See-Through Aerial Display with AIRR by Using Retro-Reflector as a Speaker

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1. Introduction

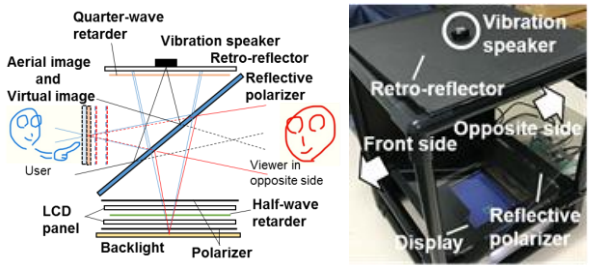
Aerial imaging by retro-reflection (AIRR) is a method to form an aerial image by use of a retro-reflector [1]. Use of polarization modulation in AIRR, which is called polarized AIRR (pAIRR), increases visibility of the formed aerial image [2]. The aerial image formed by AIRR has a wide viewing angle horizontally and vertically. However, when the formed aerial image is used for an interpersonal interface, the conventional AIRR had the problem that the user on the opposite side cannot see the aerial image.

In this paper, we propose a new aerial display that makes the aerial image and the user's gesture visible from the opposite side. Furthermore, we have introduced the vibrating speaker system in the AIRR [3] in order to make the sound emit from the aerial image.

2. Principle of see-through aerial display with AIRR by using retro-reflector as a speaker

Fig. 1 shows principle and the prototype devices' photograph of our see-through aerial display with AIRR by using retro-reflector as a speaker.

First, we illustrate the principle of our see-through aerial display in Fig. 1 (a). 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 that is visible for a user in the left side in the figure.



(a) (b)

Fig. 1 (a) Principle of our see-through aerial display when using the retro-reflector in AIRR as a speaker and (b) a photograph of our prototype device.

Next, the effect of vibrating the retro-reflector to be a speaker is shown in Fig. 1 (b). As shown in Fig. 1, the vibration speaker is attached to the backside of the retro-reflector. As a result, the retro-reflector vibrates and functions as a speaker. Sound generated from the retro-reflector is reflected by the beam splitter. Since this reflected sound reaches the user, the user can feel on it sound comes from the aerial image.

3. Experimental Results

Fig. 2 shows photographs of a user observing the aerial image from the front side using the see-through aerial display prototype. Fig. 2 (a) is a photograph taken from the

(a) (b) (c)

Fig. 2 Touching the aerial 3D image with both fingers (a) viewed in front of the user, (b) viewed from the opposite of the user, and (c) viewed from a right side of the user.

viewpoint position of the user. The user confirmed the aerial image and fixes the finger to the center position of F and B in the aerial display. Fig. 2 (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. Fig. 2 (c) is a photograph taken of the user from the right side. From the position of the finger of the user, it was found that the depth direction of the aerial image could be recognized.

In addition, because of vibrating the retro-reflector and using it as a speaker, the retro-reflector functioned as a sound source and was able to hear the sound from an aerial image. In addition, the aerial image was not disturbed by the vibration of the retro-reflector.

4. Conclusions

By using the retro-reflector as a vibration speaker, we proposed new see-through aerial display that we can hear the sound from the aerial image and the virtual image both of the front and the opposite users.

References

[1] H. Yamamoto, et al., Opt. Exp. 22, 26919 (2014).
[2] M. Nakajima, et al., Proc. IDW '15, FMC5-3 (2015).
[3] K. Fujii, et al., Proc. IDW '17, FMCp2-2 (2017).