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NON-LINEAR THRESHOLDING DIFFUSION METHOD FOR SPECKLE NOISE REDUCTION IN ULTRASOUND IMAGES

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ABSTRACT
Ultrasound (US) medical images are very important tools in modern medicine used for the diagnosis and study of various illnesses. Speckle is the important phenomenon that affects the quality of ultrasound images. This paper presents a new speckle suppression method in US images. The idea is based on the combination of different filters in serial as well as parallel form. The speckle noise affected image is separated into two parts using adaptive weighted median filter. These two parts are then filtered using wavelet transform and the wavelet coefficients are processed with soft thresholding. Then the processed coefficients of each parts are transformed back in to the space domain. The two processed parts are then summed. Finally diffusion filter is used to get the better de-noised image. A comparative study of different filters, conventional method with the proposed method is present in this paper. The experimental results show that the proposed method has the better noise reduction.

INTRODUCTION
Ultrasound images widely used as diagnostic tool in modern medicine because it is economical, comparatively safe, transferable, adaptable, and inexpensive when compared with other imaging techniques such as magnetic resonance imaging (MRI) and computed tomography (CT). It visualise the muscles and many internal organs, their size, structure, pathological injuries with real time tomographic images and also visualise the foetus during routine and emergency prenatal care. Unfortunately, the usefulness of US images are reduced by the presence of noise. The main noise that affects the US images is speckle noise. It affects edges and fine details of the image and limit the contrast, resolution then make diagnosis more difficult. So in medical image processing, image de-noising has become a very essential for better information extraction from the images. The main need of de-speckling of US images is to improve the human interpretation, diagnosis value, speed of image processing techniques such as segmentation and feature extraction.

Noise reduction technique for ultrasound imaging can be classified as compounding and filtering. Compounding techniques involve, a series of US images of the same target which are acquired from different scan direction and with different transducer frequencies. Then the images are averaged to form a composite image. Over the years, a number of data fusion strategies have been attempted including minimum, maximum, median, root mean square (RMS), and various forms of weighted averaging. The disadvantage of the compounding is the loss of important details in the final output and increasing system complexity. Filtering is one of the main methods used to de-noising the US images [1].

A number of post-processing filters have been developed for suppressing speckle noise in medical ultrasound images. Mean filter, median filter and Wiener filter are the basic filters to remove noise in the any images. But these filters cannot reduce the speckle noise in US images [2][3]. In 1980s J.S.Lee develop an adaptive filter which utilise the local statistics for speckle suppression. It can be used for both additive and multiplicative noise, but the main disadvantage of this filter is it ignores speckle noise in the edges[4]. To overcome this D.Kuan introduce an filter know as Kuan filter in 1985, it is also enhanced lee filter[5]. In 1989 Loupas developed a filter called adaptive weighted median filter, it is also known as enhanced median filter. It introduces the concept of weighting coefficient for the pixels in the window. The adaption of weight based on the imaged characteristics in the area inside the window [6]. Another speckle noise reduction method is wavelet transform. The noise present in the high frequency component in an image. This is eliminated by doing wavelet transform. The main disadvantage of this is that some important details in the image may also lost. Peorna and Malic introduce a anisotropic diffusion filter in 1990s. It is the better filter for speckle noise suppression in the US images[7].

In this paper a new filtering method which combines some of the filters is introduced. It uses adaptive weighted median filter for separating the noisy image into two parts. Then applying wavelet transform and nonlinear thresholding for each part then doing the inverse wavelet transform for bring it back in to the special domain. Then combine the two parts and finally the diffusion filter is used to get the better filtered image.

SPECKLE NOISE IN ULTRASOUND IMAGES

The presence of noise in the US images affects edges and fine details which limit the contrast resolution and makes diagnosis more difficult. The noises can be categorised as external noise and internal noise. External noises may due to factors like temperature difference, pressure change and other external factors. Shadowing, rolling noise are examples of external noise. Internal noises may due to the internal effect while scanning is done. Speckle is the main internal noise found in US images.

Speckle noise:

Speckle noise is a type of acoustic phenomenon responsible for the granular appearance of ultrasound images caused by the constructive and destructive interference of echoes produced by scattering of ultrasound at random, small-scale, tissue in homogeneities. It is a direct consequence of 1) the stochastic nature of the reflectivity of scattering media, and 2) the coherent nature of the piezoelectric transducer. The presence of speckle in US image results decrease in quality of image and it become quite difficult for human to diagnose and interpret the changes with naked eye. It also reduces the resolution of the image which has low contrast and degrades the speed and accuracy of ultrasound image processing tasks such as segmentation and registration. Suppressing noise and speckle will improves the image quality and diagnostic value of ultrasound image.

Speckle noise model:

In medical literature, the speckle noise is termed as ‘texture’. The effective de-speckling requires an accurate statistical model of ultrasound signals. A generalized model of the speckle imaging can be written as:

$$g(n,m) = f(n,m) * u(n,m) + h(n,m) \quad (1)$$

Where $g(n,m)$ is the observed image, $u(n,m)$ is the multiplicative component and $h(n,m)$ is the additive component of the speckle noise. Here, n and m denotes axial and lateral indices of image samples. For the ultrasound imaging, only multiplicative component of the noise is to be considered and additive component of the noise is to be ignored. The equation 1 becomes

$$g(n,m) = f(n,m) * u(n,m) \quad (2)$$

Speckle noise follows the gamma distribution, and it given as

$$F(g) = \frac{g^{\alpha-1}}{(\alpha-1)!\,a^{\alpha}} e^{\frac{g}{a}} \quad (3)$$

Where a is the variance and g is the gray level. Fig. 1 shows the graphical representation of speckle noise [8][9].

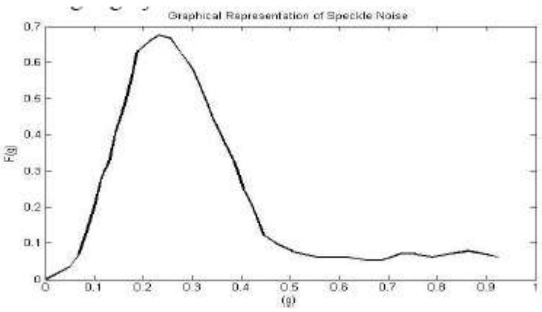
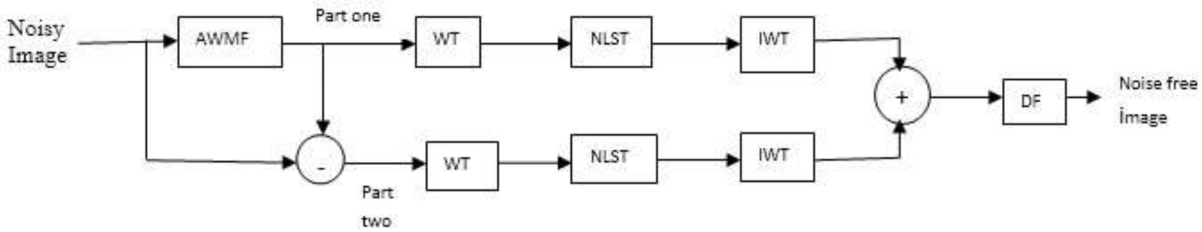


Figure 1: Graphical representation of Speckle noise

PROPOSED METHOD

In this paper the combination of Multi-Scale Non-Linear Thresholdig Adaptive filter(MSNLT-A) [10] and Diffusion filter is presented.Noises present in ultrasound image affects edges and fine details which limits the contrast resolution and make diagnosis more difficult. While reducing the noise it has to be maintained the trade-off between noise reduction and preservation of actual image details.



AWMF- Adaptive Weighted Median Filter, WT-Wavelet Transform
NLST- Non-linear Soft Threshold, IW – Inverse Wavelet Transform, DF- Diffusion Filter

Fig.2. Proposed system

Here the noisy image is first divided in to two parts. For that an adaptive weighted median filter is used. It is worked based on the adaption process (adjust the filter parameter) and filtering process. It uses the weights of surrounding pixels and the filtering is done based on this weights. Local statistics such as local mean and variance are used for finding this weight. Here the weighing coefficients are varied around each pixels. The filtering is done based on the weighted median filter. The filtered image can be called signal dominant part. And the noise dominant part can be obtained by subtracting signal dominant part from the original noisy image. The SNR of both the two parts will be different. The two parts are then filtered separately. They are decomposed by 2D-wavelet transform for eliminating the high frequency noise. Wavelet filters attempt to remove noise while preserving the boundaries of anatomic structures. The wavelet coefficients are then processed with nonlinear soft thresholding method. Two different threshold scales are used here because of the SNR is different for the two parts. After the thresholding both the two parts are inversely transformed into special domain. Now these two images have the low noise component then they are combined together to form a new noise reduced image.

Finally, to make the image become more noise free and to make the edges of the filtered image become more clear, the anisotropic diffusion filter is used at the end of this MSNLT-A filter. Anisotropic diffusion filters is uses non-linear partial differential equation for smoothing image and it has the very good edge preserving property. The image feature is introduced in to the diffusion equation first, then the appropriate coefficient in-order to control the diffusion behaviour is determine. Here the diffusion coefficient is a function of the differential structure of the evolving image and the smoothing is carried out depending on the edge and their direction ie, the smaller diffusion along the gradient direction and large diffusion in the vertical region. It smoothes homogeneous region but retain the image edges. Within the partial differential equation, a diffusion coefficient is utilized in order to identify edges within the image and encourage noise suppression within homogeneous regions instead of across edges. Here the tool that used to find the strength and direction of the edge is gradient. Based on this gradient value the smoothing is performed. Generally in homogeneous region the gradient will be small, when the gradient is small smoothing will be done. Smoothing will be stopped when the gradient magnitude is high. The non-linear partial differential equation for smoothing image on a continuous domain is given by,

$$\frac{\partial I}{\partial t} = div\left[c\left(\|\nabla I\|\right).\nabla I\right] \quad (4)$$

$$I(t=0) = I_0 \quad (5)$$

Where div is the divergence operator, $\|\nabla I\|$ is the gradient magnitude of the image I, $c(\|\nabla I\|)$ is the diffusion coefficient or the diffusivity function and I_0 is the original image. $c(\|\nabla I\|)$ is controls the level of diffusion at each image position Smoothing is inhibited across image edges by choosing a monotonically decreasing function of gradient magnitude for c(.), such as $c(x) = \exp(-(\frac{x}{k})^2)$, where k is an edge threshold. c (.) should satisfies the following conditions,

$$\lim_{x \to 0} c(x) = 1 \quad (6)$$

$$\lim_{x \to \infty} c(x) = 0 \quad (7)$$

The block diagram of the proposed method of speckle suppression in US images is shown in the Fig.2.

ALGORITHM

1. Input an US image with speckle noise having variance 0.4.
2. Apply adaptive weighted median filter (AWMF) to separate the original noisy image into two parts, ie, the output of the AWMF is the signal dominant part (first part).
3. The noise dominant part is determined by subtracting the signal dominant part from the original noisy image.
4. The two parts are then decomposed by 2D-wavelet transform.
5. The wavelet coefficients are processed with nonlinear soft-thresholding. Different thresholds are used because of the SNR of two parts are different.
6. The wavelet coefficients are inverse transformed into special domain.
7. Combine the two parts into a single noise reduced image.
8. This image is finally filtered by anisotropic diffusion filter to make the image become more noise free and to make the edges of the filtered image become more clear.

SIMULATION RESULTS

This new speckle filtering method is implemented in MATLAB. The image database used for this experiment is a cardiac US image. The cardiac US image and this image with speckle noise of variance 0.4 is show in Fig 3 and 4.

Fig. 3. Original image

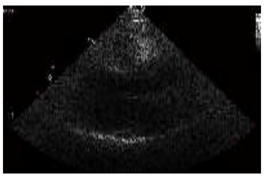


Fig. 4. Noisy image

The noise reduced image using different filters are shown below. The filtered image by mean filter, median filter, weiner filter, AWMF, MSNLT-A Filter and proposed filter is shown in figure 5,6,7,8,9,10 respectively.

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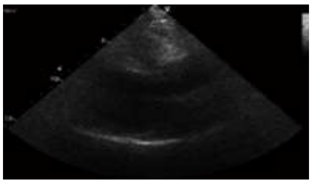

Fig.5.Filtered image using Mean filter

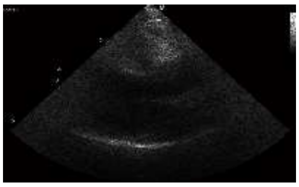

Fig.6.Filtered image using Median filter

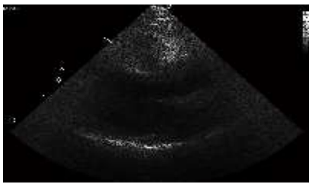

Fig.7.Filtered image using Weiner filter

Fig.8.Filtered image using AWMF

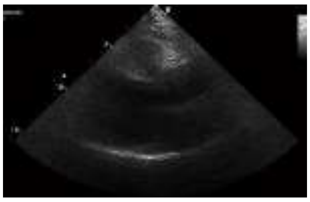

Fig.9.Filtered image using MSNLT-A

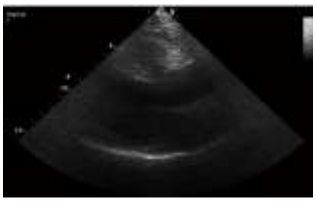

Fig.10.Filtered image using Proposed method

To analyse the filtered image and the performance of the different filters two parameters are used. Mean Square Error (MSE) and Peak Signal to Noise Ratio(PSNR). MSE gives that how different the imagrs being compared. Its lower value indicates that the estimated image is closer to the reference image. PSNR shows the relationship between the real image and the estimated image. High value indicate better performance. The experiments are carried out using different filters. MSE and PSNR values of these filters are given in table 1.

$$\text{MSE} = \frac{1}{MN}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}[I(m,n) - I^\wedge(m,n)]^2 \quad (8)$$

$$\text{PSNR} = 10\ log10\frac{255^2}{MSE} \quad (9)$$

TABLE 1 MSE and PSNR values of different filters

Sl.No	FILTERS	MSE	PSNR
0	Before filtering	201.03	24.88
1	Mean filter	44.36	31.66
2	Median filter	47.76	31.34
3	Weiner filter	62.83	30.04
4	AWMF	200.01	25.12
5	MSNLT-A	134.80	26.85
6	Proposed method	0.0010	78.13

The performance comparison of different filters based on MSE and PSNR is given in the figure 11.

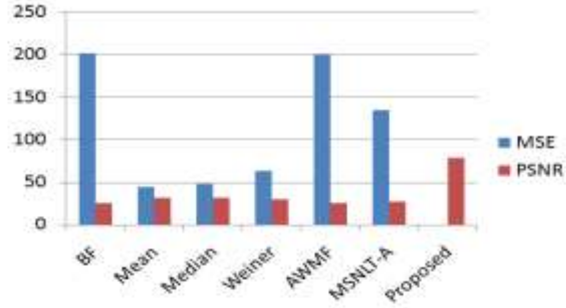

Fig. 11. Comparison of different filters based on MSE and PSNR.

CONCLUSION

In this paper we have proposed speckle suppression method in US images based on the idea of combination of MSNLT-A and an anisotropic diffusion filter. For protecting the important data of the image in the speckle noise we separately filtered the signal dominant and noise dominant images. The separation is done by AWMF. Then the two parts are processed with wavelet transform, nonlinear soft thresholding and inverse wavelet transform. Then the combined two part is filtered with anisotropic diffusion filter. The coparative study of different filters along with the proposed system is done by using two parameters MSE and PSNR. The proposed system has the low MSE and high PSNR values when compared to the all other filters. So the proposed system is much better than the other filters in the case of speckle suppression.

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