CIELAB to CMYK Color Conversion by Prism and Slant Prism Interpolation Method

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Abstract

Device dependent color signals to/from a system should be converted into a standard color signal, such as CIELAB, for media independent color reproduction. In case of applying CIELAB to the standard color signals, the relationship between CMYK and $L^*a^*b^*$ is complicated in contrast to NTSC RGB and YIQ or others. This paper presents a transformation from $L^*a^*b^*$ to printer density by the Prism Interpolation1) and Slant Prism Interpolation2) have been developed to realize a flexible and high-speed color conversion.

Introduction

The typical media independent color reproduction system is necessary for color conversion in both way from device dependent color signals to the standard color signal and the reverse. A high-speed color processor using Prism Interpolation has been already developed and estimated about the accuracy of color transformation from NTSC to $L^*a^*b^*$ and the vice versa.[1] Successively, Slant Prism Interpolation has been invented to improve the black generation by minimum density calculation.[2]

In this paper, both interpolation methods are applied to the conversion from $L^*a^*b^*$ to printer density. Color differences E^{*ab} between "original $L^*a^*b^*$" measured on a test chart and "print $L^*a^*b^*$" on printed paper are estimated for 168 test patches.

Architectures of Prism – Slant Prism Interpolation

Prism Interpolation(PI) and Slant Prism Interpo-lation (SPI) consist of 3D Look Up Table(3D LUT) and liner interpolator as illustrated in Fig.1. The LUT stores output data corresponding with input data on coarse lattice points. The upper bits of input signals are applied to generate the LUT address. In case of assigning 4bit to the upper bits, the LUT has 4,913(=17^3) output data. On the other hand, the lower bits of input signals are given to the interpolator calculating the equation (1) as weight coefficients W_R, W_G, W_B.

$$O = (1 - W_R)(1 - W_G)P_0 + (W_R - W_B)(1 - W_G)P_1 + W_B(1 - W_G)P_2 + W_G(1 - W_R)P_3 + W_G(W_R - W_B)P_4 + W_GW_BP_5 \quad (1)$$

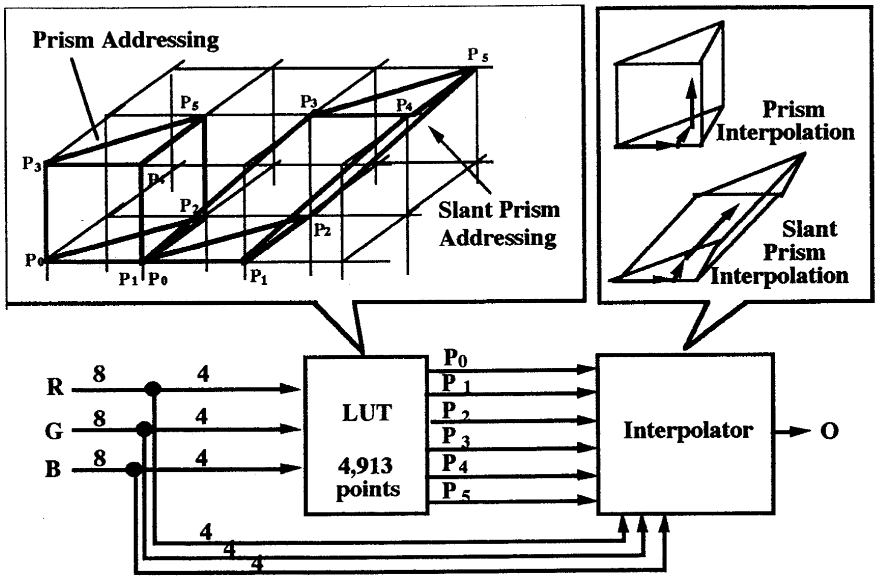

Fig.1 Architectures of prism /slant prism interpolation

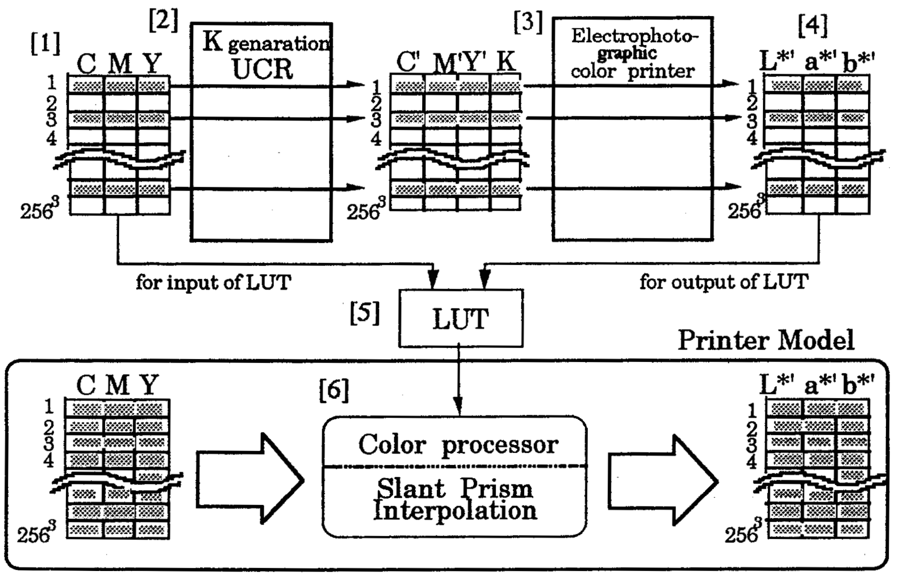

Figure 2. Printer model by slant prism interpolation method

It is possible to convert input color signals in high-speed and flexibly, because of using a small LUT and a simple weight summation. Switching the interpolation method, PI to/from SPI, can be realized by just modifying the address without changing the hardware design. A pair of triangles in "Prism" are along a vertical axis. On the other hand, a pair of triangles in "Slant Prism" are along a diagonal axis as illustrated in Figure 2.

Designs of the Color Conversion from $L^*a^*b^*$ to CMYK by Prism/Slant Prism Interpolation Method

Printer Model by Slant Prism Interpolation

It is necessary for the color conversion from $L^*a^*b^*$ to CMYK by the color processor to make LUT converting from $L^*a^*b^*$ on LUT lattice points to printer density CMYK. To realize this, the Printer Model can calculate $L^*a^*b^*$ for arbitrary CMYK has to be made. It is hard to measure $L^*a^*b^*$ of color patches generated for all combinations of CMYK(256^4). Hereby, the Printer Model is formed by interpolating representative CMYK color patch data. In this paper, the SPI is applied to this interpolation. Therefore, CMY are applied to the tri-color input of the Printer Model in 3D SPI processor as illustrated in Fig.2. Black generation and Under Color Removable(UCR) are executed by the equation (2).

$$\begin{aligned} K &= 1.5\,\delta \\ C' &= C - 0.5\,\delta \\ M' &= M - 0.5\,\delta \\ Y' &= Y - 0.5\,\delta \\ &\text{with } \delta = \min(C, M, Y) - 64 \end{aligned} \qquad (2)$$

where C, M and Y mean printer densities to make color patches, K means printer density for black given to a color printer, C', M' and Y' mean printer densities to a color printer after UCR and *min(C, M, Y)* means the minimum value of C, M, Y. In short, the Printer Model is produced by the following procedures.

1. Generation of 4,913(=17^3) CMY color patches by a computer. These color patches are on LUT lattice points.
2. Black generation and UCR according to equation (2).
3. Color patches printing by a electrophotographic color printer.
4. Measurement of $L^*a^*b^*$ of color patches printed on plane paper.
5. Making (CMY$\rightarrow L^*a^*b^*$) LUT between CMY input in [1] and $L^*a^*b^*$ output in [4].
6. Conversion from CMY to $L^*a^*b^*$ by the SPI using the (CMY$\rightarrow L^*a^*b^*$)LUT in [5].

How to Make LUT to Convert from LAB to CMY

Secondly, the ($L^*a^*b^*\rightarrow$CMY)LUT to convert from $L^*a^*b^*$ to CMY is produced by the Printer Model. In other words, the CMY output on a lattice point in $L^*a^*b^*$ color space is calculated by the Printer Model. Hereby, it is useful to assign CMY gives minimum ΔE^{*ab} between lattice point $L^*a^*b^*$ and color patch $L^*a^*b^*$ by searching through full color space in LAB. However, it is hard to do that, because the calculation times of ΔE^{*ab} in the Printer Model reach ($256^3 \times 17^3$). Therefore, the procedures in ($L^*a^*b^*\rightarrow$CMY)LUT making are reduced as follows (See Figure 3).

1. Detection of CMY gives minimum ΔE^{*ab} between the requested lattice point $L^*a^*b^*$ and the color patch $L^*a^*b^*$ produced to make the Printer Model.
2. CMY to $L^*a^*b^*$ conversion by the SPI in the local searching area of (33×33×33) cube centered on CMY given in the procedure[1].
3. Detection of CMY gives minimum ΔE^{*ab} between the requested lattice point $L^*a^*b^*$ and the color patch $L^*a^*b^*$ given by the procedure [2].

The CMY value given by the procedure [3] is assigned to the CMY output on the requested $L^*a^*b^*$ lattice point.

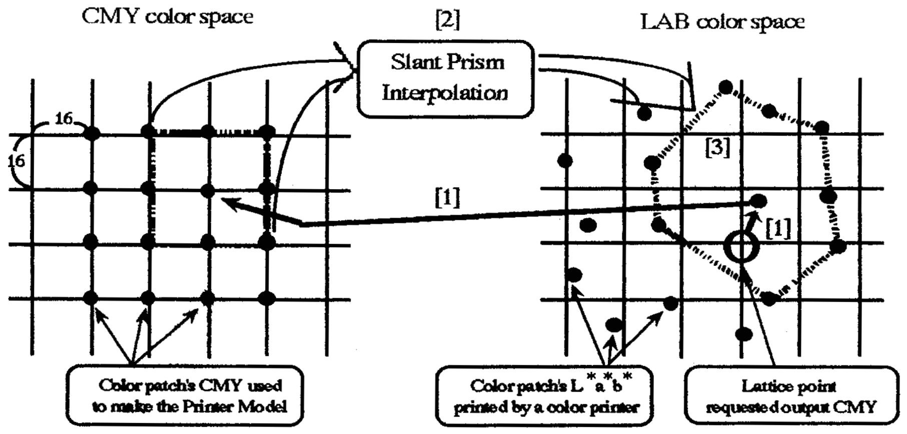
CMY color space
[2]
LAB color space
Slant Prism Interpolation
16
16
[3]
[1]
[1]
Color patch's CMY used to make the Printer Model
Color patch's L*a*b* printed by a color printer
Lattice point requested output CMY

Figure 3. Flowchart to design LUT to convert from $L^*a^*b^*$ to CMYK

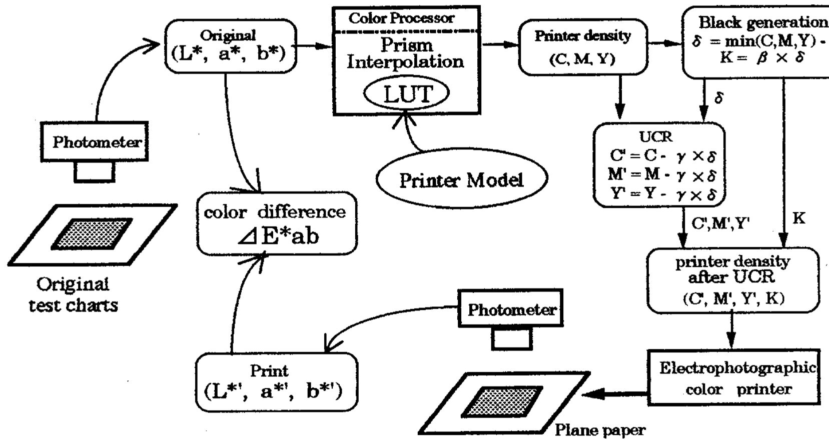

Figure 4. Flowchart to estimate color conversion from $L^*a^*b^*$ to CMYK by Prism / Slant Prism Interpolation

The ($L^*a^*b^* \rightarrow$CMY)LUT is made up by executing the procedure[1]-[3] for 4,913 selected lattice points in LAB color space.

Estimation of Color Conversion from $L^*a^*b^*$ to CMYK by the Prism / Slant Prism Interpolation

The color conversion from $L^*a^*b^*$ to CMYK by the PI and the SPI has been tested by calculating ΔE^{*ab} between "original $L^*a^*b^*$" measured on the original test charts and "print $L^*a^*b^*$" on prints by a electrophotographic color printer as illustrated in Figure 4. It is necessary to execute black generation and UCR for CMY calculated by the PI. JISZ8102 color chart(168 colors) is used as a test chart. ΔE^{*ab} between "original $L^*a^*b^*$" and "print $L^*a^*b^*$" is 4.8 in average and 21.4 in maximum.

Considerations and Conclusions

A fast and easy color conversion method from CIELAB to CMYK has been presented by applying the PI and SPI technologies. It is not necessary for this method to calculate approximate function or dot gain model etc., because this method can realize only by measuring $L^*a^*b^*$ of printed color patches which are made by known printer densities.

However, it is important for this method to make the color patches as being in CIELAB color space uniformly. Because CMYK values are given by interpolating output values on representative lattice points linearly. In this paper, the color patches have been produced as being in CMY color space uniformly. Black generation has been used eq. (2). Therefore, how to generate color patches should be considered to qualify color reproductivity. Additionally, it is necessary to improve how to make the ($L^*a^*b^* \rightarrow$CMY)LUT from the viewpoint of calculation time. It takes 27.5 hours to calculate this LUT with EWS(SPARCstation SS-10).

References

1. K. Kanamori et al., "Fast color processor with program mable interpolation by small memory(PRISM)", *Journal of Electronic Imaging* **2**(3), 213-224, 1993.
2. T. Fumoto et al., "A high-speed color processor by 3-D LUT and 'SLANT_PRISM' interpolation", the 24th Joint Conference on Image Technology, Japan, 1993.