Device-Independent Imaging System for High-Fidelity Colors

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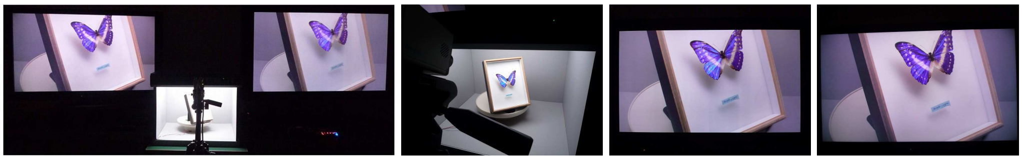

(a) (b) (c) (d)

Figure 1: *(a) Device-independent imaging system working at real-time. Multi-Primary Color (MPC) display system (right) and a comparable RGB-based display (left) are located with our capturing system (center). (b) Capturing system to take the whole visible spectrum. (c) Representation on an MPC display system. (d) Representation on a comparable conventional display. Note that the cyan parts of Morpho are accurately captured and faithfully reproduced by our imaging system.*

1 Problem Statement

An imaging system, in general, consists of a capturing system (i.e., a camera), a signal transmission process, and an output device (display and/or printing systems). When capturing a picture, colors are captured by an imaging sensor on a camera, whose spectral responses are, in general, highly different from the color matching functions of CIE 1931. Such cameras show non-colorimetric response and provides inaccurate color information of a captured object. Additionally, when storing data, different digital cameras generate different signals in red, green, and blue (RGB), whose reproduction is highly dependent each device. Then, a display device applies its own color conversion based on RGB format. As a result, no colors are correctly captured and reproduced. A severe miscommunication happens between capturing and displaying systems as far as using device-dependent imaging systems. In order to really reproduce images of high-fidelity colors on a display, it is essential for the imaging system to adopt colorimetric method not only in displaying and but also in capturing images. Therefore, we propose a device-independent imaging system which can accurately capture colors and faithfully reproduce colors.

2 Capturing System

There are two major ways to capture colors accurately: employing a camera with a single sensor whose sensitivities satisfy Luther-Ives conditionor using a multi-spectral camera. We chose to develop a camera with three sensors and three filters which captures all signals from different bands of spectral distribution simultaneously like conventional digital cameras.This camera has the equivalent spectral distribution to the color matching functions and is in a handheld size. Monochrome CMOS image sensors are mounted with the resolution of 3.2 mega-pixels at 12 bits/pixel. The camera is adopted color spectral sensitivities of three filters which satisfy the Luther-Ives condition.In the end, matrix calculation is applied to convert the spectral sensitivity functions to the tristimulus values of an object. The least square error method is used to obtain the matrix in order to closely fit the spectral sensitivity curves of the CIE color matching functions. As a result, our capturing system can take the whole range of the visible spectrum. Accuracy of capturing colors of the camera is examined by comparing the data taken by our camera and by a spectral colorimeter for MacBeth Color Checker (24 colors). The color difference between measured and captured data is quite small at the average of $\Delta E = 0.27$ in CIE L*a*b*. High accuracy is achieved in capturing colors by our camera system.

3 Display System

One of the multi-primary color (MPC) display systems, QuintPixel, was presented in 2010.While conventional liquid crystal displays (LCD) are assembled with three primary colors: RGB. QuintPixel employs additional Yellow and Cyan primaries in addition to RGB. The primary goal of QuintPixel was to accurately reproduce the real-surface colors with high efficiency and, in the end, it achieved over 99% reproduction of the real-surface colors. Besides its wide color gamut, some other benefits of MPC display systems are already known based on MPC's characteristic of color reproduction redundancy. For our new device-independent imaging system, we employ QuintPixel display system with six sub-pixels (the area for red is doubled) for the resolution of 1920×1080 pixels in 60-inch size.

4 Device-Independent Imaging System

Now, there is a device-independent imaging system consisting of a capturing system, signal transmission, and a display system. Our capturing system provides output signals in one of the device-independent formats, XYZ, via CameraLink with the resolution of 1920×1080 pixels for 30Hz. After doubling the video frequency from 30 to 60Hz, QuintPixel converts the XYZ signals to its own input signals in red, green, blue, yellow, and cyan and reproduces images. A comparable conventional display applies a gamut-mapping and reproduces images within RGB-structured color gamut. Additionally, our imaging system can be working at real-time. As shown in Figure 1, if some colors are located out of the RGB-based color gamut (e.g., sRGB), such colors are clipped onto the gamut boundary and cannot be reproduced on conventional RGB display while QuintPixel display system can accurately reproduce those colors. Overall, our device-independent imaging system can accurately capture and faithfully reproduce colors.

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