Reduction of Speckle Noise in Ultrasound Images using Various Filtering techniques and Discrete Wavelet Transform: Comparative Analysis

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ABSTRACT- Speckle noise becomes a dominating factor in degrading the image visual quality and perception in medical images. Speckle noise is a particular kind of noise which affects all coherent imaging systems including medical ultrasound images and astronomical images. It is essential to keep the useful data in the exact original form. So we need to process the data by applying transformations. DWT (Discrete wavelet transform) is the latest and best technique for image denoising. This paper presents study of various techniques for removal of speckle noise from biomedical images such as Spatial and frequency domain filter and a modified algorithm for speckle noise reduction using wavelet based Multiresolutional analysis and combined filtering techniques with wiener and median filters. A comparative analysis of three methods: DWT with wiener filtering, DWT with median filtering and DWT with both wiener and median filtering techniques has been presented. Results are compared in terms of PSNR, Mean squared Error and processing time.

Index Terms- De-noising, Speckle Noise, Ultrasonic Imaging, Wavelet transform, PSNR and MSE.

1. INTRODUCTION

The main purpose of Image denoising techniques is to remove noises while retaining as much as possible the important signal information. Introduction section offers concise knowledge about different available denoising schemes [1]. Ultrasound images are widely used in medical field as it is comparatively safe, economical, adaptable, and transferable but one of its main disadvantage is the poor quality of images, which are corrupted by speckle noise. The presence of speckle noise is not attractive as it reduces the image quality and it affects the tasks of individual interpretation and diagnosis. [2]. Filtering used for speckle noise reduction is used for analysis, recognition and extraction of features from medical images. Earlier a number of methods have been adopted for speckle noise reduction for improving the quality of image required in different applications [3]. De-noising is very important task in the field of the medical image processing. It is very vital to do it before data is taken. In order to remove the noise content present in the image and to acquire the useful information from low frequency content of the image, regardless of the high frequency contents of the image where information content present is low denoising is done.

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 [4].

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.

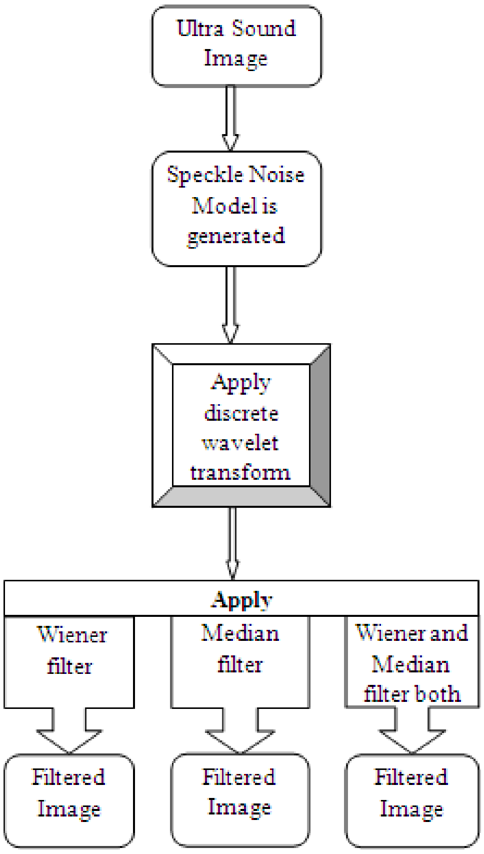


Figure 1: Block Diagram of proposed Algorithm

The classical Wiener filtering is not adequate type of filtering because it is designed primarily for additive noise suppression [6]. Multiplicative noise is translated into additive noise which is easier to remove by taking log of the image and applying wiener filter this approach is known as Homomorphic approach. In order to calculate statistical information of the image such as its gray value, local mean and variance adaptive filter is used and it is used in order to calculate new pixel value of the image as it changes or adapt itself to central pixel value of the image [7].

2. NEED FOR IMAGE ENHANCEMENT IN ULTRASOUND IMAGING

Image enhancement has played a vital role in improving the image quality and reducing artefacts such as noise reduction from average image, simple algorithms for enhancing edges and adjustment of gray levels to boost contrast resolution. Image processing in ultrasound images is used for various reasons:

i. Ultrasound images are more complex as there are large number of image characteristics which includes diagnostic and artifactual.

ii. Medical professionals resist to a processed appearance and are scared of loss of data or variation in diagnostic criteria.

iii. As there are large number of clinical applications therefore computational power essential for real-time (20–60 frames/s) image rates.

3. VARIOUS METHODS FOR IMAGE DENOISING

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. 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.

1. Median Filter

In image processing the best known order statistics filter is the median filter 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.

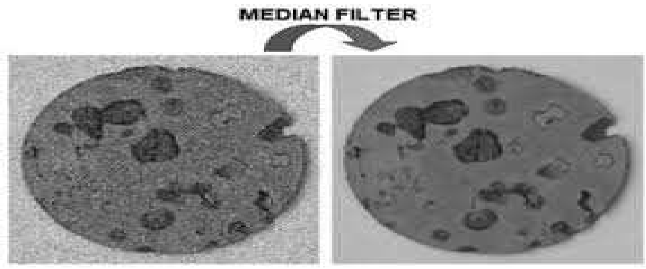


Figure 2: Results of median filter

ii. Wiener Filter

Wiener filter is a type of linear filter that is applied to an image adaptively, According to the local image variance it adjust 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.

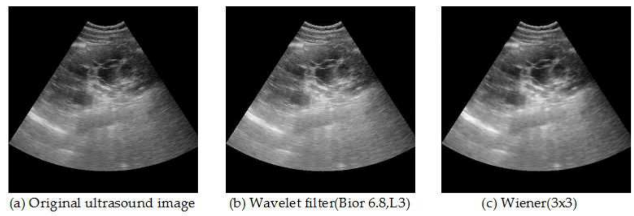


Figure 3: Ultrasound image showing Results of wiener filter and wavelet filter

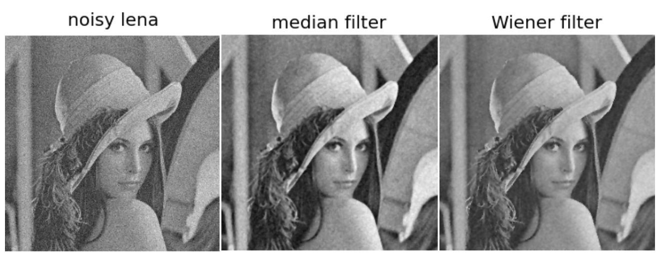


Figure 4: Comparison of noisy, median and wiener filtered image

iii. Discrete Wavelet Transform

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. DWT is mostly used in coding of the signals where properties of the transform are exploited to represent a discrete signal in a more redundant form, frequently as a preconditioning for data compression.

DWT has one more advantage that if information content present in some region of image is more than we can use long time duration for that region of image and shorter time duration for region of image where information content is low. The transform is basically based on a wavelet matrix, which can be computed more rapidly than the analogous Fourier matrix.

Previous techniques of thresholding includes filtering in spatial domain but in case of DWT the whole analysis is shifted from spatial domain to frequency domain having both time–scale aspects. In DWT on different locations and scales the image is represented as sum of wavelet functions and it is admired because it denoised the image using its property of de-correlation and it has wide applications in compression of videos and many contemporary images. The process of wavelet decomposition will divide the given image into four parts having two rows and two columns this is called first level of decomposition and from this approximation and detail coefficients are obtained having one approximation coefficient and two three detail coefficients i.e. horizontal, vertical and diagonal coefficient[12] and the outcome decomposition coefficients are constructed and approximation coefficient will reside in top-left section of the matrix, horizontal coefficients will reside in the bottom-left section of the matrix, vertical coefficients will reside in the top-right section of the matrix and the diagonal coefficients will reside in the bottom-right section of the matrix[13].

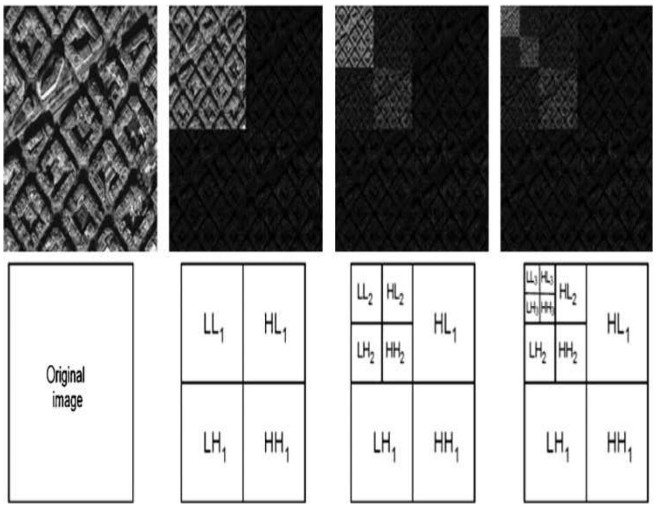


Figure 5: Wavelet decomposition of image using wavelets

GENERAL DENOISING MODEL USING DWT TECHNIQUE

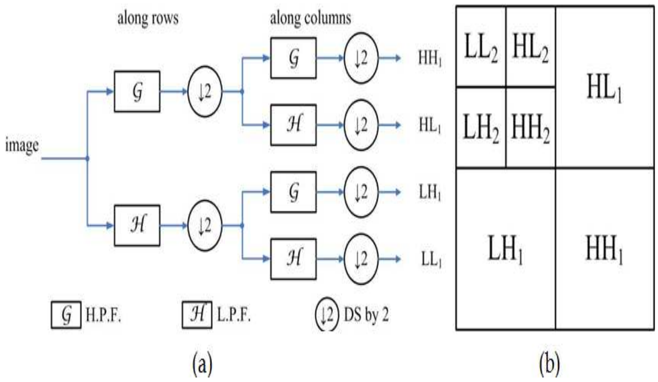
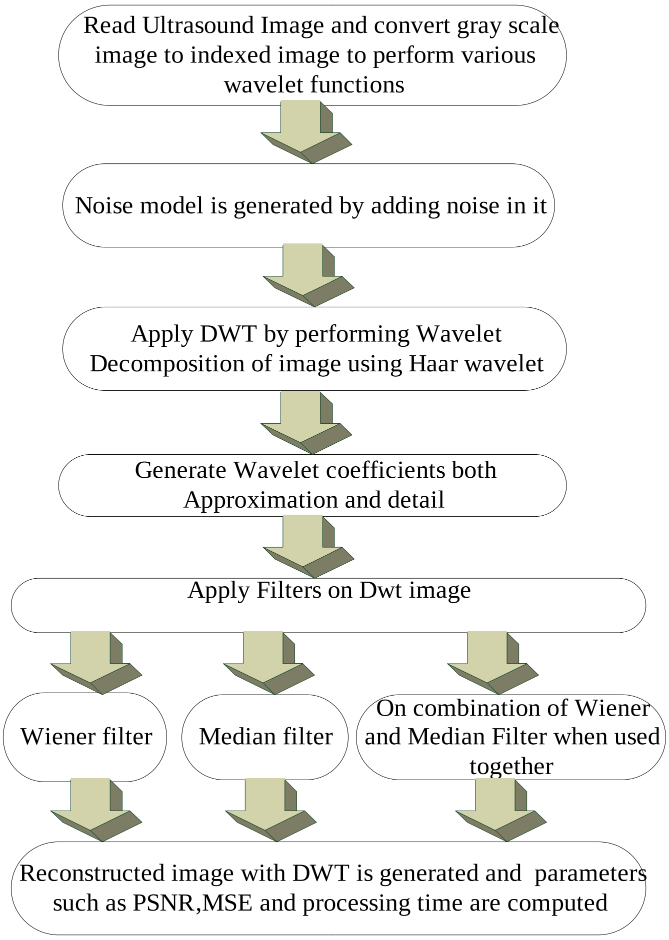


Figure 6: Image Denoising using Discrete wavelet transform

4. PROPOSED ALGORITHM



This algorithm has been developed and implemented in MATLAB software using Image Processing Toolbox and Wavelets toolbox and performance parameters such as PSNR, MSE and processing time of the image is checked.

6. 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.

I. 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.

II. MEAN SQUARED ERROR (MSE)

The mathematical equation of MSE is giver by the equation

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

Where, I_1 - the perfect image, I_2 - the fused image to be assessed, i – pixel row index, j – pixel column index, m, n- No. of row and column

7. Qualitative RESULTS

Results on ultrasound images corrupted with speckle noise

Figure 5: Original Ultrasound image

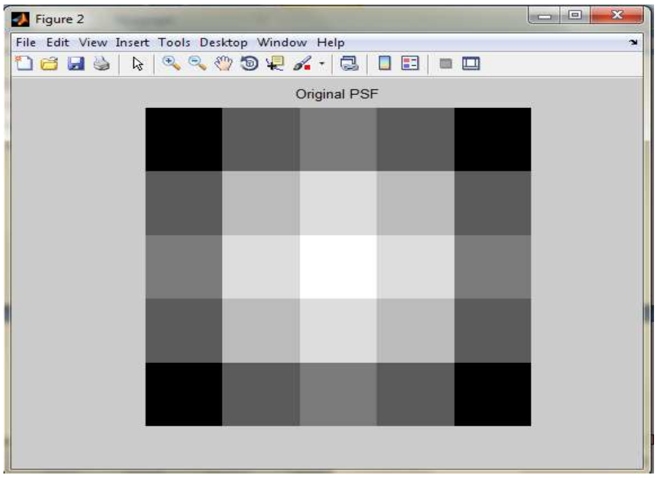


Figure 6: PSF of original image

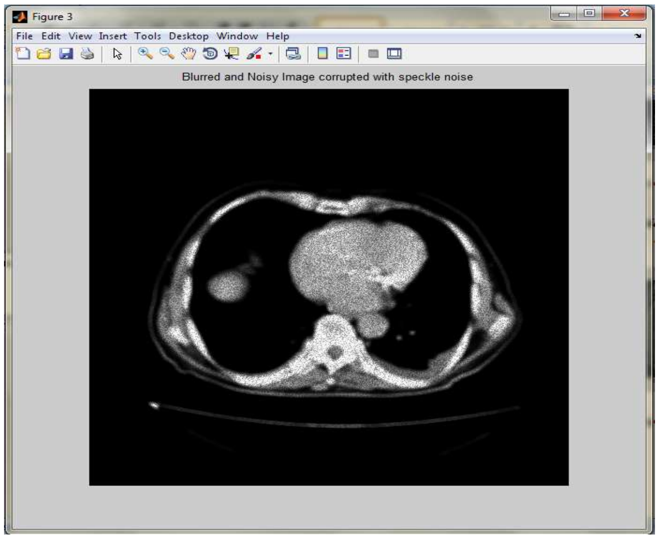


Figure 7: Blurred image corrupted with speckle noise

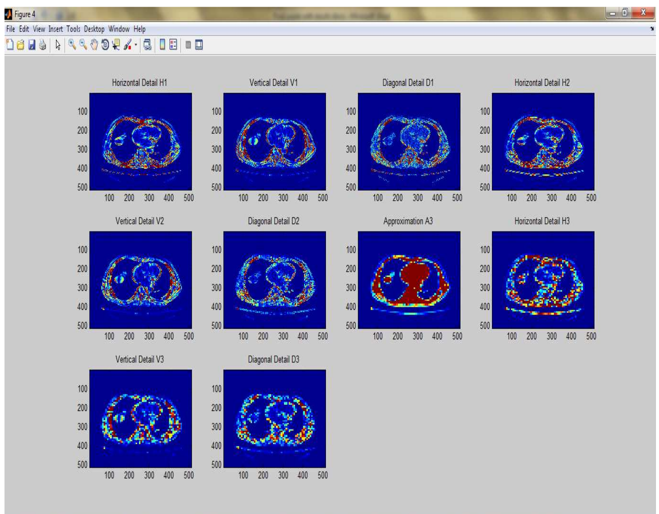


Figure 8: Approximation and detail coefficients

Figure 10: Restored image with DWT and Wiener filter

Figure 12: Restored image with DWT and Median filter

Figure 12: Restored image with DWT, Wiener and Median filter

8. Quantitative results and Comparative Analysis of different techniques

Name of Technique	PSNR	MSE	Processing Time
DWT with wiener filter	35.54	12.47%	2.458082 sec
DWT with median filter	37.0744	12.7539%	2.434188 sec
DWT with both median and wiener filter	37.1695	12.4777%	2.639929 sec

8. CONCLUSION

Quantitative and Qualitative results of median and wiener filter along with DWT approach are analysed and their comparative analysis is done. Ultrasound image corrupted with speckle noise is compared with denoised Ultrasound image, when wiener and median filter along with DWT are being applied. DWT is applied to construct detail and approximation coefficients and after multilevel decomposition and filtering, reconstruction image will be produced using reconstruction coefficients. Best value of PSNR is 37.1695 and MSE is 12.4777% and it is attained by using combination of filters (Hybrid filter) in which output of wiener filter with DWT is applied to Median filter to further improve the results as compared to PSNR value of wiener filter with DWT and median filter with DWT approach. 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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