Auto White Balance Using Chromatic Coordinates of Detected Human Faces

Jung-Wook Lee[1], and Kyu-Ik Sohng[1]

[1] School of Electrical Engineering and Computer Sciences Kyungpook National University,
1370 Sankyuk-dong, Buk-gu, Daegu 702-701, Korea
Tel: +82-53-940-8633, Fax: +82-53-940-8533
E-mail: nojesu@ee.knu.ac.kr, kisohngn@ee.knu.ac.kr

Abstract - This paper proposes auto white balance algorithm for the picture that is taken for people. General white balance algorithms bring neutral region into focus. But, other objects can be basis if its spectral reflectance is known. In this paper the basis for white balance is human face. For experiment, first, transper characteristic of image sensor is analyzed and camera output *RGB* on average face chromaticity under standard illumination is caculated. Second, Output rate for the image is adjusted to make *RGB* rate for the face photo area taken under unknown ilumination *RGB* rate that is already caculated. Input tristimulus *XYZ* can be calculated from camera outpu *RGB* by camera transfer matrix. And input tristimulus *XYZ* is transformed to standard color space (s*RGB*) using s*RGB* transfer matrix. For display, *RGB* data is encoded as eight-bit data after gamma correction. Algorithm is applied to average face color that is light skin color of Macbeth color chart and average color of various face colors that are actually measured.

Keywords: auto white balance, color constancy, human skin, camera characterization

1. INTRODUCTON

An output image of a digital camera is affected by the physical contents of the scene, the incident illumination on the scene, and the spectral sensitivity of the image sensor. Because the human visual system has ability called Color Constancy to reduce effect of incident illumination, the camera should have this function called White Balance. Auto White Balance (AWB) is one of the most important functions of the video camera to achieve high quality image. Typical AWB method adjusts camera outputs *RGB* ratio for all pixels in the image order to make equal *RGB* output for white or gray regions.

Basic and widely used methods for AWB are gray world assumption (GWA) and white regions estimation (WRE). GWA method is to adjust output *RGB* hypothesized that whole average color for the image is neutral, and WRE method is to search for the area of white and grey in the image, and then to adjust output rate for the whole image to make its each output *RGB* value is identical. Even though these methods are generally matched to the right results, it shows false results when the image is not match to the indicated hypothesis. GWA method can show the color close to the neutral one when the whole image chromaticity is inclined to the one direction. WRE can cause completely false results when the neutral area searched in the image is not actually neutral. In addition, if camera output *RGB* of white area that is searched as a neutral area is saturated, the results are false. These defects cannot be perfectly supplemented because it is caused due to the insufficient image analysis.

Algorithm to supplement these defects requests a great deal of database on the sensor, the background of the scene and various illumination.

This paper proposes AWB method using human face color in image. This has advantage because it is not affected by the environment image and it does not demand a great deal of database. The latest digital cameras have face recognition ability. When it takes the pictures generally, we take a shot for a person. We keep the accent on color of human face than color of objects or background. If color of background isn't changed largely, it wants to represent color of human face exactly. The color difference in chromaticity coordinates makes no large difference in skin color of human face from white blond to negro. Edwards et. al. calculates coordinates data about various skin color under D65 and D40 light. Because this paper is independent of background of image, it will get a little error about high chroma background. However, errors can appear because every person has the different face color.

With the increased popularity of electronic imaging devices comes a need for a default standard color space. For example, images captured with a digital camera have to be calibrated so that they can be displayed on a color monitor with good color and tone reproduction. Since cameras are manufactured by many different companies, the only way to make color reproduction feasible in the open system environment is to set up a common, default, color space on which color images can be exchanges over different devices. For this purpose, *sRGB* was accepted by the International Electrotechnical Commission (IEC) and the International Standards Organization (ISO) as the default color space for multimedia applications. Transfer characteristic of image sensor can be expressed as 3*3 matrix , it is corrected , and finally transferred to *sRGB* color space.

2. PROPOSED ALGORITHM

The process of camera signals is simply indicated as the following Fig. 1.

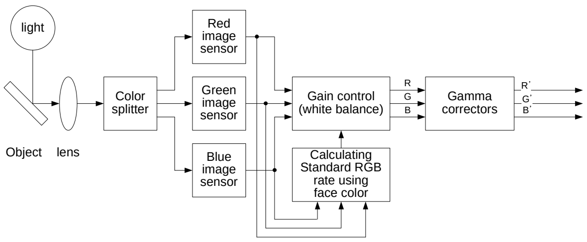

Fig. 1. The process of camera signals.

As the Fig. 1 shows, the camera transfers input tristimulus *XYZ* to output signal *RGB*. Therefore, transfer matrix can be measured when white balance of camera is fixed. Each image sensor outputs about human face area are used to make gain control.

In order to determine the standard face color, average of tristimulus value over many people face under the standard illumination is estimated. There is a need to distinguish the races because the deference of brightness and chromaticity is comparatively distinctive according to races. Some people's face colors are estimated to determine Korean or Asian's average face color. The result is shown in Table 1. This result shows that chromaticity of human face color is in uniform range.

sample	Y[cd/m^2]	x	y
1	138.8	0.3843	0.3621
2	138.9	0.4004	0.3788
3	79.14	0.4059	0.3702
4	74.36	0.3858	0.3717
5	113.9	0.4012	0.379
6	115.8	0.4027	0.3782
7	83.96	0.4071	0.3702
8	73.32	0.4046	0.3747
9	79.14	0.4059	0.37
10	74.36	0.3998	0.3656
11	71.53	0.4009	0.3613

Table 1. Tristimulus value of the human face color.

Tristimulus value of the face under the standard illumination is estimated and is averaged to determine the standard face color. Next, camera output *RGB* is calculated with applying camera transfer characteristics that is already calculated. Last, *RGB* rate on the people's face pictures under unknown illumination is made as *RGB* rate of face color under standard illumination by adjusting the whole *RGB* rate of the image, which is white balance.

3. EXPERIMENTAL RESULTS

Standard color space for multimedia applications is the *sRGB*. Because a reference white of the *sRGB* is illuminant D65, camera white balance needs to set illuminant D65.

For the experiment, digital camera GX-10 from Samsung was used, and white balance is fixed to white from the Macbeth color chart with color box illumination setting D65 under the circumstance that does not include the outside illumination.

Gamma correction process is executed in the output of camera to correct gamma characteristics of the display. In order to examine gamma characteristics of the camera, camera output and *XYZ* tristimulus on 6 gray patches from Macbeth color chart under the D65 illumination were measured. Camera output for the Luminance is the following Fig. 2.

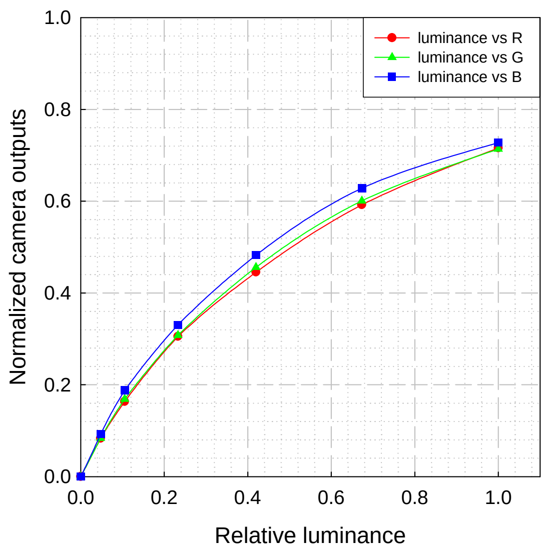

Fig. 2. Normalized camera digital output (*RGB*) as a function of relative luminance.

Widely used cameras don't have simple gamma characteristics because black gamma and knee control along with gamma correction is processed. Black gamma is completed to enhance the contrast of the dark area from the taken image, and knee control is the process to express the change of the part that is brighter than white because of the direct reflection of the light.

Because the brightness of Asians is approximately 35 % of the reference white brightness, it is not affected by these corrections. As a result, black gamma and knee control do not need to be regarded when transferring linear to camera output for the face.

In order to calculate transfer characteristics of the image sensor, least squares polynomial modeling (LSPM) method is used. Tristimulus values from 24 patches Macbeth color chart under the standard illumination D65 are measured by the spectroradiometer, and the camera outputs *RGB* is calculated with the white balanced condition from D65 illumination.

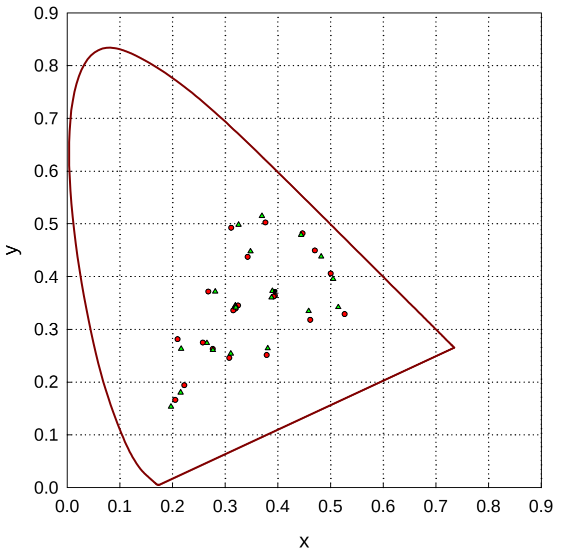

Fig. 3. Comparison measured chromaticity (circles) and calculated chromaticity by LSPM method (triangles) in the x-y chromaticity coordinates.

Fig. 3 shows the error of measured value and the stimulated value calculated from the camera transfer characteristics for the 24 samples.

1. Establishment of reference face color
   1.1 Measure tristimulus value $X_sY_sZ_s$ of human face color under D65.
   1.2 calculate camera output $R_sG_sB_s$ using transfer function of the camera

$$\begin{bmatrix} R_S \\ G_S \\ B_S \end{bmatrix} = \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix} \begin{bmatrix} X_S \\ Y_S \\ Z_S \end{bmatrix}$$

   1.3 calculate gain factor $k_R=R_s/G_s$, $k_B=B_s/G_s$
2. white balance
   2.1 transform gamma corrected camera output R'G'B' to linear output *RGB*
   2.2 calculate average $R_fG_fB_f$ of face area in image
   2.3 calculate compensation factor $c_R=G_f/R_f$, $c_B=G_f/B_f$
   2.4 for all red pixels, multiply the value with k_R and c_R, and for all blue pixels, multiply the value with k_B and c_B.

$$R_{WB} = k_R \times c_R \times R$$
$$G_{WB} = G$$
$$B_{WB} = k_B \times c_B \times B$$

3. The camera characteristic compensation
   3.1 calculate *XYZ* from white balanced output *RGB* using camera transfer characteristic matrix

$$\begin{bmatrix} X_E \\ Y_E \\ Z_E \end{bmatrix} = \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix}^{-1} \begin{bmatrix} R_{WB} \\ G_{WB} \\ B_{WB} \end{bmatrix}$$

   3.2 calculate linear *RGB* of s*RGB* from calculated tristimulus using following matrix

$$\begin{bmatrix} R_S \\ G_S \\ B_S \end{bmatrix} = \begin{bmatrix} 3.241 & -1.5374 & -0.4986 \\ -0.9692 & 1.876 & 0.0416 \\ 0.0556 & -0.204 & 1.057 \end{bmatrix} \begin{bmatrix} X_S \\ Y_S \\ Z_S \end{bmatrix}$$

   3.3 encode as eight-bit nonlinear R'G'B'

In order to demonstrate the performance of AWB, we use three pictures shown in the Fig. 4. Left images are raw images taken under lower color temperature illuminance than D65, and Right images are white balanced images. Because proposed algorithm is independent from background, the same background is used. It can be seen that the proposed AWB algorithm handle the colors well. In third pictures, white shirt in proposed white balanced image is shown more white than raw image.

Fig. 4. The pictures with raw images and the proposed AWB algorithm.

4. CONCLUSION

After processing proposed white balance, the chromaticity of illumination is remained. First reason is difference individual face color and reference face color used in this paper. Second reason is that the calculated camera characteristic has a little error. This error is caused by using a completed camera in the experiment.

Even though neutral patches in white balanced images have chromaticity, they are less than them in raw images. It shows that proposed algorithm has good performance. This paper assumed that the camera has human face detection function and it is perfect. If human face detection is incorrect, white balanced result can have large error. And human face chromaticity is similar each other, but it is a little difference. Proposed white balance algorithm cannot avoid error caused by it. But, if a human race is well classified, this algorithm has good result.

Most of auto white balance algorithms are affected by background contents in the image. It is difficult to estimate these contents. The best point of proposed algorithm is independent from background contents. Therefore the camera can perform white balance using less database and less time.

5. REFERENCE

[1] E.A. Edwards and S.Q. Duntley, "Pigment and color in living human skin," *American Joural of Anatomy*, 65, 1-33, 1939.

[2] Wen-Chung Kao, Sheng-Hong Wang, Chih-Chung Kau, and Chi-Wu Huang, "Color Reproduction for Digital Imaging Systems," *Circuits and Systems, 2006, Proc, 2006 IEEE international Symposium*

[3] Shoji Tominaga "Natural image database and its use for scene illuminant estimation," *J. Electronic Imaging*, Volume 11, Issue 4, 434-444 (2002).

[4] K. Barnard, V. Cardei, and B. Funt, "A comparison of computational color constancy algorithms-part I: methodology and experiments with synthesized data," *IEEE Trans, Image Processing*, vol, 11, no, 9, pp. 972-983, Sep. 2002.

[5] K. Barnard, V. Cardei, and B. Funt, "A comparison of computational color constancy algorithms-part II: experiments with image data," *IEEE Trans, Pattern Analysis and Machine Intelligence*, vol. 23, no. 11, pp. 1209-1221, Nov. 2001.

[6] H. C. Lee, *introduction to color imaging science*, Cambridge University Press, 2005.

[7] Mark D. Fairchild, *color appearance models*, John Wiley & Sons, Ltd, 2005

[8] G. Hong, M. R. Luo, and P. A. Rhodes, "*A study of digital camera colorimitric characterization based on polynomial modeling*," J. of Color Research and Application, vol. 26, no. 1, pp. 76-84, Feb, 2001.

[9] H. R. Kang, "Colour scanner calibration," *Journal of Imaging Science and Technology*, vol. 36, pp. 162-170, Mar./Apr. 1992.