Digital camera auto white balance based on color temperature estimation clustering

Lei Zhang[a], Peng Liu[a], Yuling Liu[a], Feihong Yu*[a]

[a]State Key Laboratory of Modern Optical Instrument, Optical Engineering Department, Zhejiang University, Hangzhou 310027, P.R.China

ABSTRACT

Auto white balance (AWB) is an important technique for digital cameras. Human vision system has the ability to recognize the original color of an object in a scene illuminated by a light source that has a different color temperature from D65-the standard sun light. However, recorded images or video clips, can only record the original information incident into the sensor. Therefore, those recorded will appear different from the real scene observed by the human. Auto white balance is a technique to solve this problem. Traditional methods such as gray world assumption, white point estimation, may fail for scenes with large color patches. In this paper, an AWB method based on color temperature estimation clustering is presented and discussed. First, the method gives a list of several lighting conditions that are common for daily life, which are represented by their color temperatures, and thresholds for each color temperature to determine whether a light source is this kind of illumination; second, an image to be white balanced are divided into N blocks (N is determined empirically). For each block, the gray world assumption method is used to calculate the color cast, which can be used to estimate the color temperature of that block. Third, each calculated color temperature are compared with the color temperatures in the given illumination list. If the color temperature of a block is not within any of the thresholds in the given list, that block is discarded. Fourth, the remaining blocks are given a majority selection, the color temperature having the most blocks are considered as the color temperature of the light source. Experimental results show that the proposed method works well for most commonly used light sources. The color casts are removed and the final images look natural.

Keywords: digital camera, auto white balance, color temperature

1. INTRODUCTION

With the rapid spread of the consumer electronics, customers have higher and higher requirements for the quality of the products. For digital cameras, the quality of the captured image is a key quality metric to evaluate the performance of the digital cameras. Many digital cameras provide the auto white balance functionality, which may help experienceless users to take a photo under an unknown illumination condition that has the same chromatic representation as the ones taken under sun light. Sometime, this functionality does help people acquire a wonderful image easily, but for some certain circumstances such as scenes containing large color patches, some auto white balance algorithm will lead to larger color casts.

There are many auto white balance algorithms existing in literature. Retinex theory, gray world assumption and white patch[1–3] methods are commonly used. Those methods work well for most of the circumstances, but for scenes with a large color patches, those methods may fail. The reason why those methods may fail is that large color patches may be considered color casted by the illuminant. Consider the following extreme scenario: a

Optoelectronic Imaging and Multimedia Technology, edited by Toru Yoshizawa, Ping Wei, Jesse Zheng, Tsutomu Shimura, Proc. of SPIE Vol. 7850, 78502J · © 2010 SPIE · CCC code: 0277-786X/10/$18 · doi: 10.1117/12.871051

pure red wall is illuminated by a standard D65 sunlight. There is no color cast in the scene, but those methods may consider the red as the color cast and the result of the auto white balance may be undesirable.

An object under low color temperature illumination look reddish while under high color temperature illumination look bluish.[4] The key point to perform auto white balance is to find the correct color temperature of the illuminant from the image. If the color temperature can be correctly estimated, different gains can be adjusted to make the color casted image near the true color of the scene.

In this paper, a method to estimate the color temperature of an image is proposed. The method employs a prior knowledge of several daily-used light sources to judge whether the image is taken under a certain illumination and whether and how to perform the white balance. Experimental results show that the proposed method has a good performance and is practical for daily use.

2. REVIEW OF EXISTING AUTO WHITE BALANCE METHODS

There are many auto white balance methods, some use additional devices to detect the color temperature of the illumination and others employ the contents of the image to estimate the color temperature of the illumination. Each approach has its own advantages and disadvantages. The advantages of the additional device approach are that it is accurate at detecting the color temperature of the illumination and seldom fails, while the disadvantages of the additional device approach are that it is expensive and makes the system more complex, which leads to a vulnerable system. For the color temperature estimation methods, it estimates the color temperature of the illumination from the contents of the image and requires no other devices, thus this kind of methods is ealy to implement and cheap. However, sometimes this kind of methods may fail under some certain circumstances.

2.1 Extra-device auto white balance approach

This kind of methods usually empolys two or three extra color sensors. For a two-sensor auto white balance systems, the extra two sensors are masked with red and blue optical filters respectively. The three-sensor auto whtie balance systems use all of three color channel, red, green and blue for color measurement. The red channel gain of the image sensor is determined by the ratio of red to green, while the blue channel gain is determined by the ratio of blue to green.[4]

2.2 Content based auto white balance approach

1. Gray world assumption[5]

   The gray world assumption assumes that given an image with sufficient color information, the average values of the red, green and blue channels are equal to each other. This assumption holds very well for many real world scenarios: in an real world image, there are usually enough color variations. However, gray world assumption will predict large color cast in extreme case of biased surroundings.

2. White patch retinex approach[6]

   This method assumes that the brightest pixels in an image represents the specular surface, white reflect the actual color temperature of the light source.

3. Fuzzy logic approach[7]

The image to be white balanced are divided into several regions. The average of Cb and Cr values are calculated for each region. Then according to the fuzzy logic, these averaged Cb and Cr values are used to estimate the color temperature of the illumination.

4. Face detection based approach[8]

   This method employs the priori knowledge about human faces that the UV components in a human face are limited in a small area to emplement the auto white balance algorithm.

5. Color by correlation[9]

   This method assumes that the observed color and the light source mutually depend on each other. The observed colors in an image vote for the light source they may belong to, the light source with the most votes are the probable illumination of the image.

6. Neural network[10]

   This method assumes that the relationship between an image of a scene and its illumination can be obtained by training a neural network.

3. AUTO WHITE BALANCE BASED ON COLOR TEMPERATURE ESTIMATION CLUSTERING

For images containing objects with large color patches, many auto white balance methods may fail because they cannot tell whether the color is caused by the illumination or is the object's color.

In order to solve this problem, an auto white balance based on color temperature estimation clustering is presented in this paper. First, a prior knowledge of several color temperatures of commonly used illumination should be obtained. This is used to judge whether the color in the image is caused by the illumination or is the object's color itself. Second, the image to be white balanced should be divided into N blocks, where N should satisfy the following:

$$N = N_x \times N_y \tag{1}$$

where N_x and N_y are empirically determined according to the width/

After the image is divided into N blocks, the average R, G and B values are calculated for each image block. Then the color temperature for each image block are estimated according to the following equation *:

$$xD = \begin{cases} \frac{0.27475e^9}{T^3} - \frac{0.98598e^6}{T^2} + \frac{1.17444e^3}{T} + 0.145986 & 2000 \leq T \leq 4000 \\ \frac{-4.6070e^9}{T^3} - \frac{2.9678e^6}{T^2} + \frac{0.09911e^3}{T} + 0.244063 & 4000 < T \leq 7000 \\ \frac{-2.0064e^9}{T^3} - \frac{1.9018e^6}{T^2} + \frac{0.24748e^3}{T} + 0.23704 & 7000 < T \leq 15000 \end{cases} \tag{2a}$$

$$yD = -3 \times xD^2 + 2.87 \times xD - 0.275 \tag{2b}$$

$$X = \frac{xD}{yD} \tag{2c}$$

$$Y = 1 \tag{2d}$$

$$Z = \frac{1 - xD - yD}{yD} \tag{2e}$$

*http://www.brucelindbloom.com/

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 3.24071 & -0.969258 & 0.0556352 \\ -1.53726 & 1.87599 & -0.203996 \\ -0.498571 & 0.0415557 & 1.05707 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \tag{2f}$$

For given R, G and B values, a binary search strategy can be used with the equation 2:

通过迭代的方式找到色温

1. Set the initial values of the color temperature lower limit $T_{min} = 2000$, upper limit $T_{max} = 15000$
2. If $T_{max} - T_{min} < 10$, the color temperature can be regarded as found, else set the color temperature $T = \frac{T_{min}+T_{max}}{2}$;
3. Use equation 2 to calculate the R', G' and B' values corresponding to the color temperature T;
4. If $\frac{B'}{R'} > \frac{B}{R}$, $T_{max} = T$, else $T_{min} = T$, then repeat step 2.

After all the N blocks are calculated, N color temperatures are obtained, each corresponding to one image block. Each of the N color temperatures is compared with the color temperatures in the color temperature list of commonly used illuminations. For an empirically determined threshold T, if the color temperature of an image block is within the threshold of one color temperature C in the color temperature list, this color temperature of an image block is considered to vote for the color temperature C, otherwise, the color temperature of the image block is disgarded. After each color temperature of the image blocks is compared with the list, the color temperatures of the image blocks are clusterd into several groups. The group with the most votes are selected as the final estimated color temperature of the illumination. The image can be easily white balanced with this information.

4. EXPERIMENTAL RESULTS

In order to test the performance of the proposed white balance method, an image of x-rite ColorChecker taken under 3600K light source is prepared to perform the the proposed white balance method:

Figure 1. x-rite ColorChecker illuminated under a 3600K light source

The image is divided into 24 blocks, and color temperatures corresponding to each block are listed in table 1:

Table 1. Color temperatures corresponding to each image block

Image Block NO.	Color Temperature	Image Block NO.	Color Temperature
1	3069.58	13	6002.20
2	3355.22	14	3501.22
3	4275.63	15	3183.84
4	3494.87	16	3037.84
5	3951.90	17	3532.96
6	3913.82	18	5119.87
7	3063.23	19	3583.74
8	4516.85	20	3621.83
9	3253.66	21	3628.17
10	3698.00	22	3602.78
11	3075.93	23	3983.64
12	3044.19	24	3729.74

From the color temperatures listed in table 1, the color temperature of the actual illuminant can be easily obtained with the method described in section 3. The color temperature estimation is not affected by the large color patches in the image:

Figure 2. Result of the proposed auto white balance method

The result of the gray world method is given for a comparison:

Figure 3. Result of the Gray World auto white balance method

5. CONCLUSIONS AND DISCUSSIONS

Traditional auto white balance methods work well under most circumstances while may fail for scenes with large color patches in it. In order to solve this problem, a digital camera auto white balance method based on color temperature estimation clustering are proposed in this paper. The proposed method employs the prior knowledge of color temperatures of several commonly used light sources. Based on this prior knowledge, the image to be white balanced are divided into N blocks to analize their color temperature property and these blocks are clustered into several groups according to their corresponding color temperature. Then the majority selection strategy is used to estimate the final color temperature, which is used to perform white balance. Experimental results show that the proposed method does well for scenes with large color patches in it.

REFERENCES

1. E. H. LAND and J. J. McCANN, "Lightness and retinex theory," *J. Opt. Soc. Am.* **61**, pp. 1–11, 1971.
2. E. Lam, "Combining gray world and retinex theory for automatic white balance in digital photography," in *Consumer Electronics, 2005. (ISCE 2005). Proceedings of the Ninth International Symposium on*, pp. 134–139, 6 2005.
3. M. Ebner, "Combining white-patch retinex and the gray world assumption to achieve color constancy for multiple illuminants," in *DAGM-Symposium*, *Lecture Notes in Computer Science* **2781**, pp. 60–67, Springer, 2003.
4. Y.-C. Liu, W.-H. Chan, and Y.-Q. Chen, "Automatic white balance for digital still camera," *Consumer Electronics, IEEE Transactions on* **41**, pp. 460–466, 8 1995.
5. H. R. Kang, *Computational color technology*, vol. PM159, SPIE Press, 5 2006.
6. K. Barnard, *Practical colour constancy*. PhD thesis, Simon Fraser University, 1999.
7. J. Wang, Y. Liu, F. Liu, H. Xiong, and C. Li, "A method of automatic white balance using fuzzy logic," in *Circuits and Systems, 2000. IEEE APCCAS 2000. The 2000 IEEE Asia-Pacific Conference on*, pp. 615–617, 2000.
8. B. Hu, Q. Lin, X. Kang, and G. Chen, "A new algorithm for automatic white balance with priori," in *Circuits and Systems, 2000. IEEE APCCAS 2000. The 2000 IEEE Asia-Pacific Conference on*, pp. 109–112, 2000.

9. G. Finlayson, S. Hordley, and P. HubeL, "Color by correlation: a simple, unifying framework for color constancy," *Pattern Analysis and Machine Intelligence, IEEE Transactions on* **23**, pp. 1209–1221, 11 2001.
10. B. Funt, V. Cardei, and K. Barnard, "Learning color constancy," in *Proc. IS&T/SID Fourth Color Imaging Conference: Color Science, Systems and Applications*, pp. 58–60, 1996.