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Contrast Enhancement Using Segmentation Based Histogram Equalization

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Abstract—

Contrast enhancement is an important area in the field of image processing which brings out contrast in images. To enhance contrast in images, histogram equalization (HE) is performed which stretches the dynamic range by calculating the probability density function (PDF) and the cumulative density functions (CDF). The drawback of HE is that, it alters the overall brightness of the image. Due to this drawback, a new method of HE is discussed which segments the histogram of the original image and controls the brightness level. In this study, the histogram of an image is segmented based on exposure threshold. The obtained sub histograms are subdivided based on the median value in to four sub histograms. Then, by calculating the clipping threshold the histograms are clipped to minimize over enhancement in images. Finally, equalization can be done by computing the transfer functions obtained for the sub images and integrating the sub images into single image. Simulation results demonstrate that, the proposed HE method is compared for various test images by computing peak-signal to-noise ratio (PSNR) using MATLAB.

Keywords— Histogram equalization, exposure, median, clipping threshold, Sub images, brightness, PSNR.

I. INTRODUCTION

Image processing brings the improvement of pictorial information for human perception. In image processing, images taken from different devices are used in different fields such as in medical, military, security and industrial fields. Image enhancement, pattern recognition, restoration, noise removal are some of the areas where image processing is used.

Image enhancement is an important area in image processing which involves processing of a given image so that the result is more suitable than the original image for particular application [1]. Enhancement involves sharpening of image characteristics such as edges, boundaries and contrast. Contrast enhancement increases the contrast of low quality images. It improves the perceptibility of objects by enhancing the brightness difference between objects and their backgrounds [2]. Contrast enhancement can be of two types direct and indirect enhancement. In direct enhancement, image contrast can be defined directly by a contrast term. Indirect method enhances contrast by continuous distribution of pixels. Mostly indirect methods are used for enhancement.

Contrast enhancement is required, when there is poor contrast in images. This poor contrast can be caused due to lack of lighting, the aperture size and shutter speed [3]. This can be avoided by enhancing the contrast. However, sometimes enhancement increases the overall brightness of the image. HE is the most suitable method for increasing contrast in images. It stretches the dynamic range of histogram to get a uniform distribution of the image which results in overall contrast enhancement which makes the image looks unnatural [4]. This can be avoided by introducing various methods of equalization in images.

One such method is a brightness preserving bi-histogram equalization (BBHE) which divides the histogram of the original image into two sub histograms based on the mean value. One histogram is having the values less than the mean value and another having values greater than the mean value. These sub-histograms can be equalized separately and the sub images thus formed can be combining to form single image [5]. This method preserves the average brightness and hence enhances contrast in images. Another method called, dualistic sub image histogram equalization (DSIHE) is similar to BBHE but it is better in terms of preserving brightness level. This method involves the sub division based on median instead of mean in BBHE, and equalization is performed separately [6]. The above mentioned methods do not provide facility image for adjusting the enhancement rate. Hence, a new method of HE is proposed which adjusts the enhancement level and maintains the brightness level. Contrast enhancement applications are in medical imaging, video surveillance and digital photography [7].

II. SEGMENTATION BASED HISTOGRAM EQUALIZATION

A. Histogram

The histogram provides details for defining the contrast and total intensity distribution of an image. The histogram of a digital image is defined as the intensity distribution of an image which is given in (1).

$$h(k) = n_k \tag{1}$$

where k is the gray level and n_k is the number of pixels in the image [8].

B. Histogram segmentation based on exposure and median

Exposure calculation

Histogram of an image is divided based on the exposure threshold. Exposure can be defined as the intensity exposure of the image. Exposure can be classified into two types as under and over exposure. Histogram of an image in the lower gray levels is termed as under exposed region and the histogram in higher gray levels are termed as over exposed region. The normalized value of exposure is 0-1. If the value of exposure is less than 0.5, then the image consists of majority of under exposed region and if it is greater than 0.5, the image contains majority of over exposed region. The intensity of exposure is calculated by using (2) which is given as,

$$\text{Exposure} = \frac{1}{L}\sum_{l=1}^{L}\frac{h(l)l}{h(l)} \tag{2}$$

where L is the total number of gray levels and h (l) is the histogram of the image [9]. The parameter called exposure threshold X_a divides the histogram of an image as under and over exposed regions which can be defined as

$$X_a = \text{L (1-exposure)} \tag{3}$$

Median calculation

The sub histograms obtained using (3) can be further divided into four sub regions by calculating the median value given in (4) and (5) as,

$$X_{ml} = \text{median (h (l))} \qquad 0 \le l \le X_a \tag{4}$$

$$X_{mu} = \text{median (h (l))} \qquad X_a + 1 \le l \le L-1 \tag{5}$$

C. Histogram clipping and equalization

Histogram can be clipped to avoid over enhancement in images. Clipping can be performed by using a clipping threshold. The values of histogram greater than this threshold are to be clipped. Clipping threshold is determined by taking the average number of gray levels present in the image [10]. Clipping threshold is calculated using

$$T_c = \frac{1}{L}\sum_{l=1}^{L}h(l) \tag{6}$$

Histogram values greater than this threshold are clipped and the histogram after clipping is given as $h_c(l)$ which is equal to T_c [10].

Computing density functions for the histograms

Histogram can be subdivided based on intensity as lower and upper histograms. This division separates a single histogram of image into four sub histograms. The PDF for these histograms are obtained as,

$$P_{Ll}(l) = \frac{h_c(l)}{N_{Ll}} \qquad \text{for} \qquad 0 \le l \le X_{ml} \qquad (7)$$

$$P_{Lu}(l) = \frac{h_c(l)}{N_{Lu}} \qquad \text{for} \qquad X_{ml} + 1 \le l \le X_a \qquad (8)$$

$$P_{Ul}(l) = \frac{h_c(l)}{N_{Ul}} \qquad \text{for} \qquad X_a + 1 \le l \le X_{mu} \qquad (9)$$

$$P_{Uu}(l) = \frac{h_c(l)}{N_{Uu}} \qquad \text{for} \qquad X_{mu} + 1 \le l \le L - 1 \qquad (10)$$

where N_{Ll}, N_{Lu}, N_{Ul}, N_{Uu} are the total number of pixels present in the histogram of sub image. The corresponding CDF for these sub images are also calculated by summing up the PDF obtained in (7), (8), (9) and (10). C_{Ll}(l), C_{Lu}(l), C_{Ul}(l), C_{Uu}(l) are the CDF obtained for the sub images respectively [11].

Histogram equalization

To equalize the histogram of the sub image ,we need to calculate the transfer function. The transfer function for the four sub images are defined as

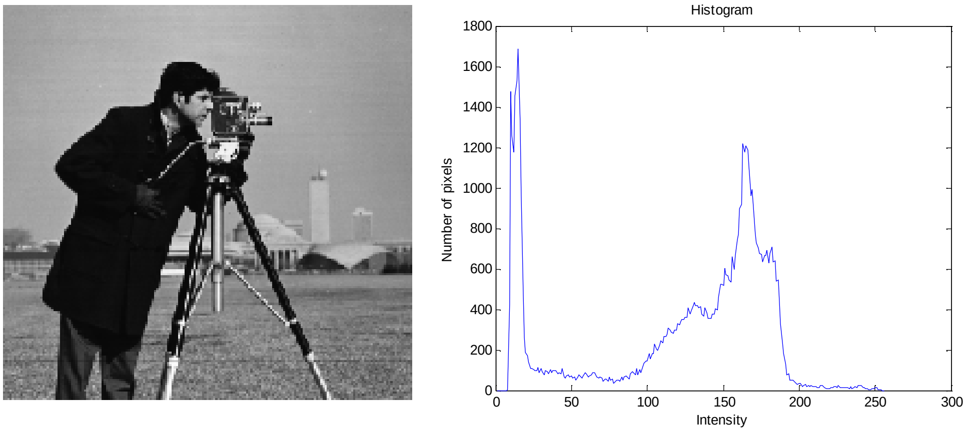
$$TF_{Ll} = (X_{ml} + 1) * C_{Ll} \qquad (11)$$

$$TF_{Lu} = (X_{ml} + 2) + (X_a + 1 – X_{ml} + 2) * C_{Lu} \qquad (12)$$

$$TF_{Ul} = (X_a + 2) + (X_{mu} + 1 – X_a + 2) * C_{Ul} \qquad (13)$$

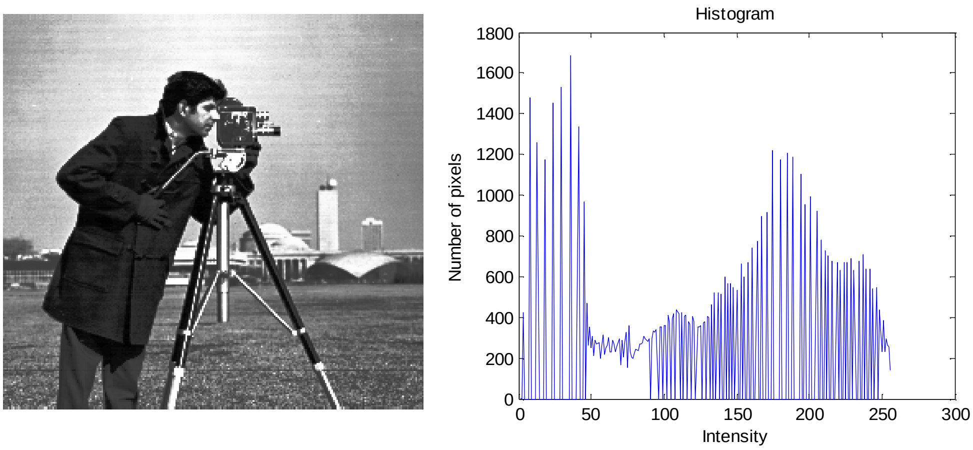
$$TF_{Uu} = (X_{mu} + 2) + (L – X_{mu} + 2) * C_{Uu} \qquad (14)$$

The transfer functions thus obtained are combined and equalization is done to obtain the single equalized image. In this section, the segmentation based HE is compared with the standard HE to evaluate the enhancement rate. Fig 1 (a) and (b) shows the original image and its histogram. Fig 2 (a) and (b) shows the standard HE and its histogram. Fig 3 (a) and (b) shows the segmentation based HE and its histogram.



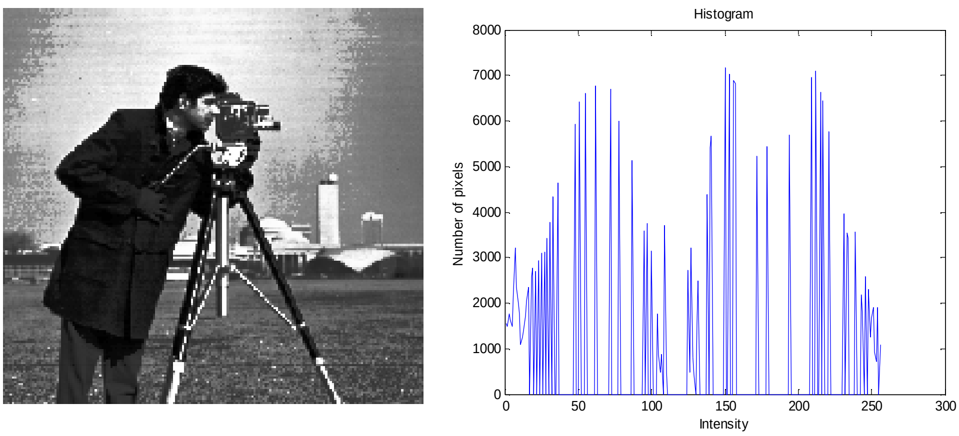
(a) (b)

Figure 1. (a) Original image (b) Histogram of original image



(a) (b)

Figure 2. (a) Standard HE (b) Histogram of Standard HE



(a) (b)

Figure 3. (a) Segmentation based HE (b) Histogram of Segmentation based HE

D. Histogram equalization for color images

Histogram equalization can be applied only for grayscale images. For color images, it can be converted into color space with a separate luminance channel such as YCbCr, NTSC, YUV. Then, histogram equalization can be done in the luminance channel by keeping other channels as it is, and then converting the image to RGB to produce an enhanced image.

For color images, the proposed HE gives better enhancement than grayscale images. Fig. 4 (a) shows the original image Fig. 4 (b) shows the standard HE and Fig. 4 (c) shows the segmentation based HE.

(a) (b) (c)

Figure 4. (a) Original image (b) Standard HE (c) Segmentation based HE

III. SIMULATION RESULTS

The segmentation based HE method is compared with the BBHE method by computing the performance metric. The segmentation based HE performs better than BBHE in terms of measuring PSNR.

Mean Square Error (MSE) and PSNR

MSE

The most frequent measurement of image quality is the mean square (MSE) and the peak signal-to-noise ratio [11]. Let a (i, j) be the original image with size MxN and a' (i, j) is the modified image with same size. The MSE is expressed as

$$MSE = \frac{1}{MN}\sum_{ij}(a'(i,j) - a(i,j))^2 \quad (15)$$

PSNR

PSNR is expressed in decibel as

$$PSNR = 10\log_{10}\left(\frac{255\times 255}{MSE}\right) \quad (16)$$

Table I. **PSNR Results**

Test images	BBHE	Segmentation based HE
Cameraman	14.20	17.67
Coins	8.48	15.68
Pout	11.07	14.10
Lena	16.66	22.39
Peppers	16.43	19.65
Football	16.09	16.39

IV. CONCLUSION

In this study, the segmentation based HE method segments and equalizes the image which results in maintaining the brightness level and provides control in enhancement rate. The simulation results shows that for various test images, the PSNR of the proposed segmentation based HE is better than the BBHE and it provides better enhancement. The segmentation based HE also provides better brightness which makes the image looks natural. Thus, the proposed method outperforms other methods in terms of enhancement and preserving brightness.

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