A Review on Speckle Noise Reduction in Ultrasound Images by Comparing Various Filters

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Abstract

Speckle noise is a different kind of noise which mostly occurs in coherence imaging system like ultrasound images, lasers, sonar, synthetic aperture of radar etc. So, in ultrasound images, the presence of speckle noise results in decrement of quality of an image and due this noise it becomes difficult for human and doctors to diagnose. So it cannot be possible to interpret the change with naked eyes. It also becomes hard to differentiate between speckle noise and clinical information because speckle noise behaves like information. So it is necessary to overcome this problem by reducing noise. Many numerical methods are proposed for filtering of speckle noise or speckle suppression. This paper presents a comparative review of various speckle reduction filters. These filters have different results and behaviour. Similarly some filters do better coherence, edge enhancement and segmentation etc. In the end, it provides some commonly used filtering techniques for de-noising.
Keywords: Speckle Noise, Ultrasound, Frost, Lee, Diffusion Tensor Anisotropic and Coherence

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I. INTRODUCTION

A noise occurrence is a major problem in bio-medical imaging technique. Each of these biomedical imaging devices is affected by different types of noise. For example, x-ray images corrupted by Poisson noise are very often but the ultrasound images are affected by the Speckle noise [1]. Speckle noise is in the form of black spots present in ultrasound images and mostly present in coherent images. Due to speckle noise presence it reduces the resolution of the ultrasound images mainly in images of low contrast .It may be difficult to explain automatic due to low SNR i.e (signal to noise ratio) in ultrasound images. This low SNR is mainly due to speckle noise present in the ultrasound image [2]. So it becomes necessary to de noising of ultrasound images. By using such technique of de noising with retaining the important features as it is [3]. It is one of the most widely used diagnostic tools in modern medical science. This technology is relatively cheap and portable, as when compared with other imaging techniques such as magnetic resonance imaging (MRI) and computed tomography (CT).It is a non-penetrating technique of imaging. It has no known long term side effects and rarely causes any discomfort to the patient [4]. It is a cheap and reliable technique. Many research work has been done to reduce the speckle noise in ultrasound images in past few years. Temporal averaging is the first technique with the help of which speckle noise in ultrasound images was reduced. Averaging of same scene multiple uncorrelated frames are to be done to reduce the noise effect in this technique. This temporal technique is very fast and simple, but it generate blurry image and some of the details are lost [2].There is an another filter also that has been proposed for speckle reduction, it uses the weights of surrounding pixels and the filter has been named as AWMF ie Adaptive Weighted Median Filter. In AWMF filter weighted median filter is used for suppressing the speckle noise presents in imaging system and this technique based on the variable weight coefficient around every pixel. ASSF i.e Adaptive Speckle Suppression has been proposed after AWMF filter. ASSF filter is also uses the same local statistics of ultrasound images. So every filter has some limitations. The optimized work is based on using diffusion anisotropic filter.

II. DIFFUSION TENSOR

Diffusion Tensor Imaging (DTI) has evolved into a primary technique for non-invasive characterization of the structure and architecture of living tissue [5]. In order to describe local variations structures presents in the image and to provide a fairly robust anisotropic diffusion, we use the diffusion tensor [6]. Such characterizations based on the Eigen parameters of the diffusion tensors measured, which includes assessment of tissue structural integrity by differences in the Eigen values and examination of architectural features by directions of the Eigen-vectors [5]. The tensor can be constructed in two ways, as a coherence-enhancing diffusion (CED) [6] or as edge-enhancing diffusion (EED). Recently the CED and EED algorithms were combined in hybrid diffusion filter with a continuous switch (HDCS). The diffusion tensor filtering equation is described by:

$$\frac{\delta u}{\delta t} = \nabla.(D\nabla_u) \quad \text{………..(1)}$$

III. NON LINEAR ANISOTROPIC FILTERS

To enhance flow-like structures in scalar images, Weickert proposed an anisotropic diffusion filtering technique that smooths images by using partial differential equation [6]. Linear diffusion equals Gaussian filtering in which the diffusion time controls the smoothing scale. For the preservation of the edges Perona-Malik introduced regularized non-linear diffusion (RPM) technique. Anisotropic diffusion filters can be used to surpass isotropic ones with the help of certain applications such as de-noising. De-noising is done for the highly degraded edges or enhancing coherent flow like images by using closing interrupted one-dimensional structure of the images [7]. Nonlinear anisotropic filter has most advantages as compare to linear filter. Most implementations in using nonlinear diffusion filters are based on finite difference methods, so they are easy to handle and the pixel structure of digital images already provides a natural a fixed rectangular grid based on natural discrete.

IV. SPECKLE NOISE REDUCTION USING VARIOUS FILTERS

For speckle noise reduction many kind of filters are to be used in case of ultrasound images. Each filter has different technique of filtering and de noising the speckle noise from ultrasound images. In this paper, some popular filters are to be discussed for the review of different filters. Every filter de-noised the noisy images on the bases of different parameters like PSNR, SNR, MSE, SSIM etc. In this paper, filters discussed are Frost, Lee, kuan and weiner filters.

A. *Frost Filter*

Frost filter is a special kind of filter. The filtering technique of such filter based on multiplicative noise order and it is a spatial domain adaptive filter. This filter is used for reducing speckle noise in the radar images while preserving the texture of information. The major limitation of frost filter is that the parameters are regulated according to variance in each area [8][10]. Smoothing will be occurs if variance is low. As the value of the variance increases, it affects the smoothing of filter. Filter’s response is represented given below:-

$$R_{(X,Y)} = \left(\frac{\sum P_n * M_n}{\sum M_n} \right) \quad \text{………….. (2)}$$

Where,

$$M_n = \exp\left(-D * \left(\frac{\delta_n}{\mu_n} \right)^2 * T \right) \quad \text{………….. (3)}$$

- $P_n$is the image pixels.
- D is the damping factor, and it is mostly equal to 1.
- F_n is the standard deviation of the filter window.
- n is mean value
- T is the absolute value of the pixel distance between its surrounding pixels and the centre pixel.

B. *Lee and Kuan Filters*

Lee filter is based on multiple-look processing. The technique used in Lee filter is window based approach and depends upon the variance. Lee filters are better at preserving image sharpness and the details while it suppresses noise from the image [10]. But Lee filter has also a major drawback that it ignores the speckle noise in the closest areas of lines and edges also. So it has limited area for its-use and applications.

Kuan Filter is better than Lee filter [9]. In this filter additive linear form is obtained from multiplicative noise model. However, its value of W i.e; weighting function and is similar to Lee filter in functionality. The formula equation for Lee and Kuan has been proposed below:

$$R_{(X,Y)} = \left(1 - W_{(X,Y)}\right) I_{(X,Y)} + W_{(X,Y)} I_{(X,Y)} \quad \text{…………….(4)}$$

Where

$I_{(X,Y)}$ is the intensity’s mean value within the filter window and W(x,y) is the adaptive filter coefficient determined using:

$$W_{(X,Y)} = \left\{ 1 - \frac{C_b^2}{C_1^2 + C_b^2} \right\}$$ for LEE filter ………………. (5)

$$W_{(X,Y)} = \left\{ \frac{1 - \frac{C_b^2}{C_1^2}}{1 + C_b^2} \right\}$$ for Kuan filter …………………(6)

where, Ci is the variation coefficient of the contaminated image and Cb is the variation coefficient of the noise. So the kuan and lee filters are both similar filters but the value of weighting function is different for each one and equation for such filters are given.

C. *Weiner Filter*

Weiner filter is based on the technique of LTI (linear time invariant) filtering technique. This filter is used to help in the generation of approximation of the required random process by using LTI. This filter reduces the mean square error between the required process and the estimated random process [12, 13]. Local image variance is given by the following expression:

$$f(u,v) = \left[\frac{H(u,v)}{H(u,v)^2 + \left[S_n(u,v) / Sf(u,v) \right]} \right]$$ …………….(7)

where, H(u,v) is the degradation function and H(u,v)* is its complex conjugate. Sf(u,v) is power spectra of original image and Sn(u,v) is power spectra of noisy images.

V. CONCLUSION

In this paper, a review of different filtering methods are done and on the basis of this review, we can conclude that every filter can be based on different filtering technique for de-noisingth image, in which some filters has better results but have some limitations also. Signal to noise ratio is less for low contrast images. This paper also gives an insight about future work. The next work can be de-nosing speckle noise of different ultrasound images based on real data set calculation of PSNR, SNR, SSIM also.

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