Study of Visual Phenomena in Edge Blur

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Abstract— **The newly discovered edge visual phenomena are as follows: when there is a blurred region at the edge, the perceived density changes in the entire area on both sides of the edge. In other words, if the edge is blurred, the contrast will be reduced in the surrounding area. Furthermore, the influence of the density change due to the observation time is not studied, but we found that the change in perceived density affects the image quality depending on the gazing time. In this paper, we quantitatively clarify visual phenomena due to edge blurring. Also, we clarify the relationship between the width of edge blur and the gazing time. To summarize the phenomenon of edge blur, if there is no blur width, Chevreul illusion occurs, and as the blurring expands, the Mach band occurs and the contrast decreases. The contrast caused by these series of phenomena becomes conspicuous as the gazing time becomes longer, and the decline of contrast leads to a phenomenon related to Troxler effect. We described the influence on texture and the necessity of gazing time in image evaluation.**

Keywords—component; formatting; style; styling; insert (key words)

I. INTRODUCTION

The following three visual phenomena have been confirmed as a visual effect occurring at an edge having a density change[1]: 1) Mach band, a phenomenon in which a line emphasized by a density gradient is perceived; 2) Chevreul illusion, a phenomenon in which a line emphasized by a density change as an edge without a density gradient is perceived; and 3) the Craik-O'Brien-Cornsweet effect, where after adding contours with density gradients in a uniform gray area, different densities are perceived in the areas on both sides of the contour[2]. These are considered to be different phenomena. However, we found that the occurrence of these phenomena depend on the width of the edge blur. The newly discovered edge visual phenomena are as follows: when there is a blurred region at the edge, the perceived density changes in the entire area on both sides of the edge. In other words, if the edge is blurred, the contrast will be reduced in the surrounding area. In glare illusion, the white area surrounded by the gradation is felt shinier than the white area surrounded by the uniform gray. The glare image was reported to be 40% brighter than a uniform gray image around it [3].

In the above studies, the influence of the density change due to the observation time is not studied, but we found that the change in perceived density affects the image quality depending on the gazing time. In this paper, we quantitatively clarify visual phenomena due to edge blurring. Also, we clarify the relationship between the width of edge blur and the gazing time.

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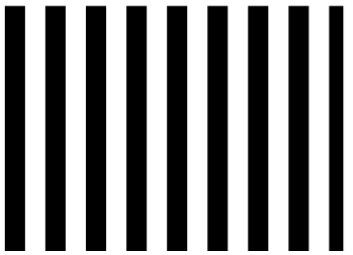

(a) Blur width 0 pixels

(b) Blur width 16 pixels

(c) Blur width 64 pixels

Fig. 1. The evaluation images for the edge visual phenomenon

II. VISUAL PHENOMENA OF EDGE BLURRING

We prepared an evaluation image in which blurring was applied to the edge portion of a black and white vertical striped pattern. When the subjects see it, they feel that the density of the stripe changes. In the case of the black band, the density appears low (bright), and in the white band, the density appears high (dark). This effect is the edge visual phenomenon.

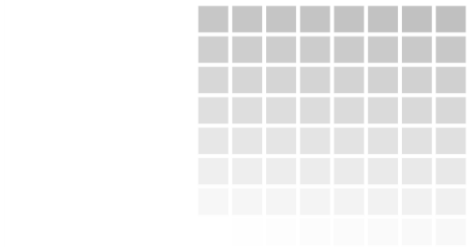

Fig. 2. An index image for evaluating the density of the white band

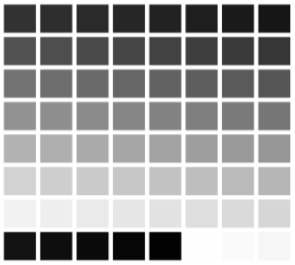

Fig. 3. An index image for evaluating the density of the black band

Fig.1 shows the evaluation image of the edge visual phenomenon. Fig. 1 (a) is an image of a black-and-white stripe of 64 pixels without blurring at the edge. Fig. 1 (b) is an image obtained by adding a blur width of 16 pixels to (a). Fig. 1 (c) is an image obtained by adding a blur width of 64 pixels to (a). In this experiment, one pixel is 0.18 mm on the paper surface. Black bands and white bands in (a), (b) and (c) are the same density except for the width of blur. Observers feel that the density of the bands is changing.

A. Experiment

In the experiment used with a monitor, the afterimages were intense, and therefore paper images printed by a printer were used instead. The number of subject was 15 people (students between 20 and 24 years old). The width of the black bands and white bands were set to 64 pixels. Patterns of vertical striped blur width were made with 7 types (0, 2, 4, 8, 16, 32, and 64 pixels). The blurring method was density linear. The density was measured using a fluorescence spectro-density-meter (KonicaMinolta,FD-7). Fig.2 is an index image for evaluating the density of the white band, and Fig. 3 is an index image for evaluating the density of the black band. Black is more difficult to feel density change than white. In order to make it easier to evaluate for an observer, in this experiment, the index image of the white band was changed by one level of density and the index image of black band was changed by four levels. Here, the level shows 256 gradation values on the PC, and in the experimental result it is replaced by the measured density value. In the experimental environment, the illumination was D50 light source, the illuminance was about 300 lx, the gazing distance was 0.625 m (the distance that a person with visual acuity 1.0 can perceive 1 pixel), the angle between the index image and the subject was 45 degrees. The subject looked near the center edge for about 2 seconds. The subject memorized the density at that time. Next, they pointed out the same density compared to the density index. In this experiment, a density evaluation of both the white band and the black band was performed. Fig. 4 is shown by experimental landscape.

Fig. 4. Experimental landscape

B. Results and Discussions

From Fig. 5 to 7 shows the results as perceived density and contrast. Our results showed that as the blur width increased, the black band density decreased and the white band density increased. The change in the density of the black belt was larger than the change in the density of the white belt. Also, it turned out that the contrast was reduced by around 5% at the maximum. We also found that the density change tended to saturate even if the edge width was too wide.

III. CHANGE IN DENSITY ACCORDING TO GAZING TIME

Similarly to experiments on the visual phenomenon of edge blurring (Chapter II), we prepare evaluation images in which blurring is applied to the edge portion of a black-and-white vertical striped pattern. When the subjects look at them, they feel a visual phenomenon of edge blur that gradually changes the density of the stripes with the gazing time. The necessity of this gazing time was found in the experiment of chapter 2, because the initial experiments showed that there was a large variation in the value of evaluation with respect to the density of the subjects. The reason for this variation is that the density changes in proportion to the gazing time. It is linked to the causal relation between perceived density change and gazing time from data variation. Therefore, in the experiment of Chapter 2, it was set to 2 seconds of the shortest evaluation time. In addition, there is a report that the Mach band disappears in less than 4 minutes in visibility [4], and the gazing time is not considered. However, by gazing for a long time, Chevreul illusion occurs and the band is visible. In this chapter, we conduct experiments on this gazing time and change in perceived density.

A. Experiment

The experimental environment was the same as in Section 3, and the number of subjects was 18. The width of the standard black band and white band were set to 64 pixels. In the experiment, the width of the blurring of the vertical stripe pattern was set to 4 types of 0, 2, 8, and 32 pixels. Gazing times were 4, 8, 12 and 16 seconds. The subject memorized the density for each observation time and

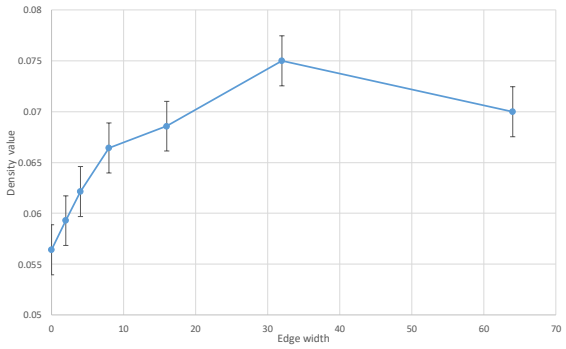

Fig. 5. Perceived density for white band with edge blur widths

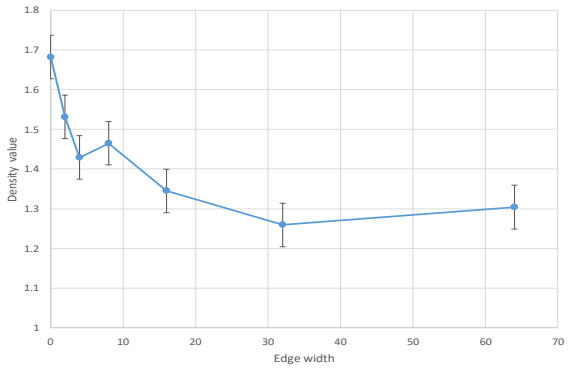

Fig. 6. Perceived density for black band with edge blur widths

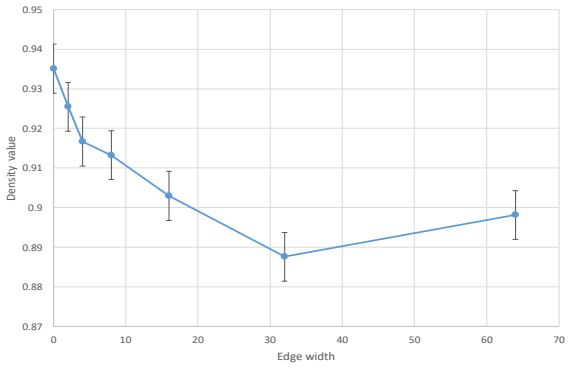

Fig. 7. Contrast with edge blur widths

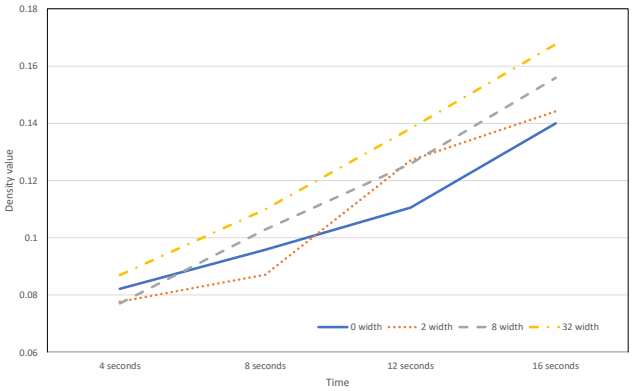

Fig. 8. Perceived density for white band with gazing time

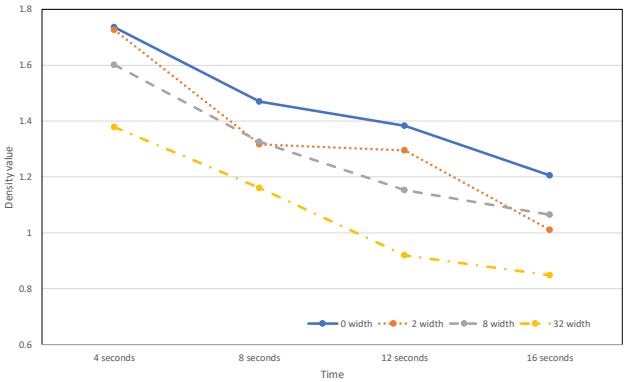

Fig. 9. Perceived density for black band with gazing time

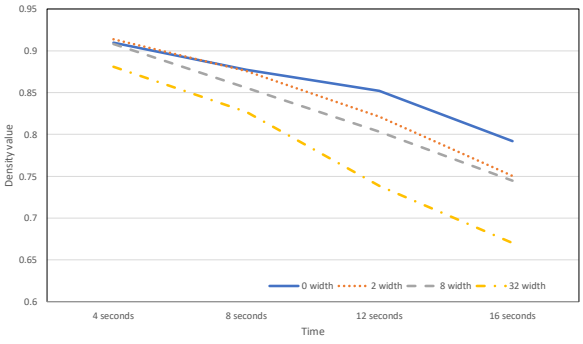

Fig. 10. Contrast with gazing time

compared it with the density index image. The experiment proceeded while confirming that there was no afterimage remaining in the eyes. The procedure of the other experiments was carried out in the same way as in Chapter 2. As the gazing time gets longer, the subjects will move their gaze. Therefore, in order to fix the gaze, a small cross mark was added to the evaluation image in one place in the center of the stripe.

B. Results and Discussions

Fig. 8 to 10 show the results as perceived density for white band and black band, and contrast. In Fig.8, the perceived density of the white band was increased as the gazing time became longer in all the blur widths. In Fig.9, the perceived density of the black band was decreased as the gazing time became longer in all the blur widths. In addition, the change

in the perceived density for the black band was larger than the change in the perceived density for the white band. Therefore, the contrast shown in Fig.10 also decreased as the gazing time increased. As a remarkable example, when the blur width is 32 pixels and the gazing time is 16 seconds, the perceived density for black band is 1.9 → 0.82 and the perceived density for white band is 0.06 → 0.165. Contrast decreased to more than 30%.

IV. Overall Discussion

When the gazing time in Fig.7 is short, it shows that the contrast decreases according to the degree of edge blur. It is said that textures can be felt on 4K, 8K displays. As a factor of improving the texture, it is thought not only to increase the resolution but also to sharpen edges. Therefore, the influence of the visual phenomenon in the edge blurring decreases and the contrast increases. In particular, texture images like cloth will be susceptible to contrast. Since the contrast changes according to the length of the gazing time, it can be seen that this gazing time is an important factor in the image evaluation method. The decrease in contrast as the gazing time gets longer is related to the Troxler effect (a phenomenon in which a thin circle with blurred edges disappears from view). Also, in preliminary experiments, we observed the phenomenon that the edge disappears and the densities on both sides appear to be the same when gazing at the low contrast image with vertical striped pattern.

V. Conclusion

In this research, an evaluation experiment was conducted on visual phenomena caused by edge density change. To summarize the phenomenon of edge blur, if there is no blur width, Chevreul illusion occurs, and as the blurring expands, the Mach band occurs and the contrast decreases. The change of the contrast caused by these series of phenomena becomes conspicuous as the gazing time becomes longer, and the decline of contrast leads to a phenomenon related to Troxler effect. As described above, we described the influence on texture and the necessity of gazing time in image evaluation. In the future, we will examine the edge blurring with the contrast on checkered pattern, color, and periodicity.

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