Transmissive Mirror Device based Near-Eye Displays with Wide Field of View

Kazuki Otao
University of Tsukuba
Pixie Dust Technologies, Inc.
kazuki.otao@pixiedusttech.com

Yuta Itoh
University of Tsukuba
Pixie Dust Technologies, Inc.
atuyoti@pixiedusttech.com

Kazuki Takazawa
University of Tsukuba
Pixie Dust Technologies, Inc.
kazuki.takazawa@pixiedusttech.com

Hiroyuki Osone
University of Tsukuba
Pixie Dust Technologies, Inc.
soneo@pixiedusttech.com

Yoichi Ochiai
University of Tsukuba
Pixie Dust Technologies, Inc.
wizard@slis.tsukuba.ac.jp

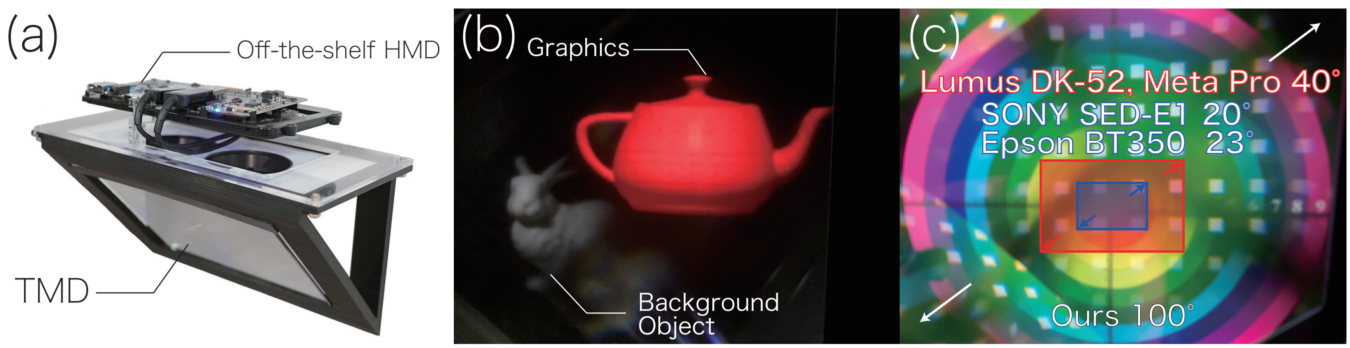

Figure 1: (a) A prototype of our TMD-based HMD. Our HMD is easily constructed with a combination of off-the-shelf HMD and TMD. (b) Obtained image of a prototype display with aerial graphics and see-through background. (c) A comparison of the field of view of our prototype display. The viewing angle of our HMD prototype was 100 degrees.

ABSTRACT

We present a transmissive mirror device (TMD) based near-eye see-through displays with a wide viewing angle and high resolution for virtual reality and augmented reality. In past years, many optical elements, such as transmissive liquid-crystal display (LCD), half-mirror, waveguide and holographic optical element (HOE) have been adopted for near-eye see-through displays. However, it is difficult to obtain wide field of view with see-through capability for beginner developer. To accomplish this, we develop a simple see-through display that easily setup from a combination of off-the-shelf HMD and TMD. In the proposed method, we render "virtual lens," which has the same function as the HMD lens in the air. By using TMD, it is possible to shorten the optical length between the virtual lens and the eyeball. Therefore, the aerial lens provides a wide viewing angle with see-through capability. We demonstrate a prototype with a diagonal viewing angle of 100 degrees.

CCS CONCEPTS

• **Hardware → Displays and imagers**;

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KEYWORDS

augmented reality, near-eye displays, transmissive mirror device

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1 INTRODUCTION

Development of mixed reality with wide viewing angle is an important issue for researchers and engineers [Maimone et al. 2014]. In recent years, several studies have proposed employing optical elements, such as half-mirrors, free-form optics, and waveguide for near-eye see-through displays. However, these optical elements suffer from the essential problem that the optical path length between the virtual lens and the eyeball become too long (Figure 2 (a)). It provides only a narrow viewing angle.

To solve this problem, we propose a novel near-eye displays using TMD [Maekawa et al. 2006] which consists of micro corner reflector array that can render real images in the air. In order to enable aerial images without special glasses, TMD is usually applied to aerial imaging systems and aerial interaction systems [Makino et al. 2016]. In contrast to previous work, we explore the combination of eyepiece interfaces and TMD. By using TMD, the physical lens

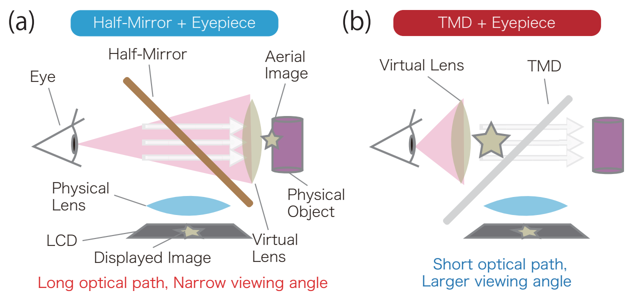

Figure 2: (a) Half mirror and physical lens configuration. The virtual lens appears between the mirror plate and the physical object. (b) TMD and physical lens configuration. The virtual lens appears between the eyeball and the mirror plate. Since the optical path length between the mirror plate and the eyeball is shortened, the viewing angle increases.

placed in the TMD behaves as an near-eye aerial lens. The user obtains the same experience as with the VR-HMD by looking into the virtual lens in the air (Figure 2 (b)).

We emphasize that TMD-based HMD never demonstrated in public exhibitions although some study was presented [Otao et al. 2017, 2018]. It is desired to present TMD-based HMD for computer graphics community.

2 SYSTEM OVERVIEW

We employ off-the-shelf HMD and consumer available TMD[1]. An Oculus Rift Development Kit 2 (Oculus VR, LLC) [2] is used as the HMD in the prototype. The resolution of LCD is 1134 × 750 (367 × 750 per eye) and the size of LCD was 125 mm × 7 mm. We remove the LCD and the lens from the HMD, and set it in a 3D printed frame. The TMD size of 140 mm × 116 mm and pitch size of 0.5 mm is adopted. The overview of our prototype is shown in Figure 1 (a).

The weight of the basic system (including LCD, lens, and TMD) was 242 g, and the weight of 3d printed frame was 189 g. The viewing angle of the original Oculus Rift DK2 is 110 degrees. The viewing angle of our HMD prototype was 100 degrees (Figure 1 (c)).

This type does not require any special software to render image sources, so that existing VR content can be applied. The obtained image in this prototype is shown in Figure 1 (b) and Figure 3.

3 DISCUSSION

3.1 See-Through Capability

As shown in the Figure 1 (b), a TMD reduces brightness from the scenery. There is a trade-off in consideration of the material and structure of TMD for observation of a comfortable real environment. Alternatively, a beam splitter can be used for the optical system in front of the eye.

[1]https://aska3d.com/en/ (last accessed May 16th, 2018)
[2]https://www.oculus.com/rift/ (last accessed May 16th, 2018)

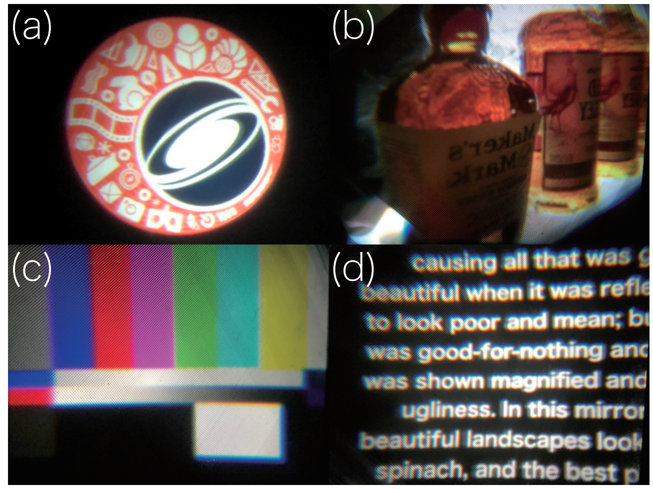

Figure 3: The image obtained from our prototype display. (a) SIGGRAPH Logo. (b) A bottle on the counter. (c) Color pattern. (d) Text information.

3.2 Ghost Image

The TMD causes double reflection images to appear diagonally. This is undesirable because ghost image obstructs the user's line of sight. To cope this problem, we have to consider to cut unnecessary light path.

3.3 Polarizing Filter

Essentially, chromatic aberration and diffusion do not occur since TMD is just a mirror. However, slight chromatic aberration and diffusion are seen due to manufacturing problems. It is expected that such errors will be reduced due to improved manufacturing accuracy. Also, we found that it is effective to adopt a polarizing filter to the LCD to reduce such diffusion.

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