Novel Method of Color Correction LUT generation for LCDs

Jae Won Jeong, Hoi Sik Moon, Brian H. Berkeley, Sang Soo Kim
Development Center, LCD Business, SAMSUNG ELECTRONICS, Asan-City, Chungcheongnam-Do, Korea

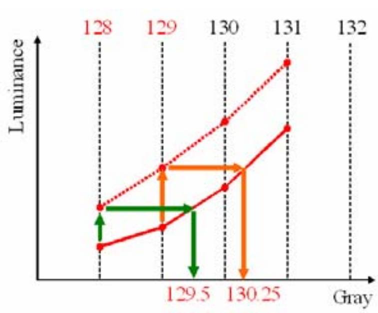
Keywords: ACC(Accurate Color Capture), FRC(Frame Rate Control), dithering, color shift

Abstract

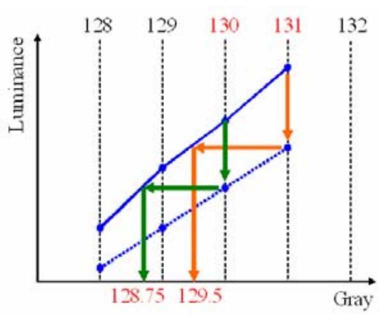
Achieving white balance is one of the key issues for LCD image quality enhancement. A well-known color correction algorithm is Accurate Color Capture (ACC). Determination of ACC correction values has been time consuming as past methods have required trial-and-error analysis of differences between predicted and measured values. We propose a new ACC value determination method that uses spatially emulated patterns and measured values on patterns.

1. Introduction

ACC (Accurate Color Capture) technology has been developed and applied to solve the color shift problem in PVA mode panels [1][2]. ACC changes RGB gamma curves separately to correct the color shift problem [1]. Figure 1 shows an example of ACC correcting a PVA panel's natural tendency for mid-gray bluing.



(a) ACC raises the red gamma curve



(b) ACC reduces the blue gamma curve

Figure 1. Example of color correction using ACC

Recent work has been conducted to extend ACC technology for uniform white balance on- and off-axis [2]. Until now, color correction by ACC has been manually accomplished using the process in fig.1. However this process takes a long time, usually at least one day. The process in fig.2 is an iterative process which repeats several calculations and measurements until the color performance is uniform over the entire gray scale range. It is time consuming due to the need for many iterations, which are required because of errors between the predicted and actual applied results. In this paper, we propose a new method to automate the color correction process for PVA mode panels. The proposed method is based on a spatially emulated pattern and it enables us to reduce total color correction time.

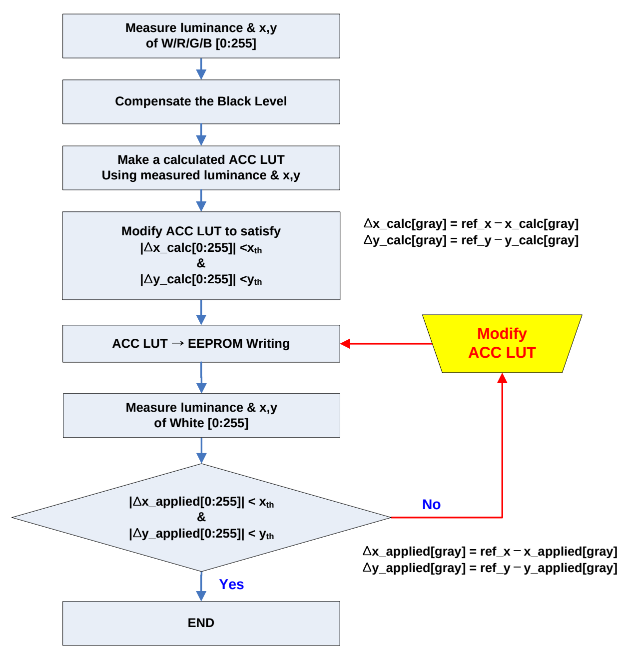


Figure 2. Conventional process for determining color correction (ACC) values

2. New ACC technique using spatially emulated pattern

The proposed algorithm uses a spatially emulated pattern to emulate ACC driving. In this work, we did not use temporal dithering. ACC driving must use spatial + temporal dithering as in Fig. 3 to hide FRC driving from human perception.

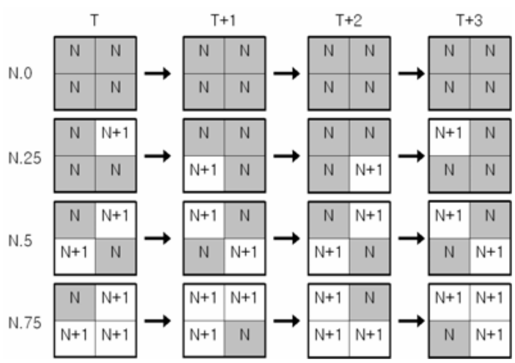
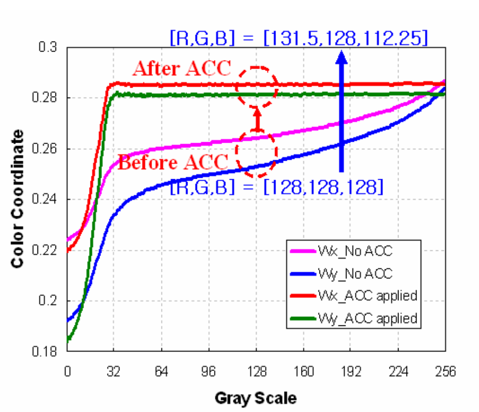
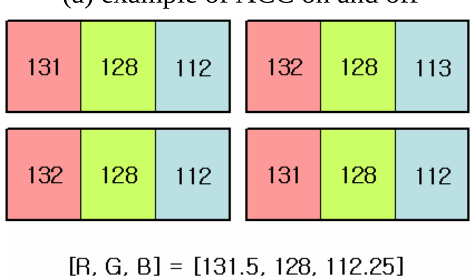


Figure 3. Example of FRC : temporal + spatial dithering



(a) example of ACC on and off



(b) spatially emulated pattern at 128 gray (2 by 2)

Figure 4. Example of ACC on and off (a) and a spatially emulated pattern at 128 gray (b)

However, from the viewpoint of the colorimeter used for ACC tuning, there is no difference between doing all dithering spatially compared to combined spatial + temporal dithering. That is because the measurement area of the colorimeter is large enough to ignore the difference (the colorimeter's diameter is tens of mm). If we can exactly predict the actual ACC results, it would be possible to correct the color shift just by measuring a spatially emulated pattern. Then the iterative process in fig. 2 would be unnecessary because iterative EEPROM writing to upload ACC LUT values could be omitted. Figure 4 illustrates an example of using a spatially emulated pattern. When we correct the color coordinate from A to B in fig. 4(a), the ACC value at 128 gray is [131.5, 128, 112.25]. And a spatially emulated pattern of this value is shown in Fig. 4(b). The automated process using this method is described in Fig. 5. In this process, EEPROM writing is needed only one time to upload the final ACC tuning result.

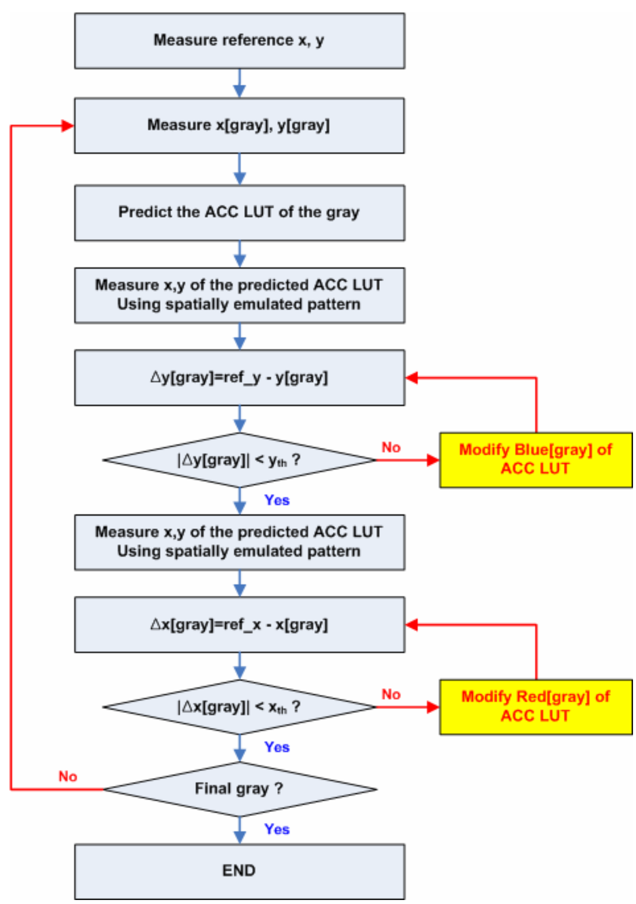
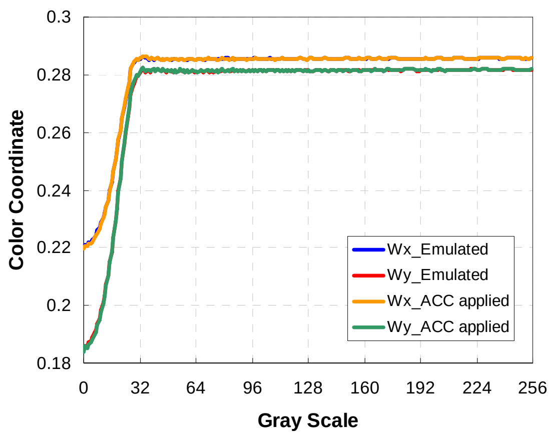


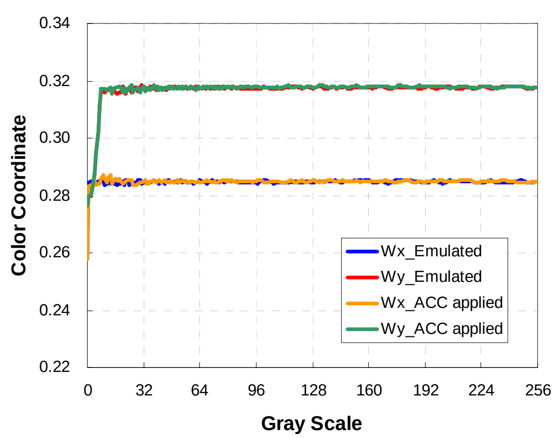
Figure 5. The automated process of color correction (ACC) using a spatially emulated pattern

3. Experiments

We made a software tool using the process in Fig. 5 and applied to find ACC LUT values for 32 inch normal PVA panel. and 40 inch S-PVA panel. It took 3 minutes to complete the entire tuning process for each panel. The results are shown in Fig. 6



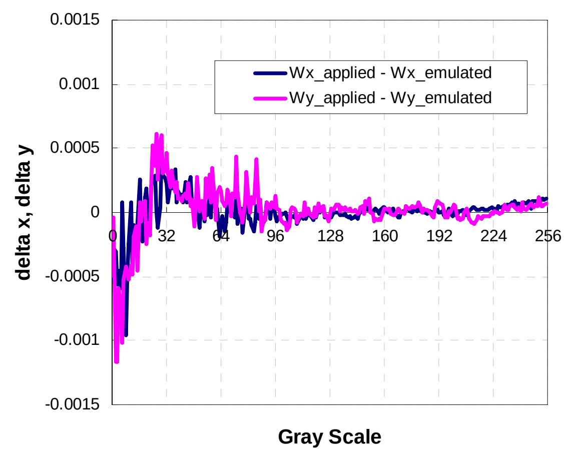
(a) 32 inch normal PVA panel



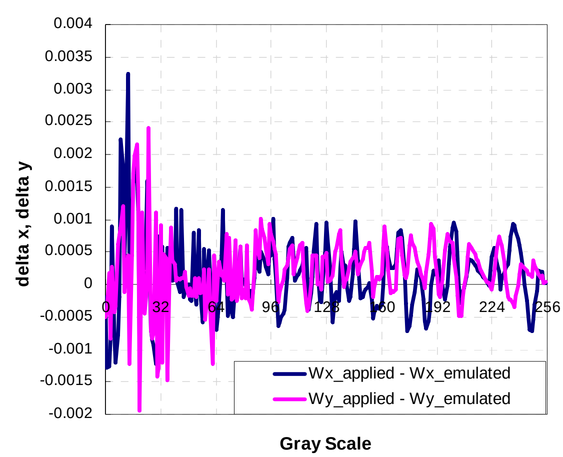
(b) 40 inch S-PVA panel

Figure 6. Comparison of the predicted result to actual ACC result

Figure 7 shows the delta of Wx and Wy that are differences between the result of actual ACC and the predicted result. The CA-210 guarantees repeatability as follows: 0.005 at 0.2 to 0.49 Cd/m2, 0.002 at 0.5 to 0.99 Cd/m2, and 0.001 at 1 to 1000 Cd/m2. In case of 32 inch normal PVA panel in Fig. 7(a), delta values at 0 to 96 gray were increased and showed the largest delta at gray level 3. Luminance at gray level 3 was about 0.33 cd/m^2 and the repeatability of CA-210 is weak below 0.49 Cd/m^2. Thus larger delta values at low gray will occur by the low gray resolution of CA-210. And we can indicate that the proposed method works well in normal PVA panel. 40 inch S-PVA panel shows relatively larger delta than normal PVA panel in Fig. 7(b). It satisfied the repeatability of CA-210 at 96 to 255 gray. However delta values were much larger than normal PVA's when the gray level become lower. Generally, the experimental results of 40 inch S-PVA panel are acceptable to practical application. And we need to verify the large delta level of S-PVA panel against normal PVA panel.



(a) 32 inch normal PVA panel



(b) 40 inch S-PVA panel

Figure 7. Delta of Wx and Wy between predicted result and actual ACC result

4. Conclusion

The proposed algorithm can automate the color correction process by using an emulated pattern with gray by gray steps. We implemented the algorithm in a software tool, and were able to reduce the color correction time from many hours to several minutes.

5. References

[1] S.W. Lee, et al., “Driving Scheme for Improving Color Performance of LCD’s: Accurate Color Capture”, SID 03 DIGEST, pp. 344-347, 2003.

[2] S.W. Lee, et al. “RGB Gamma Curve Control for Improved LCD Color Performance”, SID Symposium Digest, Vol. 37, pp. 1590-1593, 2002.