Near-Eye Light Field Displays

Douglas Lanman David Luebke
NVIDIA

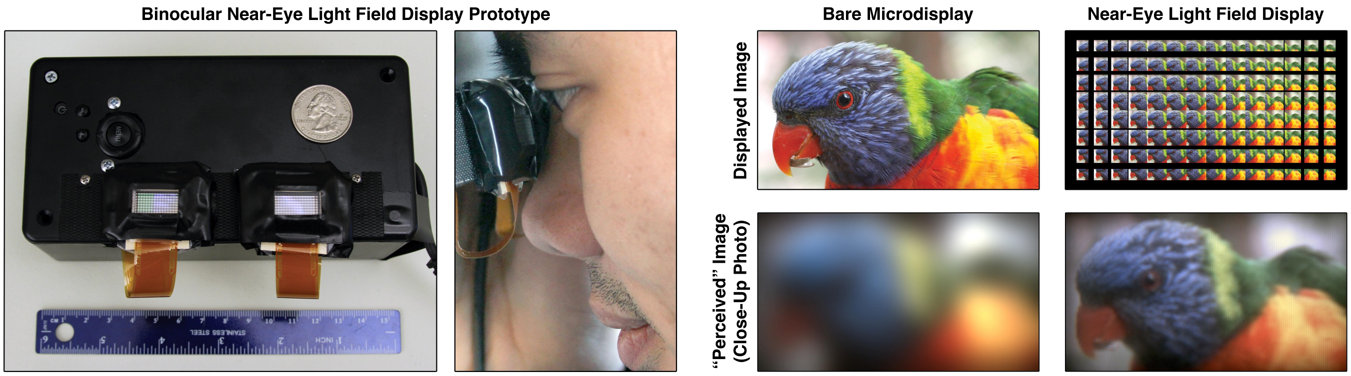

Figure 1: *Enabling thin, lightweight near-eye displays using light field displays. (Left) Our binocular near-eye display prototype is shown, comprising a pair of OLED panels covered with microlens arrays. This design enables a thin head-mounted display, since the black box containing driver electronics could be waist-mounted with longer ribbon cables. (Right) Due to the limited range of human accommodation, a severely defocused image is perceived when a bare microdisplay is held close to the eye (here simulated as a close-up photograph of an OLED). Conventional near-eye displays require bulky magnifying optics to facilitate accommodation. We propose near-eye light field displays as thin, lightweight alternatives, achieving comfortable viewing by synthesizing a light field corresponding to a virtual scene located within the accommodation range (here implemented by viewing a microdisplay, depicting interlaced perspectives, through a microlens array).*

Abstract

We propose a light-field-based approach to near-eye display that allows for thin, lightweight head-mounted displays capable of depicting accurate accommodation, convergence, and binocular disparity depth cues. Our near-eye light field displays depict sharp images from out-of-focus display elements by synthesizing light fields corresponding to virtual scenes located within the viewer's natural accommodation range. While sharing similarities with existing integral imaging displays and microlens-based light field cameras, we optimize performance in the context of near-eye viewing. Near-eye light field displays support continuous accommodation of the eye throughout a finite depth of field; as a result, binocular configurations provide a means to address the accommodation-convergence conflict occurring with existing stereoscopic displays. We construct a binocular prototype and a GPU-accelerated stereoscopic light field renderer.

Keywords: light field displays, head-mounted displays, microlens arrays, accommodation-convergence conflict, virtual reality

1 Overview

To be of practical utility, a near-eye display should provide high-resolution, wide-field-of-view imagery with compact, comfortable magnifying optics. However, current magnifier designs typically require multiple optical elements to minimize aberrations, leading to bulky eyewear with limited fields of view. We consider a simple alternative: placing a light field display directly in front of a user's eye (or a pair of such displays for binocular viewing). As shown in Figure 1, sharp imagery is depicted by synthesizing a light field for a virtual display (or a general 3D scene) within the viewer's unaided accommodation range. We demonstrate this design enables thin, lightweight head-mounted displays (HMDs) with wide fields of view and addresses accommodation-convergence conflict; however, these benefits come at a high cost: spatial resolution is reduced with microlens-based designs, although with commensurate gains in depth of field and in accurate rendering of retinal defocus. Through this work, we demonstrate how to mitigate resolution loss.

SIGGRAPH 2013, July 21 – 25, 2013, Anaheim, California.

ACM 978-1-4503-2261-4/13/07

2 Related Work

As characterized by Ng et al. [2005], light field cameras share many of the properties of our near-eye display: extending depth of field and field of view, at the cost of decreased spatial resolution. Several recent works have proposed placing integral imaging displays close to the eye (described in detail in the supplementary supporting document). Pamplona et al. [2012] apply related integral imaging displays to correct optical aberrations. In comparison to this closely-related work, we emphasize that our efforts differ in scope; we target general-purpose 3D display, rather than estimation and correction of refractive errors. Furthermore, we are the first to optimize the optical design and underlying rendering algorithms to enable thin, lightweight HMDs, while minimizing resolution loss.

3 Implementation

As shown in Figure 1, a binocular prototype was constructed using components from a Sony HMZ-T1 personal media viewer. The case and eyepieces were removed, exposing two OLED microdisplays. Fresnel Technologies #630 microlenses were affixed to each panel. We estimate each modified eyepiece achieves a spatial resolution of 146×78 pixels and field of view of 29×16 degrees. Each modified eyepiece measures $42 \times 31 \times 10$ mm with a 0.7 gram microlens array (an unmodified HMZ-T1 eyepiece is $43 \times 31 \times 37$ mm with a 57.7 gram lens). Real-time stereoscopic light field rendering was achieved by modifying the NVIDIA OptiX GPU-accelerated ray tracing engine to support quad buffering in OpenGL.

References

NG, R., LEVOY, M., BRÉDIF, M., DUVAL, G., HOROWITZ, M., AND HANRAHAN, P. 2005. Light field photography with a hand-held plenoptic camera. Tech. Rep. CTSR 2005-02, Stanford.

PAMPLONA, V. F., OLIVEIRA, M. M., ALIAGA, D. G., AND RASKAR, R. 2012. Tailored displays to compensate for visual aberrations. *ACM Trans. Graph. 31*, 4, 81:1–81:12.