De-noising of Ultrasound Image using Discrete Wavelet Transform by Symlet Wavelet and Filters

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***Abstract*—Noise is a major factor in degrading the image quality of various medical images (MRI, CT scan, Ultrasound etc.). Speckle noise is a most common noise presents in all medical images including ultrasound images. For diagnosis purpose it is essential to extract useful data in the original form so transformations are required for this. DWT (Discrete wavelet transform) is the latest and best technique for image denoising. In this work various techniques for removal of speckle noise from medical images based on Wavelet Multiresolution analysis and filtering techniques has been proposed. A comparative analysis of different methods: DWT with different wavelet families (Haar and Symlet) with wiener and median filtering has been presented. Results are compared in terms of PSNR, Mean squared Error (MSE) and processing time.**

Keywords— Denoising, Symlet, DWT, Filter, PSNR and MSE.

I. INTRODUCTION

The main objectives of Image denoising techniques are to remove noises without effecting the usefull information. There are different available denoising schemes [1]. The algorithms which are presently famous also increase image noise. Due to this some difficulties occurs in the path of further process. Now a day's wavelets are very efficient for the enhancement of denoised image and become one of the major study fields [2].

Ultrasound imaging is very popular now days because of its various advantages: it is safe, non-invasive, portable, relatively inexpensive, and provide a real time image formation. The main problem with ultrasound images are poor quality, mainly caused by multiplicative speckle noise [3,4]. Speckle is a granular 'noise' that inherently exists in and degrades the quality of the medical ultrasound images. Speckle noise results constructive and destructive interference shown as bright and dark dots in the image. Speckle noise affects the diagnosis and human interpretation. In Ultrasound images small differences that may exist between normal and abnormal tissues are confounded by noise and artifacts, often making direct analysis of the acquired images difficult [5].
Various transformations are applied in order to denoise the image but wavelet transformation is more advantageous to use because it has variable window size. We can work on that part of image where information content present is more by providing large window size to that area and where information content is low we can provide small window size, so we can adjust the window size in wavelet transform which other transforms available such as Fourier transform and Hilbert transform does not provide. Another main advantage of using discrete wavelet transformation is that after transformation it will not only provide frequency and amplitude information of signal but also provides temporal information whereas in other transformations temporal information is lost [6]. Filtering techniques are used so as to improve peak signal to noise ratio and to reduce mean square error ant to enhance the edges and lines of the image. Wiener filter [7] is a type of linear filter that is applied to an image adaptively, According to the local image variance it adjust itself and Median filter is used to preserve edges of the image in order to sharpen it and wiener filter is used as it tailors itself to local variance and perform smoothing. The Ultrasound image is taken from An open access biomedical image search engine named openi. Openi provides abstract and images from the open source literature, and biomedical image collections [8] started by National library of medicine.

II. DISCRETE WAVELET TRANSFORM (DWT)

The discrete wavelet transform (DWT) refers to wavelet transforms in which sampling of wavelet is done in a discrete way and it is significant to use DWT rather than Fourier transform as it has variable window size therefore scaling can be done in this and computation time taken in DWT transform is very less as it is very quickly done in it as compared to Fourier transform in which time taken is more. Discrete Wavelet Transform The 2-D wavelet decomposition is performed by applying 1-D DWT along the rows after that apply 1-D DWT along columns. This operation results in four decomposed sub-band images referred to as low– low (LL), low–high (LH), high–low (HL), and high–high (HH). For multi resolution analysis, the LL band of previous level is again decomposed by DWT [9]. In Figure 1 three level of decomposition is shown where L is low frequency band, H is high frequency band and 1,2,3 are the decomposition levels. Wavelet transformation is more advantageous to use because it has variable window size. The window size in

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wavelet transform which other transforms available such as Fourier transform and Hilbert transform does not provide.

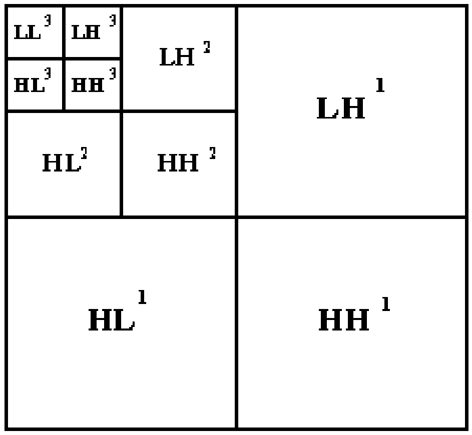

Figure 1: Structures of 2-D DWT with 3 decomposition levels[15].

Another main advantage of using discrete wavelet transformation is that after transformation it will not only provide frequency and amplitude information of signal but also provides temporal information whereas in other transformations temporal information is lost.

A. HAAR WAVELET

The Haar wavelet was proposed by Alfred Haar in 1909. It is the simplest wavelet among all of the available wavelets and its operation is also easy to understand. There are various limitations of Haar wavelet like they are piecewise constant and hence produce irregular, blocky approximations [10]. The Haar wavelet transform has a number of advantages that can be summarized as follow:

- It is conceptually simple.
- It is very fast.
- It is memory efficient. i.e, it can be calculated in place without a temporary array.
- It is exactly reversible without the edge effects that are a problem with other wavelet transforms.

B. SYMLET WAVELET

In this paper we use wavelet family like Symlet wavelet with wiener filter and median filter and level of decomposition is 3. Symlet Wavelet is a family of wavelets. They are a modified version of Daubechies wavelet with increased symmetry. The properties of the Daubechies and Symlet wavelet families are similar [11]. There are 7 different Symlet functions from sym2 to sym8. In *symN*, *N* is the order. Advantages of symlet wavelet transform are:

- Symlets are "symmetrical wavelets".
- They are designed so that they have the least asymmetry and maximum number of vanishing moments for a given compact support.

III. VARIOUS METHODS FOR IMAGE DENOISING

Wiener filter is an effective and efficient method to reduces the speckle noise having minimum mean square error. In this statistics properties of image signal and noise have been obtained and also signal variance $\sigma^2$and noise variance v^2 have been pre-estimated [12]. Various methods are available for image denoising of ultrasound images which are corrupted by speckle noise includes filtering techniques like wiener filters, median filter, adaptive filtering techniques and transform based techniques including Fourier transform, Hilbert transform and wavelet transform techniques. Speckle noise is a high frequency content present in ultrasound images. When multiplicative noise such as Speckle noise is concerned it is better to use the best effective method for reduction of speckle noise i.e. Discrete wavelet transform in which as it has variable window size and wavelet decomposition is done in it and it is effectively used to separate the noise content from original image [13]. Median filter is used to preserve edges of the image in order to sharpen it and wiener filter is used as it tailors itself to local variance and perform smoothing.

IV. PROPOSED ALGORITHM

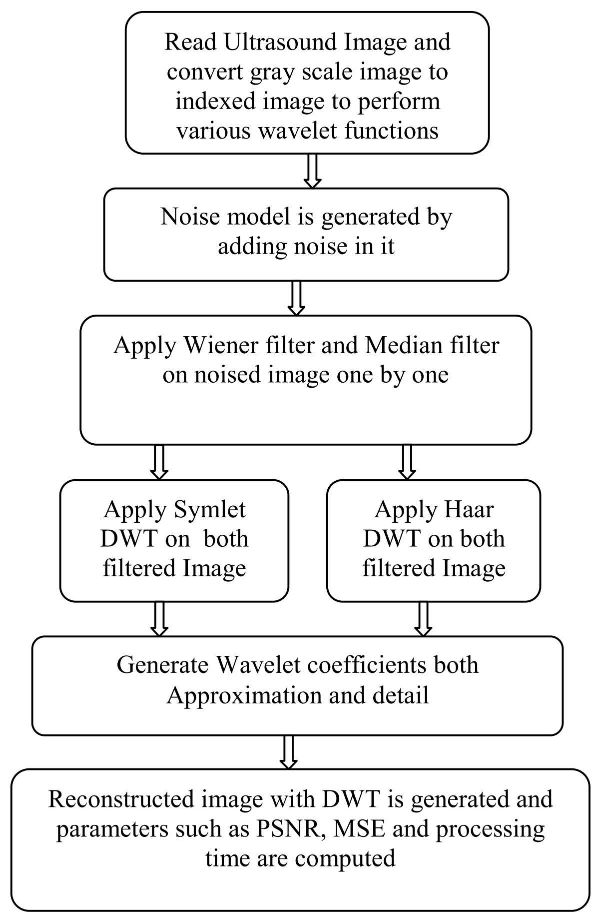

Figure 2: Proposed Algorithm

Wiener filter is a linear filter that is applied adaptively, According to the local image variance it adjusts itself. When in the image processing more smoothing is essential it adjust its variance to large value and when less smoothing is essential its variance is adjusted to small value. In this we deblur the image using deconvolution algorithm in Matlab software in which blurred image is deconvolved with wiener filter and it will returns deblured or restored image with less mean square error.

A. Median Filter

In image processing the best known order statistics filter is the median filter [14] and it is the simplest technique which is used to remove speckle noise, pulse noise or spike noise from the image. While other smoothing filters only removes noise from the signal but they are not able to preserve edges of the signal but median filter is the special smoothing filter which improves the result of later processing by removing noise from the signal and additionally preserves the edges. It follows an algorithm in which each entry of the signal is replaced one by one with median of neighboring entries and median is calculated by replacing the pixel value with the middle pixel value and such a pattern of neighboring entries forms a sliding window which slides over entire signal one by one.

V. PERFORMANCE PARAMETERS

The performance measures used in this paper provide some quantitative comparison among different enhancement schemes mainly aiming at measuring the definition of an image.

A. *Mean Squared Error (MSE)*

Mathematically MSE is given by the equation shown below:

$$MSE = \frac{\sum_{M,N}[I_1(m,n) - I_2(m,n)]^2}{M * N}$$

Where, I_1 is the perfect image, I_2 is the fused image to be assessed, I is pixel row index, j is pixel column index and m, n are the no. of row and column.

B. Peak Signal To Noise Ratio (PSNR)

PSNR is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. The PSNR measure is given by:-

$$PSNR = 10\log_{10}\left(\frac{R^2}{MSE}\right)$$

R is the maximum fluctuation in the input image data type. For example, if the input image has a double-precision floating-point data type, then R is 1. If it has an 8-bit unsigned integer data type, R is 255, etc.

VI. RESULTS

The Haar and Symlet based discrete wavelet transform with Weiner and median filter are used for speckle noise reduction, the proposed algorithm has been implemented in the MATLAB environment. Ultrasound image have been obtained from a online database. In proposed algorithm first speckle noise is added and then filters are applied to reduce noise at some extant than three level DWT is applied in wavelet domain and iDWT (inverse discrete wavelet transform) is applied to get original image back. To estimate the performance of the symlet and Haar wavelet with wiener and median filters, various statistical values (performance parameters) have been calculated from the original, noised and denoised Ultrasound image like MSE, PSNR and processing time. In figure 3 original ultrasound is shown and in figure 4 image corrupted with speckle noise is shown, figure 5 shows the noise removed by wiener filter.

Gray scale image

Figure 3: Original Ultrasound image

image with speckle noise

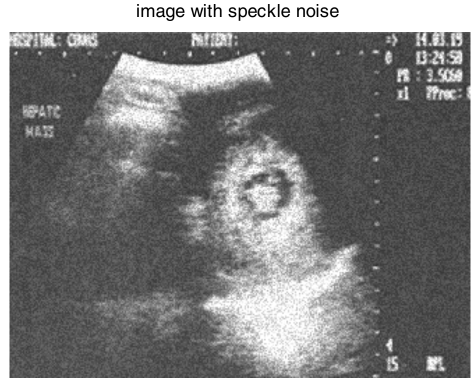

Figure 4: Blurred image corrupted with speckle noise

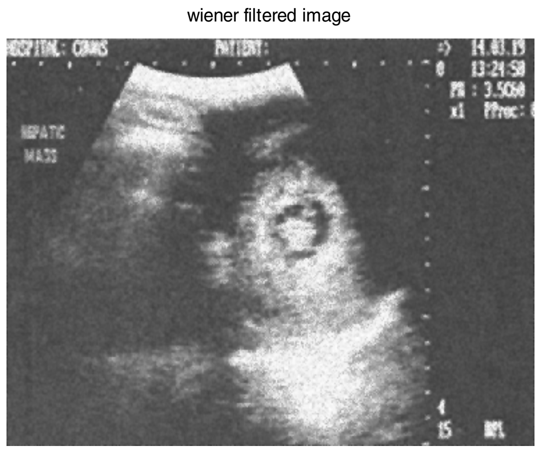

Figure 5: Noise removed by wiener filter

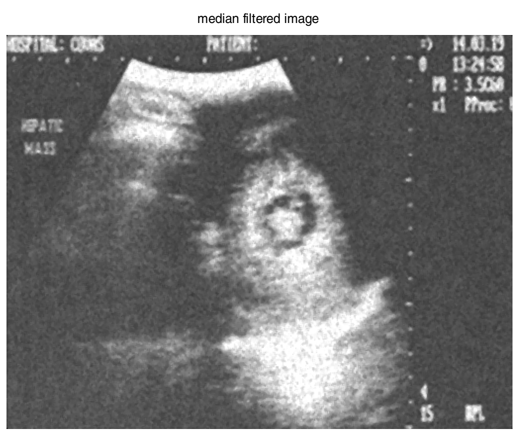

Figure 6: Noise removed by Median filter

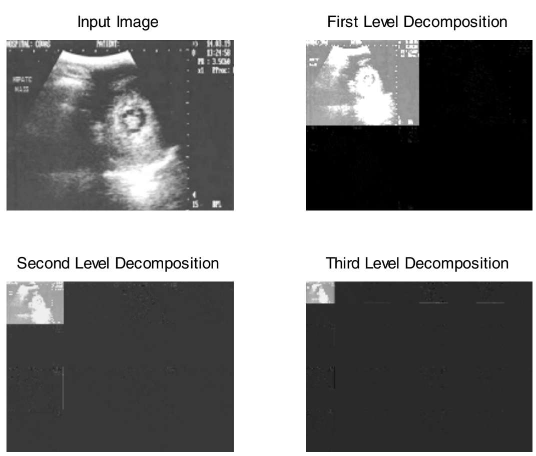

Figure 7: Three level decomposition of filtered Image using Symlet DWT

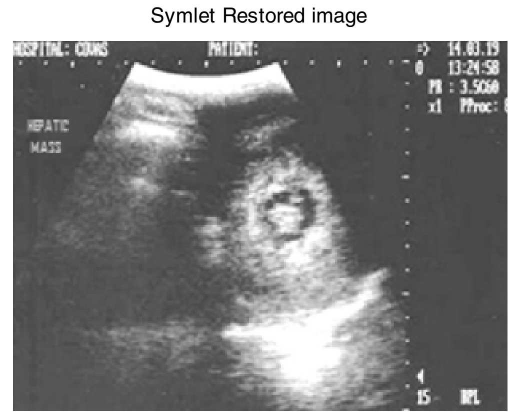

Figure 8: Restored image with Symlet DWT after Wiener filter

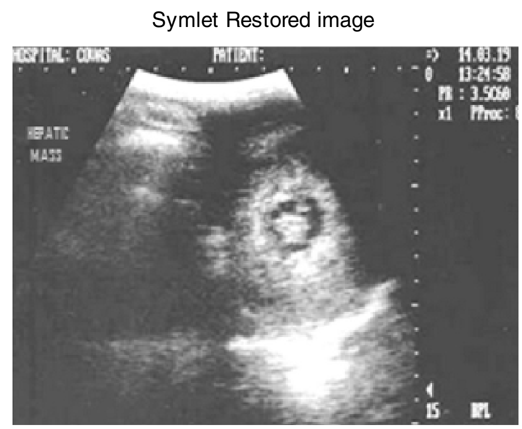

Figure 9: Restored image with Symlet DWT after Median filter

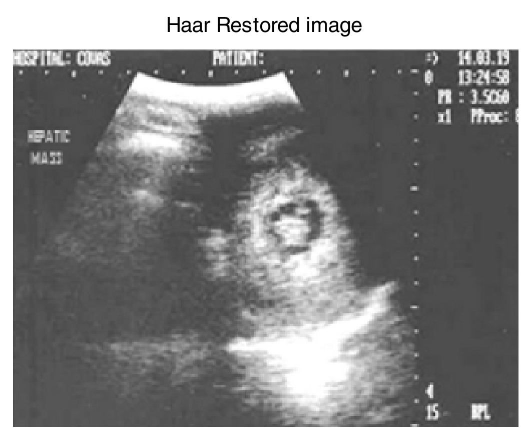

Figure 10: Restored image with Haar DWT after Wiener filter

Haar Restored image

Figure 11: Restored image with Haar DWT after Median filter

In figure 6 noise is removed by the median filter and figure 7 shows Three level decomposition of filtered Image using Symlet DWT after that original image is restored by iDWT shown in figure 8, similarly original image Restored by Symlet DWT after Median filter, Haar DWT after Wiener filter and Haar DWT after Median filter are shown in figure 9, 10 and 11 respectively. The Quantitative and Comparative Analysis of different techniques are shown in table 1 with different parameters.

Table I. Quantitative Results And Comparative Analysis Of Different Techniques

Name of Technique	PSNR	MSE	Processing Time (Sec.)
Image corrupted with speckle noise	24.0994	255	0.176
Symlet DWT with wiener filter	53.1652	0.3162	1.706
Symlet DWT with median filter	53.1187	0.3196	1.814
Haar DWT with wiener filter	53.0527	0.3245	1.823
Haar DWT with median filter	52.9626	0.3313	1.902

VII. CONCLUSION

Results of median and wiener filter along with Haar and Symlet DWT approach are analyzed and their comparative analysis is done. Ultrasound image corrupted with speckle noise is compared with denoised Ultrasound image achieved by various techniques discussed above, DWT is applied and after multilevel decomposition and filtering, finally reconstruction image will be achieved. Best value of PSNR is 53.1652 and MSE is 0.3162 is achieved by using Symlet DWT with wiener filters with minimum processing time. It has been concluded that image visual and picture quality improves as speckle noise is reduced using discrete wavelet transform technique.

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