

Color Look-Up Table Design for Gamut Mapping and Color Space Conversion

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Abstract

This paper proposes a method for designing a color look-up table (CLUT) that can simultaneously process gamut mapping and color space conversion without any complex computation. After constructing a LUT composed of the scanner and printer gamuts, fictive sample points are uniformly selected in CIELAB space and CMY values computed using gamut mapping. The scanner input RGB image is then converted into CIELAB using a regression function and the scanner RGB values converted into CMY values using the proposed CLUT that includes gamut mapping without any additional gamut mapping process. In experiments, the proposed method produced a similar color difference to the direct computation method, yet a reduced computational complexity when compared with discrete gamut mapping and color space conversion.

1. Introduction

A color management system is the technology used to reproduce color fidelity in different media from the input image to the output image through total color management. Accordingly, this paper proposes a method for designing a color look-up table that can simultaneously process gamut mapping and color space conversion, for application to a total color management system. The gamut of each color device used for reproducing color differs according to the input or output device. Thus, it is necessary to reduce the colorimetric color difference among input and output devices as well as minimize the color differences in an image perceived by the human visual system.

Conventional color space conversion methods include polynomial regression, the neural network method, and 3D interpolation method using an LUT.¹ Gamut mapping reduces the color difference by processing out-of-gamut colors from the gamut of the input device into the gamut of the output device. The gamut mapping method proposed by Morovic and Lee is 2D gamut mapping, as the hue is fixed, yet the lightness and saturation are simultaneously changed.^{2,3}

2. Scanner Characterization

The polynomial coefficients between RGB and CIELAB are computed using the linearized scanner RGB values.

A 3×6 matrix is used to consider the complexity of the system implementation.

$$L^{(c)} = \alpha_0 R + \alpha_1 G + \alpha_2 B + \alpha_3 RG + \alpha_4 GB + \alpha_5 BR$$

$$a^{(c)} = \beta_0 R + \beta_1 G + \beta_2 B + \beta_3 RG + \beta_4 GB + \beta_5 BR \quad (1)$$

$$b^{(c)} = \gamma_0 R + \gamma_1 G + \gamma_2 B + \gamma_3 RG + \gamma_4 GB + \gamma_5 BR$$

where $\alpha_j, \beta_j, \gamma_j$ are the coefficients of the polynomial regression. After the 3×6 matrix is constructed using these coefficients, the arbitrary RGB input is converted into CIELAB values using a matrix computation.

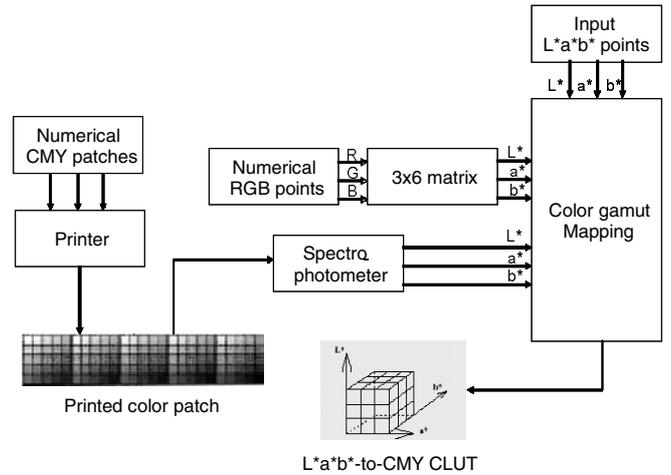


Figure 1. Block diagram of CLUT generation

3. CLUT Design

This paper proposes a method for designing a CLUT that can simultaneously process gamut mapping and color space conversion using only a LUT without complex computation. The input RGB values for the scanner are converted into CIELAB based on characterizing the scanner. These scanner values converted are then gamut-mapped into those of the printer. If all the scanner RGB values are directly computed by polynomial regression and gamut mapping, the computation time will be higher and the computational complexity increased. Thus, it is necessary to design an effective CLUT for gamut mapping and color space conversion.

Figure 1 shows a block diagram of the generation process of a CLUT. First, 1331(11×11×11) samples in CMY color space are generated numerically to construct the printer gamut. These samples are then printed to measure the CIELAB. The halftoning method used for printing is the modified-jointly blue noise mask(MJBNM) method, which generates three CMY masks to avoid any overlap between channels when considering the CMY channel correlation.⁴ The halftoning is then achieved by comparing the mask values with the input values. The above procedure is then used to generate a CMY-CIELAB LUT for the printer based on 1331 samples. Meanwhile, to make an LUT for the gamut of the input scanner, 1331 RGB values are computed numerically. These values are then used to obtain the CIELAB of the scanner and multiplied by the 3×6 matrix. The RGB-CIELAB LUT for the scanner is the generated based on 1331 samples.

After generating an LUT for each device, 1331 fictive points in CIELAB space are uniformly selected and gamut-mapped using VMAGM(variable multiple anchor points gamut mapping).³ The initial sample points are then changed to gamut-mapped CIELAB values and the corresponding CMY values identified using tetrahedral interpolation. As such, the proposed CLUT is composed of uniformly selected fictive sample points and gamut-mapped CMY values. Therefore, the scanner RGB input image is converted into CIELAB values based on a matrix using polynomial regression, then the desired CMY output values are obtained after tetrahedral interpolation using the previously generated CLUT. Another advantage to the proposed method is that the size of the CLUT can be arbitrarily controlled if the accuracy of the LUT for the scanner and printer is guaranteed.

4. Experiments and Discussion

For the experiments, a Samsung SIS-3800 scanner, HP 948c printer, and EPSON inkjet paper were used. The CIELAB values for the printer patches were measured by GretagMacbeth Spectrolino. The scanned 'IT8.7/2 color chart' image(RGB) was used. The proposed CLUT method was compared with the direct computation method.

Table 1. Comparison of Color Difference for IT8.7/2 Color Chart

	Direct computation method	Proposed method using CLUT
ΔE_{ab}^*	10.63	12.11

For comparison, the ΔE_{ab}^* color difference with the proposed method using a CLUT and direct computation method was calculated.

The ΔE_{ab}^* color difference was calculated so as to compare the original CIELAB with the direct computation method and the proposed CLUT method, respectively. Table 1 shows that the proposed method had a similar color difference to the direct computation method, indicating that the proposed method can be applied to low cost digital color devices, such as a color inkjet printer or multi-functional peripheral device.

5. Conclusion

This paper proposed a method for designing a CLUT that can simultaneously process gamut mapping and color space conversion using only a LUT without any complex computation. Accordingly, this paper demonstrated that the proposed CLUT method can be applied to low cost digital color devices, such as a color inkjet printer or multi-functional peripheral device. Also, the hardware implementation is easier because the computation normally involved in direct gamut mapping is not required as gamut mapping is included in the color space conversion process.

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