Computational Light Field Display for Correcting Visual Aberrations

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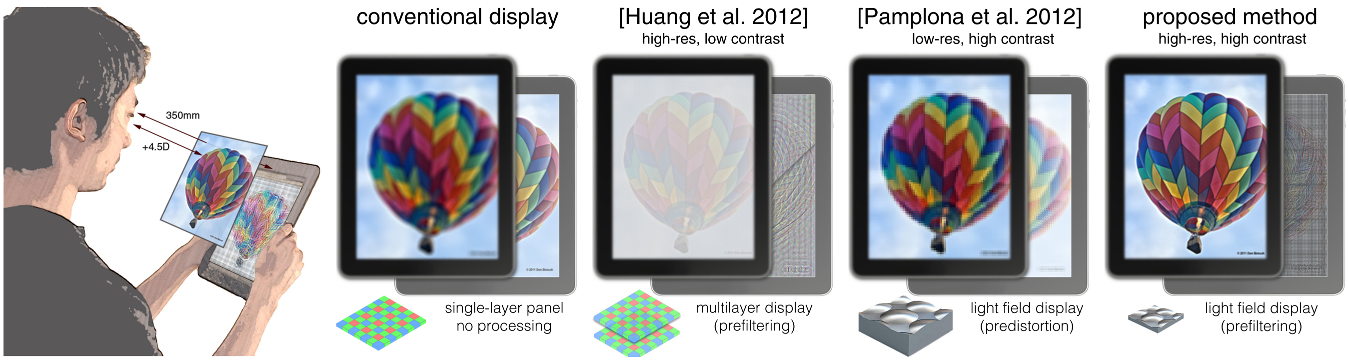

Figure 1: *Correcting myopic vision using light field displays. People with optical aberrations in their eyes see blurred images with a conventional display. Huang et al.[2012] use multilayer prefiltering to enhance sharpness, but the contrast is reduced. Pamplona et al.[2012] employ a ray tracing solution requiring very high angular resolution light field based display; unfortunately, due to hardware tradeoff, the spatial resolution is very low. Our method combines advantges from both methods, enabling both high spatial resolution and high contrast.*

Abstract

We create a computational light field display that corrects for visual aberrations. This new method enables better image resolution and higher image contrast. The prototype is built using readily available off-the-shelf components and has a thin form factor for mobile devices.

1 Introduction

Correcting for visual aberrations with a computational display would enable millions of people to see displays without wearing eyeglasses. Recent research on vision-correcting displays propose technologies that are either low resolution[Pamplona et al. 2012] or low contrast[Huang et al. 2012].

We present a new computational display approach that allows a screen to show a two-dimensional image at a distance from the physical device but within the focal range of the observer. Through designing optics hardware in concert with prefiltering algorithms, the proposed computational display architecture achieves significantly higher resolution and contrast than exhibited by prior approaches to vision-correcting image display. We evaluate our display architecture using both simulation and a prototype vision-correcting device.

2 Method

To have a desired target image received by the eye, we determine the display side object light field. he rays of the light field undergo a series of transformations such as propagations and refraction in the eye, and the retinal irradiance $I(x^e)$ can be obtained from the object surface light field using the inverted combined transforms $\mathbf{M}^{-1}$. By uniformly sampling N discrete rays over the aperture, we obtain the following expression for every target image pixel received on the retina:

$$I(x^e) = \frac{1}{N}\sum w\cdot L^o(\mathbf{M}^{-1}\cdot[x^e,\theta]^T) \Rightarrow \mathbf{L}^o = \mathbf{W}^{-1}\mathbf{I} \quad \forall \mathbf{L}^o \geq 0$$

where w is the number of ray samples that fall on a specific object light field coordinate, and $\mathbf{W}$ is the projection matrix from a 4D light field to a 2D image. For the object light fields to be physically representable, we further constrain the objective to be non-negative. This forms a basic framework for light field prefiltering; specifically, for a given target image to be received by the eye, the object side light field is determined by inverting the projection matrix gives.

3 Implementation and Results

We solve the light field and construct the experiment with hyperopic vision. On the left of Fig. 2 are the photographed results using a prototype constructed with a pinhole array mask and an iPod touch, as shown on the right of Fig. 2. Light field predistortion [Pamplona et al. 2012] requires high angular resolution, otherwise it is only slightly better than that without correction. Our approach using the same hardware produces much sharper images, matching the simulated results.

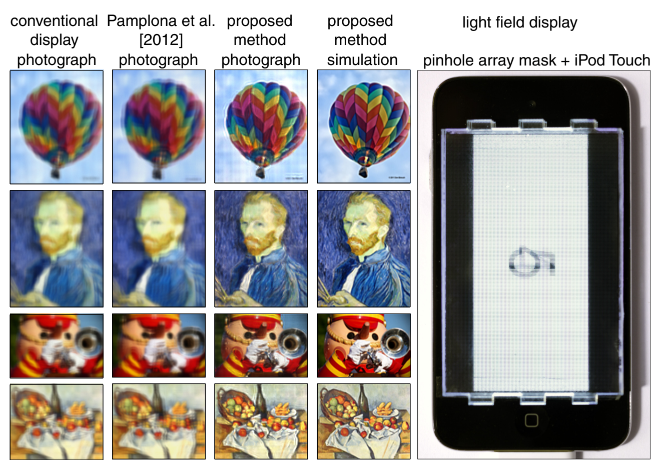

Figure 2: *Photographs of -6D hyperopic correction and prototype. The camera simulates a human pupil with a diameter of 6 mm at a distance of 25 cm to the screen, while the eye is focused at 45 cm.*

References

HUANG, F.-C., LANMAN, D., BARSKY, B. A., AND RASKAR, R. 2012. Correcting for optical aberrations using multilayer displays. *ACM Trans. Graph. (SIGGRAPH Asia) 31*, 6, 185:1–185:12.

PAMPLONA, V., OLIVEIRA, M., ALIAGA, D., AND RASKAR, R. 2012. Tailored displays to compensate for visual aberrations. *ACM Trans. Graph. (SIGGRAPH)*.

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