ICC Profiles Compensating the Color Reproductions of Liquid Crystal Display Panel

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Abstract

The color characteristics of image display devices are encapsulated in a device profile, which is defined as International Color Consortium (ICC) profile specification. The ICC profiles, which compensate the bluish color reproductions of LCD, are developed. The compensation of bluish reproduction is accomplished by modifying the inverse gamma curve for blue. The compensation of color reproductions is confirmed by experiments. The delta E(94) becomes smaller by using the ICC profile.

Introduction

The color liquid crystal display (LCD) has been widely used as a display device for personal computers and televisions, because of light weight, small volume, low power consumption and so on. The LCD also has been applied for the use of displaying fine images, such as photographic images, art images. However, the color reproduction characteristics of LCDs are a little known. It has been shown that the color reproduction area and gray images vary with input digital level.[1] The LCD panels make bluish color reproduction in the mid contrast range. The compensation of this bluish reproduction has been accomplished by using look up tables (LUT) inserted in the image display data channels.[1]

One of the color reproduction targets for LCD is to achieve the default color space sRGB.[2] The color reproductions for LCD are stated as the International Color Consortium (ICC) profile. The ICC profile is cross-platform industry standard which states the color characteristics of devices in the color management system. The parameters of ICC profiles for displays are composed of chromaticity points for three primary colors and for white, and tone reproduction curves. The tone reproduction curves for display ICC profiles are inverse gamma curve.[3]

In this paper, the color reproductions and the ICC profile for LCD are described. The ICC profile, which compensates the bluish color reproductions of LCD panel, is developed. The compensation has been made by modifying the tone reproduction curve for blue images. The compensation was measured by calculating the delta E(94). The values of delta E(94) adapting the ICC profile are smaller than that of original LCD.

Color Reproductions of an LCD

Color Gamuts & Gray Locus

Figure 1 shows the color gamut of a typical LCD (Sharp LLT1510A) varying the input digital level. The color gamut becomes smaller according to the small input value and shifted towards the blue direction. The maximum area is obtained when the input digital value is 255 for 8bit input.

The correlated color temperature for white is 6729K, and 29000K for black, as shown "Gray locus" in Figure 1. LCD transmits the light for the black input (0,0,0) so the color temperature can measure in black input. LCD shows the bluish color reproductions for medium contrast images.

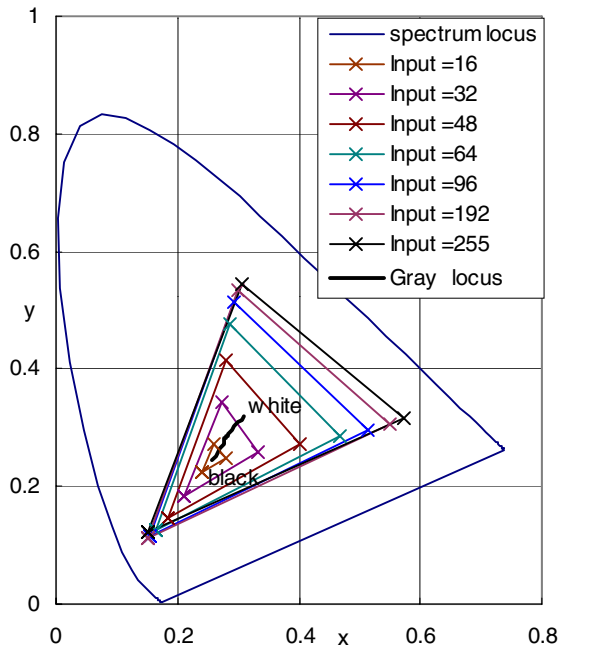

Figure 1. Color gamuts of an LCD varying the input digital level. Measurements were made by using 8 bits RGB inputs. "Input=16" indicates the gamut for R(16.0,0), G(0,16,0), B(0,0,16). "Input=255" indicates the gamut for R(255.0,0), G(0,255,0), B(0,0,255). "Gray locus" shows the locus for varying the gray inputs from white(255,255,255) to black(0,0,0).

Compensation of Reproduction Using LUT

The compensation of the bluish reproduction of LCD has been accomplished by modifying the input digital data. Figure 2 shows the compensation look up table(LUT). The lateral axis is input digital level for 8 bits, vertical axis is output digital level. The LUTs for red(R) and green(G) data are linear line, which shows that the input data equal to output data. The LUT curve for blue(B) data shows that output data becomes smaller than input digital data except white and black. The correlated color temperatures for gray input can make constant value by using this LUT. The bluish reproduction is compensated by lowered blue channel data, as shown in Figure 2.

The compensation for display data has been done by insertion of LUT to the data channel, as shown in Figure 3. The color temperatures do not change by varying the input digital level for the range 32 to 255.

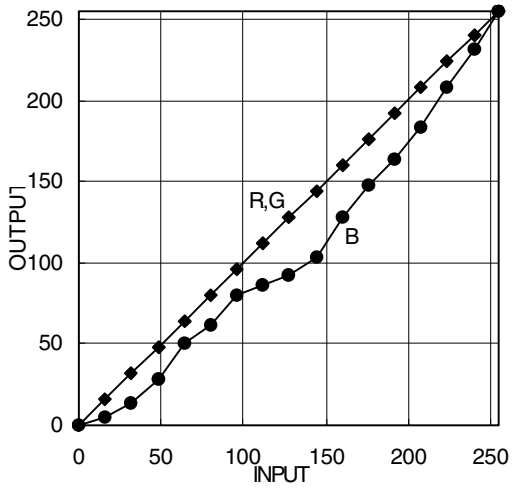

Figure 2. Compensation LUTs for an LCD.

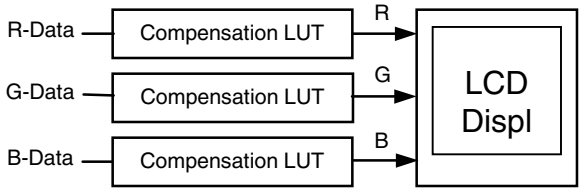

Figure 3. Schematic diagram of compensation on display data model

Color Management for Displays

Principles of Calculation Flow

The color matching calculation for display is defined by ICC. Figure 4 shows the schematic flow chart of processing model. [3] An ICC device profile connection space (PCS) is either CIEXYZ or CIELAB. The image data in the PCS are expressed as CIEXYZ data, in Figure 4. The XYZ data in the PCS are converted to RGB data by using inverse 3*3 matrix. RGB data in linear space are then converted to rendered RGB data. The rendering is carried out by inverse LUT.

ICC Profile for Display

The sample window of ICC profile viewer, which has been developed, is shown in Figure 5. The parameters for display ICC profile are composed of followings to calculate the data conversion.

(1) Chromaticity for three primary colors R,G,B.
(2) Chromaticity for white
(3) Inverse LUT for three primary colors

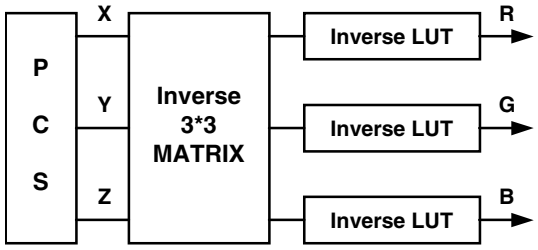

Figure 4. Schematic diagram of color processing model for displays

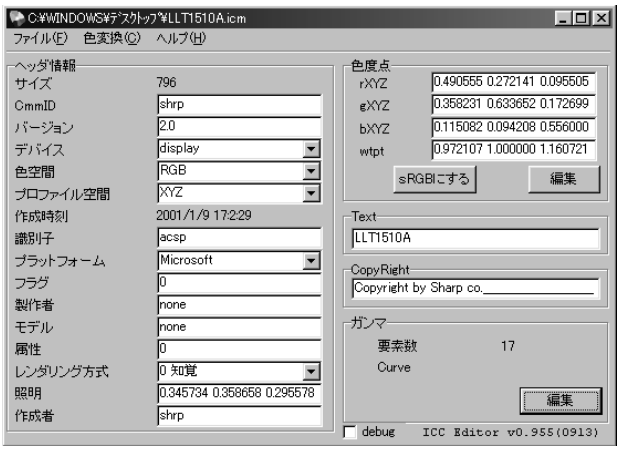

Figure 5. Displayed image of the ICC profile viewer

Except the header information, the color characteristics of display in the ICC profile are expressed by the above three parameters. The PCS is usually selected as CIEXYZ space, and the illuminant is D50.

The profile for display is quite portable. An ICC profile can be as small as 500 bytes for a minimal display profile. The same profile can be used under the Macintosh(TM) operating system, Windows(TM), Solaris(TM), or SGI's Irix(TM) operating system

Inverse LUTs for ICC Profile

The inverse LUTs for ICC profile are not the gamma curves for three primary colors. The effect of inverse LUT is to convert the image data from linear RGB space to

rendered sRGB space. It should note at the inverse LUT that the vertical axis is input and that the lateral axis is output, as shown in Figure 6.

The inverse LUTs, which compensate the bluish color reproduction of LCD, is shown in Figure 6. The inverses LUTs for red(R) and green(G) channel become same shape of gamma curve for LCD, because the compensation LUTs shown in Figure 2 are no effect for R,G. However, the inverse LUT for blue(B) compensating the bluish reproduction should be calculated according to the compensation LUT for B shown in Figure 2.

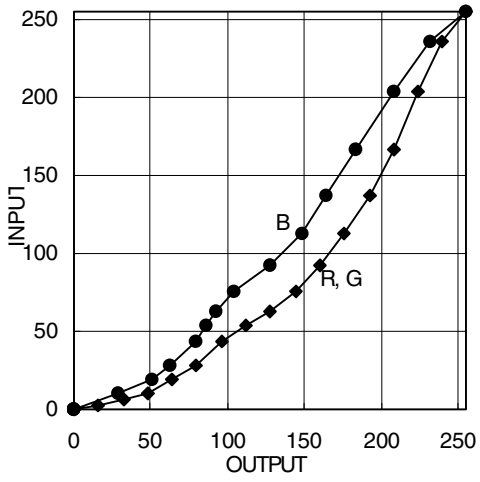

Figure 6. Inverse LUTs compensating the color reproduction on ICC profile. R: LUT for red data. G: LUT for green data, B: LUT for blue data.

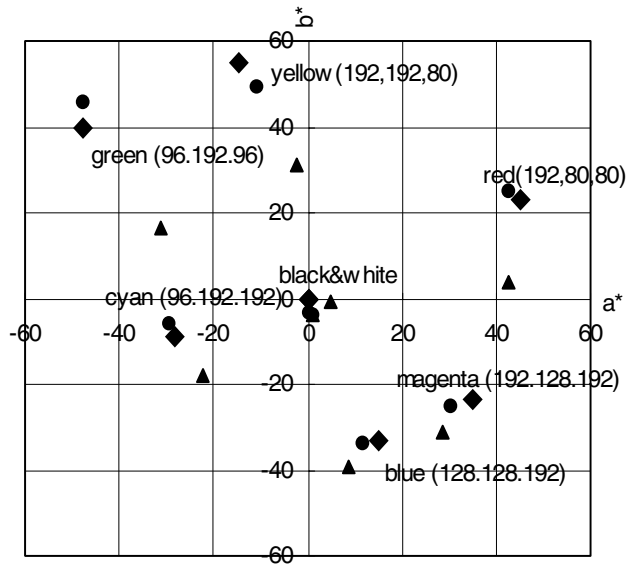

*Figure 7. Effects of compensation by the use of ICC profile. Compensation is shown as chromaticity points on a*b* diagram. Triangle mark(Λ):LCD display original(measured); Circle mark(O):with the ICC profile(measured); Diamond shape mark(<>) :sRGB standard(calculated)*

Compensation Using ICC Profile

The compensation effect of the ICC profile is confirmed by experiments. The color management software is "Imaging" which has been attached to Windows98. Color patches displayed on LCD(Sharp LLT1510A) are measured by colorimeter (Topcon, BM-5). The medium contrast color patches are selected.

Figure 7 shows the color compensation effect on a*b* plane. The chromatically points with the ICC profile are nearer the sRGB than those of without the ICC profile.

Table 1 shows the delta E(94) when applying the ICC profile. The reference chromaticity is calculated from those for sRGB. The delta E(94) becomes smaller by the use of the ICC profile.

Table 1. Variation of Delta E(94). References are sRGB.

	Delta E(94) without ICC	Delta E(94) with ICC profile
black(0,0,0)	4.35	4.48
red (192.80.80)	11.93	4.15
yellow (192.192.80)	8.77	4.34
green (96.192.96)	9.00	3.15
cyan (96.192.192)	9.65	2.07
blue (128.128.192)	9.32	2.35
magenta (192.128.192)	10.21	2.76
white (255.255.255)	4.82	3.11

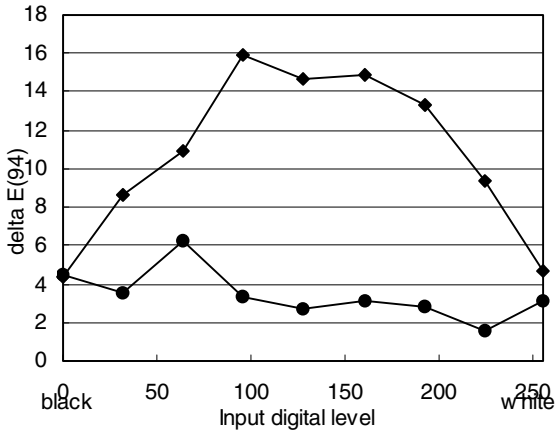

Figure 8. Delta E(94) varying the input digital level for gray patches. References are gray for sRGB. Circle mark(O) : with the ICC profile(measured); Diamond shape mark(<>): without the ICC profile(measured)

Figure 8 shows the delta E(94) for gray patches. The references where delta E(94) equals to zero are selected the gray of sRGB. Delta E(94) becomes smaller in medium contrast range using ICC profile. This means that the bluish color reproduction is compensated.

Conclusion

Although the ICC profile states the characteristics of color imaging devices, it can compensate the bluish color reproduction of LCD. The color reproduction characteristics, such as color gamuts, chromaticity for white and gamma curves, of LCD are different from those of sRGB, so it is important to use the ICC profile to ensure the faithful color reproduction.

References

1. Y.Okano, "Color Reproductions Varying the Input Level on a Liquid Crystal Display", Proc. 7th Color Imaging Conference, pg.233 (1999).
2. IEC 61966-2-1: Colour management –Default RGB colour space-sRGB(1999).
3. Dawn Wallner, Building ICC Profiles – the Mechanics and Engineering, pg. 165. (http://www.color.org/iccpofiles.html).

Biography

Yukio Okano received his B.S. degree in Applied Physics from the Osaka University in 1967 and a Ph.D. in Information Science from Chiba University in 1998. From 1967 to 1997, he worked at Minolta Corporation in Osaka, Japan. Now he has worked at Sharp Corporation in Nara, Japan. His primarily interest is focused on the image processing. He is a member of the IS&T and the SPSTJ, and an expert member of ISO/TC42/WG18.