Aerial Display with Thermal and Acoustic Sensation

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(a) (b) (c)

Figure 1: (a) Formed aerial images are observed with a screen at the image position. (b) An aerial heater is formed in the mid-air, as a thermochromic sheet shows the aerial image of fire is locally heated up. (c) An aerial speaker is formed on the left aerial image, where sound pressure locally increases.

ABSTRACT

We have developed a visual, thermal and acoustic floating aerial display. Our developed display forms aerial visual images over a tabletop and locally heats a part of aerial images. Furthermore, our display forms locally aerial speaker on a part of aerial images, where sound pressure locally increases. Aerial images are formed with aerial imaging by retro-reflection (AIRR), which features a wide viewing angle, scalability, and mass-productivity. The aerial heater and the aerial speaker are realized with double-layered arrays of rectangular mirror (WARM) and crossed-mirror array (CMA), respectively. In combination of these imaging methods, we have realized a multi-modal aerial display.

CCS CONCEPTS

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

KEYWORDS

aerial display, aerial heater, aerial speaker

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1 INTRODUCTION

Aerial display forms a information screen floating in the mid-air. Aerial screen enables us to handling visual information directly in the 3D space without 3D glasses. Aerial display of light and heat using double-layered arrays of rectangular mirrors (WARM) has been proposed [Okamoto et al. 2016]. Furthermore, aerial display of light and sound using crossed-mirror array (CMA) had been proposed [Kujime et al. 2014]. These techniques give multi-modal sensations on an aerial image by adding heat or sound to aerial display. These previously developed techniques, however, realized only two elements. This paper proposes a new system that can form visual, thermal, and acoustic floating aerial images. Our proposed system is composed of aerial imaging by retro-reflection (AIRR) [Yamamoto et al. 2014], WARM, and CMA.

The objective of this paper is to realize world's first aerial visual display combined with an aerial heater and an aerial speaker. Furthermore, a prototype system has been developed with a retro-reflector, a beam splitter, a specially fabricated WARM, and a transparent CMA for sounds. Visual, thermal, and acoustic aerial images have been formed as shown in Fig. 1.

2 PRINCIPLE OF AIRR

AIRR has been proposed as a method to form an aerial image that is floating in the air [Yamamoto et al. 2014]. AIRR features a wide viewing angle and a large-size scalability with a low-cost mass-productive optical material.

3 PRINCIPLE OF CMA

CMA is composed of crossed mirrors. The incident rays are converging into the image position because each reflection surfaces are placed perpendicularly. Since our developed CMA is composed of hollow apertures, our CMA can convergence not only visible light but electromagnetic radiations in a wide wavelength range as well.

3.1 Conversing infrared radiations by use of CMA

In the preliminary experiments, we used a soldering iron for a heat source. CMA was made of stainless mirrors. The distance between the heat source and the CMA was 30 cm. Incident angle was 35 degrees. Measured air temperature distributions are shown in Fig.2. Temperature locally increased at the convergence position.

3.2 Converging sound by use of CMA

We have also developed a CMA for sound by scaling-up its structure to meet the wavelength of sound wave [Kujime et al. 2014]. We used a parametric speaker for a sound source. Distance between the sound source position and the CMA was 100 cm. Incident angle was 45 degrees. Sound distribution on the distance and the lateral position are shown in Fig.3. The distance and the lateral dependence have maximum value at designed position. This means that sound is converged by double reflections of the prototype CMA.

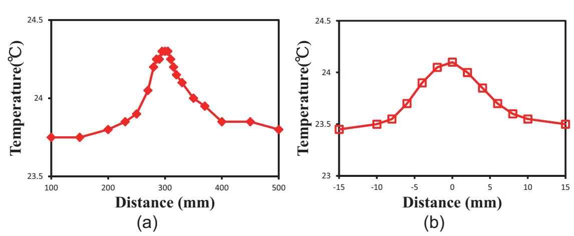

Figure 2: Dependences of temperature of the aerial thermal image by soldering iron upon (a) distance and (b) lateral position. The temperature peaks at the image position.

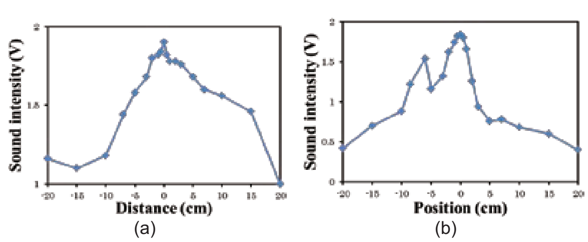

Figure 3: Dependences of sound intensity (a microphone output voltage) upon (a) the distance and (b) the lateral position. Sound is converging at the image position.

4 PRINCIPLE OF WARM

We have developed the WARM in order to converge infrared radiations from a heater to its image position [Okamoto et al. 2016]. The infrared rays from a heater are reflected twice at WARM. Then, the infrared rays are converged at the plane-symmetrical position of the heater regarding the WARM.

5 AERIAL DISLAY WITH AIRR, WARM, AND CMA

We have combined AIRR, WARM, and CMA to realize aerial visual, thermal, and acoustic aerial display. Fig. 4 shows the combined configuration. As shown in Fig. 1, we have confirmed that (a) a visual aerial screen is formed in the mid-air, (b) an aerial heater is formed on an aerial image, and (c) an aerial speaker is formed on an aerial image. In this demonstration, the aerial heater was formed on the aerial image of a fire. When we touched the aerial fire image, we felt warm, although the aerial image of a raindrop was not warm. We also heard sound from the aerial fire image, where the aerial speaker was formed.

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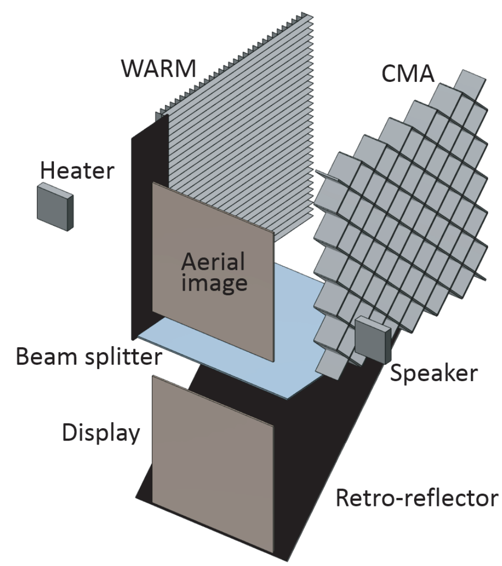

Figure 4: Composition of visual, thermal, and acoustic aerial display by use of AIRR, WARM, and CMA.

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