AiRound: a touchable mid-air image viewable from 360 degrees

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Figure 1: Touchable mid-air images that can be viewed from different perspectives.

ABSTRACT

In this paper, we describe AiRound, an optical system that displays mid-air images that can be viewed from any direction. Mid-air images are touchable floating images formed by retroreflective transmissive optical elements that can seamlessly connect the virtual world to real space without special equipment. However, they are limited by three problems, including a limited range of observation, the visibility of the light source from the outside, and the aesthetically displeasing of stray light. The proposed system combines view control films and micromirror array plates to form a mid-air image that can be observed from 360 degrees by rotating these components at high speed.

CCS CONCEPTS

• **Human-centered computing** → **Displays and imagers**.

KEYWORDS

360-degree image, augmented reality, mid-air image

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1 INTRODUCTION

Mid-air image display technologies imagined in science fiction movies and literature have recently attracted widespread interest as a topic of active research. Popular culture reflects a sustained interest in and desire for technology that can display floating images visible from any direction. For example, "Star Wars" features many scenes in which characters view images displayed in mid-air from different positions and angles.

In the real world, a micro-mirror array plate (MMAP) is an optical element that can be used to form mid-air images. MMAP consists of a two-layer mirror array, and the position of an object behind an MMAP is optically transferred to the front of the MMAP by using reflections in the mirror array. The light sources that can be used with MMAP are not limited to 2D, but can also be 3D.

Mid-air images formed by MMAP have two limitations, including a limited observation area and light-emission properties that may be undesirable for observers. The generated mid-air images have a limited range of visibility because part of the image appears to be missing or its brightness may be reduced in different viewing positions. Although some authors have expanded the area in which mid-air images formed by MMAP are visible by using multiple double-sided displays, to the best of our knowledge, no prior works have been able to expand the viewing area to 360 degrees [Takenawa et al. 2022]. In addition, unwanted light called transmitted or stray light is generated along with the image, which reduces its visibility.

In this study, we demonstrate an optical system that displays a mid-air image visible from 360 degrees in which transmitted and stray light are reduced. Specifically, transmitted and stray light are suppressed by attaching a view control film (VCF) to an MMAP device. Then, by rotating the MMAP and view control films at a high speed, the area in which the mid-air image can be seen is expanded such that the image can be viewed from 360 degrees.

AiRound has three key features: the user can touch the image directly, the image remains visible even when as the viewing position moves up and down, and the distance by which the image appears to pop out can easily be changed. 360-degree displays that use high-speed rotation generally do not allow the viewer to touch the image directly [Jones et al. 2007]. In a 360-degree display that

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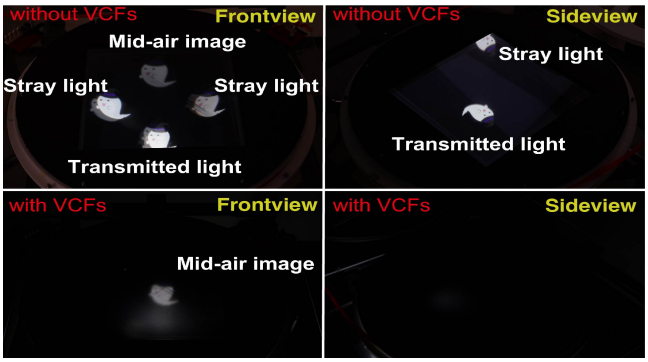

Figure 2: Reducing stray and transmitted light using view control films while maintaining the mid-air image display (Upper: A mid-air image without view control films; Lower: A mid-air image with view control films; Left: An image viewed from the front of the MMAP; Right: An image viewed from a different angle, misaligned with the front of the MMAP))

uses projectors arranged in a circle and a conical screen, the viewing area of the image is limited to a ring shape and may appear unnatural from different points of view [Yoshida 2016]. The use of two parabolic mirrors also allows a mid-air image to be viewed from 360 degrees; however, this method makes changing the distance from which the image appears to pop out difficult [Butler et al. 2011].

2 PRINCIPLE

The method used to display the 360-degree mid-air image consists of two steps. The first step is to show only the light that forms the mid-air image and suppress unwanted light. Four types of VCF are attached to the MMAP to reduce stray and transmitted light. (Figure 2). A VCF is an optical element that limits the range of incident angles of light rays by arranging partitions at regular intervals and angles. Denoting the four VCFs as VCF1, VCF2, VCF3, and VCF4 from the top, VCF2 and VCF3 remove stray light, while VCF1 and VCF4 remove transmitted light. The second step is to rotate the MMAP at high speed such that only the light forming the mid-air image is visible. In other words, by rotating the MMAP at high speed while only the mid-air image is visible from one direction and no unwanted light is visible from anywhere, the mid-air image becomes visible from 360 degrees.

3 IMPLEMENTATION

Our optical system comprises several components including a motor, a urethane belt, MMAP, VCFs, a rotating component, and a light source (Figure. 3, 4). The motor was an AC speed-control motor US560-001C manufactured by Oriental Motor Company; the MMAP was an ASKA3D-200NT (200 mm × 200 mm) manufactured by ASUKANET, and the VCF was manufactured by Shin-Etsu Polymer. (We used a VCF1329025-PC200 model as VCF1 and VCF4 and a VCF1324800-PC200 unit as VCF2 and VCF3), and the rotating part was made of an acrylic plate. The light source was a CM-S75C

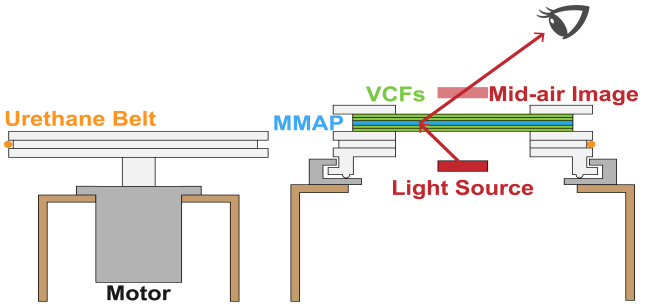

Figure 3: Optical design of the proposed system

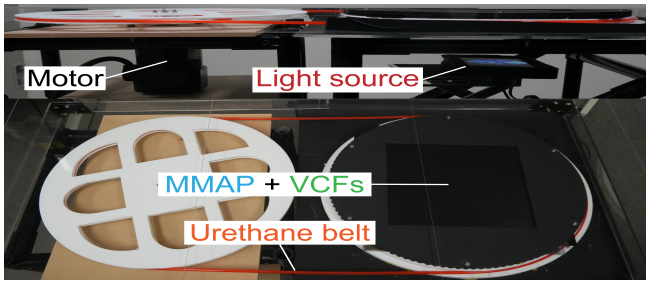

Figure 4: Implementation of the proposed method

display made by SWIT or a cylinder with characters written inside and a light.

4 CONCLUSION & FUTURE VISION

The proposed "AiRound" is an optical system that displays mid-air images that are visible from 360 degrees. This optical system can be used as a tabletop display, allowing multiple people to view a mid-air image and collaborate. As another example, this optical system can be used to present images differently according to the position of the viewer. By using a high-speed projector as the light source and synchronizing the image-switching cycle with the rotation cycle, different images can be presented to multiple people simultaneously, or 3D images can be displayed with motion parallax.

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