PortOn: Portable mid-air imaging optical system on glossy materials

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Figure 1: Left: Mid-air image on the table. Center: Mid-air image on the marble. Right: With or without erasing system.

ABSTRACT

PortOn is a portable optical system that can form mid-air images that stand on a glossy surface such as a table or the floor. PortOn is composed of micro-mirror array plates (MMAPs), an image light source, a mirror, and polarizing elements. PortOn projects light to form a mid-air image at a position that is easy for a human to see when it is placed on a flat surface.

Our contribution is a practical optical design that can be easily installed. We designed the arrangement of the MMAPs, mirror and light source to form a mid-air image by placing it on a flat and glossy surface. The advantage of our method is to erase unnecessary light and show beautiful mid-air image clearly by applying view angle control and polarization operating to the mid-air imaging system. With this method, it is possible to display computer graphics in the real world easily and realize mixed reality interaction.

CCS CONCEPTS

• **Hardware** → **Display and imagers**; • **Human-centerd computing** → Display and imagers.

KEYWORDS

augmented reality, tabletop display, mid-air image

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1 INTRODUCTION

How can we easily display a favorite character in the real world on areas such as a table or the floor? How can we display a mid-air image on various glossy surfaces?

We propose a portable mid-air imaging system named "PortOn" that can form standing mid-air images on a glossy plane such as a marble floor, glass table. Our method can clearly show the mid-air image on the glossy plate by erasing the undesired light image under it. Figure 1 shows some examples of mid-air images formed by PortOn on different surfaces. In this research, we use the reflection of an environment material to form the mid-air image. Therefore, the expression that combines environment and computer graphics is possible.

To display a mid-air image in the real world without the need to wear any special equipment is a promising way to realize mixed reality interaction. Thanks to MMAPs, it is possible to form mid-air image easily. If the viewer notices the mid-air image and the optical components simultaneously, the attractiveness of the mid-air image may decrease. This problem was solved with EnchanTable [2], an optical system installed behind a table that had a glossy surface that projected images onto the surface. This enabled viewers to see mid-air images without seeing the optical components. FairLift[1], an interaction system which can scoop up water and mid-air image with viewer's palms, was designed based on EnchanTable. FairLift uses the reflection of water surface to form mid-air image on the surface. However, it is difficult to display a standing mid-air image on a floor surface with these systems because the horizontal level of the light source must be lower than the reflective surface. Moreover, space is required behind the reflective surface to install these systems. Therefore, Enchantable and Fairlift could only be installed in limited places. In this research, we modified the previous design to make it portable, easy to install by simply placing it on a shiny surface, and to solve the limitation.

2 SYSTEM DESIGN

PortOn is divided into two subsystems: a display system and an erasing system that removes parts of an image formed by the reflection of the horizontal plane. The display system consists of MMAPs (ASKA3D-244, 244mm × 244mm, pitch width: 0.5mm), a mirror (M), a liquid crystal display (D; LITEMAX Durapixel 0708-T), a louver film (LF; LINTEC WINCOS Vision control W-0055), and a reflective surface (R) such as a marble floor or glossy table. The erasing system consists of a polarizing plate (P; MeCan Imaging SHLP41) and a quarter wavelength plate (W; MeCan Imaging MCR140N). Figure 2 (a) shows one of the proposed optical system and (b) shows its implementation. The MMAPs, louver film, and polarizer are fixed in a vertical position, and the mirror, reflective surface, and quarter wavelength plate are fixed in a horizontal position in the light shield box to block ambient light. The box size is 275 mm × 275 mm × 210 mm. This is an all-in-one portable system that does not require configuration.

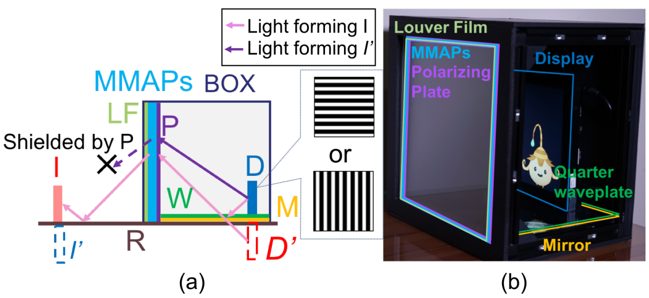

Figure 2: (a) Optical design. (b)Implementation.

2.1 Display System

We placed a mirror horizontally into the previous system [2], which uses the reflection of the glossy surface to form a mid-air image. Figure 2 (a) shows the principle of our display system. Light from D is reflected by M and forms *D'*, which is the light source of a mid-air image. The light from *D'* is reflected by the MMAPs and goes through LF, then it is reflected by R and forms a mid-air image on R. LF blocks the light that passes through the MMAPs without reflecting it. However, when only the display system is implemented, the virtual image *I'* is displayed under the horizontal plane by the light from D entering the MMAPs.

2.2 Erasing System

Since the erasing system that erases *I'* differs depending on the polarization state of D used, we designed it for each type of D. Therefore, many types of displays can be used as the light source.

When the light's polarized direction is vertical or horizontal, as shown in Figure 2 (a), we place P and W. P is placed on the MMAPs on the D side since LF diffuses the light and changes the direction of polarization. W is placed over M horizontally. In the case of using D, which is a vertical or horizontal polarization, the polarization of *D'* is the same as D. Therefore, we install W to shift the phase of light from *D'* to the MMAPs. Figure 3 shows the transition of light polarization. The light emitted from the light source changes to circularly polarized light as it passes through the wavelength plate, and its rotation direction is reversed at the mirror. Furthermore, when the circularly polarized light again passes through the wavelength plate, it changes to linearly polarized light. Since the linearly polarized light is orthogonal to the polarization direction of the light source, it can be eliminated by the polarizing plate.

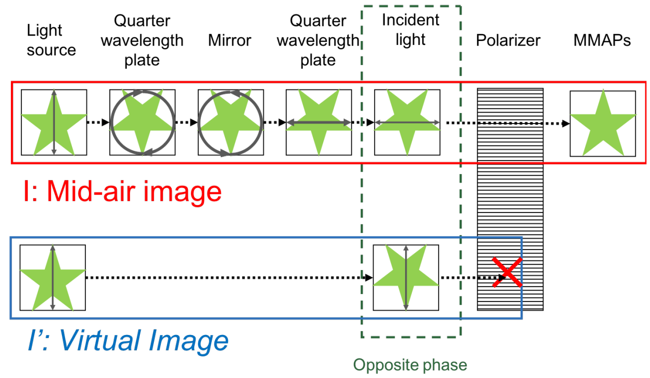

Figure 3: Transision of polarization direction.

When the light's polarized direction is oblique, P is placed on the MMAPs on the D side. In the case of oblique polarization, the polarization of *D'* is reversed in relation to D. Therefore, by installing P to be orthogonal to the transmission axis of D, light from D is not transmitted and it is possible to erase *I'*.

3 EXPERIENCE

One of our prototypes consists of a 100 mm × 125 mm MMAPs, a tablet as a light source, and a case to contain them. Nowadays, tablets have several kinds of sensors and enough computing power to realize CG character interaction. Using our prototype, we demonstrated a CG interaction where a user could call for a character to appear by knocking on the glossy floor where the ambient sound is captured by the tablet's microphone.

Users just place our equipment on the glossy surface such as a glass table, porcelain, marble or waxed floor, or a tablet, then mid-air image is formed. They can freely move the mid-air image by sliding it.

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