3D Image Depth Enlargement in Large Edge-Based DFD Display with Long Viewing Distance by Blurring Edge Images

Hideto Matsubara, Haruki Mizushina, Shiro Suyama

Tokushima University, 2-1 Minami-josanjima-cho, Tokushima-shi, Tokushima 770-8506, Japan
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ABSTRACT

We can successfully extend depth-fusion limit of front-rear gap from two image depths to one perceived depth by blurring edge image in large Edge-based DFD display with long-viewing distance. As viewing distance is increased, blurring width for depth-fusion can be effectively reduced.

1 INTRODUCTION

For high-realistic imaging or digital signage, large 3D display without 3D glasses and with sufficient large depth at long viewing distance will be promising. However, as display size is increased, glassless stereoscopic or multi-view displays have difficulty in construction of large special optical system, such as lenticular lens or parallax barrier.

On the other hand, DFD (Depth-fused 3D) display [1] can make perceive 3D image without 3D glasses and do not need complicated and expensive optics but only two layered 2D displays with a gap. In order to apply DFD display to large 3D display, it is necessary to enlarge viewing distance and front-rear gap to obtain deep 3D images. However, when front-rear gap exceeds 5 arcmin., DFD images are degraded to have depth separation into front and rear planes or uncontrollable depth around midpoint between front and rea planes as shown in Fig. 1 [2].

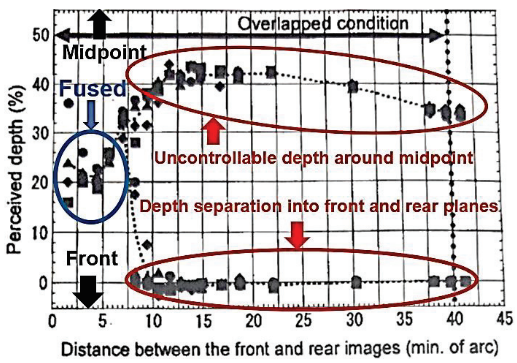

Fig. 1 Evaluation results of depth-fusion limit of front-rear gap in previous research

Nagao reported that this depth separation can be solved by blurring edge-part image as shown in Fig. 3 [3]. However, at large and long-viewing distance DFD display, depth-fusion limit of front-rear gap with burring edge image has not been clarified yet.

In this paper, we evaluated improvement of depth-fusion limit of front-rear gap and depth separation to front and rear planes in large Edge-based DFD display [4] with long-viewing distances by changing edge image blurring.

2 PRINCIPLE OF EDGE-BASED DFD DISPLAY

Principle of Edge-based DFD display is shown in Fig. 2. Edge-based DFD display is composed of projected 2D image of desired 3D image and its edge part with a gap [3]. By overlapping these two images from observer's position, a single depth can be perceived and changed according to edge-part luminance change.

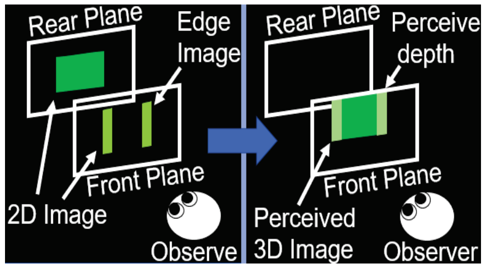

Fig. 2 Principle of Edge-based DFD display

3 EXPERIMENTAL SYSTEM FOR ESTIMATING DEPTH-FUSION LIMIT

Figure 3 shows experimental apparatus to evaluate improvement of depth-fusion limit of front-rear gap and depth separation to front and rear planes in large Edge-based DFD display with long-viewing distances by changing edge image blurring. Viewing distances were 3.5 m, 5.0 m and 10 m. Front-rear gap was changed from 1.5 arcmin. to 20 arcmin. Blurring widths were 0 pixel (no blurring), 20 pixels and 40 pixels. These blurring widths correspond to 0, 15 and 29 arcmin. at viewing distance of 3.5 m, 0, 11 and 21 arcmin. at viewing distance of 5.0 m and 0, 5.4 and 11 arcmin. at viewing distance of 10 m. As viewing distance was changed, visual angle of blurring width (arcmin.) are changed even in the same blurring pixels. Front and rear luminances were 100 % and 60 %.

Figure 4 shows measuring method of perceived depth. Two perceived depths of front side and rear side were evaluated at one trial by moving reference object from front plane or rear plane. When these two perceived depths were almost the same, DFD image was depth-fused, or different perceived depths indicate depth separation.

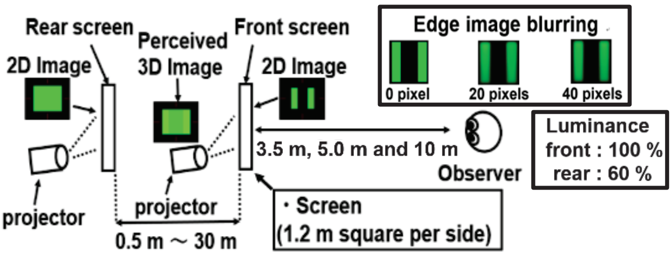

Fig. 3 Experimental apparatus of large Edge-based DFD display at long-viewing distance

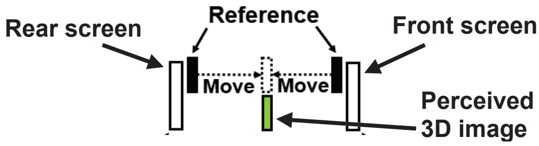

Fig. 4 Measuring method of perceived depth

4 DEPTH-FUSION LIMIT WHEN CHANGING VIEWING DISTANCES AND CHANGING BLURRING WIDTHS

Figure 5 shows depth-fusion limit difference at viewing distance of 3.5 m by changing blurring widths. (A) When blurring width is 0 pixel (no blurring), depth-fusion limit of front-rear gap is 5.6 arcmin. which is the same as that at near viewing distance in Fig. 1. On the other hand, (B) when blurring width is 20 pixels (15 arcmin.), depth-fusion limit can be increased to front-rear gap of 9.6 arcmin. Moreover, (C) when blurring is increased to 40 pixels (29 arcmin.), perceived depth can be fused up to front-rear gap of 16.2 arcmin.

Figure 6 shows depth-fusion limit difference at viewing distance of 5.0 m by changing blurring widths. (A) When blurring width is 0 pixel (no blurring), depth-fusion limit of front-rear gap is 5.7 arcmin. which is the same as that at near viewing distance in Fig. 1. On the other hand, (B) when blurring width is 20 pixels (11 arcmin.), depth-fusion limit can be increased to front-rear gap of 9.8 arcmin. Moreover, (C) when blurring is increased to 40 pixels (21 arcmin.), perceived depth can be fused up to front-rear gap of 16.5 arcmin.

As compared to viewing angles of blurring widths in Fig. 5, viewing angles of blurring widths (arcmin.) are reduced in Fig. 6. However, improved depth-fusion limits are almost the same as those in Fig. 5. This indicates that blurring effect for enlarging fusion limit is increased as viewing distance increased, resulting in comparatively higher resolution DFD images for observer.

Figure 7 shows depth-fusion limit difference at viewing distance of 10 m by changing blurring widths. (A) When blurring width is 0 pixel (no blurring), depth-fusion limit of front-rear gap is 5.9 arcmin. which is the same as that at near viewing distance in Fig. 1. On the other hand, when blurring widths are (B) 20 pixels (5.4 arcmin.) and (C) 40 pixels (11 arcmin.), depth-fusion limit exceeds front-rear gap of 5.9 arcmin.

Thus, depth-fusion limit of front-rear gap can be increased by small viewing angle of blurring width at long-viewing distance in Edge-based DFD display.

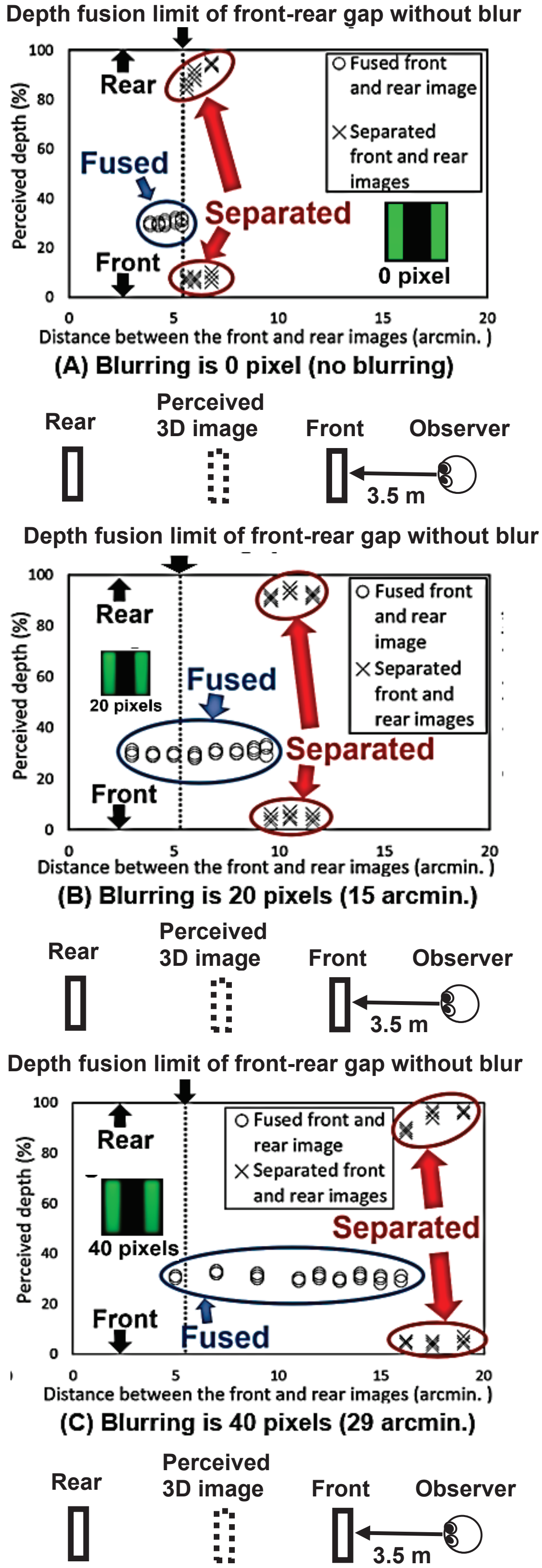

Fig. 5 Depth-fusion limit change between depth-fused and separated regions by three blurring widths at viewing distance of 3.5 m

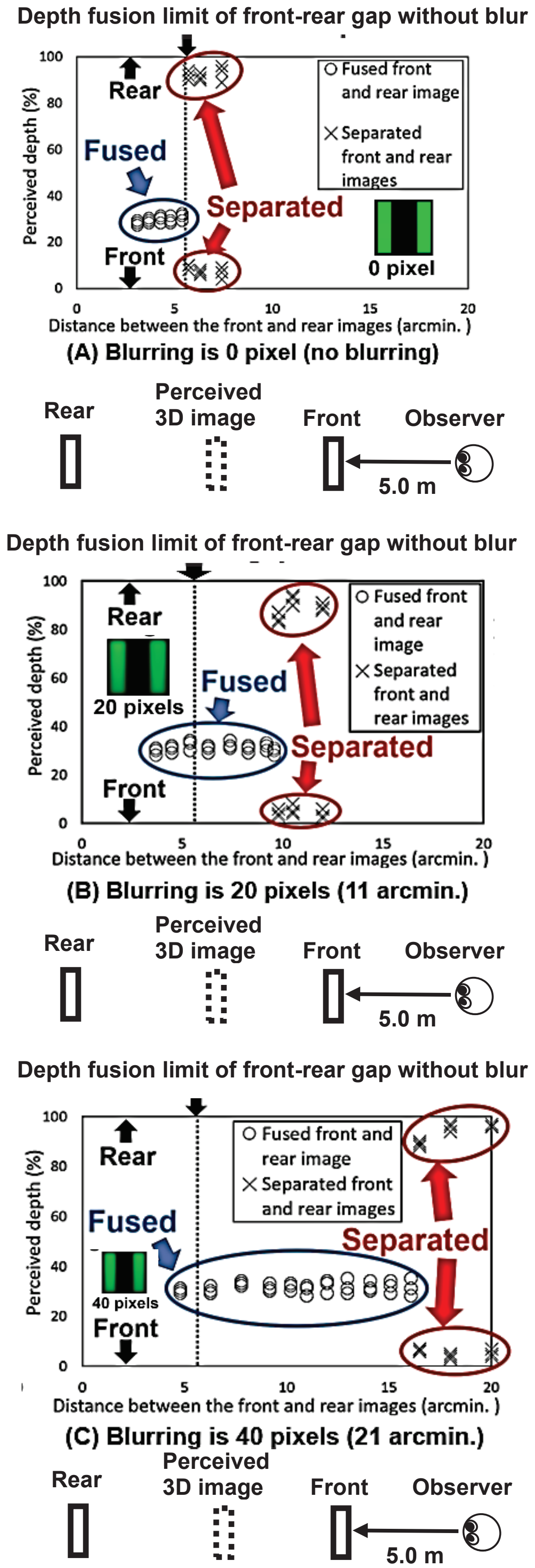

Fig. 6 Depth-fusion limit change between depth-fused and separated regions by three blurring widths at viewing distance of 5.0 m

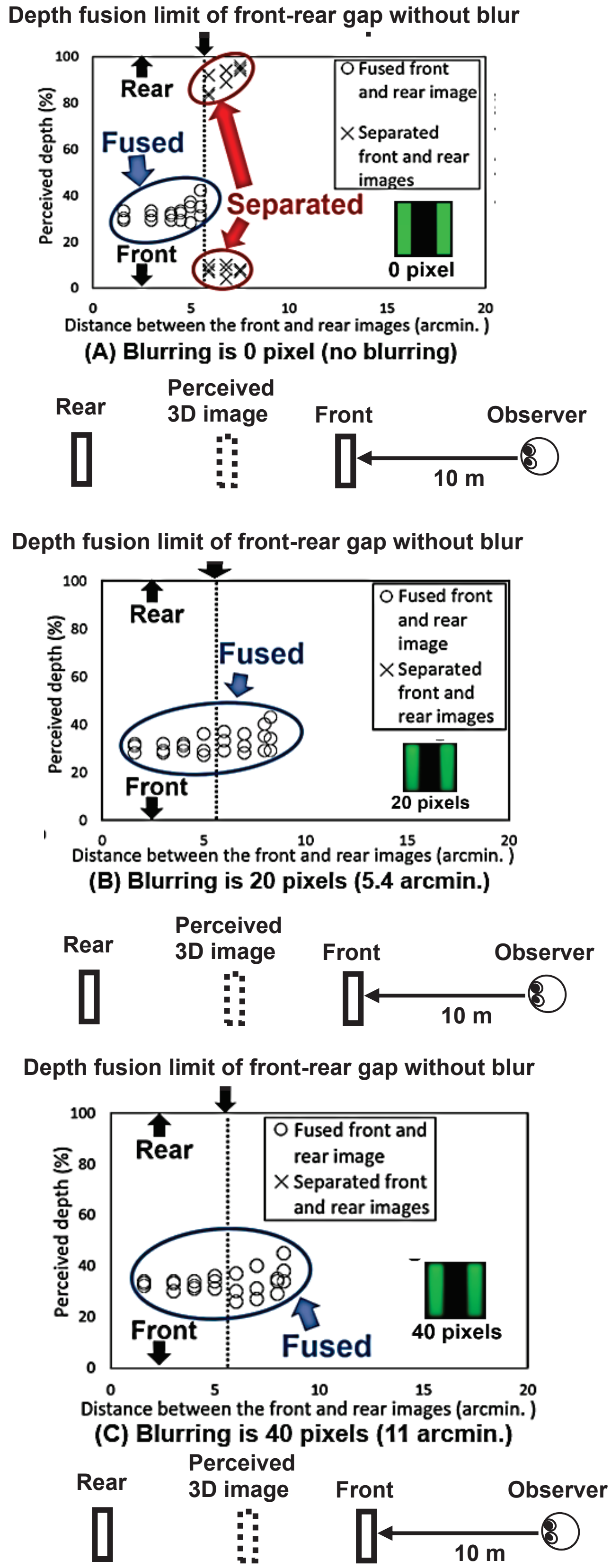

Fig. 7 Depth-fusion limit change between depth-fused and separated regions by three blurring widths at viewing distance of 10 m

5 DEPTH-FUSION LIMIT BY CHANGING GAZE POSITION AT VIEWING DISTANCE OF 3.5 m WITHOUT BLURRING

As shown in Fig. 1, in conventional DFD display, when distance between front and rear planes exceeds over 5 arcmin., 3D images are degraded to have depth separation or uncontrollable depth around midpoint between front and rear planes. This midpoint uncontrollable depth is perceived only when gaze position is set at midpoint and is not observed together with front or rear image.

In Edge-based DFD display, only the edge parts are overlapped. However, wide middle area is not overlapped but set at only rear plane, which is different from those in conventional DFD display. As this configuration difference seems to affect depth degradation characteristics, we examined them by changing gaze positions.

Figure 8 shows depth degradation difference at viewing distance of 3.5 m by changing gaze position without blurring. (A) When gaze position is set to the rear planes, perceived depth is separated to front and rear planes over the distance of 5.5 arcmin. which is the same as that at near viewing distance in Fig. 1.

On the other hand, (B) when gaze position is set at front plane, both midpoint uncontrollable depth and front edge images are observed at the same time over the distance of 5.5 arcmin. This phenomenon in two observable depths of midpoint and front plane is different from that in conventional DFD display, whose midpoint depth is not observed together with front or rear image. This is due to configuration difference, especially inner lines of edge images.

Thus, depth fusion characteristics are clarified to be affected by gaze position.

6 CONCLUSION

We evaluated improvement of depth-fusion limit of front-rear gap and depth separation to front and rear planes in large Edge-based DFD display [4] with long-viewing distances by changing edge image blurring.

Depth-fusion in Edge-based DFD display becomes easier as the viewing distance and blurring width of edge part increases.

Moreover, Edge-based DFD display has different characteristics of depth perception degradation from those in conventional DFD display by changing the gaze position.

Thus, depth-fusion limit of front-rear gap can be increased by small viewing angle of blurring width at long-viewing distance in Edge-based DFD display. This indicates that Edge-based DFD display is promising for various applications at long-viewing distance.

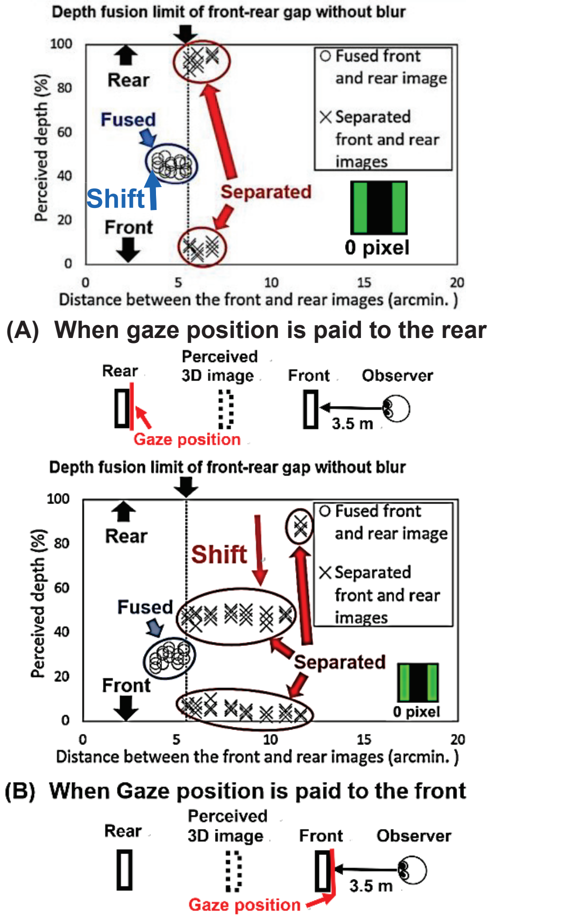

Fig. 8 Characteristics change of depth-fusion limit between depth-fused and separated regions by changing gaze position at viewing distance of 3.5 m without blurring

ACKNOWLEDGMENT

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