Study on the Reduction of Speckle Noise in Ultrasound Images

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ABSTRACT
The ultrasound images, the speckle noise is inherent in medical ultrasound images and it is the cause of reduced contrast-to-noise ratio and resolution. The presence of speckle noise is not attractive because it reduces the image quality and affects the tasks of the individual interpretation and paper diagnosis. In this paper, we study various techniques to reduce speckle noise from ultrasound images Post acquisition method as the only scale spatial filtering method and multi-scale method.

Keywords
De-noising, Speckle Noise, isotropic diffusion , Contourlet transform

1. INTRODUCTION
Ultrasound images are widely used in the medical field as it is relatively safe, economical, adaptable and transferable. Despite many advantages, ultrasound images contain noise called "speckle" that corrupts the image resolution and contrast makes the interpretation of the physical structure lying below extremely difficult for physicians.

Speckle noise in ultrasound image is introduced due to the nature of the consistency of the imaging modality, the interference of backscattered signals of each sub-cell resolution and resolution on the receiver or transducer. Backscattered waves undergo constructive or destructive interference randomly spoils the image in random granular model, known as speckle. Due to the process of acquiring the ultrasound speckle noise is multiplicative in nature, which is directly proportional to the gray level in an area and is statistically independent signals.

The main purpose of image denoising techniques to eliminate noise while preserving as much as possible the important information about the image. Thus, the speckle is considered the main source of noise in ultrasound imaging and should be treated without affecting the characteristics of important picture. The main objectives of size reduction of medical ultrasound imaging are:

1) To improve the human interpretation of ultrasound images - size reduction allows cleaning of the ultrasound image with clear boundaries.

2) Despeckling is a pre-treatment for many tasks of ultrasound images as the segmentation processing and recording - speckle reduction improves the speed and accuracy of segmentation and automatic recording and semi- automatic.

2. METHODS FOR SPECKLE REDUCTION
Several techniques have been proposed for removing impurities in the medical ultrasound imaging. In this section, we present the theoretical overview and classification of existing techniques despeckling

2.1 Compounding Methods
In the mixing method [1] - [3] a series of ultrasound images of the desired image are acquired from different directions and at different scan frequencies or transducers in different strains. Then, images are averaged to form a composite image.

The method of composition may improve the detectability of the desired image, but they suffer from degraded spatial resolution and increased system complexity.

2.2 Post-Acquisition Methods
This method does not require much technical system modification of image processing .The post-acquisition falls under two categories (1) scale spatial filtering methods (2) multiscale

2.2.1 Scale Spatial Filtering Methods
Speckle reduction filter that modifies the degree of smoothing depending on the ratio of local variance to local mean is that developed. In smoothing method is increased in the region where homogeneous and fully developed speckle is reduced or avoided by other regions to preserve the details.

In this method, we assume that the pixels that have similar gray level and connectivity are related and likely to belong to the same object or region. After all pixels are allocated to different groups, the spatial filtering is performed on the basis of local statistics adaptive regions whose sizes and shapes are determined by the information content of the image.

The main difficulty in applying region growing based methods is to design appropriate similarity criteria for region growing. Various types of filters are used in the application of ultrasonic imaging despeckling. The types of filters most commonly used are:

a. Lee and Kaun Filter [4] - The Lee filter [5] is based on the approach that the smoothing is performed on the area having low variance. The Lee filter form an output image by calculating a linear combination of the intensity of the center pixel in the filter window with the average intensity of the window.The Kuan filter [6] is a generalization of the Lee filter. The Kuan filter converts the multiplicative model of speckle into an additive linear form. However, the formulation is different from lee fiter.The main disadvantage of Lee filter is that it tends to ignore speckle noise in the areas closest to edges and lines. This filter is incapable of removing high frequency noise and also it cannot remove noise in high and low variance regions whereas in kaun filter, calculation of ENL, which determines the level of speckle in an image is measure problem.

b. Frost Filter [7]: It strikes a balance between averaging and the all-pass filter. the response of the filter varies locally with the coefficient of variation. In case of low coefficient of variation, the filter is more average-like, and in cases of high coefficient of variation, the filter attempts to preserve sharp features by not averaging. Thereby, it is useful in preserving the edges and boundaries of the image.

c. Enhanced Lee and Frost filter: are used to modify the performance locally depending on the threshold value. Pure average is induced when the local variation factor is smaller than a lower threshold. The filter behaves as a strict all pass filters when the local variation factor is larger than an upper threshold. When the coefficient of variation is between the two thresholds, a balance between the operating medium and the identity is calculated.

d. Mean filter [8]: a locally owned reduce the variance and reduce SNR and asks the user to specify the size of the window. However, it has the effect of potentially blurring the image. This filter is optimal for additive Gaussian noise while the speckled pattern follows a multiplicative model of non-Gaussian noise. Therefore simple average is not the best choice.

e. Median filter: The median filter [9] is a simple nonlinear operator that replaces the middle pixel in the window with the median-value of its neighbours. This filter [10] is used for despeckling due to their robustness against noise and impulsive advanced features preserved. The median filter produces less blurry images. The mixing process uses both the mean and median filters.

f. Map Filter: The purpose of the Gamma or maximum a posteriori (MAP) filter is to minimize the loss of texture information by assuming that the image of the forest areas, agricultural lands and oceans are gamma distributed scenes. This approach is better than the filter and Lee Frost and uses the coefficient of variation and contrast ratio with theoretical probability density function will determine the smoothing process. The algorithm is similar to the filter improved gel, except that if the local variation coefficient C_i falls between the two thresholds of C_u and C_{max}, the filtered pixel value of the estimate is based on contrast ratios gamma to within the appropriate window filters given in Eq.

$Img(i, j) = ((L - ENL - 1) * Im \sqrt{D} +) / (2 * W)$

Where W is the weighting function.

$W = (1 + Cu^2) / (Ci^2 - Cu^2)$

And D is given as

$D = I_m * I_m (W-ENL-1) * (W-ENL-1) + 4 * W * ENL * Im * C_p$

Is the coefficient of variation of particle size distribution of the moving window.

$C_i = S / I_m$

C_u is the coefficient of variation of particle size distribution using the same number of eyes

$C_u = 1 / \sqrt{ENL}$

C_{max} is the coefficient of variation of the higher granularity of the image.

$C_{max} = \sqrt{2} * C_u$

If C_i is less than the value of the filtered C_u within the filter window is replaced by the pixel using the filter window. If C_i is greater than the C_{max}, the filtered pixel value is replaced with the center pixel in the window filtered.

2.2.1.1 Diffusion Filtering :

Perona and Malik [11] proposed equation for isotropic scattering image smoothing on a continuous domain. However, in cases where the images contain speckle, isotropic diffusion will actually improve the shimmer, instead of eliminating corruption. So Yu Acton and derive an anisotropic diffusion equation model (SRAD) introducing local statistical characteristics of the diffusion coefficient in order to improve the model PM.

A method of disseminating sensitive edge called speckle reducing anisotropic diffusion (SRAD) was proposed to remove speckle while preserving the edge information. A method based on anisotropic diffusion tensor called nonlinear coherent diffusion (NCD) used for size reduction and consistent recovery.

Dissemination methods mentioned above can maintain or even improve leading edges when removing speckle. However, the methods have a common limitation retaining the subtle characteristics such as small cysts and lesions in ultrasound images.

A modified SRAD filter based on the kaun filter rather than Lee filter was develope and this approach is called Detail preserving anisotropic diffusion (DEPA) .This method is combined with the method of anisotropic diffusion matrix designed to preserve and enhance small building structures referred to as speckle reduction oriented anisotropic diffusion.

Adaptive speckle suppression approach based on Euler elastic model (Asreem) [12]

SRAD model can be regarded as the solution of the function of bounded variation

$\min [E_{SRAD} (I)] = \min [\iint f(q)\, dxdy]$

where f() is an increasing function of q is non-negative and the instantaneous coefficient of variation. As discussed above, small structures are smoothed or even lost in SRAD because of the weak anisotropic diffusion for small structures. During the iteration, the small structures are step by not smooth. Euler elastic model has the ability to ensure Continuity Of Isolux corrupted by noise. Therefore, we introduce the elastic Euler model in the function of bounded variation to preserve and improve the details.

2.2.2 Multiscale Methods

Several methods of scale based on multiple wavelet pyramid have been proposed for speckle reduction in ultrasound imaging.

2.2.2.1 Wavelet based Speckle Reduction Methods

The speckle reduction method based on wavelet generally include (1) log transformation (2) the wavelet transform (3) modification of noisy coefficient by using the function withdrawal (4) invert wavelet transform and (5) the exponential transformation. This method can be classified into three groups

• Thresholding methods - Wavelet coefficients below the predefined threshold are considered to be contributed by the noise, and then removed. Thresholding techniques have difficulty in determining an appropriate threshold.

• Bayesian Estimation Methods - This method approximates the noise free signal based on the model of the spread of noiseless signal and the noise. Thus, the reasonable distribution models are essential for the proper application of these techniques to medical ultrasound imaging.

• Correlation Coefficients Methods - This is a non-decimated or more complete method of denoising using wavelet domain correlation coefficients useful at different scales of wavelet. However, this method does not depend on prior knowledge of the exact distribution of the noise, and this method is more flexible and more robust compared to other methods based on wavelets.

2.2.2.2 Pyramid-based Method

Pyramid transform[13] was also used to reduce speckle. Approximation and interpolation filters pyramid transform properties low pass pyramid so that the transform does not require a quadrature mirror filters unlike sub band decomposition in the wavelet transform.

• A Laplacian pyramid ratio was introduced in regard to the multiplicative nature of speckle. This method extended the conventional Kaun filter to multi scale domain by processing the interscale layers of the ratio laplacian pyramid[14]. But this method differs from the need to estimate the noise variance in each Interscale layers.

• A method for reducing the granularity based on the nonlinear diffusion filtering of bandpass ultrasound images in the field of Laplace pyramid has been proposed that effectively removes the speckle while preserving the edges and detailed specifications.

2.2.2.3 Contourlet Transform Method

The contourlet transform[15] (CT) is a multi-scale and multi-frame of discrete image. It is the simple directional extension for wavelets that fixed the problem of sub-band mixing and improves its directivity. The desirable properties of CT for image representation includes multi-resolution, which allows images to be estimated at a beautiful coarse way; location of the basis vectors in both space and frequency; low redundancy, so as not to increase the amount of data to be stored; directivity, allowing representation of the basic elements oriented in many directions; and anisotropy, the ability to capture images with smooth contours, using building blocks that are to a variety of elongated shapes having aspect ratios.

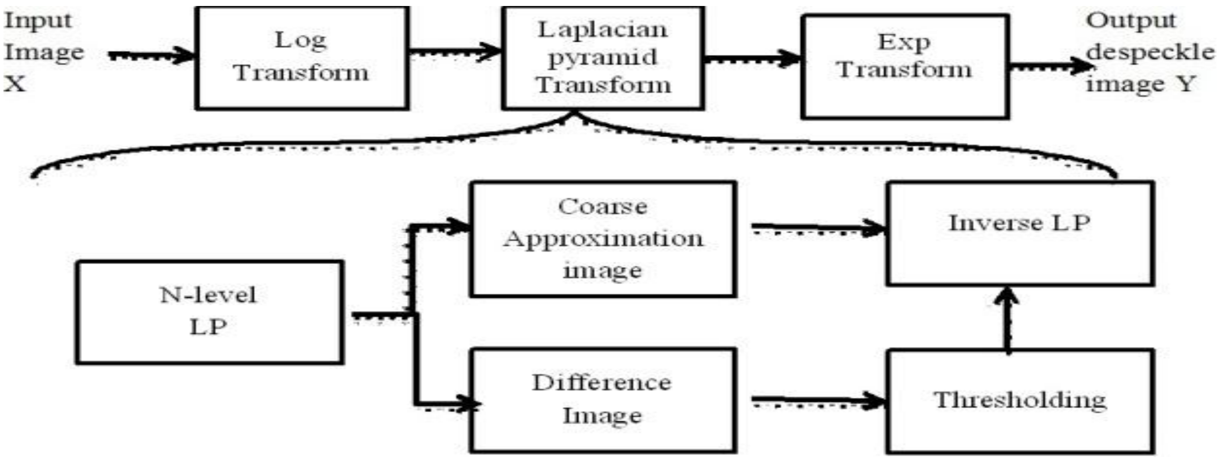

Figure 1: Schematic diagram of the speckle noise suppression using the Laplace transform pyramid

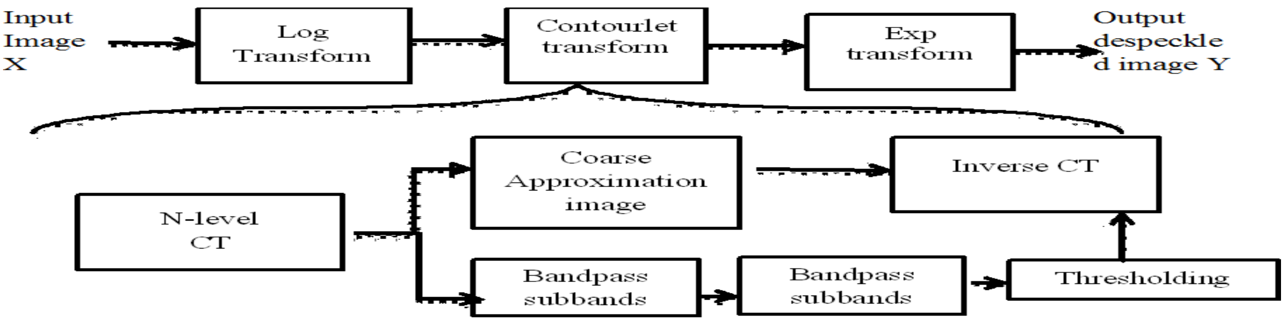

Figure 2: The general model for speckle reduction using contourlet transform.

3. CONCLUSION

The existence of speckle noise in the ultrasound image is undesirable since it disgrace image quality by affecting edges and local details between heterogeneous organs which are the most interesting part for diagnostics. As we have studied that there are two types of speckle reduction spatial techniques i.e. single scale and multiscale. In single scale, we have seen different types of linear filter such as lee filter, Kaun filter, frost filter, Weiner filter, and nonlinear filters such as SRAD filter. In multiscale spatial filtering, we mainly focus on denoising based on wavelet filtering in which wavelet coefficient is most important criteria to preserve edges while denoising. This is very helpful to assist radiologists in their quest and diagnostic. Future work will include real time speckle reduction and 3D ultrasound images denoising.

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