Scene-adaptive RGBW conversion algorithms for RGBW LCDs

H. I. Baek, K. J. Kwon, H. H. Sohn, C. R. Seo and I. J. Chung
LG.Philips LCD R&D Center, 533, Hogae-dong, Dongan-gu, Anyang, Gyongki-do, 431-080, Korea
Phone: +82-31-450-7467, E-mail: cyberist@lgphilips-lcd.com

Abstract

LCDs with an additional white sub-pixel (RGBW LCDs) have been developed mainly to achieve higher panel transmittance. However this RGBW pixel structure causes the perceptual color difference between RGBW and RGB LCDs due to decreased primary color luminance. To solve this problem, we proposed and developed RGBW conversion algorithms that function adaptively as a displayed image changes. The test results show that the perceptual color difference could be solved to some degree by applying these new algorithms.

1. Objective and Backgrounds

As the color gamut required in LCDs becomes higher, the transmittance of Color Filter layer becomes lower. Therefore the LCD panel transmittance is very poor especially in LCDs for TV application. For example, the transmittance of the CF layer for achieving 100% EBU gamut with CCFL backlight is only 27 %.

The RGBW pixel structure [1, 2] has been developed as one of the efforts to increase the overall panel transmittance. By adopting an additional white sub-pixel into the conventional RGB pixel structure the overall panel transmittance becomes higher up to 1.5 times although the physical dimension of R, G, and B sub-pixel is decreased to 0.75 of that of RGB type.

This means the white luminance becomes 1.5 times while the luminance of other primary colors becomes 0.75 times. Therefore a higher contrast as well as a perceptual color difference is caused in displayed images against those of the conventional RGB LCDs [2]. And this drawback would limit the application of the RGBW LCDs.

To compensate this demerit of the RGBW LCDs, several approaches to the RGB-to-RGBW conversion algorithms have been tried but the results were not so satisfactory [3-5]. So, here we proposed scene-adaptive RGBW conversion algorithms that function adaptively as a displayed image changes

2. Methods

In color data conversion maintaining hue and saturation is very important, so we based on the Equation (1) where a constant gain is multiplied to the RGB input luminance data. Then we make the luminance gain, 'Gain' change as scene changes. To make 'Gain' changes adaptively there should be a rule that decides how much gain would be applied.

$$\begin{aligned}(R_A, G_A, B_A) &= Gain \times (R_I, G_I, B_I) \\ (R_O, G_O, B_O) &= (R_A, G_A, B_A) - W_O \\ W_O &= \min(R_A, G_A, B_A, 1)\end{aligned} \quad \text{......(1)}$$

To make a reasonable rule, we analyzed two different kinds of images as follows

Figure 1 shows an example of highly saturated image. The data plot on RG domain shows that the highly saturated red region is out of RGBW gamut. And the converted RGBW image shows perceptual difference against RGB image when one of static conversion

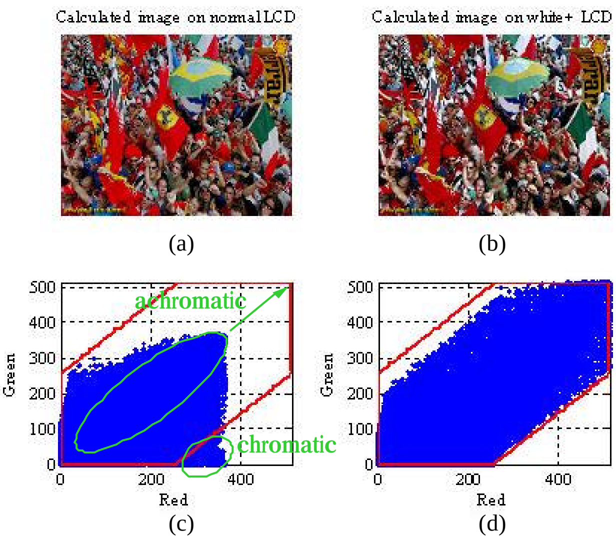

Figure 1. An example of highly saturated image and data plot on RG domain (simulated);
(a) Image on RGB, (b) Image on RGBW
(c) Data plot of (a), (d) Data plot of (b)

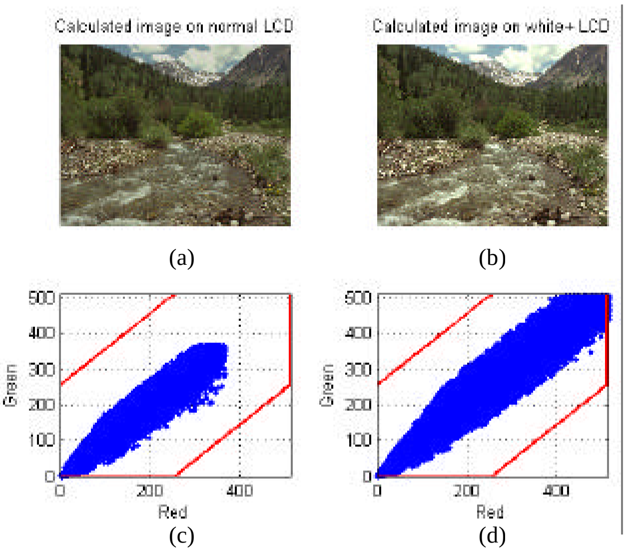

Figure 2. An example of rather unsaturated image and data plot on RG domain (simulated);
(a) Image on RGB, (b) Image on RGBW
(c) Data plot of (a), (d) Data plot of (b)

algorithms is used. It mainly because of increased luminance contrast between achromatic and chromatic regions. To reduce this phenomenon we should apply rather lower luminance gain on highly saturated images.

On the contrary, figure 2 shows an example of rather unsaturated image. The converted image doesn't show any perceptual difference because there is no data out of RGBW gamut. In this case we can maximize the overall brightness by applying rather higher luminance gain.

To achieve this characteristic, we discriminate the input RGB signal into chromatic and achromatic signals. Then counting the number of achromatic signals at every image frame to generate the luminance gain, which will be multiplied to the input RGB luminance signals. Figure 3 shows the block diagram of the gain generator.

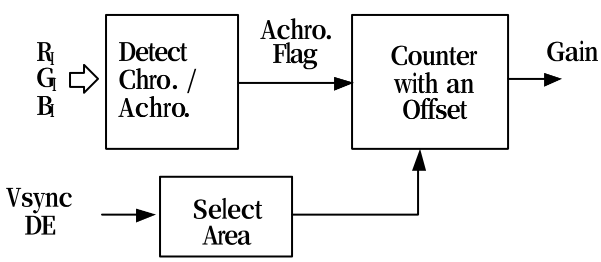

Figure 3. The block diagram of the gain generator

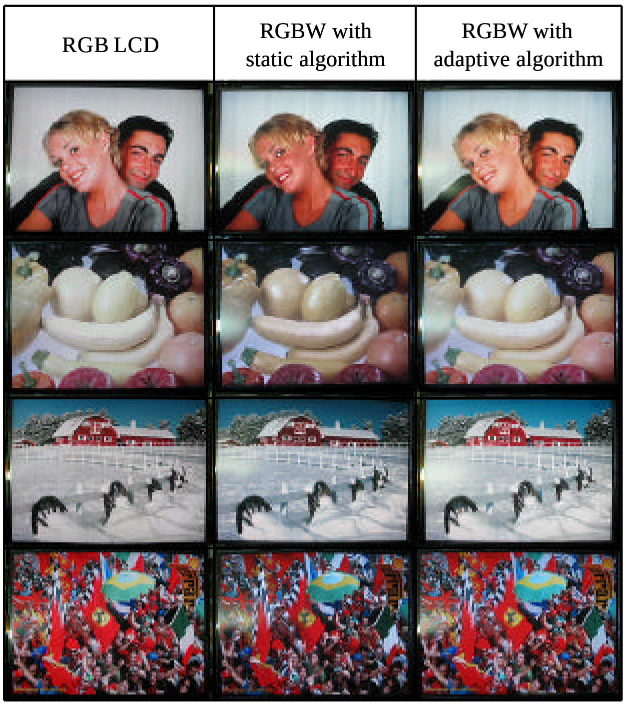

Figure 4. Comparison of displayed images on 15" XGA RGB and RGBW LCD (Photographs was taken under same exposure condition)

Several values of the decision rule for the chromatic / achromatic signal have been tested and optimized through the image simulations and then we programmed 15.0"-XGA-RGBW demonstrator with the optimized value.

3. Results and discussion

Figure 4 shows the real images displayed on the RGB normal display and RGBW display with static/ adaptive algorithms using same BLU (Back Light Unit). We could verify proposed scene-adaptive RGBW algorithm with chromatic / achromatic discrimination rule worked well and showed very similar perceptions over divers test images.

The overall image brightness and the degree of degradation in highly saturated region show a trade-off characteristic. So we should adjust the threshold value as a main application of RGBW LCD is changed.

In addition to this, a kind of adaptive backlight luminance control methods could be combined to maximize the effect of proposed scene-adaptive RGBW conversion algorithms and many other decision rules for gain generation could be applied to enhance the characteristics of RGBW LCDs

4. Impact

Our newly proposed scene-adaptive RGBW conversion algorithms would give more opportunity to the RGBW LCDs by reducing the difference from RGB LCDs in the perceptual aspect without losing the overall brightness gain in the general images.

5. Acknowledgement

We would like to thank Mr. Hans van Mourik in Philips CE for discussing and giving me an idea on this subject.

6. References

[1] S. Hirano et al. International Patent Publication Number WO 01/37249 A2

[2] B. W. Lee et al, SID 03 Digest, 1212 (2003)

[3] H. I. Baek et al, IDW '03, 1735 (2003)

[4] S. D. Lee et al, 10^{th} Color Imaging Conference, 287 (2002)

[5] B. W. Lee et al, SID 04 Digest, 111 (2004)