Wide Gamut Display Using LED Backlight - Technical Developments and Actual Products

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Abstract

Color management is an efficient means of ensuring the quality of color reproduction and is regarded as being one of the major issues in the printing industry. It is a total technology that manages the color reproduction of input devices such as scanners and digital cameras and of output devices such as display monitors and printers. It also ensures that satisfactory controls are applied throughout the process as far as the final printing. In color management, the display monitors must be able to offer a display performance that confirms a stable and long term, quality color finish. For this purpose, an LCD panel with a wide field angle was developed that features a wider color reproduction gamut and more impressive luminance/chrominance stability than has been available with previous display monitors.

Keywords

display, wide gamut, LED, backlight, color management, color calibration

1. Introduction

The widespread dissemination of digital cameras is changing the workflow patterns in the printing industry. The input that has previously been the color images such as silver-salt films is being replaced gradually with RGB data captured using digital cameras. This shift is because the RGB data does not require the cost or time that used to be required for the film and post-shooting exposure processing of silver-salt pictures and makes it possible to reduce the delivery term as well as various other costs. This change in the workflow is particularly noticeable for press and commercial pictures.[1)]

However, this trend is now encountering a major problem, which is the absence of a display system that can reproduce the colors correctly. The results of shooting or editing may be checked either on a display or at a printer, etc., but the printout method necessitates the cost and labor of the ink and the output operation and does not contribute to color management efficiency. This is why displays are required to offer a display performance that allows the color finish to be confirmed stably for a long period.

This paper considers how to achieve a display performance that satisfies the standards that are required of color management.

2. Widening of the Color Reproduction Gamut

The display used for checking the color finish should be able to reproduce a wider color gamut than other devices. Comparison of the color gamut of each device **(Fig. 1)** shows that a display enabling an Adobe RGB color performance can meet this requirement.

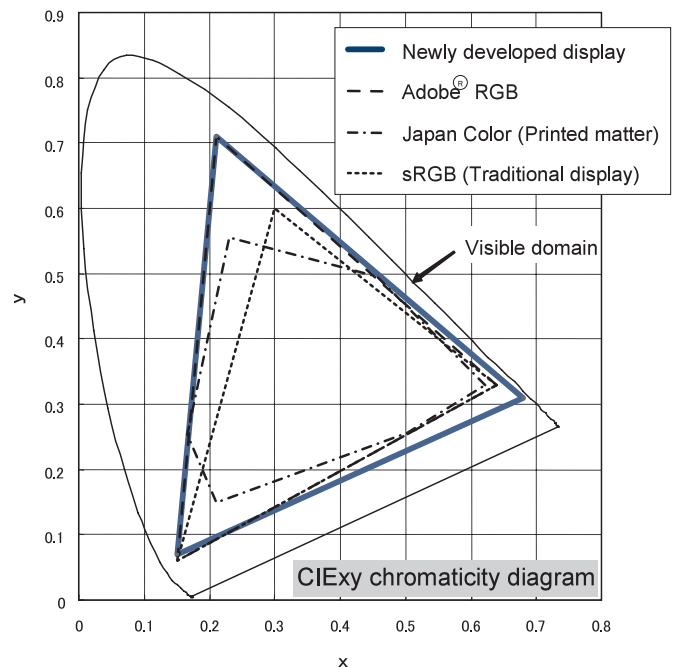Before discussing the specific methods for achieving this

Fig. 1 Comparison of the color reproduction gamut of various devices.

purpose, we will introduce two methods for widening the color gamut of LCD panels[2].

The first method is to widen the gamut of the cold cathode fluorescent lamp (CCFL) that is used as the mainstream backlight source. This method does not necessitate a major modification of the structure, but results in a drop in the luminance and a shortening of the service life.

The second method is to use a light-emitting diode (LED) as the light source. This method can provide high luminance and long service life, but the lower light emitting efficiency (i.e. light intensity divided by input power) than the cold cathode fluorescent lamp, which necessitates the installation of a large-scale heat radiation structure. In addition, a larger color mixing area than is the case for the cold cathode fluorescent lamp must be prepared in the backlight in order to obtain uniform plane light emission.

In our efforts for implementing a display that can cover the Adobe RGB specifications, we recently modified the light source of the LCD panel and fine-adjusted the color filters as detailed below.

The individual color coordinates in the Adobe RGB are;

Red (0.64, 0.33) / Green (0.21, 0.71) / Blue (0.15, 0.06).

Meanwhile, the color coordinates of the current mainstream LCD panel that uses the cold cathode fluorescent lamp are;

Red :(0.65, 0.33) / Green (0.29, 0.62) / Blue:(0.14,0.08).

Here, the largest difference in coordinates is observed in the Green-domain. We therefore describe our method by taking this domain as an example. **Fig. 2** shows the light spectrum in the display of Green.

The main wavelength is 544nm but sub peaks are also observed at 495nm and 582nm. As a result, the Green coordinates of the chromaticity diagram are weight-averaged and deviated toward yellow from the target coordinates (to 0.29, 0.62). This problem can be corrected by shifting the main wavelength toward a shorter one (around 530nm) or by modifying the sub-peaks. It is required to develop a new fluorescent substance for the cold cathode fluorescent lamp or new pigments for the color filters. However, considering the luminance life and reliability, it has been very difficult to develop the materials that can meet the quality required for use in the LCD panels.

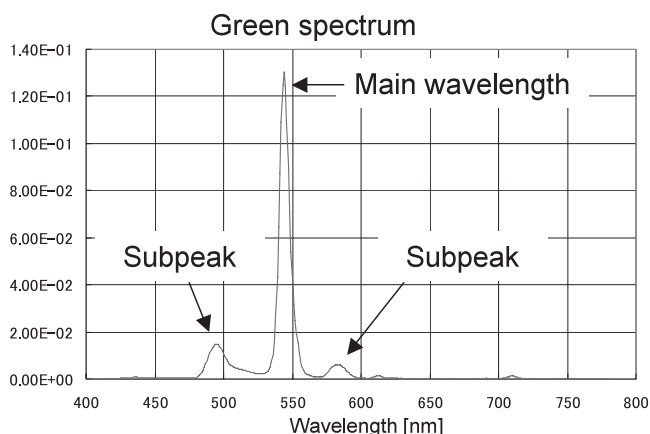We therefore attempted to solve this problem by using an

Fig. 2 Spectrum for displaying green.

LED with a relatively narrow light spectrum and by fine adjustment of the color filters.

We first attempted to set the main Green wavelength at 533nm, which is a position shifted toward the shorter wavelength compared to the cold cathode fluorescent lamp, in order to expand the color reproduction. However, when we used a traditional color filter with the green LED, the light at the skirt of its short-wavelength end leaked, causing the color coordinates of Blue to shift toward Green. We corrected this phenomenon by adjusting and improving the composition ratio of pigments for the Blue color filter to cut out the light of unnecessary wavelengths, and eventually achieved a result that approached the target coordinates for Blue.

The color coordinates that we achieved were Red (0.679, 0.309) / Green (0.205, 0.705) / Blue (0.147, 0.064), which are almost equal to those of the Adobe RGB as shown in Fig. 1. The color reproduction gamut that we achieved for Red was even better than that of the Adobe RGB.

Next, let us discuss how we obtained uniform plane emission for the new LCD panel.

Since the new LCD panel uses three RGB LEDs, the three colors should be mixed properly to obtain white light. A certain area is required to mix the three colors however, if this area is located at the side of the image display area, the area of the bezel outside the display area would be too big its value as an LCD panel product would be spoiled. Therefore, we avoided an increase in the bezel size by placing the color mixing area on the backside of the display area and guiding the obtained white light to the display area by means of a mirror.

Finally, we designed the heat radiation mechanism as follows.

Lowering the junction temperature allows the light emitting

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efficiency of the LEDs to be increased and the drop in luminance to be attenuated. However, the actual light emitting efficiency of LEDs has hitherto been only about a half of the cold cathode fluorescent lamp and it has not been easy to prevent the rise in temperature because 80% to 90% of the input power has been converted into heat. In addition, since display monitors are installed in the proximity (about 50cm) of the user, forced air-cooling using a fan cannot be used due to noise. This has forced us to adopt natural air-cooling using air convection.

We first attached the LEDs on an aluminum base board using an adhesive agent with high thermal conductivity, attached the board approximately at the center of a 430 × 310 × 8mm aluminum plate, and then installed aluminum ventilating fins with a height of about 35mm on the other side of the aluminum plate. Next, to cool the heat conducted on the aluminum plate and radiating fins, we optimized the ventilation holes of the cabinet and internal chassis and improved the air convection inside the bezel. In addition, we also solved the problem of strength, produced as a result of the installation of the large heat radiation plate, by attaching other structural parts in order to reinforce it. These modifications have made it possible to guarantee a longer life as well as to reduce noise.

As described above, we adopted LEDs as the light source and fine-adjusted the color filters while solving disadvantages (color mixing and heat generation) and succeeded in reproducing colors that have not been available with previous LCD panels, such as emerald green. The TN LCD panels cannot expand the color reproduction gamut due to important color shifting when the screen is seen from an oblique direction. To solve this problem the newly developed display adopts the Advanced Super-Fine TFT LCD panel to improve the viewing angle characteristic (85° in both horizontal and vertical directions with a contrast ratio of 10:1 or higher), thereby reducing the color shifting during oblique viewing as well as improving the general appearance.

3. Highly Stable Luminance/Chrominance Achieved

Ordinary LCD panels use the cold cathode fluorescent lamp as the source of backlight. The cold cathode fluorescent lamp is subject to deterioration over age (drop in luminance, yellowing of colors, etc.) just as in the fluorescent lamps that are used in homes and offices. Also, any light source deteriorates with time although the degree of deterioration may vary.

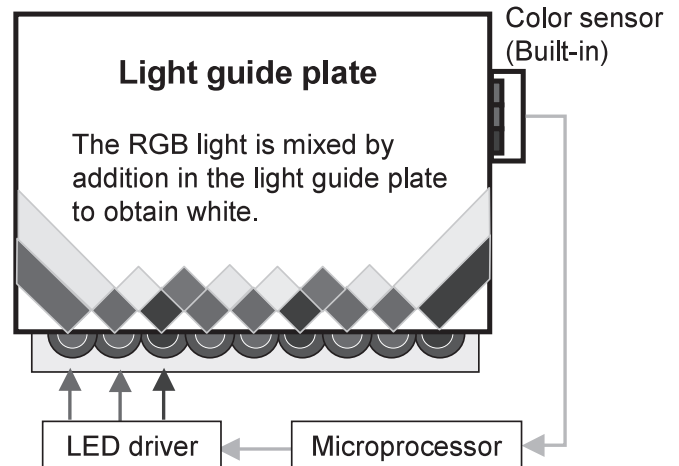It was therefore decided to adopt RGB LEDs that are capable

Fig. 3 Automatic luminance/chrominance correction system using a color sensor.
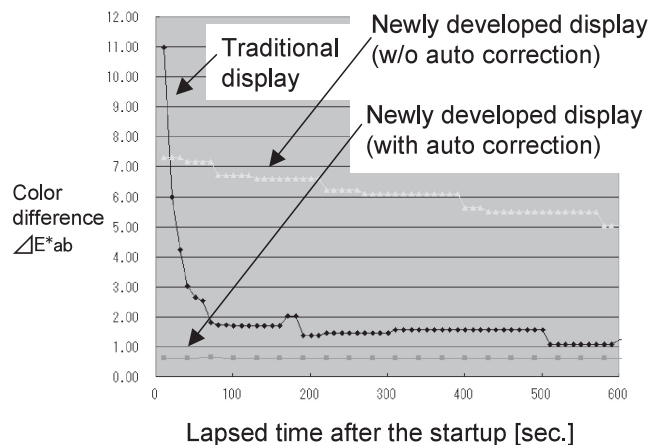

Fig. 4 Comparison of change in luminance and chrominance over age.

of being adjusted to the target luminance and chrominance in cases where deterioration is evident. We added an automatic luminance/chrominance correction system to the light source to enable a stable display, as detailed below (**Fig. 3**).

1) Firstly, the luminance and chrominance are detected by the built-in color sensor and the data is sent to the microprocessor.

2) Secondly, a control signal is sent to each LED driver to minimize the difference between the measured and reference values.

3) This control signal varies the light emitting intensity of each LED.

Operations 1) to 3) are repeated permanently from immediately after the startup (**Fig. 4**). ΔE*ab represents the variations

of luminance and chrominance from their initial values. When $\Delta E^*ab < 1$, the variations are almost indistinguishable to the human eye.

4. Achievement of Uniform Display Performance

Simulation of print results on a display screen requires that it can display uniform white just like print paper. This is because human eyes sense colors based on a relative comparison with the background color. Even when the center is white, it looks different if the color of the surroundings varies even slightly.

Ordinary LCD panels often contain points where the differences in luminance and chrominance are $\Delta E^*ab > 10$. This is due to the gaps between the liquid crystal cells, irregularities in the thickness of the color filters and alignment films and in the light emissions of the light source. The locations where these irregularities occur vary between units. The new LCD panel presents more color irregularities because it uses the LED light source as well as because of the factors described above, so we developed a display irregularity correction technology, which is explained in the following.

1) The luminance and chrominance of the 26 × 19 grids (at horizontal 64-dot and vertical 64-line intervals) are measured with an optical metering CCD.

2) Secondly, the correction reference value for luminance is set at the "value of the darkest grid" and that for chrominance is set at the "value at the screen center." Then, the correction value for minimizing the differences between the measured and reference values of each grid is calculated for each RGB and saved in the EEPROM in the system.

3) Finally, the correction values are applied to all of the LCD panel pixels (horizontal 1,600 dots, vertical 1,200 lines) **(Fig. 5)**. The correction values for the spaces between the grids are calculated by interpolation.

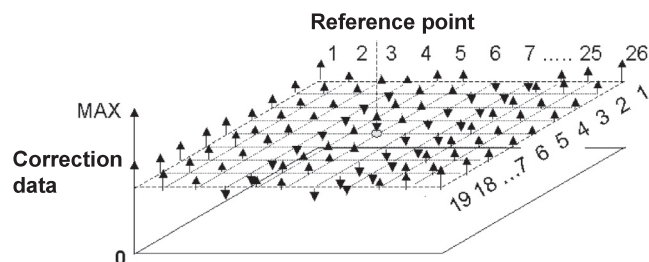The above correction has made it possible to limit the differences in luminance and chrominance on the screen within $\Delta E^*ab < 3$ to 4 (actual achievements).

5. Development of Color Calibration Software

This section considers two important issues in color matching with the print result. One is to align the white in the print result with that on the display screen. The white on the print result represents the light reflected from the print paper itself and it is altered if either the environmental light or the print paper is changed. The second point is to prepare each ICC profile (each file describing the color gamut of the equipment) for the display and print result.

The most difficult task is to ensure a consistent environmental light. The most general way of achieving this is to adjust the white of the display screen each time. However, most displays do not allow strict color adjustment because they only have specific white present in them. This means that calibration of the display is necessary.

There are roughly speaking two methods of calibrating a display. One is the software calibration, which consists of adjusting the RGB output levels of the graphics card. This method can be applied regardless of the display type, but it also presents disadvantages including the incapability of adjusting the luminance and chrominance of the backlight and the reduction in the number of displayable tones.

The other method is hardware calibration, by which the optimum tone is selected from the LUT (Look Up Table) built into the display and displayed. This method is capable of allowing each display to manifest its particular tone reproduction ability.

The calibration software employed in the new LCD display adopts the hardware calibration method, which displays 256 tones by selecting them from the built-in 10-bit LUT. It is also capable of adjusting the luminance and chrominance of the backlight, and ICC profile is generated automatically after every adjustment.

6. Conclusion

This paper introduced the performance requirements for a wide gamut display with a color management capability and discuss examples of developments that we have introduced.

Improvements in the performances of digital cameras and printers, and the dissemination of DTP (Desk Top Publishing) using PCs are expected to increase the need for wide gamut displays to a greater degree than hitherto. We expect that the

Fig. 5 Luminance/chrominance irregularity corrections by signal processing.

newly developed display products will be applied in many fields including the printing industry and will consequently help to improve workflows.

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