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# Medical Image Enhancement by Image Fusion in Wavelet Domain

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***Abstract*** *– Owing to advances in medicine, with the increased demands on clinical services, quality enhancement of medical images attracts many attentions. The noise and contrast are the important issues related to the medical images. This paper proposes a new algorithm for noise reduction and contrast improvement of medical images which is based on wavelet transform. Firstly the image's details are obtained by Haar transform. Then, the noise of the image is removed by stationary wavelet transform (SWT). After that, different methods of image fusion are employed to enhance the mentioned image. Finally, the image histogram is equalized by contrast limited adaptive histogram equalization (CLAHE). The simulation result indicates that the proposed algorithm significantly improves the quality of an image while removing its noise.*

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## INTRODUCTION

Medical images have a significant influence on the process of diagnosis. In recent years, in order to increase radiologists' diagnostic performance, a lot of medical image analysis methods have been developed with aim of enhancing images. Among of all methods, wavelet transform proves to be very useful because of their multi resolution properties. With studying the medical images, we will encounter with this fact that these images are always contain noise. Furthermore, these images suffer from the low contrast. So, in the process of analyzing the medical images, contrast and noise are the main features to be considered.

Wavelet transform, a typical method for studying image, is based on frequency domain. One of the most important characteristics of wavelet transform is that its different scale high frequency components are accessible [1]. In other hand, the characteristics of image details, such as the noise, are in the high frequency components. So, by utilizing the wavelet transform, the noise of the images can be removed from the high frequency components and the quality of images can be enhanced.

In order to enhance the quality of images, most researchers focused on the images' details information. So, decomposing the high frequency sub-images provide more image details [2]. The medical images usually have noises which cannot easily be eliminated in image processing. In some researches Stationary Wavelet Transform (SWT) was used for denoising the medical images [3, 4].

For enhancing the images, in [5], image fusion technology is utilized in wavelet based for ECT images. Researchers show that richer and accurate image can be extract from different source images than single source images. In this paper, edge feature detection, which uses the feature of different frequency domain of wavelet decomposition, is suggested.

In [6], a novel infrared-to-visible image fusion algorithm is proposed for enhancing contrast and visibility. Researchers used pixel level and feature level fusions to propose a new level fusion method based on contrast enhancement. They show that quality and visibility of fusion images can be improved significantly, for target detection.

From the perspective of frequency and time domain, Wavelet transform has perfect localized characters [7]. This perfect time-frequency localized capability makes wavelet transform suitable for edge detection of images [8]. Image fusion combines complimentary information and redundant information through different images in order to obtain more comprehensive and accurate image description [9-11].

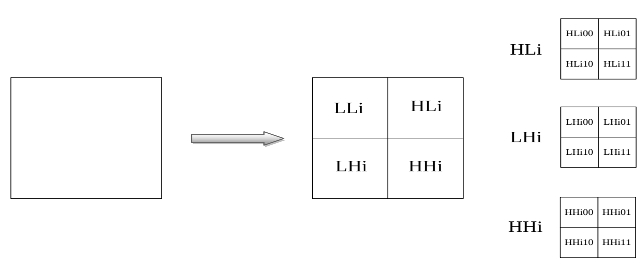



**Figure 1.** Decomposing the high frequency sub-images

Wavelet transform has an ability to select frequencies in both space and time. In terms of the features which improve the quality of images, the fused images have superior characteristics [12].

Contrast enhancement methods are designed to improve the contrast and theoretically to enhance particular characteristics rather than increasing and supplementing the inherent structural information in an image [13, 14]. Contrast Limited Adaptive Histogram Equalization (CLAHE) is an example of contrast enhancement methods which limits the noise enhancement by establishing a maximum value (clip limit) a bin can hold in the histogram of an image tile [15]. In CLAHE, the value at which the histogram is clipped depends on the normalization of histogram [16].

The remainder of the paper is outlined as follows. Section II describes the concepts which are related to this research. In section III, we present our methodology and explain it in detail. The experimental results and their analyses are given in section IV. Finally, we give our conclusions in section V.

## NEEDED CONCEPTS

In this section, the concepts which are related to this research are described in five subsections. These subsections provide the theoretical base for the proposed methodology which will be describe in section III.

**A. High Frequency Information in Wavelet Transform:** Images' details information is concealed in high frequency characteristics. In wavelet transform, more details of images can be achieved by decomposing the high frequency sub-images. According to Figure 1, all level sub-images except the low frequency ones are decomposed to four sub-images:

$$\{HL_{i00}, HL_{i01}, HL_{i10}, HL_{i11}\}$$
$$\{LH_{i00}, LH_{i01}, LH_{i10}, LH_{i11}\} \quad (1)$$
$$\{HH_{i00}, HH_{i01}, HH_{i10}, HH_{i11}\}$$

**B. Stationary Wavelet Transform Denoising:** In wavelet transform, the images are denoised by means of thresholding. There are two types of thresholding methods: soft-thresholding and hard-thresholding. This paper utilizes the soft thresholding to decrease noise from images. Because this type of thresholding enhances the images more visually and achieves the optimal min-max rate. The function of Soft-thresholding is defined as follows [17]:

$$\eta_{\lambda}(x) = \text{sgn}(x).\max(|x| - \lambda, 0) \quad (2)$$

Equation (2) takes the argument (x) and shrinks it toward zero by the threshold λ.

The Stationary Wavelet Transform (SWT) is a method which is used for denoising the medical images. The SWT denoising includes two filters: low-pass and high-pass filters. These filters employ each level of sub-images.

In the SWT, the filters will be up-sampled at each level as follows:

$$a_1[n] = g_1[n] * I[n] \quad (3)$$

$$d_1[n] = h_1[n] * I[n] \quad (4)$$

For $k = 1, 2, .., k_0 - 1, (k_0 \le k)$, the above equation can be extended as:

$$a_{k+1}[n] = g_{k+1}[n] * a_k[n] \quad (5)$$

$$d_{k+1}[n] = h_{k+1}[n] * a_k[n] \quad (6)$$

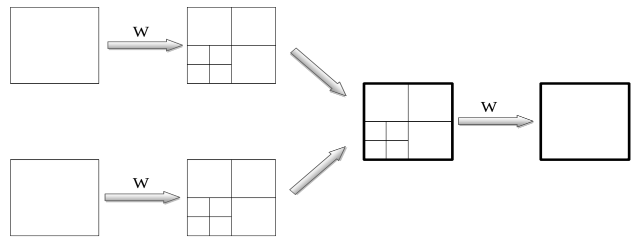



**Figure 2.** Image fusion

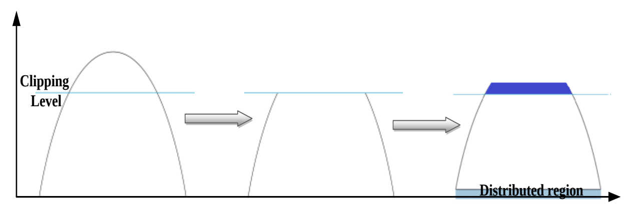



**Figure 3.** Histogram modification in CLAHE

In equation (3), $I[n]$ is an input signal, $g_1[n]$ and $h_1[n]$ are low-pass and high-pass filters, respectively. In equation (5), $g_{k+1}[n]$ is up-sample of $g_k[n]$ and $h_{k+1}[n]$ is up-sample of $h_k[n]$. $a_k[n]$ and $d_k[n]$ are approximation coefficient and detail coefficient, respectively.

**C. Edge Detection in Wavelet Transform:** The edge detection is a fundamental application in the analysis and enhancement of images. Details coefficients represent edges in an image. Also, approximation coefficient is supposed to be noise. By setting the coefficient values of wavelet transforms to zero, the horizontal, vertical and diagonal edges of images can be obtained. This simple method removes the low frequency from an image. By means of this method, the most expressive edges are found [18]. In this paper, we use the diagonal edge. So, the lowest scale approximation coefficient will be set to zero.

**D. Image Fusion:** Image fusion is a technique which combines some features or all features of several input images in order to gain a higher quality image. The process of image fusion based on wavelet transform is shown as Figure 2.

Wavelet transform provides a specific capability in image fusion. By using this capability which is applied to different values of approximation and details, various images will be achieved. These achieved images can have different applications.

By constructing the wavelet transforms (W) of the two registered input images $I_1$(x, y) and $I_2$(x, y) and combining them with the fusion rule ∅, the fused image I(x, y) is reconstructed by inverse wavelet transform. The function of image fusion is defined as follows [19]:

$$I(x,y) = W^{-1}(\phi(W(I_1(x,y)), W(I_2(x,y)))) \quad (7)$$

**E. Contrast Limited Adaptive Histogram Equalization:** Contrast limited adaptive histogram equalization (CLAHE) is a method for contrast enhancement which is based on adaptive histogram equalization (AHE). CLAHE is used to optimize the histogram by obtaining the contextual region of affected pixels. CLAHE is an improved form of AHE. In this method, the enhancement calculation is adjusted by maximizing the contrast enhancement factor.
As shown in Figure 3, CLAHE restricts the amplification by clipping the histogram at a specific value and the clipped region is distributed among all the histogram. Images processed with CLAHE have more natural appearance and facilitate the comparison of different areas of the image.

## MATERIAL AND METHODS

The method which will be introduced in this section focuses on the enhancement of contrast and denoising and improves visibility in medical images. Figure 4 shows the framework of the proposed method. In order to implement the proposed method, we go through six stages as follows:

**Decomposing high frequency sub-images:** In this stage, the high-frequency sub-images of the original image are achieved. These sub-images are decomposed with Haar transform. There are noises in these decomposed sub-images which must be reduced in the next stage.

**Stationary wavelet transform denoising:** In the second stage, SWT-denoising, which were described in section II, is applied to each sub-image. By choosing the appropriate thresholds in each level, each sub-image can properly be denoised. So, in this stage the noise of the original image is reduced.

**Wavelet inversing:** In this stage, inverse Haar transform is applied to the output of the previous stage.

**Edge detection:** in the fourth stage, edges of the original image are detected by setting the value of the lowest scale approximation of the Haar transform to zero. To do so, it is essential to select the convenient level for the maximum edge detection. On the other hand, it should be noticed that the blurring of the image must be acceptable.

**Image fusion:** In this stage, the results of the third stage and the fourth stage are combined together by using image fusion.

**Applying Contrast limited adaptive histogram equalization method:** In the final stage, the image histogram is equalized by contrast limited adaptive histogram equalization method.

## EXPERIMENTAL RESULT

In this research, extensive experiments on a medical image (original image), which is a nuclear whole body bone scan and is used to identify infection, tumors and etc., has been conducted. The original image contains noise and has low quality and contrast. After applying the proposed method, which is described in previous section, to the original image, an enhanced image has been obtained. By comparing the original image with the resulted enhanced image, a significant difference between them can be recognized. These differences are shown in figure 5.

As the figure depicts, the enhanced image reveals more skeletal details, which is very important in these kinds of images. Also, the enhanced image improves the contrast in comparison with the original image. In addition, with considering figure 5, it can be concluded that the result of the proposed method is an image which have low level noise.

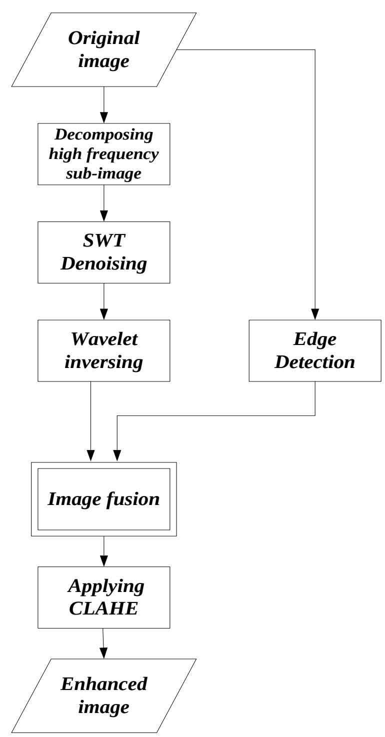
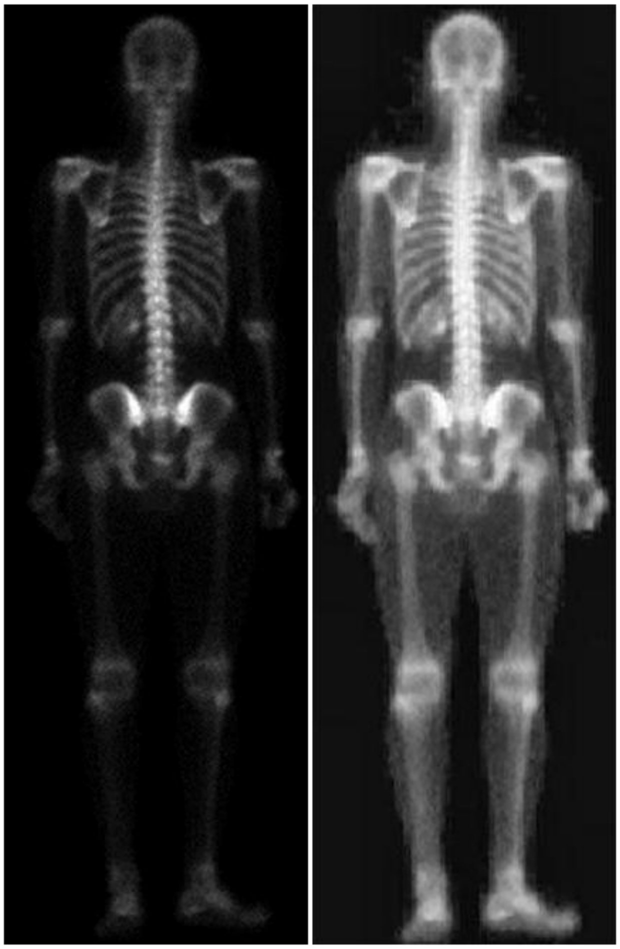



Figure 4. The framework of the proposed method

For example, in Figure 5, it can obviously be observed that the hands and legs regions of the original image have lower contrast and more noises than the other parts of the body whereas these regions are significantly improved in the enhanced image which is the result of applying the proposed method.



(a) (b)

**Figure 5.** Original image(a), the enhanced image (b)

## CONCLUSION

In the process of analyzing the medical images, contrast and noise are the main features to be considered. In this paper, we introduce a new method to enhance the medical images. In this method, which is based on the wavelet transform, we catch the high frequency information and denoise the sub-images in each level. The experimental results indicate that the proposed method enhances the low quality images from different aspects such as contrast, visibility and etc.

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