Comparative study of Histogram Equalization Enhancement Techniques for Medical Images

Ahmed N. Ismael, Noura H. Ajam, Zainab S. Jumaa

Abstract

Image enhancement plays a fundamental role in vision applications. Enhancement is the manner of improving the superiority of an electronic digital stored image. Recently much work is completed in the field of images enhancement. Many techniques have previously been proposed up to now for enhancing the digital images. This paper applies three enhanced techniques which are histogram equalization(HE), adaptive histogram equalization(AHE) and contrast-limited adaptive histogram equalization(CLAHE). Structural similarity index matrix (SSIM), entropy and signal to noise ratio (SNR)are used as measures to compare between the enhanced images by three techniques. Experimental results showed that different values between enhanced images for techniques. The AHE produced an images have higher SSIM values with lower entropy when comparing with HE and CLAHE. In addition, AHE produced maximum entropy values with batter SNR values compared with other techniques. Analysis of the enhanced results by HE, AHE, and CLAHE are given in this paper.

Keywords: *Image Enhancement Techniques; Histogram Equalization, Structural Similarity Index Matri,EntropySignal to noise ratio*

—————————— ◆ ——————————

1- INTRODUCTION

The basic goal of image enhancement is to process the image so that we can view and Assess the visual information it contains with greater clarity. The primary condition for image enhancement is that the information that you want to extract ,emphasize or restore must exist in the image[1] .So that the image enhancement problem can be formulated as follows : given an input low quality image and the output high quality image for specific application .It is well-known that the image enhancement as an active topic in medical imaging has received much attention in recent years [2]. Image enhancement involves manipulation in contrast, changes in image brightness. Digital image is subjected to various modifications include contrast stretching and removal of noise in order to improve the quality of image.   Image enhancement techniques can be broadly categorized into two techniques: Spatial Domain Enhancing Techniques and Frequency Domain Enhancing Techniques. The spatial domain Enhancing techniques will directly operate on the pixels of digital image[3]. The intensity values of images are manipulated in order to achieve required image enhancement. The Spatial based domain techniques are easy to understand and conceptually simple so that complexity has been reduced[4]. The frequency domain techniques are mainly user for transforming image into frequency domain by computed the Fourier transform of the image This technique has low computational complexity and it can manage the frequency composition of the image but it is unable to enhance all the portions of image concurrently in better way and there is a complexity in using this process[5]. In this paper a comparative analysis based on spatial domain enhancement using Measures of image enhancement is applied on a data set includes 15 of medical images represent a different sections of bone captured through a digital camera. The results of this Comparative analysis are given in tables showing the values of improved images when the spatial domain techniques and measures of enhancement are applied. The rest of the paper has been ordered as follows: second section describes various image enhancement techniques of acquired medical images, third section gives parameters to evaluate the techniques and forth section provides experimental results. Finally, fifth section shows overall conclusion of the paper.

2- IMAGE ENHANCEMENT TECHNIQUES

Image enhancement techniques can be based on either spatial or frequency domain . Histogram equalization is a well-known spatial domain enhancement technique due to its strong performance and easy algorithm in medical images. In this paper, three different HE techniques have been used which is (HE, AHE,CLAHE) and compare them among using image quality metrics. Description of each one as follow:

2.1- Histogram Equalization (HE)

Histogram Equalization is a popular technique of image's contrast enhancement in image processing. This technique used to improve the contrast of images by distributing the most frequent intensities of values on the histogram[6]. It uses the same transformation function derived from the image histogram to transform all pixels. This works well in images with background and foreground that are both bright or both dark, but when the image contains regions that are significantly lighter or darker than most of the image, the contrast in those regions will not be sufficiently enhanced. In particular, this technique treats the image globally, thus it is reasonable to adopt adaptive technique for improving the local contrast of image and bringing out more details. This technique called AHE which it is extension to HE [7].

2.2 Adaptive histogram equalization (AHE)

AHE is another enhancement technique used to improve contrast in images. Its idea is different from ordinary HE [8]. In AHE, several histograms are computed, each corresponding to a distinct tiles of the image, rather than the entire image and uses them to redistribute the intensity of the image[9]. AHE uses a transformation function derived from a neighborhood region to

transform each pixel. Simply, each pixel is transformed based

on the histogram of a square surrounding the pixel. However, AHE has a tendency to over amplify noise in relatively homogeneous regions of an image. A variant of adaptive histogram equalization called contrast limited adaptive histogram equalization (CLAHE) prevents this by limiting the amplification. This technique emphasizes local contrast, rather than global contrast[10].

2.3 Contrast-Limited Adaptive Histogram Equalization (CLAHE)

CLAHE is a variant of AHE used for reduce contrast amplification in homogenous region of images since ordinary[11].. The contrast amplification in the vicinity of a given pixel value is given by the slope of the transformation function. This is proportional to the slope of the neighborhood cumulative distribution function (CDF) and therefore to the value of the histogram at that pixel value. CLAHE limits the amplification by clipping the histogram at a predefined value before computing the CDF. This limits the slope of the CDF and therefore of the transformation function [12].

The value at which the histogram is clipped, the so-called clip limit, depends on the normalization of the histogram and thereby on the size of the neighborhood region. Common values limit the resulting amplification to between 3 and 4. It is advantageous not to discard the part of the histogram that exceeds the clip limit but to redistribute it equally among all histogram bins [13]. The redistribution will push some bins over the clip limit again resulting in an effective clip limit that is larger than the prescribed limit and the exact value of which depends on the image. If this is undesirable, the redistribution procedure can be repeated recursively until the excess is negligible.

3- EVALUATION OF ENHANCEMENT TECHNIQUES

The comparison among proposed and other available techniques will be drawn by taking the following parameters:

1- Structural similarity index matrix

2- Entropy

3- Signal to noise ratio

3.1 Structural Similarity Index Matrix

is generally used to estimate the image excellence and differences between the original and the processed image [14]. It is a well-known quality metric used to measure the similarity between two images. It was developed by Wang and is considered to be correlated with the quality perception of the human visual system (HVS) Instead of using traditional error summation techniques, the SSIM is designed by modeling any image distortion as a combination of three factors that are loss of correlation, luminance distortion and contrast distortion according to the following formula [15].

$$\text{SSIM } (f.g) = I(f.g)\, c(f.g)\, s(f.g) \qquad \ldots\ldots(1)$$

$$I(f.g) = \frac{2ufug + C1}{u2f + Y2g + C1}$$

$$c(f.g) = \frac{2\sigma f \sigma g + C2}{\sigma 2f + \sigma 2g + C2} \qquad \ldots\ldots(2)$$

$$s(f.g) = \frac{\sigma fg + C3}{\sigma f \sigma g + C3}$$

The first term in (2) is the luminance comparison function which measures the closeness of the two images' mean luminance (µf and µg). This factor is maximal and equal to 1only if µf=µg. The second term is the contrast comparison function which measures the closeness of the contrast of the Here the contrast is measured by the standard deviation σf and σg.

This term is maximal and equal to 1 only The third term is the structure comparison function which measures the correlation coefficient between the two images f and g. Note that σfg is the covariance between f and g.The positive values of the SSIM index are in [0,1]. A value of 0 means no correlation between images, and 1 means that f=g. The positive constants C 1, C 2 and C 3 are used to avoid a null denominator.

3.2 Entropy

The average information content known as entropy is used for measure of image quality. Larger the value of entropy, more the information content in the image[16]

$$\text{ENT} = -\sum_{1=0}^{L-1} I(1)\log I$$

Where ENT (i) represents entropy, I(l) is probability density function of image having l intensity level and L number of gray levels.

3.3 Signal to noise ratio

Consider r(x,y) be the original image and t(x,y) is enhanced image. The noise estimation in enhanced fundus image is analyzed by[17]

$$SNR = 10.\log_{10} \dfrac{\sum_{0}^{nx-1}\left(\sum_{0}^{ny-1} r[(x.y)]2\right)^{0}}{\dfrac{1}{nxny}\sum_{0}\left(\sum_{0}^{ny-1} r[(x.y)] - t(x.y)]2\right)}$$

4.EXPERIMENTAL RESULTS

This section presents the relative performance and comparison of various equalization enhancement techniques. Three measures have been chosen to applied on techniques which are SSIM, entropy and SNR respectively. Medical images have been taken as dataset for apply the techniques. The images captured by digital camera and stored as JPEG format with dimensions 520*520 pixels. Totally, there are 15 medical images in the dataset. The comparison between all enhanced images achieved using MATLAB R2017a software running window XP as operating system. Samples of dataset images are shown in

below figure.

techniques. we analysis that AHE technique has produced the maximum entropy values and CLAHE has a less values among three techniques. Also, the performance for three techniques has been measured in terms of calculating the values of SNR. Moreover, AHE technique has a batter of SNR values for enhanced images while HE technique produced worst values for images. The statistical
analyses of SNR for enhancement techniques are shown in table 2.

Table 1: SSIM values of techniques

Image	HE	AHE	CLAHE
1	0,9583	0,9437	0,9593
2	0,9543	0,9507	0,9698
3	0,8738	0,8623	0,9036
4	0,8966	0,9075	0,9219
5	0,9110	0,8823	0,9364
6	0,9327	0,9322	0,9469
7	0,8694	0,8462	0,9115
8	0,8176	0,8028	0,8518
9	0,9401	0,9115	0,9422
10	0,9626	0,9535	0.9774
11	0,9361	0,8923	0,9228
12	0,8551	0,7835	0,9031
13	0,9007	0,9035	0,9278
14	0,8598	0,8438	0,9072
15	0,9406	0,9260	0,9601

From the analysis of SSIM values of techniques in Table1, it has been seen that the HE technique produces higher SSIM values in enhanced images as compared to other

Table 2: SNR values of techniques

Image	HE	AHE	CLAHE
1	-0.9892	-0.6238	-0.9513
2	-1.4805	-0.2345	-0.7898
3	-1.2187	-0.3545	-0.6120
4	-3.2805	-1.3044	-2.0060
5	-1.9345	-0.8974	-1.0241
6	-2.7422	-1.0923	-1.6757
7	-1.1423	-0.0005	-0.0956
8	-0.6180	-0.0008	-0.0049
9	-2.3431	-1.0662	-1.1328
10	-3.8534	-2.0095	-2.0929
11	-2.6508	-1.0167	-1.1852
12	-0.3814	-0.1728	-0.2125
13	-0.0426	-0.0054	-0.0118
14	-0.1150	-0.0314	-0.1056
15	-4.8533	-1.0002	-2.4653

Table 3: Entropy values of technique

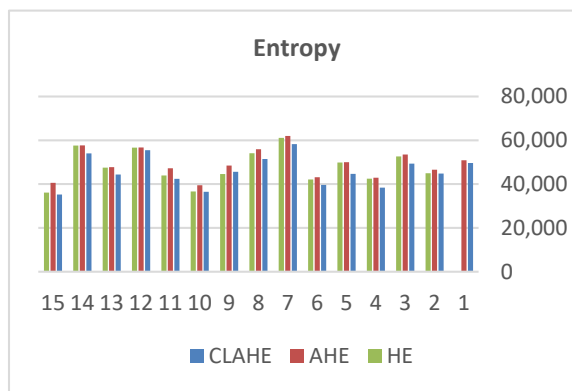| Image	HE	AHE	CLAHE
1	5.0544	5,0856	4,9608
2	4,4948	4,6594	4,4820
3	5,2637	5,3508	4,9365
4	4,2458	4,2893	3,8402
5	4,9888	4,9988	4,4705
6	4,2105	4,3125	3,9613
7	6,1080	6,1979	5,8281
8	5,4115	5,5925	5,1472
9	4,4577	4,8500	4,5598
10	3,6609	3,9452	3,6453
11	4,3933	4,7196	4,2392
12	5,6663	5,6731	5,5508
13	4,7553	4,7765	4,4411
14	5,7576	5,7699	5,4021
15	3,6124	4,0598	3,5266

Fig 4. Entropy for Enhancement Techniques

Fig 3. SSIM for Enhancement Techniques

Fig 5. SNR for Enhancement Techniques

Fig. 3 gives an analytical view of SSIM. SSIM analysis shows that enhanced images by CLAHE has higher average values. The SSIM decreases by using HE technique for enhance images which shows some information loss has occurred. On the other side, AHE shows less average SSIM values, which means that this technique is enhancing with noise components

Fig. 4 shows that the maximum value of entropy is present in AHE technique and CLAHE have produced a minimum values of entropy respectively. In addition, AHE technique has produced a batter SNR values when comparing with other enhancement techniques which can be seen visually in fig 5.
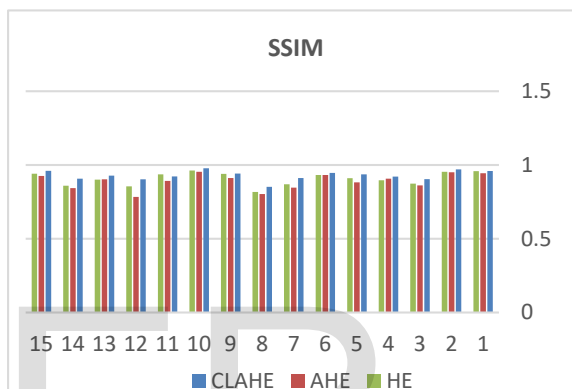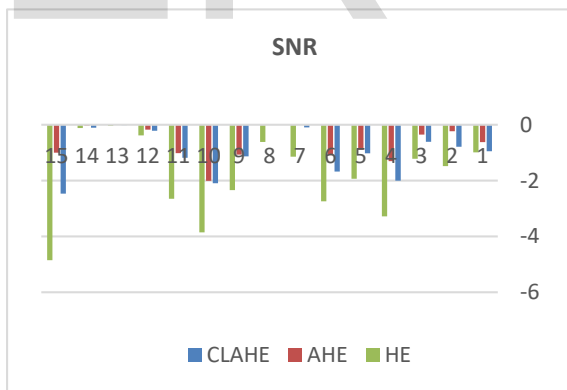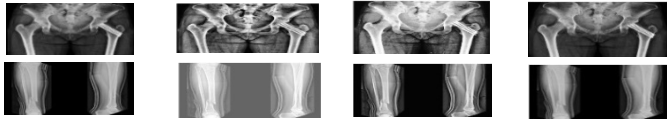

AHE   HE   Original

Fig 6.Results of techniques on the three images

In addition, the techniques which discussed in paper have tested by visually acceptable to human eye and should have natural appearance. Some of images are presented here. The below fig 6 shows the three original images with enhanced images by HE,AHE and CLAHE.

5.CONCLOSIN

This paper presented a comparative analysis of various enhancement techniques for medical images. It was found that amongst the three histogram equalization techniques for enhance of medical images, which are HE, AHE, and CLAHE. Three measures are used to compare between the enhanced images by three techniques. It was observed that AHE had better entropy values and batter SNR values but had bad SSIM. Hence, AHE technique in enhancement of medical images will certainly help to reduce the false detection of diseases. On other hand, CLAHE technique had a higher SSIM values with moderate entropy and SNR values. In future there is scope to implement enhancement equalization techniques on another type of images.

6.References

[1]   R. Butola, S. Pratik, and U. Kumar, "RESEARCH ARTICLE A Comparison of Thresholding Based Image Enhancement Techniques," vol. 4, no. 1, pp. 314–319, 2015.

[2]   A. P. Approach, [Chris_Solomon,_Toby_Breckon]_Fundamentals_of_Digi(BookZZ.org).pdf. .

[3]   P. Agrawal, V. Chourasia, R. Kapoor, and S. Agrawal, "A Comprehensive Study of the Image Enhancement," Int. J. Adv. Found. Res. Comput., vol. 1, no. 7, pp. 84–89, 2014.

[4]   B. Rupa, G. Karuna, and G. V. R. Reddy, "A Survey on Spatial Domain Image Enhancement," vol. 6, no. Iv, pp. 302–307, 2018.

[5]   S. Mahajan and R. Dogra, "A Review on Image Enhancement Techniques," vol. 4, no. 11, pp. 108–113, 2015.

[6]   S. S. Sankpal and S. S. Deshpande, "A review on image enhancement and color correction techniques for underwater images," vol. 9, no. 1, pp. 11–23, 2016.

[7]   S. Kaur, "Review and Analysis of Various Image Enhancement Techniques," vol. 4, no. 5, pp. 414–418, 2015.

[8]   C. Paper, "Comparative Analysis of Fundus Image Enhancement in Detection of Diabetic Comparative Analysis of Fundus Image Enhancement in Detection of Diabetic Retinopathy," no. December 2016, pp. 0–5, 2017.

[9]   S. S. Bedi and R. Khandelwal, "Various Image Enhancement Techniques- A Critical Review," vol. 2, no. 3, 2013.

[10]   G. Kaur and M. Kaur, "A Study of Transform Domain based Image Enhancement Techniques," vol. 152, no. 9, pp. 25–29, 2016.

[11]   J. Li, Y. Dong, and F. Jiao, "An Efficient Sparse Code Fusion Method for Image Enhancement," vol. 10, no. 8, pp. 55–64, 2015.

[12]   D. R. Nayak and I. I. I. P. R. S. Ystem, "Image Enhancement

Using Fuzzy Morphological Transformations," vol. 4, no. 6, pp. 58–59, 2016.

[13] R. Kiefer, "SATELLITE IMAGE ENHANCEMENT: SYSTEMATIC APPROACH FOR DENOISING AND Satellite image enhancement: systematic approach for denoising and resolution enhancement," no. February 2017, 2016.

[14] A. Horé, "Image quality metrics: PSNR vs . SSIM Image quality metrics: PSNR vs . SSIM," no. August, 2010.

[15] D. J. Bora, "IMPORTANCE OF IMAGE ENHANCEMENT TECHNIQUES IN COLOR IMAGE SEGMENTATION: A COMPREHENSIVE AND COMPARATIVE STUDY," 2017.

[16] R. Firoz, S. Ali, M. N. U. Khan, and K. Hossain, "Medical Image Enhancement Using Morphological Transformation," no. February, pp. 1–12, 2016.

[17] S. A. Saleem, "Survey on Color Image Enhancement Techniques using Spatial Filtering Survey on Color Image Enhancement Techniques using Spatial Filtering," no. May 2014, 2015.

IJSER