ESTIMATING TRI-STIMULUS RGB VALUES FOR DIGITAL CAMERA

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ABSTRACT

It is necessary to have complete tri-stimulus RGB values of each pixel because for digital camera many image processing pipeline were proposed each of them adopt different sequence of processing pipeline stages. In each of these stage different alogorithms for estimating tri-stimulus RGB value is used. In this paper we are reviewing algorithms for Auto-level Streching, White balance, Color interpolation that will be helpful in enhancing final image picture quality.

Keywords: CIELAB,IPP,RGB

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I. INTRODUCTION

The demand of Digital Still Cameras (DSCs) grows dramatically in the past years worldwide. Auto white balance is one of key technologies in digital cameras.DSCs usually adopt Charge-Coupled Device (CCD) or Complementary Metal Oxide Semiconductor (CMOS) as photoreceptor elements. Due to the limitation of current sensor manufacture technology; there still exist differences of response curves between human eyes and photoreceptor elements. Besides, each sensor has individual spectrum response curve even under the same light source. This phenomenon makes image colors captured by a sensor different from colors observed by human eyes. Auto white balance mainly compensates such differences and makes captured colors consistent with colors observed by human eyes. In high-end digital still camera market, an additional sensor is used to detect spectrum or illumination of environments and image colors are reproduced accurately by environment information. To reduce cost, a secondary spectrum sensor is often unavailable in most consumer digital cameras so various auto white balance methods based on image information rather than environment illumination are proposed to compensate the differences of response curves between sensors and human eyes. Whatsoever it may be present some lens imperfection such as dark current and camera flare which is removed from the image by performing Auto level stretching which gives sensor maximum image detail as possible.

Finally, the color interpolation method is used to compute the missing color component of a pixel. In this way the wan chung kao used to collect complete information about RGB of pixel which is used for futher processing.

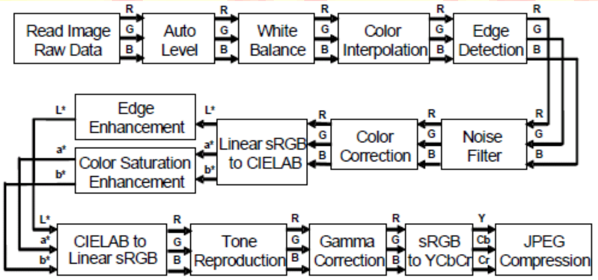
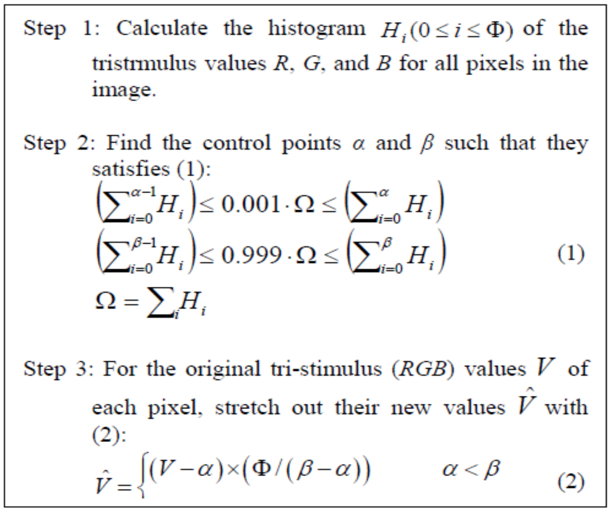


Figure1: Image processing pipeline.

II. THE AUTO LEVEL STRECH



Step 1: Calculate the histogram $H_i (0 \le i \le \Phi)$ of the tristrmulus values R, G, and B for all pixels in the image.

Step 2: Find the control points α and β such that they satisfies (1):

$$\left(\sum_{i=0}^{\alpha-1} H_i\right) \le 0.001 \cdot \Omega \le \left(\sum_{i=0}^{\alpha} H_i\right)$$
$$\left(\sum_{i=0}^{\beta-1} H_i\right) \le 0.999 \cdot \Omega \le \left(\sum_{i=0}^{\beta} H_i\right) \qquad (1)$$
$$\Omega = \sum_i H_i$$

Step 3: For the original tri-stimulus (RGB) values V of each pixel, stretch out their new values $\hat{V}$ with (2):

$$\hat{V} = \begin{cases} (V-\alpha)\times(\Phi/(\beta-\alpha)) & \alpha < \beta \end{cases} \qquad (2)$$

Figure 2:The Exposure correction Algorithms

The circuit offset caused by dark current and camera flare resulted from lens imperfections must be corrected first before other processing steps. Even in some cases the actual dynamic range of the scene is narrower than the sensor dynamic range.

Under such conditions an auto level stretch is performed in order to subtract the offset factors and allow the sensor to express more details of the scene. algorithm shown in Fig. 3 first analyzes the histogram

$H\ (0 \le i \le \Phi)\ i$ of the raw data, where Φ denotes the maximum code of the imaging system. The next step is to find the two control points corresponding to 0.1% and 99.9%, respectively. These two values are selected based on experience and can be adjusted by the designer. The dynamic range between the two control points is stretched out to fit the entire dynamic range of the output codes. It should be noted that this process is done before color interpolation. Each pixel only contains one of the three color components. The exposure correction is done without considering what the color is in the pixel. In addition, the control point α is mainly used to remove the possible black level offset and flare caused by the lens imperfection. Thus the value α should be limited to a low level, even if the distribution of the pixels only occupies relatively higher levels.

If the histogram spreads only on the upper portion of the input dynamic range and it is expected to actually increase the dynamic range of the final image. The easiest way is to modify the tone reproduction curve in the later stage to map the input dynamic to the output dynamic range. If the raw image data are subtracted by a higher constant value during stretching, the color will become incorrect since the ratios of the RGB components are also changed. One important thing in applying auto-level stretch is dynamic range stretching usually reduces data precision, or increase quantization noise significantly. Hence the input dynamic range should be much wider than the output. Since the output JPEG (Joint Photographic Experts Group) file only adopts 8-bit data, the final image will contain significant contour effect if the input image sensor only generates 8-bit of raw data. In practical camera system design, the sensor input should be equipped with a 10-bit or even 12-bit analog-to digital- converter (ADC).

III. AUTO WHITE BALANCE.

A study on AWB algorithm combines three illuminant estimation technologies:

- Color temperature curve (CTC)calibration,
- Gray world assumption,
- Macro edge detection.

Macro edge detection extracts object boundary information with higher noise immunity and prevents the statistical histograms from being dominated by larger areas of uniform color. According to gray world assumption, the statistics values of the three color channels for these macro edges are assumed to be very close in typical scenes. Finally, the color temperature of the illuminant is estimated by projecting the statistical values onto the CTC, which is calibrated for a given sensor to reflect the spectral property of gray objects illuminated by natural light sources. In the following subsections, I have first give problem formulation of AWB, and then the sensor calibration for guiding AWB is describe and the complete algorithm is stated.

A . The Problem Formulation of AWB

The measuring values of image sensors are dependent on the three factors:

(a) spectral power distribution of the incident illuminant L(λ) falling on the objects, where λ represents the wavelength,

(b) surface reflectance U(λ) of the objects in the scene in the direction of the camera.

(c) relative spectral response P(k) (λ) (k = R, G, or B channel) of the CCD/CMOS sensors. the image formation I (k) for each channel k of the sensors can be described by (3).

The objective of AWB is to compensate for the color shift caused by the illuminant L(λ) .

$$I^{(k)} = \int P^{(k)}(\lambda)U(\lambda)L(\lambda)d\lambda \qquad (3)$$

The aim of AWB is to guess the illumination under which the image is taken and compensate the color shift affected by the illuminate. The AWB problem is usually solved by adjusting the gains of the three primary colors R, G, or B of the image sensors to make a white object to appear as white under different illuminants.

Under different illuminants, typical AWB adjustment is to make the levels of the red (R), green (G) and blue (B) components balanced for the object whose nature color is gray or white. Many available algorithms for AWB rely on some heuristic ideas such as simple gray world assumption or Retinex theory [1].

These heuristic rules can attain good results for many scenes, but it is easy to enumerate the fail cases. For example, with gray world assumption, an image of a gray object in front of a large green grass field will more likely integrate to green rather than gray. Even if applying Retinex theory that detects the maximum values for R/G/B values in the captured image, it still can not work normally if parts of the regions are overexposed. The scenes mentioned above are typical cases because usually the dynamic range of

the sensor can not cover the entire range of outdoor scenes. The drawbacks in these kinds of algorithms lie in the fact that they do not fully utilize the sensor characteristics to help predict the types of illuminants. That is, it lacks enough information in the raw data for predicting the color temperature of the ambient light. Other algorithms first calibrate the sensor characteristics and create correlation tables or gamut maps for different illuminants. It is believed that the color reproduction result with sensor calibration should be better than the ones without sensor calibration. But these methods fully rely on the huge image database, which includes several thousands of pictures and each picture has been annotated with its illuminant condition. These labels are referred to as “truth” annotations and are used for training the correlation table or gamut map.

B. Color Temperature Curve Calibration of the Image Sensor

The proposed AWB process is guided by color temperature curve calibration. Assuming the photo-response non uniformity (PRNU) and defects of the sensor and the vignette effect of the lens are negligible or well corrected, the fundamental step of AWB design is to find the color characteristic of the sensor. By using the standard Macbeth color checker [2] as the scene target with a uniform natural light source, the average values of six gray blocks in the bottom row are used to calculate the R, G and B components.With a simple linear approximation to the data points, the offset caused by lens flare can be removed and sensor white balance can be characterized. As shown in Fig. 4, the horizontal axis represents the reflectance of the gray blocks in color checker, and the three measured R/G/B values corresponding to the gray blocks should be linear because the reflectance of these blocks have been calibrated as direct proportion. The offset values are denoted as R s , G s , and B s for R, G, and B channels, respectively. Note that the sensitivity of G channel is usually higher than the other ones for typical image sensors. In addition, with light sources of higher color temperature, the stimulus values of B channel for these gray blocks are usually higher than the stimulus values of R channel.

After subtracting the offset values of R s , G s , and B s for R, G, and B channels, respectively, the slopes R p , G p , and B p of the three lines can be used to represent relative sensitivities of the colors and the ratios of / G R p p and / G B p p can be computed to characterize the sensor performance undera given illuminant. By taking raw images under sun light at different moments of the day, it is possible to get several values of / G R p p and / G B p p under different color temperatures. In real application, average values of R, G and B are used. It is possible then to take G/R and G/B as coordinates and plot these points for different light sources and the resulting curve is called color temperature curve (CTC) of the sensor.

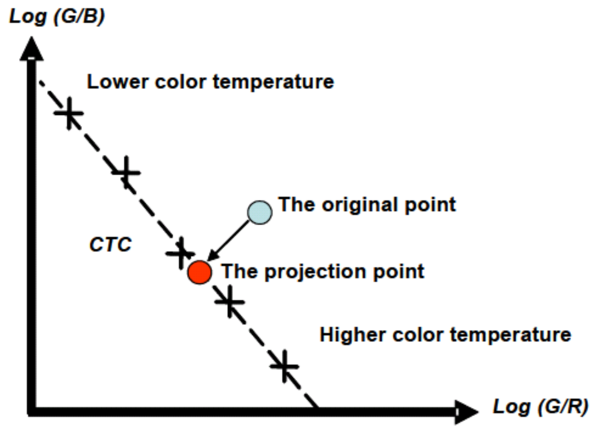


Figure 3: Color Temperature curve.

Since the data researcher are dealing with ratios of two values, it is customary to take logarithm of the values calculated such that multiplication can be replaced with addition. The resulting curve is roughly linear for natural light sources[3][4] as shown in Fig. 4. In general, when the color temperature of the light source is higher, the blue component is stronger and the red component is weaker. The sensor output level of R is lower than B. thus the ratio G/R is larger than G/B, and the data point lies on the lower right portion of the space.

On the other hand, with lower color temperature illuminant, researcher will obtain opposite result and the data point will lie on the upper left corner of the space. From this feature, it can be concluded that essentially the slope of the curve is negative. With proper constraints and statistical analysis performed, it is possible to derive an average color data point in the log(G / B) − log(G / R) space.

Note that the measurement point for gray objects or patches will locate in the CTC if they are illuminated by a natural light source. However, the real scenes are colorful. the approach to utilizing the calibrated CTC is combining macro edge detection and gray world assumption. The algorithm detects macro edges and then the average values of three color channels are calculated based on only these macro edges. The point in the log(G / B) − log(G / R) plane can be determined accordingly. As shown in Fig.4, the point may not locate on the CTC curve because the proposed approach based on macro edges detection and gray world assumption is still just an estimation of color temperature. This estimation point is then projected on the CTC, and the projection point is assumed as the color temperature of the ambient light source.

C. The Advantages of AWB Algorithm

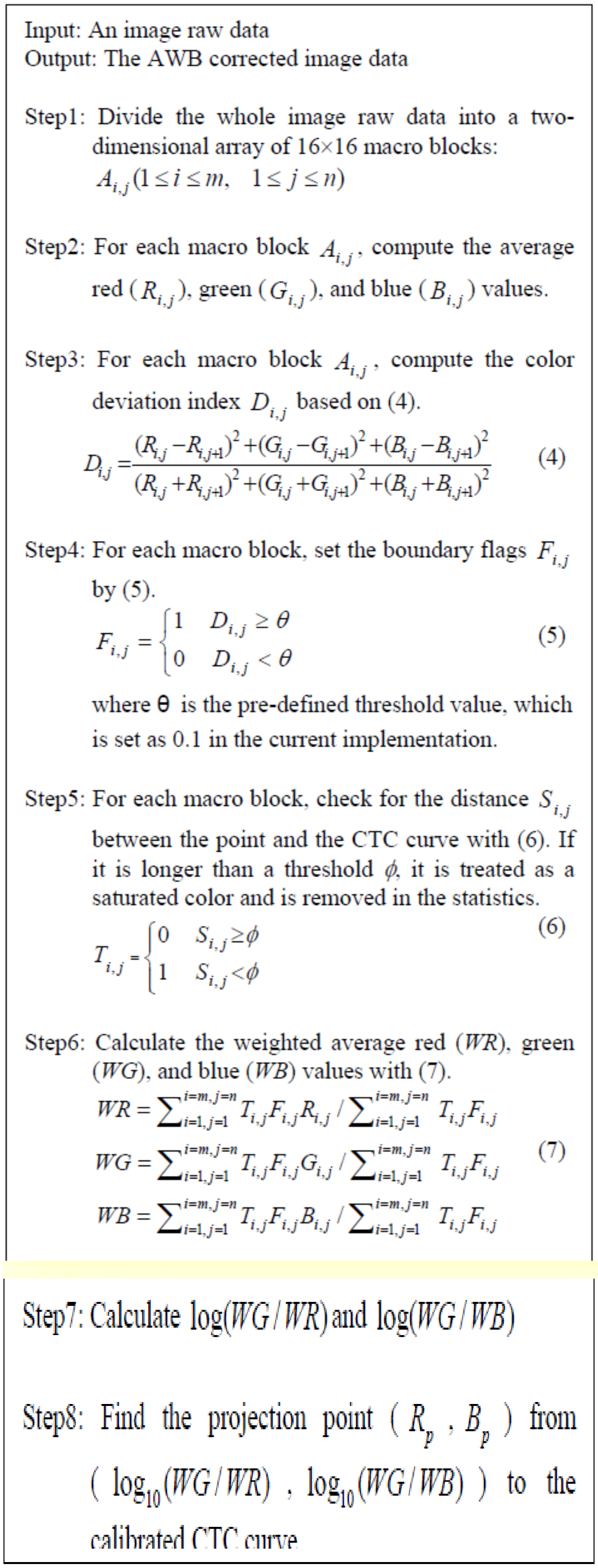
The detailed AWB algorithm is listed in Fig. 4. Compared to other approaches, the improvements include following items:

(a) It fully utilizes the sensor characteristics with calibrated color temperature curve.

(b) In order to prevent large uniform color blocks from dominating the AWB calculation, the proposed algorithm performs edge detection on coarse grids (16×16 macro blocks) instead of performing edge extraction on the pixel level.

The noise immunity with macro blocks is much better than with pixel levels.

(c) Unlike color by correlation, the color temperature curve can be calibrated with few images taken under different illuminants.



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Input: An image raw data
Output: The AWB corrected image data

Step1: Divide the whole image raw data into a two-dimensional array of 16×16 macro blocks:
       $A_{i,j} (1 \le i \le m,\ \ 1 \le j \le n)$

Step2: For each macro block $A_{i,j}$, compute the average
       red ($R_{i,j}$), green ($G_{i,j}$), and blue ($B_{i,j}$) values.

Step3: For each macro block $A_{i,j}$, compute the color
       deviation index $D_{i,j}$ based on (4).
       $D_{i,j} = \frac{(R_{i,j}-R_{i,j+1})^2+(G_{i,j}-G_{i,j+1})^2+(B_{i,j}-B_{i,j+1})^2}{(R_{i,j}+R_{i,j+1})^2+(G_{i,j}+G_{i,j+1})^2+(B_{i,j}+B_{i,j+1})^2}$   (4)

Step4: For each macro block, set the boundary flags $F_{i,j}$
       by (5).
       $F_{i,j} = \begin{cases} 1 & D_{i,j} \ge \theta \\ 0 & D_{i,j} < \theta \end{cases}$   (5)
       where θ is the pre-defined threshold value, which
       is set as 0.1 in the current implementation.

Step5: For each macro block, check for the distance $S_{i,j}$
       between the point and the CTC curve with (6). If
       it is longer than a threshold $\phi$, it is treated as a
       saturated color and is removed in the statistics.
       $T_{i,j} = \begin{cases} 0 & S_{i,j} \ge \phi \\ 1 & S_{i,j} < \phi \end{cases}$   (6)

Step6: Calculate the weighted average red (WR), green
       (WG), and blue (WB) values with (7).
       $WR = \sum_{i=1,j=1}^{i=m,j=n} T_{i,j}F_{i,j}R_{i,j} / \sum_{i=1,j=1}^{i=m,j=n} T_{i,j}F_{i,j}$
       $WG = \sum_{i=1,j=1}^{i=m,j=n} T_{i,j}F_{i,j}G_{i,j} / \sum_{i=1,j=1}^{i=m,j=n} T_{i,j}F_{i,j}$   (7)
       $WB = \sum_{i=1,j=1}^{i=m,j=n} T_{i,j}F_{i,j}B_{i,j} / \sum_{i=1,j=1}^{i=m,j=n} T_{i,j}F_{i,j}$

Step7: Calculate $\log(WG/WR)$ and $\log(WG/WB)$

Step8: Find the projection point ( $R_p$ , $B_p$ ) from
       ( $\log_{10}(WG/WR)$ , $\log_{10}(WG/WB)$ ) to the
       calibrated CTC curve
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Figure 4: The AWB Algorithm.

IV: CFA Interpolation

Typically, digital cameras employ only a single sensor to capture an image, so the camera can only obtain a single color component for each pixel even though three components are necessary to represent RGB color.CFA interpolation is the process of interpolating two missing color components for each pixel based on the available component and neighboring pixels. CFA interpolation is primarily a transform function that does not vary based on sensor or lighting conditions, and therefore no tuning of this image-processing pipeline stage is required. However, it is still one of the most complex algorithms in the image-processing pipeline, and the quality of its output is highly dependent upon the expertise of the silicon vendor

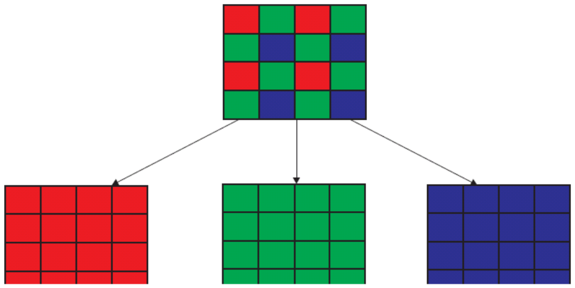


Figure5: Color interpolation.

V. SAMPLE EXAMPLE

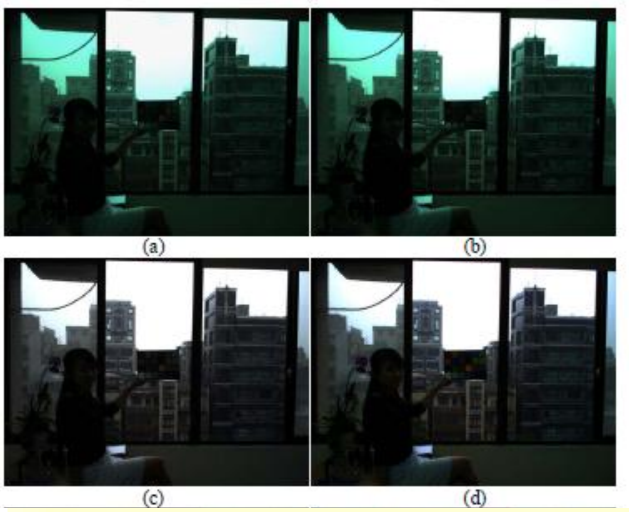
The partial results are shown in the figures:

(a) The raw image,

(b) The image after auto-level stretch,

(c) The image after AWB,

(d) The image after colour correction



(a) (b) (c) (d)

VI. CONCLUSION

Given image processing pipeline (IPP) that will focusing on Sequencing image processing steps for digital camera This image processing pipeline provide good reference. the algorithms used in the intial steps gives fine compensation in different scene and situation by estimating correct RGB value . It is also possible to design an IPP chip with such a robust flow for real-time video and still image processing, which will be future work.

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