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Medical Image Enhancement based on Adaptive Histogram Equalization and Contrast Stretching

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Abstract

Image enhancement techniques aim to improve the quality of images. In field of medical image processing, low contrast is considered as one of the main and most important issues. As Histogram Equalization (HE) is an effective and simple technique, it is widely used as contrast enhancement. In this paper, efficient method to enhance the quality of medical images has been proposed. This method depends on Discrete Wavelet Transform (DWT) to decompose an input image as the first step. HE and contrast stretching were carried out on the results of DWT separately. Adaptive Histogram Equalization (AHE) was applied on the main part that is resulted from DWT. Contrast stretching was applied on the remaining parts. The results that been gotten showed goodness and efficiency of the proposed method.

Keywords: Medical images, histogram equalization, contrast stretching, DWT, adaptive histogram equalization.

1. Introduction

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 of a medical image.

Many studies have been achieved on medical image enhancement, mainly on grayscale transform and frequency domain transform. Studies of frequency domain transform basically concentrate on the wavelet transform, and histogram equalization is a quite typical method of image enhancement in the spatial field. The wavelet transform is a time frequency analysis tool developed in the 1980s, which has been successfully applied in the image processing domain [1].

The organization of this paper is as follows. In section 2, related works are introduced. In section 3, we present background information. 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 7.

2. 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 [1], authors proposed method to enhance color medical images. In this method, image colors will convert 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.

In [2], 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 [3]. 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 [4].

In [5], a nonlinear algorithm has been proposed to enhance image using wavelet transform. The first step of the proposed algorithm is to use a multi scale wavelet transform in order to decompose the input image. Secondly, wavelet threshold was utilized to de-noise image and coefficients with low frequency were enhanced by linear piecewise function. As a third step, the high frequency coefficients that are resulted from wavelet decomposition are enhanced by a nonlinear enhancement operator which is presented by authors. Lastly, enhanced image will be gotten using inverse wavelet transform.

H. Yuanyuan and Z. Ping have presented an approach to enhance the medical image [6]. Firstly, they utilized wavelet transform to decompose the medical image. As a second step in the proposed approach, authors used wavelet threshold method for noise removing. Third step is to modify the high frequency coefficients using nonlinear method while the low frequency coefficients were modified using unmasking method. Finally, the enhanced medical image will obtain by applying inverse wavelet transform.

1. Background Information

In this section, essential information that is related to this research will be elaborated. It consists of several sub-sections. The first sub-section presents modalities of medical images while the second one describes DWT. In the third sub-section, several proposed methods of histogram equalization are introduced. Last sub-section shows contrast stretching concept.

3.1 Medical Images

Medical images are special type of images. Medical image is used for diagnostics of cases of patients. There are several means to get medical images. X-Ray is the most popular one among them due to its simplicity, low cost and small doses of radiation. Medical images play a very important role in disease diagnosis. The image acquisition for diagnostic and planning purposes has become a crucial tool in health care. Magnetic Resonance Imaging (MRI), Computed Tomography (CT) Scan, Ultrasound images, X-Ray, Mammography and other image modalities are utilized by clinicians in order to accurately diagnose a disease and efficiently plan a treatment. From images formation to the final analysis, medical imaging is still facing challenges [1].

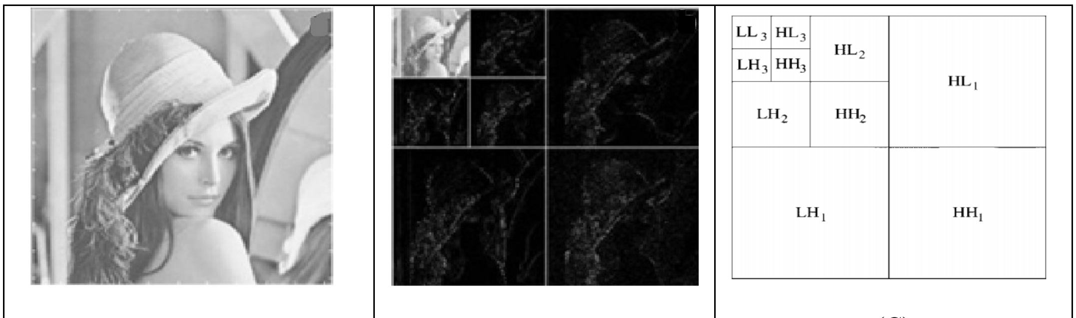
Therefore and because of the main role of medical images in diagnosis of patients, diseases, medical images are always required to be in high resolution. Image enhancement techniques are usually used to improve the contrast of images. As the information that contained in medical image is very important. These techniques should manage contrast enhancement of medical images carefully. Information in medical image is very important and losing of some of this information will highly affect the resulted diagnosis [3].

1. Discrete Wavelet Transform (DWT)

Wavelet transform is one of important and useful computation tools for a variety of signal and image processing applications. Wavelet transform has a great advantage of being able to separate the fine details in a signal. Very small wavelets can be used to isolate very fine details in a signal ,while very large wavelets can identify coarse details. wavelet transform based approach is better than the existing minutiae based method and it takes less response time which is more suitable for online verification with high accuracy [7].

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 will 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].

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. 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 [4].

3. Contrast Stretching

The contrast stretching algorithm is often called histogram normalization. It is used to enhance the contrast of the image by stretching the range of the intensity values to occupy a wider or desired range. Unlike the histogram equalization, the contrast stretching algorithm is only confined to the linear scaling function to the pixel values. Each pixel is scaled using the following function [11]:

$$P_o = (P_i - c)\frac{(b-a)}{(d-c)} + a \quad (1),$$

Where:

1. P_o is the normalized pixel value; P_i is the considered pixel value.
2. a is the minimum value of the desired range;
3. b is the maximum value of the desired range;
4. c is the lowest pixel value currently present in the image;
5. d is the highest pixel value currently present in the image;

6. Evaluation Criteria

In order to evaluate the proposed method, we used two of quality measurements. Peak Signal-to-Noise Ratio (PSNR) and image histogram. In the following sub sections, these measurements will be described.

4.1 PSNR

In measuring the quality of the enhanced image, two mathematical metrics are used. One of them is Mean Square Error (MSE), which measures the cumulative square error between the original and the enhanced image. The other is the Peak Signal-to-Noise Ratio which is known as *PSNR*. The formula for MSE is giving as [12]:

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

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

The formula for PSNR is given as:

$$PSNR = 10\log_{10}\frac{255^2}{MSE} \quad (3),$$

For a gray-level image with 8 bits per pixel, the maximum value is 255. Generally, the smaller the MSE, the higher the PSNR and the better the image quality.

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 [13].

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 [14].

7. Proposed Method

In this method, discrete wavelet transform has been utilized as a first step. As mentioned before, DWT is often used in field of image processing and it is active in image enhancement. Four sub images will be gotten, namely: LL, LH, HL, and HH. In the second step, modified adaptive histogram equalization will be applied on the part of LL that is resulted from the first step. Then pass the rest sub images (LH, HL, and HH) in second level of DWT. As the third step in this method, contrast stretching has been implemented on the result of applying the modified histogram equalization and soft threshold will be carried out on the result of applying the second level of DWT on all sub images except the HH as it often refers to the noise in the image. In the fourth step, the inverse of DWT applied on all parts to get the completed and enhanced image. Fig. 2 illustrates the flow chart of proposed method.

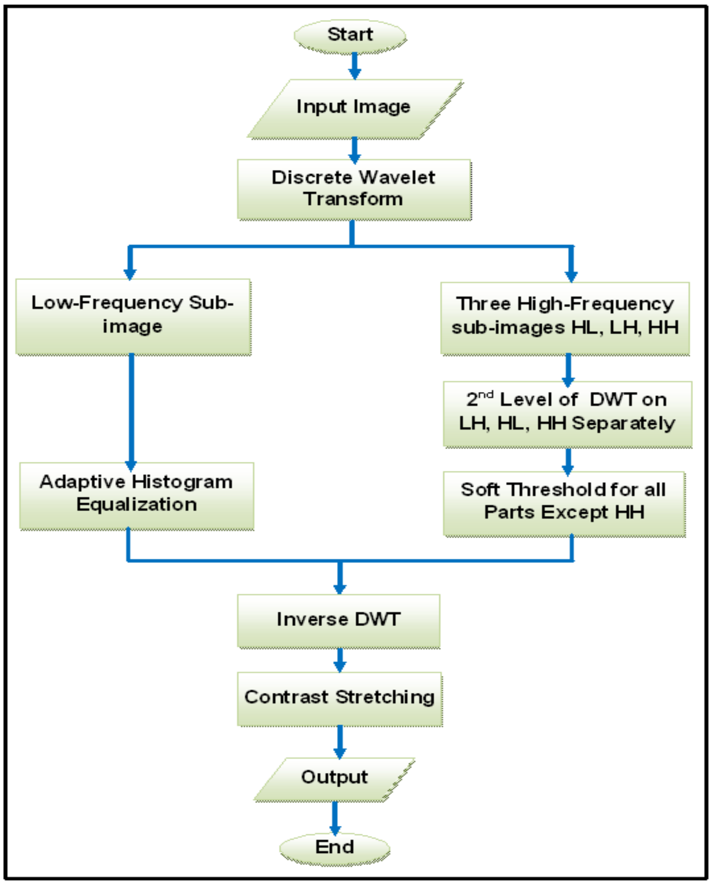
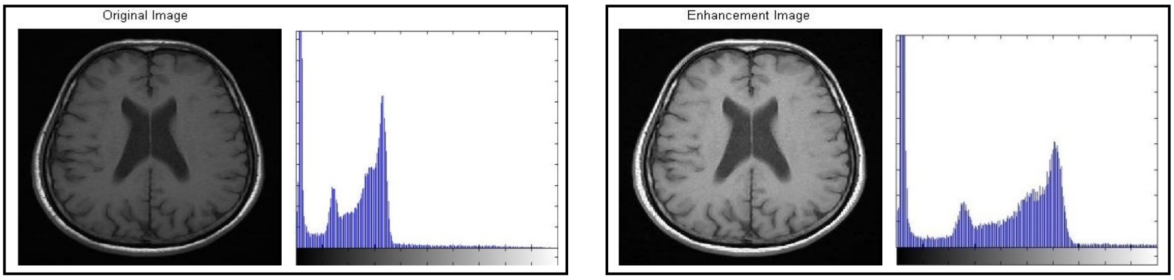


Fig. 2: Flowchart of Proposed Method.

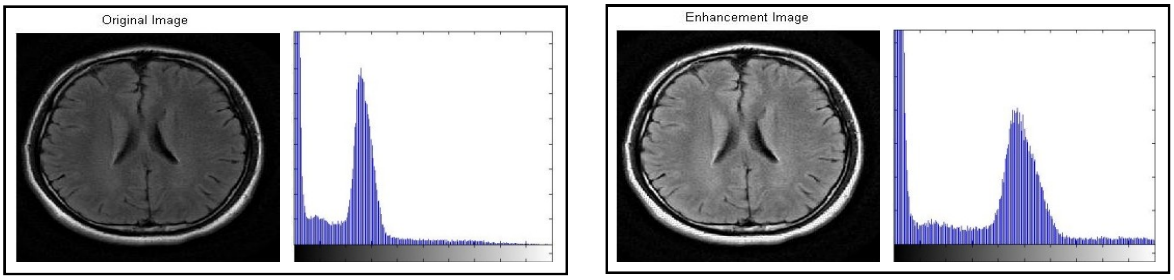
6. Experiments Results

For the purpose of experiments, the proposed method was implemented using Matlab 7.14.0 program and tested on several medical images, MRI and CT scan images. PSNR results that are gotten from carrying out the proposed method are shown in table below. The values of PSNR in table have been put in two columns. The first one shows the PSNR values that are obtained from standard Histogram Equalization which is attached to Matlab environment. The second column illustrates the values of PSNR that are obtained from applying the proposed method.



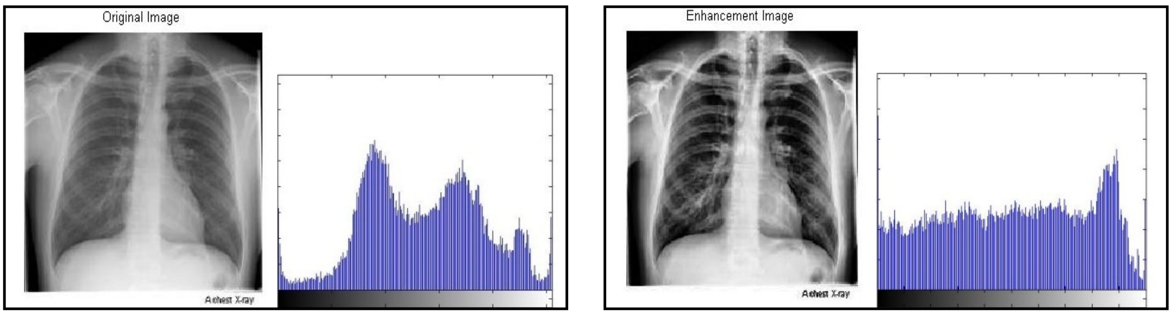
1. (b)

Fig. 3: BRAIN1 MRI (a) Original image and its histogram (b) Enhanced image and its histogram.



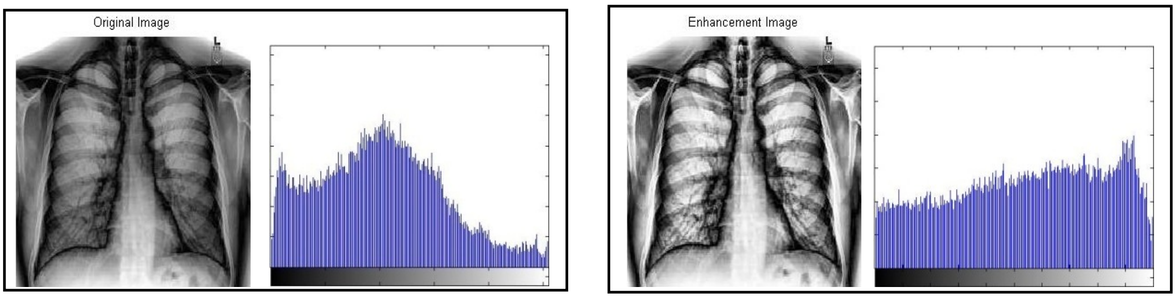
1. (b)

Fig. 4: BRAIN2 MRI (a) Original image and its histogram (b) Enhanced image and its histogram.



1. (b)

Fig. 5: CHEST1 CT (a) Original image and its histogram (b) Enhanced image and its histogram.



1. (b)

Fig. 6: CHEST2 CT (a) Original image and its histogram (b) Enhanced image and its histogram.

Table 1 : PSNR Values of the proposed method.

Medical Image ID		PSNR	
		Histogram Equalization	Proposed Method
MRI	Brain1	8.465	12.757
	Brain2	8.254	12.959
CT Scan	Chest1	24.065	84.837
	Chest2	24.065	86.931

1. Discussion and Conclusions

After applying the proposed method on MRI of brain, the images obtained were in better quality compared to images obtained from applying of Histogram Equalization. PSNR values that are shown in Table 1 above give an idea about the efficiency of the proposed method.

In terms of Histogram, from Fig.3, Fig.4, Fig.5, and Fig.6, it is clearly noticed that histogram obtained from applying the proposed method is wider than the histogram of the original image and this gives an indication of a good performance of proposed method.

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تحسين الصورة الطبية بالاعتماد على طريقة تسوية المدرج التكراري المتكيف و طريقة شد التباين

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

الخلاصة

تهدف تقنيات تحسين الصور المختلفة لتحسين نوعية الصورة. في حقل معالجة الصور الطبية، تعتبر قلة التباين واحدة من المشاكل الرئيسية التي تعاني منها الصور الطبية.تستخدم طريقة تسوية المدرج التكراري (Histogram Equalization) بشكل واسع في حل مشكلة قلة التباين و ذلك لكونها طريقة سهلة و فعالة في نفس الوقت. في هذا البحث، تم اقتراح طريقة فعالة لتحسين الصورة الطبية. تعتمد هذه الطريقة على التحويل المويجي المتقطع (Discrete Wavelet Transform) كخطوة أولى ثم بعد ذلك يتم تطبيق طريقة تسوية المدرج التكراري المتكيف (Adaptive HE) و طريقة شد التباين (Contrast Stretching) على مخرجات الخطوة الأولى بشكل منفصل، أي تطبيق طريقة تسوية المدرج التكراري المتكيف على الجزء الرئيسي من مخرجات الخطوة الأولى (DWT), و تطبيق طريقة شد التباين على الجزء المتبقي من تلك المخرجات. النتائج التي تم الحصول عليها أوضحت كفاءة الطريقة المقترحة في تحسين نوعية الصورة الطبية.

الكلمات الدالة : الصور الطبية، تسوية المدرج التكراري، شد التباين، التحويل المويجي، تسوية المدرج التكراري المتكيف