# Local Dimming Design for LCD Backlight

Shih-Chang Hsia(✉), Xin-Yan Jiang, and Shag-Kai Wang

National Yunlin University of Science and Technology/Electronic, Douliu, Taiwan
hsia@yuntech.edu.tw

**Abstract.** The local-dimming backlight has recently been presented for use in LCD TVs. However, the image resolution is low, particularly at weak edges. In this work, a local-dimming backlight is developed to improve the image contrast and reduce power dissipation. The algorithm enhances low-level edge information to improve the perceived image resolution. Based on the algorithm, a 42-in. backlight module with white LED (Light-Emitting Diode) devices was driven by a local dimming control core. The block-wise register approach substantially reduced the number of required line-buffers and shortened the latency time. The measurements made in the laboratory indicate that the backlight system reduces power dissipation by an average of 48 percents and exhibits no visible distortion compared relative to the fixed backlighting system. The system was successfully demonstrated in a 42-in. LCD TV, and the contrast ratio was greatly improved by a factor of 100.

**Keywords:** Backlight · Local-dimming · LCD · LED · Image

## 1 Introduction

Conventional LCD utilizes a fixed backlight to illuminate the LCD panel uniformly. This method consumes much power and causes light leakage from the liquid crystals in the black areas. Recently, the local-dimming backlight was proposed to overcome this drawback [1–5]. The lighting level of the backlight follows the local features in the image. It is dynamically adjusted by the content of the image blocks for local-dimming control. When an image block is bright, the lighting level of the backlight turns high also. Oppositely, the backlighting level is adjusted to low in a black region. This arrangement reduces power dissipation and light leakage from the LCD, increasing the image contrast on the display.

## 2 Design Methodology

The local dimming method can turn the lighting level low in the black regions, to reduce power dissipation and improve the image contrast. When an image is displayed on an LCD, the most important information is at the edge. However, if the edge is in a low-brightness region, then the estimated level of the backlight is relatively low, and the system turns the level of backlighting to low in this region. Unfortunately, a weak edge is missed and the details of the image may not be perceived, and the resolution is then low.


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To solve this problem, an efficient algorithm was developed to improve the edge information a weakly lit region. Figure 1 presents the proposed local dimming scheme. An image is divided into M $\times$ N blocks, and each of which corresponds to one lighting source in the backlight. If the block contains edges, then the lighting level is enhanced to make them more visible on the LCD. Generally, an edge block exhibits a high variance in an image. The mean variance can be used to find the edge blocks. The local block mean-variance (BMV) can be calculated from

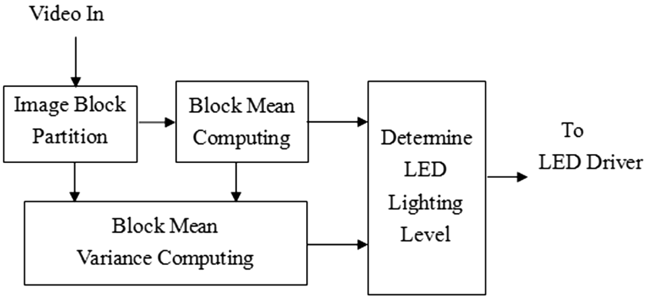



**Fig. 1.** The proposed local dimming diagram.

$$BMV = \sum_{j=0}^{m}\sum_{k=0}^{n} |F_{jk} - Block_{Mean}|, \quad (1)$$

$$Block_{Mean} = \frac{1}{m \times n}\sum_{j=0}^{m}\sum_{k=0}^{n} F_{jk}. \quad (2)$$

Wherein $F_{jk}$ is the gray-level luminance value of the (j, k)th pixel in a block, and the block size is m $\times$ n. If *BMV* is high, then the block contains edge information. Firstly, the maximum BMV value ($BMV_{max}$) of the image is determined from the estimated frame. The enhancement factor (*Ef*) is defined by

$$Ef = \frac{BMV_{current}}{BMV_{\max}} \times \alpha, \quad (3)$$

where $BMV_{current}$ is estimated from the currently processed block, and $\alpha$ is an constant factor. If $Ef > 1$, then let $Ef = 1$. The block backlighting can be calculated by

$$Block_{light} = (1 - Ef) \times Block_{meanlight} + Ef \times Block_{\max light}, \quad (4)$$

where $Block_{meanlight} = \beta \times Block_{mean}$.

$Block_{maxlight}$ is the maximum lighting level on backlight, which corresponds to the highest gray level of the image. $Block_{meanlight}$ is the mean level lighting that is mapped to the estimated block mean with Eq. (2) by the $\beta$. The $\beta$ value is used to control the brightness of the display. If $\beta$ is set to high, then the average of backlight level becomes high and the power saving is reduced. When the current block contains edge information, the enhanced factor is increased. From Eq. (4), the block lighting can be raised to improve the perceived resolution of the weak edges on an LCD panel. To reduce one multiplication, the Eq. (4) can be reformed to

$$Block_{light} = Block_{meanlight} + Ef \times (Block_{\max light} - Block_{meanlight}) \tag{5}$$

If $Ef = 1$, then the backlighting is maximal. If $Ef = 0$, then the backlighting is at its average level.

## 3 Processing Flowchart

Figure 2 presents the processing flowchart. The color video RGB is converted to YUV using a linear matrix [15]. The Y-signal is used to calculate the lighting level for a white LED backlight. Y-image is divided into M × N blocks, and each of which corresponds to one LED module. Each module contains several LED components. The local-dimming algorithm can compute the LED PWM (Pulse Width Modulation) duty cycle to control the lighting in a manner consistent with image brightness. Since the LED is a discrete light source, multi-layered optical diffuse films are necessary to smooth the LED lighting to make the illumination uniform. The multi-layered optical diffuse films were simulated using multiple-time recursive 7 × 7 low-pass filters [15]. The implemented system uses common diffuse films over the isolated blocks. Figure 3(a) shows the original local-dimming backlight. Figure 3(b) shows the smoothing result after the recursive low-pass filters have been applied 100 times to reduce the LED blocky effect. The low-pass filter effectively simulates the function of the optical diffuse films, which is to make the LED lighting more uniform.

The final image is composed of the original image and the backlight brightness. Each pixel of a displaying image is given by

$$Y_{ij} = (\frac{F_{jk} \times B_{jk}}{B_{max}}), \tag{7}$$

where $F_{jk}$ is the original pixel and $B_{ik}$ is the backlighting level at the (j, k)th pixel. One local-dimming block has the same backlighting level that is estimated from (5), which can be given by

$$B_{jk}^{P} = Block_{light}^{P}, for\ j = 0\ to\ n-1,\ and\ for\ k = 0\ to\ m-1 \tag{8}$$

when the block size is n × m. $B_{jk}^{P}$ and $Block_{light}^{P}$ denote the backlighting for the (j, k)th pixel at the P-th block and the P-th block, respectively. $B_{max}$ is the maximum brightness of the backlight in the estimated frame. If $B_{jk}^{P} = B_{max}$, then $Y_{jk} = F_{jk}$. The image can be completely reconstructed. When the backlighting is zero, the pixel output $Y_{jk}$ is zero and so the pixel appears a black dot on display.

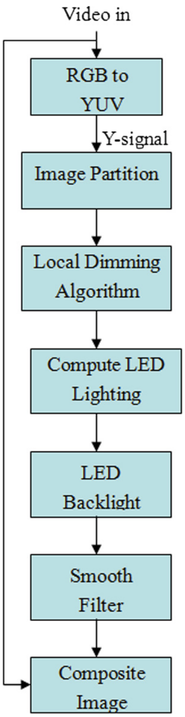



**Fig. 2.** The flowchart of simulation for local-dimming algorithm

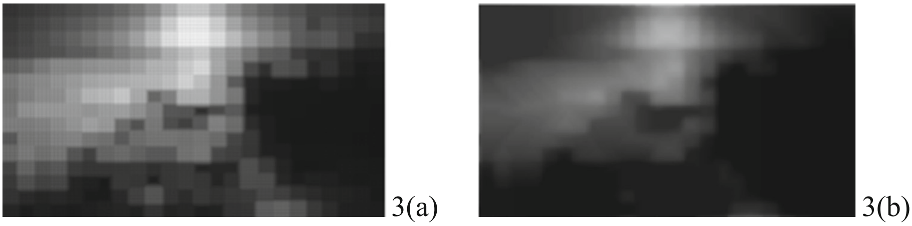



**Fig. 3.** The original and its filtering image

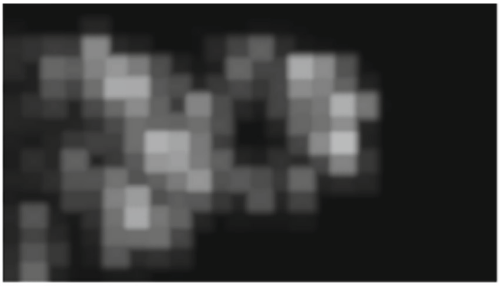
## 4 Simulations and Comparisons

Now, various local-dimming algorithms are simulated by C-programming, according to the processing flowchart above. The backlight is designed for a large LCD panel, such as 42-in. Full HD (high-definition) with 1920 × 1080 pixels. It is divided into 24 × 15 blocks for local-dimming control. Each block contains a 2 × 2 LED array, and each block illuminates 5760 pixels. Figure 4 shows the original test image. Figures 5(a), (b), (c) and (d) shows the local dimming backlighting realized using the average, the maximum, the reference [6] and our proposed methods, respectively. In the simulations, our proposed algorithm enhances the backlight level at the low-level edges with $\alpha = 1.25$ in Eq. (3) and $\beta = 1$ in Eq. (4) in simulations. Figures 11(a), (b), (c) and (d) shown the reconstructed images on the LCD obtained using the average, the maximum, the reference [6] and our proposed methods, respectively. The average and the maximum methods can not capture the details of the low-level edges. The reference method [6] improves the detail of the most of the edges. The proposed algorithm further improves the quality of weak edges.

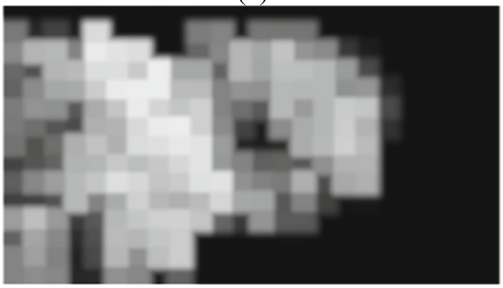
**Fig. 4.** Original image.

The error values are calculated as the absolute difference between the original image and that of the reconstructed image obtained using each algorithm. Figures 12 (a), (b), (c) and (d) show the error images of the average, the maximum, reference [6] and our proposed methods, respectively. Obviously, the average and maximum methods have large errors. The error in Chen's method [12] is largely reduced. The proposed algorithm can almost exactly reproduce the original image with a very small error.

Next, the parameters are evaluated on various video sequences. Table 1 shows the results with PSNR (peak signal to noise ratio) values and error values. The PSNR values are low in the results of the average and the maximum methods. The reference method [6] has much better 10 to 20 dB than those of the average and maximum methods. Our proposed algorithm yields PSNRs that are further improved by 4 to 5 dB over that of the reference method [6]. The error values are the sum of the absolute errors of one frame in various video sequences. Clearly, the proposed algorithm achieves a lower error than the other local-dimming algorithms (Fig. 6).



5(a)



5(b)

5(c)

5(d)

**Fig. 5.** (a), (b), (c) and (d) local dimming backlight with the average, the maximum, the reference [6] and our proposed methods, respectively.

6(a)

6(b)

6(c)

6(d)

**Fig. 6.** (a), (b), (c) and (d) the reconstructed image as backlight with the average, the maximum, the reference [6] and our proposed methods, respectively.

## 5 Conclusion

This work presents a high-performance local-dimming algorithm to enhance weak edges and thereby improve the perceived image resolution. Unlike other local-dimming algorithms, the proposed method reproduces images on a LCD without visible distortion. The difference between the fixed and the proposed backlight was almost imperceptible.

## References

1. Chen, C.-C., Wu, C.-Y., Wu, T.-F.: LED back-light driving system for LCD panels. In: Proceedings of Applied Power Electronics Conference, pp. 381–385 (2006)
2. Lin, F.C., Liao, C.Y., Liao, L.Y., Huang, Y.P., Shieh, H.P.D.: Inverse of mapping function method for image quality enhancement of high dynamic range LCD TVs. SID Symp. Dig. Tech Papers **38**, 1343–1346 (2007)
3. Lee, T.W., Lee, J.-H., Kim, C.G., Kang, S.H.: An optical feedback system for local dimming backlight with RGB LEDs. IEEE Trans. Consum. Electron. **55**(4), 2178–2183 (2009)
4. Liao, L.Y., Chen, C.W., Huang, Y.P.: Local blinking HDR LCD systems for fast MPRT with high brightness LCDs. J. Disp. Tech. **6**(5), 178–183 (2010)
5. Lai, C.-C., Tsai, C.-C.: Backlight power reduction and image contrast enhancement using adaptive dimming for global backlight applications. IEEE Trans. Consum. Electron. **54**(2), 669–674 (2008)
6. Chen, H., Sung, J., Ha, T., Park, Y., Hong, C.: Backlight local dimming algorithm for high contrast LCD-TV. In: Proceedings of ASID 2006, New Delhi, pp. 168–171, October 2006