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히스토그램 스트레칭을 이용한 효율적인 명암 향상 알고리즘

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Efficient Contrast Enhancement Algorithm using Histogram Stretching

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<Abstract>

In this paper, an efficient contrast enhancement algorithm using histogram stretching is proposed. Histogram equalization (HE) and histogram stretching (HS) are effective techniques for contrast enhancement. However, HE and HS result often in excessive contrast enhancement. Proposed technique not only produces better results than those of conventional contrast enhancement techniques, but is also adaptively adjusted to image contents.

Key Words : Contrast Enhancement, Histogram Equalization, Histogram Stretching

Ⅰ. Introduction

Contrast enhancement is an important one of image processing applications. Many images may not reveal the details and have unpleasing looks because of acquisition problems and displaying devices. Contrast enhancement eliminates these problems and obtains enhanced images.

Contrast enhancement methods can be categorized to two groups: direct methods such as HPF(High Pass Filter) and indirect methods such as histogram modification. Direct methods using HPF may have halo artifacts around edge. Thus, we focus into the histogram modification method.

Many contrast enhancement algorithms using histogram modification are proposed to improve the quality of an image.

Algorithms can be categorized into two approaches as a global contrast enhancement (GCE)[1] and a local contrast enhancement (LCE)[2]. GCE use a single mapping function and LCE use a local mapping function, respectively. GCE does not suffer from blocking artifacts and preserves ordering of altered gray levels.

Histogram equalization (HE) is the most popular contrast enhancement technique[1, 6, 8]. HE expands the contrast of the high histogram region and compresses the contrast of the low histogram region. This technique is simple and effective, but it can produce excessively enhanced and unpleasing images.

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Thus, various methods have been proposed to overcome the limiting. Bi-histogram equalization was proposed to reduce mean brightness difference[3]. This method separates one histogram into two histograms with mean intensity and equalizes independently. Dualistic sub-image histogram equalization was also proposed as a similar method [4]. It separates the histogram at the median gray level instead the mean. These techniques usually have better performances than that of the basic HE. However, they have the same limitations of HE and cannot adjust the level of enhancement.

Another unconventional approach based on the histogram has been proposed. Gray-level grouping (GLG) groups histogram bins and redistributes these bins uniformly over the gray scale, iteratively[5]. GLG can adjust the level of enhancement. However, mean brightness is changed and the approach cannot be used in the video sequence playing.

One of the famous image enhancement techniques is histogram stretching (HS)[7]. The technique stretches histogram maps to darker and brighter. However, because of limitation of adjusting stretching level, the method creates artifacts.

Existing various contrast enhancement techniques usually perform well. However, they have limitations and cannot obtain a natural looking in the certain classes of images. Our purpose of this paper is to obtain a natural and enhancement method with low computational complexity

The contributions of our proposed method are:

- To present efficient stretching method with low computational complexity
- To apply automatically in a various images

In the next section, the existing techniques will be described. In the Section III, the proposed method based on stretching is explained. Then, experimental results are presented in Section IV. Finally, the conclusion is presented in Section V.

Ⅱ. Existing Techniques

Histogram based contrast enhancement techniques are widely developed and used. We introduce the existing histogram equalization and stretching.

A. Histogram Equalization (HE)

HE flattens and stretches the dynamic range of the image's histogram[6]. Thus, it obtains overall contrast enhancement. However, it may significantly change the brightness of an input image. In HE, the transformation function $T(X_k)$ is given by the following relations.

$$T(X_k) = (2^L - 1)\left\lfloor \sum_{j=0}^{k} p(X_j) + 0.5 \right\rfloor \qquad (1)$$

where L is the number of bits used to represent the pixel value, $k \in [0, 2^L - 1]$, and X_k is the input pixel of level k. The normalized histogram $p(X_j)$ of an image gives the probability density function (PDF) of its pixel intensities. Thus, the cumulative density function (CDF) is obtained from the sum of $p(X_j)$. The transform function for mapping is as called version of the CDF.

A general framework based on histogram equalization (FHE) was also proposed[8]. The method is implemented given in

$$\tilde{H} = ((1+\lambda)I + \alpha I^B)^{-1}(H_i + \lambda U), \qquad (2)$$

where $\tilde{H}$ is modified histogram, H_i is input histogram, I^B is a diagonal matrix, $I^B(i,i) = 1$ and U is uniformly distributed histogram. λ is the level of contrast enhancement, and α is black and white stretching level.

B. Histogram Stretching (HS)

Histogram stretching is simple but effective technique which is widely used[7]. HS makes dark pixel darker and bright pixel brighter. Thus, it enhances the contrast of the image. HS can be implemented by the linear mapping as follows:

$$T(X_k) = \begin{cases} X_k \times f_b & X_k \le B_b \\ X_k \times T'(X_k) & B_b < X_k < B_w \\ B_w + (X_k - B_w) \times f_w & B_w \le X_k \end{cases} \tag{3}$$

where B_b is the maximum gray level to be stretched to black and B_w is the minimum gray level to be stretched to white. f_b, f_w are compression factor. $T'(X_k)$ is a linear stretching function. However, HS cannot adjust the level of enhancement according to the image content.

Ⅲ. Proposed Technique

In this section, a histogram distribution information and stretching is presented. The block diagram of the proposed method is illustrated in Fig. 1. It stretches the histogram according to the distribution information. The proposed algorithm adjusts the level of enhancement adaptively to the input image's contrast. Thus, it can obtain the natural looking image.

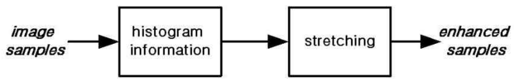


Fig. 1. Block diagram of the proposed method.

Histogram stretching (HS) is widely used in image enhancements. HS stretches histogram distribution to black and white. It makes dark pixel darker and bright pixel brighter. The proposed HS method separates one histogram of an image into two histograms with mean intensity and stretches left region histogram and right region histogram to additionally same expanded length, respectively.

The procedures of HS are as follows.

1) Obtain distribution information of histogram: Generate histogram and obtain the distribution information as shown in Fig. 2. Boundary and mean intensity information are obtained. Boundaries B_b and B_w and mean m are obtained by accumulation the histogram.

2) Stretch Histogram: Stretch histogram according to the information by the linear mapping is given as

$$T(X_k) = \begin{cases} X_k \times f_b & X_k \le B'_b \\ X_k \times T_b'(X_k) & B'_b < X_k \le m \\ X_k \times T_w'(X_k) & m < X_k < B'_w \\ B'_w + (X_k - B'_w) \times f_w & B'_w \le X_k \end{cases} \tag{4}$$

where m is the mean gray level which is not changed while stretching. B'_b and B'_w are new boundaries according to the histogram distribution. $|B'_b - B_b|$ is equal to $|B'_w - B_w|$. This length is adjusted as $\alpha \times |B_b - B_w| = |B'_b - B'_w|$. α is the level of contrast enhancement. $T'_b(X_k)$ is a left stretching function and $T'_w(X_k)$ is a right stretching function. The proposed method stretches histogram while maintaining the original image brightness.

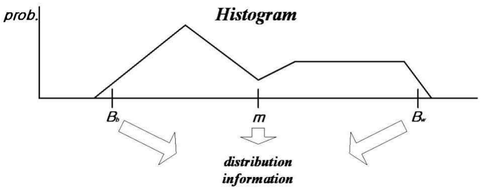


Fig. 2. Distribution information

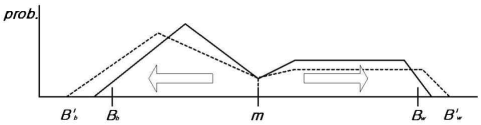


Fig. 3. Histogram stretching of the proposed method

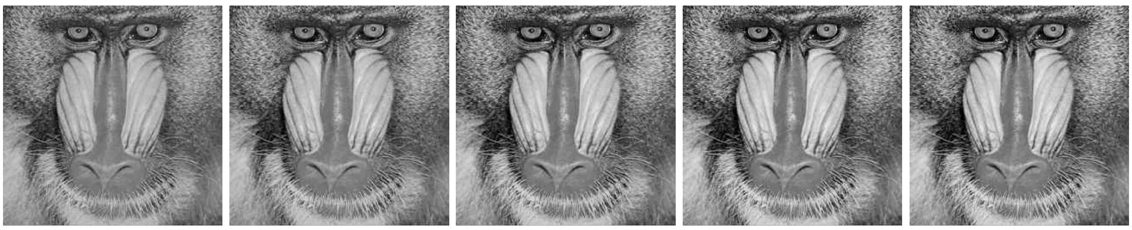
Ⅳ. Experimental Results

In this section, the proposed algorithm and existing algorithms (HE[6], FHE[8], and HS[7]) are simulated on several images, and the results are compared. In our proposed method, the level of contrast enhancement α is set to 1.2, experimentally. For comparison, we provide results according to several α values.

Subjective assessment is used to compare contrast enhancement techniques. Additionally, we use the following quantitative measure such as Absolute Mean Brightness Error (AMBE). If metrics such as standard deviation and entropy are used, HE, FHE, and HS can achieve the better performances even though they may not produce natural looking images.

Fig. 4 and Fig. 5 show contrast enhanced images using the proposed method according to the α values. As shown in Fig. 4 and Fig. 5, results with α=1.2 have natural and enhanced looking without artifacts. As subjective assessment, α is set to 1.2, experimently.

Fig. 6. and Fig. 7 show the original test images and their corresponding contrast enhanced images.



(a) (b) (c) (d) (e)

Fig. 4. Results for Baboon image using the proposed method.
(a) α=1.0, (b) α=1.1, (c) α=1.2, (d) α=1.4, (e) α=1.6

(a) (b) (c) (d) (e)

Fig. 5. Results for Baboon image using the proposed method.
(a) α=1.0, (b) α=1.1, (c) α=1.2, (d) α=1.4, (e) α=1.6

HE images result in the best transformation of the dynamic range of the pixel values. However, this often does not obtain natural images. Also, the mean value of brightness is changed. This means that HE cannot be used in video playing to flickering. In Fig. 6(b) and Fig. 7(b), these situations are observed. On the other hand, FHE, HS, and the proposed algorithm generate natural images. However, as shown in Fig. 6(c), (d) and Fig. 7(c), (d) the mean brightness is changed. Also, details in the background are lost due to over brightening.

Comparison results of quantitative measures are showed in Table 1. Results show that our proposed algorithm preserves the mean brightness better than the existing methods.

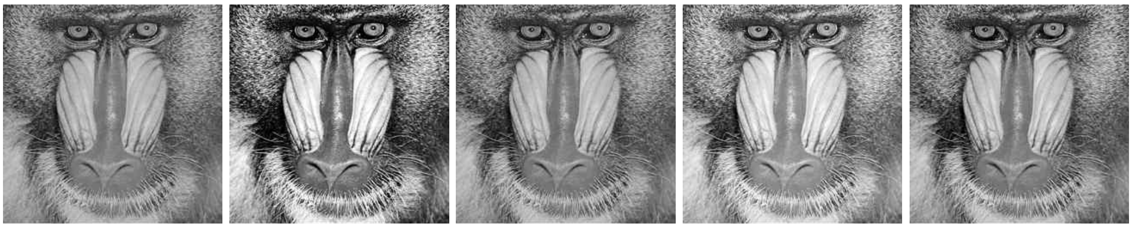
<TABLE I> Quantitative Measurement Results

Image	AMBE			
	HE	FHE	HS	Prop.(α=1.2)
Baboon	0.81	3.39	22.25	1.06
Lena	28.80	1.82	22.72	0.16
Einstein	20.85	0.01	13.30	0.01
Pepper	21.16	0.12	18.79	0.03

Ⅴ. Conclusions

We proposed an efficient contrast enhancement method without visual artifacts while preserving the mean brightness.

Experimental results show the proposed method has better performance than those of the conventional methods. It obtains visually pleasing and artifact free images. The proposed method can be well used for video applications.



(a) (b) (c) (d) (e)

Fig. 6. Results for Baboon image. (a) Original image, (b) enhanced image using HE, (c) FHE, (d) enhanced image using HS, (e) enhanced image using the proposed algorithm (α=1.2)

(a) (b) (c) (d) (e)

Fig. 7. Results for Lena image. (a) Original image, (b) enhanced image using HE, (c) FHE, (d) enhanced image using HS, (e) enhanced image using the proposed algorithm (α=1.2)

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