Optical Design for Heterogeneous Imaging Based on Retro Reflection Using Parallel Roof Mirror Arrays

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1. Introduction

A retro reflective imaging element has been proposed for an aerial image display system [1]. This type of aerial imaging display system has an advantage that there is no image distortion by Seidel's aberration. However, the proposed imaging element is expensive to produce. On the other hand, heterogeneous imaging based on retro reflection, which forms an aerial real image in a crosswise direction and a virtual image in a lengthwise direction, has been introduced [2] by Maekawa et al. This imaging can be a low cost solution to an aerial image display for limited application. However, the aerial image is tilted and stretched.

In this paper, we propose a heterogeneous imaging system consisting of two roof mirror arrays (RMAs) to reduce the tilt and stretch of the aerial image.

2. Retro Reflection and Imaging

Figure 1 shows a structure of the RMA and imaging by the RMA. A point light source is formed as a heterogeneous image. When a two-dimensional (2D) display is placed, a tilted and stretched heterogeneous 2D image is formed in midair. Making the heterogeneous imaging system with two parallel RMAs can cancel out the tilt and stretch of the image created by parallel rays from the 2D display, as shown in Fig. 2. To form the aerial image, it is needed that the distance a between the 2D display and the first RMA is smaller than the distance b between the RMAs. And the distance d of the aerial image from the second RMA is

$$d = b - a. \qquad (1)$$

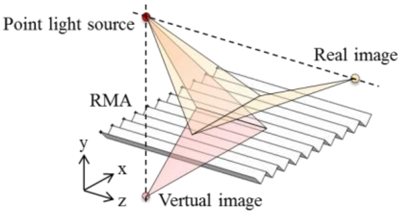


Fig. 1. Heterogeneous imaging by the RMA. The x-axis is the crosswise direction and the z-axis is the lengthwise direction.

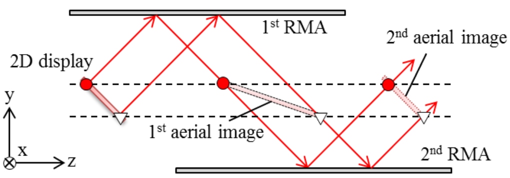


Fig. 2. Optical setup using two RMAs. Image tile and stretch caused by the first RMA is canceled by the second RMA.

In this situation, an observer can see the aerial 2D image when both eyes are parallel to the crosswise direction and get enough distance from the second RMA to see a tiny range of rays spreading in the lengthwise direction. When the observer moves in the lengthwise direction, the aerial image shifts in the same direction as his/her move, as shown in Fig. 3.

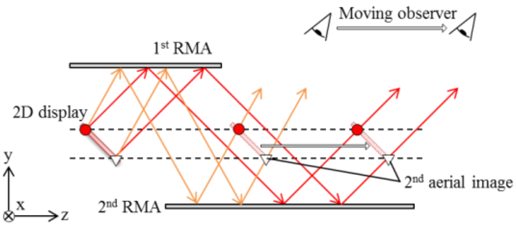
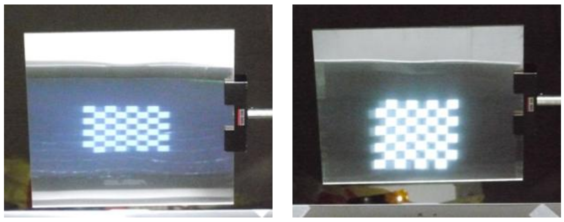


Fig. 3. Image shift with the movement of a viewing position.

3. Experimental Imaging System

In this study, we used mirror-coated 90° prism sheets as RMAs. Figure 4 shows an aerial image of a laptop screen formed by the proposed imaging system with a = 5 [cm] and b = 20 [cm]. We confirmed the proposed imaging system reduced the tilt and stretch of the aerial image.



(a) One RMA　　(b) Proposed system

Fig. 4. Aerial image of a square check formed by the RMA and the proposed imaging system.

4. Conclusion

We proposed the optical design for the heterogeneous imaging system using two parallel RMAs. The proposed system has limited application because a viewing position is fixed in the lengthwise direction to reduce the image shift. On the other hand, this unique vision of the aerial image with shift can apply to digital signage or entertainment.

References

[1] Maekawa, S. et al., "Transmissive Optical Imaging Device with Micromirror Array," Proc. SPIE 6392, 63920E (2006).
[2] Maekawa, S. et al., "Advances in Passive Imaging Elements with Micromirror Array," Proc. SPIE 6803, 68030B (2008).