Despeckling of Ultrasound Medical Images using DW and WP Transform Techniques

P. Kalavathi [#1], S. Boopathiraja[#2] and M. Abinaya[#3]
[#]Department of Computer Science and Applications
The Gandhigram Rural Institute-Deemed University, Gandhigram – 624 302, Tamilnadu, India
[1]pkalavathi.gri@gmail.com
[2]boopathiraja777@gmail.com
[3]abinayasree91@gmail.com

Abstract—**The existences of noise in the medical images impose misleading of diagnostic processes, because of the radiation problem while acquiring images. The medical images mostly affected by the speckle noise over other natural noises. There are number of noise removal techniques for speckle noise is proposed in both spatial and frequency domain. In this paper, we propose a frequency domain method using wavelet based noise removal technique to remove speckle noise that exists in the ultrasound images. Moreover, we have implemented two different methods in terms of decomposing the images. We used Discrete Wavelet Transform (DWT) and Wavelet Packet Transform (WPT) for decompose the images. For comparative analysis, the performance of these filtering techniques is quantitatively evaluated through Peak Signal to Noise Ratio (PSNR).**

Keyword-Speckle Noise, Ultrasound Image, Discrete Wavelet Transform (DWT), Wavelet Packet Transform (WPT).

I. INTRODUCTION

In the medical imaging field, the noises occurring in the images are a crucial issue that leads to faulty decision during the patient diagnostics processes. There are variety of noise removal techniques also exists for mixed noises [1]. Noise removal techniques are constructed through spatial or frequency domain. Spatial filtering is nothing but the filtering operations that are performed directly on the intensity of the pixels [2]. It works by simply moving the kernel (i.e. filter mask) throughout the image from point to point. It mainly classified into smoothing, order-statistics and sharpening filtering. Ultrasound is one of the low cost medical imaging modality with simpler operations and so that used widely. High frequency sound waves are used to capture the inner organs [3]. The ultrasound image is produced by the reflection of the waves from the body structures. The amplitude of the signal and time taken for the wave to travel through the body are the two main factors to construct an ultrasound image. Moreover, ultrasound is a sound wave with frequencies higher than the upper audible limit of human hearing. The frequencies that operated in ultrasound devices are ranges from 20 kHz up to several gigahertz. Health care professionals uses ultrasound images to view the internal organs. During pregnancy, doctors are uses ultrasound to view the fetus, because it does not expose any radiation like other modalities. The noise occurrence in this modality is a big problem that occurs due to the value of the clear nature of the trend transferring [4]. These noises corrupt the images and often lead to incorrect diagnosis [5]. Medical imaging modalities are affected by different types of noises especially the ultrasound images are mainly affected by speckle noise.

Speckle is a granular noise that exists inherently and it degrades the quality of the images such as synthetic aperture radar (SAR), medical ultrasound and optical coherence tomography images [6]. Reducing these speckle noise from a noisy image is the complicated step in medical image processing. Speckle noise degrades image quality with a backscattered wave appearance which originates from many sources like microscopic spreader reflections that pass through internal organs. It makes much difficulty for the observer to discriminate fine detail of the images while diagnostic processes. Thus, denoising or reducing these speckle noise from a noisy image has become the predominant step in medical field. Some spatial domain filtering techniques are existing for removing noises [7]. Ultimately, the speckle noise addresses the contrast related problems on images. So, there is great need to construct a denoising method to remove the speckle [8]. In this paper, we experimented the ultrasound images which are affected by speckle noise for denoising. A wavelet based image filtering technique is applied to ultrasound images which effectively remove the noises. In addition, the performance of aforementioned filters is compared (in terms of PSNR) and discussed in the following sections. This paper is further organized as follows: Section 2 contains the brief introduction about the Discrete Wavelet Transform (DWT) and Wavelet Packet Transform (WPT), our proposed method is explained in section 3, the results and discussion included in section 4 and we conclude our paper in section 5.

II. DISCRETE WAVELET TRANSFORM AND WAVELET PACKET TRANSFORM

A multiresolution analysis formally introduced to image processing by Mallat [9]. It provides a way for simultaneous analyzing of digital images in different scales. In practical, an image is analysed in different frequencies with various resolution. The Discrete Wavelet Transform (DWT) encompasses the properties of multiresolution analysis which analyze the images progressively into finer sub-bands. In digital images, wavelets have done the scaling and translation through morphological operations. An image is applied with two filters namely high-pass and low-pass filters and it yields one approximation sub-band and three detail coefficients [10]. These operations are progressively applied on approximation sub-band of next successive decomposition levels. The Fig. 1 shows the decomposition structures of 2D-DWT.

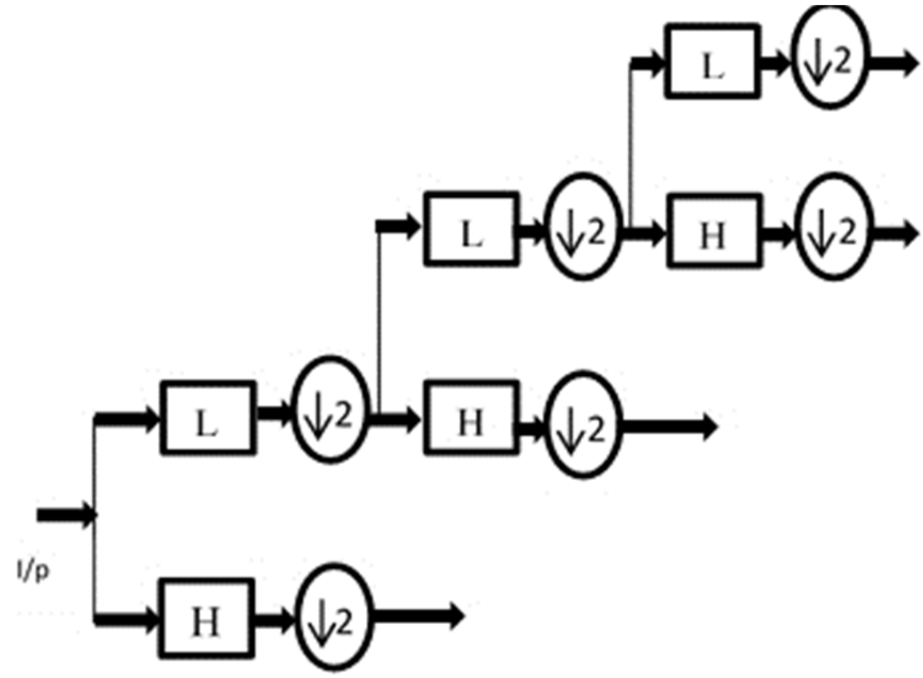

Fig1.Decomposition structure of DWT

The generalization of wavelet decomposition structure is known as the wavelet packet transforms (WPT) [11]. In the way of applying filters on an image, it differs from the DWT. Approximation details only decomposed further (applying complementary filters) in DWT but the detail sub-bands also decomposed in WPT which is depicted in Fig.2. The optimal decomposition tree is then chosen as final decomposition structure based on the entropy-based criterion for the given level [12].

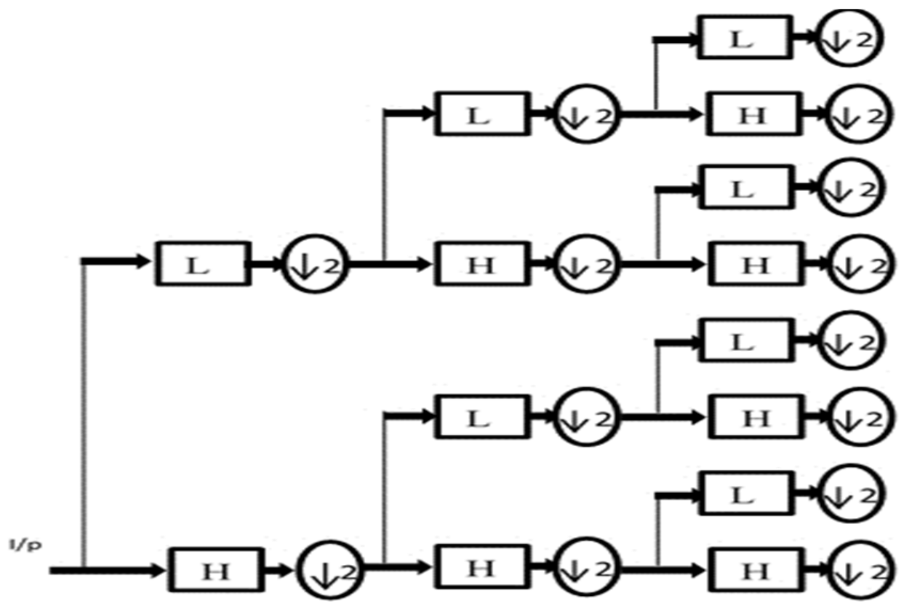

Fig2. Decomposition structure of WPT

III. PROPOSED METHOD

A. Methodology

As we proposed a wavelet based method, a noisy image is decomposed with a wavelet basis. In this paper, we used two different wavelet decomposition structures such as Discrete Wavelet Transform (DWT) and Wavelet Packet Transform (WPT). The results of using these two methods are depicted and the comparison of those two strategies is discussed separately in following sections. The implementation steps of our proposed method are given as follows.

Step 1: Input noisy image

Step 2: Decomposition of the image through wavelet

Step 3: Threshold the wavelet coefficients for noise removal

Step 4: Reconstruction of denoised image through inverse wavelet operations

The flowchart of our proposed method is given in Fig 3.

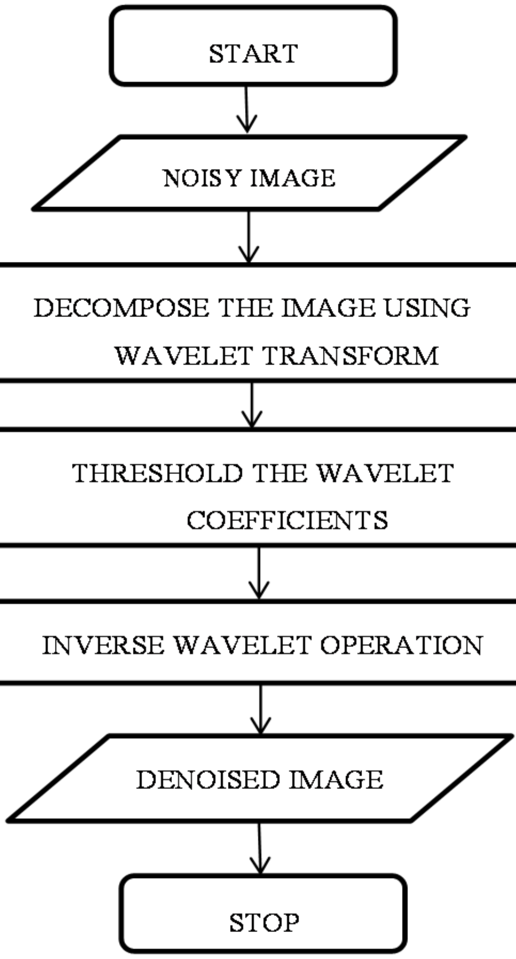

Fig3. Flowchart of Our Proposed Method

The detailed implementation of above mentioned steps are as follows.

Step1: Input noisy image

To evaluate our proposed method, the ultrasound images from various internet sources are selected to test our algorithm. The normal ultrasound images are subject to add the speckle noise with given noise level. Then, the noisy ultrasound image is put as an input to our proposed algorithm.

Step 2: Decomposition of the image through wavelet

As the mode of decomposition structures are discussed in above section, the DWT decompose the approximation sub-band in successive levels but the all other detail sub-bands are also decomposed further in WPT. All the obtained wavelet coefficients are taken for further processes.

Step 3: Threshold the wavelet coefficients

The thresholding part of this algorithm is a major part of the denoising process. We have experimented our methods with different thresholding values. The selection of the threshold value is taken by around the value of universal threshold. We implement both the hard and soft thresholding on the wavelet coefficients and those results are taken into account for further reconstruction process. In addition, we keep the approximation coefficients as it as which means that the detail coefficients only subject to threshold.

Step 4: Reconstruction of denoised image through inverse wavelet operations

The inverse operations like inverse Discrete Wavelet Transform and inverse Wavelet Packet Transform are applied to the thresholded wavelet coefficients to get the denoised image.

B. Evaluation Metrics

To assess the quality of the denoised images, the evaluation metric called Peak Signal to Noise Ratio (PSNR) is used. The formula for PSNR is defined as follows.

$$PSNR = 10.\log_{10}\left(\frac{Max_i^2}{MSE}\right) \quad (1)$$

where, Max_i is maximum intensity in an image, and MSE is defined as

$$MSE = \frac{1}{MN}\sum_{y=1}^{M}\sum_{x=1}^{N}[Im(x,y) - Im'(x,y)]^2 \quad (2)$$

where, $\mathrm{Im}(x,y)$ is the original image, $\mathrm{Im}'(x,y)$ is the denoised image and M, N is the dimensions of the images.

IV. Results and Discussion

As mentioned earlier, a noisy ultrasound image is decomposed with the wavelet transform (here we used DWT and WPT). There are number of wavelet families are existing such as Haar, Daubechies, Symlets, Coiflets, Biorthogonal wavelets, Reverse biorthogonal wavelets, Morlets and so on. The selected wavelets are used to decompose the image in DWT and WPT. The Table.I shows that the results of our proposed method with the threshold value of fifty for an ultrasound image that is include as a first image of the fig 4.

Table I. Results for different selected wavelet family

Wavelet	**PSNR (db)**			
	DWT		**WPT**	
	Hard	**Soft**	**Hard**	**Soft**
Haar	30.6487	28.6423	30.8941	28.7777
db4	33.5759	31.2298	33.5259	31.2451
sym9	33.7627	33.7765	33.8230	31.5034
coif5	33.8364	31.6037	34.6503	33.4755
bior6.8	34.1719	31.6291	34.8438	33.5626
rbio5.5	34.3806	33.1056	34.3575	33.0729

From our analysis, it is evident from Table. I that biorthogonal wavelet (bior6.8) given good PSNR values than others. For the further results taken for different threshold values, we have used this biorthogonal wavelet.

The resultant images of our proposed algorithms are given in Fig 4. A threshold level of fifty is set to threshold the wavelet coefficients in order to denoise the given ultrasound image. In Fig.4, the Column 1 contains the original tested image, column 2 contains the speckle noise added image, and the denoised images using DWT are given in column 3 and the denoised images using WPT is given in column 4.

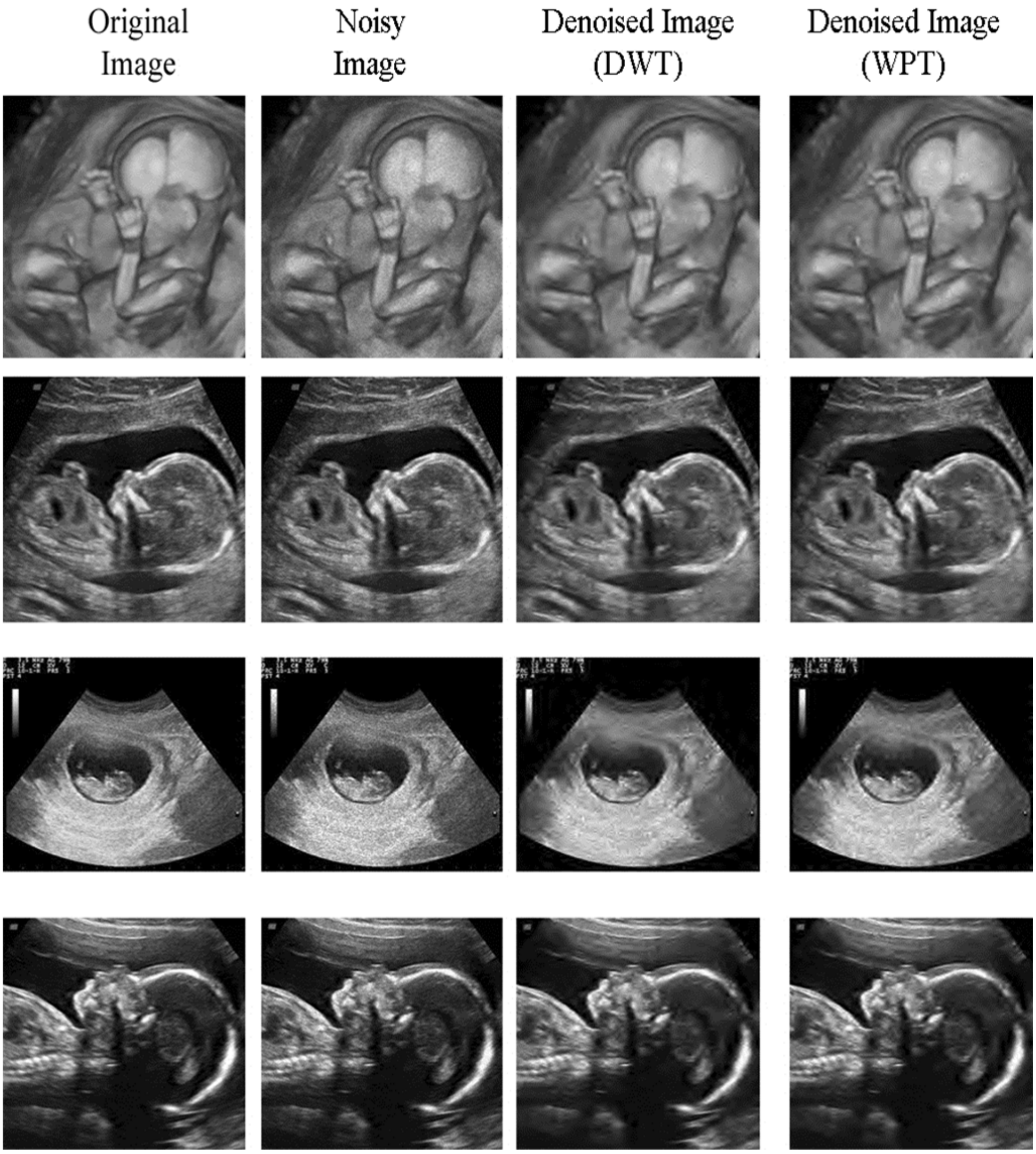

Fig 4. Resultant images of our proposed method

The numeric results for our proposed method in terms of PSNR for different threshold values are given in Table. II. It shows that hard thresholding of wavelet coefficients gives better results than the soft thresholding technique. Moreover, it is established that using of Wavelet Packet Transform for decomposing those images yields a comparable small scaled result than Discrete Wavelet Transform.

Table II. Results for different threshold values

Image	Threshold value	PSNR (db)			
		DWT		WPT	
		Hard	Soft	Hard	Soft
Image 1	50	34.1719	31.6291	34.8438	33.5626
	55	33.9390	31.2040	34.6637	33.2206
	60	33.6697	30.8679	33.6780	30.8957
	80	32.2168	29.6898	32.3351	29.7163
Image 2	50	30.1974	27.7343	30.3965	28.4895
	55	29.7528	27.3675	30.0630	28.2086
	60	29.3944	27.0262	29.6529	27.9485
	80	28.2186	26.0070	28.2074	26.0245
Image 3	50	27.4448	25.4626	27.9249	26.8004
	55	27.1234	25.1673	27.3221	25.5455
	60	26.8336	24.8636	27.0086	25.2738
	80	25.7625	23.9166	26.0374	24.4498
Image 4	50	30.1751	27.7712	30.3598	28.5635
	55	29.8350	27.4155	29.8884	27.4069
	60	29.5136	27.0487	29.5212	27.0619
	80	28.3352	26.0147	28.3636	25.9666

V. Conclusions

In this paper, we proposed a frequency domain noise removal technique that uses wavelet transforms. Particularly, this despeckling algorithm tested with ultrasound images with two different decomposing strategies such as DWT and WPT. By having the results obtained with our proposed method we can conclude that WPT decomposition structure gives little more better results than DWT. DWT sometimes give good results than WPT but it is evident from our obtained results that the WPT dominantly gives better results over DWT. For the type of ultrasound images, a wavelet based denoising method yields good performance particularly on the hard thresholding.

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AUTHOR PROFILE

P. Kalavathi Associate Professor and Head in the Department of Computer Science and Applications, Gandhigram Rural Institute-Deemed University, obtained her BCA degree from Mother Teresa Women's University, Kodaikanal; Post-Graduate Degree in Computer Applications (MCA) in GRI-DU; M. Phil in Computer Science from Bharathidasan University, Trichirappalli; and Doctoral Degree in Computer Science and Applications from GRI-DU, Gandhigram. She Qualified UGC-NET for Lectureship in 2000. She has 17 years of Teaching and 10 years of Research Experience. The Author has more than 50 research articles in various journals and edited volumes. Her research area focuses on Digital Image Processing, Medical image Segmentation & Analysis and Medical Image Compression. She is also serving as a reviewer of many international Conferences and various journals in IEEE, Springer, Elsevier etc. The author is Life Time Member of Indian Society for Technical Education (ISTE), New Delhi.

S. Boopathiraja Research Scholar in Department of Computer Science and Applications, Gandhigram Rural Institute-Deemed University, obtained his Under-Graduate degree in Mathematics from GRI-DU; Post-Graduate Degree in Computer Applications (MCA) from Institute of Road and Transport Technology (IRTT), Erode; M. Phil in Computer Science from GRI-DU; He has two years of Research Experience and his research area focuses on Medical Image Analysis and Digital Image Compression.

M. Abinaya Pursuing her M. Phil Degree in Computer Science from Department of Computer Science and Applications, Gandhigram Rural Institute-Deemed University, Gandhigram.