Anamika Bhardwaj, Manish K.Singh / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 2, Issue 3, May-Jun 2012, pp.2356-2360

A Novel approach of medical image enhancement based on Wavelet transform

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ABSTRACT
Low contrast and poor quality are main problems in the production of medical images. Wavelet transform based denoising techniques are of greater interest because of their performance over Fourier and other spatial domain techniques. Selection of optimal threshold is crucial since threshold value governs the performance of denoising algorithms. For threshold selection we used normal shrink method. By using the wavelet transform and Haar transform, a novel image enhancement approach is proposed. First, a medical image was decomposed with Haar transform. then again high-frequency sub-images were decomposed .secondly noise in the frequency field was reduced by the soft-threshold method. Then high frequency coefficients are enhanced by different weight values in different sub images.Then the enhanced image was obtained through the inverse Haar transform. Lastly, the image's contrast is adjust by nonlinear contrast enhancement approaches. Experiments showed that this method can not only enhance an image's details but can also preserve its edge to increase human visibility.

Keywords - **Wavelet Thresholding, Image Denoising, Contrast Enhancement**

1. Introduction

Medical image enhancement technologies have attracted much attention since advanced medical equipments were put into use in the medical field. Enhance images are desired by a surgeon to assist diagnosis and interpretation because medical image qualities are often deteriorated by noise during acquiring and illumination condition. The noise present in the images may appear as additive or multiplicative components which have been modelled in a number of ways in the literature [9],[10] such as Gaussian noise, Speckle noise, Salt & Pepper noise, Impulse noise etc... Targets of medical image enhancement are mainly to solve problems of low contrast and the high level noise of a medical image. Medical image enhancement technologies have attracted many studies, mainly on greyscale transform and frequency domain transform.wavelet transform is a time-frequency analysis tool developed in the 1980s, which has been successfully applied in the image processing domain after Mallat [1] presented the fast decomposition algorithm.There are many image enhancement methods based on wavelet transform, such as Lu et al. [2], Yang and Hansell [3], Fang and Qi [4], Zhou et al. [5], Wu and Shi [6], etc. In these papers, methods of image enhancement based on wavelet transform were proposed. An image's different scale detail information can be obtained through wavelet transform, but there will be some high-frequency information hidden in high-frequency sub-images of wavelet transform. If we decompose these high-frequency sub-images, we can obtained more image high-frequency information which can help us to enhance a medical image effectively. Also, we can obtain a better enhancement image if we use both spatial field and transform field procession to enhance an image. In addition, we should remove or reduce noise for the reason that there are lots of noise in high-frequency sub-images. We proposed a approach which is used to enhance a medical image based on Haar transform, soft Thresholding and nonlinear approach for contrast enhancement.

2. Noise Removal

2.1 Frequency domain filtering

Frequency domain filtering can be used for periodic noise reduction and removal . This category of filters include band pass filter, band stop filter, Notch (Reject/Pass) filters. The appropriate filter can be chosen with the prior knowledge of noise distribution. The various Fourier domain filtering techniques such as Inverse filter, Wiener filter and least square filter are found in literature[9] [10]. Fourier transform has been found to be an important image processing tool for image processing and analysis. The major advantage of Fourier domain analysis is that, it can explore the geometric characteristics of a spatial domain image [11]. It has been used for the removal of additive noises from the images.

2.2 Wavelet Denoising

Unlike Fourier transform, Wavelet transform shows localization in both time and frequency and hence it has proved itself to be an efficient tool for a number of image processing applications including noise removal [14]. Fourier transform based methods are less useful because, they cannot work on non-stationary signals and they can capture only global features. But in the real scenario, as the images are only piecewise smooth and the noise distributions are random in nature, Fourier transform cannot perform well for the stochastic noise, but wavelets can do. Hence wavelet based noise removal has attracted much attention of the researchers for several years [12],

[13]. The wavelet transform is a time-frequency analysis tool developed in the 1980s, which has been successfully applied in the image processing domain after Mallat [1] presented the fast decomposition algorithm. Wavelet transform is the mathematical tool used for various image processing applications such as noise removal, feature extraction, compression and image analysis. The general method of wavelet based denoising is that, the noisy image may first be transformed to wavelet domain [15] [16].The transformed image appears as four subbands (A, V, H, and D) .Based on the level of decomposition 'j'. 2D discrete wavelet transform leads to decomposition of approximate coefficients at level 'j' into four components i.e. the approximation at level 'j+1' and details in three orientations (Horizontally, Vertically and Diagonally) [19]. Since the noisy components are of high frequency, the three higher bands may contain the noisy components [19], and proper threshold may be applied to smooth the noisy wavelet coefficients followed by the inverse 2D-DWT may be applied to reconstruct the denoised image. Selection of optimal threshold is crucial for the performance of denoising algorithm. Threshold is selected based on the image and noise priors such as mean and variance [17] [18]. Selection of optimal threshold along with various types of wavelet threshold methods like vishu shrink ,bayes shrink ,normal shrink etc.

Vishu Shrink is proposed by Donoho & Johnston .it is also known as Universal threshold

$$T= \sigma\sqrt{2\log M} \qquad (1)$$

where 'σ' is an estimate of the population's standard deviation and 'N' is the number of pixels in the image. In practice, 'σ' is calculated as the mean of the absolute difference (MAD) which is more robust than the standard deviation of the sample. The universal threshold method assumes that all wavelet coefficients less than T are noise, and these are eliminated.

Bayes Shrink has attracted much attention since it sets different thresholds for every subband. Here subbands are frequency bands that differ from each other in level and direction. Since huge information about the noise is available at the diagonal coefficients of first level wavelet decomposition (HH1) the noise variance 'σ' is calculated using the robust estimator

$$\sigma^2=[\text{median}(Y_{ij})/0.6745]^2,\ Y_{ij} \in \text{subband HH} \qquad (2)$$

$$\sigma_x =\sqrt{\max((\sigma^2_y- \sigma^2_v),0)} \qquad (3)$$

With this background, the threshold using Bayesshrink is calculated as

$$T= \sigma^2_v/\sigma_x \ . \qquad (4)$$

Minimax Threshold uses a fixed threshold chosen to yield minimax performance for mean square error against an ideal procedure. The minimax principle is used in statistics in order to design estimators. Since the de-noised signal can be assimilated to the estimator of the unknown regression function, the minimax estimator is the one that realizes the minimum of the maximum mean square error obtained for the worst function in a given set. Minimax threshold does not give good visual quality, but it has the advantage of giving predictive performance.

Waveshrink is an expansion based estimator proposed by Donoho and Johnston. With the orthonormallitty property of the wavelets is has been prove din the literature that the least square estimate of the wavelet coefficients is unbiased and the risk function values are equal to the risk in coefficient values. A mere least square estimate does not denoise the original image. Hence, to estimate wavelet coefficients at minor risk Donoho and Johnston have applied a component wise function which shrinks the least square estimate towards zero. Total risk factor is calculated by summing component wise risks. With this background, the threshold function is modified as

$$T= \sqrt{2\log(N\log N)} \qquad (5)$$

N is total number of pixels in image.

NormalShrink is an adaptive threshold estimation method for image denoising in the wavelet domain based on the generalized Gaussian distribution (GGD) modeling of subband coefficients... The threshold is computed by

$$T=\beta\sigma^2/ \sigma_y \qquad (6)$$

where σ and σ_y are the standard deviation of the noise and the subband data of noisy image respectively. σ^2 is Noise variance estimated from High Frequency sub band by eq.2. β is the scale parameter, wcalculated by eq.8.which depends upon the subband size and number of decompositions**,**

2.2.2 Medical Image Enhancement Algorithm

In Medical image Some useful information is hidden in high frequency sub images.An image's different scale detail information can be obtained through wavelet transform, but there will be some high-frequency information hidden in high-frequency sub-images of wavelet transform. If we decompose these high-frequency sub-images, we can obtained more image high-frequency information which can help us to enhance a medical image effectively. Also, we can obtain a better enhancement image if we use both spacial field and transform field procession to enhance an image. In addition, we should remove or reduce noise for the reason that there are lots of noise in high-frequency sub-images. In approach which is used to enhance a medical image based on wavelet transform, Haar transform and soft thresholding with vishu shrink and nonlinear histogram equalization was used for Enhanced image.[20].

3.Contrast Enhancement

Two types of the contrast enhancement techniques, linear contrast techniques and non-linear contrast techniques.

3.1 Linear Contrast Enhancement

This type referred a contrast stretching, linearly expands the original digital values of the remotely sensed data into a new distribution. By expanding the original input values of the image, the total range of sensitivity of the display device can be utilized. Linear contrast enhancement also makes subtle variations within the data more obvious.These types of enhancements are best applied to remotely sensed images with Gaussian or near-Gaussian histograms, meaning, all the brightness values fall within a narrow range of the histogram and only one mode is apparent. linear contrast techniques applying three methods, Max-Min contrast method, Percentage contrast method and Piecewise contrast technique[8].

3.2 Nonlinear Contrast Enhancement

Nonlinear contrast enhancement often involves histogram equalizations through the use of an algorithm.In non-linear contrast techniques applying four contrast methods, Histogram equalization method, Adaptive histogram equalization method, Homomorphic Filter method and Unsharpe Mask.[8]

4. Proposed Work

The idea is that we decompose a medical image at 1 level then we decompose high-frequency sub-images with Haar transform.

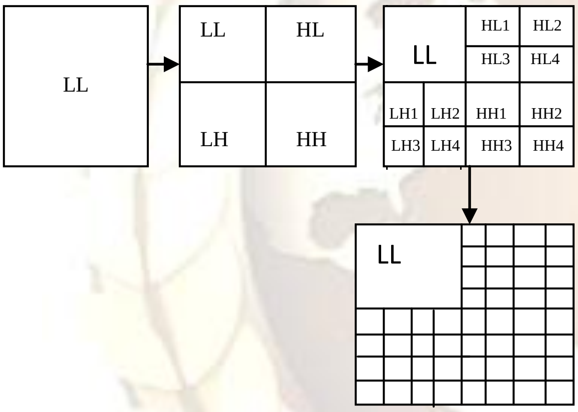

Fig.1 Image decomposition and high-frequency sub-images decomposition by Haar transform up to 3 level

The nonlinear soft threshold filtering method is used to remove noise, and the nonlinear histogram equation is used to stretch the intensity range after a medical image's decomposition. An image can be seen as a 2D signal, so an image's sub images are obtain by Haar Transform. In the wavelet frequency field, an image's edge feature information and detail information are distributed in high-frequency sub-images. There is still more detailed information in these high frequency sub-images. In order to obtain more image detail information, all high-frequency sub images are decomposed with Haar transform up to 3 level. This method is simpler than the wavelet packet transform and the general multi-wavelet transform for that Haar transform is the simplest inverse symmetry orthogonal transform and is only used to decompose high-frequency sub-images. It can help us to obtain more detailed information in all level sub-images except low-frequency sub-images here. There is abundance of image detail information in high-frequency sub-images. But there are also plenty of noise in these sub-images. The wavelet transform's smooth function can help us to reduce an image's noise, but it cannot meet our requirements. Haar transform can also help us to reduce some noise, but still there is much noise in high frequency sub-images. If we enhance high-frequency coefficients at this time, image detail information and noise are all enhanced. We reduce noises of high-frequency sub-images through the nonlinear method. Because the noise properties are different in different high frequency sub-images, different soft thresholds are used to reduce noise in different sub-images. To set the soft threshold use normal shrink[7] formula which is adaptive to different sub band characteristics and shows very good result as compare to other thresholding method[7].

$T=\beta\sigma^2/\sigma Y$

As stated in equation 6,where Estimate Noise Variance (σ^2) from High Frequency Sub band. σY Standard deviation of sub band.

$\sigma^2=[\text{median}(Yij)/0.6745]^2, Yij \in$ sub band HH
as stated as equation 2.

$$\beta=\sqrt{\log(Lk/J)} \quad (7)$$

Where scale parameter β is computed once for each scale using Equation 7. Lk is Length of Subband, J is total number of Decomposition.
where T are threshold value which are calculated for each subband. In Medical images different high-frequency subimages denote different detailed information of an image. After applying soft thresholding on noisy coefficient. Different high frequency sub images denote different detailed information of an image , so we should enhance different sub images through different enhancement weight values. Denoised high Frequency coefficient are multiply by 1.5(assign weight value)to get enhanced coefficient. Finally by inverse haar transform enhanced image is generated. But the pixel grayscale range of the enhanced image is narrower than a normal image. Also it makes an image look unclear. There are lots of contrast enhancement method but we choose nonlinear method over liner method. Nonlinear contrast Enhancement is used to stretch the grayscale range. Nonlinear method is used to obtain new intensity range. Enhanced image is having good human visibility which is really very important in medical images.

5.Experimental Result

The proposed method is used to enhance the medical image. We use three level wavelet transform here.The nonlinear Contrast Enhancement(Adaptive Histogram Equalization) for enhancing contrast, Fig 2 shows experiment results. Figs. 2a and d are original images, Figs. 2b and e are enhanced images via sub band wavelet thresholding by vishu shrink and histogram equalization, and Figs.2c and f are the results of Proposed Algorithm.

The PSNR value of Fig. 2b is 18.64, and of Fig. 2c 28.08, the PSNR value of Fig. 2e is 20.04, and that of Fig. 2f is 38.53. From the enhanced results, enhanced images with the method proposed are better than results with other method.In Figs. 2c and f, not only are the image's blur and low-contrast detail enhanced, but the image's textures are clearer.

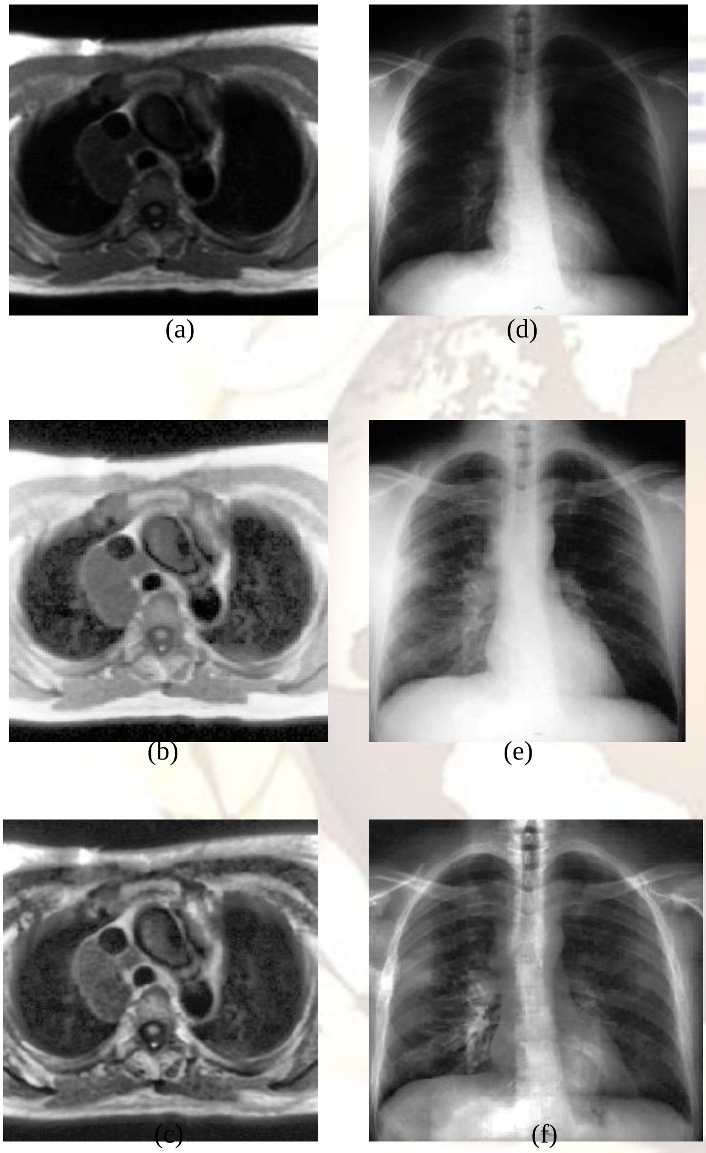

Fig. 2 Medical Image Enhancement experiments

a) Initial CT Image
b) Enhanced Image by Wavelet Thresholding and Histogram Equalization
c) Enhanced Image by Proposed Algorithm
d) Initial X-ray Image
e) Enhanced Image by Wavelet Thresholding and Histogram Equalization
f) Enhanced Image by Proposed Algorithm

5.Conclusion

An important problem of medical image enhancement based on Haar wavelet transform is how to extract high-frequency information and to decompose the high-frequency sub-images of wavelets. This helps us to extract high-frequency information effectively. Normal shrinkage is applied for Wavelet denoising purpose Nonlinear contrast enhancement are used in the process of medical image enhancement. They can also help us to enhance a medical image effectively. Results of experiments show that the algorithm not only can enhance an image's contrast, but also can preserve the original image's edge property effectively. Finally result will be having good human visible property which is very important in medical images for diagnostic purpose.

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