A Real-Time Liquid Crystal Signal Compensation Method for High Dynamic Range LCD

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Abstract

Blur-mask approach was developed to simulate the backlight distribution of locally-controlled dimming LED backlight with lower computational complexity which is less than 1% of conventional convolution method. The blur-mask approach was demonstrated to perform high image quality and high contrast ratio (~20,000：1) on a 37" LCD-TV. Compared with convolution, blur-mask approach has much lower computational complexity and successfully demonstrated for real-time applications.

1. Introduction

A high dynamic range LCD (HDR-LCD) can much enhance the contrast ratio of image upon the locally-controlled backlight [1]. The backlight distribution, however, will affect the image brightness. Therefore the LC images need to be modified to compensate brightness. Conventionally, the backlight distribution can be simulated by convolving the extended backlight signals with the light spread function (LSF). According to the convolution result and target image, the compensation signal of liquid crystal (LC) can be derived, and an HDR image will be displayed by combining the backlight distribution and the compensated LC signal.

In convolution approach, the light spread function (LSF) has to be stored in hardware for simulating the backlight distribution, and the result of the distribution can be utilized for compensating the LC signal. However, the computation of convolution operation would be very complex. For conventional hardware, it is not easy to perform in real-time.

Therefore, we proposed a novel method named "blur-mask approach" to approximate the backlight distribution that can much reduce computational complexity. From this proposed method, the compensated LC signal can be derived according to the target image and the backlight distribution which was produced by blur-mask approach.

2. Blur-Mask Approach

Blur-mask approach utilizes a low-pass-filter (LPF) to blur the original backlight grayscale image whose values were determined in advance. After expanding and blurring, the gray-level image of backlight will be similar to the real light distribution of backlight illumination. Subsequently, dividing the target image by the blurred backlight image and taking gamma effect (γ) of the display device into consideration, the compensation signal of LC can be obtained.

In our experiments, the backlight unit of a full-HD (1920×1080) 37" LCD was designed as 8×8 zones to reduce the number of driver ICs and simplify the hardware computational complexity. In the procedure of blur-mask approach, the first step is to obtain the original backlight image whose size is 8×8 pixels, as shown in Fig. 1(a). Second, the length and width of the 8×8 image will be expanded by a factor of 2. After expanding, the 16×16 image is convolved by the blur mask whose size is 3×3, as shown in Fig. 1(b), and the weighting value of the blur mask is set as the power of 2 for simplifying the hardware loading. Subsequently, the procedure of expanding and blurring are repeated until the blurred image is expanded to 256×256. Finally, this blurred image is expanded to 1920×1080 to represent the simulation of real backlight distribution. The complete procedure of blur-mask approach is shown in Fig. 2

In blur-mask approach, only the 3×3 blur mask is required instead of a large memory for LSF storage. Through the simplification, only 589,824 multiplications and 524,288 additions are required to calculate the backlight distribution per frame. In the comparison, convolution method which the resolution of LSF is chosen as full resolution needs 101,606,400 multiplications and 62,726,400 additions.

3. Simulation and Experimental Results

The simulation results by blur-mask and convolution approach of partly magnified test image, Lily and Space Robot, are shown in Fig. 3(a)~(f). Both of the backlight signals are first determined by Inverse-of-Mapping Function (IMF) method [2]. Obviously, the image quality of blur-mask approach is close to that of convolution one. Moreover, from Fig. 3(a)~(c), the image details at high brightness region are clearer by using blur-mask approach, and from Fig. 3(d)~(f), the blur results can also keeps the high brightness. Thus, the results show that blur-mask approach is feasible.

The blur-mask approach was implemented on a 37" HDR-LCD, and the measurement results were listed in Table 1. The image quality by using two backlight simulation approaches: blur mask and convolution will be discussed by four main parameters, distortion ratio

(D), brightness, contrast ratio (CR), and computational complexity. The distortion ratio, D, is defined as following for quantizing the distortion of displayed HDR image,

$$D \equiv \frac{N_c}{N_t} \times 100\ \%$$

where Nc is the total clipped sub-pixel number, and Nt is the total sub-pixel number. The computational complexity will be separated into multiplication and addition parts. The computational complexity of convolution approach was set as 100 % to compare with the blur-mask method. From Table 1, the distortion ratio by using blur-mask approach are much lower than that of convolution one. Although the CR by using blur-mask approach is slightly lower, blur-mask approach still keeps very high contrast ratio(~20,000 : 1), and has similar image luminance as convolution one. The most important is the computational complexity of blur-mask approach was dramatically reduced to become less than 1% of convolution one. Therefore, blur-mask approach can be easily applied on real-time TV application.

4. Conclusions

A novel real-time LC signal compensation method for high dynamic range liquid crystal displays (HDR-LCDs), named blur-mask approach, was proposed. Blur-mask approach utilizes a low-pass filter to blur the original backlight grayscale image. Through expanding and blurring, the size and shape of blur result can be achieved the real backlight distribution for LC signal compensation. Blur-mask approach only requires less than 1% of convolution in hardware calculation, and the experimental results proved that the blur-mask approach has almost the same image quality as that of convolution ones. Due to the simplicity, blur-mask approach is demonstrated for realizing in simple hardware and processed in real-time for locally-dimming HDR-LCDs.

5. References

[1] H. Seetzen, et al., “High Dynamic Range Display Systems”, SIGGRAPH 2004, ACM Transactions on Graphics, 23(3), pp. 760-768, 2004.

[2] Fang-Cheng Lin, et al., “Inverse of Mapping Function (IMF) Method for Image Quality Enhancement of High Dynamic Range LCD TV“, SID 39.4, pp.1343-1346, 2007

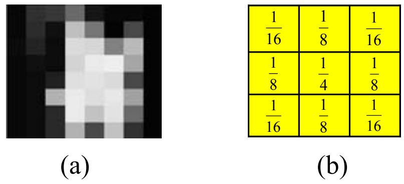

Fig. 1 (a) the gray-level image of backlight and (b) the blur mask

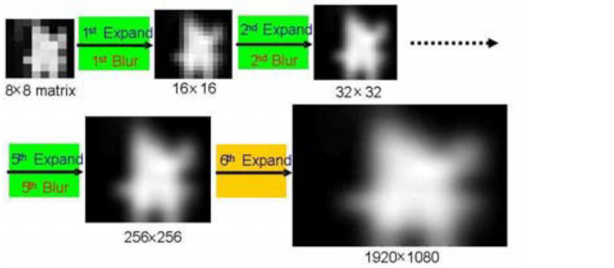

Fig. 2 The procedure of expanding and blurring in blur-mask approach.

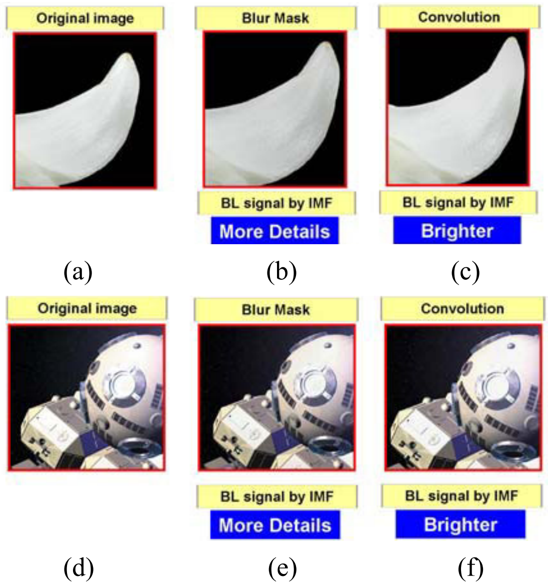

Fig. 3 The HDR images of partly magnified test image, Lily and Space Robot. (a)(d)The original image, (b)(e) by blur-mask approach, and (c)(f) by convolution method respectively.

Table 1. The distortion ratio, brightness, contrast ratio and computational complexity of test images, Lily and Space Robot, by using the convention, blur-mask approach.

Image / LC	Lily					Space Robot				
	D(%)	Lmax(nits)	CR	Computational Complexity		D(%)	Lmax(nits)	CR	Computational Complexity	
Conv	1.79	431.5	21575	Multiplication	100.00%	2.39	463.0	3858	Multiplication	100.00%
				Addition	100.00%				Addition	100.00%
Blur	0.44	396.6	19830	Multiplication	0.35%	0.3	462.3	3853	Multiplication	0.35%
				Addition	0.60%				Addition	0.60%