Appropriate Evaluation Image for Quantitative Evaluation of Halo Effect

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ABSTRACT

The halo effect is a negative side effect of mini-LED displays, and various quantitative methods for evaluating halos have been studied. However, the evaluation images used in these studies were not optimized or unified. In this study, we verified the conditions of appropriate evaluation images for quantitative halo evaluation.

1 INTRODUCTION

In recent years, local dimming control technologies, specifically mini-LED displays, have been attracting attention for their ability to achieve a high contrast ratio and low power consumption, and their adoption in high-dynamic-range displays is increasing. However, local dimming control displays have an image quality problem called the halo effect. The halo effect is a phenomenon in which light leaks to the black background from the high-brightness areas and causes blurring around these bright areas, as shown in Figure 1. Because the halo effect degrades the image quality, it has been evaluated subjectively. However, subjective evaluation has problems, including individual differences and the time and effort required for evaluation. Therefore, some quantitative methods for halo evaluation have been proposed [1,2,3]. Standards for halo evaluation methods, such as IDMS [4], have also been developed.

The selection of the evaluation image is important for the quantitative evaluation because the glare effect depends on the evaluation image. The glare effect is a phenomenon in which the light scattering inside a human eye or a measurement instrument spreads out the light intensity around the high-brightness areas in an evaluation image [5]. This glare effect makes it difficult to evaluate the halo accurately. However, in studies to date, evaluation images for quantitative evaluation have not been sufficiently studied and have not been standardized. In this study, we conducted quantitative and subjective evaluation experiments using various evaluation images to investigate the correlation between them. We also analyzed and discussed the conditions of appropriate evaluation images for quantitative evaluation of the halo.

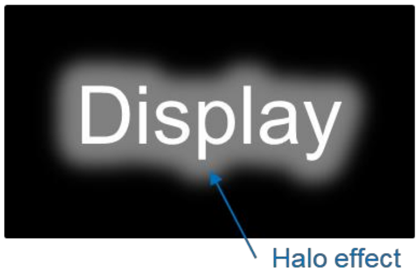


Figure 1. Example of the halo effect

2 QUANTITATIVE EVALUATION OF HALO

In this study, we used the quantitative halo evaluation method that relies on the luminance distribution in the display screen [2]. In this evaluation method, as shown in Figure 2, a white window area (white level: 255/255) is displayed in the center of a black background (white level: 0/255), and the luminance distribution is measured between "A" and "B" in the horizontal direction from the center of the display. Normalization is performed by calculating the contrast (CR) distribution from the measured luminance distribution and the white luminance at the center of the display. The CR distribution between "A" and "B" is affected by the halo. The CR ratio in the area near the white window becomes smaller due to the light leakage caused by the halo, and the CR ratio becomes larger away from the white window.

To confirm the effectiveness of this evaluation method, we prepared two types of displays, a mini-LED display with a large halo effect and a dual-layer LCD display with a small halo effect, as shown in Table 1. We verified whether the halo can be discriminated. In addition, to evaluate the impact of the size of the white window, we prepared evaluation images that included three different sizes of white window (area ratios of 10%, 1%, and 0.1%). We displayed each image on the two displays and measured the displayed images using a two-dimensional luminance colorimeter.

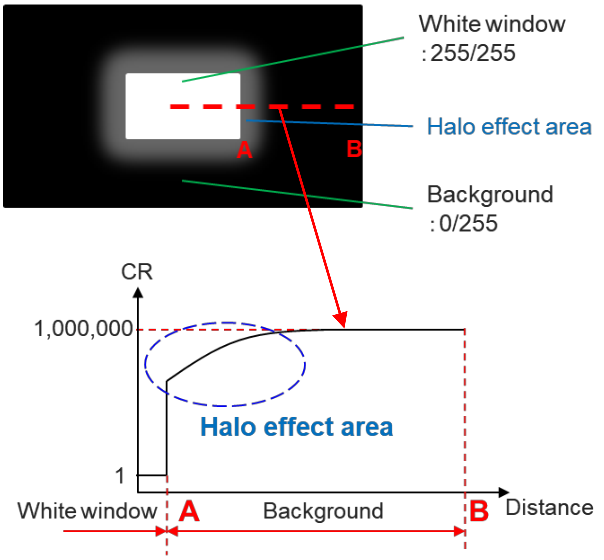
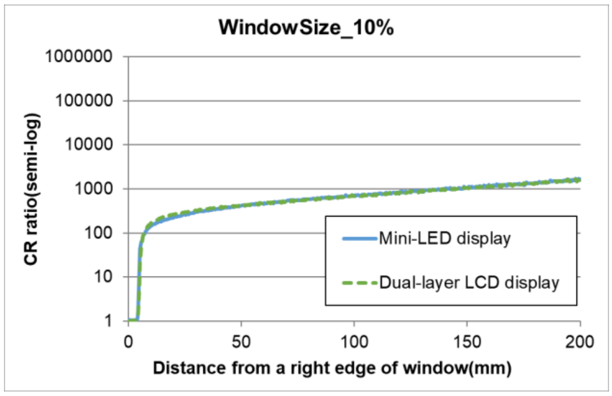


Figure 2. CR distribution

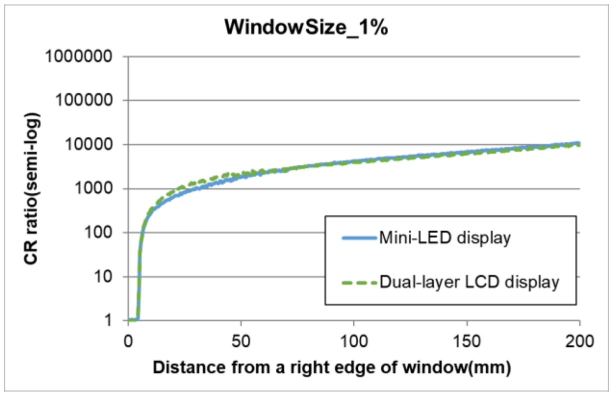
Table 1. Specifications of mini-LED and dual-layer LCD displays

Item	Mini-LED display	Dual-layer LCD display
Resolution	6,016x3,384(6K)	4096x2160(4K)
Pixel pitch	218ppi	149ppi
Local dimming segments	576	-
White Luminance	1000 nit	1000 nit
CR	1,000,000:1	1,000,000:1
Halo	Visible	Invisible

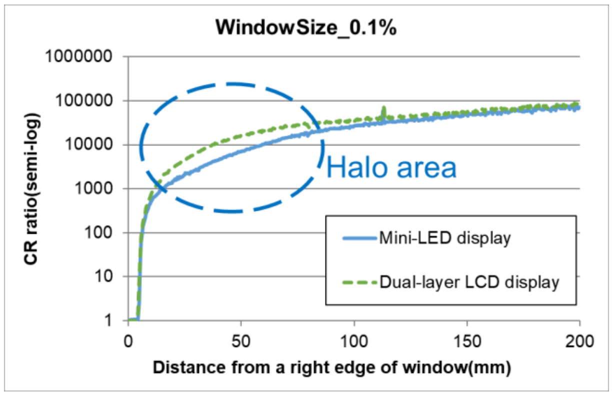
Figure 3 shows the measured CR distribution for each white window size for the two displays. When the white window size was (a) 10%, there was no difference in the CR distribution between the two types of display, and halo discrimination was not possible. The reason is thought to be that the glare effect on the optical system of the measurement device cannot be ignored and the halo discrimination was hindered because the high-brightness area was large. Conversely, when the window size was (b) 1% and (c) 0.1%, the CR ratio of the mini-LED display near the white window was lower compared to the dual-layer LCD display. These results indicate that by reducing the window size, the glare effect can be avoided, and the halo can be discriminated quantitatively.



(a) CR distribution at window size of 10%



(b) CR distribution at window size of 1%



(c) CR distribution at window size of 0.1%

Figure 3. Measurement results of CR distribution across the right edge of the white window. Results are shown for window sizes of (a) 10%, (b) 1%, and (c) 0.1%. The CR ratio was calculated using the white luminance at the central position.

3 SUBJECTIVE EVALUATION OF HALO

The results of the quantitative evaluation in Section 1 indicate that it is necessary to select an evaluation image with a small window size to avoid the glare effect. Then, we also conducted a visual subjective evaluation to verify the correlation between the size of the white window and perception of the halo. The number of evaluation images was five and the sizes of the white window were 10%, 5%, 1%, 0.5%, and 0.1%. The two types of displays in Table 1 were arranged side by side, and the evaluation images were displayed in order. Inspectors selected the image having a stronger halo than the other image or answered that there was no difference between the two displayed images.

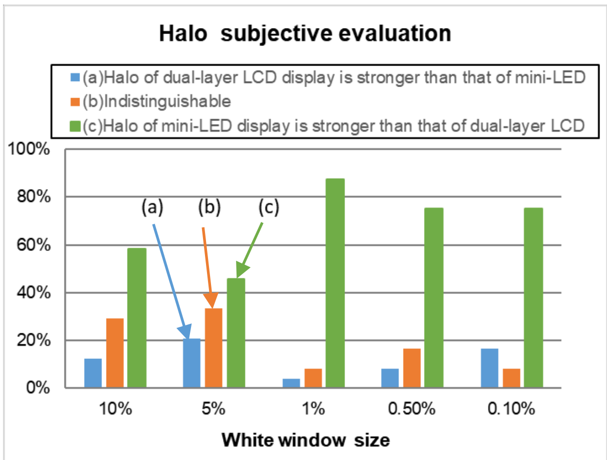


Figure 4. Results of the subjective halo evaluation. The evaluation was made with three choices: (a) halo of dual-layer LCD display is stronger than that of mini-LED, (b) halos are indistinguishable, or (c) halo of mini-LED display is stronger than that of dual-layer LCD. The number of inspectors was 24. The inspection was performed in a dark room environment at a visual distance of 500 mm with the displays in front of the evaluator.

Figure 4 shows the results of the subjective evaluation. When the size of the white window was 10% or 5%, about 50% of respondents selected (c), while 30% of respondents selected (b). This result indicates that it is difficult to perceive the halo when the size of the white window is relatively large. Conversely, when the size of the white window was 1%, 0.5%, and 0.1%, the percentage of respondents who selected (c) was high at nearly 80%. This result indicates that it is easy to perceive the halo when the size of the white window is small. Similar to the results of the quantitative evaluation, the subjective evaluation also suggested that an appropriate evaluation of the halo can be performed by reducing the size of the white window to avoid the glare effect.

4 CONCLUSION

We analyzed and discussed the conditions of appropriate evaluation images for the quantitative evaluation of a display halo using the CR distribution of a display area. In addition, we conducted quantitative and subjective evaluations using various evaluation images to investigate the correlation between them.

Our conclusions are as follows:

- The results of the objective evaluation indicate that it is possible to evaluate the halo using evaluation images with a white window area of 0.1% to 1%. However, it is impossible to evaluate the halo using the images with a white window area over 1% due to the glare effect.
- The results of the subjective evaluation also indicate that the evaluation images with a white window area of 0.1% to 1% are appropriate for evaluation of the halo.

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