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Illuminant Color Estimation in an Image under Several Illuminants Based on Gray-World Assumption

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Abstract

Illuminant color estimation method for the scene illuminated by several illuminants is proposed. In the past, most of the conventional methods focused on the scene under one illuminant and assumed the color of the illuminant is constant throughout the scene, however, these are not always the case. These days, the methods for estimating several colors of the scene illuminants are studied. Some of them are based on dichromatic reflection model, and assume that colors of the illuminant in the small region in the image is only one and constant throughout the region. Proposed method is based on Gray-World assumption, which doesn't need the specular reflection components but variety of colors in the image. In the method, image is divided into small regions and the illuminant colors are estimated for the small regions after the judgement whether each small region in the image includes variety of colors is or not. By clustering the estimation for each small region, final result is derived. In the experiments, simulated images under two illuminants are used and the estimated results are evaluated. The results show that the estimation error by the proposed method is smaller than those by the conventional one.

Introduction

In color image processing such as template matching, object recognition, image retrieval and etc., these techniques depend on the pixel values in the image which are influenced by colors of scene illuminants. If the images taken under white illuminants are used, it is comparatively easier to apply the above techniques. However, there are several cases where scenes are illuminated under colored scene illuminants such as twilight (sunlight) or bluish light (artificial illuminant). While a lot of images are taken and shared via the internet by means of SNS (Social Networking Service). When sharing the images, some of them are needed for changing colors because those are not captured under white illuminants. Therefore it is useful for color image processing to extract colors of scene illuminants in the images and convert colors of them taken under white/non-colored illuminants.

As colors in the images include colors of both objects and scene illuminants, it is convenient to handle these colors individually. Therefore, the methods for estimating colors of scene illuminants in the images have been studied. The conventional methods are divided into two categories; the first ones use the physical properties of objects and/or illuminants known as retinex theory [1] and dichromatic reflection model [2], the others use statistical characteristics of the scene known as gamut-based method [3], [4] and Gray-World method [5]. However, these methods assume that the color of the scene illuminants is constant throughout the scene while most of the illuminant environments surround us are illuminated by two and more illuminants.

The purpose of my study is to estimate several colors of the scene illuminants in an image and convert colors of the image under white illuminant. Tominaga's method [6] is based on dichromatic reflection model and assumes that the color of scene illuminant in the small region in the scene is only one and is constant through the region. Therefore, the image is divided into small regions and the color of the scene illuminant for each region which includes specular reflection can be estimated. Riess's method [7] is basically based on dichromatic reflection model and estimates the colors of the scene illuminants by merging the color estimation derived from each small region in the image. In his study, the results using the conventional methods for one illuminant such as gamut mapping, Gray-World, White-Patch, and etc., are shown and compared with the proposed one. Gijsenij's method [8] uses the conventional methods for one illuminant and applies them for each small region in the image and compares their estimation errors. Their approach focuses on how to set up the small regions, i.e., they are grid-base, key point-base, and segment-base are investigated and compared. By using dichromatic reflection model, color of scene illuminants can be estimated directly when there are dielectric materials in the scene, however, it is not always the case. As for the conventional methods for one illuminant used above, original and typical methods are used. Thus, if the revised methods for one illuminant were used in each small region, the final estimation would be improved.

In this paper, Gray-World-based method is focused on because the algorithm is simple, easy to implement and also the revised one was proposed [9]. Gray-World assumption itself hypothesizes that the average color of all objects in the scene is gray or achromatic. Therefore, if the scene satisfies the above assumption, the average color derived from the image corresponds to the color of scene illuminants. However, the scenes doesn't always satisfy the assumption. Gray-World based method doesn't work well when it is applied for the image which doesn't satisfy the assumption. The method proposed in this paper uses the judgement whether each small region satisfies the Gray-World assumption or not and estimates the color of illuminant for each small region is estimated for the one which satisfies the assumption. The judge is based on standard variation. The method also assumes that the color of the scene illuminants is only one and constant throughout the small region as the other conventional methods do. Unifying the estimated results for each small region using k-means algorithm, colors of the scene illuminants in the image are estimated.

The proposed method consists of five parts; (1) division of small regions, (2) judgement of Gray-World assumption for each small region, (3) illuminant color estimation for each small region, (4) integration of the estimated results derived from the small region, and (5) estimation of colors of scene illuminants.

In the next section, proposed method is explained in detail, and in the following section experiments I conducted and the results obtained are described. Lastly, the summary section concludes the results of experiments and some comments with the future work.

Approach

As I mentioned above, Gray-World doesn't work well when the images or the regions in the image do not satisfy the assumption, which the average color of all the objects in the image or the region is gray. Thus, in order to avoid the problem, my approach uses the judgement whether each small region is practical to apply. Figure 1 shows the procedure of applying the method.

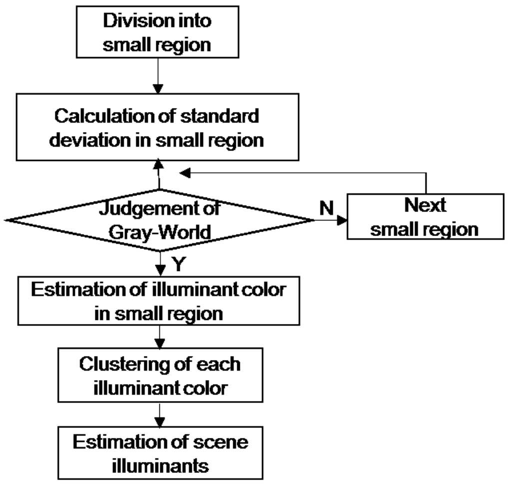


Figure 1.A flowchart of the proposed method

Firstly, the image is divided into small region and assumes that the color of scene illuminants is constant throughout the small region as the other conventional methods do. Size of the small region is identical to all regions in the image. After that, standard deviation is calculated in the small region for judging the Gray-World assumption. The following equation is used for calculating standard deviation for each small region and the subscript c means color channel R, G and B. In equation (1), $P_c(i,j)$ shows pixel value of i-th in column and j-th in row pixel in the small region, $\overline{P}_c$ means the average color in the small region derived using equation (2). N and m are horizontal and vertical size of the small region.

$$stdev_c = \sqrt{\frac{1}{n \times m}\sum_{i=1}^{n}\sum_{j=1}^{m}\left\{P_c(i,j) - \overline{P}_c\right\}^2} \tag{1}$$

$$\overline{P}_c = \frac{1}{n \times m}\sum_{i=1}^{n}\sum_{j=1}^{m} P_c(i,j) \tag{2}$$

The judgement whether the small region satisfies Gray-World assumption or not is applied for the region. In judgement, if 2 and more channels of $stdev_c$ is TH and over, the small region is regarded as one which satisfies the Gray-World assumption shown in equation (3). This criteria is derived the property that when the region includes a variety of colors, the standard deviation in the region is large. Here, standard deviation is calculated in each color channel. Thus in case where two channel's standard deviation is large, it means there are a variety of colors in the region.

$$stdev_c \geq TH \tag{3}$$

According to the flowchart, if the small region is judged to be applicable for Gray-World assumption, the next step is processed, and if not, the judgement is continued for the next small region.

After that, the illuminant color is calculated as the average pixel values for each small region. Next, estimated colors of illuminants derived in the small regions are integrated by k-means clustering. In the clustering, k=2 is used. The average value in each cluster is calculated as the colors of scene illuminants.

Experiments

Experimental setting

In the experiment, images are generated using surface reflectance and spectral distribution data which Gijsenij used in their paper [8] and uploaded in their homepage [10]. In their site, camera sensitivity data is also shown, thus the pixel values of each color channels in the images are calculated using the surface reflectance, spectral distribution of the illuminant and the camera sensitivity. The equation for calculating the pixel value is shown in the following. In the equation, P_c is pixel value and the subscript c shows the color channel R, G or B and $\rho(\lambda)$, $E(\lambda)$ and $Cam_c(\lambda)$ are the surface reflectance, spectral distribution of the illuminants, and the camera sensitivity. In the calculation, data of 380 nm through that of 780 nm, which corresponds to visual wavelength, is used.

$$P_c = \int Cam_c(\lambda) \cdot E(\lambda) \cdot \rho(\lambda) d\lambda \tag{4}$$

Surface reflectance used in the experiment is selected randomly from the dataset which includes Macbeth chart and the number of colors in which is totally 10124. Two kinds of illuminants which are Solux's 3500 K color temperature lamp (reddish illuminant) and the filtered one (white illuminant) are used. Spectral distribution of these two illuminants (reddish illuminant and white one) is shown in figure 2. The spectral distribution of the reddish illuminant is shown as broken line and the white one is shown as solid line.

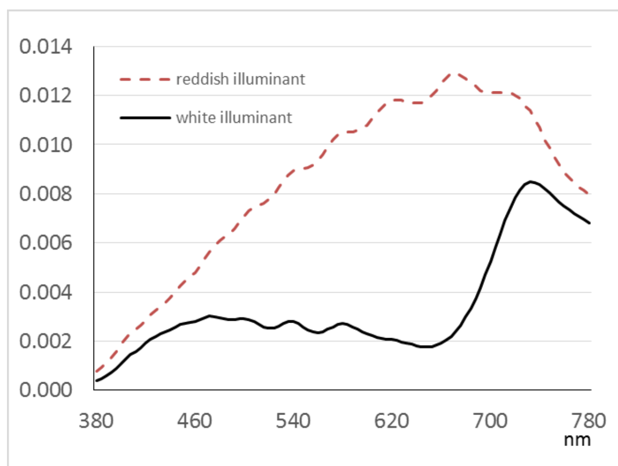


Figure 2. Spectral distribution of two illuminants used in the experiments. Broken line and solid line show reddish illuminant and white illuminant. A flowchart of the proposed method.

The image is generated to simulate the scene which is illuminated by two kinds of illuminants from left and right. Each pixel value is calculated using equation (4). In camera sensitivity shown in the above site [10], sensitivity of shorter wavelength which means to blue is relatively higher than those of other two colors. Thus, the sensitivity of camera is adjusted to have same integral value throughout the visual wavelength. The original camera sensitivity and the revised one used in the experiments are shown in Figure 3 and Figure 4.

(b)

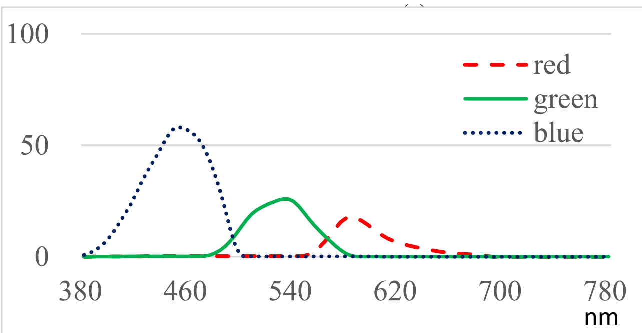


Figure 3. Original camera sensitivity derived from the site [10].

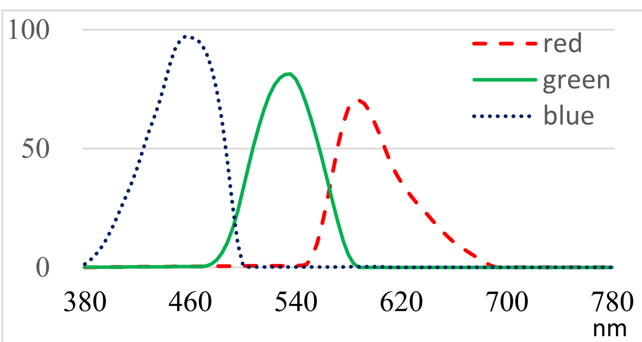
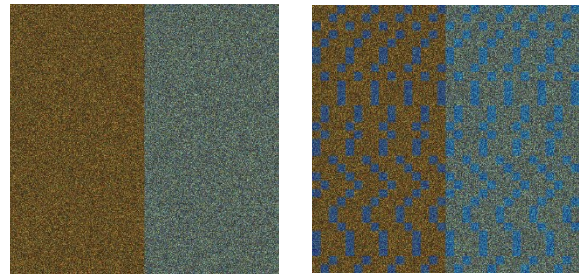


Figure 4. Adjusted camera sensitivity to have the same integral value in each channel.

Generated images which are consist of 512*512 pixels are shown in Figure 5. Image A is generated by selecting surface reflectance randomly from the dataset and two illuminants are illuminated from left (reddish) and right (white), and image B is generated by changing the balance R, G and B. In image A, average color of each small region is set to be gray which means average colors of R, G, and B in each small region are almost the same, however, one fourth of image B is generated by shifting R and B channel by about 20%. In the experiments, size of small region is set to be 16*16 pixels and TH is 15.



(a)ImageA (b) Image B

Figure 5. Images used in the experiments. Image A is consisted by selecting reflectance randomly and the average of small region is set to be gray. Image B is generated using image A and pixel values of R and B channel is shifted by about 20%.A flowchart of the proposed method.

Evaluation of estimation

In the experiments, illuminant colors by three methods are estimated and compared. Three methods are (1) Gray-World based method without clustering, (2) Gray-World based method with clustering, and (3) proposed method.

Estimated illuminants are evaluated by calculating angles of two colors in RGB color space as estimation errors in the following equation (5).

$$\theta = \cos^{-1}\left(\frac{(illum_{est}, illum_{cor})}{|illum_{est}| \cdot |illum_{cor}|}\right) \quad (5)$$

In the above equation, $illum_{est}$ and $illum_{cor}$ are the estimated illuminant color and the correct one and they are used as vectors. (,) is the inner product and | | is the size of vector. When the angle θ is small, it means that the estimated color is close to the correct one.

Results

Estimation error which means the angle of correct illuminant color and estimated one derived by the method (1) through (3) are shown in Table 1. In the table 1, upper number is the estimation error of reddish illuminant while the lower number is that of white one.

Table 1: Estimation errors derived by three methods

	Method (1)	Method (2)	Method (3)
Image A	0.83 1.30	0.82 1.33	0.82 1.32
Image B	12.14 8.75	9.35 0.84	0.84 1.30

According to the image, the results by Method (1) is influenced by the average color of the image. Thus, the estimation error by Method (1) using image B is large. However, by clustering the results estimated by the Gray-World assumption, this effect is removed

Summary

In this paper, illuminant color estimation method for the image under several illuminants based on Gray-World assumption is proposed. The method divides the image into small region and judges the region which satisfies the Gray-World assumption. If the each region satisfies the assumption, illuminant color is estimated in each small region. After that, unifying the results by k-means clustering, final scene illuminants are estimated. Experimental results using simulated image show that proposed method can estimates color of scene illuminants stably rather than that of the conventional one. In the future, another judgement such as PCA will be studied and evaluated by the actual images. Also, in the case where images under three and more illuminants are needed for evaluating the methods.

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Author Biography

Harumi Kawamura received B.S. in mathematics from Tokyo Women's Christian University (1989) and D.S in Global Information and Telecommunication Studies from Waseda University (2014). She joined Nippon Telegraph and Telephone Corp. in 1989, where she has engaged in modeling of color perception, color constancy. She is currently an associate professor at Salesian Polytechnic and a member of the Institute of Electronics, Information and Communication Engineers (IEICE), Information Processing Society of Japan (IPS).