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Brain MRI Enhancement using Brightness Preserving Dynamic Fuzzy Histogram Equalization

Hikmat Z. Neima
Hzn2007@yahoo.com

Department of Computer Science, College of Science, University of Basrah, Basrah, Iraq.

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Abstract

In the field of digital image processing, medical imaging is one of the most important applications areas. However; low contrast and poor quality are the main issues in medical image. So it is essential to enhance images so that the result is more suitable for post processing and diagnosis. Histogram equalization has been proved as an effective and simple technique used as contrast enhancer. This paper presents an efficient method for brain MRI image enhancement. Discrete Wavelet Transform (DWT) has been utilized to decompose MRI image. Brightness Preserving Dynamic Fuzzy Histogram Equalization (BPDFHE) applied on the important part of the decomposed image. Finally, inverse of discrete wavelet transform is carried out to get the enhanced image. Experiments results that were obtained showed the effectiveness of proposed method.

Keywords: Medical images, histogram equalization, fuzzy logic, discrete wavelet transform.

1. Introduction

In the last two decades, image becomes more and more important in the domain of medicine. Medical imaging plays a main role in modern diagnosis. A high resolution medical image is very helpful for doctors to make an accurate diagnosis and consequently the correct treatment planning [1].

Medical image enhancement technologies have attracted much attention since advanced medical equipments were put into use in the medical fields. Enhanced medical images are desired by a surgeon to assist diagnosis and interpretation because medical image qualities are often deteriorated by noise and other data acquisition devices, illumination conditions, etc. Also targets of medical image enhancement are mainly to solve problems of low contrast and the high level noise Medical image enhancement technologies concentrate mainly on grayscale transform and frequency domain transform. Studies of frequency domain transform at most focus on the wavelet transform. Histogram equalization is a quite typical method of image enhancement in the spatial field [2].

There are several modalities in medical imaging such as X-ray, computed tomography (CT), magnetic resonance imaging (MRI), ultra sound (US), etc. X-ray images are being used for a long time to image the internal structure of human body. X-ray is the most popular diagnosis tool especially in checking bone fractures. The main advantages of use of x-ray are its simplicity and low cost [3].

In computed tomography (CT), x-ray beams are directed to patient's body in different angles. These beams pass through the body of patient to get attenuated. After that attenuated signal is detected are reconstructed to produce a CT image [4].

Magnetic Resonance Imaging (MRI) is a popular modality used in medical imaging. MRI is invented in 1970 and it basically uses the properties of hydrogen nucleus as it is sensitive for magnetic resonance. It provides a greater contrast between the different soft tissues of the body than image produced by CT. MRI plays an important role in non-invasive diagnosis of brain tumors and it is one of the most widely used imaging modality in medical studies [5].

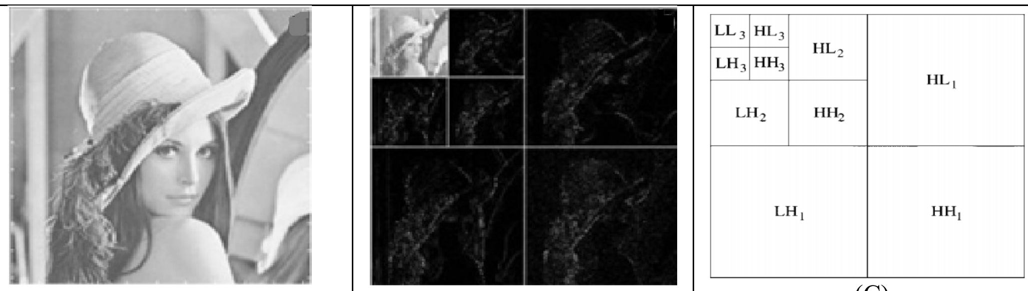
This paper is organized as follows. In sections 2, we present necessary background information. Related works are introduced in section 3. Section 4 describes evaluation criteria. The proposed method is explained in section 5. Section 6 gives the experimental results. Finally, the paper has been concluded in section 6.

2. Background

In this section, description about necessary background is given so that the proposed method can be understood easily.

2.1. Discrete Wavelet Transform (DWT)

Wavelet transform is one of important and useful computation tools for a variety of signal and image processing applications. In image processing field, the main process in wavelet transform is to filter signal of image by two filters, namely, low pass filter (L) and high pass filter. Then, it is down sampled by factor of two leading to compose transform of one level. Repeating of one level transform on the part of low pass output only, results multiple level transform. Two dimensional (2-D) wavelet transform can be obtained by applying 1-D wavelet transform, wavelet filter separately. This computation is done by carrying out 1-D transform on the rows signals one time and on the columns signal another time. As a result of that, it separates image signals into four sub-band images: LL (low frequency in horizon and vertical), LH (low frequency in horizon and high frequency in vertical), HL (high frequency in horizon and low frequency in vertical), HH (high frequency in horizon and vertical). Therefore, it is possible to use different methods for the sake of enhancement of the details in different frequency domain [6,7]. LL sub-band image often contains the most important information of the original image and it is usually called approximations the three other sub-band images are named as details. HH sub-band normally includes the small coefficients which are more likely due to undesirable noise [8]. Fig.1 shows an example of DWT for Lena image.



(A) (B) (C)

Fig.1: A) Lena image, B) Three levels Discrete Wavelet Transform of Lena image, C) Low and High sub-bands resulted from three levels DWT [8].

2.2. Histogram Equalization

Histogram equalization (HE) is the most common technique used for image enhancement. Based on the distribution of probability of the input gray level of the image, the gray level will be remapped. It flattens the dynamic range of the images histogram. HE is very simple technique and proved to produce better performance on all almost all types of images. However, HE lends to change the brightness of image being processed and this problem is considered as the main drawback of HE technique. There are several techniques have been proposed in order to improve the performance of the HE. Mean preserving bi-Histogram equalization (BBHE). In this technique, image histogram will be separated into two parts based on the mean value of the original histogram. Afterward, the two histograms will be equalized independently [9].

Minimum mean brightness error bi-histogram equalization (MMBEBHE) is the extension of BBHE that provides better preservation of image brightness. The main difference between BBHE and MMBEBHE is the way in which threshold is selected. Threshold in BBHE is the mean of the input image, while in MMBEBHE, the threshold is the minimum mean brightness error between the input image and the output image. Dynamic Histogram Equalization (DHE) is another technique used for image enhancement. DHE divides histogram of the input image into number of sub-histogram. The process of division continues until reach to insurance of no dominant part is presented in any of these new sub-histograms. The next step is to allocate a dynamic gray level (GL) range for each sub-histogram to which its gray level can be mapped by HE [10].

Brightness preserving dynamic histogram equalization (BPDHE) is the extension of DHE. The difference between (BPDHE) and DHE is the mean of partition. BPDHE derives histogram of input image based on the local maximums of the smoothed histogram. Then and similar to DHE, each partition will be mapped to a new dynamic range. After that, the HE will be applied on these partitions. The final step of BPDHE is involving the normalization of the output intensity to correct the affect of mean brightness changing that is caused by changes in dynamic range [11].

2.3. Fuzzy set

Fuzzy set theory has been proposed by Lotfi A. Zadeh in 1965. It was presented as a mean to model the ambiguity of complex systems. Fuzzy set theory is the extension of crisp (conventional) set theory. Instead of fully truth (either completely true or completely false), it handles the concept of partial truth (values of truth are between 1 (completely true) and 0 (completely false)).

The idea behind fuzzy set is simple and nature. Fig.2 shows the differences between fuzzy and crisp theory. For instance, if gray levels that share in darkness are needed to be defined. In case of crisp set theory, a value of threshold should be defined. So that all levels sandwich between 0 and this threshold are elements of this set. However the darkness is a matter of degree. So, fuzzy set can model this property better than crisp set. Two threshold values are needed, (50, 150 in Fig.2). All gray levels are less than 50 are full member of the set. All gray levels greater than 150 are not member of this set while the gray levels between 50 and 150 have a partial membership in the set [12].

Fig.2. Representation of "dark gray-levels" with a crisp and a fuzzy set [12]).

Fuzzy logic provides an alternative way to represent linguistic and subjective attributes of the real world in computing. It is able to be applied to control systems and other applications in order to improve the efficiency and simplicity of the design process [13].

3. Related Work

In the field of medical image enhancement, there are many researcher have presented many methods in order to overcome the problem of low contras that presents in medical images types. In [2], authors proposed method to enhance color medical images. In this method, image colors will be converted from RGB model to HSV color model. When the RGB components are obtained, then they use wavelet transform in order to get image coefficients. Afterward, sharpening of the sub-image coefficients will be applied separately by different weight values.

In [14], a novel histogram mapping method is proposed. This method uses a fast local feature generation technique to establish a combined histogram that represents voxels' local means as well as grey levels. Different sections of the combined histogram, separated by individual peaks, are independently mapped into the target histogram scale under the constraint that the final overall histogram should be as uniform as possible. The proposed method speeds up the histogram equalization process, and, relatively, good enhancement results are also achieved.

A novel algorithm to enhance the contrast of medical image has been proposed in [15]. Authors have proposed a calculation that can control and prevent the appearance of unexpected effects. They called this calculation as weighted calculation. In addition to that, the Local Bi-Histogram Equalization (LBHE) has been utilized in order to reduce the problem of over-enhancing artifacts.

P. Jagatheeswari et al. proposed an efficient method to enhance medical images. The proposed method consists of three steps. Contrast Stretching of original medical image as the first step. In this step, histogram equalization based on a local modified contrast-stretching is performed and replacement of each original intensity value. In the second step, Minimum Mean Brightness Error Bi-Histogram (MMBEBHE) was used of stretched image. Afterward, median filter will be applied on the image that is resulted from the second step [16].

A fuzzy logic-based histogram equalization (FHE) is proposed in [17]. As a first step of proposed method, fuzzy set theory has been used to compute fuzzy histogram. Authors utilize fuzzy histogram in order to handle the inexactness of gray level values. Secondly, median value of the original image was employed to divide the fuzzy histogram into two partitions. After that, histogram equalization will be used to normalize each partition independently.

In [18], A. Sarrafzadeh*, et al.* presented algorithm that is called brightness preserving fuzzy dynamic histogram equalization. Their algorithm consists of five steps. In the first step, input image is smoothed by Gaussian smoothing function. Second step finds the local maxima points. Point is considered as local maxima if its amplitude is higher than the values of its neighbors. The third step is composed of two parts. First part is to find the length of each interval and the frequency of intensities in the same interval. While the second part in the third step is to fuzzify the multiplication of these two factors (i.e. length and frequency of interval). Fifth step of proposed algorithm is to equalize the histogram of each interval separately.

4. Evaluation Criteria

In order to evaluate the proposed method, we used peak signal-to-noise ratio (PSNR), image histogram, and universal image quality index (UIQI). In the following subsections, they will be described briefly**.**

4.1 PSNR

The term peak signal-to-noise ratio, often abbreviated PSNR, is an expression for the ratio between the maximum possible value of a signal and the power of distorting noise that affects the quality of its representation. As signals have a very wide dynamic range, PSNR is described in terms of logarithmic decibel scale. The formula of PSNR is given in Eq.1 [19]:

$$PSNR = 10\log_{10}\frac{255^2}{MSE} \quad (1)$$

$$MSE = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left[f(i,j) - g(i,j)\right]^2 \quad (2)$$

Where: $f(i,j)$: Original image,
$g(i,j)$: Enhanced image.
N, M: Dimensions of image.

Generally, with referring to Eq1 and Eq2, when the value of MSE is small then high PSNR value is obtained. It is obviously that better image quality is gotten when PSNR value is high.

4.2 Image Histogram

An image histogram is a graph that displays the frequency of the brightness value. A histogram for an image is the link between the image and the description of probabilistic for this image [20].

Many researchers have used histogram as a method to compare an original image and its enhanced version. Generally, wider histogram means better visual appeal. The relationships in the histogram of an enhanced image should be maintained as it was in the histogram of an original image. In a histogram of enhanced image, the curves should be varied consistently [21].

4.3 Universal Image Quality Index (UIQI)

Universal image quality index is an effective objective method which can be used to evaluate the quality of different types of images. This assessment method can model any type of distortion by consider it as a combination of three factors: loss of correlation, luminance distortion, and contrast distortion. Definition of UIQI is shown in Eq.3 and Eq.4 as following [22]:

$$Q = \frac{4\,\sigma_{xy}\,\bar{x}\,\bar{y}}{(\sigma_x^2 + \sigma_y^2)[(\bar{x})^2 + (\bar{y})^2]} \tag{3}$$

Where

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i\,, \qquad \bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_i$$

$$\sigma_x^2 = \frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2\,, \qquad \sigma_y^2 = \frac{1}{N-1}\sum_{i=1}^{N}(y_i - \bar{y})^2$$

$$\sigma_{xy} = \frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})(y_i - \bar{y})$$

$$Q = \frac{\sigma_{xy}}{\sigma_x\sigma_y}\cdot\frac{2\bar{x}\,\bar{y}}{(\bar{x})^2+(\bar{y})^2}\cdot\frac{2\sigma_x\sigma_y}{\sigma_x^2+\sigma_y^2} \tag{4}$$

The value of Q is dynamically elapsed between (-1, 1). The best value is 1 which can be obtained when $y_i = x_i$ for all *i=1, 2, ..., N*. While the worst value -1 is achieved when $y_i = 2\bar{x} - x_i$, for all *i=1, 2, ..., N*.

5. Proposed Method

Proposed method consists of several steps. Following points describe the steps of this method briefly.

Input: Brain MRI Image.
Output: Enhanced Brain MRI Image.

Step 1: Discrete wavelet transform has been utilized as a first step in order to partition the input image into four sub-images. By applying DWT, four sub images will be gotten, namely: LL, LH, HL, and HH.

Step 2: In the second step, histogram of sub-image (LL), which is resulted from the first step, will be computed depending on fuzzy logic concepts using the following Eq.5 and Eq.6 [17].

$$h(i) = h(i) + \sum_x \sum_y \mu_{\tilde{I}(x,y)_i}, i \in [a, b] \quad (5)$$

where: $\mu_{\tilde{I}(x,y)_i}$ the triangular fuzzy membership function defined as

$$\mu_{\tilde{I}(x,y)_i} = max(0, 1 - \frac{|I(x,y) - i|}{4}) \quad (6)$$

And $[a, b]$ is the support of the membership function.

Step 3: Point can be considered as a local maxima if its amplitude is higher than the values of its neighbors. The number of local maxima points determines the number of sub-histogram. Local maxima points can be obtained by utilizing the first and second derivation equations (Eq.7 and Eq.8) of fuzzy histogram [23].

$$h^{\circ}(i) = \frac{dh(i)}{di} \triangleq \frac{h(i+1) - h(i-1)}{2} \quad (7)$$

$$i_{max} = i \forall \{h^{\circ}(i+1) * h^{\circ}(i-1) < 0, h^{\circ\circ}(i) < 0 \quad (8)$$

Where $h^{\circ}(i)$, $h^{\circ\circ}(i)$ represent the first, second order derivative, respectively, of the fuzzy histogram $h(i)$ corresponding to the i^{th} intensity level.

Step 4: After calculation of maxima points, they will be used to determine partition the histogram into sub-histograms. The number of these sub-histograms depends on the number of maxima local points.

Step 5: Once the histogram of the brain MRI image is divided into several sub-histograms, Normalization of the sub-histograms using dynamic histogram equalization (DHE) will be individually applied on each one of these sub-histograms.

Step 6: In the final step of the proposed method, combine all equalized sub-histograms that are normalized in the previous step. Afterward, inversion of discrete wavelet transform is employed in order to get the enhanced image. Fig.3 illustrates the flow chart of the proposed method.

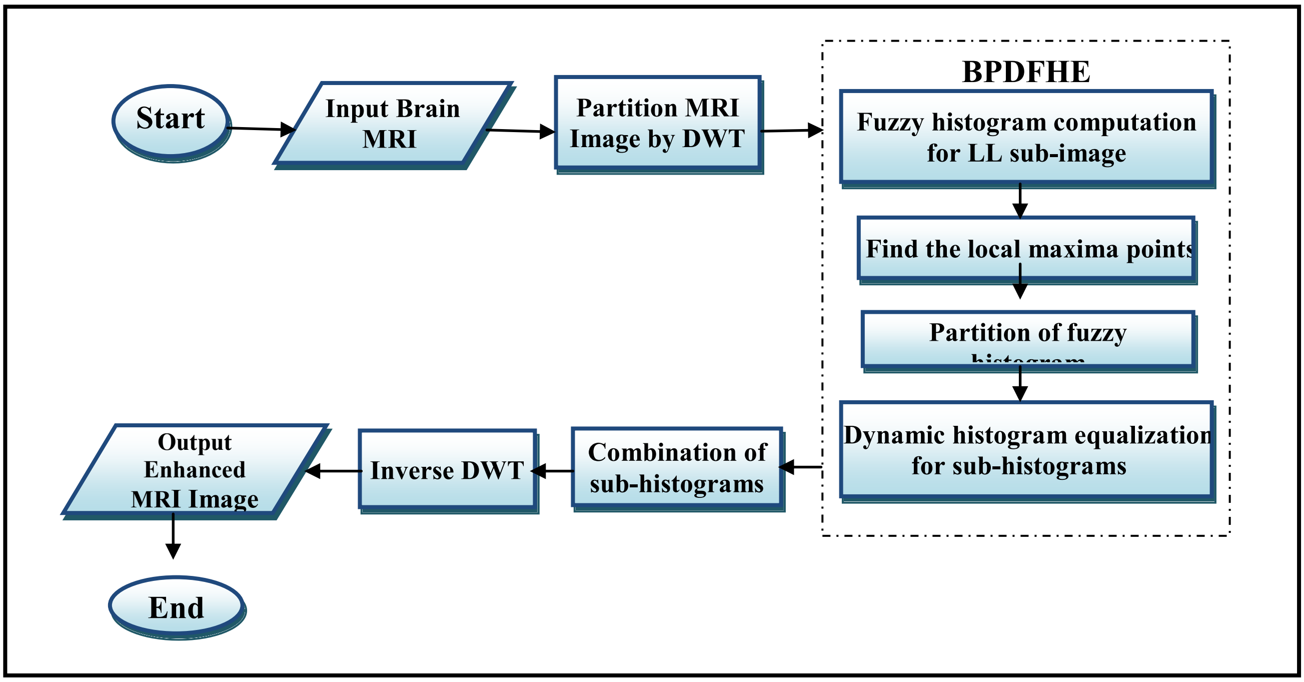
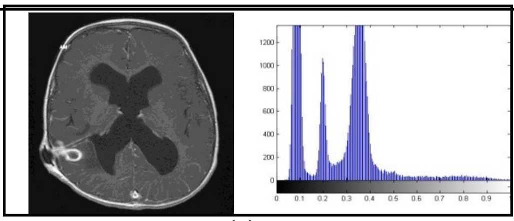


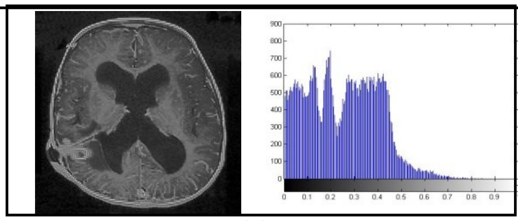
Fig. 3: Flow Chart of Proposed Method.

6. Experiments Results

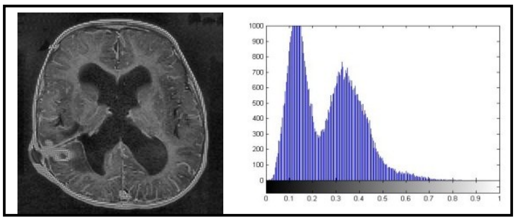
For the purpose of experiments, the proposed method was implemented using Matlab R2012a program and tested on more than 20 of brain MRI images. Results that are obtained from applying of proposed method have shown the effectiveness of this method. In order to assess the proposed method, three of assessment metrics are used; namely, PSNR, image histogram, and UIQI. In addition to that, brain MRI image was enhanced using two of popular histogram enhancement methods which are histogram equalization (HE) and adaptive histogram equalization (AdHE). A comparison of results of HE, AdHE, and proposed method is provided in Fig.4 and Table1.

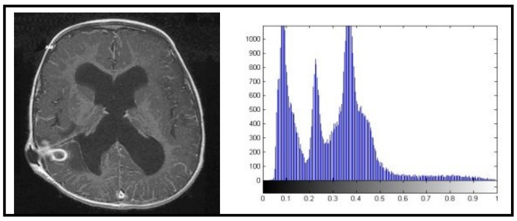
Fig.4(a) illustrates the original brain MRI image and its histogram. Fig.4(b, c, and d) show the enhanced MRI image using HE, AdHE, and proposed method respectively and its associated histogram. Table1 demonstrates the values of PSNR and UIQI which are obtained from applying HE and AdHE in addition to the proposed method. Values of PSNR and UIQI were used to compose the chart which is shown in Fig.5.



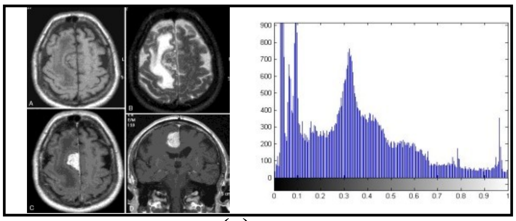


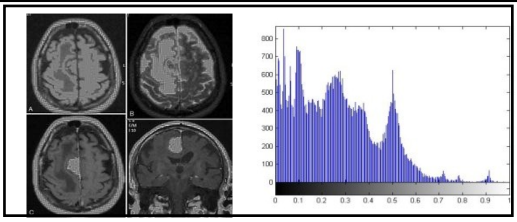
(a) (b)



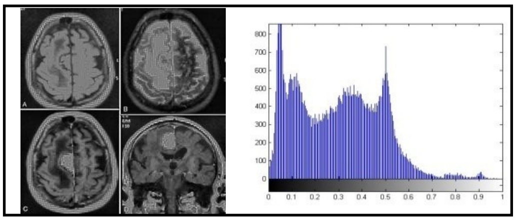


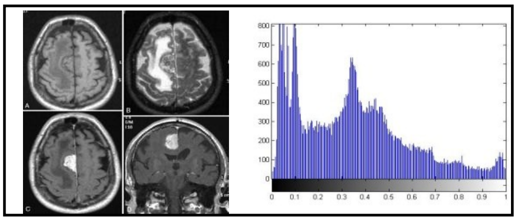
(c) (d)





(a) (b)





(c) (d)

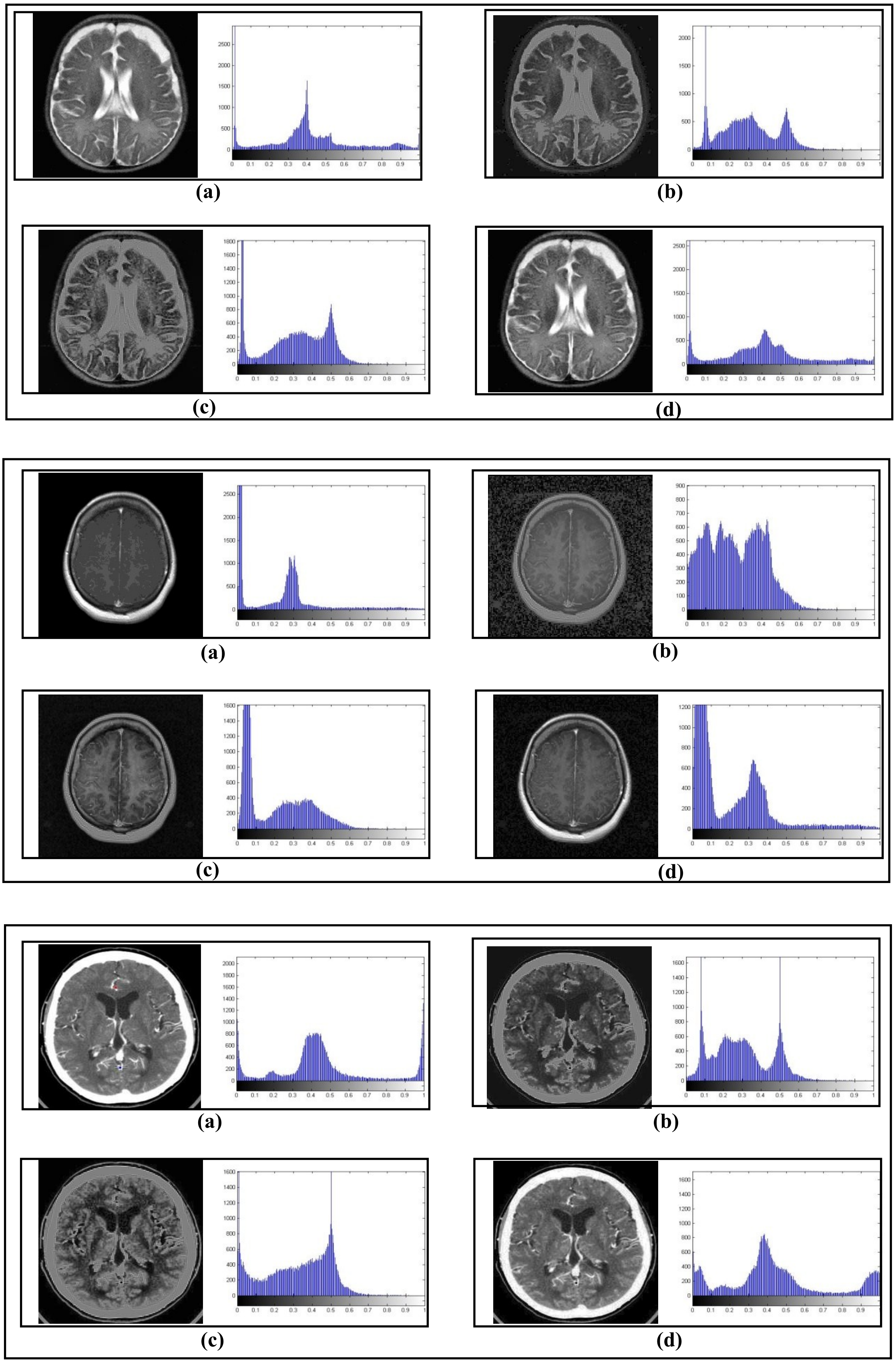


Fig. 4: Image and its histogram (a) Original (b) HE (c) AdHE (d) Proposed method .

Table 1 : PSNR and UIQI Values.

Medical Image ID	Histogram Equalization		Adaptive Histogram Equalization		Proposed Method	
	PSNR	**UIQI**	**PSNR**	**UIQI**	**PSNR**	**UIQI**
B_MRI1	***64***	0.510	***69***	0.521	***78***	0.889
B_MRI2	***68***	0.644	***70***	0.636	***82***	0.867
B_MRI3	***66***	0.307	***68***	0.364	***75***	0.722
B_MRI4	***69***	0.702	***73***	0.663	***80***	0.757
B_MRI5	***68***	0.533	***68***	0.595	***81***	0.652
B_MRI6	***60***	0.626	***60***	0.642	***79***	0.736
B_MRI7	***65***	0.855	***71***	0.783	***76***	0.925

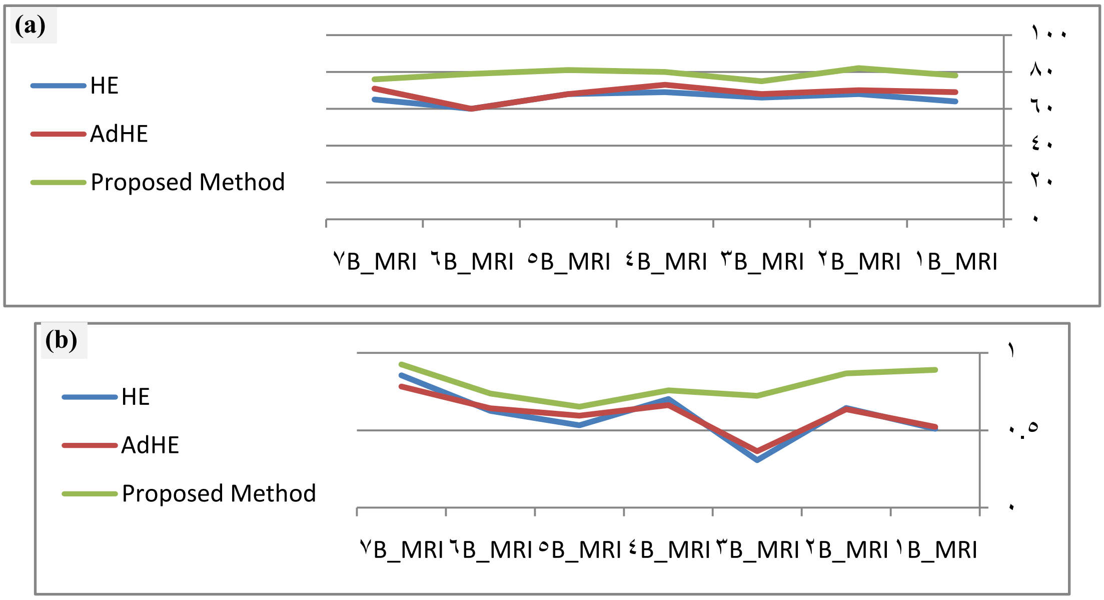


Fig. 5: Chart of evaluation criteria: (a) PSNR (b) UIQI.

7. Conclusion

In this paper we presented a method to enhance the contrast of MRI brain image. This method is mainly dependent on DWT and BPDFHE. The results have shown that the proposed method can preserve brightness and provide better contrast enhancement as compared to HE, and AdHE. In addition to that, it preserves the overall brightness to generate the natural looking images without causing of visual artifacts.

Additionally, It can be observed from the obtained results that enhancing the image without much influence of the original data. This feature of proposed method is very important since the huge changes in original data mean losing information of brain MRI image which may affect the case diagnosis.

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تحسين صورة الرنين المغناطيسي للدماغ بأستخدام طريقة تحسين المدرج التكراري المضببة المحافظة على السطوع

حكمت زنيد نعمة
Hzn2007@yahoo.com

قسم علوم الحاسبات ، كلية العلوم ، جامعة البصرة ، البصرة ، العراق.

الخلاصة
تعتبر الصور الطبية من أهم التطبيقات في حقل معالجة الصور الرقمية. قلة التباين و نوعية الصورة غير الجيدة تعتبران من المشاكل الرئيسية في الصور الطبية. لذلك فمن الضروري تحسين الصورة الطبية لكي تكون الصورة المحسنة مناسبة للمعالجة اللاحقة و تساعد على التشخيص. تم إثبات طريقة تسوية المدرج التكراري للصورة Histogram Equalization على أنها طريقة تحسين تباين كفوءة و بسيطة في نفس الوقت.
هذا البحث يقدم طريقة كفوءة لتحسين صورة الرنين المغناطيسي MRI للدماغ. تم اسخ دا م التحويل المويجي المتقطع لغرض تجزئة صورة الرنين المغناطيسي. بعد ذلك تم استخدام طريقة BPDFHE على الجزء المهم من الصورة الناتج من الخطوة الأولى. و كخطوة أخيرة تتم عملية دمج هذا الجزء بعد تحسينه مع أجزاء الصورة الأخرى للحصول على الصورة المحسنة.النتائج التجريبية التي تم الحصول عليها أوضحت كفاءة الطريقة المقترحة.

الكلمات المفتاحية : الصور الطبية, تسوية المدرج التكراري، المنطق المضبب، التحويل المويجي المتقطع.