Color Image Arrangement Based on Histogram Matching Using Smoothed Brightness Histogram (I) --- Overall Smoothing ---

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Abstract

Although we have already reported that automated color image arrangement by Histogram Matching based on Gaussian Distribution (HMGD) gives good feeling impression if the brightness histogram of the original image has a single peak. However, if there are multiple peaks in the histogram, the HMGD processing does not always bring good results. In this paper, we propose a Histogram Matching method using overall smoothing over the brightness histogram of original image as the reference one instead of using Gaussian distribution. Also in this paper, we present the experimental results.

Keywords: Image processing, Brightness Histogram, Histogram matching, HMGD

1. Introduction

These days, automated image processing for enhancement of color images has been more familiar to us, for example, Digital Signage, Smart Phone, etc[1-3].
In the previous paper, we have already presented that the Histogram Matching based on Gaussian Distribution (HMGD) processing is one of the automated image arrangement method using Elastic Transformation[4-5] based on the brightness axis and gives good feeling impression if the original images have single peak[6].
However, we have understood that if the original images have multiple-peak brightness histogram, HMGD processing does not always give good feeling impression. Through the experimental results, we have considered if the reference histogram make change to satisfy brings good results whether or not the number of original image brightness histogram peaks[7].
In this paper, we propose a Histogram Matching method using overall smoothing over the brightness histogram of original image as the reference one instead of using Gaussian distribution. Also in this paper we illustrate the experimental results using proposed Histogram Matching method.

2. Principle of Histogram Matching based on Gaussian Distribution (HMGD)

In the section, we describe the principle of HMGD processing.

Fig. 1 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. The PDF is corresponding to histogram of image brightness level which is discretely defined.

In addition, let $y=\phi(x)$ be a continuous and monotonic increase function corresponding to cumulative histogram of image brightness level between variables x and y [7-9]. And let $y=\phi(x)$ be defined by Eq. (1).

$$y = \phi(x) = L\int_0^x f(x)dx. \tag{1}$$

At first, we have to expand brightness level of original image histogram and convert into uniform distribution histogram, because we aim to match Gaussian distribution. From Eq. (1) and Fig. 1, we can derive Eq. (2) and (3).

$$f(x) = h(y)\phi'(x) = h(y)Lf(x). \tag{2}$$

$$h(y) = \frac{1}{L}. \tag{3}$$

We understand the histogram of original image $f(x)$ becomes uniform distribution $h(y)$ by Eq. (3). This means that brightness level of original image $f(x)$ is expanded to $h(y)$.

Then, let $Gauss(z)$ and $\gamma(z)$ be the function that is defined by Eq. (4) and (5), respectively.

$$Gauss(z) = \frac{1}{\sqrt{2\pi\sigma^2}}\exp\left(-\frac{(z-\mu)^2}{2\sigma^2}\right). \tag{4}$$

$$\begin{aligned} y = \gamma(z) &= L\int_0^z Gauss\ (z)dz \\ &= \frac{1}{\sqrt{2\pi\sigma^2}}\int_0^z \exp\left(-\frac{(z-\mu)^2}{2\sigma^2}\right)dz. \end{aligned} \tag{5}$$

Here, Fig.1 shows the relationship between $y=\phi(x)$ and $y=\gamma(z)$. So we can be obtained following Eq. (6).

$$L\int_0^x f(x)dx = \frac{L}{\sqrt{2\pi\sigma^2}}\int_0^z \exp\left(-\frac{(z-\mu)^2}{2\sigma^2}\right)dz. \tag{6}$$

And we can derive Eq. (7) from differential of Eq. (6).

$$\frac{d}{dx}L\int_0^x f(x)dx = \frac{d}{dz}\frac{L}{\sqrt{2\pi\sigma^2}}\int_0^z \exp\left(-\frac{(z-\mu)^2}{2\sigma^2}\right)dz. \tag{7}$$

If we perform Eq. (7),

$$L\phi'(x) = L\gamma'(z) \tag{8}$$

That is, we understand that $f(x)$ becomes Gaussian distribution $Gauss(z)$ when we take the transform function as (1) and (5). Thus, HMGD processing is the function which defined by cumulative histogram transformation the original histogram into Gaussian histogram[6,7].

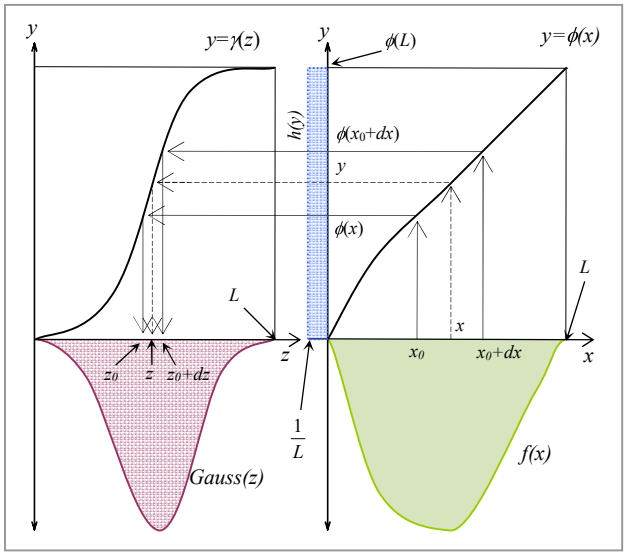


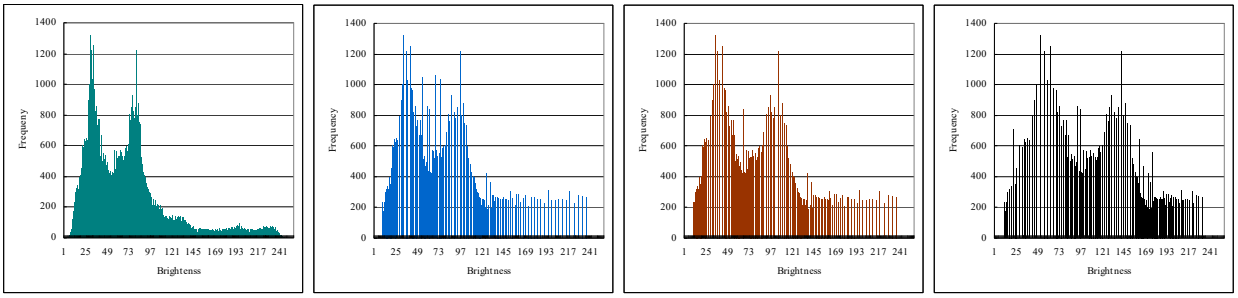
Fig. 1. Conceptual image of HMGD[6, 7].

3. Histogram Matching Using Smoothed Brightness Histogram

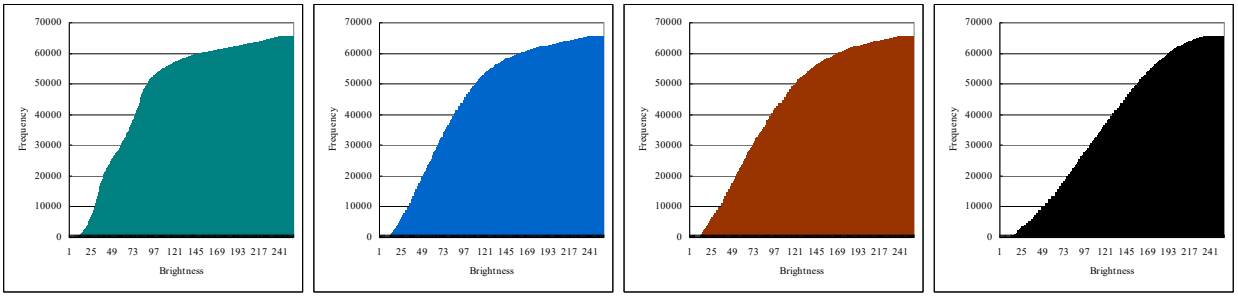
In the previous section, we have described about the principle for HMGD processing. In this section, we propose the concrete process of Histogram Matching using smoothed brightness histogram

(i) Input original image and calculate moving average of brightness histogram of the one.
(ii) If not need to calculate moving average of it further (if it satisfies number of times recursive), proceed to (iii). Otherwise, calculate moving average of the brightness histogram recursively.

(a) Image: Original[6, 7] (far left), Histogram Matching using Moving Average (5 times: second from left, 10 times: second from right, 100 times: far right)



(b) Histogram: Original (far left), Histogram Matching using Moving Average (5 times: second from left, 10 times: second from right, 100 times: far right)



(c) Cumulative Histogram: Original (far left), Histogram Matching using Moving Average (5 times: second from left, 10 times: second from right, 100 times: far right)

Fig. 2. Example of results and the corresponding histogram.

(iii) Generate the reference histogram h_r from the result of (ii).
(iv) Perform Histogram Matching processing of using reference histogram as h_r.
(v) Output processed image.

4. Experimentation

In this experimentation, we perform moving average a range of ± 25 with respect to each brightness value of original image histogram.
Fig. 2 shows the example of results and the corresponding histogram. In this case, we understand that Histogram Matching processing image using moving average of brightness histogram is enhancing contrast than original image.
From far right of Fig. 2(a) ~ (c), we notice that these results like Histogram Equalization (HE) or Histogram Matching based on Gaussian Distribution (HMGD). That is, we consider that this processing result will get close to HE or HMGD if we increase in the number of times moving-average recursive. And we consider that the processing result does not always give us good Kansei impression in such case.

5. Conclusion

In this paper we have proposed the color image arrangement based on histogram matching using moving average of original image brightness histogram.
As for the concrete processing method, we have used moving average recursively from the original image brightness histogram to generate reference histogram. Then we have taken a histogram-matching processed image.

From the experimentation, histogram matching processed image is enhancing contrast from original image and this processing result will get close to HE or HMGD if we increase in the number of times moving-average recursive. That is, we consider that proposed method is simple and convenient as Kansei impression enhancement instead of HMGD.

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