Perceiving 3D from a 2D Mid-air Image

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Abstract

In this study, we aim to quantify the sense of depth and perceived position in mid-air images. In the experiment, the participants were instructed to indicate the nearest frontal point and zenith of both mid-air images and actual spherical objects. The results suggest that the frontal surface of mid-air images is generally perceived on the image plane or behind it. However, when depth is recognized, it appears slightly less pronounced compared to actual objects.

CCS Concepts

• **Human-centered computing** → **Visualization**.

Keywords

mid-air image, perception, depth, thickness

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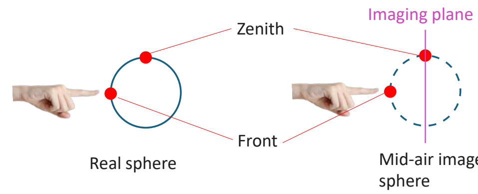

Figure 1: Front and Zenith pointing positions

1 Introduction

We focused on the fact that many users reported perceiving mid-air images as three-dimensional when presented on a 2D light source display. Furthermore, we are interested in how often users move their fingers past a mid-air image when touching it. This phenomenon suggests that while subjects experience a sense of three-dimensionality in relation to the mid-air image, they struggle to accurately localize its precise spatial position.

In this study, we quantified the perceived depth and position of two-dimensional mid-air images, as reported by participants, using a pointing task paradigm. Specifically, the user is instructed to point to two locations: the nearest front and zenith of the sphere, which is displayed as a mid-air image, as shown in Figure 1. First, to determine the perceived position of the nearest front, participants moved their index fingers. Subsequently, they pointed to the zenith. It clarifies the sense of depth in a spherical mid-air image by measuring the difference in the distance from the nearest front to the zenith. Additionally, the participants performed the same pointing movements as the real object. The two were compared to investigate the relationship between the three-dimensionality of the mid-air image and the real object.

2 Related work

A mid-air image is a real image formed in air through the reflection and refraction of light emanating from a source and is manipulated by specific optical elements. The micro-mirror array plate (MMAP)[Maekawa et al. 2006] and aerial imaging by retro-reflection (AIRR)[Yamamoto et al. 2014] are well-known optical systems for mid-air imaging. These systems facilitate the direct observation of mid-air images without the need for specialized viewing apparatus.

MARIO[Kim et al. 2014] is an interaction system that uses mid-air images. In this system, a shadow is displayed under a mid-air image to make it easy for the user to determine the depth of the mid-air image. However, it remains unclear how users perceive the position of mid-air images without these cues.

In a study of perceptual changes in mid-air images, Yano et al. examined the effect of shadow length on the perceived thickness of mid-air images [Yano and Koizumi 2023]. They found that longer shadows increased perceived thickness, whereas shorter shadows decreased it. However, this study did not quantitatively measure the perceived thickness without shadows.

3 Method

White polystyrene with a diameter of 10 cm was used to present a real sphere. We chose Styrofoam to minimize the impact on the perception of three-dimensionality due to surface texture using a material where gloss and shadows are less pronounced. However, to show a spherical mid-air image, a monochromatic white sphere was displayed to make it look similar to the real object. The mid-air image was adjusted to a diameter of 10 cm when displayed on a screen. A position of the fingers, Trio optical motion capture system OptiTrack V120: Trio was used to measure the finger position. A spherical mid-air image is presented using MMAP as shown in Figure 2. The imaging plane was positioned 47 cm away from the center of the MMAP. During the experiment, the participants' head

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