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Multiple Illuminants' Color Estimation using Layered Gray-World Assumption

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Abstract

Illuminant color estimation in an image under multiple illuminations is proposed. In the most conventional methods, the image is divided into small regions and estimated the local illuminant in each region by applying the methods for one illuminant. By unifying the derived local illuminants, scene illuminants are estimated. The methods for one illuminant used in the conventional ones are typically gray-world, white-patch, first-order and second-order gray-edge, and so on. However, these methods are not modified properly. Therefore, they have possibilities for improving in illuminant color estimation. Proposed method is gray-world based and applies to each small region to estimate the local illuminant. There are two features in the methods. The first feature is the selection of the small regions; the method uses criteria for the regions whether they satisfy the gray-world assumption and estimates the local illuminants in the selected small ones. The second one is the use of multi-layered small regions; in general, appropriate size of the small region depends on the image, thus, several-sized small regions corresponding to the resolution are used and unified. Experiment results using Mondrian pattern images under the reddish and white illuminants show that the estimation error by the proposed method is relatively smaller than that by the conventional one.

Introduction

Applications using augmented reality and/or mixed realty are more common in entertainment, educational and medical systems these days. In these systems, actual images and computer graphics are mixed as if they are in a same scene. However, when the scene illuminants in the images and color of illuminant used for generating graphics are different each other, the mixed images look something strange and added graphics look like two-dimensional planes even if they are three-dimensional objects. In this situation, adjusting the colors of illuminants of graphics to that of the actual image makes it possible to be seen in a same scene.

The purpose of my study is to estimate colors of scene illuminants in an actual image. There are several methods for estimating color of scene illuminants in an image. Most of them are focusing on the scenes where the color of the illuminant is same throughout the scene. However they are not always the case. For example, in the window side room, the scene is illuminated by the fluorescent light inside room and also sunlight coming through the window. In this case, the colors of the scene illuminants change depending on location to location in the scene.

These days, methods of estimating colors of multiple illuminants are under study. These methods are divided into two categories; one is learning based [1][2] and another uses the conventional methods for one illuminant because these methods hypothesis that the color of scene illuminant in a small area is limited to only one and also constant [3]-[6]. That's why the conventional methods for one illuminant are applied for small region in the image under multiple illuminants. The methods used there are gray-world [7], white-patch [8] and first-order and second-order gray-edge [9] and so on. However these methods are typical one and not adjusted to improve one. If these methods are improved, it is thought that the total results would be better.

Among these conventional methods, gray-world based method is picked up because the algorithm is simple and easy to implement. However, there are some problems to apply this method to an image. The first problem is that when the image or the small region doesn't satisfy the gray-world assumption, the estimated colors are far from the correct one. The second one is that the image or the region is applicable for the gray-world based method is unknown because colors in the image include colors of scene illuminants and color of object. In my recent study, the method for estimating colors of multiple illuminants in an image by applying gray-world assumption is proposed. In the method, the small regions which are judged to satisfy the gray-world assumption are used. However, the estimation derived in each small region varies depending on the small region size. Therefore, the purpose of this study is to propose a new method to solve the above problem. The proposed method divides an image into small regions but the size is not fixed. Local illuminants derived from the several sizes of small region are unified as the final estimation.

There are two features in the proposed method; First one is that the method uses the small regions which are judged to satisfy the gray-world assumption and the second one is that several sizes of small regions are used for the local illuminant color estimation.

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 mentioned above, the proposed method uses local illuminant color estimation from several sizes' small regions. Figure 1 illustrates the outline of the method proposed here. In the method, local illuminant is estimated for each small region of several sizes which is judged to satisfy the gray-world assumption. By clustering the local estimation derived in the same size's small region, two kinds of illuminant colors are estimated for each image which has different small region. Final estimation is derived by unifying the clustering results. There are five steps; at first, an image is divided into small regions of several sizes, and secondly, each small region is judged whether the region satisfies the gray-world assumption or not. After that, local illuminants are estimated using the small regions which are judged as those which satisfy the above assumption. By clustering the local estimates, two illuminants are derived for each divided image. Lastly, colors of scene illuminants are estimated by calculating as the average color of clusters and unified by averaging the corresponding clusters. Each procedure is explained in detail in the following.

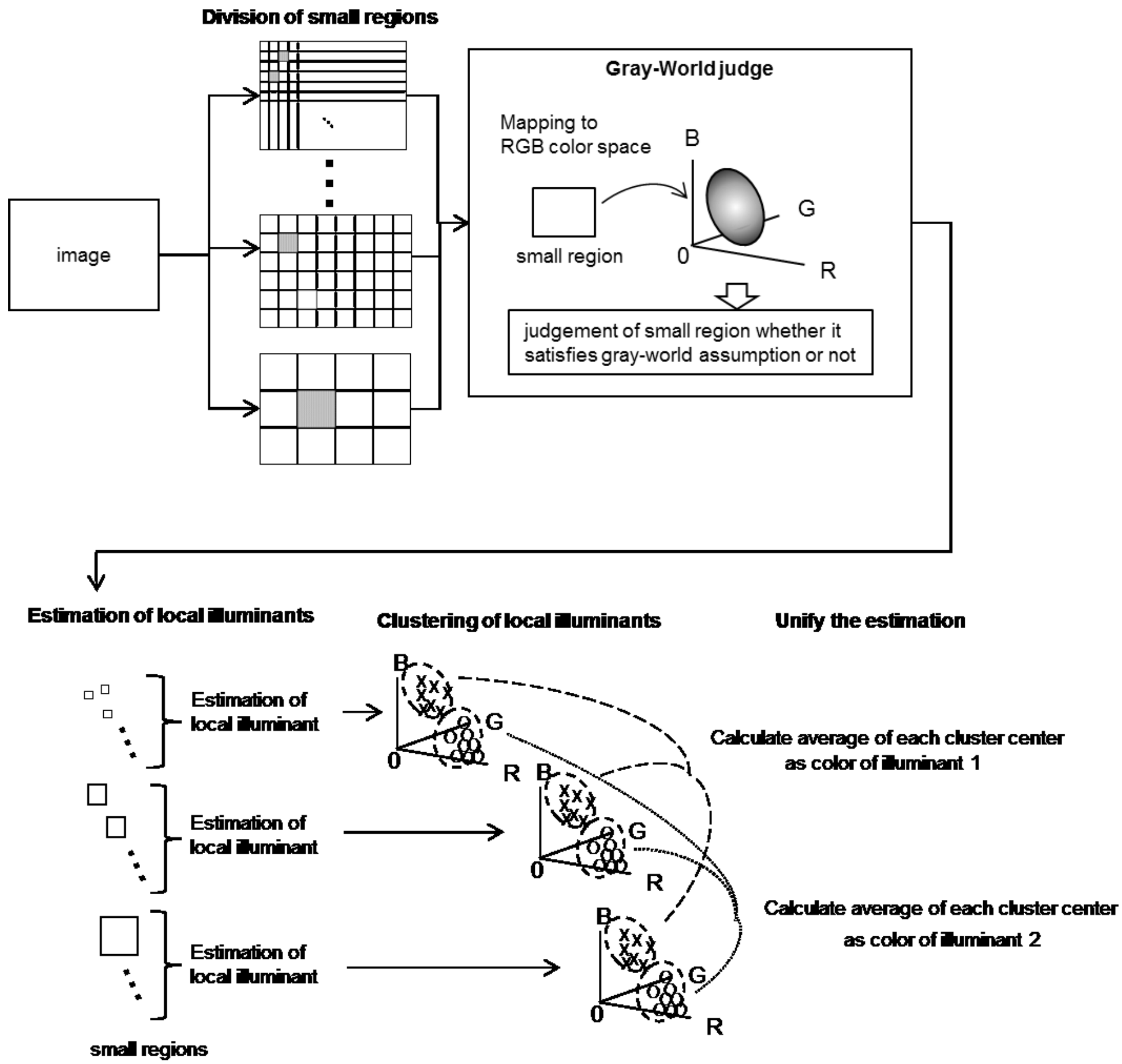

Figure 1. Outline of the proposed method

Division of small regions

Input image is divided into same size of small regions. In the method, size of small region is not only one. Several sizes of small regions are derived in an image shown in Fig. 1.

Judgement of gray-word assumption

As mentioned above, gray-world based method uses the hypothesis that the average color of all the objects in the image is gray, which means that the image includes variety of colors. In order to apply the gray-world based method for the small regions, the regions are needed to satisfy the above hypothesis. However, all small regions don't always include variety of colors in general. Therefore it needs to select the regions which satisfy the gray-world assumption.

In the proposed method, standard deviation is used as criteria to judge whether the regions satisfy the gray-world assumption. As the reason of this, property that the standard deviation becomes large when the region includes variety of colors is used here. In the proposed method, when the standard deviation "stdev" of two or three color channels c in a small region is larger than threshold TH, the region is judged as those which satisfy the above assumption.

$$stdev_c \geq TH \quad (1)$$

The reason that the standard deviation of two or three color channels are used is the following properties; in case where two or three color channels' standard deviation is large, the color distribution of the small region is spanned like a plane or a sphere in RGB color space. This plane- or sphere- like distribution in the color space means that there is variety of colors in the region. Whereas in case where only one color channel's standard deviation is large, color distribution of the region is like a line in the color space shown in Figure 2.

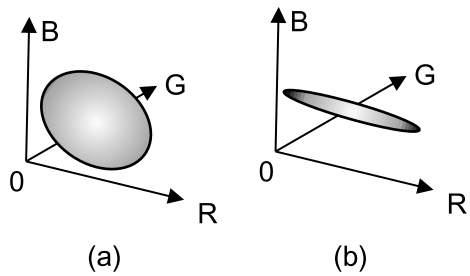

Figure 2. Color distribution. (A) shows the case where two color channels' standard deviation are large and (b) shows the case where only one color channel's standard deviation is large.

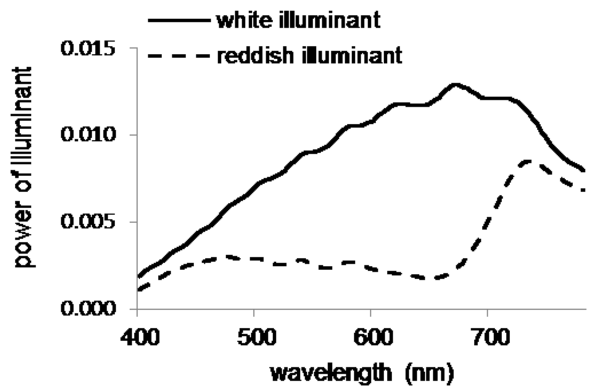

Figure 3. Spectral power distribution of the illuminants used in the experiments. Solid and broken lines represent white and reddish illuminant respectively.

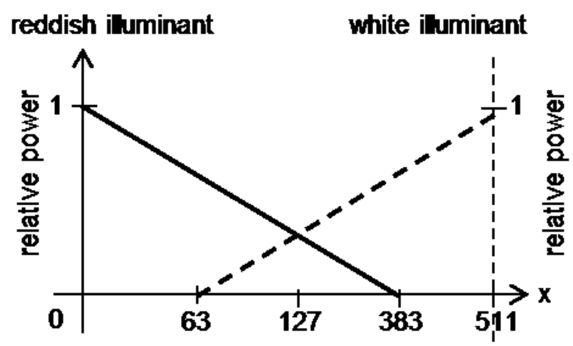

Figure 4. Spatial distribution of two illuminants. The abscissa of the above graph is the horizontal location of the image and the ordinate represents the relative power of each illuminant. The power of both illuminants varies linearly depending on the distance to right or left edge.

Estimation of local illuminants

Color of the local illuminant is estimated for the small region which is judged to satisfy the gray-world assumption by the former step. In the gray-world based method, average color of the image/region is regarded as color of illuminant. Therefore the local illuminant color is derived by calculating the average of the small region. This step is applied for all images of different small region size.

Clustering of local illuminants

In the method, scene illuminants in the image are set to be two. Thus the derived local illuminants from the small regions are divided into two clusters by k-means clustering.

Unify the estimation

According to the last step, colors of the scene illuminants are estimated from each image which has different small region size each other. Averaging the each color derived in each image, final estimation is derived.

Experiments

Experimental setting

In the experiments, Mondrian images are used. Color of each Mondrian patch is calculated using surface reflectance $\rho(\lambda)$, spectral distribution of illuminants $E(\lambda)$ and camera sensitivity $S_C(\lambda)$ where c shows color channels R, G, or B followed by equation (2). P_c shows the value in each color channels.

$$P_C = \int S_C(\lambda) \cdot E(\lambda) \cdot \rho(\lambda) d\lambda \tag{2}$$

Surface reflectance, spectral distribution of illuminants and camera sensitivity are downloaded from the site [10]. In this site, a lot of data for evaluating color constancy algorithm are arranged. Using these data, 1024 surface reflectance are randomly selected from over 10,000 reflectance dataset.

Two illuminants, which are also downloaded from the site, are selected from the dataset. They are Solux's lamp whose color temperature is 3500 K as reddish illuminant and filtered lamp to change to have higher color temperature as white illuminants. The Mondrian image is simulated by irradiating to the Mondrian pattern from left and right respectively. The spectral distribution of these two illuminants and spatial distribution in the image are shown in Figure 3 and Figure 4. In Fig.3, solid line represents spectral power distribution of white and broken line corresponds to that of reddish illuminant. In Fig.4**,** Two illuminants' strength varies lineally depending on the horizontal location which means the distance to the right or left edge in the image. Camera sensitivity used here is arranged from the original one in the site because the original data has a kind of properties that blue sensitivity is relatively high compared to that of red and green. Thus the sensitivity of red and green is adjusted to have the same amount of that in blue sensitivity.

The image used in the experiment is shown in Figure 5. Color in each Mondrian patch is randomly selected from the dataset as mentioned above, thus the average color of the Mondrian patches is similar to gray. Furthermore, color-biased images are added in the experiments. Color-biased images are generated by adding value to a certain color component. For example, red-biased image is generated by adding a certain value to R channel's to the original image. In this way, green-biased, blue-biased, cyan-biased, magenta-biased, and yellow-biased images are generated. Figure 6 represents the whole images added to the image in Fig.5. They are generated by adding value to one or two color channels. In Fig.6, (a) red-biased, (b) green-biased (c) blue-biased, (d) cyan-biased, (e) magenta-biased and (f) yellow-biased images are shown.

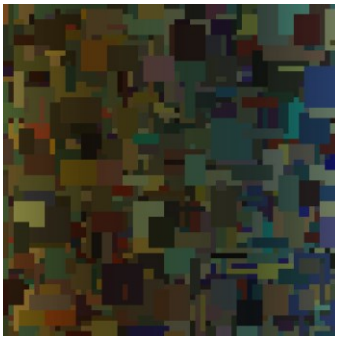

Figure 5. Image used in the experiment. Mondrian image is simulated to be irradiated under reddish and white illuminant from left and right side respectively.

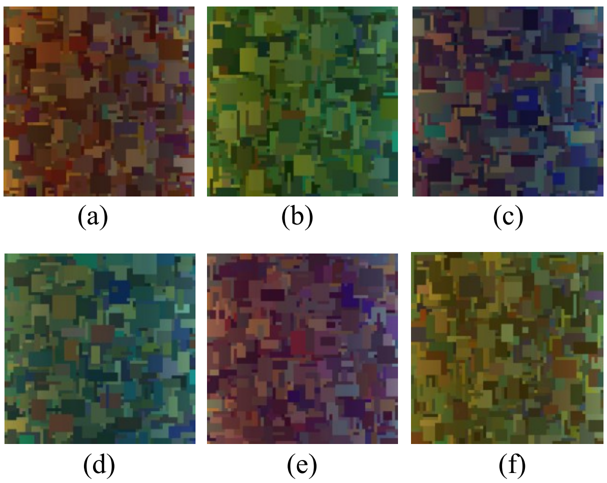

Figure 6. Color-biased Images used in the experiment. (A) red-biased, (b) green-biased, (c) blue-biased, (d) cyan-biased, (e) magenta-biased, and (f) yellow-biased images are shown. Totally seven images including image in Fig.5 are used.

Image size is 512*512 pixels and size variation of small regions is 8*8, 16*16, 32*32, 64*64, 128*128 and 256*256. Threshold to judge the gray-world assumption using the standard deviation expressed as "TH" in equation (1) set to be 25 in the experiment. When generating color-biased images, 30 pixel values are added to the corresponding color channel.

Evaluation

In the experiments, estimation error of scene illuminants by the proposed method is evaluated as an angle between estimated color and the correct one which is calculated using the data in the site. The angle θ is calculated followed by the equation (3) where $illum_{est}$ and $illum_{cor}$ are estimated color and correct illuminant color respectively. In the equation, parenthesis represents the inner product and | | shows the absolute value.

$$\theta = \cos^{-1}\left(\frac{(illum_{est}, illum_{cor})}{|illum_{est}|\cdot|illum_{cor}|}\right) \qquad (3)$$

In order to verify the proposed method, the gray-world based method is applied and compared to the proposed one using the above equation.

Experimental results

Experimental results evaluated by the angle between the estimated color and the correct one are shown in Table 1 and Table 2. Table 1 represents the results of "white" illuminant which irradiates form the right side to the Mondrian pattern while Table 2 represents that of "reddish" illuminant. Base image represents the one in Fig.5 and the numbers in the "color-biased image" row show the average angle derived by applying the six images shown in Fig.6. Numbers in "Average" row shows the average angle derived by seven images. "Conventional method" in Table 1 and Table 2 shows the gray-world based method.

According to Table 1 and Table 2, average angle derived by the proposed method is comparatively smaller than that of the conventional method.

Table 1: Estimation of "white" illuminant. Each number in the table represents the angle of estimated color and the correct one followed by equation (3).

Image	Conventional method	Proposed method
Base image	1.74	0.65
Color-biased image	14.8	11.2
Average	12.9	9.7

Table 2: Estimation of "reddish" illuminant. Each number in the table represents the angle of estimated color and the correct one followed by equation (3).

Image	Conventional method	Proposed method
Base image	1.13	4.3
Color-biased image	14.8	10.4
Average	12.8	9.5

Summary

In this paper, illuminant color estimation method based on gray-world assumption using local illuminant derived from several size of small region. Firstly an image is divided into the same size of small regions with several sizes. Next, local illuminants are estimated in the small regions which are judged to satisfy the gray-world assumption. In this judgement, standard deviation of the small region is used. By clustering the local illuminants in each image with different small region size, two illuminant colors are estimated. After that, colors of scene illuminants in an image are finally estimated by averaging the colors of the scene illuminants using the clustering results. Experimental results show that the angle derived by the proposed method is relatively smaller than that of the conventional one.

However angles derived for the color-biased images by the proposed method is still not so small. The reason is that the local estimation depends on the selection of small regions which are derived by the judgement of gray-world assumption. Therefore appropriate threshold used for the above judgement should be considered and another ways to judge are also considered in the future. Furthermore, another Mondrian pattern image and actual images are applied and evaluated in the future.

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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 and 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).

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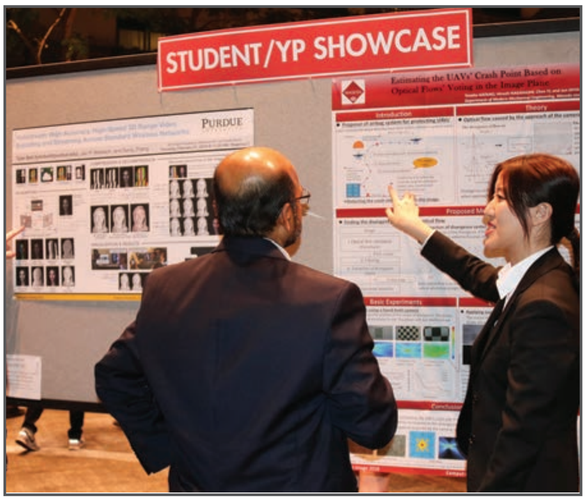

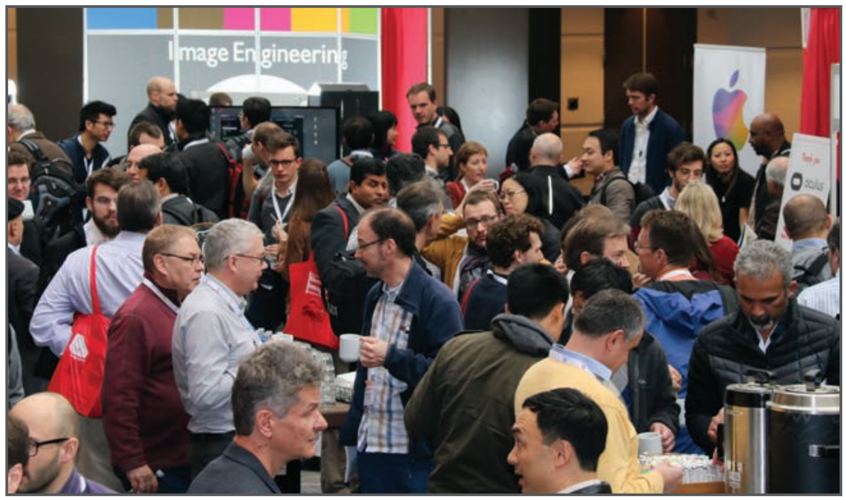

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