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Enhancement of Ultrasound Images Using RADWT

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Abstract— Feature preserved enhancements are necessary in medical ultrasound images. The quality and important information present in ultrasound images are affected by speckle which makes the post processing difficult. A technique based on rational dilation wavelet transform (RADWT) is applied on medical images to enhance the quality of speckle noise affected images. A new family of wavelet transform is presented for which the frequency resolution can be varied to provide the effectiveness of noisy coefficients. Denoising efficiency is improved by applying bilateral filter and different threshold schemes to noisy RADWT coefficient and edge features are preserved effectively, blurring associated with speckle noise is less and important details are enhanced properly for better visual illustration of ultrasound images. This approach helps us to improve the quality of the ultrasound images. Experimental results are shown for noise suppression, feature and edge preservation in different measures.

Index Terms— Bilateral Filter, Image Enhancement, Rational Dilation, Speckle Noise, Thresholding, Ultrasound Images, Wavelet Transform.

1 Introduction

NOw a days, Image enhancement is a necessary need in medical images, in medical images ultrasound are widely used among others, because of its cost, effectiveness portability and safety [1].Ultrasound obtained are of very poor quality which makes the processing complex and difficult. Images obtained from coherent energy source suffer from backscattered echos generated from randomly distributed scatters called speckle [2].

Speckle is a multiplicative noise which has undesirable interference effect on the images which makes the diagnosis difficult. Reduction of these speckle are necessary to improve the quality of ultrasound image. Sometimes most important data is suppressed while processing the reduction of speckle. So, the algorithm should be designed in such a manner that significant information should not lose or suppressed and smooth image should obtain.

Ultrasound reduction method can be classified by two methods: - image averaging and image filtering.

Image averaging [3] is usually achieved by averaging a series of uncorrelated ultrasound images in the spatial or frequency domain. We could use filtering method as an alternative for clinical purpose which can be further classified as spatial filtering such as non-linear, linear etc. Linear spatial [4] introduces severe blurring and loss of data which is based on pixel replication many non linear filter have been introduced such as median and weighted median filter (AWMF) to eliminate the requirement in median filtering [5]. The various filters used in spatial domain are as proximity based [6], filters Order statistic filter [7] and Wiener filter [8]. Weiner filter works better when the noise is of constant power additive noise while proximity filters help in removing the noise at the cost of blurring the edges.

Efforts have been made to reduce the speckle noise and overcome the drawback of spatial domain filtering using wavelet transform. Denoising method [9] in soft thresholding method is presented in which main critical task of thresholding is the selection of the trhreshold value [10]. Earlier in denoising of images Baysian approach was used but now a day, the research is concentrated on wavelet based method, which can be optimised for different wavelet coefficients [11] by using different noise models [12]. Total variation filtering method based on wavelet [13] is also proposed in which several iterations are taken from noisy images for suppressing the gaussian noise the exceedings numbers of iterations, exceeds to blurring effect. Wavelet thresholding was proposed as an alternative method [14] to the bilateral filter, which is a non linear filter and is used in spatial domain for edge preserved denoising. It provides effective denoising [15] and is better in sense of edge preserved denoising. This method is proposed to keep the potential feature of both bilateral filter and wavelet thresholding simultaneously.

Wavelet domain has basic properties like decomposition of wavelet coefficients and sparsity, because of these properties researchers are more focused on this wavelet domain [16]. Sparsity property of the wavelet transform and the capacity for analyzing the time frequency information are combined together with the different frequency subbands, making the wavelet area ideal. Whereas, the wavelet transform is an effective tool but it has a poor frequency resolution and low Q-factor for smoothing the signal. A non linear filter depending on the combination of wavelet transform and rational dilation is used to enhance the ultrasound images [17]. The combination of bilateral filter and rational dilation wavelet transform is applied over the various test images to enhance the quality of corrupted and noisy medical image and its analysis is presented in this paper.

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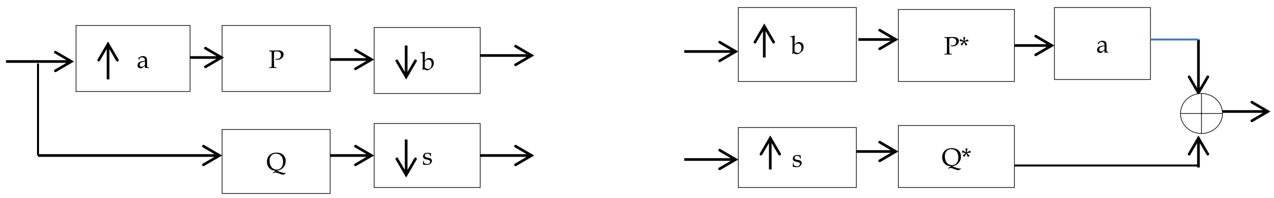

Fig.1 Analysis and Synthesis filter bank

2 Rational dilation wavelet transform

2.1 RADWT

RADWT is a discrete wavelet transform with the wavelet variables of frequency and time subbands as a scale and position along with the rational-dilation factor. Different wavelet transform are used in applications of image processing such as sharpening, denoising, debluring etc. those application are inveritible for which the transform are required. In RADWT, flexibility is provided by increasing the resolution from one resolution to another resolution level because of the low Q-factor [18] the dyadic wavelet transform limits the effectiveness of RADWT.
The RADWT is implemented by using two iterated channel filter bank as shown in Fig. 1 with rational dilation factor (a and b), and a high pass sampling factor (s). the RADWT is charterised by its redundancy i.e. oversampling rate [19].
P is a low pass filter and Q is a high pass filter in the analysis filter bank. If RADWT has a perfect reconstruction property then it is self inverting. The condition of the filter P and Q to get the perfect reconstruction are explained as follows:

$$P(\omega) = 0 \quad for|\omega| \in \left|\frac{\pi}{b}, \pi\right| \tag{1}$$

$$Q(\omega) = 0 \quad for|\omega| \in \left|0, \left(1 - \frac{1}{s}\right)\pi\right| \tag{2}$$

$$\frac{1}{ab}\left|p\left(\frac{\omega}{a}\right)\right|^2 + \frac{1}{s}|Q(\omega)|^2 = 1 \quad for\,\omega \in [0, \pi] \tag{3}$$

The length of the signal should be multiple of b and s for the perfect reconstruction of the wavelet transform. Inverse rational-dilation wavelet transform (IRDAWT) is computed by transform of RADWT. By choosing parameters a, b and s high-Q factor can be achieved.

2.2 Bilateral Filter

Bilateral Filter (BLF) is a type of non linear filter for denoising with in the spatial domain, while preserving the edge information. The pixel values are obtained by a weighted sum of pixel in a neighborhood in bilateral filtering method and the weight depends on the the spatial distance of the pixel around the local neighborhood of a pixel. The combination of domain filter and range filter is required to achieve it. The output of BLF for a pixel located at i is :

$$\hat{x}(i) = \frac{1}{C}\sum j \in N(i) D_f(i, j)x(j) \tag{4}$$

Where i and j are coordinate vectors,
$Df(i,j)$ is representing the domain filter and $Rf(i,j)$ is representing range filter as components of bilateral filter, which are defined as:

$$Df(i, j) = \exp\left(\frac{-\| j - i \|^2}{2\sigma_d^2}\right) \tag{5}$$

$$Rf(i, j) = \exp\left(\frac{-\| x(j) - x(i) \|^2}{2\sigma_r^2}\right) \tag{6}$$

N (i) is the spatial neighbourhood of x,
C is the normalization constant defined as below

$$C = \sum j \in N(i) Df(i,j) Rf(i,j) \tag{7}$$

Where σ_d and σ_r are the domains and range parameters which control the behaviour of the weights [20]. The bilateral filter will act as a smoothing filter and will blur the image if parameters values are set too high. If the values are too low, noise cannot be removed.

2.3 Thresholding Method

In thresholding the energy of a signal is focused on few coefficients and the energy of noise is spread coefficients in RADWT domain [21]. Denoising can be achieved by applying thresholding function to the coefficients. The important key feature of the original image are preserved, when the transformed coefficient are compared against threshold to remove the noise from image. There are two types of thresholding as given below:

2.3.1 Soft Thresholding

If the coefficients having value less than the particular threshold are set to zero and the non zero coefficients are scaled, the thresholding scheme are called the soft thresholding. It is used to approximate the noisy coefficients of the signal.
So the soft thresholding [22] is computed as follows:

$$THR(d(i, j)) = \begin{cases} d(i, j) - T; & d(i, j) > T \\ d(i, j) + T; & d(i, j) < -T \\ 0; & |d(i, j)| < T \end{cases} \tag{8}$$

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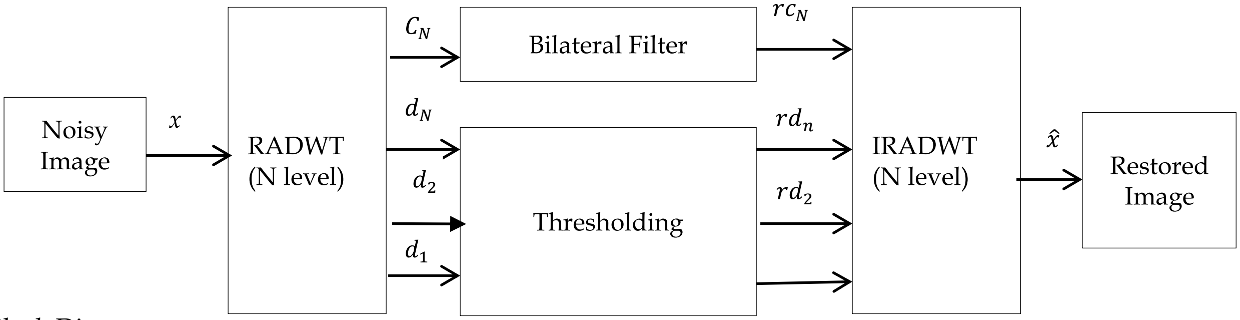


Fig.2 Block Diagram

2.3.2 HARD THRESHOLD

The coefficient whose absolute values are lower than the threshold (T) set to the value zero and the other values are left the same is done in hard thresholding [23]. The noise free coefficients are estimated as follows.

$$THR(d(i,j)) = \begin{cases} d(i,j); & |d(i,j)| > T \\ 0; & otherwise \end{cases} \tag{9}$$

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

Where N is the Length of the signal and σ_N is the estimated standard deviation of noise.

3 RADWT METHOD

Three basic steps are involved in denoising process as shown in Fig 2

1. For computation, the RADWT noisy coefficient, select the number of decomposition level, dilation factor (a and b) and high pass sampling factor
2. To obtain the modified RADWT coefficient, select and perform filtering algorithm on these noisy coefficient.
3. By using inverse RADWT, reconstructed image is obtained.

Apply RADWT (W_{RADWT}) on noisy input image signal $x(i,j)$ at different level. Decomposed set of RADWT coefficients as a vector of ζ consisting of N subbands with different spectral resolution such as

$$W_{RADWT}x(i,j) = \zeta(i,j) \tag{10}$$

Where $\zeta = (d_1, d_2, d_3 \ldots.. d_N, C_N)$

Lower stage coefficient coefficients (d_1) contain high frequency noise element.and in the last stage coefficient (C_N) noise is approximately negligible. Noise is suppressed in each layer after perfoming the appropriate filtering.

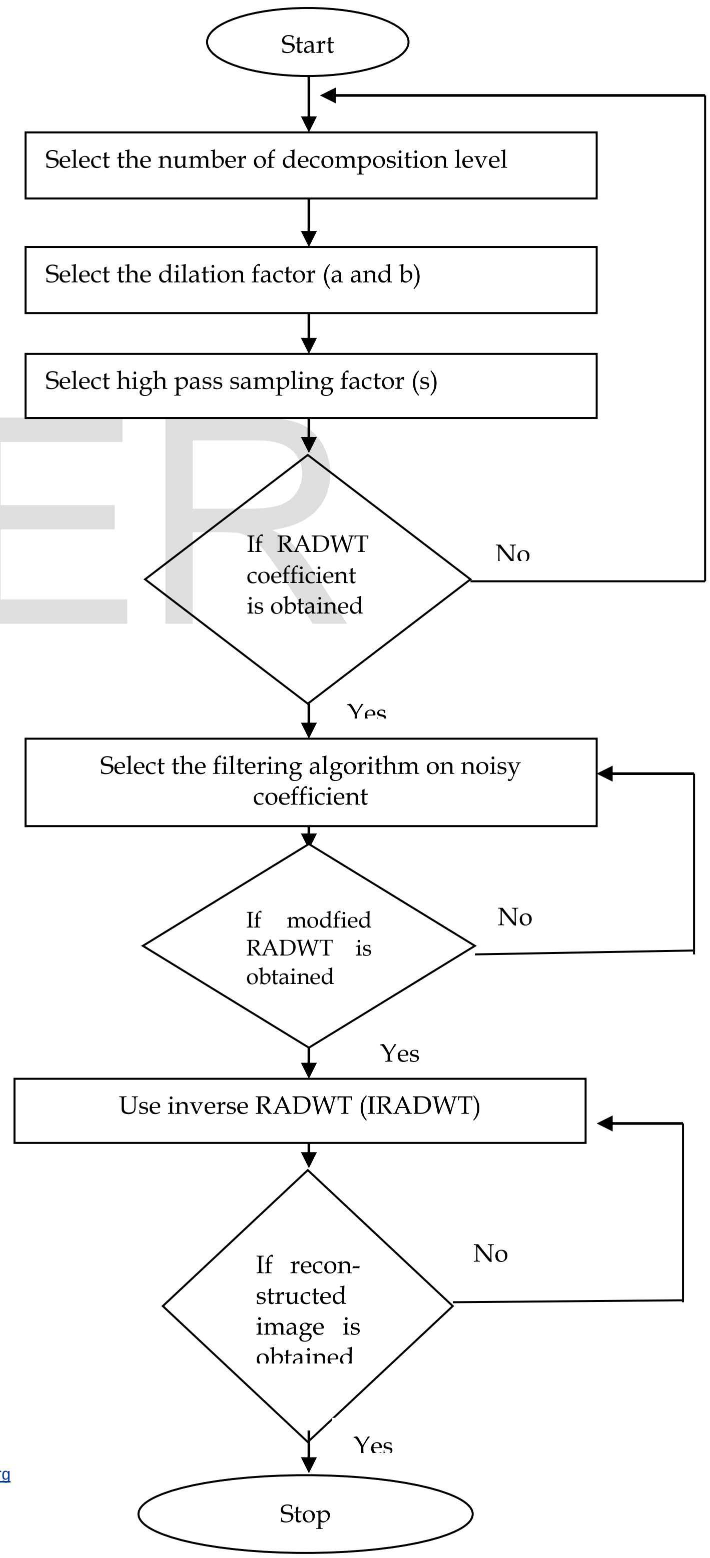
Finally, bilateral filter (BLF) is applied on RADWT coefficient i.e. low frequency component(C_N) and rest of all RADWT coefficient i.e.χ_N is threshold by appropriate thresholding technique (THR)

$$rC_N = BLF(C_N) and\ r\chi_N = THR(\chi_N) \tag{11}$$

Where $r\chi_N = [rd_1, rd_2, rd_3 \ldots..rd_N]$

To get the reconstructed signal, IRADWT (W_{RADWT}^{-1}) is applied on the filtered coefficients which is the approximation of the noisy image signal $\hat{x}(i,j)$

4 Flowchart



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5 Results and Discussion

There are several parameters on which the performance of this method depends such as dilation factor (a and b), decomposition level (J) and high pass sampling factor (s), σ_d and σ_r.The optimal value of parameters used for this method are a=3, b=4, s=2, J=4, for RADWT, window size 11x11, $\sigma_d = 1.8$ and $\sigma_r = 2\sigma_n$.

The performance of the model is tested over various test images. The PSNR, MSE and Threshold values are calculated for the test images (Liver, Kidney, Pancreas and Gall Bladder) are shown in table 1 and table 2 for qunatitaive comparisons and Graph1 and Graph 2 is showing its pictorial presentation.

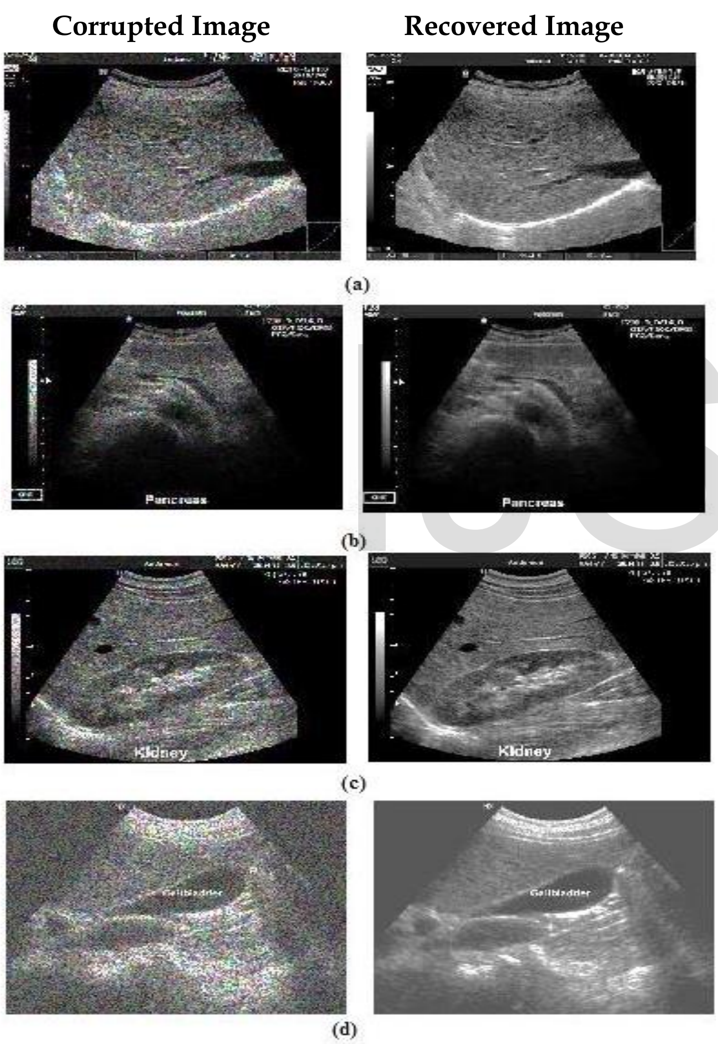


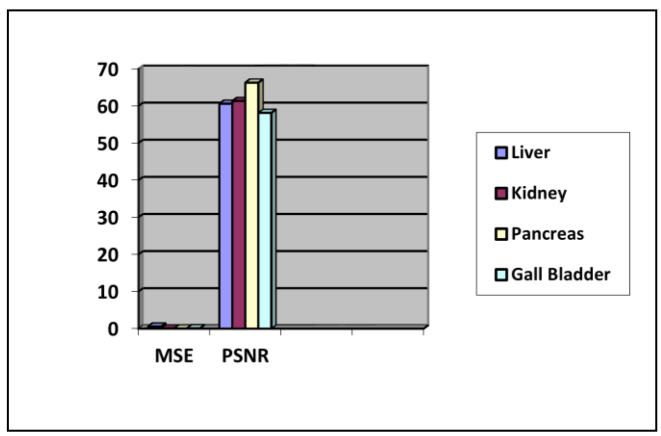
Fig 3. Visual illustration of ultrasound images with speckle noise and enhanced image (a) Liver (b) Pancreas (c) Kidney (d) Gall Bladder

Test Image	MSE	PSNR
Liver	0.5710	60.5951
Kidney	0.0482	61.3341
Pancreas	0.0154	66.2791
Gall Bladder	0.1005	58.1410

Table 1 Values of MSE and PSNR on different test images.

Test Image	Threshold (T1)	Threshold (T2)	Threshold (T3)
Liver	0.1579	0.1828	0.2067
Kidney	0.1057	0.1374	0.1665
Pancreas	0.0155	0.0255	0.0371
Gall Bladder	0.0329	0.0625	0.0923

Table 2 Vlaues of Threshold T1, T2, and T3 on different test values



Graph.1 Comparative values of MSE and PSNR

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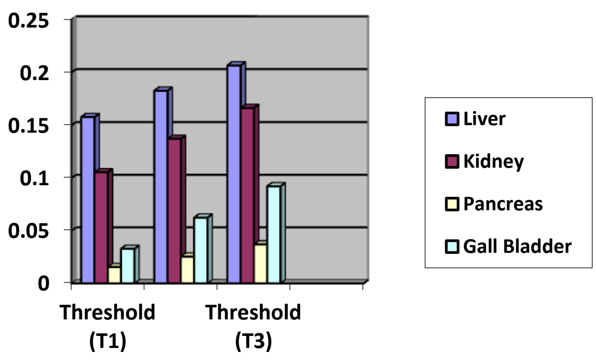

Graph.2 Comparative values of Threshold T1, T2, T3

6 Conclusion

A non-linear filtering scheme based on RADWT has been implemented on the various standard medical images. In this method the frequency resolution variation feature of the RADWT is used to decompose the noisy image into different subbands at different levels. BLF reduces the high amplitude noise components and thresholding upgrades the denoising efficiency. The results have shown in visual context as well as quantitative parameters in terms of PSNR and MSE.

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