A Two-Stage Blind Image Color Correction Using Color Cast Estimation

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Abstract. The color cast images usually have serious loss of the color information and are inconvenient for visual observation and image analysis. To tackle this problem, a novel two-stage image color cast correction scheme is proposed in this paper. Firstly, the proposed approach performs the color cast and stable channel detection by using extreme intensity ratio of the original image. Second, the distorted image color is restored by solving the constrained problem with the degree of color variation and the above-detected color cast and stable channel. The experimental results using surveillance videos demonstrate that the proposed scheme is not only feasible but also effectively. In addition, the results satisfy human subjective perception as well.

Keywords: Color cast image, stable channel detection, color cast estimation, blind color correction.

1 Introduction

Color cast means the variation between the collected images and the real color of object surface. It is usually incurred by the influence of the environmental light source, reflection characteristics of the object, and the parameters of acquisition device. This color variation may introduce undesirable effects for human perception (e.g., police investigation). Moreover, it may negatively affect the performance of computer vision methods for different applications such as object recognition, tracking [1-2].

The aim of color correction is to eliminate the effect of the color cast. Over the past decade, a variety of algorithms are used to color correction for color cast images and videos. The *Shades of Gre*y (SoG) approach [3] introduces Minkowski-norm into Grey World algorithms. It utilizes the Minkowski-norm distance to replace the simple averaging method. Although they are conceptually simpler, it can not realize color correction for the original image that does not matching the grey hypothesis. The Grey Edge hypothesis in [4] from observation of the distribution of image color derivative in opponent color space is a relative regular

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ellipse, and the axis of the ellipse and the direction of light are same. Then, this method assumes the average of the reflectance differences in a scene is achromatic to realize color correction. However, the Grey Edge method gets insufficient color restoration for badly color cast images, due to the hypothesis is invalid. Color correction in multi-scaled retinex [5] is proposed using a modified local average image to improve the color rendition and reduce the color distortion by the dominant chromaticity of the original image. Due to the use of complex image processing techniques, it is time-consuming. The survey of many recent developments and state-of-the-art color constancy methods is presented in [6]. Its main focus is on the estimation of the illuminant using a single image from a regular digital camera. Due to use regular digital camera, it does not result in satisfactory results for surveillance videos. Spectral reflectance estimation method in [7] is proposed to utilize images including both near-infrared image and visible light image to realize spectral reflectance estimation, and then achieves color correction. However, near infrared imaging system usually have higher prices than traditional visible cameras. This disadvantage limits the scope of the application.

This paper studies blind color correction, where the input image is not known to be color cast. For that, a novel color correction scheme is proposed in this paper. The core of the proposed scheme lies in seeking a stable channel and achieving color correction by the guided of this stable channel. The proposed approach consists of two stages. First, the input color cast image is preprocessed for obtaining extreme intensity ratio. And then the proposed approach performs the color cast detection and stable channel detection. Second, difference intensity ratio is calculated to estimate the degree of color variation. And then, the bind color correction is realized.

The rest of this paper is organized as follows. First, the stable color channel detection is proposed in Section 2. The proposed color correction approach is proposed in Section 3. Experimental results are presented in Section 4. Finally, Section 5 concludes this paper.

2 Stable Channel Detection

Various methods have been proposed to achieve color correction. It is important to note that the reference image cannot be obtained from video surveillance systems. It leads to a blind problem, which is difference from the conventional assumptions for most of color correction methods. The proposed scheme is focus on blind surveillance video images.

Three types of *color variation* (CV) are presented to describe the bias of color channels in an original image. They are (i) additive variation, (ii) subtractive variation, and (iii) stable. The first type represents that the intensity of one color channel is larger than other color channels. The second type represents that the intensity of one color channel is smaller than other color channels. The third type represents that the intensity among color channels is balance.

A red cast image is shown in Fig. 1(a). The Fig. 1(b) shows the histogram of the original image. The curve with dotted line represents red channel, the curve with solid line represents green channel, and the curve with point and line represents blue channel. It can be found that the intensity of blue is smaller than other two colors, and the intensity of red is larger than other two colors. Based on the description of color variation, the proportion of bright pixels and dark pixels in each channel are calculated as follows.

Considering an image with RGB color space, the bright channel information $\mathbf{H}_{bri}$ and the dark channel information $\mathbf{H}_{dark}$ of image $\mathbf{I}$ are defined as:

$$\mathbf{H}_{bri} = \max(\mathbf{I}^R, \mathbf{I}^G, \mathbf{I}^B), \mathbf{H}_{dark} = \min(\mathbf{I}^R, \mathbf{I}^G, \mathbf{I}^B) \tag{1}$$

where $\mathbf{I}^R, \mathbf{I}^G, \mathbf{I}^B$ represent red, green and blue component of image $\mathbf{I}$, respectively. $\max(.)$ and $\min(.)$ denotes the operator of maximum and minimum. The *extreme intensity ratio* (EIR) can be calculated as:

$$EIR_i^c = S_i^c / (H \times W), c \in \{R, G, B\} \tag{2}$$

where H and W represent the height and width of image $\mathbf{I}^c$. EIR_i^c represents the bright and dark intensity ratio of RGB channels. Moreover, $S_i^c \in \{S_{bri}^c, S_{dark}^c\}$ is defined as:

$$S_i^c = \sum_{\mathbf{x}} \mathbf{L}_i^c(\mathbf{x}) \tag{3}$$

$$\mathbf{L}_i^c(\mathbf{x}) = \begin{cases} 1, & \text{if } \mathbf{I}^c(\mathbf{x}) = \mathbf{H}_i(\mathbf{x}) \\ 0, & \text{otherwise} \end{cases} \tag{4}$$

where $\mathbf{x}$ represents spatial position in the image, $\mathbf{I}^c(\mathbf{x})$ represent the gray value in pixel $\mathbf{x}$, $\mathbf{L}_i^c(\mathbf{x})$ is the symbol of bright or dark pixel in $\mathbf{x}$, S_i^c represents the total number of pixels that satisfy the conditions.

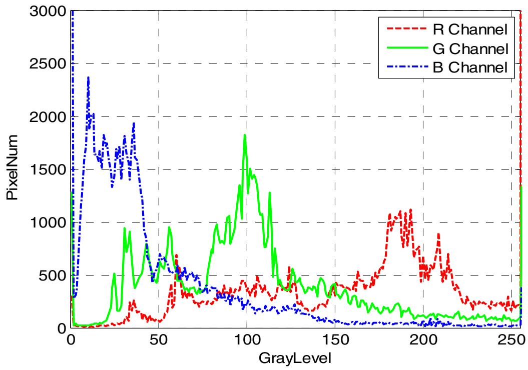
Defining V_{bri}^{st}, V_{bri}^{nd} and V_{dark}^{st}, V_{dark}^{nd} respectively as the 1st and 2nd maximum value of EIR_{bri}^c and EIR_{dark}^c. The CV of each color channel can be determined as follows:

$$\mathbf{I}^c \in \begin{cases} \text{additive}, & \text{if } V_{bri}^{st} - V_{bri}^{nd} \ge T_1, EIR_{dark}^c = \min(EIR_{dark}) \\ \text{subtractive}, & \text{if } V_{dark}^{st} - V_{dark}^{nd} \ge T_2, EIR_{bri}^c = \min(EIR_{bri}) \\ \text{stable}, & \text{otherwise} \end{cases} \tag{5}$$

where T_1 and T_2 are pre-defined threshold. If the three channels are all stable, the original image does not have color cast. The additive channel is that its intensity is larger than other two channels. The subtractive channel is that its intensity is smaller than other two channels. Otherwise, the channel is stable.

In Fig. 1(b), the intensity distribution of blue channel and red channel arise the polarization phenomenon. On the basis of equation (5), the blue is subtractive type, and the red channel is additive type, and the green channel is stable type.

(a)



(b)

Fig. 1. Example of color variation. (a) Original image. (b) Histogram of the image (a).

3 Color Correction

According to section 2, the stable channel is detected. The color correction for the color variation channels based on the stable channel is proposed in this section. It is based on a simple conception, using the color channel with more reliable information as a guider to restore the other channels [8].

Inspired by the image degradation model proposed in [9], which is formulated as follows:

$$\mathbf{g}(\mathbf{x}) = \mathbf{f}(\mathbf{x})t(\mathbf{x}) + A(1 - t(\mathbf{x})) \tag{6}$$

where $\mathbf{g}$ represents the original image, $\mathbf{f}$ represents the scene radiance, $t(\mathbf{x})$ is the medium transmission, and A is the global atmospheric light. The proposed scheme uses the degradation model (6) to color correction.

Let $\psi(\mathbf{x}) = 1 - 1/t(\mathbf{x})$, $\mathbf{q}(\mathbf{x}) = A - \mathbf{g}(\mathbf{x})$, it gives

$$\mathbf{f}(\mathbf{x}) = \mathbf{g}(\mathbf{x}) + \mathbf{q}(\mathbf{x})\psi(\mathbf{x}) \tag{7}$$

To achieve this end, the unknown term $q\psi$ in (7) need to be estimated. In the following, how to estimate the parameters as well as obtain the restored image is presented.

Considering the variation of color channels, it can have large or small bias. The key is to find some features to classify the serious or slight situation. It can be perceived that there are differences among the intensity of color channels through observation defined as *difference intensity* (DI). It can be calculated as follows:

$$DI^c(\mathbf{x}) = \sum_{\mathbf{x}} (\Delta^c(\mathbf{x})) / S_{bri}^c \tag{8}$$

where S_{bri}^c represents the number of bright pixels using equation (3) and (4), respectively. $\Delta^c(\mathbf{x})$ can be computed as:

$$\Delta^R(\mathbf{x}) = \Delta\mathbf{RG}(\mathbf{x}) + \Delta\mathbf{RB}(\mathbf{x}) \tag{9}$$

where $\Delta^R(\mathbf{x})$ denotes the intensity difference between red channel and the rest channels, $\Delta\mathbf{RG}(\mathbf{x})$ and $\Delta\mathbf{RB}(\mathbf{x})$ defined as:

$$\Delta\mathbf{RG}(\mathbf{x}) = \begin{cases} \mathbf{I}^R(\mathbf{x}) - \mathbf{I}^G(\mathbf{x}), & \text{if } \mathbf{I}^R(\mathbf{x}) = \mathbf{H}_{bri}(\mathbf{x}) \\ 0, & \text{otherwise} \end{cases} \tag{10}$$

$$\Delta\mathbf{RB}(\mathbf{x}) = \begin{cases} \mathbf{I}^R(\mathbf{x}) - \mathbf{I}^B(\mathbf{x}), & \text{if } \mathbf{I}^R(\mathbf{x}) = \mathbf{H}_{bri}(\mathbf{x}) \\ 0, & \text{otherwise} \end{cases} \tag{11}$$

It can be extended to G and B color channels. After that, the *difference intensity ratio* (DIR) can be obtained as follows:

$$DIR^c = \frac{1}{1 + e^{-(DI^c - a)/b}} \tag{12}$$

where a and b represent pre-parameter and can self-adapting select based on the luminance of image.

For the aim of color correction, the *degree of color variation* (DCV) is presented to quantize the intensity variation, defined as α_{DCV}. It is calculated as follows.

$$\alpha_{DCV} = \sum_{c \in \{R,G,B\}} (EIR_{bri}^c \times DIR^c) \tag{13}$$

where $\alpha \in [0,1]$, EIR_{bir} and DIR denotes the bright intensity ratio and DIR, respectively.

First, considering the property of DCV, assuming the combination of the DCV and the stable channel as the estimation of $q\psi$. That is

$$q\psi \approx \alpha_{DCV}\, \boldsymbol{p} \tag{14}$$

where $\boldsymbol{p}$ represents the guided matrix. Then, $\boldsymbol{f}$ can be solved from $\boldsymbol{g}$ in equation (7) by solving the optimization problem stated in equation (15) using conjugate gradient method with initialized $\boldsymbol{f}_0 = \boldsymbol{g}$ as follows:

$$\hat{\boldsymbol{f}} = \arg\min_{f} \sum_{i \in c} \left\| \boldsymbol{f}_i - \boldsymbol{g}_i - \boldsymbol{q}_i \psi_i \right\|^2 + \lambda \left\| w(\mathrm{sgn} \cdot \Delta \boldsymbol{f}_i) \right\|^2 \tag{15}$$

where $\Delta f = f_i^n - f_i^{n-1}$ denotes difference between the current iterative result and the previous iterative result. sgn is a sign function.

$$w(\mathrm{K}) = \begin{cases} 0, & \mathrm{K} \le 0 \\ \beta, & \mathrm{K} > 0 \end{cases} \tag{16}$$

$$\mathrm{sgn} = \begin{cases} 1, & \text{if } \boldsymbol{f}_i \text{ is additive} \\ -1, & \text{if } \boldsymbol{f}_i \text{ is subtractive} \\ 0, & \text{if } \boldsymbol{f}_i \text{ is stable} \end{cases} \tag{17}$$

where β denotes penalty factor, and $\boldsymbol{f}_i$ denotes the current result.

The overall framework of the proposed algorithm is summarized in Fig. 2 and described as follows.

Step1: Given an input image, calculate EIR by equation (2), and determine color variation of each channel by equation (5). Finally, achieve stable channel and color cast detection basing on color variation.
Step2: Calculate DIR by equation (12), and then obtain the DCV by equation (13);
Step3: Perform color variation correction by solving the constrained equation (15) based on the estimation of unknown parameters $\boldsymbol{q}\psi$ in equation (14).

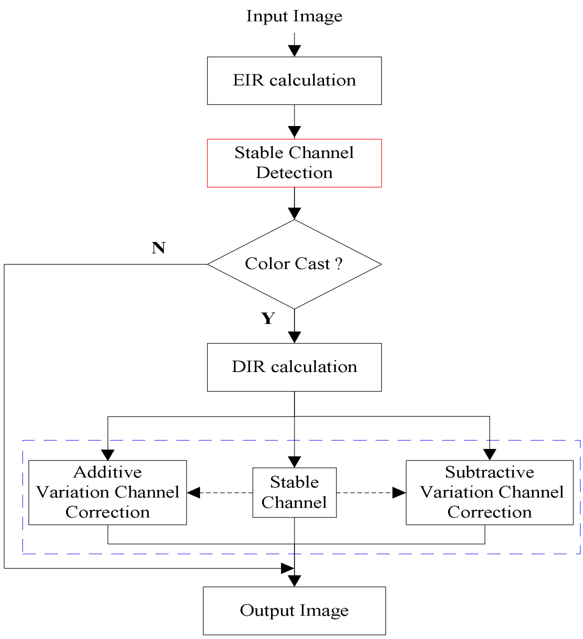
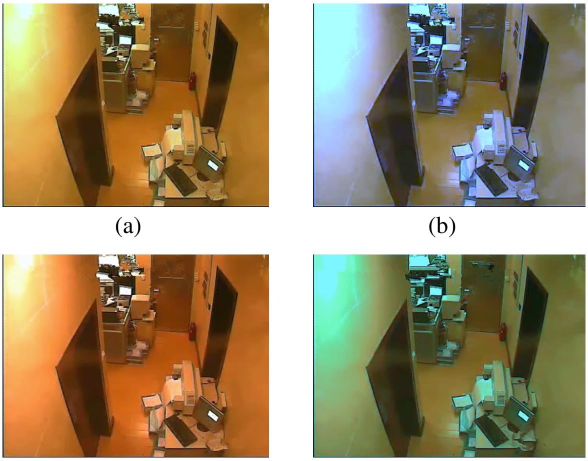


Fig. 2. The overview of the proposed approach

4 Experiments

The proposed method is assessed by testing it on several surveillance videos. In the experiment, the logo and time are masked for privacy. The T_1, T_2 used in the proposed approach are set to be $0.6, 0.6$. It is worthy mentioning that the proposed method is designed for blind surveillance video images for real-life applications.

Fig. 3 compares various experimental results of image (in Fig. 1(a)) obtained by the proposed method, the Grey Edge method [4], the Grey World method [1], the Max-RGB method [2] are respectively presented. As seen in Fig. 3, the proposed approach achieves more natural image result for human perception. For example, the wall in Fig. 3(a) and Fig. 3(c) displays yellow and orange, and in Fig. 3 (b), the wall is white cast. By contrast, the result of proposed scheme is more comfortable for human visual perception. In addition, the fire extinguisher in the corner is also better.



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

Fig. 3. Various corrected color image (Fig. 1(a)). (a)-(c). Results of [4, 1, 2]. Respectively; (d) Proposed method.

Fig. 4. Color correction of the proposed method. The first column is the input image, and the second column is the output image.

Fig. 4. *(Continued)*

Fig. 4 shows the results of other surveillance videos by the proposed scheme. It can be observed the proposed method significantly restores the color of the images. It almost does not have excessive corrections, and also has a well visual effect with human subjective evaluation.

5 Conclusions

In this paper, a novel two-stage scheme for color correction is proposed. The proposed scheme uses the extreme intensity ratio to process the color cast and stable channel detection, and then restores color by solving the constrained problem based on the degree of color variation and above prior color cast and stable channel detection. Experimental results show that the proposed method is capable of achieving color correction and improves the perceptual quality.

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