QuintPixel: Multi-Primary Color Display Systems

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1 Problem Statement

Today's conventional *Liquid Crystal Displays* (LCD) are assembled with three primary colors (red, green, and blue: RGB). Further, the most common color gamut standards are defined in RGB-primary colors. Such a system lacks the capability to reproduce all of the real-surface colors; for example, sRGB cannot cover Pointer's real-surface color dataset which consists of the measurement over the existing colors in the world except self-luminous objects [Pointer 1980] at most of the hue angles (see Figure 1 right). However, recent developments on display devices have made it possible to have wider color gamut than before. However, as long as there are only three primary colors, such display system still cannot cover the real surface colors efficiently. An example of relatively wide gamut (DCI 2005) in Figure 1 still shows poor coverage ratio against Pointer's dataset.

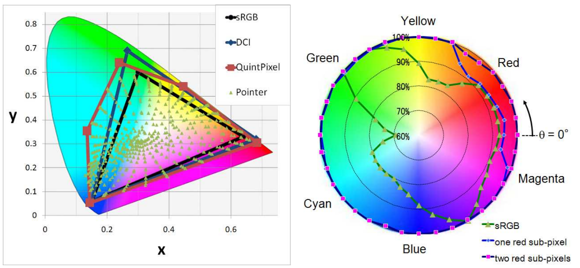

Figure 1: *Left: Color gamut comparison of sRGB, DCI, and our QuintPixel against Pointer's dataset in xy chromaticity diagram. Right: Coverage ratios against Pointer's dataset at every 10 degrees of hue angle (θ). The outermost circle represents 100% coverage.*

2 Multi-Primary Color Display Systems

The *Multi-Primary Color* (MPC) systems solve this problem with one or more additional sub-pixels. There have been presented several ideas of MPC systems such as [Yang et al. 2005; Chino et al. 2006], however, they neither considered to reproduce the real-surface colors nor had wide-enough color gamut. In this paper, we introduce our MPC display system *QuintPixel* which employs yellow and cyan sub-pixels besides RGB. This achieves over 99% coverage ratio against Pointer's dataset.

As seen in Figure 1 (left), large numbers of colors in yellow and cyan regions are missing in RGB-primary system. QuintPixel introduces additional yellow and cyan sub-pixels but does not enlarge the area of the overall pixel. By decreasing the area per one sub-pixel, we balance high luminance reproduction with real-surface color reproduction. QuintPixel also consists of two red sub-pixels for compensating its low luminance reproduction. Additionally, the most preferable layout of six sub-pixels are computed by using spatio-chromatic Fourier analysis. Finally, QuintPixel leads to over 99% in the coverage ratio against Pointer's dataset (see Figure 1 right). It may reproduce the colors of sunflower's yellow, golden mask of Tutankhamen's mummy, emerald green sea, and pigment colors. Such colors are located out of the color gamut of conventional display devices.

Figure 2: *QuintPixel display (left) and its comparable conventional LCD (right). Note much deeper reproduction of yellow.*

Figure 2 shows a screenshot of our QuintPixel emerging technology prototype in 60-inch size with the resolution of 1920 × 1080 pixels with its comparable conventional display[1]. Note that QuintPixel reproduces much deeper yellow than the conventional LCD. An input signal is given in xvYCC format for both displays. Then, if some colors are located out of a display's color gamut, those colors are clipped onto a display's gamut for both. QuintPixel may take not only xvYCC but also a conventional RGB format.

3 Further Benefits and Applications

Because most input signals are still in RGB-based primaries, there exists a system of equations with three equations and five unknowns for reproducing a given color in QuintPixel. This mathematically leads to infinitely many solutions of the combination of primary colors. It is a strong advantage of MPC display systems.

Power-saving There exist the combinations of primaries such that the primaries turn on as least as possible by using a simple linear programming method.

Pseudo-super resolution MPC display systems consist of much more sub-pixels than RGB-primary display systems. Those sub-pixels can be used for sub-pixel rendering for "pseudo-super resolution" which increases perceptual resolution of a display device.

Rendering improvement at different viewing angles For a given color in a pixel, MPC takes the combination of primaries which reproduce the color with the smallest perceptual difference in different viewing angles.

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[1] These are the photos of actual displays and both color gamuts are reduced as seen on print or display. However, their relative color saturation differences are still presented in this figure.

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