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Efficient Contrast Enhancement Using Histogram Specification

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히스토그램 명세화를 이용한 효율적인 영상 대비 향상

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Abstract In this paper, an efficient contrast enhancement algorithm using histogram specification is proposed. Histogram equalization and its modified methods have been effective techniques for contrast enhancement. However, they often result in excessive contrast enhancement. Besides conventional histogram specification also has a problem to get the desired histogram. We propose a method that utilizes a simple high frequency filter to get the desired histogram. The proposed technique not only produces better visual results than conventional contrast enhancement techniques, but is also adaptively adjusted to the statistical characteristics of the image.

요 약 본 논문에서는 히스토그램 명세화에 기반을 둔 효과적인 영상 대비 개선 알고리즘을 제안한다. 히스토그램 평활화나 이로부터 파생된 방법들은 영상 대비 개선에 효과적인 도구로 사용되어 왔으나, 과도한 대비 개선이라는 부작용을 수반하는 결과를 자주 낳게 된다. 반면 기존의 히스토그램 명세화는 의도한 히스토그램을 얻기에 부적절하다는 단점을 가지고 있다. 본 논문에서는 의도한 히스토그램을 얻기 위해서 고주파필터를 활용한 방법을 제안한다. 제안한 방법은 기존의 영상 대비 방법에 대해서 향상된 화질을 제공할 뿐만 아니라, 영상의 통계적 속성에 적응적으로 대응하는 속성을 보여주고 있다.

Key Words : Histogram, Equalization, Specification

1. Introduction

Providing enhanced image is a crucial role in services such as DMB, IPTV, and video conference. Especially, the contrast enhancement is an important category of image enhancement. Various images may not reveal the details and may have unpleasing looks. Contrast enhancement eliminates these problems and obtains enhanced and natural images.

Various contrast enhancement algorithms were proposed to improve the quality of an image [1-9]. Histogram equalization (HE) is a well known and simple contrast enhancement technique [1,7]. HE stretches the contrast of the high cumulated histogram region and compresses the contrast of the low cumulated histogram region. However, it produces often excessively enhanced and unnatural images.

Thus, various methods have been proposed by the modification. Bi-histogram equalization [3] and Dualistic sub-image histogram equalization [4] were proposed. These methods separate one histogram into two histograms and then equalize them independently. However, they have the same limitations of HE and cannot adjust the enhancement level.

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Another histogram based approach has been proposed. Gray-level grouping (GLG) groups histogram bins. Then, GLG redistributes these bins uniformly, iteratively [6]. However, the mean brightness is often changed and the approach cannot be used for the video applications.

One of the famous contrast enhancement methods is histogram stretching (HS) [8,9]. The method stretches histogram to darker and brighter. However, the method has the limitation of adjusting stretching level and the mean brightness is often changed.

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

In the next section, the existing histogram based techniques will be described. In the Section 3, the proposed method based on specification and stretching is explained. Then, simulation results are presented in Section 4. Finally, the conclusion is presented in Section 5.

2. Overview of Existing Techniques

Histogram based contrast enhancement techniques is widely used. We introduce the conventional histogram equalization and stretching.

2.1 Histogram Equalization (HE)

HE flattens and stretches the dynamic range of the image's histogram [7]. Thus, it obtains the 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.

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

where L is the number of bits used to represent the pixel value, k∈[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 a scaled version of the CDF.

2.2 Modified Histogram Equalization (MHE)

The method is implemented given in

$$\overline{H} = \left((1+\lambda)I + \alpha I^B\right)^{-1}(H + \lambda U), \tag{2}$$

where $\overline{H}$ is modified histogram, H is input histogram, I^B is a diagonal matrix, I^B=1 and U is uniformly distributed histogram. l is the level of contrast enhancement, and a is black and white stretching level [9]. However, this method has limited contrast enhancements because of not considering the various image contents.

2.3 Modified Stretching (HS)

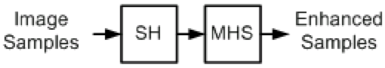
Histogram stretching is simple but effective technique which is widely used [8,9]. HS makes dark pixel darker and bright pixel brighter. Thus, it enhances the contrast of the image. HS can be implemented by the linear mapping as follows:

$$S(X_k) = \begin{cases} X_k \times f_b & X_k \le B_b \\ X_k \times S'(X_k) & B_b \le X_k \le B_w \\ B_w + (X_k - B_w) \times f_w & B_w \le X_k \end{cases} \tag{3}$$

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, while f_b and f_w are compression factors. $S(X_k)$ is a linear stretching function. However HS also has limitations as HE, thus it cannot adjust the level of enhancement.

3. Proposed Algorithm

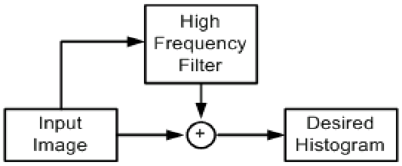
In this section, a simple histogram specification using high frequency filter and stretching is presented. The block diagram of the proposed method is illustrated in Fig. 1. It modifies the histogram to a desired histogram by using high frequency filter and then stretches the histogram according to the distribution.



[Fig 1] Block diagram of the proposed adaptive predictor.

3.1 Specification of Histogram (SH)

We propose a histogram specification method using the desired histogram derived by high frequency filter. Histogram specification method maps the histogram of input image to the desired histogram. Thus, the method converts input image so that it has a particular histogram as specified. In histogram specification, the desired histogram is very important. According to the desired histogram, we could obtain the enhanced image. The desired histogram is obtained by the high frequency filter is illustrated in Fig. 2.



[Fig 2] Block diagram of the obtaining of the desired histogram

We choose an operator as high frequency filter as shown in Fig. 3.

	-1/4	
-1/4	1	-1/4
	-1/4	

[Fig 3] High frequency filter mask

According to the amount of contrast enhancement, we are able to use higher or lower frequency filter.

3.2 Modified Histogram Specification (MHS)

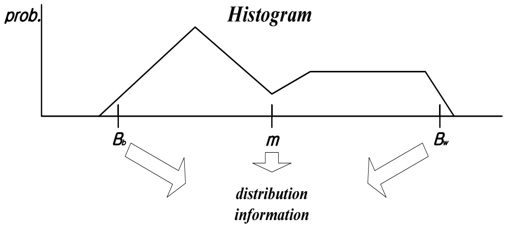
Histogram stretching is widely used in image enhancements. HS stretches histogram distribution to black and white. It makes dark pixel darker and bright pixel brighter. The proposed method separates one histogram of each sub-image into two histograms with mean intensity and stretches left region histogram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

-Obtain distribution information of histogram: Generate local histogram and obtain the distribution information as shown in Fig. 4. Boundary and mean intensity information are obtained. Boundaries B_b and B_w and mean m are obtained by accumulation of the histogram.

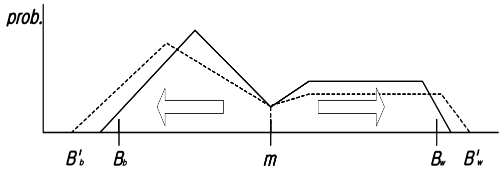
-Stretch histogram: Stretch histogram according to the information as shown in Fig. 5. The proposed histogram stretching by the linear mapping is given as

$$S(X_k)=\begin{cases} X_k \times f_b & X_k \le B'_b \\ X_k \times S'_b(X_k) & B'_b \le X_k \le m \\ X_k \times S'_w(X_k) & m \le X_k \le B'_w \\ B_w + (X_k - B'_w)\times f_w & B'_w \le X_k \end{cases} \tag{4}$$

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. $|B'_b-B_b|$ equals to $|B'_w-B_w|$. $S_b(X_k)$ is a left stretching function and $S_w(X_k)$ is a right stretching function. The proposed method stretches histogram while maintaining the original image brightness.



[Fig 4] Distribution information



[Fig 5] Modified histogram stretching of the proposed method

4. Experimental Results

In this section, the proposed algorithm and existing algorithms such as HE, MHE, and HS are simulated on several images, and the results are compared. Subjective assessment is used to compare contrast enhancement techniques. Additionally, we use the following quantitative measure such as Absolute Mean Brightness Error (AMBE) [10] and contrast factor (CF) [11]. CF is the average of difference values between the reference pixel and its neighboring pixels as explained given in

$$CF = \frac{1}{4}\left(\left|x_{i,j} - x_{i-1,j}\right| + \left|x_{i,j} - x_{i+1,j}\right| + \left|x_{i,j} - x_{i,j-1}\right| + \left|x_{i,j} - x_{i,j+1}\right|\right) \tag{5}$$

If metrics such as CF are used, HE has the best performance even though that may not produce natural looking images. Figs. 6-7 show the original test images and their corresponding contrast enhanced images.

(a)

(b)

(c)

(d)

(e)

[Fig 6] Results for *"Boat"* image: (a) Original image, (b) enhanced image using HE, (c) enhanced image using MHE, (d) enhanced image using HS, (e) enhanced image using the proposed algorithm.

(a)

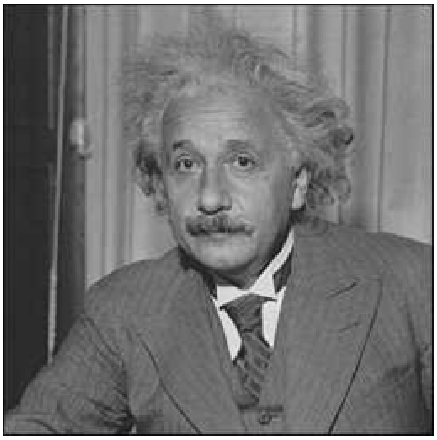
(b)

(c)

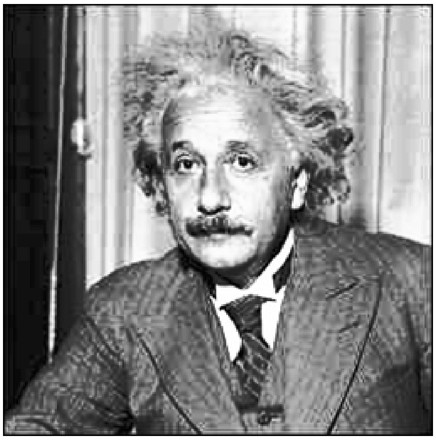
(d)

(e)

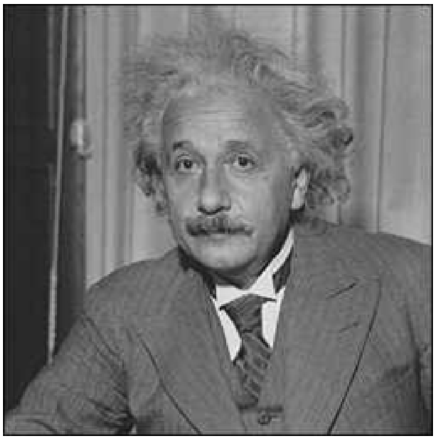
[Fig 7] Results for "*Lena*" image: (a) Original image, (b) enhanced image using HE, (c) enhanced image using MHE, (d) enhanced image using HS, (e) enhanced image using the proposed algorithm.



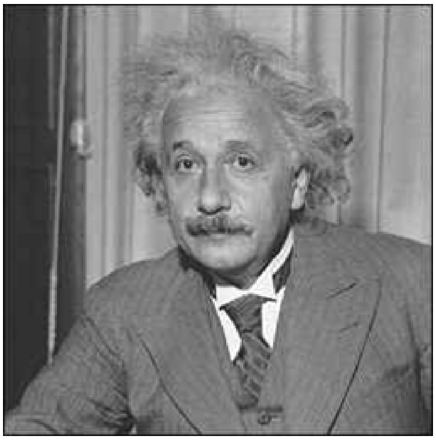
(a)



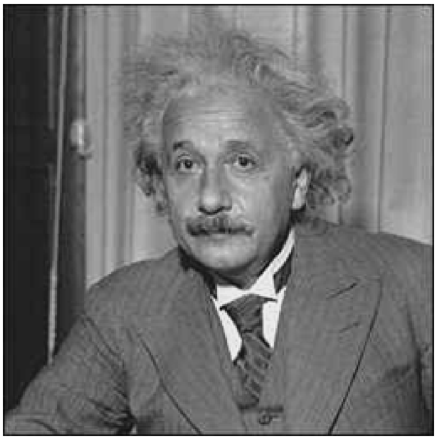
(b)



(c)



(d)



(e)

[Fig 8] Results for “*Einstein*” image: (a) Original image, (b) enhanced image using HE, (c) enhanced image using MHE, (d) enhanced image using HS, (e) enhanced image using the proposed algorithm.

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 Figs. 6(b), 7(b), and 8(b), these situations are observed. MHE has better results than those of HE. However, the method has same limitation of HE. On the other hand, HS and the proposed algorithm generate natural images. However, as shown in Figs. 6(d), 7(d), and 8(d), the mean brightness is changed. Also, details in the cloud are lost due to over brightening.

Comparison results of quantitative measures are showed in Table 1 and Table 2. Results show that our proposed algorithm preserves the mean brightness better than the existing HE and HS methods. Although, MHE has better AMBE performance than our method, it has less CF performance that our method. Our proposed algorithm shows better results than those of HE, MHE, and HS while maintaining natural looking.

[Table 1] Quantitative measurement results, AMBE.

Image	AMBE			
	HE	MHE	HS	Prop.
Boat	0.99	0.12	11.19	0.17
Lena	28.80	0.97	22.72	0.37
Einstein	20.85	0.01	13.30	0.09

[Table 2] Quantitative measurement results, CF.

Image	CF			
	HE	MHE	HS	Prop.
Boat	17.74	8.83	9.88	9.87
Lena	8.71	5.89	7.48	6.20
Einstein	6.99	3.40	3.62	3.62

5. Conclusions

We proposed a simple contrast enhancement method using histogram specification and stretching. The proposed method enhances image by histogram specification using a desired histogram which is derived by high frequency filter. Also, the method stretches input histogram with histogram information. Thus, the contrast of the image can be enhanced with preserving the mean brightness.

Experimental results show the proposed method has better performance than those of the conventional methods while maintaining natural looking.

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