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Recognition of Object Domain by Color Distribution

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[Article by Takako Mugitani, Information Processing and Manufacturing System Division, NEC Corp.; Mitsuru Mifune, Second System Engineering Division, Chugoku NEC Software Co., Ltd.; Shigeki Nagata, Second Application System Division, NEC Software Co., Ltd.: "Setting of Surface Model of Reflected Objects; Verification of Surface Model of Reflected Objects; Recognition of Object Colors and Extraction of Object Domain"]

[Text] **1. Introduction**

For the image processing of an object in its natural image, it is necessary to extract in advance the object to be processed from its image. To accomplish this the outer shape of an object is extracted through human instructions, which requires a great deal of time and patience.

This paper describes a method involving the setting of a model of color distribution on the surface of an object, thereby automatically providing "color" recognition, a piece of knowledge to represent the properties of an object, from its natural image. In addition, it describes a method for recognizing and extracting the object in the image according to the color recognized.

2. Setting of Surface Model of Reflected Objects

In computer graphics, various methods of expressing the surface of an object have been proposed in order to obtain realistic images. The authors studied a color distribution model with the light constantly contained in natural images taken into consideration by applying a model phong, which is often used for expressing bright surfaces, etc.

A phong model is often used for plastic-like material expression. The reflected light S_p at point P on the surface can be expressed by the expression (1):

$$S_p(\lambda) = C_p(\lambda)\{\cos(i)\ (1 - d) + d\} + W(\lambda,i)\ \{\cos(s)\}^n \quad (1)$$

where

C_p: diffuse reflectance at point P on an object
i: angle of incidence of illumination light
w: mirror reflectivity
s: angle between the directions of mirror reflection and the line of sight
n: power value for mirror reflection model by each material
d: ambient light reflection coefficient

Since S_p is a function of light wavelength λ, the three stimulus values of R, G, and B can be obtained by integrating them with sensor sensitivity;

$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \int S_p(\lambda) \begin{matrix} r(\lambda) \\ g(\lambda) \\ b(\lambda) \end{matrix} d\lambda \qquad (2)$$

Since the terms dependent on wavelengths are $C_p(\lambda)$ and $W(\lambda,i)$ alone, substituting expression (1) for expression (2), we have

$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} R_o \\ G_o \\ B_o \end{pmatrix} \{\cos(i)\ (1 - d) + d\} + \begin{pmatrix} R_s \\ G_s \\ B_s \end{pmatrix} W(\lambda,i)\{\cos(s)\}^n \qquad (3)$$

where

$$R_0 = \int C_p(\lambda)r(\lambda)d\lambda \qquad R_sW(i) = \int W(\lambda,i)r(\lambda)d\lambda$$
$$G_0 = \int C_p(\lambda)g(\lambda)d\lambda \qquad G_sW(i) = \int W(\lambda,i)g(\lambda)d\lambda$$
$$B_0 = \int C_p(\lambda)b(\lambda)d\lambda \qquad B_sW(i) = \int W(\lambda,i)b(\lambda)d\lambda$$

It is considered that W(i) is dependent on color term i of the light source and is separable. Setting $\alpha = \cos(i)\ (1 - d) + d$, $\beta = W(i)\ \{\cos(s)\}^n$, we find that expression (3) results in

$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} R_o \\ G_o \\ B_o \end{pmatrix} \alpha + \begin{pmatrix} R_s \\ G_s \\ B_s \end{pmatrix} \beta \qquad (4)$$
$$(0 \leq \alpha \leq 1, \quad 0 \leq \beta \leq 1),$$

where $(R_o, G_o, B_o)t$ and $(R_s, G_s, B_s)t$ can be regarded as colors appearing in diffuse reflection of an object (hereafter called object color) and those of illumination light (hereafter called light source color), respectively. It is considered that the color of reflected light at each point changes according to the surface direction and illumination at each point and the positional relation between itself and the observer, and that these factors are mixed at rates of α and β.

If the expression (4) model is correct, the color of the object surface must exist in a plane passing the black, the light source color and the object color. The report by Tajima and his colleague[1] indicates that the color of an object is distributed on a plane and that the slippage between this plane and the one passing the black, the light source color and the object color is about 5 degrees, with these two planes almost according with each other.

Figure 1 shows a projection drawing in which the body color of an automobile parked on a street is projected on this distribution plane with the black-white axis from the black (0,0,0) in RGB space to the white (255,255,255) displayed at the same time. From the picture, the light source color seems to be white, while the color of the object surface is distributed not only in the plane decided by the black, light source color and object color, but also in a triangle with the black, light source color (white) and object color as its vertexes. From this, expression (5) is considered to hold:

$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} R_o \\ G_o \\ B_o \end{pmatrix} \alpha + \begin{pmatrix} R_s \\ G_s \\ B_s \end{pmatrix} \beta \qquad (5)$$

$$0 \leq \alpha \leq 1, \quad 0 \leq \beta \leq 1, \quad 0 \leq \alpha \leq + \beta \leq 1$$

We will call this color distribution model a reflected object surface model.

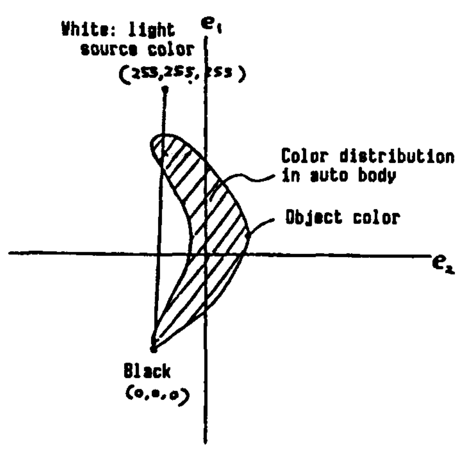

Figure 1. Color Distribution in Automobile Body

3. Verification of Reflected Object Surface Model

We decided to verify the efficiency of the reflected object surface model of the expression (5) proposed in section 2 with several natural images. The processing for the distribution drawing in Figure 1, however, was conducted by deciding a distribution plane after the dispersion was obtained, so that it required about 40 minutes with a minicomputer with processing performance of 3 mips. To facilitate the verification, we considered a method for expressing color distribution without seeking

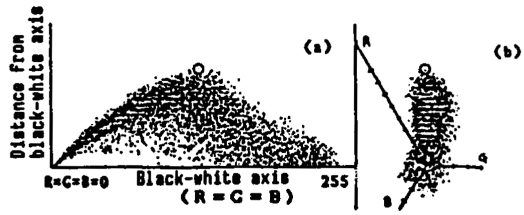

Figure 2. Color Distribution in Automobile Body

dispersion and succeeded in the processing above with a 16-bit personal computer. Figure 2(a) and (b) show the result of the above processing for the same picture of the automobile.

The axis of abscissas in Figure 2(a) is the black-white axis where factors of R, G, and B become equivalent, while its axis of ordinates represents the distance from the black-white axis. Figure 2(b) shows individual points projected on plane vertical to the black-white axis. If examination of a natural image of an object other than an automobile shows its color to be distributed as in this distribution drawing, it will demonstrate that the reflected object surface model is correct.

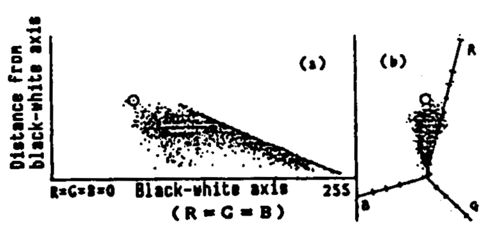

Figure 3. Color Distribution in Cleaner

Figure 3(a) and (b) show a color distribution of a natural image of a cleaner with a plastic-like surface for a phong model. Here, too, the light source color can be assumed to be white, and it can be found that as is the case with an automobile, the color is distributed in a triangle with the black, light source color and object color as its vertexes. In addition, the authors examined such objects of materials with great mirror reflection as a TV set, a telephone and a desk, and obtained a similar result, thus confirming the reflected object surface model as correct.

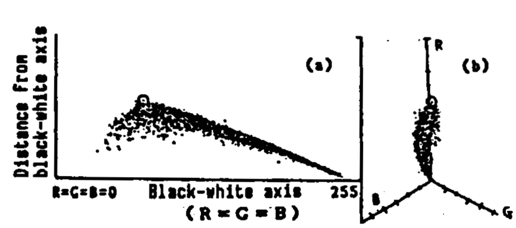

Figure 4. Color Distribution in Suit

With respect to the surface of a suit material lacking mirror reflection, a similar result to that shown in Figure 4(a) and (b) was obtained, indicating that its color is distributed in the same way. With respect to interior light equipment, which has great mirror reflection and is made of material permitting light to permeate, the result shown in Figure 5(a) and (b) was obtained, and it has been confirmed that its color is distributed as well.

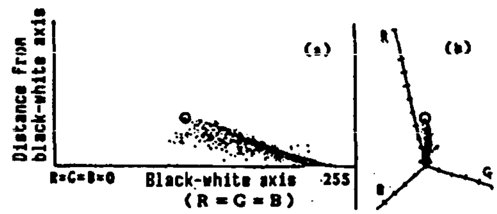

Figure 5. Color Distribution in Interior Lighting Equipment

From the above results, it has been confirmed that the color of the surface of an object, irrespective of the materials used in the object surface, is distributed in a triangle, with the black, light source color and object color as its vertexes. Therefore, the reflected object surface model the authors have proposed is applicable, irrespective of the materials used in the object surface.

4. Recognition of Object Color and Extraction of Object Domain

Since the light source color can very often be assumed as white, as is the case with sunlight the light source color is regarded as white in the following description. In a reflected object surface model, the color of the object surface exists on a plane with a black-white axis as its bottom end and the object color itself is the one farthest from the black-white axis. Therefore, if any color on an object is specified and its distribution plane is decided, the color farthest from the black-white axis on this plane can be recognized as the object color. The authors considered that by doing so, what entered the scope of a triangle with the white, black, and object color as its vertexes could be automatically extracted as a portion of the object.

However, as verified in section 3, the object color in a natural image is distributed not in a perfect plane, but in a certain width. The lightness of color changes due to the effect caused by light sources such as shadows, but the hue does not, so it can be considered that the width of color distribution extends in the direction vertical to the hue surface. When viewed in the color distribution in Figure 2, since the plane with the black-white axis as its end can be approximately regarded as the hue surface in RGB space, the water droplet type shown in Figure 2(b) can be regarded as the width of color distribution. For practical performance, the authors conducted an experiment having a water droplet type approximate to a fan type, confirming that use of a fan-type model with a given interior angle permits the object color to be recognized without posing any problem for its practical use.

Table 1. Width of Color Distribution

Object	Interior angle
Automobile	58
Cleaner	42
Suit	37
Interior lighting equipment	28

The object color could be recognized by using a fan-type model with a given interior angle; however, with respect to the automatic extraction of a portion of an object, since the width of the interior angle of one image is largely different from that of another, the unrecognizable portion of the object increases when the interior angle is too narrow, while something other than the object is also recognized by mistake when the width of the interior angle is too wide. For the automatic extraction of object domain, it is necessary to strictly set the interior angle. The authors succeeded in extracting object domain by providing the dispersion of hue in terms of parameter through visual observation.

5. Conclusion

The authors have so far conducted an experiment on the automatic recognition of object domain from its natural image, but they could not automatically recognize the width of color distribution. From the analysis result of natural images obtained so far, the width of color distribution is considered to be caused by materials of the object surface; therefore, if knowledge of materials with the width of color distribution taken into consideration can be obtained, more perfect automatic extraction of object domain together with color will be possible.

References

1. Joji Tajima and Takako Mugitani, "Color Changing Algorithm for Color Image Portion," Information Processing Society's 35th National Convention.

2. B.T. Phong, "Illumination for Computer Generated Pictures," COMM. ACM, Vol 18, No 6, 1975.

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