RESEARCH ARTICLE OPEN ACCESS

Contrast Enhancement of Color Images with Bi-Histogram

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ABSTRACT
Histogram equalization is a widely used scheme for contrast enhancement in a variety of applications due to its simple function and effectiveness. One possible drawback of the histogram equalization is that it can change the mean brightness of an image significantly as a consequence of histogram flattening. Clearly, this is not a desirable property when preserving the original mean brightness of a given image is necessary. Bi-histogram equalization is able to overcome this drawback for gray scale images. In this paper, we explore the use of bi-histogram equalization based technique for enhancing RGB color images. The technique is based on cumulative density function of a quantized image. From the results it is concluded that bi-histogram equalization is able to improve the contrast of colored images significantly.
Keywords— histogram equalization, histogram specification, Image enhancement, maximum entropy, mean brightness preserving.

I. INTRODUCTION

Histogram equalization is a well-known method for enhancing the contrast of a given image in accordance with the sample distribution. In general, histogram equalization flattens the density distribution of the resultant image and enhances the contrast of the image as a consequence [4]. In spite of its high performance in enhancing contrasts of a given image, however, Global histogram equalization may change the original brightness of an input image, deteriorate visual quality, or, introduce some annoying artifacts [woods].

Brightness preserving Bi-Histogram Equalization (BBHE) has been proposed to overcome these problems [2]. BBHE first separates the input image's histogram into two by using the image mean. Next, it equalizes the two sub-histograms independently. It has been analyzed that BBHE can preserve the original brightness to a certain extent when the input histogram has a quasi-symmetrical distribution around its mean. Later, equal area Dualistic Sub-Image Histogram Equalization (DSIHE) has been proposed [6], it claims that if the separating level of histogram is the median of the input image's brightness, it will yield the maximum entropy after two independent sub-equalizations [1]. Another scheme, named Recursive Mean-Separate Histogram equalization (RMSHE), has been proposed to preserve the brightness. RMSHE uses the BBHE iteratively. It is claimed theoretically that when the iteration level n grows larger, the output mean converges to the input mean, and thus yields good brightness preservation [7].

II. HISTOGRAM EQUALIZATION

Histogram equalization can be categorized into two methods: global and local histogram equalization. Global histogram equalization uses the histogram information of the whole input image as its transformation function. This transformation function stretches the contrast of the high histogram region and compresses the contrast of the low histogram region. In general, important objects have a higher and wider histogram region, so the contrast of these objects is stretched. On the other hand, the contrast of lower and narrower histogram regions, such as the background, is lost.

This global histogram equalization method is simple and powerful, but it cannot adapt to local brightness features of the input image because it uses only global histogram information over the whole image. This fact limits the contrast-stretching ratio in some parts of the image, and causes significant contrast losses in the background and other small regions. To overcome this limitation, a local histogram-equalization method has been developed, which can also be termed block-overlapped histogram equalization. [1]

Digital image with gray levels in the range [0, L −1], Probability Distribution Function of the image can be computed as equation,

$$P(r_k)=\frac{n_k}{N} \quad k=0,\ldots\ldots.L-1 \quad (1)$$

Where r_k is the k^{th} gray level and n_k is the number of pixels in the image having gray level r_k. Cumulative Distribution Function (CDF) can also be computed followed,

$$C(r_k) = \sum_{i=0}^{i=k} P(r_i) \quad (2)$$

$$K=0,\ldots\ldots.,L-1,\ 0 \le C(r_k) \le 1 \quad (3)$$

Let X={X(i,j)} denotes a given image composed of L discrete gray levels denotes as $\{X_0, X_1, \ldots\ldots X_{L-}$

$_1$},where X(i,j) intensity of the image at the spatial location (i,j) and X(i,j)Є{X_0,X_1, X_{L-1}}. In image X, the probability density function p(X_k) is defined as,

$$p(X_k)=\frac{n^k}{n} \quad (4)$$

In which k=0,1…….L-1, where n^k represents the number of times that the levels X_k appears in the input image X and n is the total number of samples in the input image. A plot of n^k and X_K is known as the histogram of X, based on the probability density function, we define the cumulative density function as,

$$C(x) = \sum_{j=0}^{k} p\,(Xj) \quad (5)$$

In this equation X_k =x for k=0,1…..L-1. Histogram equalization is a scheme that maps the input image into the entire dynamic range, (X_0, X_{L-1}) by using the cumulative density function as a transform function. That is, let ns define a transform function f(x) based on the
Cumulative density function as,

$$F(x)=X_0 + (X_{L-1}-X_0)\, c(x) \quad (6)$$

then the output image of the histogram equalization,
Y = {Y (i,j) } , can be expressed as,
Y=f(X)

$$=\{f(X(I,j))\forall X\,(i,j)X\} \quad (7)$$

III. BI HISTOGRAM EQUALIZATION(BHE)

Bi Histogram Equalization is used for improved histogram equalization (HE) method for contrast enhancement.[5] BHE first finds average point in histogram of the image and then divides histogram to two segments based on this point. After that histogram equalization operation is applied on each segment. There are two cumulative distribution functions for two segments. Gray level (rk) under the average point are pointed to the new gray level (S_k) as it can be seen in equation.[2]

$$S_k = (L_1) \times C_1(r_k)(8)$$

$$C_1(r_k) = (\textstyle\sum_{i=0}^{k} n_i) \,/\, (\sum_{j=0}^{k} n_j); \; (9)$$

K=0,1,……,L-1

Where L1 is the average of gray levels of the histogram and it can be computed as in equation. [5]

$$L_1 = \sum_{k=0}^{L-1} P_{(r_k)} * r_k \quad (10)$$

IV. DUALISTIC SUB-IMAGE HISTOGRAM EQUALIZATION

DSIHE [5] is very similar to BBHE, except that the separating point $X_D$is selected as the median gray level of the input image, i.e., $X_D$satisfies,

$$\int_0^D p_r\,(r)dr = 0.5 \quad (11)$$

For the applicable case, it may be modified as,

$$X_D=\text{argmin}_x\ |\int_0^x p_r\,(r)dr - 0.5 \; (12)$$

The purpose of DSIHE is to find a separating point, based on which the desired histogram (PDF) can obtain a maximum entropy. And it has been proved that the brightness of the output image is,

$$\mu_z= 0.5\ (X_D+ 0.5) \quad (13)$$

It is clear that DSIHE always pulls the output brightness toward the input middle level from the input median level.

V. RMSHE and MMBEBHE

RMSHE [6] is to recursively implement BBHE to the histogram. Obviously, recursive separation on the histogram will divide the histogram into very small pieces. If the recursive level tends to infinite, equalization to each small piece will not change the whole histogram, and thus can preserve the mean brightness. So an infinite recursive level results in the same output image as the input one. BBHE and DSIHE belong to “two-piece-separating” histogram equalization algorithm, and so does HE in a broad sense.

ProposedScheme forContrast Enhancement of Color Images

I. Read color image and find mean of image
II. Find two histogram of input image one is

xlpdf=hist(xl,[0:xm]); (14)

Second is xupdf=hist(xu,[xm+1:255]); (15)

III. Apply the code for enhance the image

skl=xm*xlnpdf*triu(ones(xm1));. (16)

sku=(xm+1)+((L-1
(xm+1))*xunpdf*triu(ones(xm2))); (17)

IV. Find the non-zero values

list=find(I==k);

V. Increase the list of value
y0(list)=sk(k+1);

VI. Results and Discussion

The proposed method was tested using different colored images. For testing a dataset is generated by taking good contrast images and saving them as benchmarks, after that their contrast is reduced and these low contrast images are enhanced using the proposed algorithm. The result was evaluated both qualitatively and quantitatively. The qualitative results compared with the benchmark images are shown in the Fig. 1 for two different images.
The results of the proposed algorithm for two test images are shown in Fig 1. As is evident from the

output images (E, F) their contrast is significantly improved from low contrast images (C, D) and even from the benchmark image (A, B).

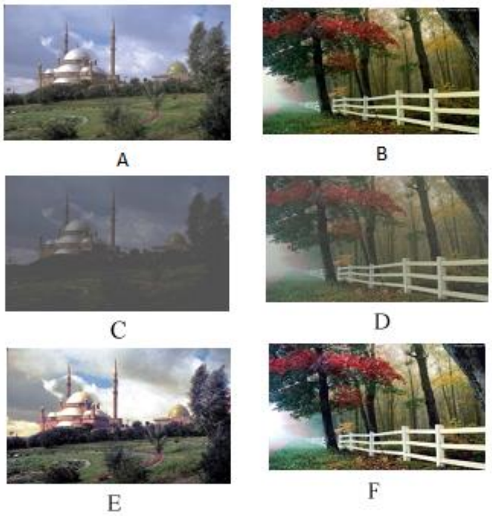

Figure 1: original images shown as A, B. Images after decreasing their contrast C, D. Results of the proposed algorithm for the three images E, F.

For quantitative measures peak signal-to-noise ratio (PSNR) is used to evaluate the results of the proposed algorithm. The PSNR, is an engineering term for the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Because many signals have a very wide dynamic range, PSNR is usually expressed in terms of the logarithmic decibel scale.

The PSNR is defined as:

$$PSNR = 10.\log 10 \left(\frac{MAX^2}{MSE}\right) \quad (18)$$

Table 2 gives PSNR values. PSNR values of the enhanced images are significantly imposed by applying Bi-histogram recursively to low contrast images. On average is 25% improvement from original low contrast images

Table 2: PSNR values of low contrast and enhanced images

No.	Original Image	Low Contrast	Bi-Histogram	Recursive Bi-Hist
1	A	14.5287	20.1598	42.1489
2	B	17.6055	19.2628	36.8856
3	C	13.6470	20.6009	40.9992
4	D	12.2553	22.0261	32.2151
5	E	15.7666	23.4272	41.2501

The role of different color channels in RGB images is also analyzed. In experiment two channels are kept the same and only one channel is enhanced before combining the three to get the output RGB image. The results are shown in Figure 2 and Table 3.

Figure 2 shows the visual results for one test image. The results show that modification in the Red channel gives the highest PSNR values for test images. Hence we may conclude that enhancement is more sensitive to Red channel.

Low contrast Image

Enhanced using Red channel

Enhanced using Green channel

Enhanced using Blue channel

Fig 2: Test image A and its enhancement using individual color channels (RGB)

Table 5.3: PSNR values after enhancing single color channel

Test Images	Red	Blue	Green
1	26.9683	26.1012	24.7322
2	27.2416	26.5309	29.1843

VII. CONCLUSION

In this paper, a bi-histogram algorithm used in gray scale images is modified for colored image contrast enhancement. The proposed algorithm gives promising results. The other advantage of using this method is its simple implementation and low time complexity.

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