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Chromaticity-matched Superimposition of Foreground Objects in Different Environments

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Abstract—**The illumination chromaticity is one of the important factor for appearance of objects in images. When we superimpose some objects on another scene to generate composite images, the resulting image may give us strangeness if the illumination chromaticity of foreground scene and background scene are different. In this paper, we propose a composite image synthesis method which can achieve illumination chromaticity consistency. Our goal is to generate a illumination chromaticity-matched composite image from two images which are taken under different illumination environment. We estimate chromaticity of two scenes based on segmented color regions. Subsequently illumination chromaticity matching is performed based on estimated chromaticity of two scenes. After the chromaticity matching process, we extract the target person by using the grab cut segmentation. The result image is obtained by superimposing the target person or object onto background scene. We demonstrate that our method can perform some different illumination chromaticity environment.**

I. Introduction

Making a composite image is an important functionality of image editing for entertainment experiences. Typical application is superimposing a person into a different image that captures different scene. However, we may feel something is strange if the illumination color of two scenes are different. Illumination chromaticity is one of the most essential factor that decides how a person in a image looks like. Therefore, we should achieve the consistency of illumination chromaticity of a foreground object and a background scene when we make composite images.

Some illumination chromaticity estimation methods based on the assumption of "Dichromatic Reflection Model" as reflectance property of the target scene. have been proposed. The dichromatic reflection model represents surface reflectance as a combination of an object color by diffuse reflection and a illumination color by specular reflection. We can assume that a most of everyday things, such as things made of plastic, usually have specular reflection, but there are some exception such as general clothing with low specular reflection.

The dichromatic reflection model is widely used as the model which can approximate surface reflectance of general things. This model was proposed by Shafer et al. [1]. Klinker et al. showed that it is possible to apply the dichromatic reflection model to real scenes and to determine the illumination color from the model [2]. Lehmann et al. proposed a method that applied the two-dimensional dichromatic reflection model to the regions around the specular highlights in a color image, and estimated the illumination chromaticity [3]. Finlayson et al proposed illumination chromaticity estimation method using the black-body radiator in two-dimensional space. [4]. Tajima showed the illumination chromaticity estimation using the two dimentional dichromatic reflection model with imperfect image segmentation [6]. Tajima also showed that the two dimentional dichromatic reflection model can be applied to apparently lambertian surface with multiple colors.

In this paper, we propose a composite image synthesis method which can achieve illumination chromaticity consistency. Our goal is to generate a illumination chromaticity-matched composite image from two images which are taken under different environment. We estimate illumination chromaticity of two scenes from multiply segmented region which have different colors. The illumination chromaticity estimation is based on the method proposed by Tajima [6]. Subsequently illumination chromaticity matching is performed based on estimated chromaticity of two scenes. After the chromaticity matching process, we extract the target person or object region by using the grab cut segmentation algorithm. Finally, the result image is obtained by superimposing the target person or object onto background scene.

II. Proposed method

Our goal is to achieve illumination chromaticity consistency on composite images from two images which are taken under different environment. At first, illumination chromaticity of input images are estimated from multiple color segmented region. This process is based on the work proposed by Tajima [6]. We estimate illumination chromaticity from a color image consists from multiple color. The input color images are segmented into multiple region and estimate illumination chromaticity on each input image. After the illumination chromaticity estimation process, we adjust the chromaticity of the scene which has a target person or object to be superimposed. Subsequently, the region of target person or object is subtracted based on the grab cut segmentation. Finally, the target person or object is superimposed on background scene.

A. Illumination Chromaticity Estimation

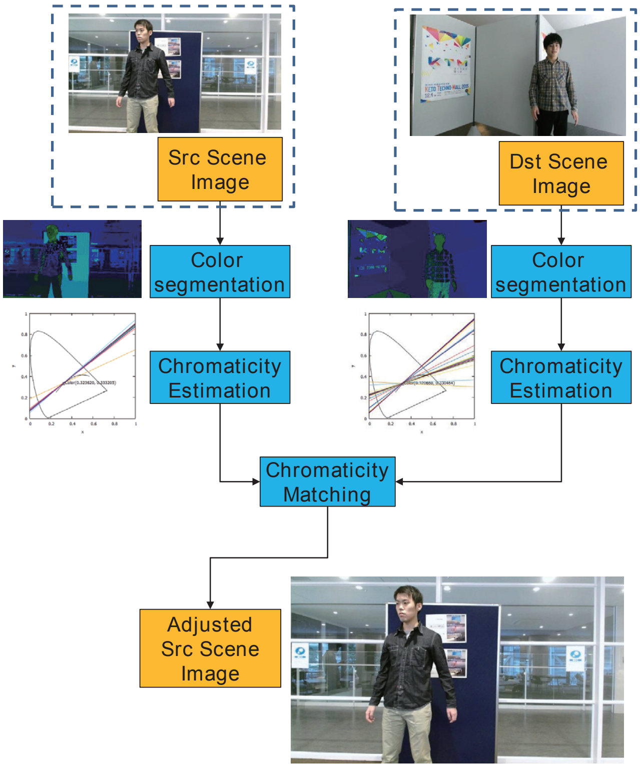


Fig. 1. Target region extraction and superimposition

Before the explanation of illumination chromaticity estimation, we define the name of the input scene. Src scene is the scene which has the object to be superimposed. Dst scene is the scene to be the background of the composite image. Our chromaticity estimation part is based on a method by Tajima [6].

At first, the input color images are converted from RGB color space into HSV color space. The color segmentation is done in five dimensional space: hue, saturation and value from HSV color space and x, y from color image coordinate. Each of these five properties has different value range so each property is weighted to get appropriate segmentation result. The important point is that objects having the same color and consisting from the same material should be divided into the same region because the illumination chromaticity estimation is based on this assumption.

(a) (b)

Fig. 2. (a) Input image for color segmentation (b) the result of color segmentation

After the color segmentation, we estimate illumination chromaticity. We assume that illumination chromaticity is constant throughout the input image and illumination intensity is not taken into account. First, we convert the input color image from RGB color space to CIE-XYZ color space to obtain each value (X, Y, Z). Subsequently we calculate the chromaticity by using the following equation.

$$x = \frac{X}{X+Y+Z}, \quad y = \frac{Y}{X+Y+Z} \tag{1}$$

Since we have obtained chromaticity values on each point, we plot the clustered points (x, y) which are assigned in each segmented region on the CIE-xy chromaticity diagram. The principal component analysis (PCA) algorithm is applied to each clusters and obtain the first principal component and the centroid. Illumination chromaticity is assumed to lie on the line which corresponds the direction of first principal component and the centroid of the cluster. The chromaticity lines can be expressed as shown in Equation (2).

$$a_j y + b_j x = c_j \tag{2}$$

$a_j b_j c_j$ are the coefficients of the jth chromaticity line. So we can estimate the illumination chromaticity from an intersection of all lines.

However, all lines do not always intersect each other at a single point. Therefore, we estimate the point (x_l, y_l) that minimizes the distance between all lines and point (x_l, y_l) by using the least square method. We can express Equation (2) in a matrix system as shown in Equation (3)

$$\boldsymbol{A} = \begin{bmatrix} a_1 & b_1 \\ a_2 & b_2 \\ \vdots & \vdots \\ a_n & b_n \end{bmatrix}, \boldsymbol{x} = \begin{bmatrix} x \\ y \end{bmatrix}, \boldsymbol{c} = \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_n \end{bmatrix} \tag{3}$$

We minimize the error $|\boldsymbol{A}\boldsymbol{x} - \boldsymbol{c}|^2$ and obtain (x_l, y_l).

After that, (x_l, y_l) is constrained to the curve of the black-body radiator. Natural light sources such as sunlight or light from light bulbs can be approximated by the black-body radiator. The power spectrum $E(\lambda, T)$ of the black-body radiator can be shown by Equation (4)

$$E(\lambda, T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{kT\lambda}} - 1} \tag{4}$$

T is the temperature of the black-body in Kelvin. h is the planck constant and k is the Boltzmann constant. c shows the speed of light. We project the curve of the black-body radiator(Equation (4)) onto CIE-xy chromaticity diagram and obtain the quadratic function [7].

Since we have a point (x_l, y_l) which minimizes the distance between all lines, the final result of illumination chromaticity (x_c, y_c) can be obtained by estimating the nearest point on the black-body radiator curve from (x_l, y_l). This illumination chromaticity estimation process is done on both the foreground scene and the background scene.

B. Chromaticity Adjustment

We have estimated the illumination chromaticity as described in the section II-A. The purpose of this section is to achieve the chromaticity consistency between the src scene image and the dst scene image. The illumination chromaticity (x_c, y_c) that we have estimated are normalized values. z_c can be obtained easily from (x_c, y_c) and Equation (5)

$$x_c + y_c + z_c = 1 \tag{5}$$

Here we can get chromaticity of src scene $(x_c^{src}, y_c^{src}, z_c^{src})$ and dst scene $(x_c^{dst}, y_c^{dst}, z_c^{dst})$. Then, the chromaticity of src scene is adjusted to match the chromaticity of dst scene by the ratio of the chromaticity shown in Equation (6).

$$\begin{bmatrix} Ix_{out}(\boldsymbol{p}) \\ Iy_{out}(\boldsymbol{p}) \\ Iz_{out}(\boldsymbol{p}) \end{bmatrix} = \begin{bmatrix} \frac{x_c^{dst}}{x_c^{src}} & 0 & 0 \\ 0 & \frac{y_c^{dst}}{y_c^{src}} & 0 \\ 0 & 0 & \frac{z_c^{dst}}{z_c^{src}} \end{bmatrix} \begin{bmatrix} Ix_{in}(\boldsymbol{p}) \\ Iy_{in}(\boldsymbol{p}) \\ Iz_{in}(\boldsymbol{p}) \end{bmatrix} \tag{6}$$

$(Ix_{in}(\boldsymbol{p}), Iy_{in}(\boldsymbol{p}), Iz_{in}(\boldsymbol{p}))$ indicate input pixel values which converted to CIE-XYZ color space at a point $\boldsymbol{p}$ and $(Ix_{out}(\boldsymbol{p}), Iy_{out}(\boldsymbol{p}), Iz_{out}(\boldsymbol{p}))$ shows output pixel values respectively. This processing is applied to all pixels of the input image.

Note that $(x_c^{src}, y_c^{src}, z_c^{src})$ and $(x_c^{dst}, y_c^{dst}, z_c^{dst})$ are normalized values. This means that it shows the ratio of (X, Y, Z) values. Therefore, we don't take into account the difference of the illumination intensity(brightness) on src scene and dst scene. The input image and adjusted image are shown in Figure II-B.

(a) (b)

Fig. 3. (a) Src scene before chromaticity adjustment. (b) After chromaticity adjustment.

C. Target Region Extraction and Superimposition

We have obtained adjusted color image of src scene. In this section, we introduce the target region extraction and superimposition on dst scene. In our method, we use the grab cut segmentation algorithm [8] to extract the target region. Firstly, a target region is selected with a rectangular and the first iteration is performed subsequently. If there are some redundant regions or regions which are needed but removed in the first iteration result, users can touch up the segmented result. Users can set four tags: definitely foreground, definitely background, probably foreground and probably background. After the tagging, the second iteration is performed. This iterative process is performed until the extraction result is appropriate. An input image, the first iteration result, the tagged image and the final extracted result image are shown in Figure 5.

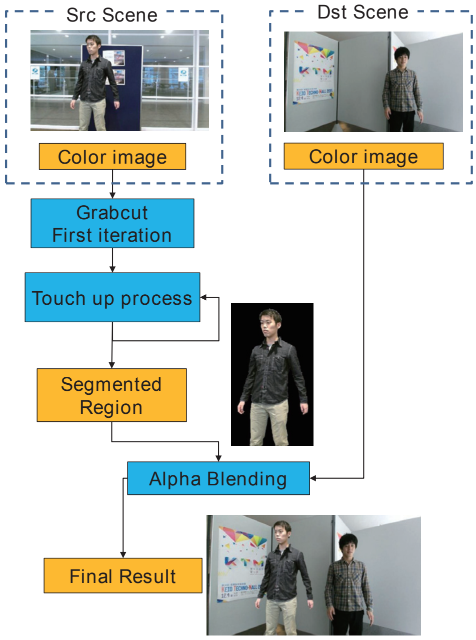
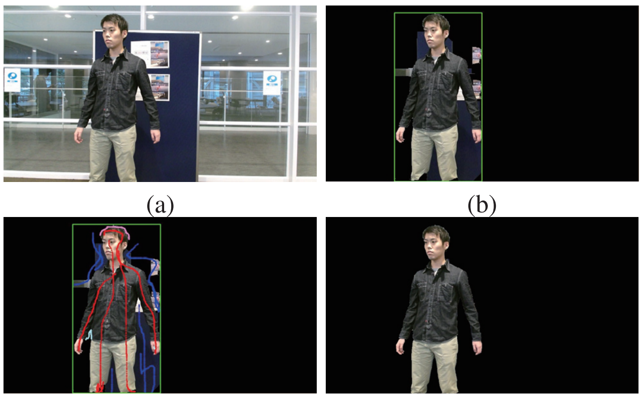


Fig. 4. Target region extraction and superimposition



(a) (b)

(c) (d)

Fig. 5. (a) Input image (b) After the first iteration of grab cut segmentation (c) user input of touch up process (d) final segmentation result

Our goal is to make composite images so the boundary of the target object and background scene is very important. We apply the alpha blending around the boundary of the object when the target object is superimposed on dst scene. We consider the illumination chromaticity consisntency only and don't take care of geometrical consistency in our method.

III. Experiments

In this section, we present experiments performed to demonstrate the effectiveness of the proposed method. We capture an image of a person standing in arbitrary illumination environment. Illumination chromaticity of the scene is unknown in this case. We estimate illumination chromaticity of Src scene and Dst scene, and adjust the Src scene's chromaticity to fit to Dst scene. Finally, we get the final result by superposing the person to the background images.

A. Experiment condition

We captured a person under slightly amber illumination for src scene. Dst scene is the other place and consists from slightly bluish illumination for "Pattern 1", as shown in Figure 6. For "Pattern 2", src scene is captured in indoor scene which has fluorescent lamps. Dst scene is the same scene as src scene of "Pattern 1", which has slightly amber illumination as shown in Figure 7.

(a) (b)

Fig. 6. Input images for experiment 1. (a) Src scene (b) Dst scene

(a) (b)

Fig. 7. Input images for experiment 2. (a) Src scene (b) Dst scene

Illumination chromaticity is estimated by using each segmented region including not only human region, but also background area. The number of segmented region for chromaticity estimation is 48, and regions whose size is less than 1000 pixels is excluded in the illumination chromaticity estimation. Since we don't consider the illumination intensity matching, the brightness of src scene is adjusted manually.

B. Experiment result

The result images of "Pattern 1" are shown in Figure 8. Illumination chromaticity for a man standing on the left side and that of background scene is different in "result without chromaticity adjustment" (Figure 8(b)) comparing to the "ground truth" which shows the target person actually standing in dst scene. Applying our method, the final result achieved illumination chromaticity consistency between a superimposed and background scene. Focusing on a pants of the superimposed person, we can say that the chromaticity matching process is done correctly. As shown in Figure 8(d) and (e), each line is obtained from pixel values from each segmented area. They show us that we could estimate the chromaticity from multiple region which labeled as different color region.

The result for "Pattern 2" are shown in Figure 9. Illumination chromaticity of Src scene is estimated as white and that of Dst scene is estimated as a little amber, as shown in Figure 9(d), (e) and (f). Comparing Figure 9(a), (b) and (c), our method could estimate and match the chromaticity and generate a composite image with illumination chromaticity consistency.

IV. Conclusion

In this paper, we proposed a composite image synthesis method which can achieve illumination chromaticity consistency. Illumination chromaticity of two scenes were estimated from multiple segmented regions with different colors. Using multiple color regions, the illumination chromaticity can be estimated even without rich specular reflection.

Subsequently illumination chromaticity matching was performed based on estimated chromaticity of two scenes. After the chromaticity matching process, we segment the target person or object on the grab cut segmentation algorithm. Finally, the result image is obtained by superimposing the target person or object onto background scene. In experiment, we tested our method to show the utility and quantitative evaluation.

The future work are the quantitative evaluation and making our method more robust and applying our method to light sources which drastically stay off the black body radiator.

References

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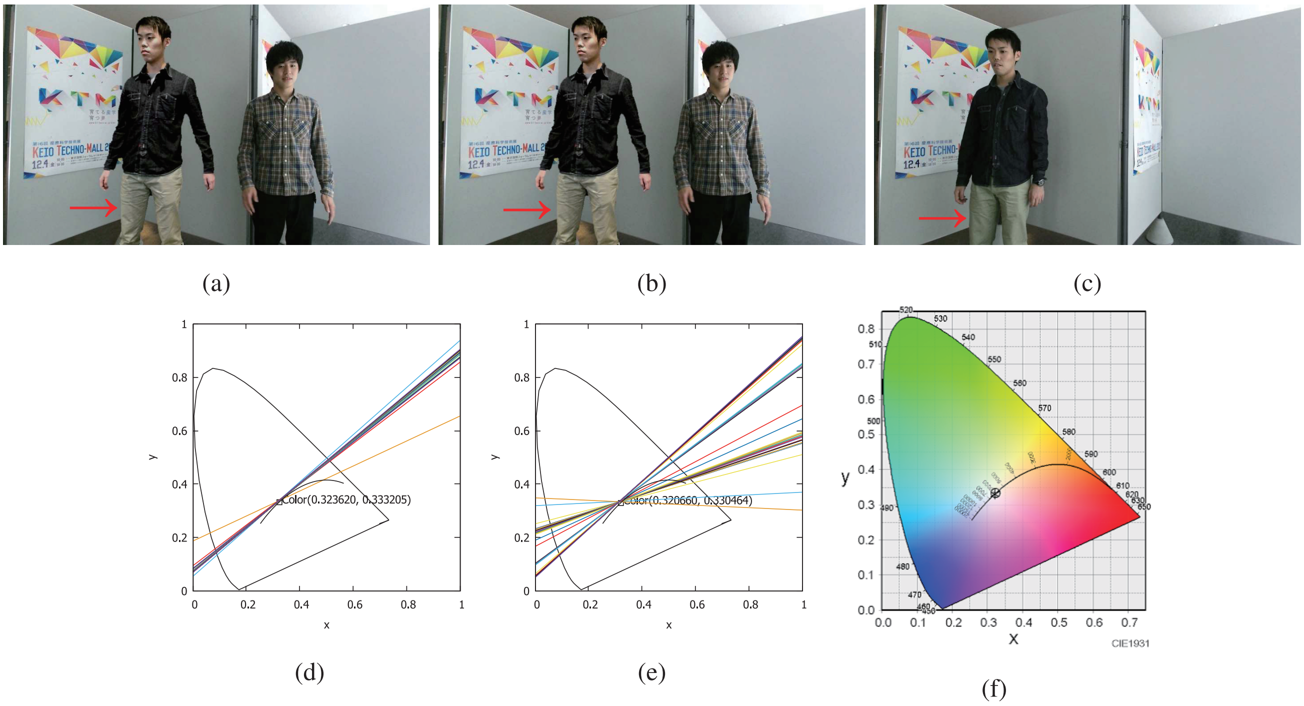

Fig. 8. Results for experiment 1. (a) Result image (b) Result without chromaticity adjustment (c) Ground truth (d) Estimated chromaticity on Src scene (e) Estimated chromaticity on Dst scene (f) Chromaticity matching, a circle for src chromaticity and an asterisk for dst chromaticity

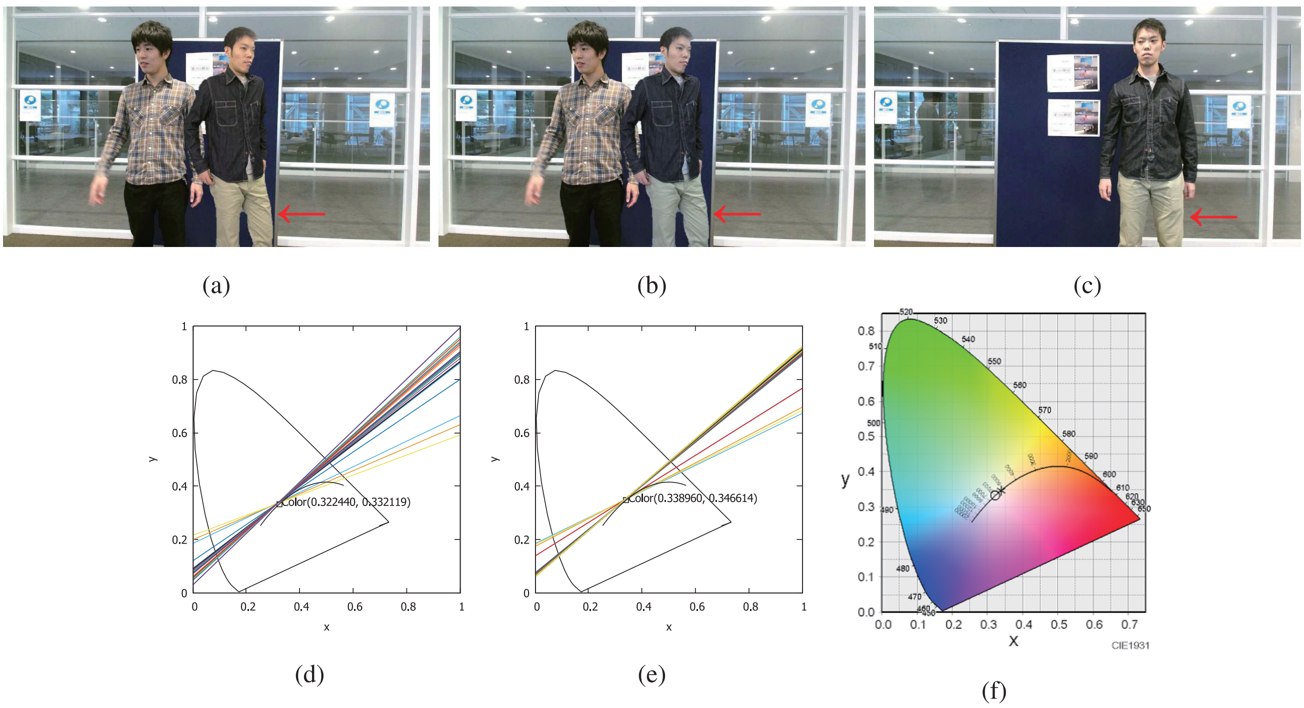

Fig. 9. Results for experiment 1. (a) Result image (b) Result without chromaticity adjustment (c) Ground truth (d) Estimated chromaticity on Src scene (e) Estimated chromaticity on Dst scene (f) Chromaticity matching, a circle for src chromaticity and an asterisk for dst chromaticity