Histogram Matching Based on Gaussian Distribution on the HSB Color System

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Abstract

This paper proposes Histogram Matching based on Gaussian Distribution (HMGD) processing on the HSB color system which is close to the human visual property. In the previous paper, we have proposed HMGD processing on the brightness axis which is calculated from RGB color system. And we have considered that HSB color system is more suitable for HMGD processing, because it contains brightness axis. In this paper, we describe how to transform the color image from RGB color system into HSB color system first. Second, we describe that the principal of HMGD on this color system. And then, we also explain how to re-transform HSB color system to RGB color system.

Keywords: Histogram matching, RGB, HSB, Image processing, HMGD

1. Introduction

Recently, the automated image arrangement has become more familiar to us[1-3]. For example, if we take a photo using Digital Camera or Smartphone, these devices will process which aimed to improve feeling impression from raw taken one. And the method of image processing is in the research stage.

In the previous papers, we have proposed histogram Matching based on Gaussian Distribution (HMGD), as the automated image processing which is one of the elastic transform. This HMGD has been the processing on the brightness axis which is calculated from RGB color system.

As for the method of improvement the feeling (or Kansei) impression, we have apply curvature computation for detect multiple-brightness peak of image. Also, we have applied variance estimation to optimize for reference histogram which is used HMGD. Through these improvements, HMGD processing works well not only single-brightness peak image but also multiple-brightness peak image.

However, we have considered that HSB color system[4, 5] is more suitable for HMGD processing, because HSB color system is more close to visual feature of human.

In this paper, we describe about HSB color system first. Next, we illustrate principle of transform the color image from RGB color system into HSB color system. Then, we propose the principle of HMGD on this color system. Last, we also propose the method of HMGD on the HSB color system.

2. Principle

2.1. *HSB color system*

HSB (or HSV) color system is the color system due to Hue, Saturation and Brightness, as shown in Fig. 1. This color space has been proposed from A. R. Smith, the author of Ref. 5 published in 1978.

Hue means the primary color and it is the angular dimension[5] starting at the red primary at 0º. And green primary and blue primary is located at 120º and 240º, respectively, and then primary color become red at 360º.

Next, saturation is corresponding to the clearness of color. This means that the high saturation color is close to primary, and the low saturation color is close to achromatic.

Then, brightness is corresponding to brightness of color. This means that the high brightness color is bright color, and the low brightness color is close to black.

That is, HSB color system is the most common cylindrical-coordinate representations of points in a RGB color system.

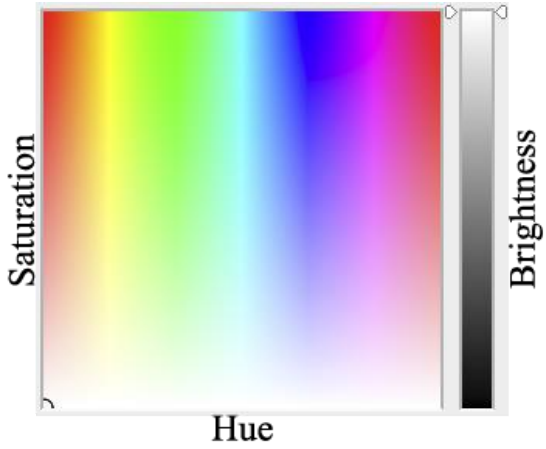

Fig. 1. Conceptual image of HSB color space

2.2. *Color system conversion*

In the previous section, we have described the principle of HSB color system. So, we describe the principle of interconversion between RGB color system and HSB color system in this section.

2.2.1. *Color system conversion from RGB to HSB*

Let $b_{\max}$ and V be the maximum value of RGB color system in one pixel and the brightness value on HSB color system in one pixel, respectively. And, let H and S be the hue value and saturation value. Then, V is defined by Eq. (1).

$$V = b_{\max}. \tag{1}$$

If $b_{\max}$= 0, let H and S is defined by Eq. (2).

$$H = 0, \quad S = 0. \tag{2}$$

And let be $b_{\min}$ the minimum value of RGB color system in one pixel, S is defined by Eq. (3).

$$S = 255 \times \frac{b_{\max} - b_{\min}}{b_{\max}}. \tag{3}$$

From Eq. (1) ~ (3), we understand that we can derive saturation (S) and brightness (V) of HSB color system. And, let R, G, and B be defined red, green, and blue value of RGB color system, we can derive the H by Eq. (4).

$$\begin{cases} H = 60 \times \left(\dfrac{B-G}{b_{\max} - b_{\min}} \right). & \left(b_{\max} = R\right) \\ H = 60 \times \left(\dfrac{R-B}{b_{\max} - b_{\min}} \right) + 120. & \left(b_{\max} = G\right) \\ H = 60 \times \left(\dfrac{G-R}{b_{\max} - b_{\min}} \right) + 240. & \left(b_{\max} = B\right) \end{cases} \tag{4}$$

In Eq. (4), H may be taken negative value H'. If H is H', we have to correct by following Eq. (5) because H is defined 0º ~ 359º.

$$H = H' + 360. \tag{5}$$

2.2.2. *Color system conversion from HSB to RGB*

Let *R*, *G*, and *B* be defined red, green, and blue value of RGB color system, respectively. And let *H*, *S*, and *V* be defined hue, saturation, and brightness value of HSB color system, respectively. If we take into account of definition of HSV color space, *S*=0 must be black color by Eq. (6).

$$R=0, G=0, B=0. \quad (S=0) \tag{6}$$

And here, let H_F, *I*, *J*, K, and *L* be defined following equations.

$$H_F = \lfloor H/60 \rfloor \tag{7}$$

$$I = (H/60) - H_F \tag{8}$$

$$J = V\left(1-\frac{S}{255}\right), \quad K = V\left(1-\frac{S}{255}F\right), \quad L = V\left(1-\frac{S}{255}(1-F)\right). \tag{9}$$

From Eq. (7) ~ (9), conversion equation of *R*, *G*, and *B* is derived by Eq. (10) and (11).

$$\begin{cases} H_F = 0 \Rightarrow R=V, G=L, B=J. \\ H_F = 1 \Rightarrow R=K, G=V, B=J. \\ H_F = 2 \Rightarrow R=J, G=V, B=L. \end{cases} \tag{10}$$

$$\begin{cases} H_F = 3 \Rightarrow R=J, G=K, B=V. \\ H_F = 4 \Rightarrow R=L, G=J, B=V. \\ H_F = 5 \Rightarrow R=V, G=J, B=K. \end{cases} \tag{11}$$

2.3. *Histogram Matching based on Gaussian Distribution*

In this section, we describe the principle of Histogram Matching based on Gaussian Distribution (HMGD).
HMGD is one of a kind of automated image arrangement method based on the Elastic Transformation[6, 7].
Fig. 2 shows the conceptual image of HMGD. Let *f*(*x*) and *h*(*y*) be two probabilistic density functions (PDF) on real variables *x* and *y*, respectively. PDF is corresponding to the brightness value histogram of HSB color system. And, we define the relationship between *x* and *y* by Eq. (12).

$$y = \phi(x) = L\int_0^x f(x)dx. \tag{12}$$

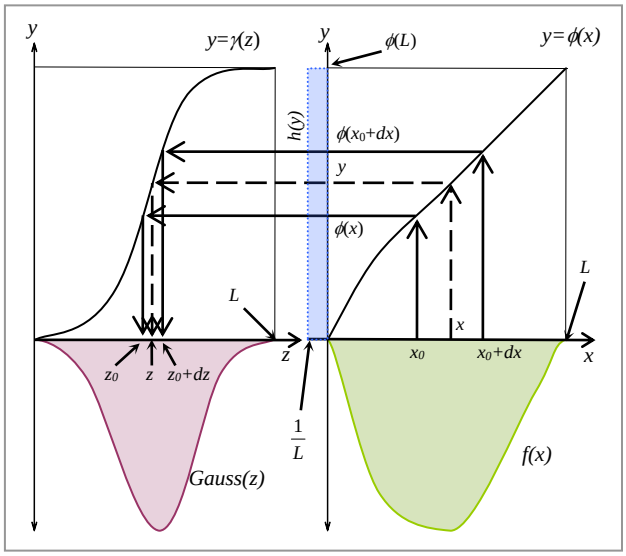

Fig. 2. Conceptual of Histogram matching based on Gaussian Distribution (HMGD) [8-10].

By Eq. (12), we define that $\phi(x)$ means the cumulative histogram of *f*(*x*).
First, we transform from original histogram *f*(*x*) into uniform distribution histogram *h*(*y*) because we need to expand brightness value for histogram matching. We can derive Eq. (13) and (14) from Eq. (12) and Fig. 2.

$$f(x) = h(y)\phi'(x) = h(y)Lf(x). \tag{13}$$

$$h(y) = \frac{1}{L}. \tag{14}$$

Then, let *Gauss*(*z*) and $\gamma(z)$ be the function that is defined by Eq. (15) and (16), respectively. And we obtain Eq. (17) from the relationship between $y=\phi(x)$ and $y=\gamma(z)$ as shown in Fig. 2.

$$Gauss(z) = \frac{1}{\sqrt{2\pi\sigma^2}}\exp\left(-\frac{(z-\mu)^2}{2\sigma^2}\right). \tag{15}$$

$$y = \gamma(z) = L\int_0^z Gauss(z)dz. \tag{16}$$

$$L\int_0^x f(x)dx = \frac{L}{\sqrt{2\pi\sigma^2}}\int_0^z \exp\left(-\frac{(z-\mu)^2}{2\sigma^2}\right)dz. \tag{17}$$

So, we can derive Eq. (18) and (19) from differential of Eq. (17).

$$L\int_0^x f(x)dx = \frac{L}{\sqrt{2\pi\sigma^2}}\int_0^z \exp\left(-\frac{(z-\mu)^2}{2\sigma^2}\right)dz. \quad (18)$$

$$L\phi'(x) = L\gamma'(z), \quad f(x) = Gauss(z). \quad (19)$$

That is, we understand that we can match the original histogram $f(x)$ to Gaussian distribution histogram $Gauss(z)$.

3. Method of HMGD on the HSB Color System

In the previous chapter, we described the principle of HSB color system, its conversion, and HMGD. In this chapter, we propose the method of HMGD on the HSB color system.

(i) Load original image.
(ii) Perform color system conversion from RGB to HSB.
(iii) Perform HMGD on the brightness axis of HSB color system.
(iv) Perform color system conversion from HSB to RGB.
(v) Output processed image.

4. Conclusion

In this paper, we have proposed about Histogram Matching Based on Gaussian Distribution (HMGD) on the HSB color system, and we have described principles of color conversion and HMGD.

As the proposed method, we have performed color system conversion and HMGD on the brightness axis of HSB color system image. And then, we have performed re-conversion of color system as the post processing.

For the further study, we have to validate investigation feeling (or Kansei) impression evaluation through the questionnaire survey, for the review proposed method for effectiveness. Also we have to review the proposed method for effectiveness.

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