Reducing Speckle Noise in Medical Ultrasound Image Using Diffusion Filter Algorithm – Review

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Abstract— The quality of medical ultrasound is generally limited due to a number of factors, which originate from physical phenomena underlying the image acquisition. As a result, in the past few decades considerable efforts in the field of ultrasound imaging have been made for improving the image quality to make ultrasound imaging better for the perception of radiologists and more suitable for processing by autonomous machines for segmentation and registration. The major problem of ultrasound imaging technique is inheritance of Speckle noise. Speckle noise tends to reduce the image contrast and blur image details, thereby decreasing the quality and reliability of medical ultrasound. Many denoising methods such as Lee filter, Kuan filter and Frost filter have been developed so far for despeckling of ultrasound images but sometimes important diagnostic details are lost while denoising because of over smoothing. Diffusion filters are able to reduce noise but it requires large number of convergence .Wavelet based filters rarely cause over smoothing but they fail to perform well near edges. The proposed algorithm remove speckle noise without resulting into over smoothing and perform well near edges. Here In this thesis work, the proposed Algorithms designed to reduce speckle noise by the combination of PDE based Speckle Reducing Anisotropic Diffusion filter and wavelet based Threshold Shrink technique. Than The proposed algoritham is compared with spatial domain filters.
Key words: Speckle Noise, Ultrasound, Wavelet Thresholding, Anisotropic Diffusion

I. INTRODUCTION

Ultrasonic imaging is a widely used medical imaging procedure because it is economical, comparatively safe, transferable, and adaptable. Though, one of its main shortcomings is the poor quality of images, which are affected by speckle noise. The existence of speckle is unattractive since it disgrace image quality and it affects the tasks of individual interpretation and diagnosis. Medical digital images have become an essential part in the healthcare industry for diagnosis of diseases. These images are produced by various medical imaging devices like x-ray, CT / MRI scanners and electron microscope all of which produce high resolution images. However, imperfect acquisition instruments, transmission errors often distort the visual signals obtained. These distortions are referred to as "Noise" and have to be removed to improve the quality of the image. The techniques used to remove noise are termed as "Image Denoising".

One of the major disadvantages of ultrasound images is that they suffer from a special kind of noise called 'speckle'. Speckle is a complex thing and it significantly makes image quality very bad. Speckle appears interference of back-scattered wave from many microscopic diffused reflection which passing through internal organs and makes it more difficult for the observer to determine fine detail of the images in diagnostic examinations.

There are two techniques of reduce speckle noise, i.e., multi-look process and spatial filtering. Multi-look process is used at the data acquisition stage while spatial filtering is used after the data is stored. No matter which method is used to reduce the noise, they should edge information and spatial resolution.

The goal of any speckle noise reduce algorithm should be to enhance the corrupted images by maintaining the quality of the image. After studying research papers regarding medical ultrasound image restoration techniques in different-different domain, I found interest in diffusion and wavelet based filtering because it has better special reduction property without losing useful information required for diagnosis of disease. My efforts in this area will surely give important results to reduce the speckle noise in ultrasound image for better diagnosis and restore the medical ultrasound images.

II. SPECKLE NOISE

Speckle noise is defined as multiplicative noise, having a granular pattern it is the inherent property of ultrasound image.

Speckle degrades the quality of US images and thereby reducing the ability of a human observer to determine the fine details of diagnostic examination. Speckle is a random, deterministic, interference pattern in an image formed with coherent radiation of a medium containing many sub-resolution scatterers. Speckle has a negative impact on ultrasound imaging. The presence of speckle noise in images shows a reduction of lesion delectability. This radical reduction in contrast resolution is responsible for the poorer effective resolution of ultrasound compared to x-ray and MRI. Presence of speckle noise prevents Automatic Target Recognition (ATR) and texture analysis algorithm to perform efficiently and gives the image a grainy appearance.
Speckle noise follows a gamma distribution and is given as:

$$F(g) = \frac{g^{\alpha-1}}{(\alpha-1)!a^{\alpha}} e^{-\frac{g}{a}} \qquad (1)$$

Where a^{α} the variance and g is is the gray level. On an image, speckle noise (with variance 0.05) looks as shown in Figure 1a and the corresponding gamma distribution is given in Figure 2.1

Fig. 1: Ultrasound Image Corrupt By Speckle Noise

A. *Techniques for Speckle Reduction:*

1) Incoherent processing techniques
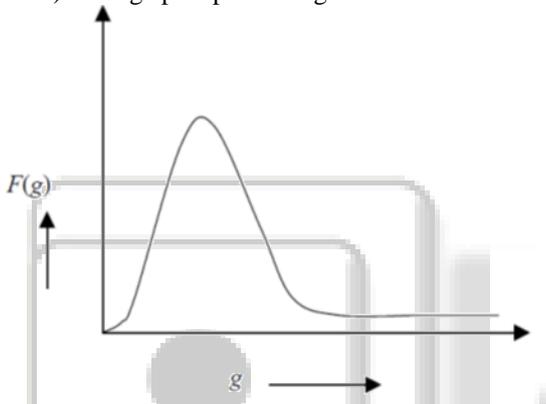2) Image post processing

Fig. 2: Gamma Distribution

1) Incoherent Processing Techniques:

These are based on the averaging of multiple images of the same scan plane, where the images are obtained by varying transducer frequency and/or view angle to achieve independent or partially uncorrelated speckle patterns. These imaging techniques increase target-detection capability of phased array scanning at the expense of increased system complexity and loss of spatial resolution.

2) Image Post Processing:

Speckle Suppression schemes based on image post processing involve adaptive, anisotropic diffusion and wavelet based filtering techniques. These techniques do not require any hardware modification in the image reconstruction system, and hence have found a growing interest. In this the images are obtained as usual and the processing techniques are applied on the image obtained. However, one of the chief difficulties of filtering methods proposed in literature is the understanding the nature of speckle.

III. ULTRASOUND IMAGING

Ultrasound imaging is most widely used imaging technique because of its non-invasive nature, low-cost and capability of forming real time imaging. Ultrasound is a non-ionizing pulse-echo imaging modality, predominantly used as a diagnostic tool in modern medicine. The technology is relatively inexpensive and portable, especially when compared with other imaging techniques such as magnetic resonance imaging (MRI) and computerized tomography (CT). It has no known long-term side effects and rarely causes any discomfort to the patient. Since it does not use ionizing radiation, ultrasound yields no risks to the patient. It provides live images, where the operator can select the most useful section for diagnosing thus facilitating quick diagnoses. Ultrasound uses high frequency (1 to 5 megahertz) acoustic waves to visualize tendons, muscles and other internal organs, their size, structure and any pathological lesions. These acoustic waves are generated using a piezoelectric transducer which converts electrical signal of 2 to 10 MHz (called as carrier frequency Wc)into acoustic waves. The sound waves travel into the body and they get reflected upon striking a boundary between tissues. The reflected waves are received by the transducer which converts them into RF electrical signals. The amplitude of the acoustic signal gets attenuated as the wave travels down the tissue, therefore the returned signal is first amplified in proportion to the distance travelled. The higher the frequency of sound waves the more the attenuation.

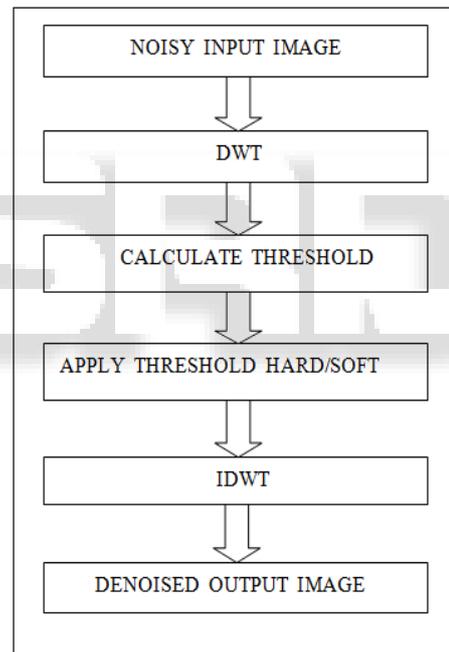## IV. WAVELET BASED THRESHOLDING

Fig. 3: Wavelet Based Denoising Process

The Figure.1 shows wavelet based denoising method for speckle reduction implemented in this study is described as follows. Compute the discrete wavelet transform (DWT). For each sub band: Compute a threshold. Apply the threshold on the wavelet coefficients of each band. Compute the inverse DWT to reconstruct the despeckled image.

V. ANISOTROPIC DIFFUSION FILTER

Anisotropic diffusion is an efficient nonlinear technique for simultaneously performing contrast enhancement and noise reduction. It smoothes homogeneous image regions and retains image edges. The main concept of anisotropic diffusion is the introduction of a function that inhabits smoothing at the image edges. This function is called diffusion coefficient. The diffusion coefficient is chosen to vary spatially in such a way to encourage intraregion

smoothing in preference to interregion smoothing (Perona and Malik 1990). Anisotropic Diffusion is a nonlinear smoothing filter which uses a variable conductance term, that controls the contrast of the edges that influence the diffusion. This filter has the ability to preserve edges, while smoothing the rest of the image to reduce noise. The anisotropic diffusion has been used by several researchers in image restoration and image recovery. SRAD is an edge-sensitive Partial Differential Equation (PDE) anisotropic diffusion approach to reduce speckle noise in images. The anisotropic filtering in SRAD simplifies image features to improve image segmentation and smoothes the image in homogeneous area while preserving edges and enhances them. It reduces blocking artifacts by deleting small edges amplified by homomorphic filtering. SRAD equation for an image u is given by the Equation

$$SRAD(u') = ut + 1ut + \frac{\Delta t}{4} \, div(g(ICOV(u'))X \quad \nabla w') \quad (2)$$

Where t is the diffusion time index, Δt is the time step responsible for the convergence rate of the diffusion process (normally in the range 0.05 to 0.25), g(.) is the diffusion function and is given by equations

$$G(ICOV(u')) = e\text{-}(P) \qquad (3)$$

The performance of SRAD is superior to the traditional anisotropic diffusion filters. However, SRAD has the disadvantage that the diffusion time increases with the image features and it is already known that when diffusion time increases the image quality of the denoised image decreases.

VI. BAYESIAN SHRINKAGE

The goal of BayesShrink method is to minimize the Bayesian risk, and hence its name, BayesShrink. It uses soft thresholding and is subband-dependent, which means that thresholding is done at each band of resolution in the wavelet decomposition. Like the SureShrink procedure, it is smoothness adaptive. The Bayes threshold, tB, is defined as

$$t_{B\,=}\, \sigma^2/\sigma_s^2 \qquad (4)$$

Where $\sigma 2$ is the noise variance and $\sigma s2$ is the signal variance without noise. The noise variance $\sigma 2$ is estimated from the subband HH1 by the median estimator shown in Equation . From the definition of additive noise,

$$w(x, y) = s(x, y) + n(x, y) \qquad (5)$$

Since the noise and the signal are independent of each other, it can be stated that

$$\sigma_w^2 = \sigma_s^2 + \sigma_w^2 \qquad (6)$$

σ_w^2 Can be computed using Equation. From this the variance of the signal, σ_s^2 can be computed using Equation

$$\sigma_w^2 = \frac{1}{n^2}\sum_{x,y=1}^{n} w^2(x, y) \qquad (7)$$

$$\sigma_s = \sqrt{max(\sigma_w^2 - \sigma^2, 0)} \qquad (8)$$

With $\sigma 2$ and $\sigma 2s$, the Bayes threshold is computed from Equation (12).

VII. PROPOSED SYSTEM

The existing models suffer from blocky effects, which in the present study are removed by using fourth order PDE. This technique preserves edges and boundaries which are more stable through the scale 't'. Another difficulty faced by the existing models is that, if the image is very noisy, the gradient Δu will be very large, and as a result, the function c(.) will be close to zero at almost every point. When the

smoothing is introduced the noise will remain consequently. This difficulty is solved by using a suitable filter that can reduce noise and at the same time be combined with fourth order PDE based anisotropic diffusion.

So the SRAD filter was considered and to speed up the convergence, BayesShrink is used. The main objective is to reduce the blocking artifacts produced by reducing the number of iterations required to reach a convergence point. The iteration process in the proposed model will continue till the input signal 'y' is converged to the output signal 'Y'.

The convergence of the image processed by SRAD filter. The convergence point is at P. Suppose at P we will get the better image, with the assumption that the input image is a noisy one. If this convergence point P can be shifted towards y-axis, its movement will become better. Now if we pull the point P towards y- axis, it will move in a left-top fashion. Here the Bayesian shrinkage is the catalyst, which pulls the convergence point P of the SRAD towards a better place.

Steps perform by this flow:
1) Give input as a noisy image.
2) Apply SRAD filter technique
3) Apply bayes shrink technique
4) Get output
5) Output compare with spatial filter.

Most important thing is howmany iterations are there?
The iteration process in the proposed model will continue till the input signal 'y' is converged to the output signal 'Y'.
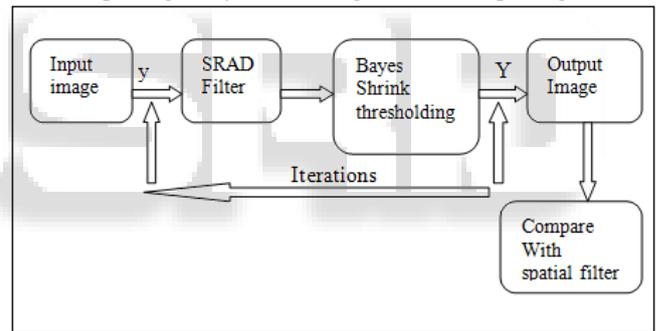

Fig. 4: Proposed Denoising Algoritham

VIII. PARAMETERS PERFORMANCE

The selection of the denoising technique is application dependent and therefore, it is necessary to learn and compare denoising techniques to select the technique that is application for the application of interest. Here I took one Liver Ultrasound.tif image for experiments and apply some special noise then it applied for the denoising techniques based three different shrinking techniques (VisuShrink, SureShrink and BayesShrink) in MATLAB 7.8.0(2009) . The models proposed are given in Table 1. For the evaluation we calculate the MSE, SNR, COC and PSNR.PSNR is a quality measurement between the original and a denoised image. The higher the PSNR, the better is the quality of the compressed or reconstructed image. To compute PSNR, the block first calculates the Mean Squared Error (MSE) and then the PSNR.

A. Mean Squared Error (MSE):

The MSE calculates the difference between the original image and filtered image. MSE can be represented in mathematically by

$$MSE = \frac{\sum_{MN}[I_1(m,n) - I_2(m,n)]^2}{M*N} \qquad (9)$$

Here M and N, m and n are number of rows and columns in the input and output image respectively

B. Signal to Noise Ratio (SNR):

The signal to noise ratio measure the noise per image. It can be represented by

$$SNR = \frac{\sum_{MN}[I_1{}^2(m,n) - I_2{}^2(m,n)]^2}{\sum_{MN}[I_1(m,n) - I_2(m,n)]^2} \qquad (10)$$

It measures the signal to noise ratio between the original and processed images in an M X N window

C. Peak Signal to Noise Ratio (PSNR):

The PSNR is a quality measurement between the original and a denoised image. The higher the PSNR, the better is the quality of the compressed or reconstructed image.

$$PSNR = 10 log10 \left[\frac{R^2}{MSE}\right] \qquad (11)$$

In (11) R is the maximum possible pixel value of the image. When the pixels are represented using 8 bits per sample, this is 255.

IX. CONCLUSION

The current need of healthcare industries is to preserve useful diagnostic information with minimum noise. Ultrasound images often suffer with a special type of noise called speckle. The major problem of ultrasound imaging technique is inheritance of Speckle noise.

Speckle noise tends to reduce the image contrast and blur image details, thereby decreasing the quality and reliability of medical ultrasound. As a result, image processing methods for Restoration or reduction of speckle noise from ultrasound images has become the predominant step in medical image processing. Many denoising methods such as Lee filter, Kuan filter and Frost filter have been developed so far for despeckling of ultrasound images but sometimes important diagnostic details are lost while denoising because of over smoothing. Diffusion filtersare able to reduce noise but it requires large number of convergence .Wavelet based filters rarely cause over smoothing but they fail to perform well near edges. The proposed algorithm remove speckle noise without resulting into over smoothing and perform well near edges.

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