Research on the Measurement Method of Halo Effect in HDR LCD Displays

Li Song, Jiangen Pan, Qian Sun, Xian Tang
Everfine Corporation, Zhe Jiang, China

Abstract

Based on the instantaneous dynamic range of the human eye to light, this paper proposes a high-precision and efficient measurement method for the halo effect through the ratio of the halo area. By studying the error factors of imaging luminance meter used for the halo effect measurement, an improvement method is put forward. The consistency of the measurement results between the new method and the traditional masking method is verified through measurement results comparison. And the technical characteristics and advantages of the new measurement method are discussed and summarized.

Author Keywords

Halo Effect; Measurement Method; Mini-LED backlight; Local Dimming

1. Introduction

In recent years, with the continuous improvement of the pursuit of the fidelity of displayed images in the consumer market, high dynamic range (HDR) display technology has developed rapidly. Based on local dimming technology, Mini-LED backlight LCD is the main technical route for current LCD to achieve HDR display [1]. Since Mini-LED backlight LCD display is an upgrade based on LCD display technology, it can make full use of the existing LCD industry chain and reduce the production cycle and cost. In addition, with the continuous progress of Mini-LED backlight packaging technology and driver technology, the performance of product is continuously improving [2].

However, the Mini-LED backlight LCD still has some technical problems that affect the display quality, the most intuitive of which is the halo effect. The halo effect is the light leakage phenomenon that occurs around the bright image on the dark background of the display, as shown in Figure 1. This phenomenon occurs because some part of the light will exceed the expected range, resulting in "extra" light in the surrounding dark areas, which is because of the displayed object is located at the junction of local dimming and due to the diffusion characteristics of the backlight unit [3]. The halo phenomenon can be optimized by advanced optical design, the incoming backlight structure and the improved light control algorithm, but the premise is that the halo phenomenon can be measured objectively and effectively.

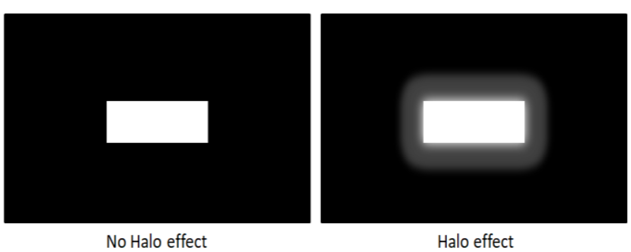

Figure 1. Schematic diagram of halo effect

Chaoping Li et al. use camera to evaluate the halo effect, calculated for halo effect by the grey value obtained by the camera [4]. Since the camera can only obtain the grey value, but cannot obtain the luminance value felt by the human eye. There is a certain deviation in its results compared to that of the human eye. Tan et al. use an imaging colorimeter to measure and calculate the peak signal-to-noise ratio in CIE 1976 L*a*b* color space to evaluate the halo effect [5]. Since the imaging light measurement device (ILMD) has a certain amount of stray light influence, and the stray light will directly affect the measurement of the light distribution around the bright area. This paper will propose a high-precision and efficient evaluation scheme for the halo effect by imaging luminance meter, and analyze the error factors of the measurement based on the imaging principle of the imaging luminance meter, and put forward an improvement method.

2. Calculation of Halo Effect

Currently, there are some calculation methods for halo effect. For example, it can be measured by the ratio of the peak luminance of the halo to the peak luminance of the white box. These methods cannot match the actual effect as seen by the human eye. The instantaneous dynamic range of the human eye in the same environment is generally considered to be about 10^3. Based on this, this paper uses 0.5% center luminance as the halo boundary perceptible to the human eye.

Figure 2 shows the test pattern with a white box in the center on a black background. The gray scale of the white box is (255, 255, 255), and the length and width are 1/4 of the total length and width. The gray scale of the black background is (0, 0, 0). Use an imaging luminance meter as the light measuring device for halo effect, which can be obtain the luminance distribution of the image through a single measurement.

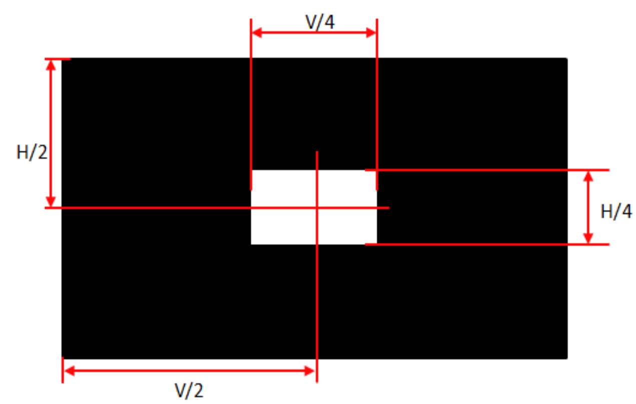

Figure 2. Test pattern of halo effect

First, get the luminance L_0 of the center of white box, and the measurement area is a V/10 circular area in diameter. Then, the two positions with luminance of 0.5% L_0 in the horizontal direction can be obtained by image algorithm, and thus the horizontal width $x_{0.5\%}$ of the halo is obtained. The vertical height $y_{0.5\%}$ of the halo is obtained by the same way. The ratio P_{halo} of the halo area S_{halo} to the area S of the white box is calculated through Equation 1. The halo effect can be evaluated through P_{halo}. When P_{halo} is close to 0, it indicates that the halo area relative to the luminous region area is extremely small, meaning the halo phenomenon is hardly noticeable and the display quality

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in terms of this aspect is relatively good. As P_{halo} increases, it means the proportion of the halo area is getting larger compared to the luminous region area. A larger P value implies a more significant halo effect, which may have a greater impact on the visual experience and the overall display clarity.

$$P_{\text{halo}} = \frac{S_{\text{halo}}}{S} = (x_{0.5\%} \times y_{0.5\%})/(V/4 \times H/4) \qquad (1)$$

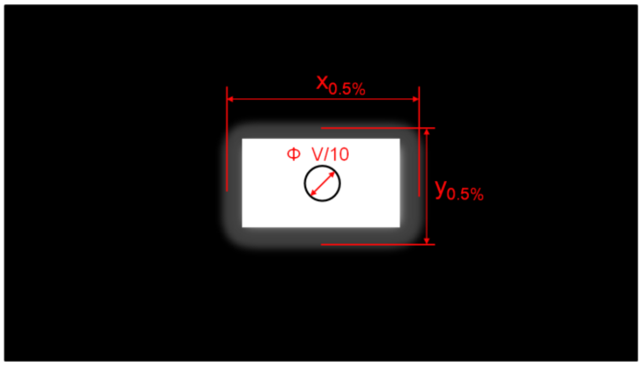

Figure 3. Area of halo effect

3. Measurement Method and Key Aspects

In order to measure the halo effect accurately, the performance of the imaging luminance meter is the key to the measurement. Therefore, the influencing factors of measuring halos with an imaging luminance meter should be analyzed before formulating the measurement method.

1) **The mismatch of V(λ).** Different from camera, the imaging luminance meter matched the human eye optical efficiency function V(λ) to ensure that the test instrument is consistent with the human eye sense for accurate measurement of the luminance is required. Therefore, the accuracy of V(λ) mismatch of the instrument directly affects the accuracy of luminance measurement.

2) **High dynamic range.** The Mini-LED backlighting LCD is an HDR display technology, its contrast ratio can be as high as 100,000:1. And the measurement pattern for halo effect contains the highest luminance and the lowest luminance that the display can show. If the dynamic range of the imaging luminance meter cannot cover the contrast ratio of the measured display screen, it will be impossible to accurately obtain the luminance of the image and the boundaries $x_{0.5\%}$ and $y_{0.5\%}$ of the halo simultaneously.

3) **Stray light**. Stray light of the imaging luminance meter significantly impacts halo measurement. It adds an unwanted background light, blurring the distinction between the halo and the surrounding area. This makes it difficult to precisely define the luminance of halo boundaries, leading to potential errors in evaluating the halo effect.

Therefore, to achieve accurate measurement of the halo, the prerequisite is to select an imaging luminance meter that is well-matched of V(λ) and has a large dynamic range. Subsequently, it is necessary to avoid the influence of stray light.

In order to avoid the influence of stray light in the imaging system, the mask method is generally adopted to carry out the measurement. Specifically, a mask sheet with the same size as the white box is attached to the white box area on the display screen. This helps prevent the light emitted from the white box from affecting the imaging system of the imaging luminance meter. As the measurement process of the mask method requires manual intervention, and the operation is relatively complicated. It is cumbersome and not suitable for daily R & D and production activities.

In order to achieve high-precision and efficient measurement for the halo effect, we propose a stray light correction method to avoid the influence of stray light on the measurement of the halo. The steps of the stray light elimination method are as follows:

1) Choose a standard display without backlight or halo (e.g. OLED display). Place the imaging luminance meter and align it with the center of the screen with the optical axis of the imaging luminance meter perpendicular to the screen.

2) Control the standard display to display a 10 x 10 pixel white spot in the center of the screen with a black background, stable for 10 minutes.

3) Control the imaging luminance meter measurement to obtain the stray light correction matrix *H*.

4) Control the display under test to display the measurement pattern shown as Figure 2, and stabilize it for 10 minutes.

5) Controlling the imaging luminance meter measurement screen to obtain 2D luminance distribution matrix g with stray light, g is a real-valued matrix of $N \times M$;

6) The real 2D luminance distribution matrix f can be calculated by formula 2.

$$f_{n+1} = f_n - K \times (f_n * H - f_n) \qquad (2)$$

Where * represents the convolution operation, n is iteration number of times, K is $1/\max(f_n)$. Select the initial condition as $f_0 = g$ iterate. When n continues to increase, f_{n+1} converge to the real image signal *f*. And then the stray light can be corrected, the true halo distribution can be measured.

The steps 1) -3) can be calibrated before the device leaves the factory, and the user can directly use the imaging luminance meter to complete the halo measurement.

4. Comparison Measurement and Discussion

In order to verify the effect of the stray light correction method on stray light suppression, the luminance distribution data of the white box image measured before and after the stray light correction were compared, as shown in Figure 4. It can be found that the stray light elimination method can effectively suppress the stray light of the imaging luminance meter itself.

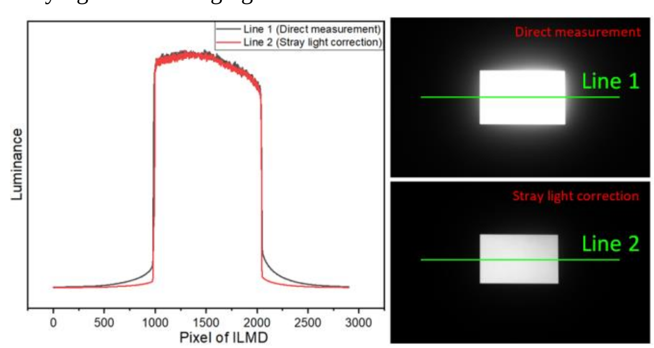

Figure 4 The effect of stray light correction

In order to verify the accuracy of the stray light correction method, this paper respectively adopts the mask method, the stray light correction method, and the direct measurement method to measure three Mini-LED backlight LCD samples with different degrees of halo effect.

The result is shown in Table 1. It can be found that the results of the three samples obtained by direct measurement are almost the same. It is due to the influence of the stray light of the selected imaging luminance meter, and the measured boundaries are not the halo boundaries but the stray light. The results obtained by the stray light correction method is basically the same as the mask method, indicating that the stray light correction method described in this article can effectively correct the stray light of the imaging luminance meter, and can achieve fast and accurate measurement of the halo.

Table 1. Results of different halo measurement method

	Direct measurement	**Mask**	**Stray light correction**
Sample 1	1.53	1.08	1.10
Sample 2	1.56	1.12	1.13
Sample 3	1.51	1.38	1.40

5. Conclusion

By studying the error factors of imaging luminance meter used for the halo effect measurement, this paper proposes that, in addition to V(λ) mismatch and dynamic range, the stray light of the imaging luminance meter will directly affect the halo measurement results. By correcting the stray light of the imaging luminance meter through the stray light correction method described in this paper, the influence of stray light on the measurement results can be effectively suppressed, so as to achieve the measurement results comparable to the traditional mask method. In addition, the calculation method based on the instantaneous dynamic range of the human eye proposed in this paper can also be used as a reference for the halo evaluation scheme in the industry.

6. References

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