Color Reproductions Varying the Input Level on a Liquid Crystal Display Panel

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Abstract

Color reproductions for LCD (Liquid Crystal Display) panels are different from that of CRT (Cathode Ray Tube) display. Color reproductions for a typical color LCD panel for personal computer (TFT transmissive type for Sharp Mebius MN930-X23) are examined. The reproduction color gamut on the (x,y) chromaticity diagram are measured by varying the input digital levels. The color reproduction area becomes smaller in accordance with the lower input digital level. The correlated color temperatures also vary with the input digital levels. The lower the input digital levels, the higher the correlated color temperatures. The method for making the correlated color temperature constant is shown in this paper. The gamma curves for three primary colors are modified to fix the correlated color temperatures. The compensation of the correlated color temperature has been confirmed on the LCD panel.

Introduction

Color LCD (Liquid Crystal Display) has been widely used for personal computers and video monitors, because of light weight, small volume, low power consumption and so on. When we compare the color LCD and CRT (Cathode Ray Tube) display, the color reproductions for LCD are different from that of CRT. LCD shows the bluish reproductions for medium contrast images. Tamura[1] pointed out that the correlated color temperatures for a color LCD panel varied with input digital levels. However, the characteristics of color reproductions for LCD are a little known.

In this paper, we measured the color gamuts, correlated color temperatures and gamma characteristics of a typical color LCD panel for a personal computer. The color reproduction characteristics for a LCD have been analyzed. It is found that the color gamuts are changed with input digital levels.

The compensation method of variation of correlated color temperatures according to the input digital level has proposed. The compensation has been confirmed by the experiment.

Method

The characteristics of a transmissive TFT-LCD panel for personal computer (Sharp Mebius MN 930-X23) were measured using spectral radiation meter (Spectroscan #650 and Topcon SR-2). The screen size of the LCD panel was 15”-XGA (1024*768 pixels). The test area (154*154 pixels) which was surrounded by black area was set at the center of the LCD. The spectral radiation meter is set the right angle to the LCD panel. The measuring spot of the meter is in the test area.

The tristimulus values (X,Y,Z) for three primary colors R(red), G(green), B(blue) and Gray were measured by varying the input digital levels. The digital levels were changed from 0 to 255 every 8 steps for 8 bits test areas.

Measured Results

Color Gamut

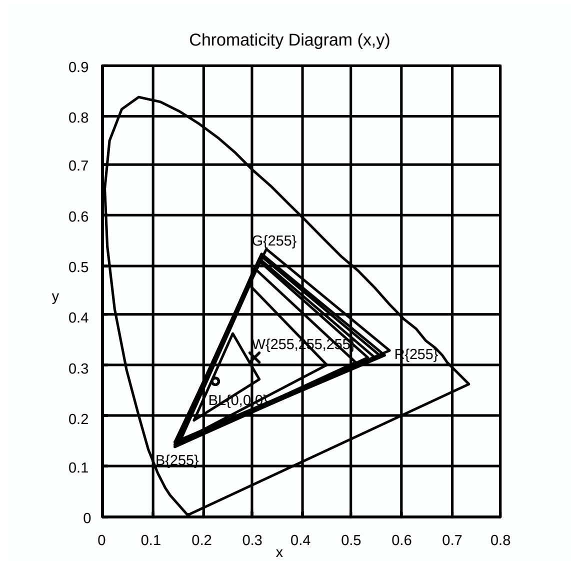

Figure 1. Color gamuts of a LCD varying the input digital levels. The largest triangle is for the R{255},G{255},B{255} and the smallest is for R{32},G{32},B{32}. W *is chromaticity point for white and* BL *for black.*

The color gamuts on chromaticity diagram (x,y) which are calculated from measured tristimulus values (X,Y,Z) are shown in Figure 1. The largest triangle is for the R{255}, G{255}, B{255} and the smallest for R{32}, G{32}, B{32}. Triangles are drawn every 32 steps. It is shown that the color gamuts for LCD vary with the input digital levels.

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The lower the input digital levels, the smaller the color gamuts. Moreover, the gamuts shift towards the blue region.

In Figure 1, the chromaticity point for white [R{255}, G{255}, B{255}] and black [R{0}, G{0}, B{0}] are also shown. The mark(x) is for white and the mark(o) for black. The LCD panel has chromaticity point for black, because the light transmission through the LCD panel occurs in black situation. The chromaticity point for black is different from that for white.

Correlated Color Temperatures

Figure 2 shows the measured chromaticity point for achromatic gray inputs. The variation of the chromaticity points of gray images varying the input digital levels from white [R{255}, G{255}, B{255}] to black [R{0}, G{0}, B{0}] is shown in Figure 2. The mark(o) shows the chromaticity point for white (x=0.3037, y=0.3163), the mark(x) for black(x=0.2284, y=0.2688). The marks on the curve indicate the chromaticity points in every 16 steps. It is shown that the gray images become bluish, according to the low input digital level.

The correlated color temperature is about 7180K for white, 29130K for black and 11200K for medium gray [R{128}, G{128}, B{128}]. The blackbody locus is also shown in Figure 2 by broken line.

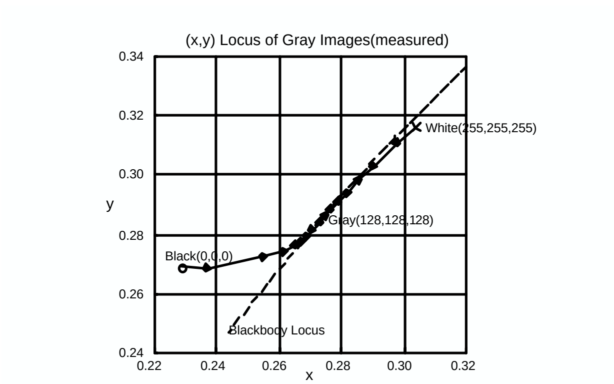

Figure 2. Locus of gray chromaticity points on (x,y) diagram varying the input digital level

Measured Gamma Curves

The gamma curves for R,G,B calculated from measured Y values (normalized to unity at maximum Y values) are shown in Figure 3. The curves do not coincide with each other, and do not become zero at input digital level=0.

The gamma curve for Red is almost equal to the gamma=2.2 curve. The Blue curve is higher than others are. This fact means that the output light level for B is brighter than R and G, in the case of same input digital level.

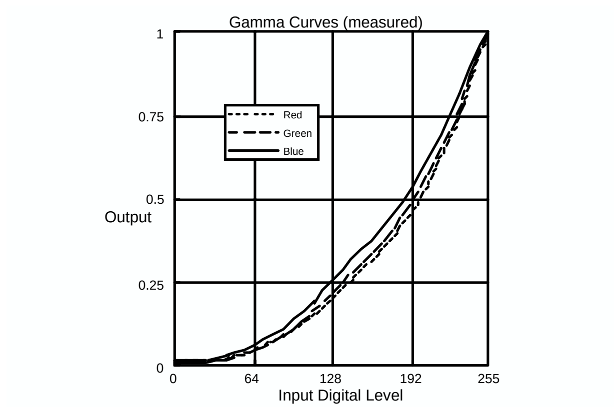

Figure 3. Gamma curves for three primary colors

Compensation of Color Reproductions for a LCD

The LCD can apply the additive color mixing.[2] The bluish color reproduction can be compensated by less contribution of blue components. The compensation of correlated color temperature can be done by using LUT (Look Up Table), shown in Figure 4. The curve for B of the compensation LUT is lower than for R and G. The bluish color reproduction could be compensated by lower the blue component. For example, Gray{R=128, G=128, B=128} is equal to the correlated color temperature 11200K, but Gray{R=128, G=128, B=104} becomes about 7340K. The correlated color temperatures compensated by the LUT are around 7700K except for low input digital level(from 0 to 72). At the low input level we can not achieve around 7700K by additive color mixing.

The estimated locus of the correlated color temperatures compensated by the LUT is shown in Figure 5. The gamma curves applying the compensation LUT is shown in Figure 6.

Compensation of Correlated Color Temperature

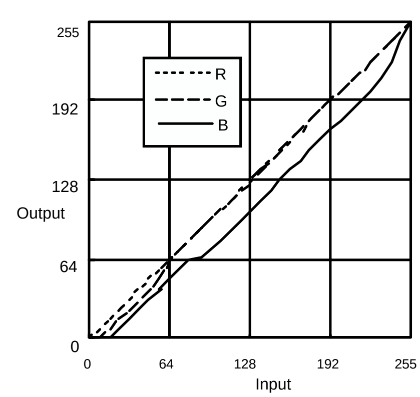

Figure 4. LUTs which compensate the variation of the correlated color temperatures for a LCD shown in Figure 2.

Estimated Locus of Correlated Color Temperatures

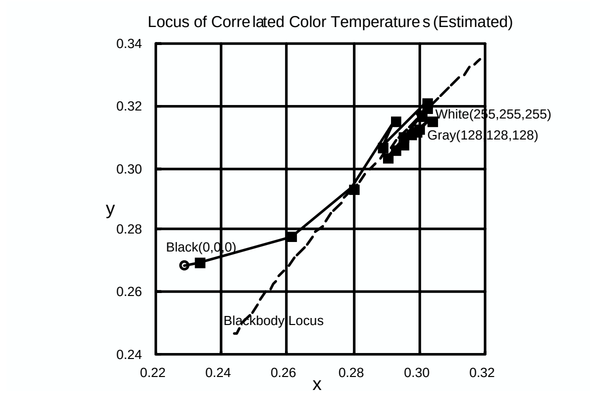

Figure 5. The estimated locus of the correlated color temperatures varying the input digital level, using compensation LUT shown in Figure 4. The mark (x) is for white and the mark (o) is for black. The marks are pointed every input digital steps 16.

Compensated Gamma Curves

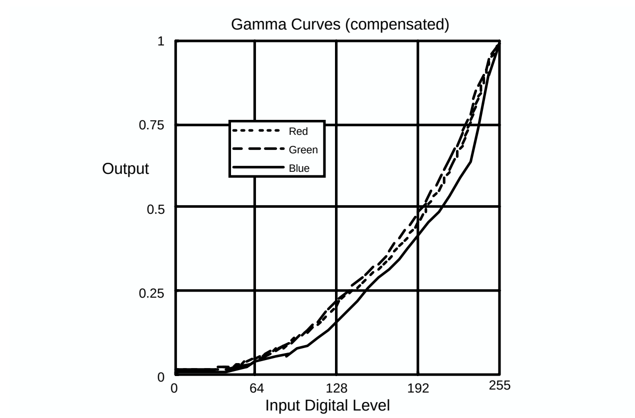

Figure 6. The gamma curves varying the input digital level, applying compensation LUT shown in Figure 4.

Color Shifts Caused by LCD

The color gamuts vary with input digital level, so the colors on the LCD panel are different from that of CRT display. The color shifts for typical medium contrast colors are calculated.

Figure 7 shows the color shift on the (x,y) chromaticity diagram. The mark(x) are chromaticity points, where the gamut does not change according to the input digital level, like CRT. The mark(o) are the chromaticity points for the measured LCD. It is shown that the colors shift towards blue direction.

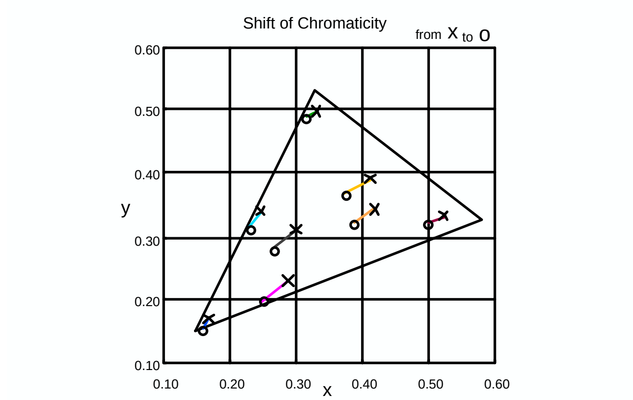

Figure 7. Color shifts for typical medium contrast colors. The mark(o) are the chromaticity points for the measured LCD. The mark(x) are chromaticity points, where the gamut does not change according to the input digital level

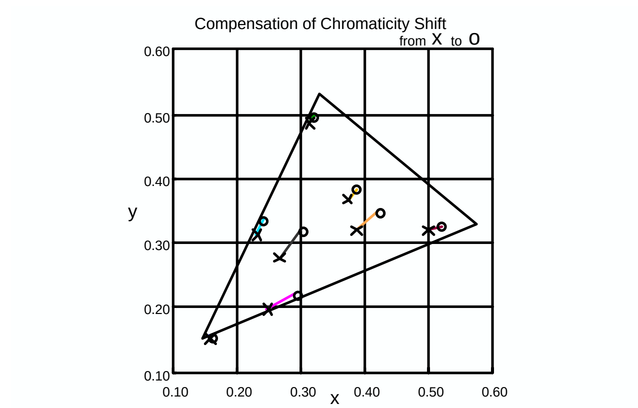

Figure 8. Color shifts applying compensation LUT shown in Figure 4. The mark(o) are the chromaticity points for the LCD applying compensation LUT. The mark(x) are chromaticity points for non compensating LCD.

The color shifts of compensated LCD using the LUT shown in Figure 4 are calculated. Figure 8 shows the result of calculations. The mark(o) are the chromaticity points for the LCD applying compensation LUT. The mark(x) are chromaticity points for non compensating LCD. The compensation of blue shifts can be seen in Figure 8.

Experimental Results of Compensation

The gray images compensated by the LUT shown in Figure 4 were measured by the above-mentioned method. The locus of chromaticity points varying the input digital level is shown in Figure 9. It is shown that the correlated color temperatures are around 7000K except for low input level. The variation of the correlated color temperatures is minimized using compensation LUT.

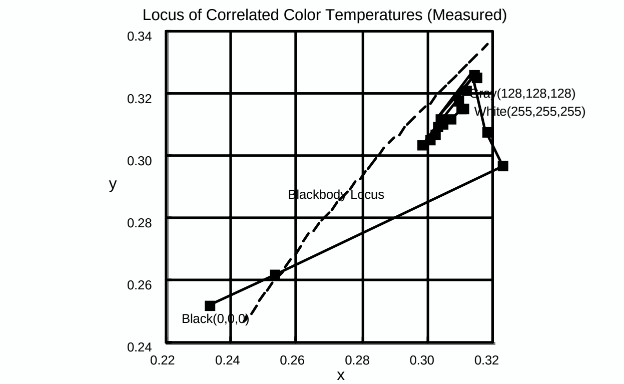

Figure 9. The measured correlated color temperature applying the compensation LUT shown in Figure 4

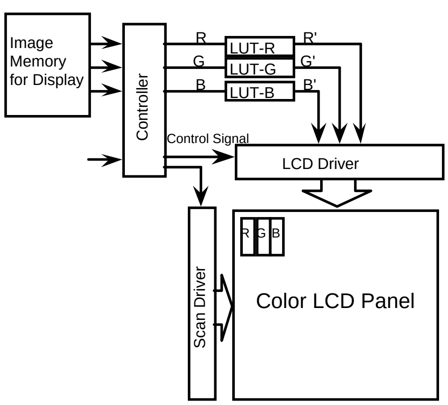

Figure 10. The schematic diagrams for applying the LUTs for LCD panel of a personal computer.

Application to PC

For still pictures, the color reproduction of the LCD panel can be compensated by using the icc-color profiles in which the compensated gamma curves are imbedded. However, for movie pictures, it is necessary that the color compensations should be carried out in real-time operation. The LUTs shown in Figure 4 should be inserted in the image data to LCD panel, as shown in Figure 10.

Conclusions and Discussions

The color gamut and correlated color temperatures for a LCD panel change according to the input digital level. Hence, the CRT does not change its color gamut and correlated color temperature. It is shown that the LCD reveals the bluish color reproductions. The compensation of correlated color temperatures using LUT is proposed.

The compensation can not be done for low input digital level, but for human vision, it is hard to aware the bluish black. It is important to compensate the medium contrast bluish images.

In this paper, we propose the compensation of the correlated color temperatures using LUT. The same technique can apply for modifying the correlated color temperatures of the LCD panel. It is possible that the average correlated color temperature can be changed to higher(for example 11000K) or lower (for example 5500K) by modifying the LUT.

It is considered that the bluish reproduction of the LCD is caused by the physical properties of liquid crystal, and by the transmissive characteristics of polarizing materials. It is necessary to develop the materials which do not have the blue shift for the low input digital level.

References

1. Tohru Tamura, *J. Institute of Image Information and Television Engineers*, **52**, 1527 (1998).
2. Noboru Ohta, *Introduction to Color Reproduction Technology*, CORONA, Tokyo, Japan, 1997, pg. 69.