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Pseudo Gaze Direction Change for 2D Communications by Spatial Blending and Boundary Blending of Luminance of 2D Face Images with Different Gaze Directions

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ABSTRACT

Perceived gaze direction can be successfully changed by spatial blending of two faces with different gaze directions. Composite face image by spatial blending can easily change perceived gaze direction only by changing blending ratio. Boundary blending of luminance at boundary region also facilitate face spatial blending.

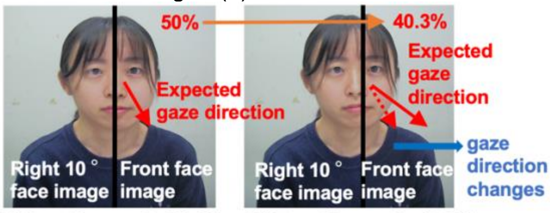
1 Introduction

In meetings where a large number of people participate, such as web conferencing tools that have become mainstream in today's COVID-19 situation, it is a problem that the speaker does not know whom he/she is talking to [1]. This is because it is difficult to determine where the other party is facing on the 2D display. In communication, gaze direction of participants plays an important role in transmitting nonverbal signals [2,3]. Of course, it can be solved by using a 3D display, but it is not practical at present because the 3D display equipment is large and expensive, or head mounted display covers eyes area. In order to solve this problem practically, we propose a pseudo gaze direction change method by spatial blending of 2D face images by image reconstruction in brain as a system that can easily express the orientation of the face using only a 2D display and two cameras.

In this study, as a basic study before applying it to actual images, we evaluated the possibility of expressing a pseudo gaze direction by combining 2D face images taken from various directions. Unnaturalness and changes in the gaze direction due to the spatial blending of the face and comparison of the gaze directions when boundary blending of luminance is applied at boundary of two face images in spatial blending are also estimated.

2 Proposal of pseudo gaze direction change method by spatial blending of 2D face images

Figure 1 shows an example of a composite face image in a gaze expression method that combines 2D face images taken by two cameras with different camera angles. When face images taken from the front and left or right side are combined and a thick line is displayed boundary of two faces, the invisible image behind thick line is reconstructed in the brain by the occlusion (shielding) effect, and it looks like one composite face image. In this study, this perceptual phenomenon is called spatial blending. If this line is absent or thin, the occlusion effect will be small, and it will be difficult to feel natural face image connected behind the line. In the composite face image shown in Fig. 1 (a), it can be perceived as facing slightly to the right with respect to the front. In addition, by changing the size ratio of the combination of the left and right face images as shown in Fig. 1 (b), the gaze direction of the composite face image can be perceived as changing to right direction by spatial blending. That is, in Fig. 1 (b), the gaze direction changes further to the right than that in Fig. 1 (a).



(a) Front face ratio:50.0% (b) Front face ratio:40.3%
Fig. 1 Examples of composite face images by spatial blending of 2D face image

3 Evaluation experiment of gaze direction by spatial blending

3.1 Experimental Method

Figure 2 shows an experimental system for capturing 2D facial images from various angles. A 2D camera was set to 0°, and the other 2D camera was set at the angle θ position from the front camera. θ was changed from −40° to + 40°, and two faces were photographed at the same time. The captured facial images were combined as shown in Fig. 1, the unnaturalness of the face was evaluated, and the appropriate combination of the imaging angles of the facial images was selected. The size of the composite face image used for the evaluation is 61.0 cm × 21.3 cm, and the thickness of the line at the joint was 37 mm.

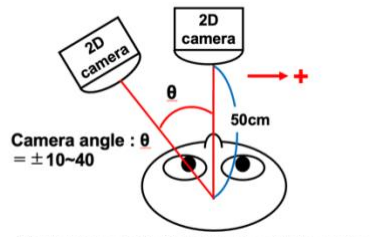


Fig.2 Camera angles for taking face photographs at the same time

Figure 3 shows an experimental system for evaluating the gaze direction of synthetic facial images. Using a combination image of face angles with less unnaturalness, the subjects were asked to evaluate where the gaze was perceived by changing the size ratio of the left and right with a ruler in front of the subject. The ratio of the left and right combination was taken from the front face, and the ratio was changed from 35.6% to 62.0%, which was the range that can be recognized as a natural face.

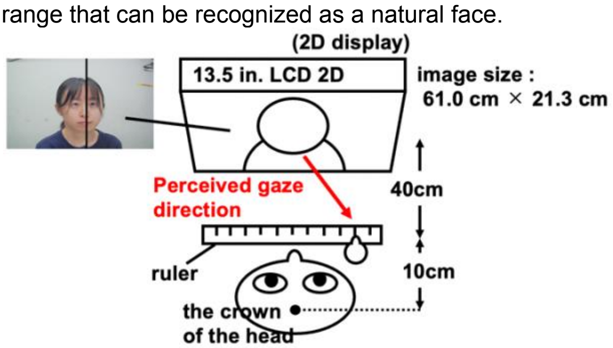


Fig.3 Experimental system for evaluation of perceived gaze in the composite face image

3.2 Experimental Results

Table 1 shows the results of evaluating the unnaturalness of the composite face image by changing the shooting angle of the face from -40° to + 40° with the front as 0° and combining these with the ratio of the front face by 50%.

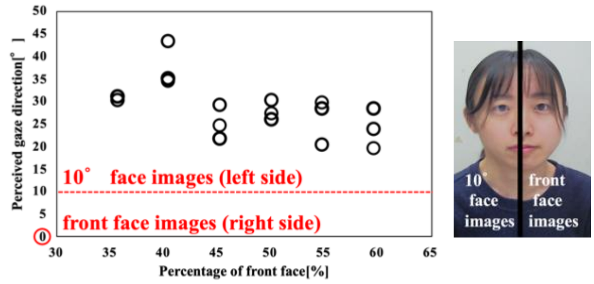
Table 1. Evaluation of the appearance of the composite face image of each angle and front face

θ [°]	Evaluation [○△×]	θ [°]	Evaluation [○△×]
−10	○	10	○
−15	○	15	○
−20	○	20	○
−25	△	25	○
−30	△	30	△
−35	×	35	×
−40	×	40	×

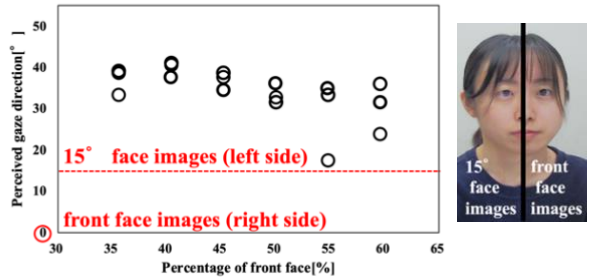
[○]:"Natural as a face",
[△]:"Slightly unnatural as a face",
[×]:"Unnatural as a face"

This indicates that, in order to express the gaze direction by spatial blending, the limit of naturalness as a face without discomfort is 10° to 20°. Unnaturalness or discomfort is felt as a face above 35°. According to the subject's introspection report, the laterality of the facial contour also affects the unnaturalness.

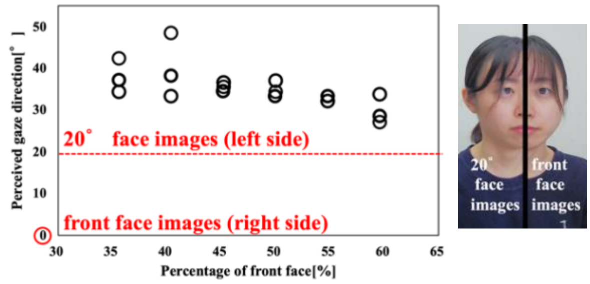
The perceived gaze direction of the composite face image with changing the size ratio of front face image was evaluated using the combination of the 10°, 15°, and 20° face images and the front face, whose combinations were less unnatural due to the spatial blending of the 2D face image. Figure 4 shows perceived gaze direction dependences with the direction toward the nose of the subject as 0° and the right direction as positive.



(a) Combination of front and 10° face images



(b) Combination of front and 15° face images



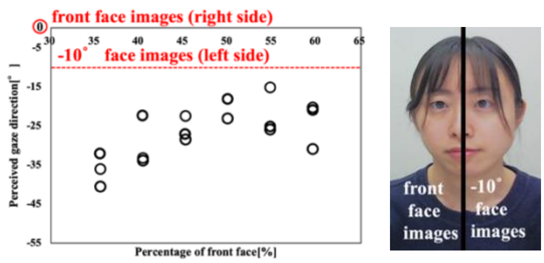
(c) Combination of front and 20° face images

Fig. 4 Perceived direction of the gaze of the composite front and right face images

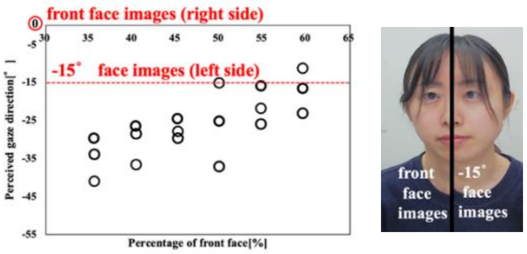
The perceived gaze direction of the composite face image was smoothly changed by changing the size ratio.

Since the perceived change in the gaze direction was larger at 20° than at 10° and 15°, the larger the combined face angle, the larger the change in the gaze direction. However, there was an introspection report that when the angle of the combined face became large, the appearance of the face became unnatural and the orientation became difficult to understand.

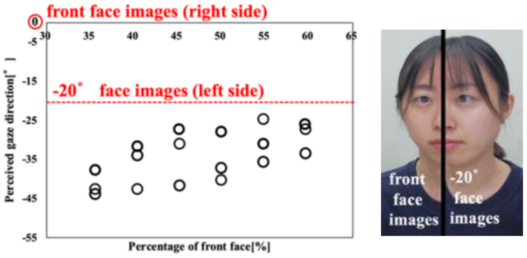
Figure 5 shows the perceived gaze direction of the composite face image in combination with the face images of -10°, -15°, and -20° taken from the left side and the front.



(a) Combination of front and -10° face images



(b) Combination of front and -15° face images



(c) Combination of front and -20° face images

Fig. 5 Perceived direction of the gaze of the composite front and left face images

The gaze direction also changed when combined with the face on the left side. In combination with -10°, when the proportion of the front face exceeded 55%, the gaze direction changed in the direction opposite to the intended direction. This is due to the laterality of the subject's face.

4 Evaluation of gaze direction by spatial blending and boundary blending of luminance

In order to eliminate the unnaturalness of the composite face image, boundary blending [4] of luminance of two face images is was performed in addition to spatial blending, and then the gaze direction was evaluated.

4.1 Synthesis method by boundary blending of luminance

Figure 6 shows the synthesis method of two face images by boundary blending of luminance. A linear gradation with a width of 37 mm was created at the boundary between the two images, and the luminance was mixed linearly. The calculation formula (1) for synthesis is as follows.

$$\{(a)\times(b)\}+\{(d)\times(e)\} \qquad \text{\_\_\_\_\_\_(1)}$$

Assuming that the coordinates in the horizontal direction are w, the luminance L is given by equations (2) and (3) for (a) and (d), respectively.

$$L = \begin{cases} 0 & (\mathrm{w} < \mathrm{w1}) \\ (\mathrm{w}-\mathrm{w1})/(\mathrm{w2}-\mathrm{w1}) & (\mathrm{w1} \le \mathrm{w} \le \mathrm{w2}) \\ 1 & (\mathrm{w2} < \mathrm{w}) \end{cases} \qquad \text{\_\_(2)}$$

$$L = \begin{cases} 1 & (\mathrm{w} < \mathrm{w1}) \\ (\mathrm{w1}-\mathrm{w})/(\mathrm{w1}-\mathrm{w2}) & (\mathrm{w1} \le \mathrm{w} \le \mathrm{w2}) \\ 0 & (\mathrm{w2} < \mathrm{w}) \end{cases} \qquad \text{\_\_(3)}$$

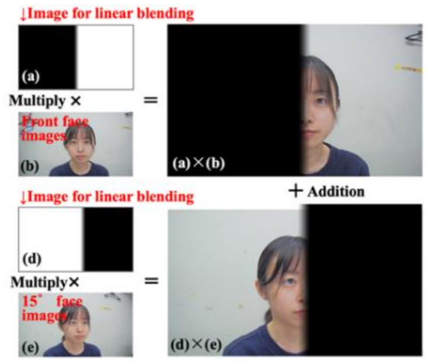


Fig. 6 Synthesis method by boundary blending of luminance

Figure 7 shows the changes before and after boundary blending of luminance. The boundary blending of luminance process has significantly reduced the unnaturalness.

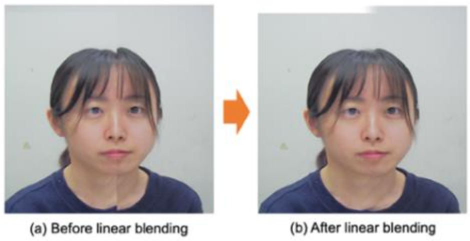


Fig. 7 Changes before and after boundary blending of luminance

4.2 Experimental Method

Figure 8 shows the composite face image used in the evaluation experiment with boundary blending. Four types of boundary blendings shown in Figs. 8 (a) to (d) were estimated. The experimental method is similar to that described in Section 3.1.

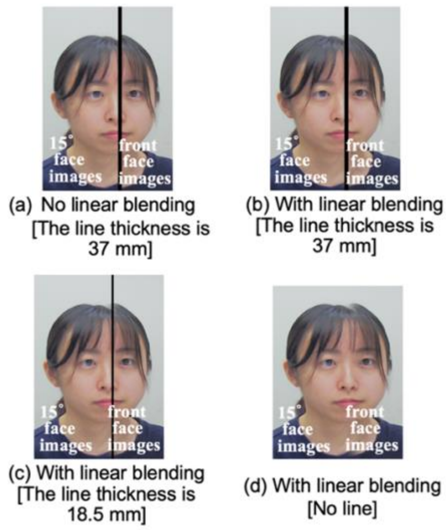
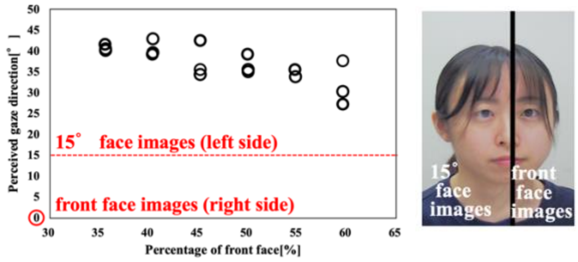


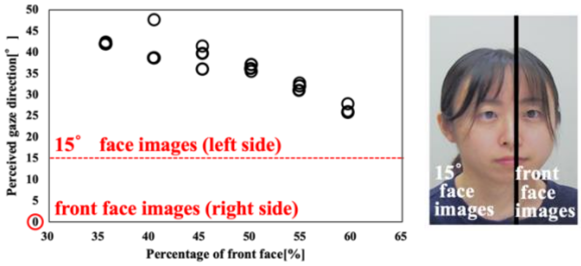
Fig. 8 Photograph used in the evaluation experiment

4.3 Experimental Results

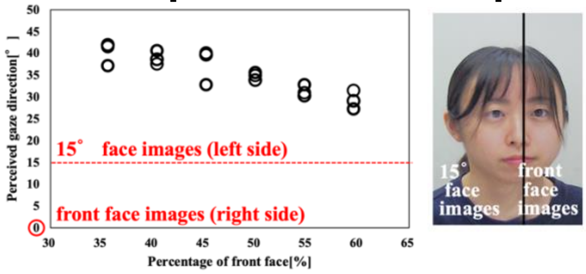
Figure 9 shows the perceived gaze direction of the composite face image by spatial blending and boundary blending of luminance with changing the size ratio of front face image.



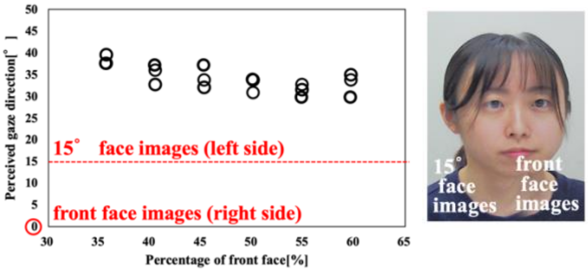
(a) No boundary blending of luminance [The line thickness is 37 mm]



(b) With boundary blending of luminance [The line thickness is 37 mm]



(c) With boundary blending of luminance [The line thickness is 18.5 mm]



(d) With boundary blending of luminance [No line]

Fig. 9 Evaluation of gaze direction by spatial blending and boundary blending of luminance

The width of the gaze movement is wider and the perception is smoother when the boundary blending of luminance is used. In addition, when there was no line at the joint of faces, perceived gaze direction change is small. This is because the boundary blending without the line makes it look like a real face, and both eyes are recognized like crossing eyes.

5 Conclusions

We evaluated the pseudo changes in the gaze direction perceived by the spatial blending of 2D facial images.

The composite face image is complemented in the brain by combining the 2D face images taken from the front and the left and right, and the perceived gaze direction can be changed by changing the size ratio of the left and right combination. In addition, the gaze direction changes more smoothly by reducing the unnaturalness by boundary blending of luminance.

Thus, our special blending of faces can successfully achieve perceived gaze direction change by combining two 2D face images, and our simple gaze display method by spatial blending of the face image ispromising.

Acknowledgement

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References

[1] Y.Takemae, “Experimental ecaluation of video editing based on participants,’ gaze for face-to-face multiparty conversations,” The Journal of Image Information and Television Engineers, vol.59, No.12, pp. 1822–1829 (2005)

[2] S.Kikuchi, M.Kamachi, S.Akamatsu, “Building a 3D Model of the Face that Transmits an Arbitrary Combination of Identity, Facial Expression, and Gaze,” The Journal of the Institute of Image Electronics Engineers of Japan, vol.37, No.3, pp.189-195(2008)

[3] K.Iso, S.Ozawa, M.Date, H.takada, Y.Andoh, N.Matsuura, “Video Conference 3D Display That Fuses Images to Replicate Gaze Direction, ”Journal of Display Technology vol.8, No.9, pp.511-520(2012)

[4] M.Date, S.Shimizu, H.Kimata, D.Mikami, Y.Kusachi, “Depth Range Control in Visually Equivalent Light Field 3D, ” Special Section on Electronic Displays, vol.E104, No.2, pp.52-58(2021)