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# Denoising Of Medical Ultrasound Images In Wavelet Domain

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**Abstract:** Ultrasonography is regarded as one of the best and most powerful techniques for diagnostic examination and analysis of various imaging organs and soft tissue structures present in human body. It is used for visualizing muscles, their shape and size, their structure and any pathological lesions. The usefulness of ultrasound imaging is degraded by the existence of a signal dependent noise called as speckle noise. This speckle pattern is further dependent on the structure of the imaging tissue as well as on various imaging parameters. In the proposed work, a novel approach has been suggested with an adaptive threshold estimator for image denoising in wavelet domain based on the modeling of different sub-band coefficients at different stages in ultrasound imaging systems. The proposed method has been found to be more adaptive as the estimated parameters for threshold value depends on image sub-band data. The calculated threshold value depends upon scale parameter, noise variance and standard deviation corresponding to each sub-band of the noisy image. The scale parameter is dependent upon the sub-band size and number of decompositions. The experimental results carried out on many ultrasound test images outperformed both qualitatively and quantitatively, when compared with some other existing denoising techniques like Normal Shrink, Median Filter, and Wiener Filter. The clinical validation by a radiologist of the results has also been performed.

**Keywords: Ultrasonography, Standard Deviation, Wavelet Thresholding, Noise Variance**

## 1. Introduction

Digital image processing is the processing of two dimensional images with a computer system by using different algorithms. It is a subcategory of digital signal procesing that performs operations on digital images. Image processing accepts an image as an input, like a photograph or any graphics or any type of frame. The outcome of this may either be an image also or may be features of the image or a set of characteristics of the image.

In image processing, an image contains a lot of sub-images called as ROIs or the interested regions. This idea confers that images mostly have a large number of objects and each object can be basis for any region. In a well adapted image processing system it must be easy to apply any operation to the selected regions of interest. Therefore one part of the input image has to be processed to suppress the blurredness while the other part is there to improve the color contrastness of the image. Mostly, image processing systems are assumed that available input images are in their digitized form. For the purpose of digitization, first the input image has to be sampled and then quantized using its countable bits. After that the digitized image is allowed to process through a computer system [1].

## 2. Image Denoising

The two major difficulties in imaging are blurredness and noise. These practically arises only in case of light limited conditions and results in a bad or ruined photograph. Image denoising represents the problem of ambiguity between high-frequencies of any un-observed noise-less image. Therefore the central approach in denoising is of developing different procedures to disambiguate solutions. Figure 1.1 shows the block diagram of denoising an image using multi-wavelet transformation and reconstructing after applying any thresholding technique.

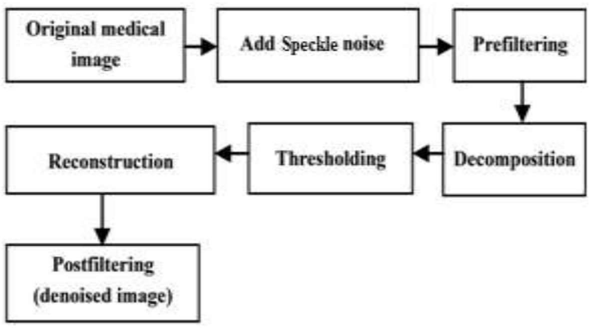


Figure 1.1: Block diagram of denoising using multi-wavelet transformation

An original input image is made noisy if it is noise free and pre-filtered for the process of decomposition up to certain stages. The next step is of choosing some wavelet transformation and applying it to the noisy image to get its decomposed image. Then apply thresholding technique to the decomposed ones for calculating detail coefficients. Finally the wavelet reconstruction is done by applying inverse wavelet transformation. The primary motive of any image denoising technique is always of suppressing noisy portion of the input signal and to recover it [2] [3].

### 3. Ultrasonography

Ultrasonography is the most realistic technique for imaging internal body organs or cells and tissues present in the body of human being. Medical ultrasonography is widely used in diagnostic imaging for visualizing and analyzing various tissues and other internal human body organs, their shape and size, and their structure or any other pathological lesions. This is commonly used over some other medical imaging techniques as it is portable, non-invasive and versatile in nature and also it does not use ionizing radiations. As the light beam strikes against the interface or boundary of the tissues, some sound waves get reflected back to the transducer in the form of echoes. These echoes are then used to convert into electrical impulses by the transducer to be displayed on an oscilloscope that presents a picture of the organ under examination [4] [5].

Ultrasonography has gained an excellent patient attraction and acceptance because of its safety procedure, painless, fast and comparatively inexpensive as compared with other imaging method. In the language of physics, ultrasound term is used for all those sound waves which have more frequency than that of the audible ability of human ear i.e. 20,000 Hz. The frequency range which is used in diagnostic ultrasound is having range between 2 MHz to 18 MHz. In the diagnostic Ultrasonography, these ultrasonic waves originated from electrically stimulated crystal i.e piezoelectric crystal called transducer. An ultrasound transducer which has been placed on the body of the patient over the region under observation sends ultrasound pulses which travel in the form of a beam into their tissues. Due to so many interfaces, some amount of energy gets reflected back which is then transformed in the form of echo signals. Then these signals are again sent into amplifiers so that two dimensional image can be generated. This phenomenon of sending waves in different directions is repeated again and again to examine the whole region of interest in the body [6].

The practicality of medical ultrasonography is getting reduced by existence of some signal dependent noise generally referred as speckle noise. The style of this speckle noise depends on the internal shape and structure of various imaging tissues or organs as well as on their many other imaging parameters. There are two main purposes for the reduction of speckle noise in medical ultrasound images, one is of improving human understanding and interpretation of ultrasound images and other is of despeckling. Despeckling is main pre-processing action for the ultrasound image processing operations like segmentation [7].

### 4. Wavelet Transformation

Figure 4.1 depicts the Wavelet Transform. It is a methodology that contains many variable sized regions. Wavelet analysis permits long span intervals at the time when more precise low-frequency information is required and smaller regions at the time when high-frequency information is required [8].

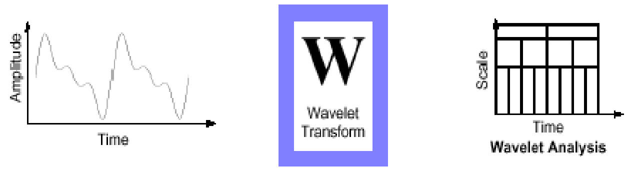


Figure 4.1: Wavelet Transformation

It is clear from Figure 4.2 that wavelet based analysis uses a time-scale region but do not use time-frequency regions. The following figure represents the relation between the time-based, frequency-based, and STFT views of a signal [9]:

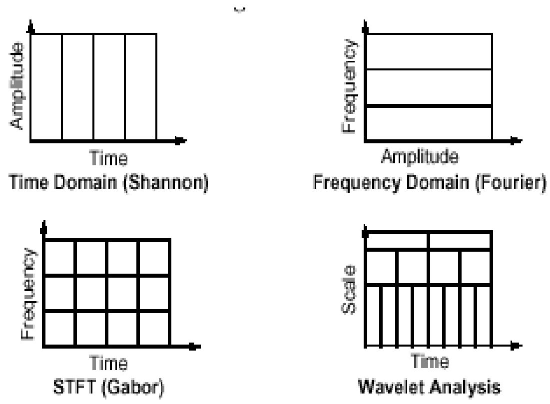


Figure 4.2: Wavelet Analysis

In case of wavelet transformation, first step is of performing the transformation for all the rows of its matrix. This process results in the formation of a matrix with left hand side containing the down-sampled low-pass coefficients of each row and the right hand side contains the down sampled high pass coefficients. After that, next step is of the decomposition which is applied to all the columns for obtaining results in four different coefficients viz. *HH, HL, LH and LL* [10].

### 5. Wavelet Thresholding

Wavelet Thresholding is an extremely simple and efficient method. This technique produces segments having pixels with similar intensities. Wavelet thresholding is a signal estimation technique that exploits the capabilities of wavelet transform for signal denoising. Thresholding is useful for establishing boundaries in images that contain solid objects resting on certain contrasting background [11].

Let $f = f_{ij}$; $\{where\ i, j = 1, 2 \ldots M\}$ indicates an $M \times M$ matrix of original image that has to be recovered and $M$ is some integral power of *2*. During transmission of the signal, it often gets corrupted by some independent and identically distributed white Gaussian Noise $n_{ij}$ with standard deviation $\sigma$ *or* $n_{ij} \sim N(0,\sigma^2)$. On the receiver side, the noisy signal $g_{ij} = f_{ij} + \sigma * n_{ij}$ is produced. The main motive is of the estimation of the signal f from those of noisy observations $g_{ij}$ so that Mean Squared error is gets reduced.

Let $W$ and $W^{-1}$ are the two dimensional orthogonal discrete wavelet transform and its inverse matrix respectively. Let $Y = W_g$ represents a matrix of wavelet coefficients of g with four sub-bands (*LL, LH, HL and HH)*. Then the sub-bands $HH_k, HL_k, LH_k$ are called details, where k is the scale that varies from *1, 2 …… J* and *J* is the total number of decompositions. The general size of the sub-band at scale k is *N/2k × N/2k*. The $LL_j$ sub-band is the low-resolution residue. Wavelet thresholding denoising method processes every coefficient of *Y* from the detail sub-band with a soft threshold function to find *X*. Finally the denoised estimate is inverse transformed to $f = W^{-1}X$ [10].

**6. Estimation of Parameters**

This section depicts a method for evaluating different denoising parameters. The following expression is used for the calculation of threshold ($T_N$) value that is adaptable to different sub-band characteristics.

$$T_N = \frac{\beta\sigma^2}{\sigma_y} \qquad \ldots (6.1)$$

In the above equation, $\boldsymbol{\sigma_y}$ is the standard deviation and is calculated for each sub-band under consideration. $\boldsymbol{\sigma^2}$ is the noise variance. $\boldsymbol{\beta}$ is the scale parameter which is calculated only a single time for each and every scale by using the following empirically enhanced equation [10]:

$$\beta = (log\left(\frac{L_k}{log(L_k)}\right))^3 \qquad \ldots (6.2)$$

Here $L_k$ is length at $k^{th}$ scale of the sub-band.
Now, $\sigma^2$ is referred to as noise variance that is computed from the sub-band:

$$\sigma^2 = \left[\frac{median(|Y_{ij}|)}{0.6745}\right]^2 \qquad \ldots (6.3)$$

Here $Y_{ij} \in$ sub-band $HH_1$
This proposed method uses soft thresholding with sub-band dependent data driven threshold function $T_N$.

**7. Image Denoising Algorithm**

The proposed image denoising algorithm includes following steps:

a) Take an input image ('.jpg', '.jpeg' '.tif').
b) Then add the speckle noise to the original input image (Noise Free image) if it is otherwise go to step c.
c) Perform the multi-scale decomposition of noise added image with the help of wavelet transformation.
d) Estimate the value of noise variance ($\sigma^2$**)** from equation (6.3).
e) After computing noise variance, compute the value of scale parameter β for each level using equation (6.2).
f) For each sub-band (except for that of the low pass residual, i.e. $LL_j$)

i. Calculate standard deviation ($\sigma_y$)**.**
ii. Calculate threshold value $T_N$ from equation (6.1).
iii. On every noisy coefficient, apply soft thresholding.

g) Invert the multi-scale decomposition for reconstructing final denoised image $f$.

**8. Experimental Results and Discussion:**

In this thesis work, the input images taken are medical ultrasound images. The results have been obtained by applying various denoising techniques on different images. The test experiments are performed on various gray scale test ultrasound images. Here, the wavelet transformation has been performed using Daubechies least asymmetric wavelet having eight different vanishing moments all at the four stages of decomposition. For comparing the performance of suggested method and for setting a benchmark against the performance of threshold estimation17, it is compared with Normal shrink method, Median filters and Wiener filtering [10].
The various quality evaluation metrics like SNR, EPI, CoC 16 taken from various methods are compared for synthetic image and the results are found by computing mean of five runs. Actual comparison of this proposed work has been made with Normal Shrink method, Median filter and Wiener filter, so that the best one out of them may be highlighted and shown in bold for each set of test at different noise levels. The proposed method outperforms in results of SNR, EPI and CoC. The visual effectiveness of this work has also been clinically validated.

The proposed method has used soft thresholding than that of hard thresholding which is more successful. It is clear and justified from analyzing the experimental results [10]. The comparisons are made with one of the best linear filtering methodology i.e. Wiener filter.

The results appeared in the Table 8.1 show that SNR (in dB), EPI, CoC are consistently better than those of other non-linear image denoising techniques. The visual quality of image is also better than those obtained by other methods. Fig. 8.1 shows the visual results corresponding to Original image, Noisy image, Proposed method and resulting images of Normal Shrink [10], Wiener filter and Median Filter. The proposed work is compared both qualitatively and quantitatively for the purpose of clinical acceptance. The numerical outcomes are represented in Table 8.1.

**Table 8.1 Results for Synthetic Ultrasound image at various values of σ**

| Noise Level (σ) | Metrics | Normal Shrink | Median Filter | Wiener Filter | Proposed |
|---|---|---|---|---|---|
| 0.4 | **SNR** | 31.7564 | 27.1015 | 32.1069 | **32.4096** |
| | **CoC** | 0.9827 | 0.9739 | 0.9784 | **0.9877** |
| | **EPI** | 0.7067 | 0.6999 | 0.6911 | **0.7182** |
| 0.5 | **SNR** | 30.4490 | 27.1183 | 31.2748 | **31.4476** |
| | **CoC** | 0.9735 | 0.9693 | 0.9812 | **0.9879** |
| | **EPI** | 0.7080 | 0.6952 | 0.6924 | **0.7162** |

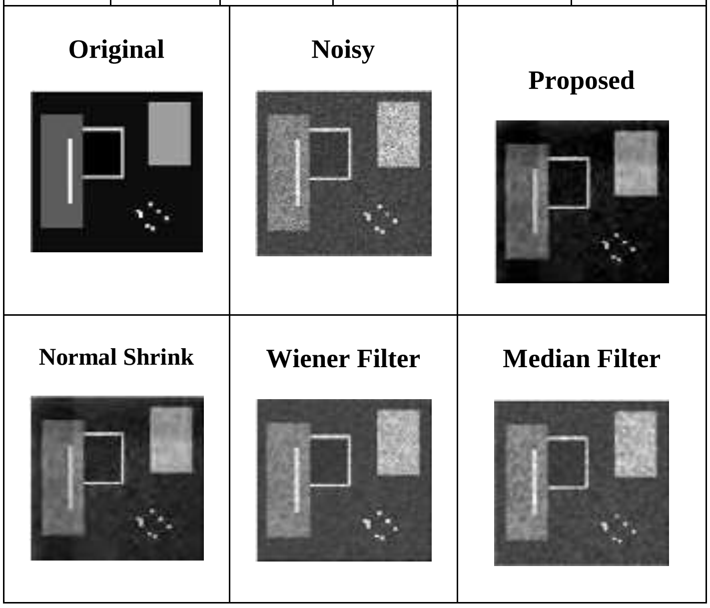


**Figure 8.1: Visual comparison of result of various despeckling techniques with proposed technique for Test Image1**

## 9. Conclusion

In proposed work, an effective technique based on wavelet domain for image denoising has suggested. This enhanced wavelet based method has shown better results than Normal Shrink method, Wiener filter and Median filter. The suggested method reduces the value of noise by preserving the important characteristics or features on several medical ultrasound test images.

The main motive of this thesis was to develop a novel technique based on wavelet transform for image denoising. The proposed technique has improved both visual and quantitative aspects of various medical ultrasound test images. In comparative study, this method of image denoising has proved to be better than those of other existing technique [10].

In proposed work, a sub-band adaptive and simple threshold has proposed for resolving the problem associated with image recovery by using its noisy counter-part. The denoising algorithm used a realistic soft thresholding methodology than hard thresholding for providing a smooth image as well as having a better edge preservation at the same time.

The study has proved in results & discussion section that the denoised images obtained after applying proposed technique preserves image quality and visual quality of input image. The experimental outcomes proved that suggested technique emerges significantly better in values of SNR, EPI and CoC as compared to other techniques for speckle noise reduction. It can be concluded that proposed method reduced speckle noise significantly and preserved edges while de-speckling in a better way than other techniques. Further, the visual results have also been clinically validated by a radiologist.

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