논문 2010-47IE-3-2

명암도 향상을 위한 가중치 기반 히스토그램 수정

(Weight based Histogram Modification for Contrast Enhancement)

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요 약

본 논문에서는 효율적인 명암도 향상 알고리즘으로 가중치 히스토그램 수정을 제안한다. 명암도 향상을 위하여 히스토그램 평활화와 히스토그램 스트레칭은 효과적인 방법들이다. 하지만, 히스토그램 평활화와 히스토그램 스트레칭은 지나친 명암도 향상을 가져올 수 있다. 가중치 히스토그램 수정을 이용하는 제안하는 방법은 부작용 없이 기존 명함도 향상하는 방법들 보다 자연스럽고 향상된 결과를 가진다.

Abstract

In this paper, an efficient contrast enhancement algorithm using weighted histogram modification is proposed. For contrast enhancement, histogram equalization (HE) and histogram stretching (HS) are effective techniques. However, HE and HS may have excessive contrast enhancement. Proposed method using weighted histogram modification produces better natural and enhanced results than those of conventional contrast enhancement methods without artifacts.

Keywords : histogram, equalization, modification, contrast enhancement.

I. Introduction

Recently, providing enhanced image is a crucial role in services such as DMB, HDTV, video conference, and mobile network. Especially, contrast enhancement is an important one of image processing applications. Various images may not reveal the details and may have unpleasing looks. Contrast enhancement eliminates these problems and obtains enhanced and natural images.

Many contrast enhancement algorithms are proposed to improve the quality of an image. Algorithms can be categorized into two groups as a global contrast enhancement (GCE)[1, 3~4, 6~7] and a local contrast enhancement (LCE)[2, 5]. GCE use a single mapping function and LCE use a local mapping function, respectively. Although, LCE increases contrast directly on a pixel, this method suffers artifacts such as ring artifacts. Thus, we focus on GCE for preserving natural looking without artifacts.

Histogram equalization (HE) is one of the most popular contrast enhancement techniques[1, 7]. HE stretches the contrast of the high histogram region and compresses the contrast of the low histogram region. This technique is simple and effective, but it produces excessively enhanced and unnatural images. Thus, various methods have been proposed for the

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접수일자: 2010년7월13일, 수정완료일: 2010년8월31일

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. Thus, they may produce unnatural images.

Another unconventional approach based on the histogram has been proposed. Gray-level grouping (GLG) groups histogram bins and then redistributes these bins uniformly over the gray scale, iteratively [6]. 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)[8, 9]. The technique stretches histogram maps to darker and brighter. However, because of limitation of adjusting stretching level, the method creates artifacts with loosing details of white and black regions.

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. 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 apply automatically in a various images
· To describe simple operation method

In the next section, the existing contrast enhancement techniques will be described. In the Section III, the proposed method using weighted histogram modification is explained. Then, simulation 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 conventional histogram equalization and stretching.

A. Histogram Equalization (HE)

HE flattens and stretches the dynamic range of the image's histogram[7]. Thus, it obtains overall contrast enhancement. However, it may significantly change the brightness of the input image. In HE, the transformation function $T(x)$ is given by the following equation.

$$T(x) = (2^L - 1)\left\lfloor \sum_{j=0}^{x} p[j] + 0.5 \right\rfloor \quad (1)$$

where L is the number of bits used to represent the pixel value, $k \in [0, 2^L - 1]$, and x is the input pixel of level k. The normalized histogram $p(x)$ 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 $p[j]$. The transform function for mapping is a scaled version of the CDF.

A general framework based on histogram equalization (FHE) was also proposed[9]. The method is implemented given in

$$\tilde{H} = ((1+\lambda)I + sI^B)^{-1}(H + \lambda U), \quad (2)$$

where $\tilde{H}$ is modified histogram, H 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 s is black and white stretching level. However, this method has limited contrast enhancements because of not considering various contrasts in the image.

B. Histogram 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:

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

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. $T'(x)$ is a linear stretching function. However, HS also has limitations as HE, cannot adjust the level of enhancement. Thus, HS could obtain unnatural images.

Ⅲ. Proposed Algorithm

In this section, a weighted histogram modification method is presented. We propose weighted modification of input histogram according to various contrasts based on FHE.

The procedures of the proposed method are as follows.

1) Obtain sub-histogram: Generate sub-histograms $H_1,\ldots,H_{2^L-1}$ from input histogram H according to various contrast which is an absolute value of a horizontal two-lagged difference operation as shown in Fig. 1.

2) Modification: Modify sub-histogram as follows.

$$H_i'=\frac{\alpha}{2^L-1}\times H_i\times\beta^\gamma+\frac{2^L-1-\alpha}{2^L-1}\times U \quad (4)$$

where $\alpha/(2^L-1)$ and $(2^L-1-\alpha)/(2^L-1)$ are weights of histograms. H_i is sub-histogram and β^γ is weight for the level of contrast enhancement according to the difference value i. U is uniformly distributed histogram. H_i' is normalized by dividing the total count of ith sub-histogram. Then, we get normalized sub-histogram $\widehat{H}_i$ with the range $[0,1]$.

3) Stretching: black and white stretching of each modified sub-histogram.

4) Histogram equalization: Equalize each modified

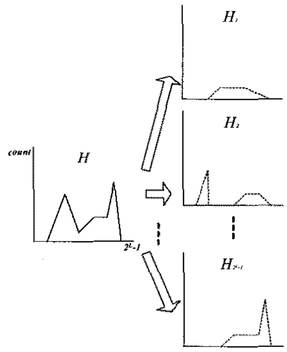


그림 1. 서브 히스토그램 생성
Fig. 1. Generation of sub-histograms.

sub-histogram and get the enhanced value by the sum according to the probabilities given in

$$y=\left\lfloor (2^L-1)\sum_{i=0}^{2^L-1}\sum_{j=0}^{x}\widehat{H}_i[j]\times p_i+0.5\right\rfloor \quad (5)$$

where x and y are input and output values, respectively. $\widehat{H}_i[j]$ and p_i are the histogram and the probability of the i difference value, respectively.

Ⅳ. Experimental results

In this section, the proposed algorithm and existing algorithms (HE[7], FHE[9], and Histogram Stretching (HS)[8]) are simulated on several images, and the results are compared. In our proposed method, the weights α, β are set to i which is the difference value. γ is the weight for the level of enhancement. For comparison, black and white stretching points B_b, B_w are set to points of 0.01 and 0.99 cumulative probabilities. In Fig. 2, we show enhanced images with different γ values.

Subjective assessment is used to compare contrast enhancement techniques. Additionally, we use the following quantitative measures such as Standard Deviation (STD), contrast factor $c_{i,j}$[10] which is the average of difference values between the reference pixel and its neighboring pixels as explained given in

$$c_{i,j}=\frac{1}{4}(|x_{i,j}-x_{i-1,j}|+|x_{i,j}-x_{i+1,j}| + |x_{i,j}-x_{i,j-1}|+|x_{i,j}-x_{i,j+1}|). \quad (6)$$

Also, we use a new contrast measure Contrast Ratio (CTR)[11] given by

$$C(s) = \sum_{0 \le j \le L} p_j s_j$$

$$\Phi = \max_{1 \le i \le L'} \{ T^{-1}(i) - T^{-1}(i-1) \}$$

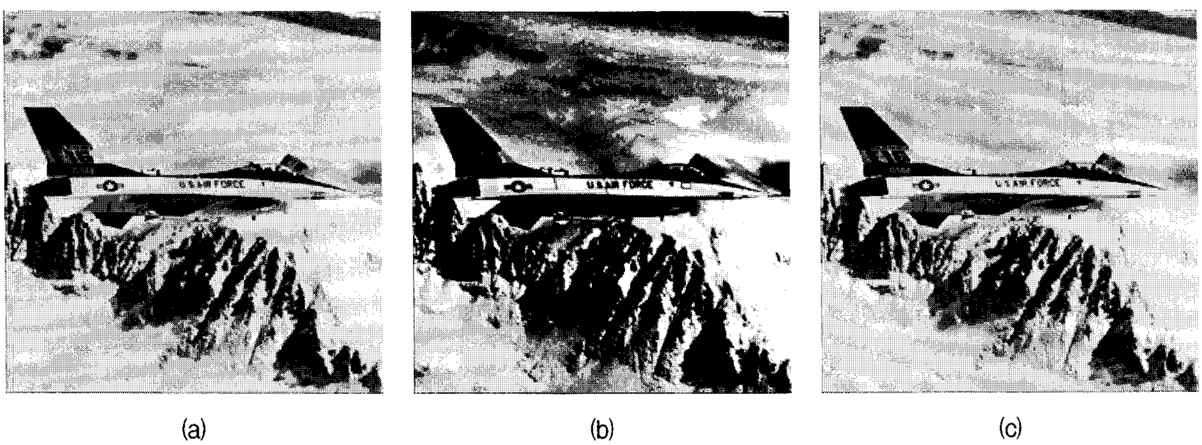
$$T^{-1}(i) = \min\{ j : T(j) = i \}$$

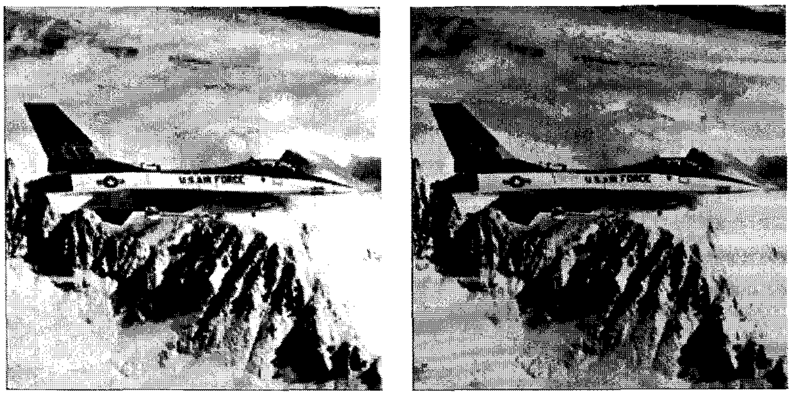
$$CTR = \frac{C(s)}{\Phi(s)} \tag{7}$$

where p_j, s_j are the probability and increment of

그림 2. Lena 영상 결과. (a) 원영상, (b) 제안한 알고리즘으로 향상된 영상으로 $\gamma=0$일 때, (c) $\gamma=1$일 때, (d) $\gamma=2$일 때, (e) $\gamma=3$일 때

Fig. 2. Results for Lena image. (a) Original image, (b) enhanced image using the proposed algorithm with $\gamma=0$, (c) with $\gamma=1$, (d) with $\gamma=2$, (e) with $\gamma=3$.

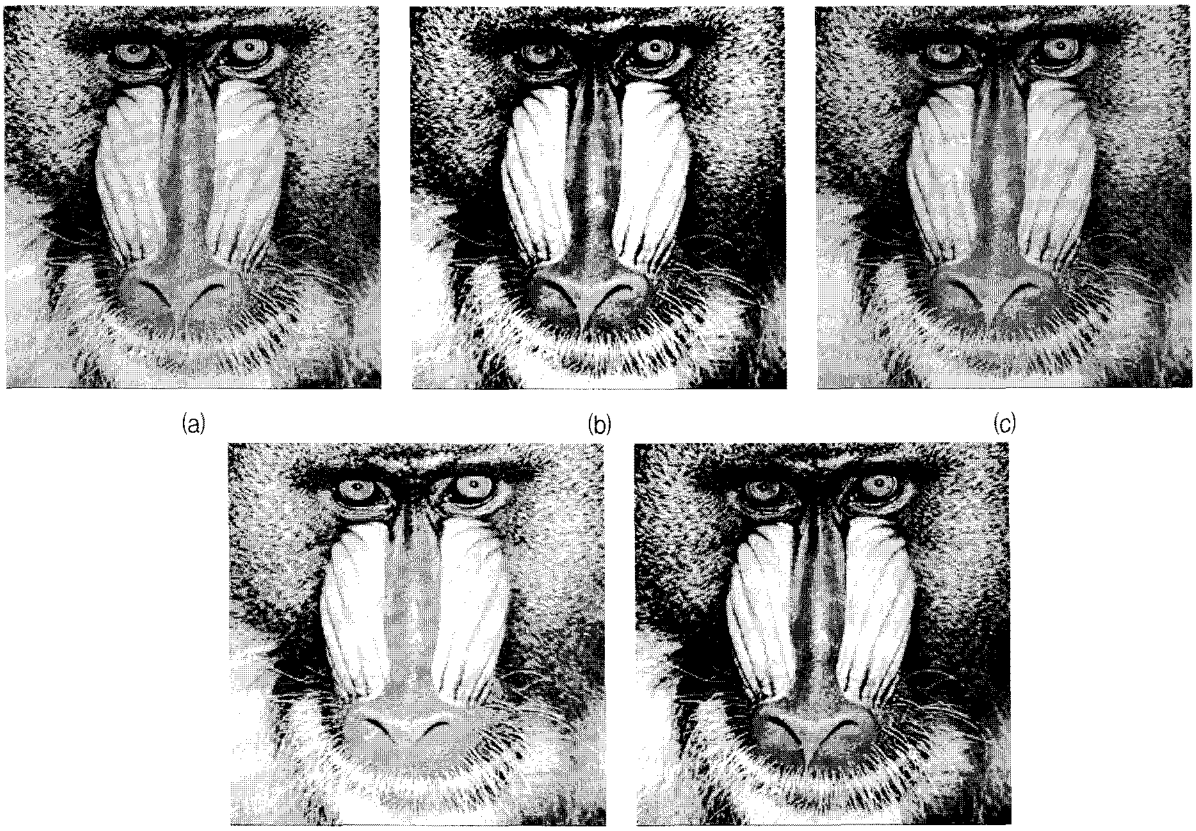




(d) (e)

그림 3. Airplane 영상 결과. (a) 원영상, (b) 제안한 알고리즘으로 향상된 영상으로 $\gamma=0$일 때, (c) $\gamma=1$일 때, (d) $\gamma=2$일 때, (e) $\gamma=3$일 때

Fig. 3. Results for Airplane image. (a) Original image, (b) enhanced image using HE, (c) FHE, (d) enhanced image using HS, (e) enhanced image using the proposed algorithm ($\gamma=2$).



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

그림 4. Baboon 영상 결과. (a) 원영상, (b) 제안한 알고리즘으로 향상된 영상으로 $\gamma=0$일 때, (c) $\gamma=1$일 때, (d) $\gamma=2$일 때, (e) $\gamma=3$일 때

Fig. 4. 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 ($\gamma=2$).

gray level j. $\boldsymbol{s}$ is $(s_0, s_1, \ldots, s_{L-1})$. T is the transfer function.

Fig. 3 and Fig. 4 show the original test images and their corresponding contrast enhanced images.

HE has the best transformation results of the dynamic range of the pixel values. However, this often does not obtain natural images with artifacts. In Fig. 3(b) and Fig. 4(b), these situations are observed. On the other hand, FHE, HS, and the proposed algorithm generate natural images. However, the proposed method shows better clear and enhanced images than those of FHE and HS.

Comparison results of quantitative measures are showed in Table 1 and Table 2. HE and HS have better $c_{i,j}$ results than those of the proposed method in Table I. However, there are artifacts and the mean values of images are more changed than those of our method. These show that HE and HS are not applicable to video applications. As shown in Table 2, our method has better STD contrast results than those of FHE and HS. Using new contrast measure CTR, we show our proposed method has higher contrast enhancement than HE, FHE, and HS in Table 3. Results show that our proposed algorithm has better contrast enhancement than the existing methods.

표 1. 정량적인 측정, $c_{i,j}$의 평균
Table 1. Quantitative Measurement Results. average of $c_{i,j}$

Image	HE	FHE	HS	Prop. (γ=2)	Prop. (γ=1)	Prop. (γ=0)
Airplane	11.35	6.40	7.83	7.73	6.88	6.07
Baboon	29.80	18.56	22.00	25.97	23.43	17.18
Lena	8.71	5.89	7.48	6.78	6.45	5.68
Pepper	10.13	7.12	8.62	8.11	7.58	6.87
Average	15.00	9.49	11.48	12.15	11.09	8.95

표 2. 정량적인 측정, STD
Table 2. Quantitative Measurement Results. STD.

Image	HE	FHE	HS	Prop. (γ=2)	Prop. (γ=1)	Prop. (γ=0)
Airplane	74.36	52.15	64.77	59.45	55.58	52.67
Baboon	73.73	45.69	53.95	65.77	57.92	48.12
Lena	73.60	49.68	53.48	59.45	54.29	50.03
Pepper	73.50	54.66	56.31	63.06	58.34	55.62
Average	73.80	50.55	57.13	61.93	56.53	51.61

표 3. 정량적인 측정, CTR
Table 3. Quantitative Measurement Results. CTR.

Image	HE	FHE	HS	Prop. (γ=2)	Prop. (γ=1)	Prop. (γ=0)
Airplane	0.17	0.59	0.06	1.37	1.16	1.16
Baboon	0.11	0.88	0.06	0.38	0.44	0.56
Lena	0.23	0.69	0.12	0.62	1.12	1.05
Pepper	0.44	0.59	0.17	1.55	1.25	1.23
Average	0.24	0.69	0.10	0.98	0.99	1.00

V. Conclusion

We proposed a contrast enhancement method using weighted histogram modification. It obtains visually enhanced images without artifacts.

Proposed method using weighted histogram modification enhances image's contrast according to the contents. Also, we could adjust enhanced level of the input image.

Experimental results show the proposed method has better performance than those of the conventional methods.

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