Color Temperature Conversion Method Using Reference White Region Estimation

Hyun-Chul Do, Sung-Il Chien, Heung-Sik Tae

School of Electronic & Electrical Engineering, Kyungpook National University

1370 Sankyunk-Dong, Buk-gu, Taegu, 702-701, South Korea

Phone: 82-53-950-5545, E-mail: sichien@ee.knu.ac.kr

Abstract

This paper presents an efficient method of estimating the correlated color temperature of an input color image and of generating a converted color image that can approximate the new target color temperature. After extracting the potential reference white region for an uncalibrated color image and estimating its correlated color temperature, the color conversion method produces a new color image with a target color temperature. Speed improvement and memory reduction have been achieved by using a simple transfer method without involving the CIE XYZ conversion step.

1. Introduction

Some displaying devices such as PDP and LCD cannot provide a range of color temperatures that are satisfactory for most viewers and thus it is, both theoretically and practically, interesting to devise a method of automatically converting color contents of an image into a resultant color image with the satisfactory color temperature.

The proposed color temperature conversion method is divided into two steps. Firstly, we aim to directly estimate the color temperature from the given image without the use of spectral distributions of illuminants adopted elsewhere [1] and for this, we propose reference white region estimation to calculate the correlated color temperature from the *RGB* color domain without changing the R, G and B values of the color image into those in the tristimulus *XYZ* domain. In the *RGB* coordinates, the neighboring pixels around the maximum peak white point are found and made take part in estimating the white point from an illuminant, which in turn is directly related to discovering the correlated color temperature of the illuminant. This estimation in the *RGB* domain allows us to fulfill faster conversion needed for real-time applications, when compared to another method [2] which performs such estimation in the *XYZ* domain and therefore requires another conversion to the *RGB* domain. Secondly, using the estimated color temperature and the target color temperature, we calculate the transfer matrix, which will be used to construct a final 3×3 transform matrix [3]. The R, G and B values of every input pixel are now converted to the final R', G' and B' values by using the transform matrix.

2. Correlated Color Temperature Determination and Color Temperature Conversion

We estimate the correlated color temperature of the input image by focusing on the reference white region and calculating its chromaticity value. The reference white region is the region whose intensity is the highest and whose chromaticity is the closest to the white among the pixels under the given illumination. The transfer matrix is then calculated using the estimated color temperature and the target temperature, thereby converting the input *RGB* values to the output *R'G'B'* values. The involved steps are summarized in Figure 1.

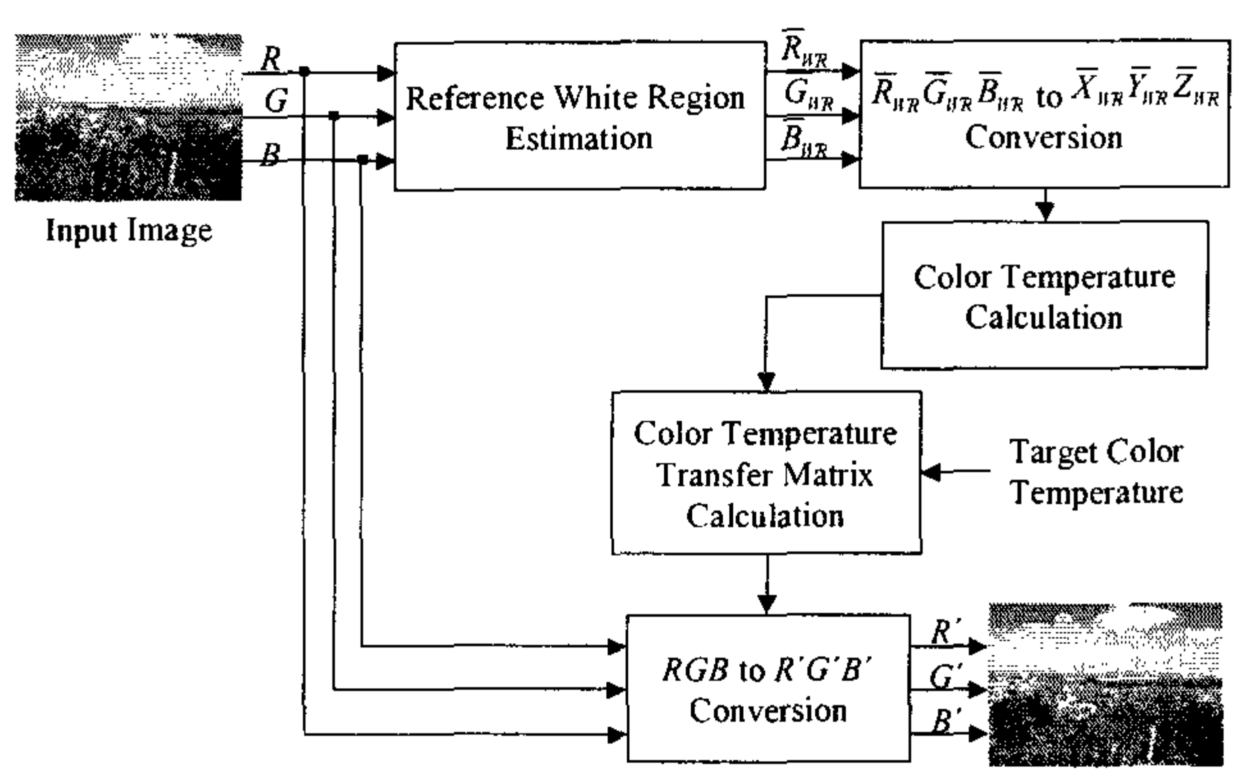


Figure 1 Flow chart of the color temperature determination and the color conversion.

2.1 Extraction of reference white region and determination of (x, y) coordinates

It is generally assumed that the region determining the effect of scene illumination looks like white. The Retinex Algorithm [4] decides that the maximum responses in three color channels determine the corresponding reference white point. However, the maximum response from the scene can be beyond the range of an input sensor and thus be clipped to cause error in illumination estimation. Therefore, we propose to consider a set of pixels similar in intensity and chromaticity to the reference white point.

For given R, G and B values of an image, the intensity is given by

$$I = \frac{1}{3}(R + G + B) \tag{1}$$

About 100 highest pixels are selected and their *RGB* values are averaged into W_R, W_G, W_B of the reference white point. The pixels of which at least one of *RGB* values is 255 are not considered in above calculation to avoid a clipping problem.

We let *RGB* components in the (i, j) *th* pixel be R_{ij}, G_{ij}, B_{ij} and their averages be $\overline{R}$, $\overline{G}$, $\overline{B}$. The selection criterion for the reference white region is given by

$$\begin{aligned} (W_R - R_{th}) \le R_{ij} \le (W_R + R_{th}) \\ (W_G - G_{th}) \le G_{ij} \le (W_G + G_{th}) \\ (W_B - B_{th}) \le B_{ij} \le (W_B + B_{th}) \end{aligned} \tag{2}$$

where the thresholds of (R_{th}, G_{th}, B_{th}) are determined experimentally. In our case, we use

$$\begin{aligned} R_{th} &= \frac{1}{2}(W_R - \overline{R}) \\ G_{th} &= \frac{1}{2}(W_G - \overline{G}) \\ B_{th} &= \frac{1}{2}(W_B - \overline{B}) \end{aligned} \tag{3}$$

As shown in Figure 2, the white region is found to be successfully located using the above algorithm.

Now three *RGB* components are averaged to $\overline{R}_{WR}$, $\overline{G}_{WR}$, $\overline{B}_{WR}$. The *XYZ* values in CIE 1930 coordinates are obtained by

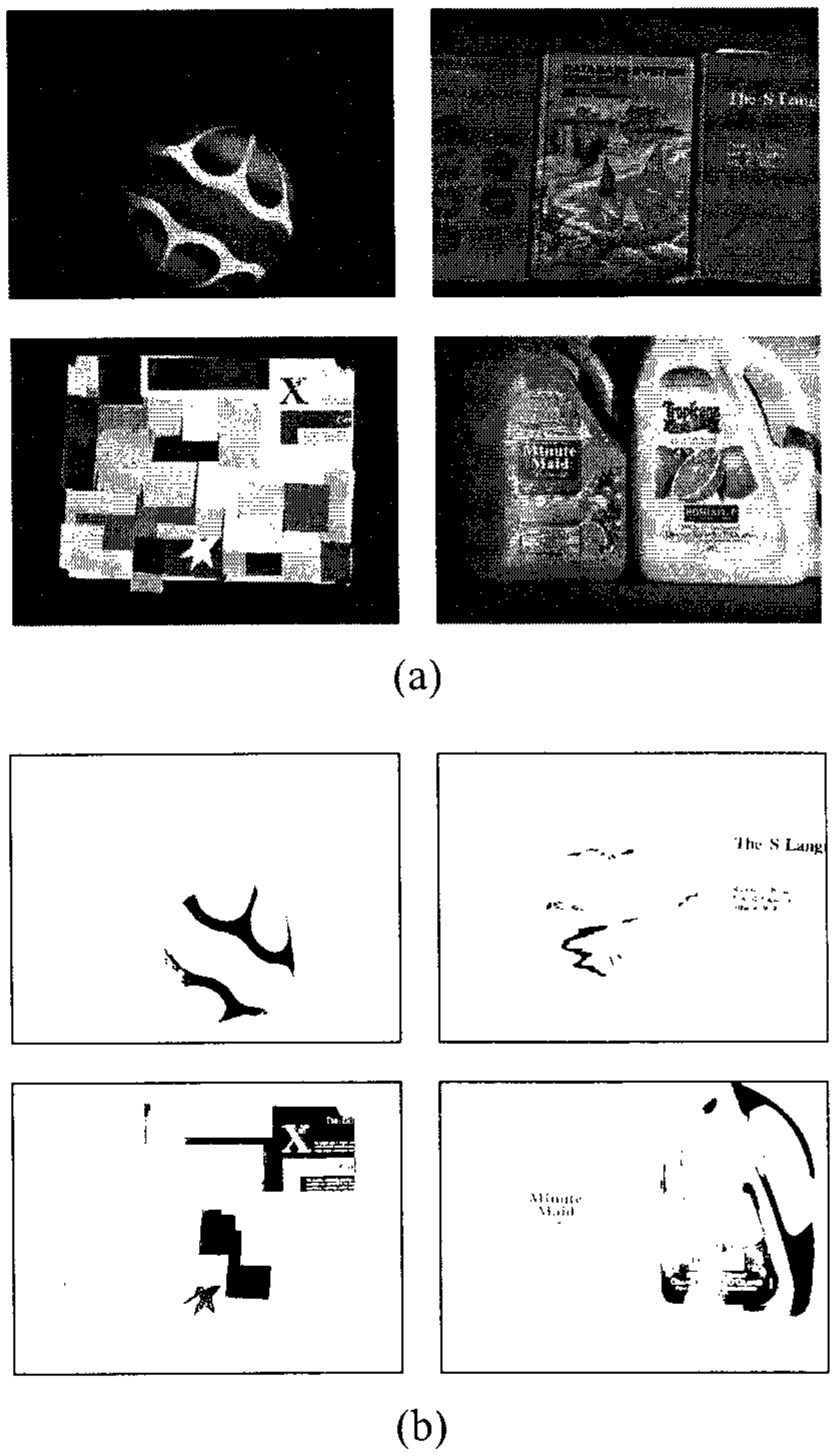


Figure 2 (a) Color image (b) Extracted reference white region.

$$\begin{bmatrix} \overline{X}_{WR} \\ \overline{Y}_{WR} \\ \overline{Z}_{WR} \end{bmatrix} = \begin{bmatrix} 0.490 & 0.310 & 0.200 \\ 0.177 & 0.812 & 0.011 \\ 0.000 & 0.010 & 0.990 \end{bmatrix} \begin{bmatrix} \overline{R}_{WR} \\ \overline{G}_{WR} \\ \overline{B}_{WR} \end{bmatrix} \tag{4}$$

Their normalized tristimulus values, called chromaticity coordinates, (x, y), are calculated based on the primaries as follows:

$$\begin{aligned} x_s &= \frac{\overline{X}_{WR}}{\overline{X}_{WR} + \overline{Y}_{WR} + \overline{Z}_{WR}} \\ y_s &= \frac{\overline{Y}_{WR}}{\overline{X}_{WR} + \overline{Y}_{WR} + \overline{Z}_{WR}} \end{aligned} \tag{5}$$

2.2 Correlated Color Temperature Calculation

The correlated color temperature is needed when the chromaticity of a radiator is not exactly equal to any of the chromaticities of a blackbody radiator. The correlated color temperature is defined as the temperature of the blackbody whose perceived color most closely resembles that of the given radiator at the same brightness [3]. Robertson developed an interpolative method of calculating the correlated color temperature in (u,v) coordinates by using 31 isotemperature lines [5]. In this paper, Robertson' s method is changed so that it can be directly used in (x,y) coordinates. It was found that no noticeable arises from such conversion. Figure 3 details how the correlated color temperature, T_c , is obtained from (x_s, y_s).

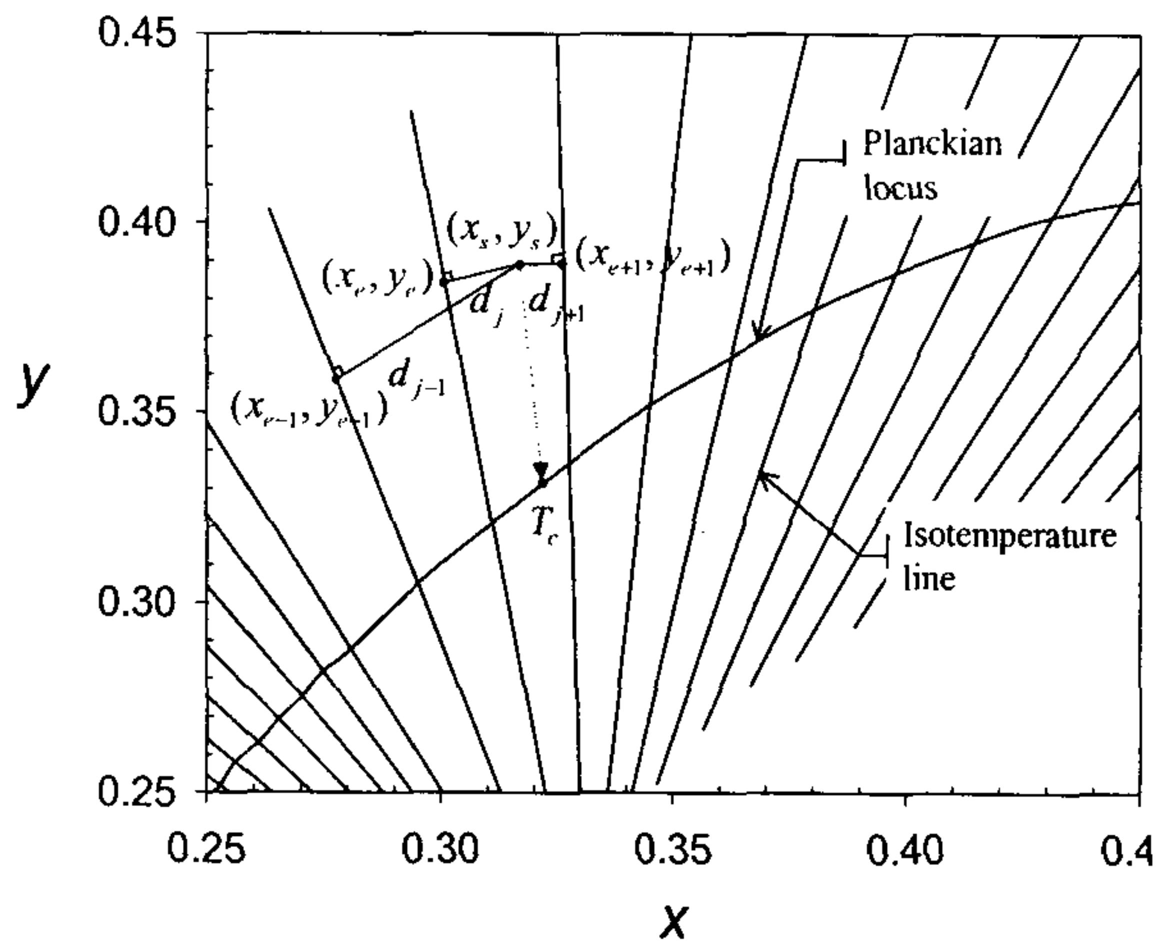


Figure 3 Calculation of correlated color temperature (T_c) in (x,y) chromaticity coordinates.

2.3 Conversion of Color Temperature

The *RGB* contents of an input image is converted into new ones of which the correlated color temperature will be a target color temperature. First, the color temperature transfer matrix should be calculated. Let the initial and final tristimulus values be (X_i, Y_i, Z_i) and (X_f, Y_f, Z_f) , respectively. The relation between these two values are given by [2]

$$\begin{bmatrix} X_f \\ Y_f \\ Z_f \end{bmatrix} = \begin{bmatrix} \textit{Color Temperature} \\ \textit{Transfer Matrix} \end{bmatrix} \begin{bmatrix} X_i \\ Y_i \\ Z_i \end{bmatrix} \quad (6)$$

It is also assumed that the initial and final luminance values remain the same, that is, $Y_i = Y_f = 1$. Then, the chromaticity values of the two colors are calculated and defined by (x_i, y_i) and (x_f, y_f) respectively. The color temperature transfer matrix is given by

$$\begin{bmatrix} \textit{Color Temperature} \\ \textit{Transfer Matrix} \end{bmatrix} = \begin{bmatrix} \frac{x_f y_i}{x_i y_f} & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & \frac{z_f y_i}{z_i y_f} \end{bmatrix} \quad (7)$$

Now, the original *RGB* values is transformed into the new *R'G'B'*

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = M^{-1} \begin{bmatrix} \textit{Color Temperature} \\ \textit{Transfer Matrix} \end{bmatrix} M \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (8)$$

$$M = \begin{bmatrix} 0.490 & 0.310 & 0.200 \\ 0.177 & 0.812 & 0.011 \\ 0.000 & 0.010 & 0.990 \end{bmatrix}$$

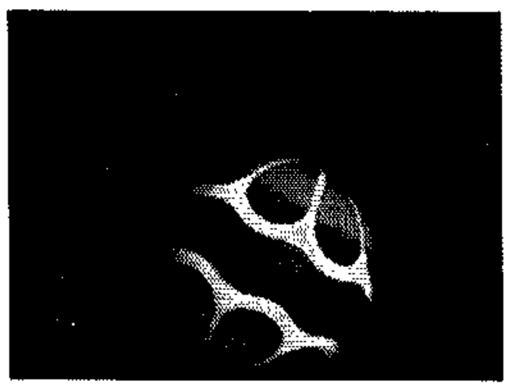
Here, *M* is the matrix which convert *RGB* values to the CIE *XYZ* values.

3. Experiment Results

The proposed method is evaluated on 205 images, which are made publicly available by Computer Vision Lab at Simon Fraser University, Canada [6]. The images consist of 30 scenes under 7 illuminants on black backgrounds: Sylvania 50MR16Q, Solux 3500K, Solux 4100K, Solux 4700K, Sylvania Warm White Fluorescent, Sylvania Cool White Fluorescent, and Philips Ultralume Fluorescent. The images under four illuminants using a blue filer are also available but are not used in our experiment, because their correlated color temperatures are too high to be used in Robertson's method. They used Sony DXC-930 3-CCD color video camera balanced for 3200K lighting with gamma correction turned off.

Figure 4 shows a sample example for the results of the color temperature estimation. As regards 205 real images, it is found that the average relative error in estimating the correlated color temperature is 0.161. The color conversion results for Figure 4 (b) using Sylvania 50MR16Q illuminant are included in Figure 5. Here, the estimated color temperature is 5277K and the target color temperature are 4131K, 6806K, and 8557K. The three resultant images can be compared with those shown in Figures 4 (a), (c), and (d), respectively.


(a) syl-wwf


(b) syl-50MR16Q

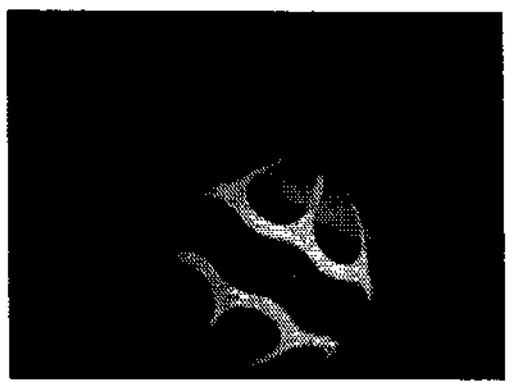

(c) solux-3500


(d) syl-cwf

Figure 4 Real values and estimated values of correlated color temperature of input image: (a) (4131K, 4022K) (b) (5515K, 5277K) (c) (6806K, 6720K) and (d) (8557K, 7805K), respectively under different illuminants.


(a)


(b)


(c)


(d)

Figure 5 Color images after color temperature conversion: (a) original image (Figure 4 (b)) (b) 4131K (c) 6806K (d) 8557K.

4 Discussion and Conclusions

In this paper, a reference white region is first estimated and the chromaticity of a scene illuminant is then calculated by averaging the *RGB* values of the region. The correlated color temperature is also calculated using Robertson's method. When the estimation is evaluated on 205 real images consisting of 30 scenes under different illuminant conditions, the average estimated relative error of the correlated color temperature is 0.161. The proposed conversion method based on the color temperature transfer matrix is employed to change the color contents of an input image according to the given target color temperature. It was found that our conversion method demonstrated about 47 ~ 724K conversion errors in the converted color images when the maximum amount of color temperature conversion is limited to 2000K.

5. References

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