Perceived Depth Instability Difference of Aerial Image in CMA (Crossed Mirror Array) by Changing Fixation Point of Eyes

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ABSTRACT

Perceived depths of aerial image in crossed mirror array have large instability towards fixation point of eyes, even when aerial image is geometrical optical real image. When fixation points are changed apart from aerial image, perceived depth deviations are increased toward fixation point in front of or behind aerial image.

1 INTRODUCTION

In digital signage, three-dimensional imaging is promising because of easily attracting attention but not in the way by walking people and multi-modal possibility in free space. One of these displays is Crossed Mirror Array (CMA) [1]. In CMA, an aerial image is formed as a geometrically optical real image at plane-symmetrical position to the light source. However, perceived depths of these aerial images are sometimes unstable, even when aerial images are geometrically optical real images. Aerial image cannot be sometimes perceived at geometrical position of plane symmetry to light sources but shifted positions around CMA or of CMA surface [2].

Figure 1 shows unstable perceived depth of aerial image with constant distance between subject and aerial image when distance between CMA and aerial image is changed [3]. When CMA and aerial image have large distance, perceived depths have large and separated deviations of shifting to CMA surface. This indicates that perceived depth instability of aerial image is not influenced by observation distance but by geometrical position of aerial image from CMA. This instability at large distance between aerial image and CMA suggests that fixation point of eyes affects perceived depth instability because both lights from CMA itself and aerial image can be equally observed optically, which is different from transparent object. In this study, in order to clarify the reason for instability of perceived aerial image depths, we estimated perceived depth difference by changing distance to fixation point of eyes.

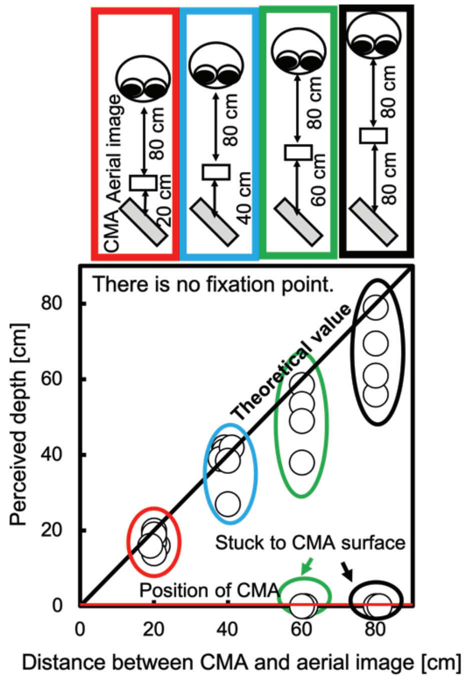


Fig.1 Perceived depth instability when distance between CMA and aerial image changes without fixation point

2 PRINCIPLE OF CMA AND CMA'S PROBLEM

Principle of CMA and the problems of CMA's aerial image instability are explained in following sections.

2.1 The principle of CMA

Structure of CMA is shown in Fig. 2. CMA is formed of comb-shaped stainless mirrors arranged in a grid. Because stainless mirrors are arranged in a grid, these are worked as dihedral corner reflector array for incident rays come inside aperture. When lights come inside the aperture, rays from light sources have double reflections. Therefore, the rays are converged at plane-symmetrical position as a geometrically optical real image.

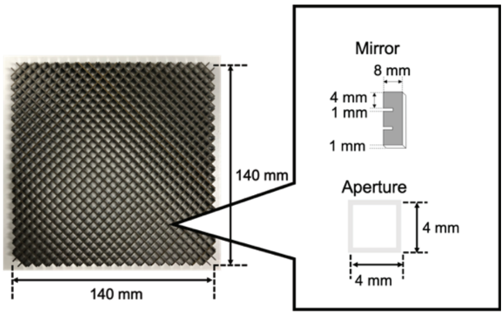


Fig. 2 Structure of CMA

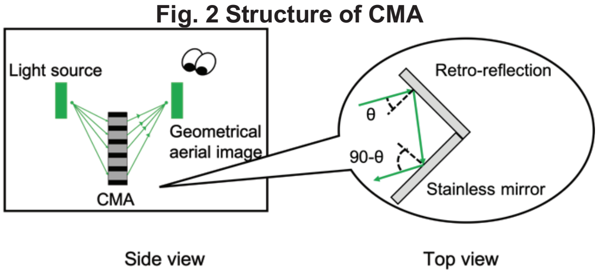


Fig. 3 The principle of CMA

2.2 Problem in aerial image and CMA

An aerial image of CMA is formed as a geometrical optical real image at plane-symmetrical position to the light source. However, as shown in Fig. 4, scattering lights of every object behind the real image are also straightly observed without change in contrast to lights from transparent sheet in front of rear object. This is essentially different from the case of transparent sheet in front of rear object, that is, the fact that observed image luminance is inevitably decreased at overlapped positions. This luminance decrease is considered to be essential for occlusion effect of transparent object in front of rear object. This indicates that additive luminance change in the case of optical real images little provide occlusion effect. Moreover, gazing rear object becomes easy at optical real image. These result instability of depth perception of optical real image.

Second problem in CMA is pseudo occlusion effect by thickness of CMA frames. As CMA frames are not transparent, optical real image at corresponding regions of CMA frames cannot be observed. This leads to alternately image changing between front optical real image and rear CMA frame images when moving observer head. This results in pseudo occlusion effect.

We consider these occlusion effects leads to instability in perceived depths as shown in Fig. 1. However, by changing gazing positions, perceived depth is expected to be fixed around them. To clarify influence of gazing positions, perceived depths are estimated by changing fixation points.

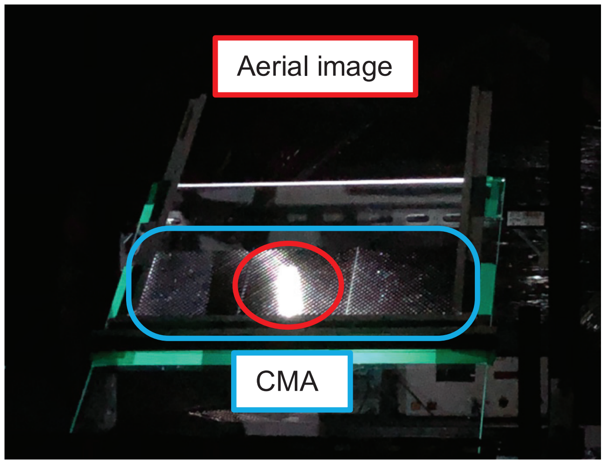


Fig. 4 Photograph of aerial image in front of CMA

3 EXPERIMENT: ESTIMATING PERCEIVED DEPTH DIFFERENCE BY CHANGING FIXATION POINT OF EYES

Figure 5 shows experimental system for estimating perceived depth difference by changing fixation point of eyes. Fixation point composed of LED light was set to 0 cm, 30 cm, 45 cm and 60 cm from CMA. Fixation point was positioned at upper and close to aerial image. Stimulus positions of aerial image were 30 cm, 45 cm, and 60 cm from CMA. Distance between CMA and observer was 200 cm. Stimulus parameters were changed in a random order. Subjects were let memorize perceived depth, and align reference to the memorized depth after stimulus and fixation point were disappeared.

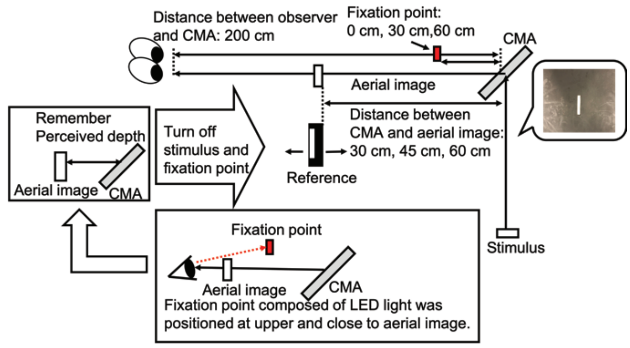


Fig. 5 Experiment system for estimating perceived depth of aerial images

4 PERCEIVED DEPTH DEPENDENCE OF AERIAL IMAGE IN CMA WHEN CHANGING FIXATION POINT

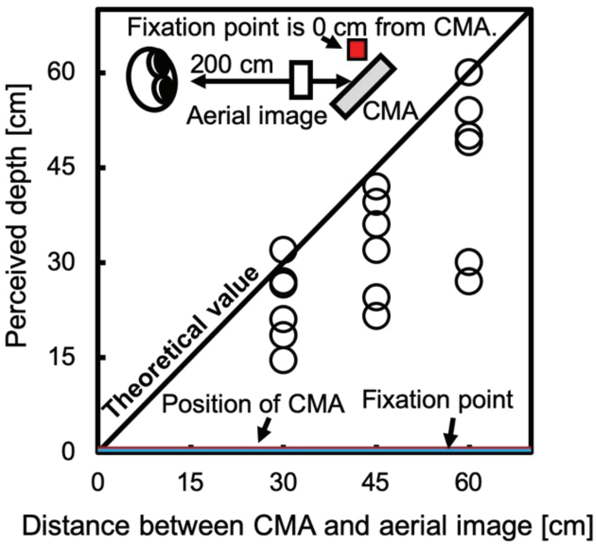
Figure 6 shows perceived depths of aerial image by changing fixation point of (a) 0 cm, (b) 30 cm, (c) 45 cm, and (d) 60 cm from CMA.

In Figure 6(a) with fixation point of 0 cm, perceived depths at all aerial image positions have large deviations toward fixation point of 0 cm behind aerial image. This indicates that perceived depths of aerial image are shifted to 0 cm when fixation point is 0 cm.

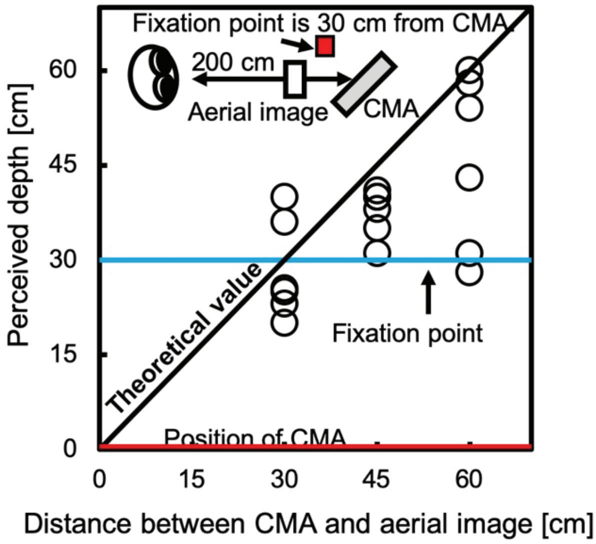
In Figure 6(b) with fixation point of 30 cm, at aerial image positions of 60 cm and 45 cm, perceived depths have large deviations toward fixation point of behind aerial image like that in Fig. 6(a). However, at aerial image position of 30 cm, perceived depth is scattered around designed positions of 30 cm. This indicates that perceived depths of aerial image are shifted to 30 cm when fixation point is 30 cm.

In Figure 6(c), with fixation point of 45 cm, at aerial image positions of 30 cm and 60 cm, perceived depths are scattered towards fixation point of 45 cm in front of or behind aerial image. At aerial image position of 45 cm, perceived depths have small deviations near designed depths of 45 cm. This indicates that perceived depths of aerial image are shifted to 45 cm when fixation point is 45 cm.

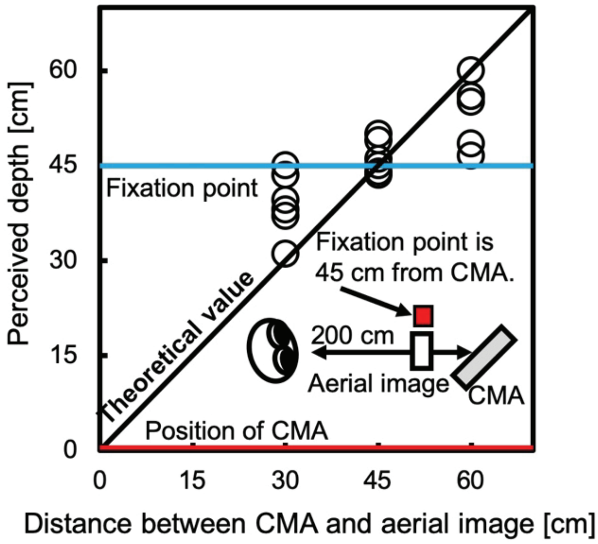
In Figure 6(d), with fixation point of 60 cm, at aerial image positions of 30 cm and 45 cm, perceived depths have large deviations toward fixation point of 60 cm in front of aerial image. At aerial image position of 60 cm, perceived depths are just at designed position of 60 cm with small deviations. This indicates that perceived depths of aerial image are shifted to 60 cm when fixation point is 60 cm.



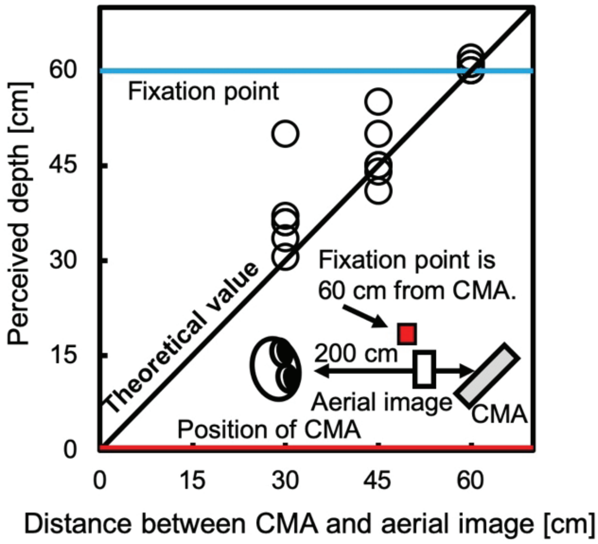
(a) Fixation point is 0 cm from CMA



(b) Fixation point is 30 cm from CMA



(c) Fixation point is 45 cm from CMA



(d) Fixation point is 60 cm from CMA

Fig. 6 Perceived depth dependence of aerial images in CMA when changing fixation point

5 CONCLUSIONS

In this study, we estimated perceived depth difference by changing distance to fixation point of eyes. The reason for perceived depth instability of aerial images in CMA is successfully clarified as fixation point difference.

When changing fixation point, perceived depths of aerial image have deviations toward fixation point and shifted to the positions of fixation point. As perceived depths of aerial image have deviations toward fixation point, instability of aerial image depths can be solved by adding appropriate fixation point, such as bright light, eye catching real object and so on. This indicates new method for solving the instability can be proposed and aerial image in CMA can be applied to various fields.

ACKNOWLEDGMENT

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