Speckle Reduction By Anisotropic Diffusion Comparative study.

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Abstract—

Speckle noise is the inherent property of ultrasound B scan image; this paper is focus on Comparative study of the speckle removal by means of anisotropic diffusion, problem of speckle removal, and the importance of the correct estimation of the statistics involved First, we derive speckle removal filter in scalar value and matrix value diffusion function filter they are classified as Anisotropic Diffusion (AD) filter and Speckle Reduction Anisotropic Diffusion (SRAD). Second the filter performance evaluation which is done by image quality and quantity matrices, analysis, performance metrics, execution time and visual inspection.

It is concluded that the optimal method is the OSRAD diffusion filter. This method is capable of strong speckle suppression, increasing the average SNRA of the simulated images by a factor of two. This method also shows favorable edge preservation and contrast improvement

I. INTRODUCTION

In an ultrasound system a target medium is interrogates with acoustic pulses, and the medium’s non-uniform density and compressibility result in returned echoes. Each ultrasound pulse encompasses a spatial volume which defines the smallest detectable structure, known as the resolution cell. Two distinct processes contribute to echo formation they are reflection and scattering. If the interaction between the sound waves and objects is larger than the pulse wavelength speckle noise is introduce [1]. The overlapping scattering echoes experience interference giving rise to a granular artifact known as speckle

\[ s(x,y)=f(x,y)h_m(x,y)+h_a(x,y) \quad (1) \]

where \( f(x,y) \) is noise free image recovered , \( s(x,y) \) is noisy image \( h_m(x,y) \) is multiplicative noise and \( h_a(x,y) \) is adaptive noise, a large number of speckle reduction methods are available which compare a wide variety of these methods on a common set of test data. The main contribution of this paper is the study of a large number of these filters
The organization of the paper is as follows. Section II the Anisotropic Diffusion filters are describe in discretization scheme which are classified into scalar value and matrix value diffusion function, Section III describes the filter performance evaluation which is done by image quality and quantity matrices and analysis, performance metrics, execution time and visual inspection, and Section IV concludes the paper.

II. ANISOTROPIC DIFFUSION

A. Perona and Malik Anisotropic Diffusion (PMAD)

Anisotropic diffusion, developed by Perona and Malik [2], is a method of selectively smoothing an image while preserving edges. The detection is done by canny detector, the following partial differential equation (PDE):

$$\frac{\partial I(x, y; t)}{\partial t} = \nabla \cdot \left[ c(|\Delta I(x,y;t)| \cdot \nabla I(x,y;t)) \right]$$

(2)

where $I(x, y; t)$ is the image under diffusion, $t$ is an artificial time dimension representing the progress of diffusion, $I_0$ is the observed image, $\nabla$ and $\nabla \cdot ()$ are the gradient and divergence operators, and $|$ represents magnitude. In edge detection discretization scheme which is perform on square lattice with four nearest neighbor discretization of the Laplacian operator [2]. The conduction coefficients are updated after every iteration as a function of the brightness gradient. The conduction coefficients is zero at boundaries of image and it act as Anisotropic Diffusion and when conduction coefficients is constant at boundaries of image and it act as Gaussian blurring (Canny Detector) as shoen in fig.1 and fig. 2

B. Speckle Reducing Anisotropic Diffusion (SRAD)

Speckle Reducing Anisotropic Diffusion (SRAD) is the Edge sensitive diffusion for speckled images, SRAD is better to speckle noise removal, SRAD use same PDF of PMAD. The conduction coefficient $C(.)$ in PMAD is now Instantaneous Coefficient of Variation (ICOV) [3] and it is denoted as $q$, the ICOV is given as ratio of local standard deviation to the mean,

$$q(x,y;t) = \frac{\text{std} [I(x,y;t)]}{I(x,y;t)}$$

(3)

The value of ICOV is calculated using nearest four neighbor window, SRAD is Edge sensitive diffusion method for speckle image and it is advanced in Mean preservation, Variance Reduction and Edge localization.
The ICOV combine with Normalize Gradient Magnitude operator and Normalize Laplacian operator and it is act like edge detector, at center of edge Laplacian term undergoes zero crossing and gradient term dominate. It can detect edge in bright and dark region.

C. Oriented Speckle Reducing Anisotropic Diffusion (OSRAD)

Oriented Speckle Reducing Anisotropic Diffusion (OSRAD) is extended Speckle reducing anisotropic diffusion method with matrix diffusion equation, OSRAD allow a directional filtering in the gradient and the principal curvature directions. It is also find that a theoretical link between the local directional variance of the image intensity in the principal curvature directions and their associated curvatures [4].
OSRAD use logarithmic compression but before using logarithmic compression it reduce the noise in the region of fully formed speckle, this speckle is statically model by

\[ (a) \]

![Fig. 2 Edge detected using (a) anisotropic diffusion (b) Gaussian smoothing (canny detector)](image)

Rician distribution. The Rician distribution can be approximated by Gaussian distribution [4].

Speckle reduction proposed to reduce the speckle effect in synthetic aperture radar (SAR) image and ultrasound image including the use of linear minimum mean square error (LMMSE), [5]-[6] and recent work use wavelets [7] and anisotropic diffusion. OSRAD has matrix anisotropic diffusion approach it add additional feature to the SRAD filter, to better restore of the image. The concept is to add to the SRAD filter a nonscalar component which can perform directional filtering of the image along the structures. While taking flux diffusion the directions of the gradient and principal curvature directions on a smoothed version of the image, it also use structure tensor [4].

OSRAD use new image restoration technique which include multiplicative model of the speckle noise in ultrasound image, it use small vessel structure [8], the OSRAD method perform over all three discretization scheme [4].
III. FILTER PERFORMANCE EVALUATION

In this section we applied five quality matrices to ultrasound clinical images, out of these three (FoM, SSIM, and edge MSE) are comparative in nature, considering two images. The CNR metric operates on a single image. To measure the change caused by filtering, the difference between the filtered and reference value is used and the SNRA metric is used to measure the decrease in speckle caused by filtering.

1) Pratt’s Figure of Merit (FoM): The figure of merit matrix is used to measure edge pixel displacement, the value of FoM is from 0 to 1. Unity represents perfect edge preservation.

2) Structural Similarity (SSIM): The Structural Similarity (SSIM) matrix is used to represent preservation of structural symmetry, the value of SSIM is from 0 to 1. Unity represents perfect structural identical image.

3) Edge Region MSE: The edge region MSE measure average difference between two images, MSE means mean square error. MSE measure average difference in edge region considering only pixel close to image edge.

4) Contrast-to-Noise Ratio (CNR): The CNR matrix quantifies the level of contrast between region of interest and background. The change in CNR calculate as CNR difference between filter and reference image.

5) SNRA: The SNRA matrix quantifies the level of speckle as ratio of mean to standard deviation of amplitude value. The value of SNRA is calculate using entire image and it measure decrees in speckle by filtering.

IV. CONCLUSION

This paper has presented the results of speckle reduction techniques for application to echocardiography. It may also be applicable to other clinical ultrasound applications. Out of which The OSRAD method is best suitable for clinical application, based on its performance on both simulated and clinical data, and also evaluation of its computational requirements is considered.

V. REFERENCES


