Merging computer graphics into real world using mid-air imaging technology

Naoya Koizumi[1, 2]
1. The University of Electro-Communications
2. Japan Science and Technology Agency PRESTO
koizumi.naoya@uec.ac.jp

Abstract: The mid-air imaging technique is a way to merge computer graphics into the real world, but there are two big issues: lack of brightness and how to hide the equipment. In this paper, I introduce two mid-air imaging research topics: a way to form a very bright mid-air image by using environmental light a way to form a mid-air image with an environment object such as a shiny wood or a glossy wall to hide the mid-air imaging component.
Keywords: *mid-air imaging, mixed reality, interaction.*

1. Introduction

Mid-air imaging is promising for glasses-free mixed reality systems in which the viewer does not need to wear any special equipment. It involves showing real images formed by reflecting and refracting the light from a light source in the air, and superimposing computer graphics (CGs) on real objects is possible. Additionally, the images can be seen without a head-mounted display (HMD). Moreover, multiple people can see the mid-air images at the same time.

There are several techniques for forming mid-air images such as reflecting a light source to form an image in the air, using plasma emission with a laser, and using a fog display. Plasma emission with a laser can realize light emission in three dimensions and with high luminance, but it is basically premised on use in spaces that are inaccessible to the human hand. Fog display is a technique for controlling the diffusion of light through projection on fog. Since fog has less effect on the human body than laser system, various interactions can be realized. On the other hand, using it outdoors is difficult because fog is affected by wind. Based on these reasons, we chose the optical method to form a mid-air image. The retroreflective optical system is easier to handle than the conventional nonlinear optical system including the Fresnel lens in that there is no restriction on the viewpoint position. There are several retroreflective optical systems called aerial imaging plate (AIP), which forms a mid-air image at the plane-symmetric position of a light source using two reflections because it is a commercially available optical device and is easy to install.

I introduce two mid-air imaging research topics: a way to form a very bright mid-air image by using environmental light and a way to form a mid-air image with an environment object such as a shiny wood or a glossy wall to hide the mid-air imaging component.

2. Mid-air imaging by using environmental light

One problem of mid-air imaging is brightness. Previous research introduced light emitting displays as a light source. However, attenuation of the brightness in a strong light environment presents a problem. In this section, we introduce a mid-air imaging optical system that uses ambient light.

Passive mid-air display is an interaction technique with a mid-air image. A user shines light with a flashlight, then a mid-air image comes up to him/her. Fig. 1(a) shows the set-up of this system, and (b) shows the mid-air image of this system. The light rays from the flashlight go to the AIP and are reflected to form image (I). Image (I) diffuse-reflects the incident light. This image then acts as the light source of the AIP and forms a mid-air image.

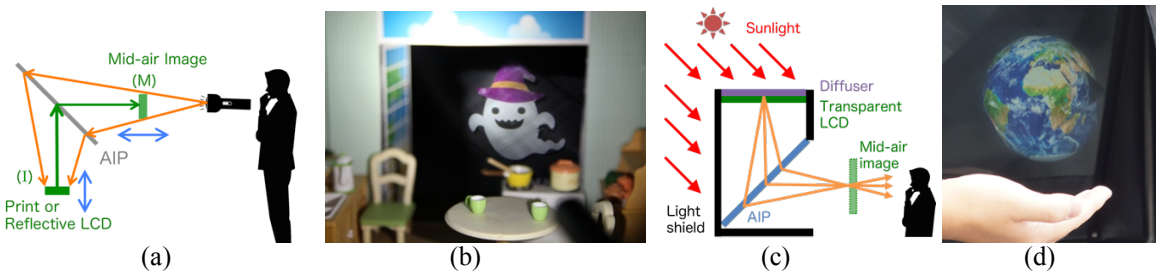

Fig. 1 Mid-air imaging by using environmental light. (a) shows principle of passive mid-air display, (b) shows mid-air image obtained by this system, (c) shows the principle of sunny day display, and (d) shows mid-air image obtained by this system.

I proposed the sunny day display to achieve a bright display that uses sunlight because the sun is the brightest light source. Fig. 1 (c) shows the set-up of this technique, and (d) shows the mid-air image obtained by this technique. The light from the sun diffuses and goes through the transparent LCD to form a virtual display. Because the light from the sun is directional light, it is necessary to diffuse it. The transparent LCD controls the graphics of the mid-air image. Then, the light goes into the AIP and is reflected to form a mid-air image. To prevent undesirable light, we shielded the set-up from light coming from all directions other than the imaging direction of the mid-air image with light-shielding material.

These two techniques do not use a light emitting display; they use an external light source from outside of the system. It is easier to control the brightness of the external light; therefore, these techniques will overcome the lack of brightness.

3. Mid-air imaging by environment reflection

Another problem of mid-air imaging is how to install and set up the optical system in a real environment. It is difficult to install an optical system in a public space because conventional mid-air imaging designs expose the optical components to light and disrupt the field of view. To enclose the system and hide it from the users view, we use the reflection of an environment object such as a shiny wood or glossy wall.

EnchanTable can display a standing mid-air image on a table [3]. Fig. 2 (a) shows the optical design of our method. The optical system consists of a display (D), actuator, AIP, view-control film (VCF), and reflective table surface. The AIP is placed perpendicularly behind the table. When the table surface does not reflect the light sufficiently, we put a half-silvered mirror film on the table to control the reflectance. The D, which is attached to the actuator, is placed behind the AIP. Light emitted from the D forms a temporary image D' through the AIP. This light is reflected by the table surface and forms a mid-air image (I). By moving the D with the actuator, the position of D' and I can be changed. The VCF can block the light to the users that directly passes through the AIP (upward), while the light for I (downward) passes through the VCF. Fig. 2 (b) shows a mid-air image of this structure.

Additionally, we designed an optical system that allows a mid-air image to be displayed in front of viewers without placing the optical components in the field of view [4]. This is accomplished by placing the light source and mid-air imaging optical component overhead, shielding the optical component by using louver films, and reflecting the light by using a glossy wall. Fig. 2 (c) shows the structure. We used several wall materials as the reflective material such as mirror, shiny wood, whiteboard, porcelain tile, and touch screen.

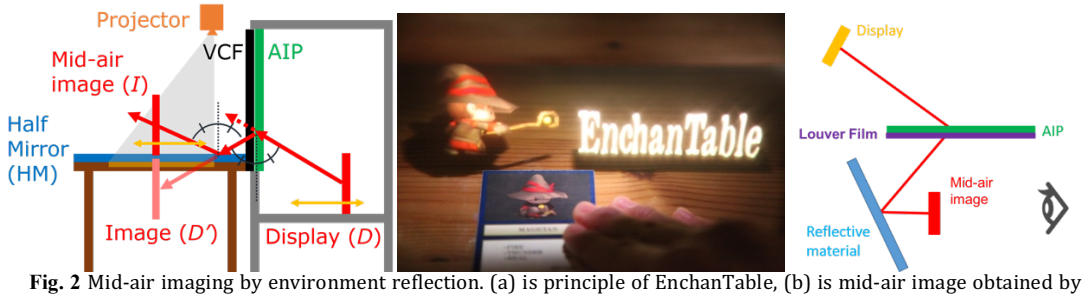

Fig. 2 Mid-air imaging by environment reflection. (a) is principle of EnchanTable, (b) is mid-air image obtained by this system, and (c) is another possible structure.

These methods help to install mid-air imaging optical systems in real situations because they hide the optical component from the user's eye and merge computer graphics into the real world.

4. Conclusion

In this paper, I introduce two mid-air imaging techniques: one using environment light and the other using environment reflection. I hope these techniques help to merge computer graphics into real world.

[1] Naoya Koizumi and Takeshi Naemura, "Passive Mid-air Display," Proc. International Conference on Advances in Computer Entertainment Technology, Article 39, 6 pages (2016).
[2] Naoya Koizumi, "Sunny Day Display: Mid-air Image Formed by Solar Light," Proc. International Conference on Interactive Surfaces and Spaces, pp. 126-131 (2017).
[3] Hiroki Yamamoto, Hajime Kajita, Naoya Koizumi, and Takeshi Naemura," EnchanTable: Displaying a Vertically Standing Mid-air Image on a Table Surface using Reflection," Proc. International Conference on Interactive Tabletops & Surfaces, pp. 397-40, (2015).
[4] Ayaka Sano, "Mid-air image technique for architecture in public space," in IS&T International Symposium on Electronic Imaging 2018, Stereoscopic Displays and Applications XXIX (2018).