A Design for Optical Cloaking Display

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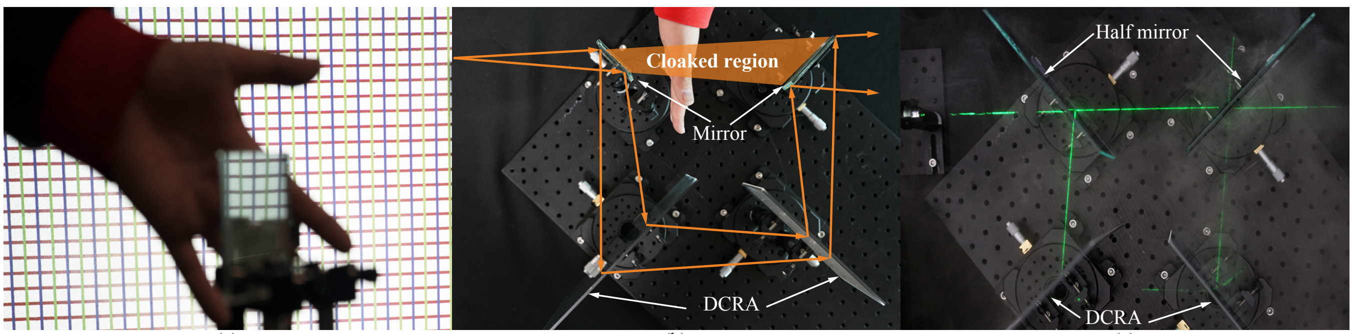

(a) (b) (c)

Figure 1: A novel cloaking display was introduced that cloaks an object based on relaying a light field. (a) Captured image. A hand is cloaked by the designed display, and a background image is transmitted properly. (b) Overview of the prototype system. The method uses two kinds of optical elements: a mirror and a dihedral corner reflector array (DCRA). (c) Light ray visualization in fog scene. An emitted light ray from a laser is split in two on the half mirror. One is passing straight through the two half mirror, and the other is reflected and refracted by mirrors and DCRAs. These light rays recombine over a cloaked region.

ABSTRACT

In the graphics research context, optical cloaking that hides an object by relaying a light field is also a kind of display. Despite much interest in the cloaking, large-size cloaking has not been achieved without some limitations and/or assumptions. To solve this problem, a computational design method is proposed for an optical cloaking display via viewpoint transformation. The method uses two kinds of passive optical elements that transfer a point into a plane symmetric point. In the experiments, a novel passive display was developed that optically cloaks the object and transmits a light field properly. Experimental results for the multiviewpoint scene that was captured are presented.

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SIGGRAPH '19 Emerging Technologies, July 28 - August 01, 2019, Los Angeles, CA, USA

CCS CONCEPTS

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

KEYWORDS

Invisible cloak, light field display, augmented reality

ACM Reference Format:
Takahito Aoto, Yuta Itoh, Kazuki Otao, Kazuki Takazawa, and Yoichi Ochiai. 2019. A Design for Optical Cloaking Display. In *Proceedings of SIGGRAPH '19 Emerging Technologies.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3305367.3327979

1 INTRODUCTION

The cloak hiding an object has attracted attention both in popular culture and in the scientific community for a long time [Fleury et al. 2015; Gbur 2013]. A cloaking system enhances augmented human viewing and is essential for an outstanding experience in art, media, and augmented reality. To develop a cloaking system, a light field must be preserved between a frontside and a backside of a cloaking region.

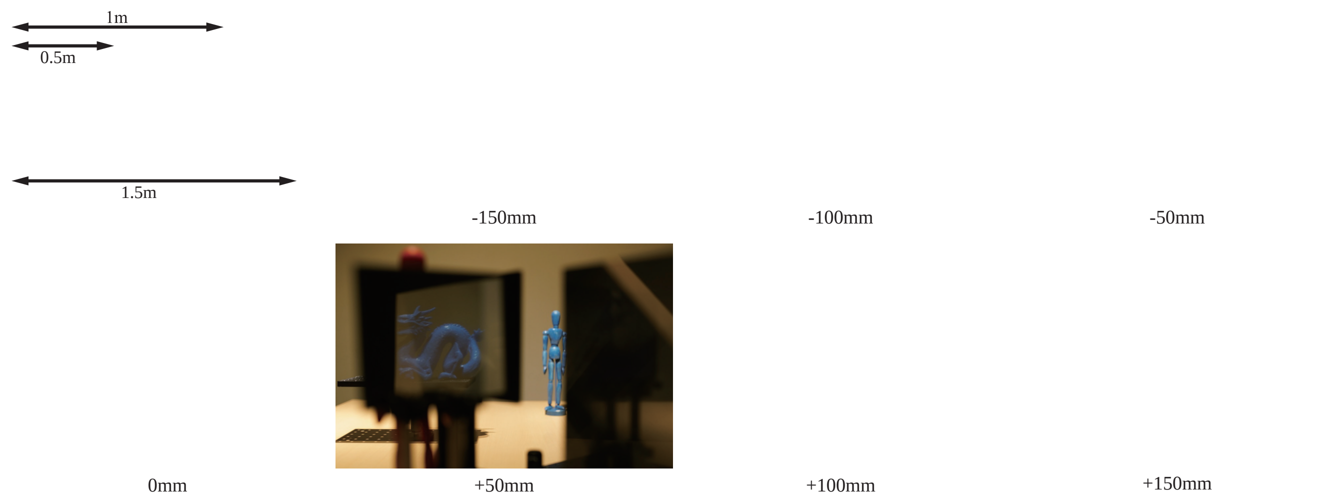

Figure 2: Comparison of viewpoint for varying horizontal position. The viewpoint was moved horizontally from -150 to 150 mm. At the top left is an overview of experimental setup, and the others are captured images.

The key idea to cloak a real-world object is to overlay an original viewpoint and a virtual viewpoint that is transformed by a combination of two types of plane symmetric transfer optical elements, as shown in Fig. 1 (a) and (b). The cloaking display presented does not preserve the wave phase of light, unlike conventional passive techniques [Chen et al. 2013; Zhang 2012]. The difficulty of phase preservation is the main obstacle for building a polarization-insensitive cloak for large objects. The difficulty can be ignored by limiting the application as a display because human eyes cannot perceive the phase and polarization of light. This makes cloak design on large scales, broadband wavelength, and perfectly preserved light field possible.

2 PRINCIPLE AND RESULTS

The combination of the optical elements transfers a viewpoint into a corresponding point. To achieve a cloaking display, the proposed method computationally designs a number of optical elements, as well as a position and a posture of each optical element, so that the two positions overlap. Figure 1 shows an example of the developed prototype system. A hand is cloaked by the system, and the background image is transmitted properly, as shown in Fig. 1 (a). Remarkably, a light ray emitted from a viewpoint is bent by the optical elements and then returns on the original light ray path, as shown in Fig. 1 (c).

An ideal optical cloaking system should function regardless of the observer's viewpoint. The effect of the viewpoint on the developed system was investigated experimentally. The red doll, the blue dragon, and the blue doll were placed at 0.5 m, 1.0 m and 1.5 m, respectively. The red doll was hidden in the optical system. The camera was moved horizontally from 150 mm to 150 mm, as shown in Fig. 2. These results indicate that the developed system is geometrically robust against the lateral movement of the viewpoint. However, the luminance value of the bent observation decreased to less than the direct observation because of the reflections and refractions.

3 EXPERIENCE

In this installation, an optical cloaking display using plane symmetric transfer optics was demonstrated. The developed display consists of mirrors and DCRAs which are mirror-based optical elements. It was confirmed that the display can relay a light field from the backside of the cloaked region to its frontside.

Some conventional methods require strong approximation of orthogonal projection [Banerjee et al. 2016] or paraxial ray approximation [Howell et al. 2014]. Thus, these methods have some limitations, such as view positions and the corresponding broadband wavelength. To the best of our knowledge, this is the first time that an optical cloaking system has been demonstrated that is view-independent, corresponding to a broadband wavelength and achieving a large-sized cloaking passively.

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