Proposal of Spatial Blending That Realizes Eye-Matching by Use of Aerial Display

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Keywords: spatial blending, p-AIRR, eye-matching, real image, blend-ratio

ABSTRACT

We realized true-eye-matching between on-site observers and the on-line face image by the blended face image formed by the new optical system using two different facing floating face images in aerial imaging by retro-reflection. Our proposed method can successfully form the blended face image of desired blend-ratio without image inversion.

1 Introduction

Eye-matching is well known to be very important in real high-level communications. However, in the online several-for-one communication by using the two-dimensional (2D) display such as online meeting, the all audience always perceive eye-matching with a speaker. Therefore, the audience cannot perceive the actual line of sight and the actual face direction of the speaker. This leads to difficulty in realistic communication. Especially, in a hybrid conference consisting of onsite and online participants, more realistic communication can be realized if the online participant's gaze can be perceived to all onsite participants.

Using a three-dimensional display is one of the solution to this problem. However, it is not only expensive but also have a restricted vision to be applied to actual conference rooms where the observers may be several meters or more away from the display of online participant.

On the hand, in the preceding study [1], simple eye-matching method has been proposed as "spatial blending" that uses the blended face image formed by two 2D face images reflected in two mirrors. However, since this method uses two virtual 2D face images reflected in two mirrors, the face image to be blended and its background image inverted left to right.

The purpose of this study is to realize the method for displaying the gaze and face direction by spatial blending without inversion. We propose a new optical system of spatial blending by using Aerial imaging by retro-reflection (AIRR) and clarify that the gaze and the face direction of the blended face image changes by automatic changing of the blend-ratio of the blended face according to change of the observation angle.

2 Principles

2.1 Spatial Blending by Use of Two Mirrors

Figure 1 shows the principle of spatial blending by using two mirrors in preceding study. In this method, two mirrors that connected to form an obtuse angle α and tilted 45 degrees in the horizontal direction are used as shown in Fig. 1 (a). Two 2D face images are placed on the floor in front of the mirrors so that a straight line passing through the midpoint of the two nostrils of each of the face images shown in the upper left of Fig. 1 (b) overlaps the contact part of the two mirrors. As a result, when the observer changes the observation position, the blend-rate of the two virtual images of the face image facing different directions reflected in the mirrors autonomously changes as shown in Fig. 1 (c), so this method can display the gaze and face direction of the blended face.

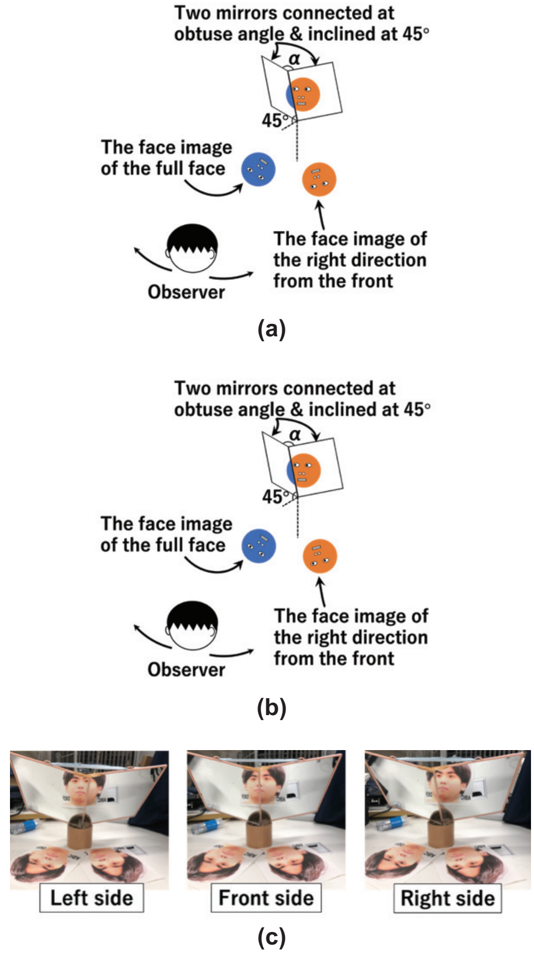


Fig. 1 Details of spatial blending by use of two mirrors. (a) Principle of spatial blending by using two mirrors. (b) Blending method of two face images in preceding study. (c) Blended face images changes by an observation position.

The left image in Fig 1 (c) shows the blended face image reflected in the mirrors when observer view it from the front left side of them. In this viewpoint, the observer can match his / her gaze and the blended face image's gaze and see that the blended face image appears to be looking at the observer.

The right image in Fig 1 (c) shows the blended face image reflected in the mirrors when observer view it from the front right side of them. In this viewpoint, the observer cannot match his / her gaze and the blended face image's gaze and see that the blended face image appears to be looking at left side of observer.

The central image in Fig 1 (c) shows the blended face image reflected in the mirrors when observer view it from the front of them. In this viewpoint, the observer also cannot match his / her gaze and the blended face image's gaze and see that the blended face image appears to be looking at left side of observer.

However, comparing the blended face image viewed from the front and front right side of the mirrors, the gaze and the face direction of the blended face viewed from the front appear to be looking more toward the observer. This indicates that spatial blending by using two mirrors can let observer perceive as if the gaze and the face direction of the blended face image reflected in the mirrors are facing a certain angle on the left side of the observer.

2.2 Aerial Imaging by Retro-Reflection by use of Polarization Modulation (p-AIRR)

Figure 2 shows the principle of aerial imaging by retro-reflection with polarization modulation (p-AIRR) [2], which is utilized for our spatial blending display.

The p-AIRR uses the optical system shown in Fig. 2, which is composed of a light source, a reflective polarizer, and a retro-reflector with λ/4 retarder film. First, light emitted from the light source impinges a reflective polarizer. This reflective polarizer reflects s-polarized light and transmits p-polarized light. The reflected s-polarized light impinges the retro-reflector through the λ/4 retarder film. Since s-polarized light passes through the λ/4 retarder film twice, s-polarized light is converted to p-polarized light. Thus, the retro-reflected light is p-polarized light. The retro-reflected light travels to converge to the light source position.

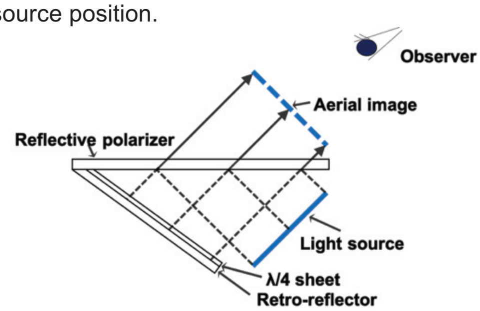


Fig. 2 Principle of p-AIRR.

After this retro-reflected p-polarized light enters the reflective polarizer again and passes through it, this light converges to the position that is plane symmetric with light source about the reflective polarizer as the axis and form an aerial image. The observer can view the aerial image only from the direction where the reflective polarizer and retro-reflector with λ/4 retarder film appear to overlap.

3 Blended Face Image Formed With p-AIRR

Figure 3 shows the photograph images of the blended face image formed by using p-AIRR, taken from the front, the front left side and the front right side. As with the spatial blending by using two mirrors shown in Fig. 1 (c), in the spatial blending by using p-AIRR, two 2D face images corresponding to the light source in Fig. 2 are placed so that a straight line passing through the midpoint of the two nostrils of each of the face images connected, when the blended face image is viewed. Herewith, the blend ratio of the two aerial face images among the blended aerial face image autonomously changes according to observer position change by the p-AIRR property that changing the area where the reflective polarizer and retro-reflector with λ/4 retarder film appear to overlap. Therefore, spatial blending by using p-AIRR also can let observer perceive the gaze and the face direction of the blended face image

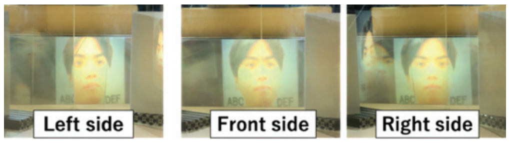


Fig. 3 Aerial image of blended face changes by an observation position.

Figure 4 shows the difference between the blended face image formed by using two mirrors and the blended face image formed by using p-AIRR. Left photograph image in Fig. 4 shows the blended face image formed by using two mirrors. By focusing on the English letters at the neck of the blended face image, the letters are reversed, so that the blended face image is also reversed. This is due to the fact that the blended face image is formed by two virtual 2D face images facing different directions.

On the other hand, right image in Fig. 4 shows the blended face image formed by using p-AIRR. By focusing on the English letters at the neck of the blended face image, unlike spatial blending by using two mirrors, observer find that the letters are not reversed, so that the blended face image is also not reversed. This is due to the fact that the blended face image is formed by the real images of two floating 2D face images facing different directions.

Figure 4 shows two blended face image formed by using the same the front-facing face image and the front right-facing face image, although the method of blending is different. However, when the blended face image formed by spatial blending using two mirrors is viewed from the front, the right half of the blended face image is formed by the left half of the front right-facing face image, while when the blended face image formed by spatial blending using p-AIRR is viewed from the front, the right half of the blended face image is formed by the right half of the front right-facing face image. This difference is also caused by the difference in whether the two 2D face images used to form the blended face image is real images or virtual images.

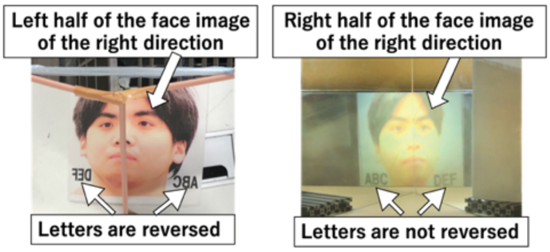


Fig. 4 Comparison of two blended face images.

4 Spatial Blending Ratio Change in New Optical System

In order to confirm whether the new optical system realize the spatial blending to display the gaze and the face direction of the blended face image, the change of the blend-ratio of two face images facing different directions among the blended face image was measured with several conditions below.

Condition 1: The light source is positioned so that when the blended face image is viewed from the front, the left half of the blended face image is formed by the front-facing image colored blue and the right half of the blended face image is formed by the face image facing 10 degrees to the right of the front colored orange

Condition 2: The light source is positioned so that when the blended face image is viewed from the front, the left half of the blended face image is formed by the front-facing image colored blue and the right half of the blended face image is formed by the face image facing 20 degrees to the right of the front colored orange

Condition 3: The light source is positioned so that when the blended face image is viewed from the front, the left half of the blended face image is formed by the face image facing 10 degrees to the left of the front colored blue and the right half of the blended face image is formed by the front-facing image colored orange

Condition 4: The light source is positioned so that when the blended face image is viewed from the front, the left half of the blended face image is formed by the face image facing 20 degrees to the left of the front colored blue and the right half of the blended face image s formed by the front-facing image colored orange.

Figures 5 to 8 show the blended face image changes when the observer changes observation angle in conditions 1 to 4, and the blend-ratio of each two face images facing different directions in the blended face image viewed several observation angles. The blend-ratio (%) was calculated by dividing the area of the aerial image of the front-facing image by the total area of the aerial image of the blended face image using the captured images of the blended face image. The observation angle (°) was obtained by converting the value of tangent calculated by dividing the movement distance (mm) of the observation position from the front of the blended face image by 800 mm that is the observation distance of the blended face image is viewed from the front.

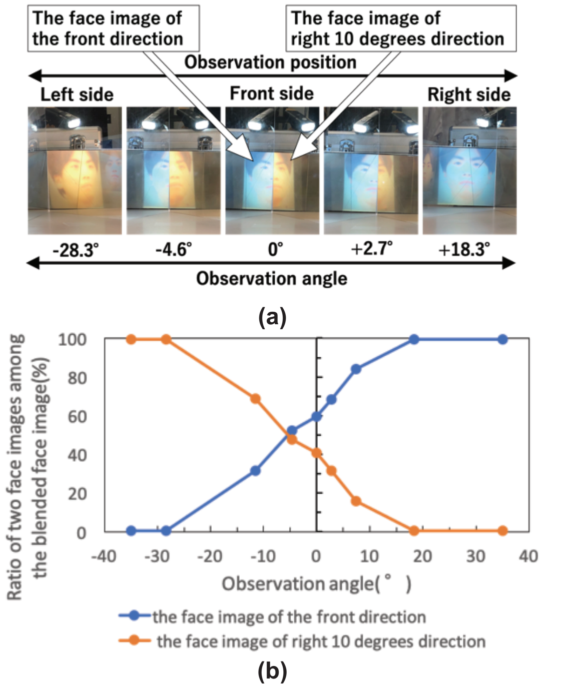


Fig. 5 Details of the blended face image in Condition 1 (orange: the face image of right 10 degrees direction, blue: the face image of the front direction). (a) Aerial image of the blended face changes by an observation position. (b) Ratio of two face images among the blended face image.

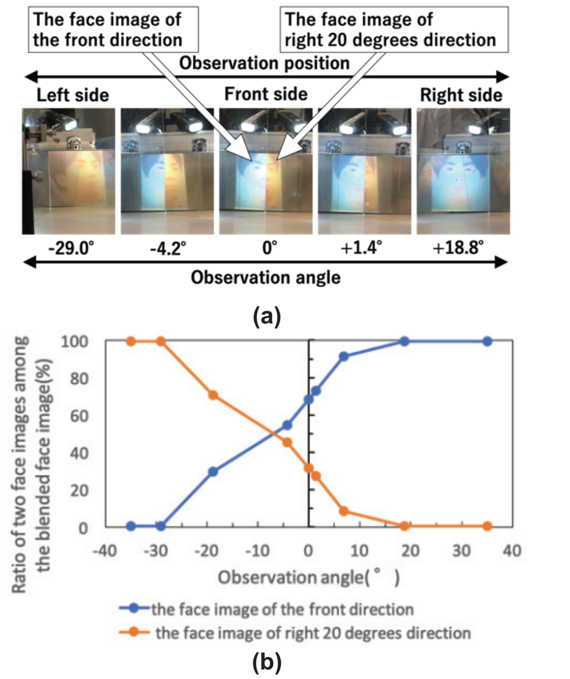
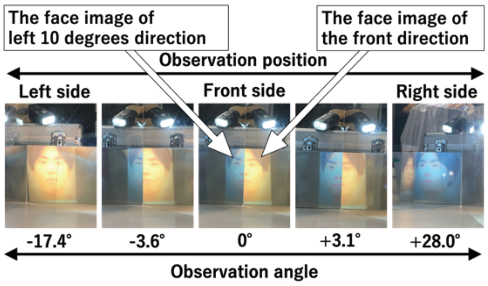
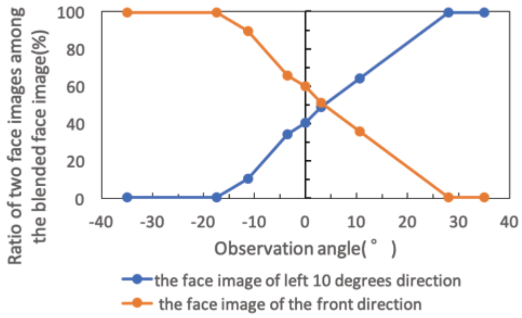


Fig. 6 Details of the blended face image in Condition 2 (orange : the face image of right 20 degrees direction, blue : the face image of the front direction). (a) Aerial image of the blended face changes by an observation position. (b) Ratio of two face images among the blended face image.

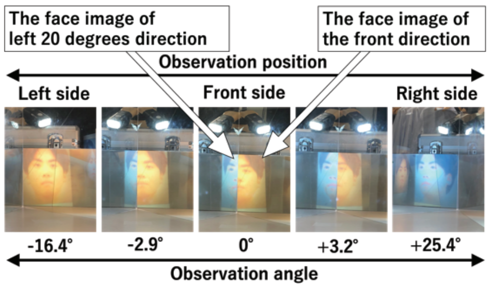


(a)

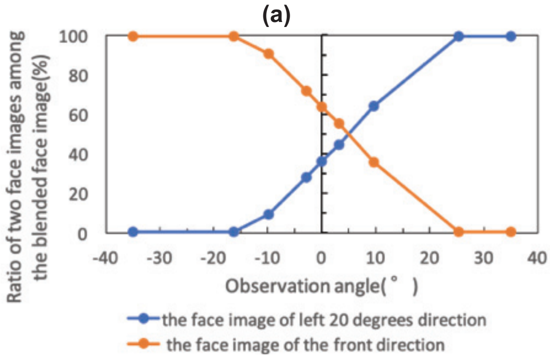


(b)

Fig. 7 Details of the blended face image in Condition 3 (orange : the face image of the front direction, blue : the face image of left 10 degrees direction). (a) Aerial image of the blended face changes by an observation position. (b) Ratio of two face images among the blended face image.



(a)



(b)

Fig. 8 Details of the blended face image in Condition 4 (orange : the face image of the front direction, blue : the face image of left 20 degrees direction). (a) Aerial image of the blended face changes by an observation position. (b) Ratio of two face images among the blended face image.

Figures 5 to 8 show that the blended face image appears to face the observer's right side when the observation position is from the left side to the front side, and the facing direction of the blended face image appears to gradually turn toward the direction of the observer as the observation position is moved from the front side to the right side in condition 1 and 2.

Figures 5 to 8 also show that the blended face image appears to face the observer's left side when the observation position is from the right side to the front side, and the facing direction of the blended face image appears to gradually turn toward the direction of the observer as the observation position is moved from the front side to the left side in condition 3 and 4. From the graphs in Fig. 5 to 8 showing the blend-ratio of the blended face image, it can be seen that the bias of the area of the two face images formed the blended face image affects the angle of visibility of the blended face image.

5 Conclusions

In this study, we have proposed the method for displaying gazing and the face direction by "spatial blending" of forming the blended face image composed by two aerial 2D face images using p-AIRR.

By using the colored face images for estimation to form the blended face image, blend-ratio of the blended face image can be successfully changed with observation angle.

Our future works include investigation of the influence that changing of the blend-ratio gives the recognition of the gaze and the direction of the face.

Acknowledgements

A part of this work was supported by JSPS KAKENHI (19H04155, 20H05702).

References

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