

P-188L: Late-News Poster: Quantification of Image Sticking for Images with Different Long-Range Non-Uniformity

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Abstract

A new estimation method for image sticking has been developed that can effectively eliminate the influence by the difference in long-range non-uniformity pattern. An 8×8 chessboard pattern was used for selective degradation, and normalization based on extracted reference and coefficient of variation were adopted for better results.

1. Introduction

Image sticking, which makes the lifetime of a display device shorter than that of a light emitting device, has become a critical issue in the development of active matrix organic light emitting diode (AMOLED) displays. Usually the image sticking originates from non-uniform degradation of the light emitting devices and may be prohibited by maintaining the luminance uniformity of a fresh display device even after prolonged and repeated usage of that device. Techniques for reducing degradation speed of an OLED and for restoring luminance uniformity through compensation are under study [1], and they need quantitative evaluation through appropriate estimation of the image sticking.

Among published estimation methods for image sticking is image sticking value (ISV) [2-3], which takes a long-range non-uniformity (LRNU) of luminance into consideration and utilizes a chessboard pattern, such as Fig. 1, for generating image sticking through degradation. Luminance of each rectangle constituting the chessboard pattern is measured for a gray level before (initial luminance, IL) and after (measured luminance, ML) the degradation. To remove the influence of the LRNU, which does not affect image sticking, on the estimate, the ML is normalized by dividing it by the IL [2] or by subtracting the IL from it [3]. The ISV is defined in terms of the normalized luminance (NL) as

$$ISV = 1 - NL_{min} / NL_{max} \quad (1)$$

where NL_{min} means its minimum and NL_{max} does its maximum [2-3]. However, the ISV is not suitable for the techniques to relieve image sticking by restoring luminance uniformity. These

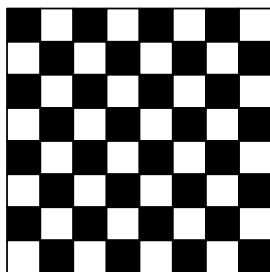


Figure 1. An 8×8 chessboard pattern which is used for aging.

techniques are liable to change the LRNU pattern of luminance. Because the LRNU-removal process relies on the initial luminance, the ISV is vulnerable to the change in LRNU pattern.

2. Proposed Estimation Method

To assess an image sticking without regard to the change in LRNU pattern, we have developed a new estimate, extracted image sticking value (EISV) for which the ML is normalized by dividing it by an extracted reference (ER). The ER is obtained on the assumption that black rectangles of the chessboard pattern reflect the LRNU pattern of a whole display since only white rectangles are stressed during the degradation process. ML of a black rectangle becomes an ER of that rectangle, and an averaged ML of the black rectangles adjacent to a white rectangle is defined as an ER of the white rectangle. All the ER values are scaled after extraction so that the average of them equals the average of the ML values. In our experiment, normalization through division or subtraction made no significant difference when the LRNU pattern was removed with the extracted reference.

In addition, we have found that a quantity based on the standard deviation and average is better suited for the image sticking evaluation than a quantity based on the minimum and maximum. Hence the EISV is defined as

$$EISV = \sigma_{NL} / \mu_{NL} \quad (2)$$

where σ_{NL} means the standard deviation of NL and μ_{NL} does the average. The EISV is the coefficient of variation [4] of the normalized luminance obtained using the extracted reference luminance.

3. Experimental Results

The proposed estimation method has been successfully applied to

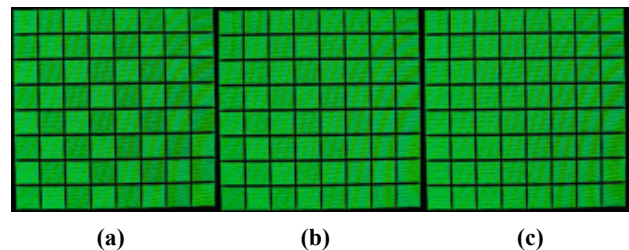


Figure 2. Full-white images obtained after 4 hours' degradation with an 8×8 chessboard pattern: (a) an image under a conventional digital driving [image A], (b) an image with negligible long-range non-uniformity (LRNU) [image B], and (c) an image with negligible measured-luminance difference between adjacent rectangles [image C].

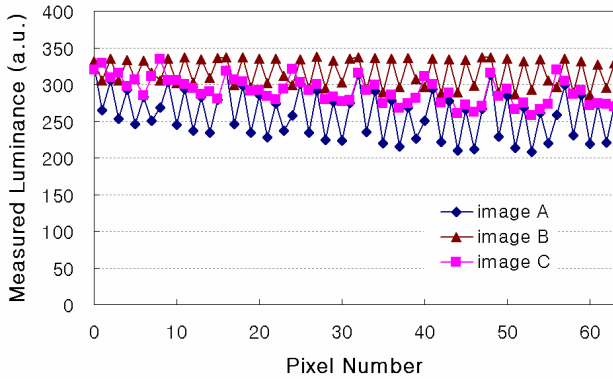
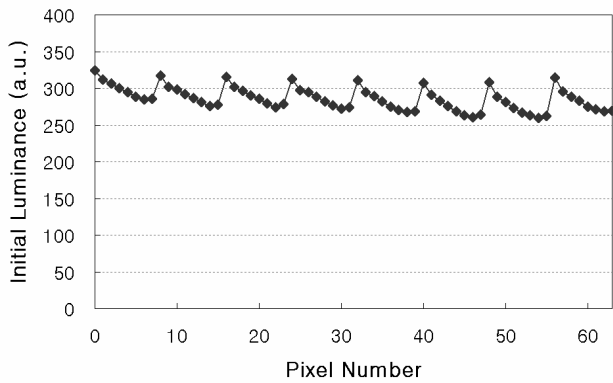
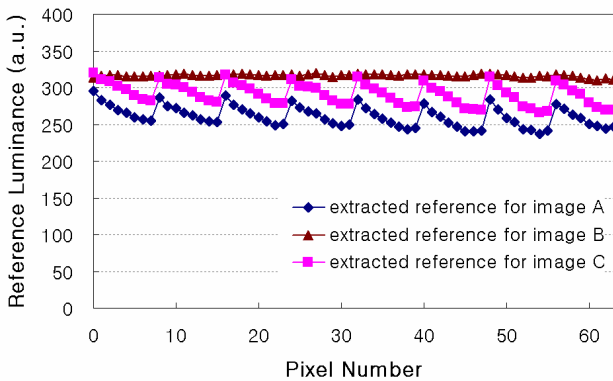


Figure 3. Measured luminance values of each rectangles in images A, B and C. Arbitrary unit (a.u.) is used because the area of a single rectangle was smaller than the area required for reading an absolute luminance value in Cd/m^2 without causing zero-point shift of the spectroradiometer used in measurement. Each rectangle has a pixel number defined as $8 \times (\text{row number}) + (\text{column number})$.

the evaluation of a driving method to relieve image sticking on an AMOLED display. It has reflected the degree of image sticking effectively during the evaluation.



(a)



(b)

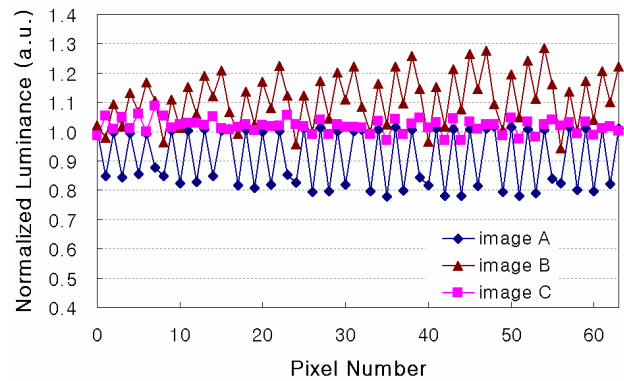
Figure 4. (a) Initial luminance values measured before aging and (b) extracted reference luminance values.

Figure 2 shows full-white images obtained from a green-colored AMOLED test cell in a size of $13.2 \times 13.2 \text{mm}^2$ after 4 hours' degradation with an 8×8 chessboard pattern of Fig. 1. Measured luminance values of each rectangle constituting the chessboard pattern are also shown in Fig. 3.

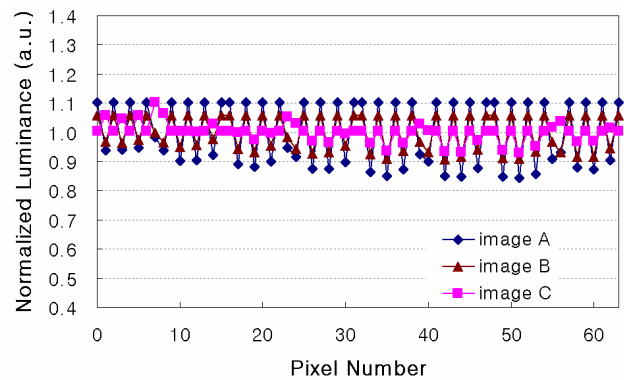
The test cell in Fig. 2(a), image A, is under a conventional digital driving, and the ML's have a much difference between adjacent rectangles. A significant LRNU of luminance also exists. The LRNU is almost removed in Fig. 2(b), image B, and the ML difference between adjacent rectangles is reduced small. This is achieved by a compensation method that controls a supply voltage and a voltage drop across a driving thin film transistor (TFT) and that makes the OLED current uniform [5]. On the other hand, the LRNU remains significant in Fig. 1(c), image C, but the ML difference between adjacent rectangles is negligible. This image was obtained by manual adjustment of data voltage.

In contrast to the initial luminance values in Fig. 4(a), each set of extracted reference luminance values in Fig. 4(b), obtained by following the proposed extraction method, appropriately represents the LRNU pattern of the corresponding image.

Normalized luminance values obtained using the initial luminance values and using the extracted reference luminance values are shown in Fig. 5. The more difference between ML's of adjacent rectangles in the image A than in the image B is more effectively represented by the normalization using the extracted reference than by the normalization using the initial luminance.



(a)



(b)

Figure 5. Normalized luminance values obtained (a) using the initial luminance values and (b) using the extracted reference luminance values.

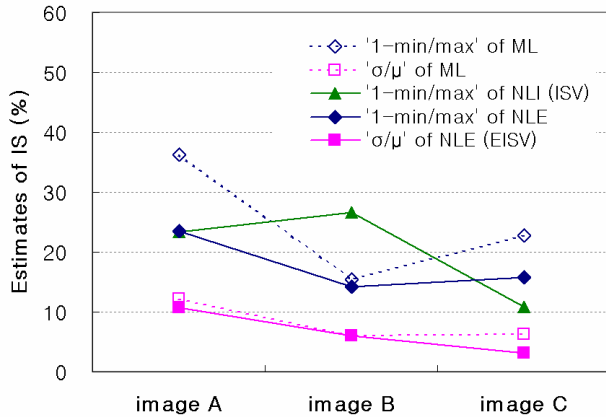


Figure 6. Quantitative estimates of image sticking (IS). Extracted image sticking value (EISV) of this work effectively reflects the degree of image sticking in Fig. 1.

As shown in Fig. 6, the normalized luminance based on extracted reference (NLE) is preferred to the normalized luminance based on initial luminance (NLI) when there is a significant change in the LRNU of luminance. The ISV of Fig. 2(b) is larger than that of Fig. 2(a). Moreover, adoption of the coefficient of variation enhances the reflection of the degree of image sticking. Among the various estimates in Fig. 6, only EISV is smaller for Fig. 2(c) than for Fig. 2(b). Estimates from ML values show the significance of appropriate reference values in normalization. If

the reference values are not appropriate, a normalization using them produces worse results as those obtained with the initial luminance values for the images A and B.

4. Conclusions

We have developed a new estimation method for image sticking, called extracted image sticking value (EISV), that can effectively eliminate the influence by the difference in long-range non-uniformity (LRNU) pattern. Using the EISV, we could evaluate the image sticking on an AMOLED test cell without regard to the change of the LRNU pattern.

5. References

- [1] Y. Matsueda, D.-Y. Shin, and H.-K. Chung, "AMOLED Technologies for Uniform Image and Sufficient Lifetime of Image Sticking," 3.3, SID 08 Digest, pp.9-12, 2008.
- [2] D.-G. Lee, I.-H. Kim, H.-S. Soh, and B. C. Ann, "A Measurement and Analysis Method of Image Sticking in LCD," P-33, SID 02 Digest, pp.324-327, 2002.
- [3] S.-C. Park, K.-H. Lim, S.-H. Choi, and H.-S. Soh, "Quantitative Analysis of Image Sticking in LCDs," 20.3, SID 07 Digest, pp.1042-1045, 2007.
- [4] T.T. Soong, "Fundamentals of Probability and Statistics for Engineers," John Wiley & Sons, England, p.81, 2004.
- [5] D.-Y. Shin, J.-K. Woo, Y. Hong, S. Kim, K.-N. Kim, and H.-D. Kim, "A New Hybrid Analog-Digital Driving Method to Improve AMOLED Lifetime," SID 08 Digest, pp.1196-1199, 2008.