

# Noise Reduction from Ultrasound Medical Images using Rotated Wavelet Filters

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**ABSTRACT:** Noise is an unwanted signal, which affect the images and degrade its quality. Different images suffers from different types of noises whose effect can be minimize or rather these noises can be remove by using certain transforms or using certain spatial domain filters. However, use of the spatial domain filters leads to loss of some useful information from the images. In this paper, we proposed a transform domain denoising technique. We have used rotated wavelet filters to improve the denoising results. We are mainly focusing on the additional directional information, which we are getting by the use of rotated wavelet filters. We have compared the results obtained using rotated wavelet filters with existing methods and results obtained with our method are found very exciting. SSIM and PSNR used as quality measures to compare denoised and original noisy images.

**KEYWORDS:** Ultrasound images, noise, Rotated wavelet Filter, PSNR, SSIM

## I. INTRODUCTION

Every system is designed to give desired output when the input is applied to the system but sometimes the system may give undesired output. In case of image this undesired signal is known as noise. This noise degrades the quality of the image. Imaging Techniques such as X-ray imaging, CT Scan, Ultrasound imaging etc. captures the images but while capturing these images we may sometimes get some unwanted signal called as noise. This noise always tries to degrade the quality of the image. The process of removing this unwanted noise from the image is called as image denoising which plays vital role in the area of image processing. This noise is broadly classified into two categories viz. additive noise and multiplicative noise. Noise type is decided on the basis of its nature. The mathematical model for additive image noise is given in equation (1) as-

$$y(t) = x(t) + n(t) \quad \dots (1)$$

Where,  $y(t)$  = noisy image,  $x(t)$  = original image and  $n(t)$  = image noise.

Examples of additive noise are Uniform noise and Gaussian noise. Similarly, model for multiplicative image noise is define in equation (2) as-

$$y(t) = x(t) * n(t) \quad \dots (2)$$

Where,  $y(t)$  = noisy image,  $x(t)$  = original image,  $n(t)$  = image noise.

Speckle noise, which is multiplicative in nature, is dominant in Ultrasound images. In the decade of 1990, Donoho introduced concept of wavelet-based image denoising. In [1] authors suggested soft Thresholding method of denoising but as it suffers the loss of important information due error difference between original and reconstructed output. Authors in [2], proposed algorithm based on circular shifts and labeled this concept as translation invariant denoising which is proved to be more efficient than [1]. Authors in [3] tried to extend the concept of [2] to Multiwavelets and proved more encouraging. Author [4] introduced another method based on a statistical model and proved that multiwavelet along with soft thresholding gives better results than previous work. Various authors [5 -7] contributed for denoising by considering neighborhood of wavelet coefficient and similarly some authors worked hard

for finding optimum value of threshold such as in [8] adaptive wavelet thresholding using Bays threshold is proposed in 2000. Authors in [9] proposed algorithm based on bivariate shrinkage function which uses the concept of parent –child relation . In [10] authors introduced a new threshold which is based on Stein’s Unbiased Risk Estimator. It is known as Sure Shrink.

Nam-Deuk Kim and Satish Udpa [11] introduced rotated wavelet filter which are capable to separate the mixed diagonal information available in discrete wavelet transform. They used this filter for texture classification. Authors [12 -14] extended use of rotated wavelet filter for Texture image retrieval application, region based segmentation application and rotation invariant texture image retrieval respectively. Reference mentioned in [11] stated that rotated wavelet filters could be useful for image denoising. References mentioned in [12-14] proved that application of rotated wavelet filter improved the performance of texture based applications. The results give alarm that rotated wavelet filters could give more directional information as compared with existing wavelet filters and directional information is vital in the field of image denoising. Rotated wavelet filters not yet introduced in the area of Image denoising application. This scenario is strong motivation for first contribution i.e. to use Rotated wavelet filters for image denoising application successfully.

This paper is organized as follows. In the section 2, we illustrate proposed work. Section 3 represents the experimental verification and discussion of proposed work. Section 4 we present the conclusion along with future scope.

## II. RELATED WORK

### Theory of Discrete Wavelet Transform and Rotated Wavelet Filter

#### A. Discrete Wavelet Transform (DWT)

‘Wavelet’ word first time used in 1984 by Morlet and Grossman used and designed Morlet wavelet. The DWT pair can mathematically represented as

$$w_{\varphi}(j0, k) = \frac{1}{\sqrt{M}} \sum_n f(n) \varphi_{j0,k}(n) \quad \dots (3)$$

$$w_{\psi}(j, k) = \frac{1}{\sqrt{M}} \sum_n f(n) \psi_{j,k}(n) \quad \text{for } j \geq j0 \quad \dots (4)$$

Equation (3) give approximation coefficients and equation (4) gives detailed coefficients.

#### B. Rotated Wavelet Filter (RWF /RDWT)

Kim and Udpa [11] introduced the concept and design of rotated wavelet filters. It can also be named as Rotated Discrete Wavelet Transform (RDWT). They used Haar wavelet to design the filter and applied for texture classification. In the previous section we described the 2D discrete wavelet filters which are shift variant and give mixed information for diagonal band. In applications like texture analysis and image denoising, recognition of specific directional information of an image is important. The limitation of mixed diagonal information in DWT can be separated using non separable wavelet transforms such as the hexagonal wavelet transforms [15] and the steerable wavelet filters [16]. Hexadecimal wavelet filter have implementation difficulty and steerable filters are over complete [11]. Compared with this [15] and [16] Rotated wavelet filters are simple and easy to implement. Rotation of 45<sup>0</sup> to 2-D DWT filter results in rotated wavelet filters. This will change the decomposition fx and fy along new axis (directions) Fx and Fy respectively as shown in figure 2.

The size of rotated filter is calculated using relation,

$$(2L-1) \times (2L-1) \quad \dots (9)$$

Where L = the length of the 1-D filter.

**Briefly about existing Algorithms:**

Noise removal is possible with the help of wavelet thresholding. Wavelet thresholding is done by decomposing an image into wavelet domain and comparing detail bands with a threshold value and modify the coefficients. Threshold can be calculated using any shrinkage technique. Then image is reconstructed from the modified coefficients.

Threshold plays important role in image denoising and is calculated on the basis of statistics of image. Threshold is responsible for smoothing of an image. Sometimes it may lose the important fine details of an image. Typically used methods are Visu Shrink, Sure Shrink, Bayes Shrink and Neigh Shrink etc. These methods decides the threshold value but how to apply this threshold value is decide by two general category of thresholding which was introduced by Donoho named as hard and soft thresholding. Shrinkage technique known as Visu Shrink [1] has hard thresholding approach. In this paper Visu Shrink, Sure Shrink and Bayes shrink techniques are implemented and compared. These three techniques are discussed below.

**Visu Shrink**

Visu Shrink uses hard thresholding approach as mentioned in following equation (10).

$$Th = \begin{cases} X & \text{for } |X| \geq T \\ 0 & \text{in all other regions} \end{cases} \dots \quad (10)$$

Wavelet coefficients are modified to new value given in equation (10) if it is greater than threshold and made equal to zero if it is less than threshold. For Visu Shrink threshold value ( $T_u$ ) is calculated based on known /estimated standard deviation of the noise. In some applications, noise variance is known but if it is not known then we may calculate it by applying the robust median estimator on the diagonal subband coefficients as introduced by Donoho [1]. It is calculated as below in equation (11)-

$$\sigma^2 = \frac{\text{median}(HH)}{0.6745} \dots \quad (11)$$

Where HH represents the detailed coefficients in the wavelet transform. Threshold for Visu Shrink is now given by equation (12)-

$$T_u = \sigma^2 * \sqrt{2 \log(\text{row} \times \text{columns})} \dots \quad (12)$$

From above equation (12), it is clear that the threshold value is not taking care of Mean Square Error.

Following are the Quality Metrics Used :

i) Peak Signal To Noise Ratio(PSNR) is given by equation (13)-

$$\text{PSNR} = 20 * \log_{10} \frac{(2^n - 1)}{\text{MSE}} \dots \quad (13)$$

Where n= no. of bits and MSE is Mean Square Error and calculated by equation (14)

$$\text{MSE} = \frac{1}{M \times N} \sum_{j=1}^M \sum_{k=1}^N (X_{j,k} - X'_{j,k})^2 \dots \quad (14)$$

ii) The Structural Similarity Index (SSIM) - calculated using equation (9)-

$$\text{SSIM}(x, y) = \frac{(2\mu_x \mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \dots \quad (15)$$

Where  $\mu_x$  = average value of original (x) image,  $\mu_y$  = average value of denoised (y) image

$\sigma_x^2$  = Original image variance,  $\sigma_y^2$  = Denoised image variance,  $\sigma_{xy}$  = Covariance of original and denoised image.

$$L = \text{Image Range or dynamic range} \quad c_1 = (k_1 L)^2, \quad c_2 = (k_2 L)^2$$

$k_1 = 0.01 \text{ and } k_2 = 0.03 \text{ by default}$

**III. DENOISING USING ROTATED WAVELET FILTERS**

Our proposed work is based on use of Rotated wavelet filters for performance improvement of wavelet based image denoising. In this proposed work, we suggest replacement of DWT by RDWT. If this energy analysis test results into increase in overall energy then apply methodology represented in figure 7.

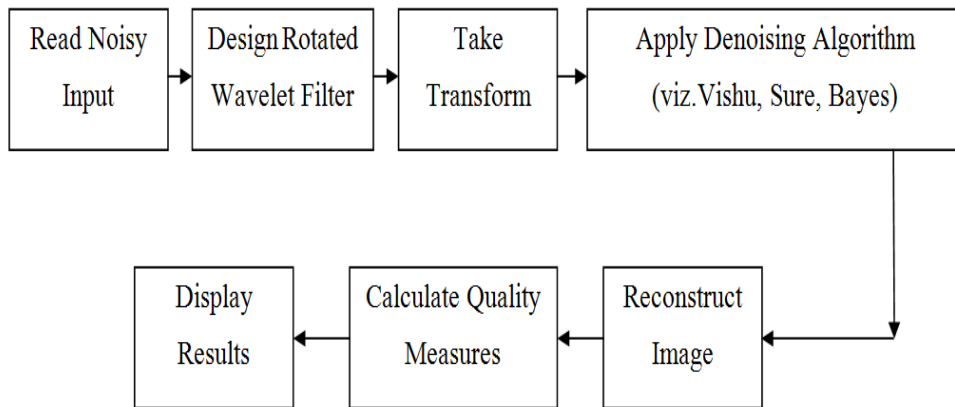


Fig.7. Block diagram for proposed methodology

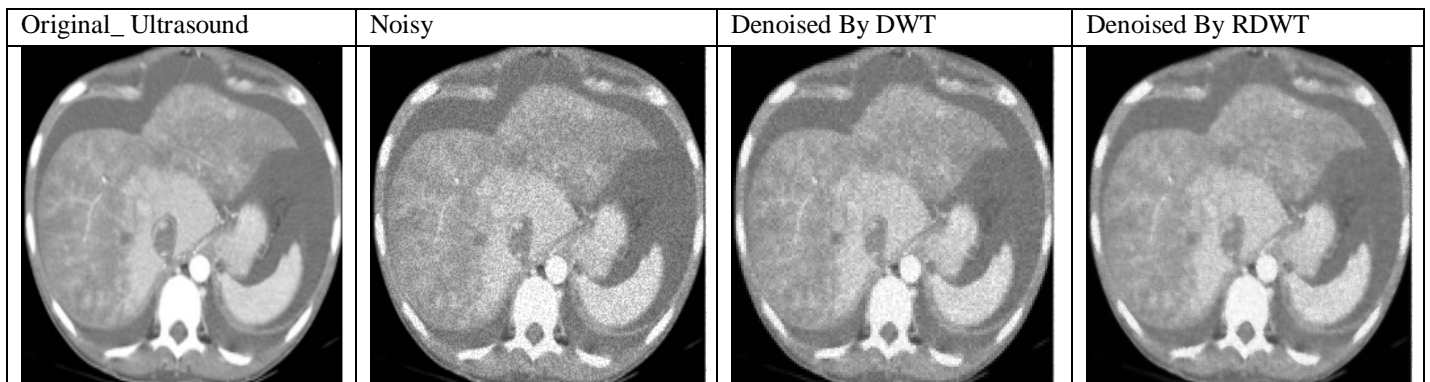
As shown in above figure 7, apply rotated wavelet filter on noisy input to decompose input image into sub bands. Then apply denoising algorithm, which includes calculation of threshold with the help of any shrinkage technique, and then apply the threshold on detailed sub bands. Images isreconstructed by applying inverse transform, then quality metrics are calculated from original and denoised image.

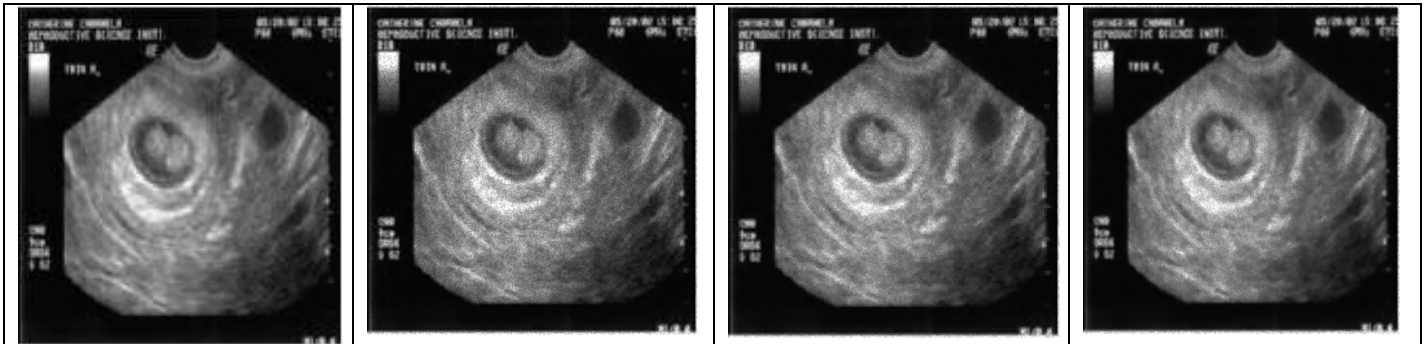
#### IV. EXPERIMENTAL RESULTS

In this paper, experiments are conducted on MATLAB R2013a environment. Gray scale images of different resolution at different noise variance are used for experimentation.

Table 1: Performance improvement of Vishu shrink Algorithm for Ultrasound images using RDWT. (PSNR in dB)

Title	DWT		RDWT	
	PSNR	SSIM	PSNR	SSIM
s1.png	31.5703	0.90910	<b>33.2767</b>	<b>0.94854</b>
s2.png	29.5798	0.87746	<b>29.6582</b>	<b>0.90586</b>
s3.png	27.9996	0.70211	<b>29.1664</b>	<b>0.77055</b>
s4.png	34.5899	0.94380	<b>35.4096</b>	<b>0.96747</b>
s5.png	29.7307	0.87822	<b>29.8495</b>	<b>0.90543</b>





## V. CONCLUSION

Rotated Wavelet based image denoising is proved to more efficient with the existing wavelet based denoising methods. It is more efficient in terms of the time complexity compared with today's state of art algorithm i.e BM3D. We proposed general methodology which is used to improve the performance of any wavelet based denoising algorithm. Our new methodology is based on Rotated wavelet filter, which will surely improve the performance of wavelet based denoising algorithm. Our experimentation proved this with quality metrics PSNR and SSIM on various types of database.

Future scope for our proposed work is to extend this Rotated wavelet filter concept to Dual tree Complex wavelet Transform. We are also interested to find out another parameter, which will decide suitability of this proposed work.

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