AUTOMATIC WHITE BALANCING USING LUMINANCE COMPONENT AND STANDARD DEVIATION OF RGB COMPONENTS

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ABSTRACT

Automatic white balancing is an essential image pre-processing component in consumer digital still cameras, and it can greatly improve the final image quality of the captured image. In this paper, a novel automatic white balancing algorithm based on both luminance component and standard deviation of RGB components of the pre-captured image is proposed. A light source model for evaluation of an automatic white balancing is also described. The simulation results indicate that the proposed algorithm can improve the final image quality of the captured image.

1. INTRODUCTION

With the rapid advance of digital image processing technologies, there are many new features in digital still cameras making them very popular these days. Among these new features, automatic white balancing (AWB) is one of important features in digital still cameras. Without AWB, a captured white object will appear reddish under a low color temperature light source and bluish under a high color temperature light source. With AWB, a digital still camera can automatically compensate for the color shifts due to the different color temperatures of the light sources by adjusting the RGB gains of the corresponding channel amplifiers using information of pre-captured image.

Some AWB algorithms use the average red (R), green (G) and blue (B) components of the pre-captured image as the light source indicator to perform AWB [1-2]. This paper describes a novel AWB algorithm, which uses both luminance component and standard deviation of each RGB components to perform white balancing.

In addition, to evaluate different AWB algorithms under different natural scenes, a light source model is used to transform a set of natural images from natural light source environment into other light source situations (e.g. a low color temperature light source) such that the final white-balanced images can be compared with their original natural light source images to test the accuracy of the AWB algorithms for different natural scenes.

2. LIGHT SOURCE MODEL

To evaluate an AWB algorithm, the most common method is by using a color checker chart and a color-viewing booth. The color chart is placed inside the viewing booth. Then, the images of the color chart with different lighting produced by the booth are captured. A given AWB algorithm is then applied to the captured images. By comparing differences between the actual values and the white-balanced values of the color checker, we can determine that the smaller the difference in these values the better the AWB algorithm is. However, by using this method, it cannot estimate the performance of a given AWB algorithm under natural scene. It is because even if a natural scene image is placed inside the viewing booth, it is impossible to align the captured image and the original image pixel by pixel. Therefore, a light source model for evaluating AWB algorithms under natural environment is needed.

To evaluate a given AWB algorithm under low color temperature light source condition in specific scene, a low color temperature light model is applied to a natural image and then followed by the given AWB algorithm. By comparing the white-balanced image and the input natural image of the light source model, the performance of the given AWB algorithm in that specific scene under low color temperature light can be evaluated. The general performance of a given AWB algorithm can be evaluated using a large image set with different light source models.

The light source model makes use of the conversion of color temperature in [3] and [4]. Suppose we want to convert a given natural image with color temperature

6500K into low color temperature illumination around 3000K, the given image is first transformed to CIE-XYZ domain and then multiplied by the conversion matrix (1).

$$\begin{bmatrix} \frac{X_{3000K\_white}}{X_{6500K\_white}} & 0 & 0 \\ 0 & \frac{Y_{3000K\_white}}{Y_{6500K\_white}} & 0 \\ 0 & 0 & \frac{Z_{3000K\_white}}{Z_{6500K\_white}} \end{bmatrix} \quad (1)$$

where X_{6500K_white}, Y_{6500K_white} and Z_{6500K_white} are the white point values of the color temperature of the input image in CIE-XYZ domain, and X_{3000K_white}, Y_{3000K_white} and Z_{3000K_white} are the white point values of the color temperature of the output image in CIE-XYZ domain. The white point values of different color temperature can be obtained on the white point line as shown in Figure 1 [5].

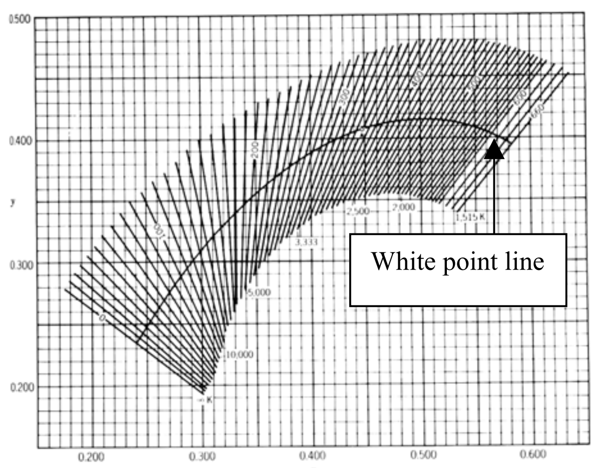

Figure 1. Isotemperature lines and white point line in (x, y) -chromaticity diagram.

where

$$\begin{aligned} X_{white} &= x_{white} / y_{white} \\ Y_{white} &= y_{white} / y_{white} = 1 \\ Z_{white} &= (1 - x_{white} - y_{white}) / y_{white} \end{aligned} \quad (2)$$

, x_{white} and y_{white} are the x and y coordinates of the white point line in Figure 1.

Similarly, other light source can be modeled by changing the nominators of the conversion matrix (1).

3. AUTOMATIC WHITE BALANCING ALGORITHMS

In digital still cameras, the CCD/CMOS sensor can be used to obtain the information of light source under which the image is being shot. Before the actual image is captured, the data from the sensor is called pre-captured image and is continuously analyzed. Most of the inexpensive AWB algorithms make use of this pre-captured image to adjust the gains of the RGB channel amplifiers to achieve automatic white balancing.

3.1. Existing Algorithms

The basic algorithm for AWB is known as Gray World Assumption (GW) algorithm. In this algorithm, the RGB channel gains are continuously adjusted, such that the average R, G and B components, $\overline{R}$, $\overline{G}$ and $\overline{B}$, of the captured image are equal:

$$\overline{R} = \overline{G} = \overline{B} \quad (3)$$

This algorithm can roughly estimate the channel gains if the given scene is composed of a large amount of different colors, but it will result in color failure if the given scene is dominated by one or two colors only.

To prevent the color failure situation in the GW algorithm, a modified version of gray world algorithm (MGW) has been proposed in [1-2]. The MGW algorithm pre-defined an appropriate region in the color differential domain as shown in the shaded area of Figure 2. The GW point shown in Figure 2 corresponds to the location of GW algorithm in the color differential domain. The shaded region can be expressed by (4).

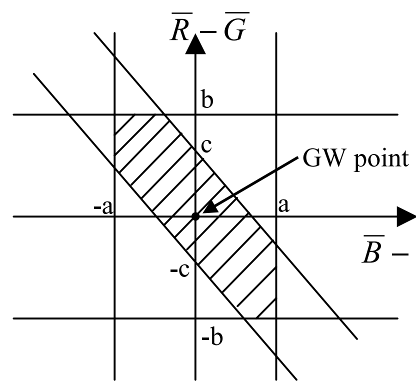

Figure 2. The pre-defined region for MGW algorithm.

$$\begin{cases} -a < \overline{B} - \overline{G} < a \\ -b < \overline{R} - \overline{G} < b \\ -c < (\overline{R} - \overline{G}) + (\overline{B} - \overline{G}) < c \end{cases} \quad (4)$$

where a, b and c are pre-defined values. If the color differential values of the pre-captured image fall into the shaded region, it is said to be appropriate. If they fall outside the shaded region, the gains of R and/or B amplifiers will be adjusted until the differential values fall into the shaded region again.

3.2. The Proposed Method SDLWGW

In the GW algorithm, if the pre-captured image contains a large amount of different colors, the probability that equation (3) holds will become high. On the other hand, if the standard deviation (SD) of the R, G or B component of the pre-captured image is high, the probability that the image contains a larger amount of different colors will become high. It is because when two or more objects appear in the image, the color difference at the object boundaries usually causes an increase in the SD of the R, G or B component of that image.

The light source estimation can also make use of the luminance information of the pre-captured image [6]. Experimental result shows that a dark color has less color deviation under different light source. Also, at high luminance, the color components are easy to be saturated. Hence, those pixels with middle luminance value in the pre-captured image are more important when performance the light source estimation.

Therefore, the proposed Standard Deviation and Luminance Weighted Gray World (SDLWGW) algorithm is based on these assumptions.

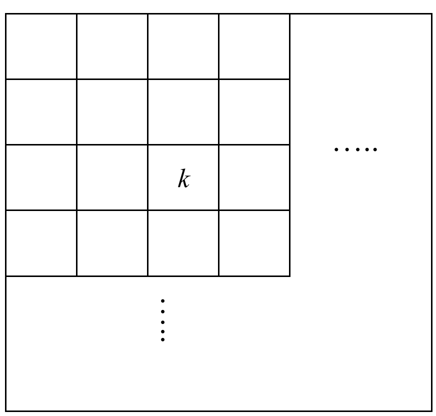

Figure 3. The division of pre-captured image.

In SDLWGW, the pre-captured image is first divided into n number of blocks as shown in Figure 3. For each block k, the luminance weighted average value and the SD of RGB component are calculated. The SD and luminance weighted average (SDLWA) of each color channel of the pre-captured image is calculated by (5).

$$\begin{aligned}
SDLWA_R &= \sum_{k=1}^{n} \frac{SD_red(k)}{\sum_{l=1}^{n} SD_red(l)} \times \overline{L_red(k)} \\
SDLWA_G &= \sum_{k=1}^{n} \frac{SD_green(k)}{\sum_{l=1}^{n} SD_green(l)} \times \overline{L_green(k)} \\
SDLWA_B &= \sum_{k=1}^{n} \frac{SD_blue(k)}{\sum_{l=1}^{n} SD_blue(l)} \times \overline{L_blue(k)}
\end{aligned} \tag{5}$$

where

$$\begin{aligned}
\overline{L_red(k)} &= \sum_{i=1}^{p}\sum_{j=1}^{q} \frac{L_weight(i,j)}{\sum_{x=1}^{p}\sum_{y=1}^{q} L_weight(x,y)} \times red_{i,j}(k) \\
\overline{L_green(k)} &= \sum_{i=1}^{p}\sum_{j=1}^{q} \frac{L_weight(i,j)}{\sum_{x=1}^{p}\sum_{y=1}^{q} L_weight(x,y)} \times green_{i,j}(k) \\
\overline{L_blue(k)} &= \sum_{i=1}^{p}\sum_{j=1}^{q} \frac{L_weight(i,j)}{\sum_{x=1}^{p}\sum_{y=1}^{q} L_weight(x,y)} \times blue_{i,j}(k)
\end{aligned}$$

and $SD\_red(k)$ and $red_{i,j}(k)$ represent the SD and the i-th row, j-th column pixel value of the R component of the k-th block respectively, and $SDLWA\_R$ represents the SDLWA of the R component of the pre-captured image. $L\_weight(i,j)$ is a positive single-peak function (e.g triangular function or Gaussian function) value for the luminance value at i-th row, j-th column of the k-th block.

The new amplifier gains of the R, G and B channel are then adjusted by (6).

$$\begin{cases}
R_{gain}' = R_{gain} \times \dfrac{(SDLWA_R + SDLWA_G + SDLWA_B)/3}{SDLWA_R} \\
G_{gain}' = G_{gain} \times \dfrac{(SDLWA_R + SDLWA_G + SDLWA_B)/3}{SDLWA_G} \\
B_{gain}' = B_{gain} \times \dfrac{(SDLWA_R + SDLWA_G + SDLWA_B)/3}{SDLWA_B}
\end{cases} \tag{6}$$

The SDLWGW algorithm without considering the luminance weight is called SD Weighted Gray World (SDWGW) algorithm and the SDLWGW algorithm without considering the SD weight is called Luminance Weighted Gray World (LWGW). The equation for SDWGW is (5) and (6) with $L\_weight(.)=1$. The equation for LWGW is also (5) and (6) with $SD\_red(.)=SD\_green(.)=SD\_blue(.)= 1$.

4. EXPERIMENTAL RESULTS

In order to evaluate the performances of SDLWGW and other AWB algorithms, the Euclidean distance (ΔE^*_{ab}) in CIELAB space between the input image of the light source model and the white-balanced image is calculated for each algorithm.

$$\Delta E^*_{ab} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

$$\begin{aligned} \Delta L^* &= L^*_{output} - L^*_{input} \\ \Delta a^* &= a^*_{output} - a^*_{input} \\ \Delta b^* &= b^*_{output} - b^*_{input} \end{aligned} \tag{7}$$

where L^*_{output}, a^*_{output} and b^*_{output} are the L*,a* and b* coordinates of the output image after AWB in CIELAB domain, and L^*_{input}, a^*_{input} and b^*_{input} are the L*,a* and b* coordinates of the input image of the light source model in CIELAB domain.

Three group of images and the color checker chart with two different color temperature light sources, 3000K and 10000K, are used for the simulation. The results are shown in Table 1 and 2. The first and second image groups represent the images with one and two dominated color(s) respectively. The third group represents the images with many different colors. The size of each segmented block is 16x16 pixels for SDWGW and SDLWGW, and the *a*, *b* and *c* pre-defined values for MGW are set to be 15. The luminance weight is set to be a triangular function with the peak at luminance value 160 (maximum value=255) and the slope equal to –1/160 and 1/160. All test images are 600x400 pixels.

As indicated in the table 1 and 2, the average ΔE^*_{ab} of SDLWGW is smaller than that of GW, MGW and other AWB methods in both 3000K and 10000K color temperature light sources for three different groups of image set. Thus, the proposed SDLWGW is the best AWB algorithm among these methods and it can greatly improve the quality of the final captured image in term of ΔE^*_{ab}.

5. CONCLUSION

In this paper, a novel AWB algorithm has been presented based on both luminance component and SD of each color channel. From the simulation results, the proposed SDLWGW method has a better performance than the existing or other AWB algorithms in term of the Euclidean distance ΔE^*_{ab} in CIELAB space. Furthermore, the presented light source model can simplify the evaluation process. It can also be used to evaluate AWB algorithms for different natural scenes.

6. REFERENCES

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Image group	Before WB	GW	MGW	LWGW	SDWGW	SDLWGW
1	31.82	16.53	21.57	17.03	14.06	11.56
2	25.76	29.18	22.42	33.09	23.19	14.63
3	33.50	4.63	10.08	4.06	6.36	3.72
Color checker	32.85	8.20	8.31	11.02	5.85	8.26

Table 1. The average ΔE^*_{ab} of four group of images before white balancing, after GW, MGW, LWGW, SDWGW and SDLWGW with 3000K color temperature light source model.

Image group	Before WB	GW	MGW	LWGW	SDWGW	SDLWGW
1	20.04	11.37	10.36	8.52	8.17	7.97
2	16.42	30.22	19.04	33.19	23.57	16.07
3	19.59	5.74	11.20	5.01	8.78	4.86
Color checker	21.30	7.89	13.73	10.14	7.60	10.65

Table 2. The average ΔE^*_{ab} of four group of images before white balancing, after GW, MGW, LWGW, SDWGW and SDLWGW with 10000K color temperature light source model.