Color matching that improves image quality on mobile phone displays

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A system for real-time color matching between cameras and mobile phones offers color fidelity without burdening memory.

With digital convergence, color reproduction technology for mobile phones continues to improve. Camera technology now enables users to take both still and moving pictures, store them as digital files, and then display or project them anywhere. Color fidelity remains a challenge, however, and LCDs on mobile phones require real-time color matching between camera and cellular screen to ensure image quality.

Our proposed color-matching system, shown schematically in Figure 1, comprises three steps: characterization of LCD and camera, gamut mapping, and application of a 16bit-based lookup table (LUT) design. Device characterization defines the relationship between the tristimulus values (color spaces CIEXYZ or CIELAB) and RGB (red, green, blue) digital values. In general, characterization is modeled by polynomial regression, and as the polynomial order increases, performance improves. However, for higher-order polynomials, most estimated tristimulus values exceed the boundary of maximum lightness and chroma. This makes implementation difficult because the relationship between tristimulus and digital RGB values has not been analyzed.

We suggest a polynomial order based on investigating the relationship between RGB digital values, then transformed using opponent color theory and CIELAB values. Meanwhile, for the mobile LCD characterization, we use a sigmoid function instead of a conventional method such as the GOG or S-curved model, to estimate the luminance curve made by the system designer. This aims at better color reproduction and improved contrast. Additionally, characterization is based on the 16bit processing that controls the mobile LCD, in contrast to digital TVs or monitors, with 24bit data.

After characterization, application of a gamut-mapping algorithm connects the source medium (mobile camera) with the target medium (mobile LCD). Figure 2 shows the gamut difference between a mobile camera under a D65 environment and an LCD. The gamut of the camera is wider than that of the LCD, and has a regular form due to linear regression. Thus, because the LCD display is unable to achieve significant portions of the camera gamut, the original colors must be altered.

For purposes of this article, we used gamut mapping with variable and multiple anchor points to reduce any sudden color changes on the gamut region boundary. But these steps all require complex computation and considerable memory. Our 3D-RGB LUT was designed based on 16bit data, thus reducing the complex computation of serial-based processing while enabling color matching for moving pictures.

To apply the proposed real-time color-matching system, the bit-depth difference between camera and LCD was solved by quantizing the 24bit moving-picture data transmitted by the mobile camera as 16bit data through a bit operation. This data was
then converted into RGB using the 3D-RGB LUT for display on the mobile LCD. Figure 3 compares the images from device-dependent color matching, in which 24bit moving-picture data is sent directly to a mobile LCD, with images generated by our proposed scheme. Although the photo in Figure 3(a) was taken against the light, the facial region is overly bright due to the electro-optical transfer function of the mobile LCD, which saturates it. In addition, colors for each square in the MacbethColor chart in Figure 3(b) appear washed out when compared with the original colors seen in the D65 lighting booth. By contrast, facial skin tone in 3(c) looks more realistic than in 3(a), while colors in the chart in 3(d) are similar to the original viewed under D65 daylight. In sum, our scheme, based on 3D-LUT, renders colors more vividly and improves color fidelity on the mobile display.

Figure 2. Gamut mismatches between mobile camera and mobile LCD: (a) projected to (a*, b*) plane and (b) projected to (L*, b*) plane.

Figure 3. Experimental results from cellular phone: (a) and (b) results of device-dependent color matching; (c) and (d) the proposed color matching.

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References