# Estimation of Illuminant Spectral Distribution with Geometrical Information from Spectral Image

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**Abstract**

In this paper, we propose a method for estimation of illuminant spectral distribution using geometrical information. To realize color constancy, it is important to separate the illuminant light color from the reflected light. The light reflected from an object consists of the surface reflection component that is equal to the light-source color, and the body reflection that corresponds the object color. Their intensities vary depending upon the light source, the camera, and the object's geometrical shape information. We estimate the illuminant spectral distribution based on the difference between these intencities, and show effectiveness of this method by experiments.

## 1. Introduction

We can properly perceive color of an object in spite of changing light conditions. This faculty is called color constancy, and is useful in image segmentation, and other engineering fields. To realize it in computer vision, it is necessary to extract the original object color after separating illuminant light color from an image. S. Tominaga[1] estimated light source color using highlight area information of light reflected from two difference-colored objects. In this research, weight coefficients related to geometrical information are used instead of the color vector in the dichromatic reflection model. We try to estimate the illuminate spectral distribution of a single colored object[2].

## 2. Estimation using the object's geometry information

In this research, we use Shafer's dichromatic reflection model[3]. In this model, the reflected light from an object surface is written as the sum of the surface reflection, which determines the highlight, and the body reflection, which determines the object color. (Equ. 1)

$$L(\lambda,i,e,g) = m_i(i,e,g)C_i(\lambda) + m_b(i,e,g)C_b(\lambda) \quad (1)$$

where $\lambda$ is the wavelength of the light, i is the incident angle, e is the reflection angle, g is the phase angle, $C_i(\lambda)$ and $C_b(\lambda)$ are the surface and body reflection components, and $m_i$ and $m_b$ are the weights of the surface and body reflection components respectively. Since the color of surface reflection is the same color as the light source, let $C_s$ be the light source spectrum, we have

$$C_i(\lambda) = m_s(i,e,g)C_s(\lambda) \quad (2)$$

where $m_s$ is the weight coefficient. The body reflection is the product of the light source color and the reflection spectrum of the object $C_{bo}(\lambda)$, and it can be considered as perfect diffuse reflection. Letting $R_b$ be the reflectance of the object, we have

$$m_b(i,e,g)C_b(\lambda) = R_b\cos(i)C_{bo}(\lambda)C_s(\lambda) \quad (3)$$

where $R_b$, $C_{bo}(\lambda)$ and $C_s(\lambda)$ are the constant.

Supposing that the viewing direction is the same direction as the light source, the reflected light (the surface reflection $L_i$ and body reflection $L_b$) is the strongest when the light shines on the object perpendicularly. The surface and body reflection components become weaker, as the incident angle increases. When the incident angle exceeds a specific angle, the surface reflection component becomes 0, at which time, the reflected light will only be accounted for by the body reflection component (Fig.1).

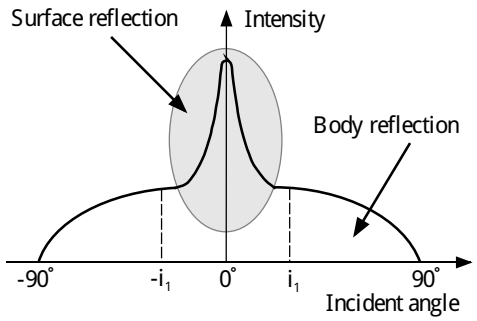



Fig. 1 Intensity Change by Incident Angle

Therefore, let the observed spectrum be $L_1$ when the incident angle is $i_1$. The observed reflected light will only be composed of the body reflection component.

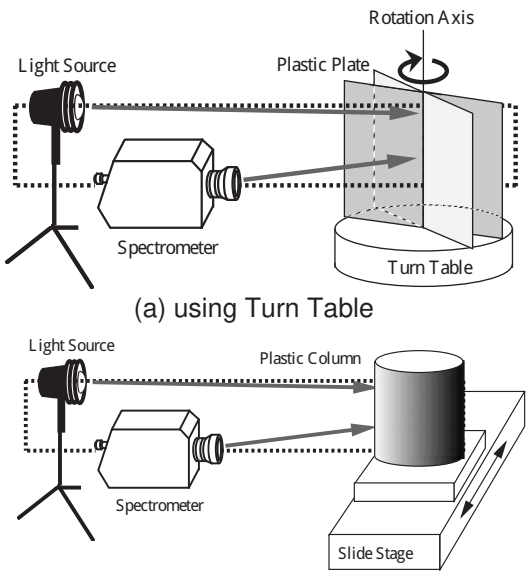
$$m_i(i,e,g)C_s(\lambda) = L(\lambda,i,e,g) - L_1\cos(i) / \cos(i_1) \qquad (4)$$

Thereby, we can estimate the light source spectrum.

## 3. Experiments

### 3.1 Preliminary Experiments

To show the effectiveness of our method, we make some experiments. The geometry information, like the incident and reflection angle, is obtained from a rotating plane controlled by a turn-table (Fig.2(a)) and from a sliding column controlled by a slide stage (Fig.2(b)). In the experiment, a turn-table is turned at 3.6 deg/step and a slide stage is moved at 3.5 mm/step for the incident angle between -90 and 90 degrees. In measurement of the reflected light spectrum, we use a spectrometer which records at 5nm intervals for the wavelength between 380nm and 760nm. Also, as the light source, we use a three-band fluorescent lamp, and colored electric bulbs (blue, green, yellow). As test objects, we use opaque glossy non-metal plastic (red, yellow, green, blue) and glossy paper (red, yellow, green, blue) . As shown in section 2, we can obtain the body reflection component at specific incident and reflection angles where the surface reflection component vanishes. Therefore, it is possible to estimate the surface reflection component, that is the spectral distribution of the light source. However, due to irregularity in the texture or surface processing of the object, it is difficult to correctly compute the angle where the surface reflection component vanishes. In this experiment, we take the angle i1 to be slightly larger than the angle where the surface reflection component vanishes. For those measurements where the incident angles are larger than this angle, we use the least square's method to perform the fitting of cos(i), and to compute the magnitude of the body reflection component.



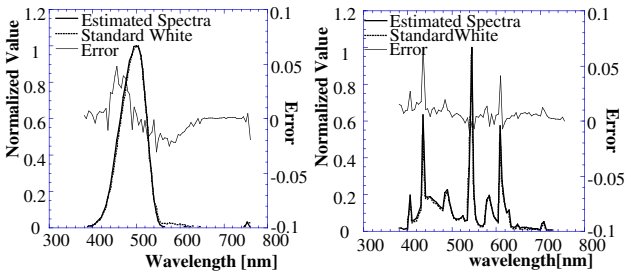

(a) using Turn Table

(b) using Slide Stage

Fig. 2 Measurement Systems

### 3.2. Estimation Results of Preliminary Experiments

Fig. 3 show two experiment results. (a) shows the result obtained with the blue colored electric bulb when using the yellow plastic plate as the object, and (b) shows the result using the three-band fluorescent lamp and the red plastic plate with the turn table. In each figure, solid lines indicate the estimated result, while dotted lines show the measured spectrum of the light source with reference standard white object. Both spectrum are normalized such that 1.0 is the maximum. Thicker lines indicate the difference between the




(a) Blue clored electric bulb
Yellow plastic

(b) Fluorescent light
Red plastic

Fig.3 Estimated Spectral Distribution using Turn Table

Table 1 Results of Preliminary Experiments

| Objects | | | light source: Colored electric bulb blue | green | yellow | three-band fluorescent light |
|---|---|---|---|---|---|---|
| plastic | blue | plane | 0.123 | 0.023 | 0.016 | 0.024 |
| | | column | ------ | 0.006 | 0.007 | 0.013 |
| | green | plane | 0.008 | 0.105 | 0.005 | 0.018 |
| | | column | 0.020 | ------ | 0.022 | 0.011 |
| | yellow | plane | 0.004 | 0.010 | 0.009 | 0.019 |
| | | column | 0.014 | 0.018 | ------ | 0.013 |
| | red | plane | 0.008 | 0.007 | 0.001 | 0.020 |
| | | column | 0.026 | 0.013 | 0.005 | 0.016 |
| glossy paper | blue | plane | 0.072 | 0.019 | 0.019 | 0.022 |
| | | column | ------ | 0.013 | 0.022 | 0.020 |
| | green | plane | 0.004 | 0.069 | 0.032 | 0.025 |
| | | column | 0.010 | ------ | 0.033 | 0.019 |
| | yellow | plane | 0.015 | 0.011 | 0.017 | 0.008 |
| | | column | 0.024 | 0.005 | ------ | 0.015 |
| | red | plane | 0.037 | 0.018 | 0.008 | 0.036 |
| | | column | 0.040 | 0.034 | 0.015 | 0.044 |

estimation result and the standard white plate result. Table 1 shows the results of preliminary experiments using a turn table and a slide stage. In table, each value is a distance between the xy chrome value of the estimation result and one of the measurement for the standard white object.

The estimation results with plane are almost better than ones with column. This is considered because it is different from the resolution of angle. Moreover the results with plastic are almost better than ones with glossy paper. This is the main cause that the body reflection could not be removed correctly because the surface refletion of glossy paper is diffused more than ones of plastic. But we observe that our method almost obtains good estimation results.

### 3.3 Experiments using Spectral Image

Our estimation method is applied to a spectral image [4,5]. Fig. 4 (a) shows a target scene; there are a red painted cup and a blue metallic pot. (b) shows the obtained spectral image. The spectral distributions in the figure are normalized to compensate the maximum intensity to 1 in each pixel. A halogen light is used as light source.

Fig. 5 shows the estimation results using a part of red cup in the spectral image (Fig. 4 (b)). (a) is the estimation result of the spectral distribution. This graph format is the same as the format of Fig. 3. And (b) is a map of color difference map between recovery color images using the estimated light color and the measured light color with the reference standard white object .

In this experiment, a color differece which shows a distance between the estimated value and the value of standard white in CIE L*a*b* space is 1.45. This value is satisfactory value to materealize the color constancy, and we see our method can be applied to estimate light source color from objects in an image by using a spectral image where pixels represent the spectral distribution.

## 4. Conclusion

In this paper, we try to estimate a color of the light source with the light reflected from an object's surface. We focus on the geometry information regarding object shape, light source position, and camera position. To show the effectiveness of our method, we use a turn table and a slide stage to change the incident and reflection angles using objects of known shapes. The result shows that estimation of light source color by our method is feasible.

### References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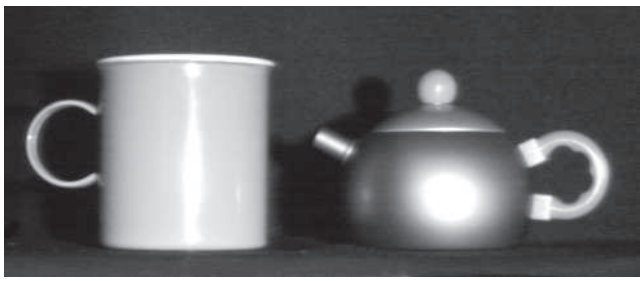
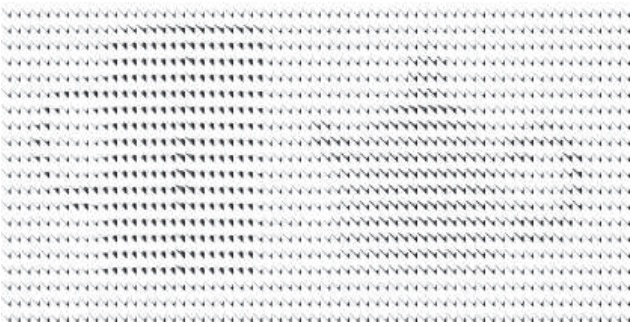
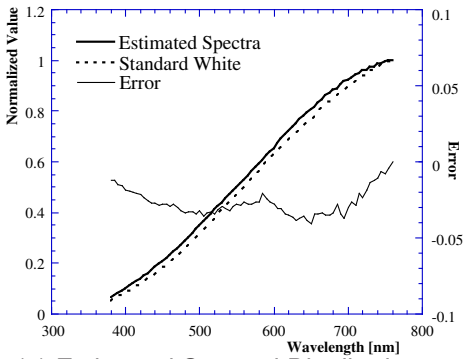


(a) Target Scene



(b) Spectral Image

Fig. 4 Input Image




(a) Estimated Spectral Distribution

(b) Color Difference Map

Fig. 5 Expriment Results