johnson et al. 2016] and user performance [Konrad et al. 2016]. Researchers have also proposed several designs [Benko et al. 2015; Sisodia et al. 2005] to address FOV issues without addressing accommodative cues. A more comprehensive review of similar work can be found in the work of Kramida and Varshney [Kramida 2016].

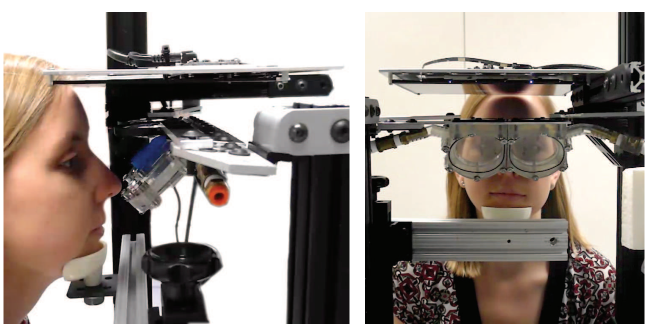


**Figure 2: Photographs showing side, and front views of our wide field of view varifocal near-eye display prototype for Augmented Reality applications.**

## 3 IMPLEMENTATION

We demonstrate an experimental see-through varifocal NED as shown in Figure 2. All the hardware components used in our final prototype are presented in a system overview diagram in Figure 3.

The core of our display and the only custom components are the deformable beamsplitters, which consist of a see-through, deformable membrane mirror and accompanying vacuum-tight, 3D-printed housing for each eye. The deformations of the membrane are controlled by modulating the pressure inside the airtight cavity

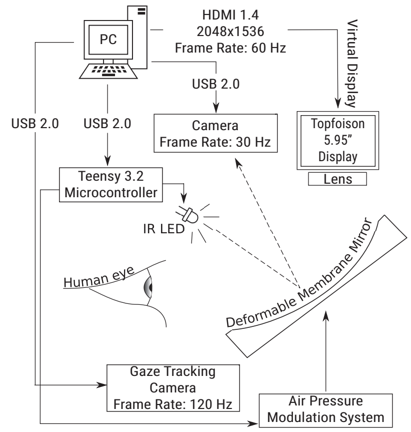


**Figure 3: A sketch showing the system overview and connections of the hardware in our prototype.**

which changes the effective focal power of the optical combiner. This allows our membrane to present a virtual image at any target depth plane within the range from 20 cm to infinity. The focal depth may be determined by using a gaze tracker integrated into the system to measure the vergence depth of the user. The benefits of using deformable beamsplitters include wide field of view (100 diagonal) and fast depth switching (20 ms near to far and 200 ms far to near).

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