Histogram Portioning and Equalization Based Enhancement Method for Multiple Applications

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Abstract

New method for image enhancement based on histogram division is introduced in this paper. Human eyes sense the differences in brightness of an image when two most significant bits of pixel value are changed. Proposed method suggests equalizing the histogram after its portioning into four parts. The advantages of this division are brightness preserving and avoiding over enhancement phenomena. The proposed method is non parametric and fast which makes it more compatible with HD images enhancement. Experimental results proved that the proposed method has high performance to enhance the image with preserving the original image brightness. Also enhancement time for proposed method is very short compared to different enhancement algorithms.

Keywords: HD image, HE, Histogram portioning, Image enhancement, Remote sensing.

1. Introduction

The aim of contrast enhancement is to improve the quality of visibility for pattern recognition, computer vision, and the processing of digital images. Captured scene under untoward ecological, absence of photographer expertise, and inadequacy of the image capture device leads to results poor image contrast. Many methods have been proposed emphasize on enhancing different properties or components of images (H. Zhu 1999). Histogram Equalization (HE) is an image enhancement technique through equalizes the frequency appearance of different grey values to increase the dynamic range. This technique is commonly employed for image enhancement because of its simplicity and comparatively better performance on almost all types of images (Manpreet Kaur 2011; Schatz 2013). The HE technique distributes pixel values uniformly and results in an enhanced image with linear cumulative histogram, as shown below (Wadi & Zainal 2012):

$$Y(i,j) = X_0 + (X_{L-1} + X_0)c(X_k) \quad (1)$$

where X_0, X_{L-1} are the minimum and maximum grey levels values, $Y(i,j)$ is the value of enhanced pixel, $c(X_k)$ is cumulative distribution probability and calculated by Eq. (2) below:

$$c(X_k) = \sum_{j=0}^{k} p(X_j) \quad (2)$$

where

$$p(X_k) = \frac{n_k}{n} \tag{3}$$

However, the high densities of background regions lead to over-enhancement for these regions when enhanced by histogram equalization at the expense of objects.

Several algorithms were proposed to address the HE technique problems. Y.T. Kgim (Yeong-Taeg 1997), proposed to divide image histogram to two parts depend on mean intensity before equalize each part alone in method named as the Brightness-preserving Bi –Histogram Equalization (BBHE). Median value instead of mean value was used to divide the histogram in Dualistic Sub-Image Histogram Equalization (DSIHE) (Yu et al. 1999). C. Wang *et al* (Chao & Zhongfu 2005), suggests method named as Brightness Preserving Histogram Equalization with Maximum Entropy (BPHEME) to get maximum entropy with preserving the mean brightness. BPHEME is a histogram specification method where preparing an equation based on the entropy and finding the optimal probability density functions (PDFs) to get maximum entropy. However, time complexity of these methods is high compared to HE technique and mean brightness still changed in enhanced image with appearance of some artifacts.

Recursive Mean-Separate Histogram Equalization (RMSHE) (Soong-Der & Ramli 2003) and Minimum Mean Brightness Error Bi-Histogram Equalization (MMBEBHE) (Soong-Der & Ramli 2003) has been proposed to reduce generation of artifacts and preserving mean brightness better. RMSHE method is based on dividing original image into sub images depend on mean brightness recursively then equalizing each part alone. Whilst, MMBEBHE method is rely on separating the image into two images using best point. This optimal point determined by finding the minimum mean brightness error between original and output images. However, these methods are more parametric and need more execution time.

Usually, human eyes are not sensitive to gradient for gray levels converged. New contrast enhancement method proposed in this paper based on image division and HE technique. Histogram of original image is divided into four regions with equally of gray levels, and then HE technique is applied on each part alone. This will guarantee contrast enhancement to images with preserving mean brightness of original image. Another advantage of proposed method is avoiding the over enhancement in background regions where division image operation included separation between background and objects regions which are equalized separately. The proposed method is more compatible with HD remote sensing image because it is nonparametric method and has low cost computations.

The rest of paper as follow: Section 2 introduces the proposed method. Experimental results and performance evaluation are given in Section 3. Conclusions finding produced in Section 4.

2. Proposed Method

Generally, the values of grey levels are in range of 0 to 255, therefore we need eight bits to represent these values in binary system. The human eyes are sensitive to the gradient of grey levels when its two most significant bits are changed as clearly shown in Figure 1. Simple experiment explained in Figure 1 where (a) represent the image with all pixel equal to 5 or $(\mathbf{00}000101)_2$, in (b) all pixel equal to 69 $(\mathbf{01}000101)_2$, in (c) pixels equal to 133 or $(\mathbf{10}000101)_2$, and in (d) pixels values are 197 or $(\mathbf{11}000101)_2$ where these figures show the difference in gradient when two Most Significant Bits changed.

The aim of proposed method is enhancement of the image contrast with preserving original image mean brightness. According to concept shown in Figure 1, we suggest to divide the original image into four sub-images then equalize each part alone using HE techniques. Also, for image which has high density of background (for example medical images) do this division to ensure separation between background and objects regions, this prevents the occurrence of over-enhancement.

Let an input image I divided into four parts R_1, R_2, R_3, and R_4 as

$$I = R_1 \cup R_2 \cup R_3 \cup R_4 \tag{4}$$

where R_1 = (0-63) or $(\mathbf{00}000000\text{-}\mathbf{00}111111)_2$, R_2 = (64-127) or $(\mathbf{01}000000\text{-}\mathbf{01}111111)_2$, R_3 = (128-191) or $(\mathbf{10}000000\text{-}\mathbf{10}111111)_2$, and R_4 = (192-255) or $(\mathbf{11}000000\text{-}\mathbf{11}111111)_2$.

Then, the probability density function PDFs of image parts is defined as

$$p_r(X_k) = \frac{n_k}{n_r} \tag{5}$$

where $k = d + (r\text{-}1)*64$; r =1, 2, 3, and 4; d=1, 2,…, 63; n_k is no. of pixels at X_k grey level in each part; n_r is no. of pixels in R_r .

The respective cumulative density functions CDFs of image regions are then obtained by

$$c_r(X_k) = \sum_{i=0}^{k} p_r(X_i) \tag{6}$$

Now, as in HE technique, the transform function of R_1, R_2, R_3 and R_4 defined as:

$$f_r(X_k) = X_{c(r)} + (X_{cc(r)} - X_{c(r)})c_r(X_k) \tag{7}$$

where $c(r)$ = (0, 64, 128, 192), $cc(r)$ = (63, 127, 191, 255), and k = 0, 1, …, 255.

Finally, the enhanced image *EI* can expressed as

$$EI = f_1 \cup f_2 \cup f_3 \cup f_4 \tag{8}$$

3. Experimental Results

This section summarizes the performance evaluation of proposed method as compared with the HE, BBHE, DSIHE, RSIHE, and MMBEBHE. Several factors used to enforce the comparison such as visual assessment, histogram analysis, entropy, contrast and mean brightness.

3.1 Visual Assessment

Two image “one HD remote sensing image (1080×1920) and the other medical image (512×512)” are used as the tests in this subsection to check the enhancement abilities for each method as in Figures 2 and 3. An HD remote sensing and medical images with low contrast is shown in Figures 2a and 3a, respectively. Images enhanced using HE and BBHE are shown in Figures 2b, 2c, 3b and 3c, where clearly show that the images enhanced by those two methods suffer from over enhancement. Enhanced image in Figures 2d and 3d appears that DSIHE method produces low contrast enhancement for original image. RSIHE method introduces enhanced image with low preserving of original image mean brightness as shown in Figures 2e and 3e. Proposed method introduced good enhancement with preserving of mean brightness as appear in Figures 2f and 3f. Visual assessment proved that the proposed method introduced best contrast enhancing for original image compared to other methods.

Histogram distribution of tests images and its enhancement by different methods are shown in Figures 4 and 5. Proposed method histogram shown in Figures 4f and 5f are the best because it is not excessively starched the original image Figures 4a and 5a compared with other methods specially HE and BBHE in Figures 4b, 4c, 5b and 5c.

3.2 Quantitative measure

Entropy value (Wadi & Zainal 2013), Absolute Mean Brightness Error (AMBE) (Celik & Tjahjadi 2012), contrast (Beghdadi & Le Negrate 1989), Peak Signal to Noise ratio (PSNR) (Yu et al. 2007), and execution time are measured to evaluate the proposed method quantitatively. More than 200 images used in quantitative evaluation where the average results are shown in Table 1.

In image processing, entropy is defined as the measure to randomness which can be interpreted as the average uncertainty of the information source. Entropy is calculated by as below:

$$H(x) = \sum_{i=1}^{K} P(x_i) \log_2 \frac{1}{P(x_i)} = -\sum_{i=1}^{K} P(x_i) \log_2 P(x_i) \quad (9)$$

where the $P(x_i)$ is the probability of symbol x_i. Table 1 shows the proposed method that produced enhanced image with higher entropy than other methods and nearest to original image entropy.

AMBE is the absolute value of the difference between mean value of original image A and an enhancement image B, where mathematically be expressed as

$$AMBE(A, B) = |MB(A) - MB(B)| \quad (10)$$

where *MB* (*A*) and *MB* (*B*) is the mean brightness value of original and enhancement image respectively. Method produce enhancement image with low AMBE is the best where means method preserved the mean brightness of original image in enhanced image. As clearly shown in Table 1, the *AMBE* of proposed method is best in compared with other methods.

PSNR is a pixel-based evaluation of image quality after pixels values changes of this image. PSNR is commonly used as image quality measure in most image processing papers. PSNR is calculated using MSE (Mean Square Error) as in equations below:

$$MSE = \frac{1}{MN} \sum_{l=1}^{M} \sum_{j=1}^{N} (x_{ij} - y_{ij})^2 \quad (11)$$

where *M* and *N* denote the images dimensions, $x_{i,j}$ and $y_{i,j}$ stand for the value of pixel (*i*, *j*) in the original and the processed images, respectively. Now PSNR calculated as

$$PSNR = 10 \times \log_{10} \frac{255^2}{MSE} \quad (12)$$

Results shown in Table 1 proved that the best value of PSNR is achieved by the proposed method.

Execution time of enhancement method is important factor especially when applied on HD image. Therefore, a comparison between different methods in term of time execution will be implemented. According to Table 1, we can find the suggested method is the fastest among other enhancement methods.

4. Conclusion

New contrast enhancement method is introduced in this paper to enhance the HD image. Generally, human eyes are sensitive for variation in pixel image value and mean brightness when two most significant bits of pixel image are changed. Therefore, to enhance the image contrast with preserving the mean brightness and avoiding the extra-enhancement we firstly divided the original image histogram into sub parts as R1 = (0-63) or (00000000-00111111)2, R2 = (64-127) or (01000000-01111111)2, R3 = (128-191) or (10000000-10111111)2, and R4 = (192-255) or (11000000-11111111)2. Then each sub part of histogram is equalized alone. The sub-histogram of image are collected after its equalized to reconstructed the enhanced image. Evaluation results produced in sec. 3 proved that the proposed method enhance the HD remote sensing images with high performance in terms of entropy, PSNR, AMBE, and enhancement time. Visual assessments show that the contrast original image is enhanced without over enhancement as in other method specially HE and BBHE. Time consumption comparison between proposed and other methods proved that the proposed method is the fastest therefore can use to HD image enhancement.

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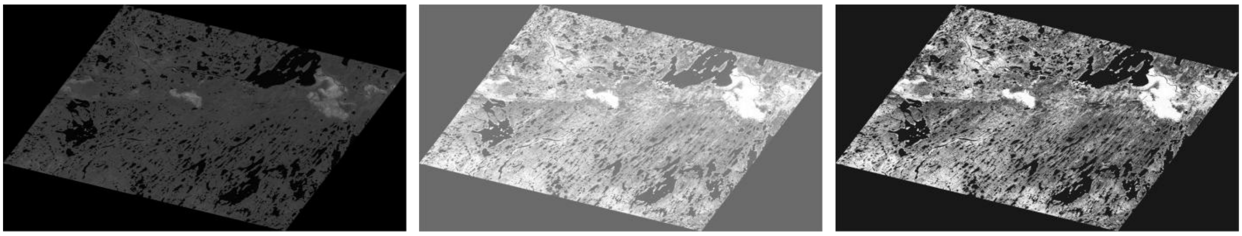
Table 1. Quantitative evaluation results.

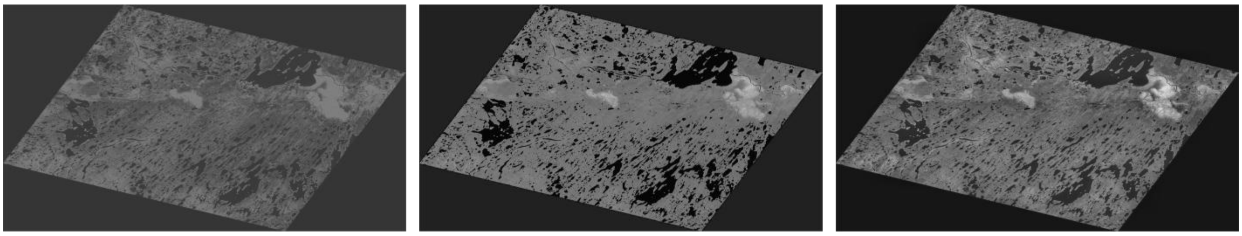
Method	Entropy	PSNR(dB)	AMBE	Time (S)
Original	5.13	-	-	-
HE	5.03	28.29	71.61	33.71
BBHE	5.05	34.28	58.18	25.54
DSIHE	4.99	29.38	7.98	25.39
RSIHE	4.89	37.01	37.91	21.15
Proposed method	**5.11**	**44.29**	**4.20**	**15.59**

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

Figure 1. An experiment to explain the gradient of image gray levels; (a) image with pixels value equal to 5 or $(\mathbf{00}000101)_2$; (b) image with pixels value equal to 69 or $(\mathbf{01}000101)_2$; (c) image with pixels value equal to 133 or $(\mathbf{10}000101)_2$; (d) image with pixels value equal to 197 or $(\mathbf{11}000101)_2$.



(a) (b) (c)



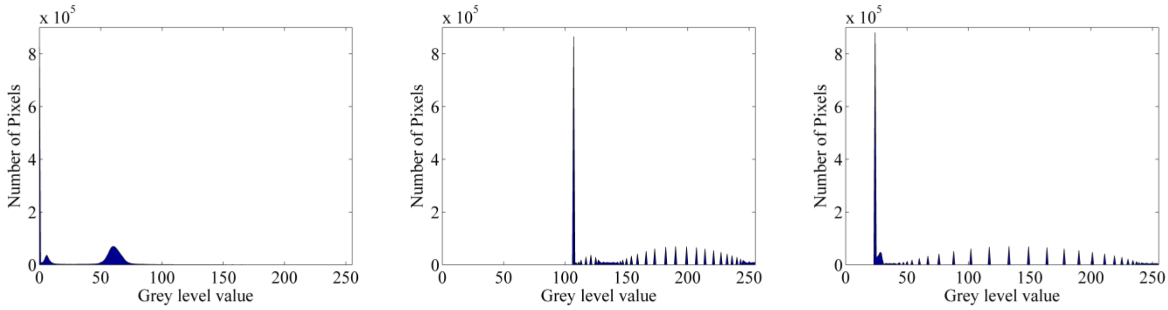
(c) (d) (e)

Figure 2. Visual assessment of test1 (remote sensing 1080×1920). (a) original image ; (b) Enhanced image by HE; (c) Enhanced image by BBHE; (d) Enhanced image by DSIHE ; (e) Enhanced image by RSIHE and (f) Enhanced image by proposed method.

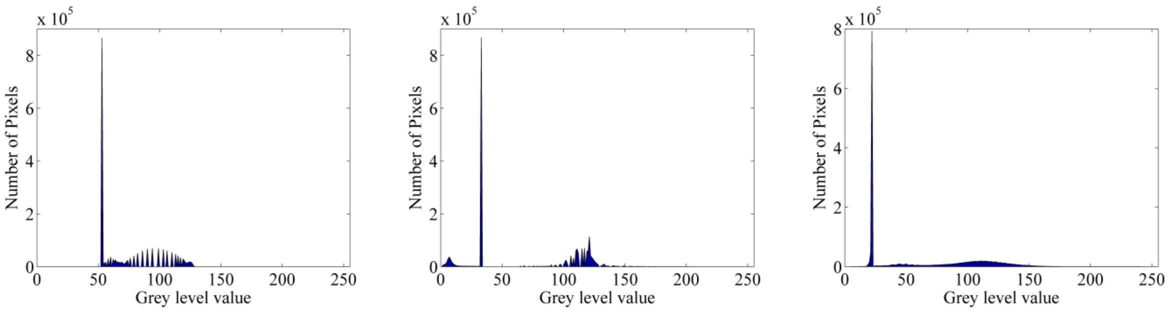
(a) (b) (c)

(c) (d) (e)

Figure 3. Visual Assessment of test2 (medical 512×512). (a) original image ; (b) Enhanced image by HE; (c) Enhanced image by BBHE; (d) Enhanced image by DSIHE ; (e) Enhanced image by RSIHE and (f) Enhanced image by proposed method.



(a) (b) (c)



(c) (d) (e)

Figure 4. Histogram distribution of test1 (remote sensing 1080×1920). (a) Original image; (b) HE; (c) BBHE; (d) DSIHE; (e) RSIHE; and (f) Proposed method.

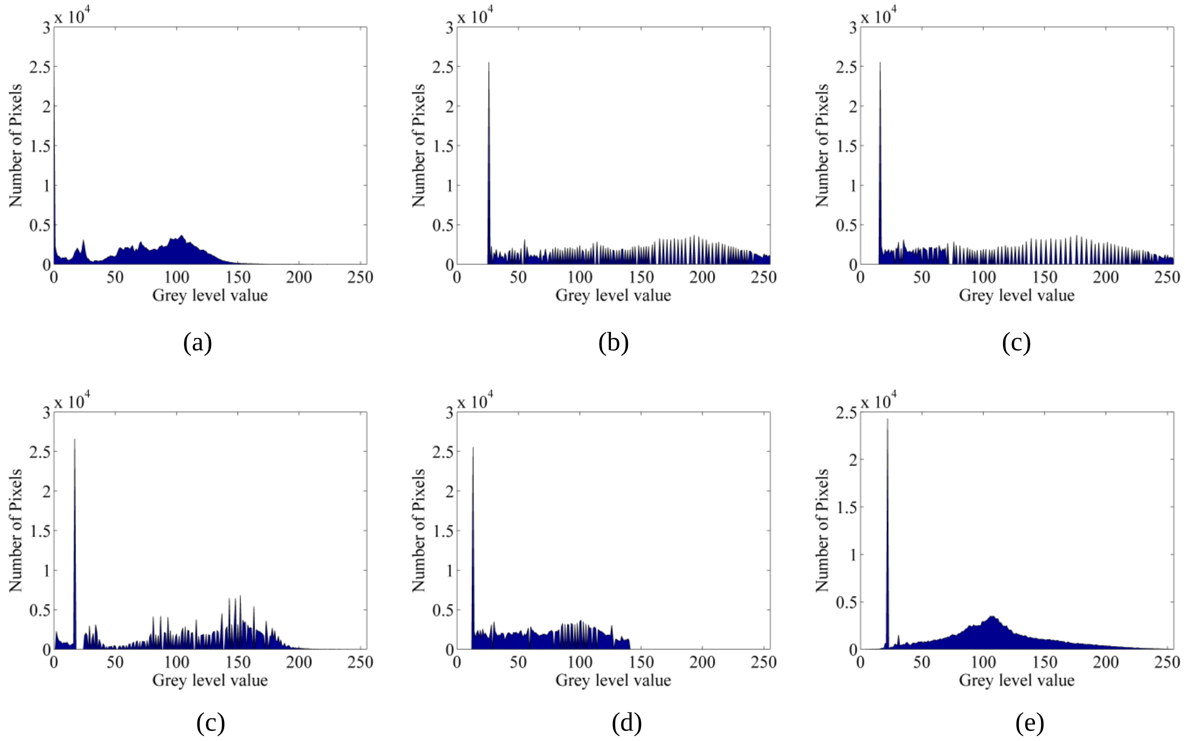


Figure 5. Histogram distribution of test2 (medical 512×512). (a) Original image; (b) HE; (c) BBHE; (d) DSIHE; (e) RSIHE; and (f) Proposed method.