Eye-Matching Video Calling System by Use of Aerial Screen with AIRR

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ABSTRACT

Aerial screen formed with AIRR has been utilized for a video calling system that features viewpoint matching. We can virtually place a camera at an arbitrary position on the aerial screen because the screen is aerial and AIRR employs a beam splitter. Polarization filtering is used to take clear pictures.

1 INTRODUCTION

Aerial imaging by retro-reflection (AIRR) is an aerial-image-forming technique [1, 2]. Fig. 1 shows an aerial image formed with AIRR. Advantages of aerial image include high sense of reality, no physical contact and precise position. Use of polarization modulation in AIRR, called polarized AIRR (pAIRR), increases visibility of the formed aerial image [2]. The aerial image formed by AIRR has a wide viewing angle horizontally and vertically. On the other hand, in the conventional setup, the visible region was limited to the front of the AIRR device. Thus, we have realized a see-through aerial display system that makes the aerial image and the user's gesture visible from the opposite side [3]. Our objective is to use an aerial display using AIRR as a video calling device. Since an aerial display can project an image that is visible with the naked eyes in the mid-air, it is expected to be a more realistic video calling than displaying the user on a flat panel display.

Fig. 1 Aerial image formed with AIRR (aerial imaging by retro-reflection).

Our previous work proposed an application of the aerial display for a video calling interface [4]. By combining the pAIRR and the see-through AIRR, it became possible to observe the user from the camera installed at behind of the beam splitter and connect the user's view and the aerial image's view. In this previous system, the captured image contains the displayed image for the user. Thus, the previous system is effective for one-way video calling system.

The purpose of this paper is to realize both-way eye-matching video calling system. In order to prevent the direct light reflection from the display to the camera image, we introduce polarization filtering. Consequently, we enhance the quality of the aerial image displayed by the video call system. Thus, we construct a video calling system combining two aerial video-calling interfaces.

2 PRINCIPLE

2.1 Aerial Imaging by Retro-Reflection (AIRR) [1]

Fig. 2 shows the principle of AIRR. This setup consists of a light source, a beam splitter, and a retro-reflector. The beam splitter reflects rays from the light source. The reflected rays are retro-reflected, that is, reflected reversely at the incident positions on the retro-reflector. The retro-reflected rays are converged to the position of the plane-symmetrical of the light source with respect to the beam splitter.

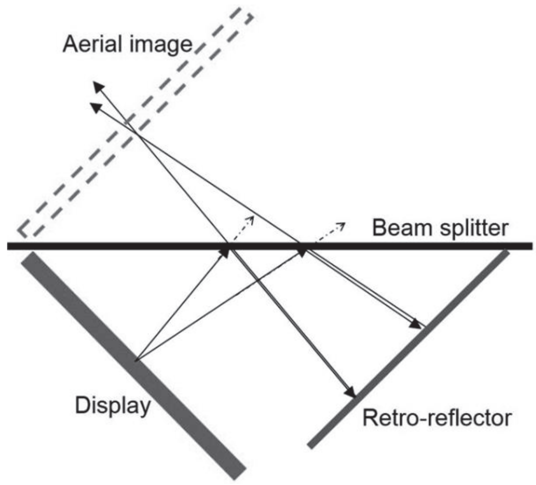


Fig. 2 Principle of AIRR.

2.2 Polarized AIRR [2]

In order to increase luminance, we utilize polarization modulation. We call this a pAIRR. This structure is composed of a light source, a reflective polarizer, a quarter-wave retarder film, and retro-reflector. We locate the reflective-polarizer and the linearly polarized light of the display in crossed-nicol arrangements. In this case, the light from the display reflects at the reflective polarizer. The polarization angle of the retro-reflected light is rotated by 90 degrees after penetrating the quarter-wave retarder twice. Therefore, the retro-reflected light transmits through the reflective polarizer and converges into the plane symmetric position of the light source regarding the reflective polarizer. In the standard AIRR, there was a loss of rays forming an aerial image due to transmission and reflection in the beam splitter. In pAIRR, loss can be reduced in this way, and a brighter aerial image can be formed.

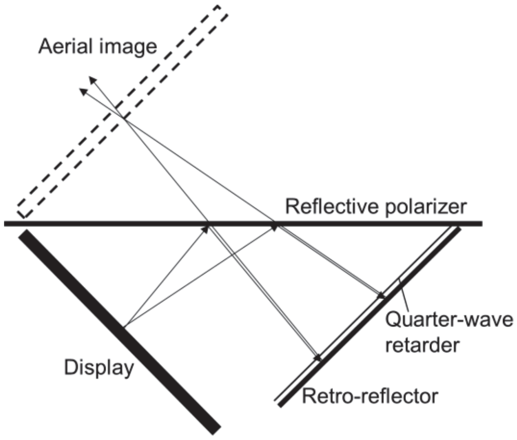


Fig. 3 Principle of pAIRR.

2.3 See-Through AIRR [3]

The conventional AIRR had a wide view angle in front of the AIRR device. The see-through AIRR makes it possible to see an aerial image from the opposite side of the AIRR device. Fig. 4 shows the principle of the see-through AIRR.

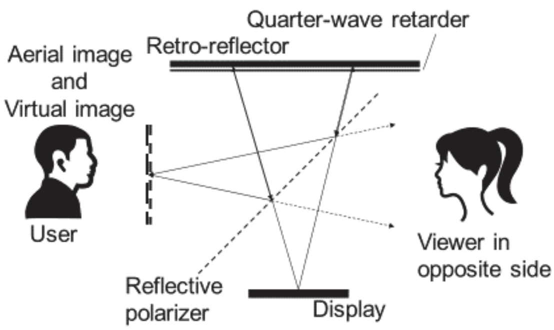
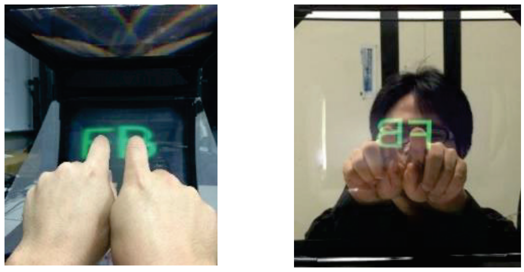


Fig. 4 Principle of see-through AIRR.

In the see-through type AIRR, the arrangement of retro-reflector is different from the conventional AIRR configuration. Of the light emitted from the light source, the light transmitted through the beam splitter enters the retro-reflector and is retro-reflected by it. The retro-reflected light is reflected by the beam splitter and forms an aerial image for the user in front of the device. On the other hand, the light reflected by the beam splitter from the light source shows a virtual image to the user view from the opposite side of the device. The apparent position of this virtual image coincides with the position of the aerial image seen from the front. As a result, the aerial image with a wider view angle can be realized by combining the view angle from the two directions opposite and front.



(a) (b)

Fig. 5 Touching the aerial 3D image with both fingers (a) viewed in front of the user and (b) viewed from the opposite of the user.

Fig. 5 shows photographs of a user observing the aerial image from the front side using the see-through aerial display prototype. Fig. 5 (a) is a photograph taken from the viewpoint position of the user. The user confirmed the aerial image. Fig. 5 (b) is a photograph taken from the opposite side of the user. From the other side, the fingers and virtual images fixed by the user was clearly visible.

2.4 Eye-Matching Video Calling System by Use of Aerial Screen with AIRR

In See-through AIRR, the user looking at the aerial image could be seen from the opposite side of the device through the beam splitter. Therefore, we proposed a video call system with a camera on the other side of the device. This camera can be placed ahead of the user's line of sight through the aerial image. Therefore, it is possible to realize a video calling with the eye-matching.

2.4.1 The Previous Optical System [4]

Fig. 6 shows the optical system of our previous video calling interface with the see-through AIRR. Fig. 7 shows a picture of the configured device used in the experiment. Fig. 8 shows a result of the user observed from the camera installed in the device. From the principle of see-through AIRR, S-polarized light from the display reflects on the reflective polarizer and shows the virtual image to a viewer in the right side in the figure. P-polarized light from the display passes through the reflective polarizer and impinges the retro-reflector through a quarter-wave retarder. Since the polarization angle of the retro-reflected light is rotated by 90 degrees, the retro-reflected light is reflected on the reflective polarizer and forms the real image, which is visible for a user in the left side in the figure. In our video calling system, the camera is installed at the position facing the user in Fig. 6 Furthermore, a polarizer is installed so as to cover the field of view of the camera. The direction of the transmission axis of this polarizer coincides with the direction of the transmission axis of the reflective polarizer. Thus, the camera can shoot the user observing the aerial image by passing through the reflective polarizer. Experimental results showed that even if the polarizer was arranged, the image was slightly reflected on the camera.

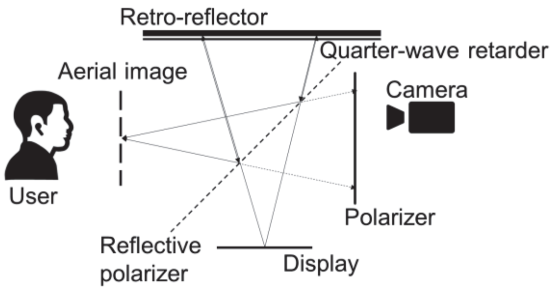


Fig. 6 The previous optical system for video calling interface with the see-through AIRR.

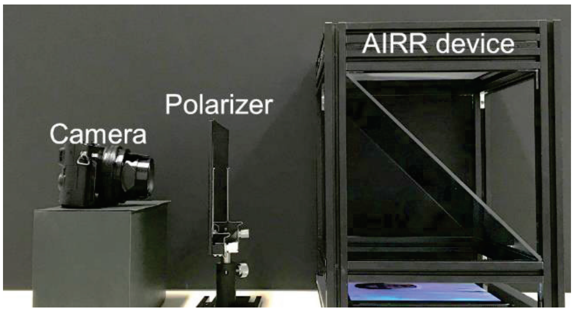


Fig. 7 A picture of the device used in the experiment in the previous optics.

Fig. 8 A result of the user observed from the camera installed in the device.

2.4.2 The New Proposed Optical System

In the conventional optical system (Fig. 6), the camera was placed behind the device. The transmission axes of the polarizer in front of the camera and the reflective polarizer plate were arranged in parallel-nicol. However, the surface of the reflective polarizing plate that reflects polarized light was facing the user side of this plate. Therefore, there is a possibility that the acrylic surface which is the base of reflective polarizer plate turned to the camera side, and a small amount of reflected light was imaged by the camera. Depending on the polarization status of the display, this light may include polarization that passes through the polarizer in front of the camera.

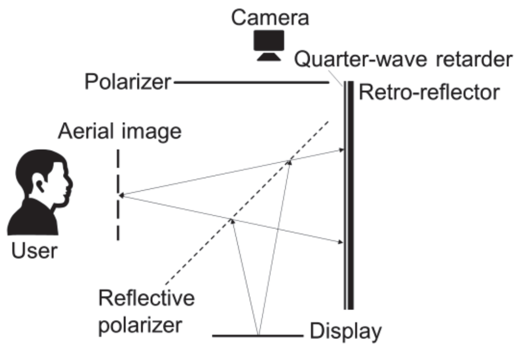


Fig. 9 Our new optical system for eye-matching video calling interface with AIRR.

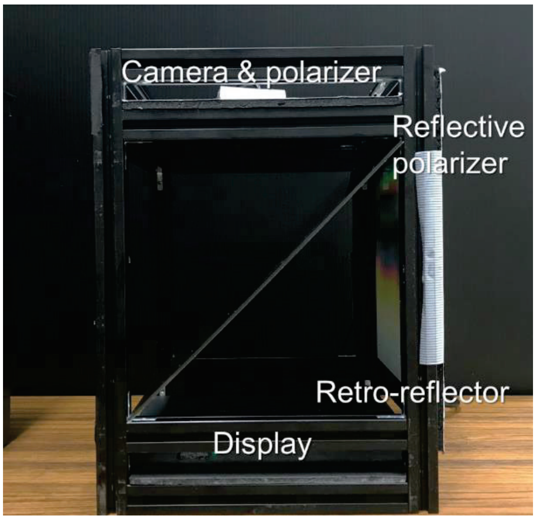


Fig. 10 A picture of the new configured device used in the experiment.

Fig. 11 Captured image of the user by the camera installed in the new optical system.

This work employs a new configuration. Fig. 9 shows our new optical system for eye-matching video calling system with AIRR. Fig. 10 shows a picture of the new configured device used in the experiment. Fig. 11 shows a result of the user observed from the camera installed in the new optical system. The positions of the camera and the retro-reflector are switched from Fig. 6. When the retro-reflector is placed on the behind of AIRR setups, the reflective surface of the reflective polarizer faces the display. Then, in front of the camera, a reflective polarizer and a polarizer with the transmission axis in a cross nicol arrangement are installed. Therefore, the light from the display is perfectly blocked and does not enter the camera. Although the camera is moved to the top of the AIRR setups, the user is captured via surface reflection of the reflective polarizer by the camera. Thus, we succeeded in maintaining the function of the video calling matching the viewpoint while completely blocking the light from the display.

3 RESULTS

We have developed the eye-matching video calling system by connecting two aerial video calling interfaces. Fig. 12 shows a photograph with two devices that show each other, where green and gray figures were placed instead of users. Fig. 13 shows the gray figure on the aerial screen and the green figure looking it. Fig. 14 shows the green figure on the aerial screen and the gray figure looking it. These results show that our new optical system is effective for eye-matching video calling system.

Fig. 12 Photograph of two aerial interfaces that show each other.

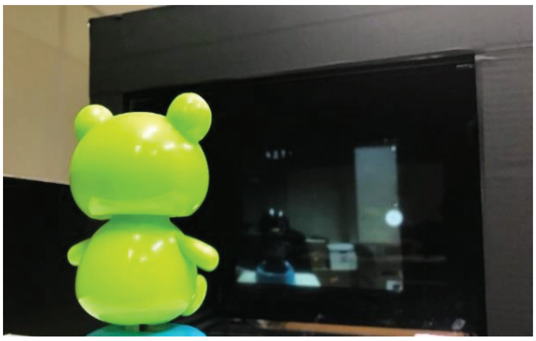


Fig. 13 The green figure watching the gray figure in the aerial screen with matching the viewpoint.

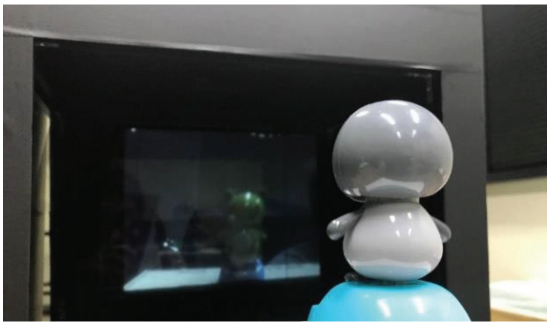


Fig. 14 The gray figure watching the green figure in the aerial screen with matching the viewpoint.

4 CONCLUSIONS

In previous research, we proposed a system that observes the user through a beam splitter, but there was a problem that the direct reflected light from the display was shown in the camera. Therefore, we proposed a method to observe the user by changing the position of the camera and the retro-reflector and reflecting it with a beam splitter, enabling clear user shooting. Using the prototype device created by this system, it was confirmed that video calls between two devices can be made with eye-matching.

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