Automatic White Balance Algorithm through the Average Equalization and Threshold

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***Abstract*—Automatic White Balance (AWB) is one of the important functions for digital cameras. The purpose is removing the color cast caused by the un-canonical illuminants where the image captured at. Images with color cast always lose the color contrast and variations, especially those with heavy color cast. For traditional white balance algorithms, the lost color contrast and variations would probably bring the incorrect color temperature predictions and the lack of contrast in the output images. In this paper, a new automatic white balance algorithm through the average equalization and threshold (AWBAAET) is proposed. The proposed approach keeps the assumption of gray world method (GW) and the wide color range of color histogram stretching algorithm (CHS) at the same time. In the simulation results, the proposed algorithm can meet the theory of GW, with similar averages on the R, G, and B channels. Also, it can enhance the color contrast and variances as CHS algorithm efficiently, without over stretching the color range and changing the character of the original image.**

Keywords-white balance, color correlation, colour cast correlation

I. INTRODUCTION

In digital cameras device, Auto White Balance is one of the most important functions. Under different illuminants, because of the difference of the spectrum distribution, the color performance for the same object will not be the same. When a white object is illuminated under a low color temperature, it will appear reddish in the recorded image. Similarly, it will appear bluish under a high color temperature [1].

Human eyes have the "color constancy" ability to cope with different lighting conditions by adjusting their spectral response, while video cameras do not [2]. The goal of white balance is to process the image such that it looks as if it is taken under canonical light [1].

In general, AWB algorithms can be divided into two groups: assumption-based algorithms and correlation-based algorithms. The assumption-based algorithms conclude the gray world method [2], the white patch method [3], the retinex theory [4] and another algorithms steadied on the former ones, as [1], [3]. The correlation-based algorithms conclude the gamut mapping [5], neural network-based approach [6] and so on.

It has been reported that the performance of correlation-based algorithms are better than assumption-based ones. However, since the correlation-based algorithms require plenty of training image data with known light sources and high computation cost for processing, the assumption-based algorithms are more widely used for the AWB process of digital cameras where fast computing is highly required [3].

The most simple and common one of assumption-based algorithms is the gray world theory (GW). The advantage is its low computation. However, the GW theory is based on the average values of all colors in an image, the average values can only be used to correct the affected image if all pixel values of each color component are equally balanced [7]. But for the images with heavy color cast, one color always dominates the whole image. Therefore, the GW theory is not suitable to enhance the heavy color cast images [7].

In the color cast images, in which many color information is covered by the color cast, the color contrast and color variation will degrade as the degree of color cast upgrade. The lost color information leads to the hardness on the color temperature prediction for the white balance algorithms. It would probably cause incorrect color adjustment.

In this paper, we propose an automatic white balance algorithm, based on the RGB color model to enhance the color contrast and color variation of the images, and combining the assumption of the gray world theory. The simulation results show that the proposed approach has better performance than the gray world theory and the color histogram stretching algorithm [8].

II. BACKGROUND

A. Color Cast Detection

Anustup Choudhury and Ge'rard Medioniin proposed a method using the standard deviations of R, G, B channels to identify whether an image with color cast [9]. The method is based on the observation that an image of a scene, taken under colored illumination, has one color channel that has significantly different standard deviation from at least one other color channel. And for the image without color cast, the three standard deviations will be similar [9].

In another paper, Yung-Cheng Liu, Wen-Hsin Chan and Ye-Quang Chen commended the idea as below. Any uniform color can be represented with a point on C_b-C_r coordinate system. A monochromatic object illuminated with a standard light source will be on a nominal position on the C_b-C_r coordinate. However, with different light sources or light intensity, the position will deviate toward C_b (indicate bluish) or C_r (reddish) coordinate [10].

B. Gray World Method

The most common and widely used white balance algorithm is the GW theory.

An image with size $M \times N$, can be presented as $I(x,y)$, where x and y donate the indices of the pixel position. The first step of the GW algorithm is calculating the averages of R, G, B channel, R_{avg}, G_{avg}, B_{avg}, as described in formula 1.

$$\begin{cases} R_{avg} = \frac{1}{M \times N} \sum_{x=1}^{M} \sum_{y=1}^{N} I_r(x,y) \\ G_{avg} = \frac{1}{M \times N} \sum_{x=1}^{M} \sum_{y=1}^{N} I_g(x,y) \\ B_{avg} = \frac{1}{M \times N} \sum_{x=1}^{M} \sum_{y=1}^{N} I_b(x,y) \end{cases} \quad (1)$$

Where, the $I_r(x,y)$, $I_g(x,y)$, $I_b(x,y)$ are the red, green, blue channel values of each pixel respectively. Then, the standard value, A_{avg}, calculated by averaging these three channel averages is described below.

$$A_{avg} = (R_{avg} + G_{avg} + B_{avg})/3 \quad (2)$$

Finally, the color value for each pixel is adjusted by the formula 3 to reach the assumption of GW theory.

$$\begin{cases} I_r'(x,y) = I_r(x,y) \times A_{avg}/R_{avg} \\ I_g'(x,y) = I_g(x,y) \times A_{avg}/G_{avg} \\ I_b'(x,y) = I_b(x,y) \times A_{avg}/B_{avg} \end{cases} \quad (3)$$

Where, the $I_r(x,y)$, $I_g(x,y)$ and $I_b(x,y)$ are the pixel values of original image. And, the $I_r'(x,y)$, $I_g'(x,y)$ and $I_b'(x,y)$ are the ones of the image adjusted by the gray world method.

The advantage of the GW method is its low computation. It has good performance if the image is equally balanced and with high color variation. However, the suitability is limited. For the image with large range of uniform color, and for the image with heavy color cast, the performance is bad. The lack of color information and color variation would probably cause low contrast and variation on the result images.

Fig. 1(a) is a reddish image [11]. Fig. 1(b), 1(c) are the related YC_bC_r and RGB histogram. The average values of C_b, C_r are 103 and 141. The difference presents the color cast. We can also find out in Fig. 1(c) the high blue and low red have few information. It means that the most color information locates in the certain range.

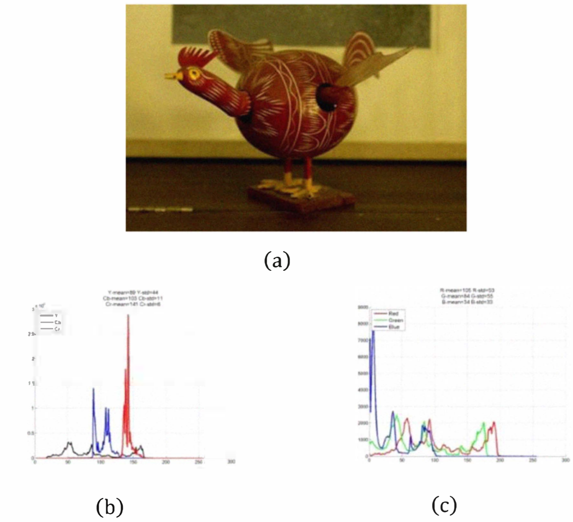

Figure 1. (a) The reddish image, (b) the related YC_bC_r histogram, and (c) the RGB histogram

Fig. 2 is the output result of Fig. 1 adjusted by GW theory. In the result of GW, the mean values of R, G, B channel and the mean values of C_b, C_r are equal. But we can see from Fig. 2(c), the distributions of three channels are changed for fitting the assumption. The high value range of red and green channel have no information. That would probably cause low color contrast and variation.

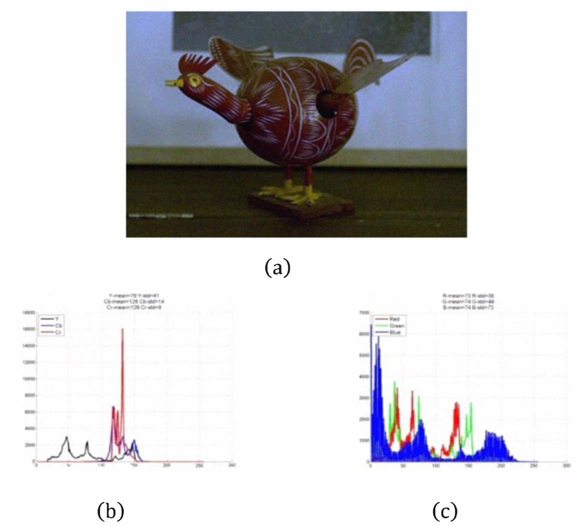

Figure 2. (a) The result of Fig. 1(a) by gray world method, (b) the related YC_bC_r histogram and (c) the RGB histogram

The lost color information caused by color cast makes the lack of information for gray world method. So, the method couldn't recover the color variation and contrast of the original image.

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C. Color Histogram Stretching

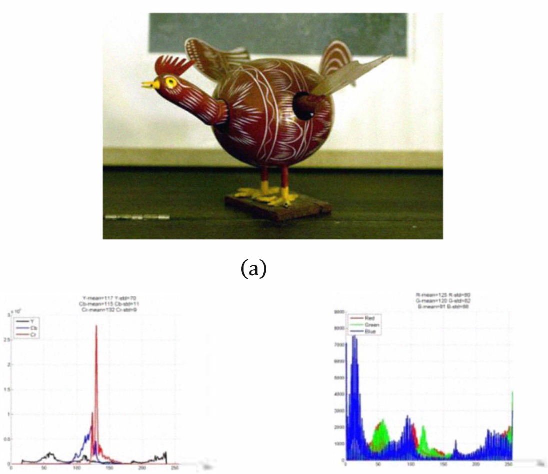
Su Wang, Yewei Zhang, Peng Deng and Fuqiang Zhou proposed a paper in 2011. Different from the traditional white balance methods which need to estimate illuminant, the algorithm exploits the color content of image directly [8].

CHS method finds two tonal thresholds and stretches the tonal between the two thresholds for each channel. In order to avoid the extreme values, the low and high thresholds are set to be the value higher than 1% of lowest pixel tonal values and the value higher than 99% of other pixel tonal values, respectively [8]. The stretching formulas are listed below.

$$\begin{cases} I_r' = \frac{I_r - R_{low}}{R_{high} - R_{low}} \times R_{max} + R_{min} \\ I_g' = \frac{I_g - G_{low}}{G_{high} - G_{low}} \times G_{max} + G_{min} \\ I_b' = \frac{I_b - B_{low}}{B_{high} - B_{low}} \times B_{max} + B_{min} \end{cases} \tag{4}$$

Where, I_X and I_X' are the values in X channel of original and result images. X_{low} and X_{high} are the low and high threshold values of X channel. And X_{max} and X_{min} are the maximum and minimum of X channel, in the 8 bits, default as 255 and 0.

Fig. 3 is the result image of Fig. 1 after applying CHS algorithm. In Fig. 3(c), the most difference in standard variations is 8; it means that the color variations are sufficient and identical. In Fig. 3(b), we can see that the mean Y increases obviously. Mean Y is 89 in Fig. 1(b) and 117 in Fig. 3(b). The increase is caused by stretching the channels to the range over the original, and it would probably change the image character.



(a)

(b) (c)

Figure 3. (a) The result of Fig. 1(a) by color histogram stretching algorithm, (b) the related YC_bC_r histogram and (c) the RGB histogram

III. PROPOSED ALGORITHM

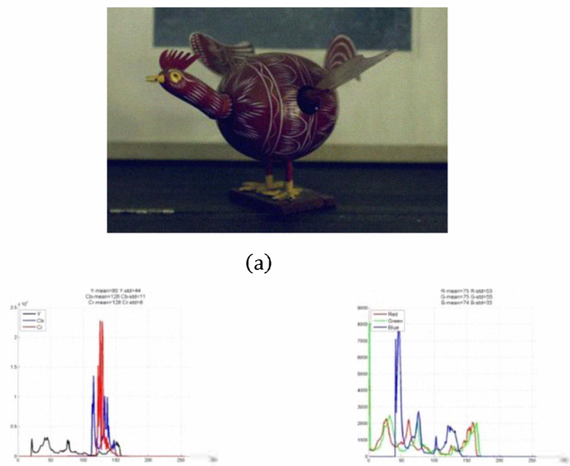
GW method and CHS algorithm both have advantages. The proposed algorithm, based on the degree of color cast, use the advantages of the CHS algorithm on color range and contrast to improve the GW theory. In order to combine these two algorithms efficiently, we modify slightly these two algorithms.

A. Modified Gray World

The original GW would change the distribution and the sharp of the histogram, as shown in Fig. 1(c) and Fig. 2(c). The proposed algorithm just wants to keep the idea of equalization the channels, so we modify the formula as below.

$$\begin{cases} I_r'(x,y) = I_r(x,y) + (A_{avg} - R_{avg}) \\ I_g'(x,y) = I_g(x,y) + (A_{avg} - G_{avg}) \\ I_b'(x,y) = I_b(x,y) + (A_{avg} - B_{avg}) \end{cases} \tag{5}$$

Fig. 4 is the result of Fig. 1 by the modified GW method. Fig. 4(c) is got by shifting the Fig. 1(c). In the shift processing, we also get the purpose of equalizing the R, G, B averages. The standard deviations of R, G, B channels are 53, 55, 33, as the same with Fig. 1(c). It means that the modified GW method can keep the color information distribution.



(a)

(b) (c)

Figure 4. (a) The result of Fig. 1(a) by modified GW method, (b) the related YC_bC_r histogram and (c) the RGB histogram

B. Modified Color Histogram Stretching

The original CHS algorithm stretches the R, G, B channels form 0 to 255. It might lead to the over stretching problems. So we modify the formula as below.

$$\begin{cases} I_r' = \frac{I_r - R_{low}}{R_{high} - R_{low}} \times A_{max} + A_{min} \\ I_g' = \frac{I_g - G_{low}}{G_{high} - G_{low}} \times A_{max} + A_{min} \\ I_b' = \frac{I_b - B_{low}}{B_{high} - B_{low}} \times A_{max} + A_{min} \end{cases} \tag{6}$$

Where, the A_{max} is the maximum value of R_{high}, G_{high}, B_{high}, and the A_{min} is the minimum value of R_{low}, G_{low}, B_{low}. We set the maximum and minimum values of the original image to be the thresholds, avoiding the over stretching.

Fig. 5 is the result of Fig. 1 by modified CHS algorithm. Fig. 5(c) is got by threshold-stretching from Fig. 1(c). The most difference in standard deviations is just 6. The mean Y is 89 in Fig. 1(b) and 92 in Fig. 5(b). The modified CHS algorithm can keep the character of the original image.

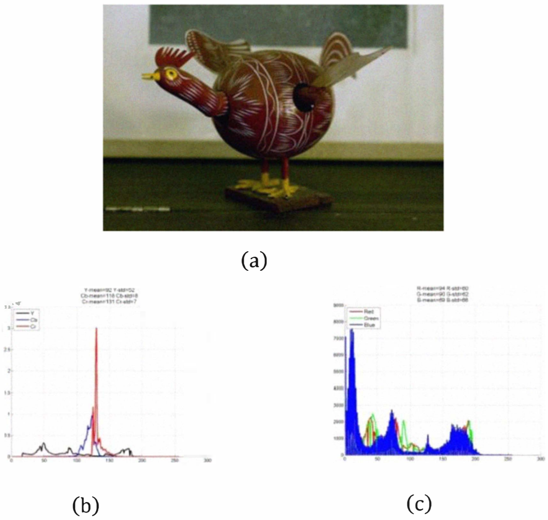


Figure 5. (a) The result of Fig. 1(a) by modified CHS algorithm, (b) the related YC_bC_r histogram and (c) the RGB histogram

C. Weighting Decision

In the proposed algorithm, we define the level of color cast as $\frac{|C_b-C_r|+|\mathrm{maxStd}-\mathrm{minStd}|}{n}$, and set it to be the weight of heavy color cast. Furthermore, set $1-\frac{|C_b-C_r|+|\mathrm{maxStd}-\mathrm{minStd}|}{n}$ to be the weight of slight color cast. Where, the $maxStd$ is the maximum value of the R, G, B channel standard deviations, and the $minStd$ is the minimum value. The formula of standard deviation is described as (7).

$$X_{std} = \frac{1}{M\times N}\sum_{x=1}^{M}\sum_{y=1}^{N}\left(I_X(x,y) - X_{avg}\right)^2 \tag{7}$$

Where, X_{std} is the standard deviation of X channel, and X_{avg} is the average value of X channel.

D. Combine Method

The flow chart of the proposed algorithm is shown in Fig. 6. First, we decide the level of color cast by the difference of mean C_b, C_r and the most difference in standard deviations of B, G, B channels. And, use the information to define the weights of these two algorithms. Heavier the color cast, bigger the weights of the CHS algorithm. Otherwise, slighter the color cast, bigger the weight of the GW method.

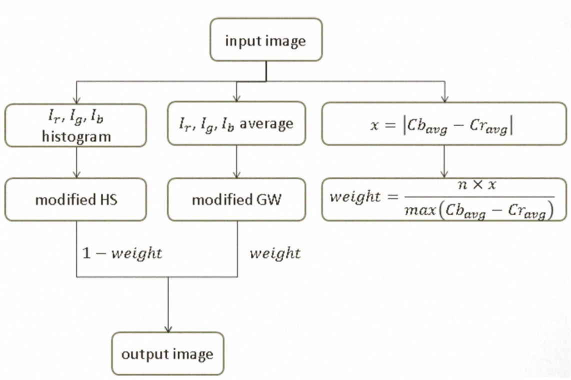


Figure 6. The flow chart of the proposed algorithm

The formula of the proposed algorithm is listed in (8).

$$X_{out} = w_1 \times X_{HS'} + w_2 \times X_{GW'} \tag{8}$$

Where, the $X_{GW'}$ is the result of the modified GW method, the $X_{HS'}$ is the result of the modified CHS algorithm, and the X_{out} is the result of the proposed algorithm.

In addition, the w_1 is the level of heavy color cast, and the w_2 is the level of slight color cast. They are described as below.

$$w_1 = \frac{|C_b-C_r|+|\mathrm{maxStd}-\mathrm{minStd}|}{n} \tag{9}$$

$$w_2 = 1 - \frac{|C_b-C_r|+|\mathrm{maxStd}-\mathrm{minStd}|}{n} \tag{10}$$

In our test, n is set to be 200. The constant is gotten by experimental results.

IV. Simulation Result

Fig. 7 is the result images from Fig. 7(a)i ~ vii by the GW method, the CHS algorithm and the proposed algorithm.

We calculate the delta E, defined by CIE 76, by the result images and the image captured under the set of sunlight, Fig. 7(a)iii. The result values are listed in Table I. In terms of the average of the delta E, the proposed algorithm has better performance than the GW method and the CHS algorithm.

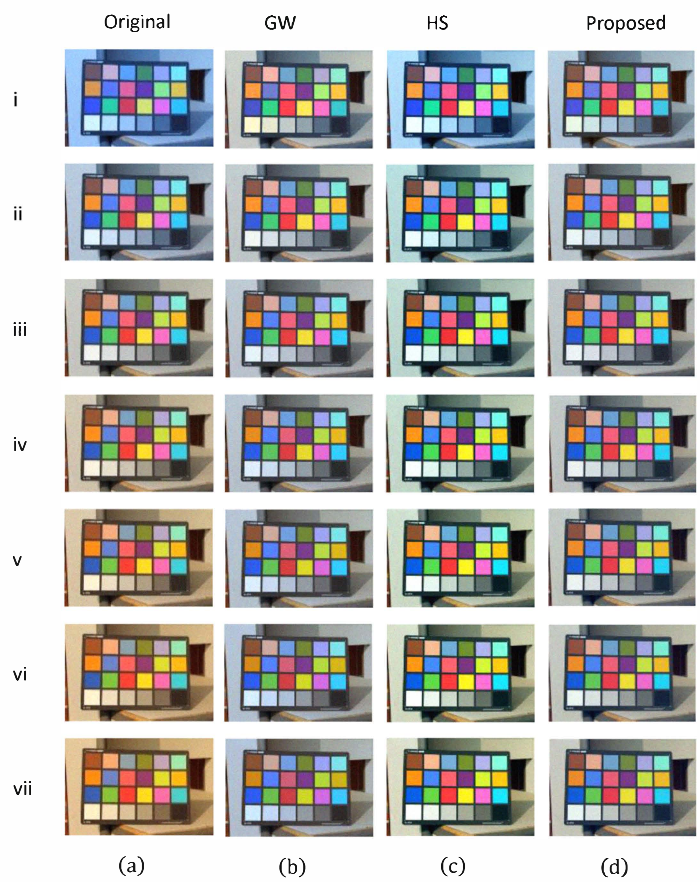


Figure 7. The result images from Fig. 7(a)i~vii by the gray world method(b), the color histogram stretching algorithm(c), and the proposed algorithm(d)

TABLE I. THE CIE DELTA E BETWEEN THE IMAGES OF FIG. 7 AND THE FIG. 7(a)III

Fig. 7 and Fig. 7(a)III	delta E		
	GW	*HS*	*Proposed*
Average	7.2653	11.848	6.520657

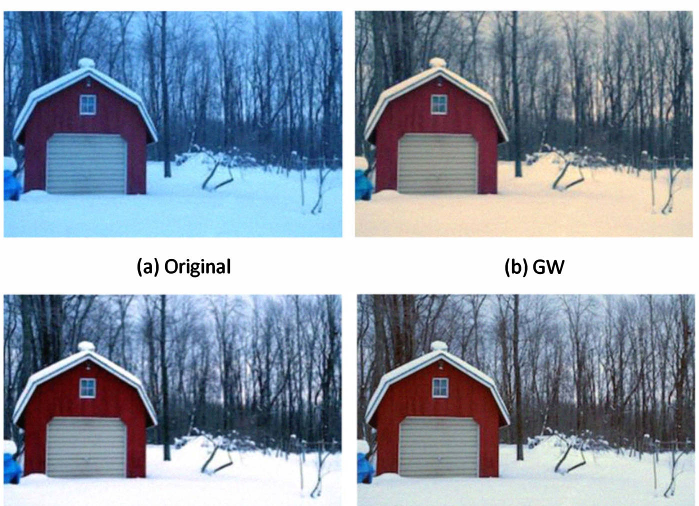
We also measure the cost time of these algorithms. The size of the test images is 400×266. The experimental environment is Intel Core 2 Duo E6300 in window 7. And the programming language is Microsoft Visual Basic 2008. The cost time is listed in Table II.

TABLE II. THE COST TIME OF THE IMAGES IN FIG. 7

Fig. 7	Cost Time		
	GW	*HS*	*Proposed*
Average	0.726857	0.739429	0.757429

Besides the test images of color checker, the proposed algorithm also applied on the natural images. Fig. 8 and 9 are the two samples of the results of the GW method, the CHS algorithm and the proposed algorithm. Furthermore, the relative information values are listed in Table III and Table IV.

As shown in Fig. 8(a), the original image is bluish [12]. The result of GW, Fig. 8(b), does not remove the cast correct because of the lost information, and looked reddish. The most difference of the standard deviations is 26. And the result of CHS algorithm, Fig. 8(c), enhances the lost color information, but the illuminant is changed at the same time. The increasing of illuminant might change the character of the original image. The proposed result, Fig. 8(d) not only can remove the color cast but also keep the illuminant. The difference between mean C_b and mean C_r is 6, the most difference between standard variations is just 9, and the increase on Y value is just 6.



(a) Original (b) GW

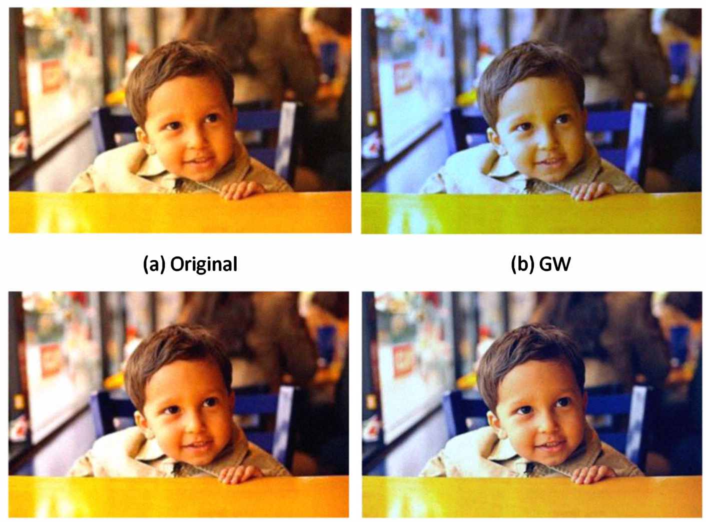
(c) CHS (d) AWBAAET

Figure 8. The bluish image and the results of the white balance algorithms

TABLE III. THE INFORMATION VALUES OF FIG. 8

Information values	Fig. 8			
	8(a)	*8(b)*	*8(c)*	*8(d)*
$\lvert maxStd - minStd \rvert$	17	26	0	9
$\lvert C_b - C_r \rvert$	51	0	16	6
Y	122	129	134	128

Fig. 9(a) is a reddish image [13]. The mean C_r is higher than the mean C_b by 58. The result of the GW method, Fig. 9(b), does not remove the color cast correctly, and the result looked bluish. The most difference between standard deviations is 38. In the result of the CHS algorithm, Fig. 9(c), the color cast is still being. The difference between mean C_b and C_r is 49. The proposed result, Fig. 9(d), decreases the most difference of standard variations and the difference between mean C_b and C_r at the same time.



(a) Original (b) GW

(c) CHS (d) AWBAAET

Figure 9. The reddish image and the results of the white balance algorithms

TABLE IV. THE INFORMATION VALUES OF FIG. 9

Information values	Fig. 9			
	9(a)	*9(b)*	*9(c)*	*9(d)*
$\lvert maxStd - minStd \rvert$	18	38	14	15
$\lvert C_b - C_r \rvert$	58	7	49	26
Y	126	115	123	119

CONCLUSION

For the images with heavy color cast, the color information and the color variation would be low, which would cause the difficulties of color temperature prediction and the appearance of the results with low color variation.

The gray world method is the most simple and common white balance algorithm. It has low computation and receives good performance in most cases. However, with the level of color cast became heavier, the correction ability of gray world would be decreasing, because of the lost color information. And the color histogram stretching algorithm correct the color cast by stretching the histogram of R, G, B channels. It can get the results with higher color variations, but it also probably causes the phenomenon of over stretching, which would change the character of the original images.

A new white balance algorithm is proposed on this paper, combining the gray world method and the color histogram stretching algorithm. The difference between mean C_b, C_r in YC_bC_r color model and the most difference in standard deviations of R, G, B channels are used to estimate the level of the color cast. After that, the weights are defined by the color cast level. Higher the level value, higher the weight of the color histogram stretching algorithm. On the other hand, lower the level value, higher the weight of the gray world method.

In the simulation results, it can be seen that the proposed algorithm has better performance than the gray world and the color histogram stretching algorithm in most cases. And the cost of time is similar to these two algorithms.

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