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Speckle Noise Reduction in Fetal Ultrasound Image Using Various Filtering Techniques

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Abstract**—** Ultrasound imaging is widely used in medical diagnosis, because of its non invasive nature, low cost, capability of forming real time imaging and continued improvement in image quality. The main drawback during diagnosis is the distortion of visual signals. These distortions are termed as speckle noise, which makes the image unclear and make diagnostic more difficult. Many denoising techniques are proposed for effective suppression of speckle noise. In this paper three adaptive filters are used and we have compared and evaluated the performance of famous filters for speckle noise reduction in fetal ultrasound image.

Keywords**—** ultrasound images, speckle, PSNR, MSE, MAE.

I. INTRODUCTION

Ultrasonography is one of the most powerful techniques for imaging organs and soft tissue structures in human body. It is preferred over other medical imaging methods because of its non-invasive, low cost, accurate, capability of forming real time images, harmless to human beings and continuing improvement in image quality and portable properties. These images are contaminated with multiplicative noise referred to as "speckle noise" which is one of the main sources of image quality degradation. Moreover in these images, the speckle noise has a spatial correlation length on each axis which is the same as resolution cell size. The spatial correlation makes the speckle noise suppression a very difficult and delicate task, hence, a trade-off has to be made between the degree of speckle suppression and feature preservation[1].

Speckle significantly degrades the image quality and therefore, makes it more difficult for the observer to discriminate fine details of the image in diagnostic examinations[2]. It causes greater degradation within bright areas of an image than in dark areas. Thus image denoising has become the predominant step in medical image processing. The purpose of image denoising is to estimate the original image form the noisy data. Image denoising still remains a challenge for researchers because denoising introduces artifacts and causes blurring of the images. Filtering techniques is one of the common methods which are used to reduce the speckle noises as preface action before segmentation and classification processes[3]. This paper focuses on speckle noise reduction techniques in fetal ultrasound images using different filtering techniques.

A. Speckle Noise in Ultrasound Images

Today, US imaging is one of the most common tool used for diagnosis over the other imaging modalities like Positron emission tomography (PET), Magnetic Resonance imaging (MRI) and Computed tomography (CT) due to its low cost and availability. Speckle noise[4] is the characteristic effect seen in US images that affects the visual quality, as these are low resolution images which are constructed by using reflection of ultrasound waves. However, speckle noise as shown in Figure 1, is significant in ultrasound images and it might cause negative impact on post-processing steps such as image segmentation and image compression.

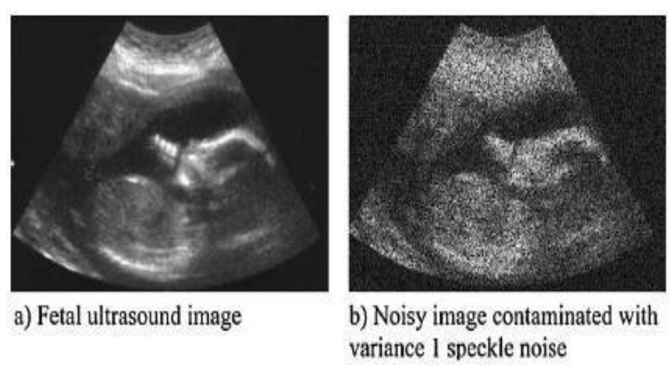

Fig.1. Comparison between Fetal Ultrasound Image with a Fetal Ultrasound Image Degraded by Speckle Noise

II. SPECKLE NOISE MODEL

Speckle is a multiplicative noise having granular patterns. To understand the speckle noise properties and its despeckling

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techniques researchers have been developing mathematical models[5][6]. In this study, a general model for speckle noise is given by [7] has been adopted as such and is given in equation (1).

$$S(x,y) = f(x,y)\eta_m(x,y) + \eta_a(x,y) \quad (1)$$

Where *S(x,y)* is the noisy image, $\eta_m(x,y)$ and $\eta_a(x,y)$ are multiplicative and additive noises respectively, and *f(x,y)* is the noise free image to be recovered. For any speckle, the contrast ratio (ξ) is defined as

$$\xi = \frac{\text{Standard Deviation of I}}{\text{Mean value of I}} \quad (2)$$

where I is the intensity field.

III. SPECKLE FILTERING

There are different kinds of noise that appears in images. Noise may occur due to various factors such as while acquiring images, capturing images, transforming images, compressing images etc. Noise may have different types, and hence it is necessary to provide different denoising techniques according to the type of noise. Speckle noise contains high frequency components due to temporal movement of organs such as brain, heart etc. So it's necessary to provide low pass filter to remove the high frequency noise. To remove speckle noise from images still now many filters are used [8]. Some filters are good in visual interpretation where as some are good in smoothing capabilities and noise reduction. Some examples of such filters are Mean, Median, Lee, Kuan, Frost, Enhanced Frost, Enhanced Lee, Wiener and Gamma MAP filters[9]. Some of these use window technique to remove speckle noise, known as kernel [10]. The window size can range from 3-by-3 to 33-by- 33 but it must be odd. To achieve better result the window size should be smaller.

A. Frost Filter:

It was developed by Frost in 1982, it is a linear, convolutional filter used to remove the multiplicative noise from images. As compared to mean and median filters it is adaptive nature and also it is an exponentially weighted averaging filter. It works on the basis of coefficient of variation which is the ratio of local standard deviation to the local mean of the corrupted image. Within the kernel size of n-by-n, the centre pixel value is replaced by weighted sum of values of the neighbourhood in kernel. The weighting factor decrease as we tend to go away from interested pixel and increase with variance. It assumes multiplicative noise. Frost filter follows formula given by equation (3).

$$DN = \sum_{n \times n} K\alpha e^{-\alpha|t|} \quad (3)$$

Where,

$$\alpha = \left(\frac{4}{n\overline{\sigma^2}}\right)\left(\frac{\sigma^2}{\overline{I^2}}\right),$$

K = Normalized constant

$\bar{I}$ = Local Mean

σ = Local variance

$\bar{\sigma}$ = Image coefficient of variation value

$|t| = |X - X_0| + |Y - Y_0|$

n = moving kernel size

B. Lee Filter:

It is developed by Jong Sen Lee[11]. It is better than other filters in edge preservation which is based on multiplicative speckle model and uses local statistics to preserve details. This filter works on the basis of variance, i.e. if variance of the area is low then it performs smoothing operation, however not for high variance. That means it will preserve details in low as well as in high contrast hence it has adaptive nature. Mathematical model for Lee filter is given in equation (4).

$$Img(i,j) = Im + W^*(Cp - Im) \quad (4)$$

Where,

Img – pixel value after filtering

Im – mean intensity of filter window

Cp – Centre pixel

W – filter window, $W = \sigma^2(\sigma^2 + \rho^2)$

σ^2 is the variance of the pixel and it is calculated as

$$\sigma^2 = \frac{1}{N}\left[\sum_{j-0}^{N-1}(X_j)^2\right]$$

N = size of filter window, X_j = pixel value at j

ρ = additive noise variance for M size of image and Y_j value of each pixel is given as

$$\rho^2 = \frac{1}{N}\left[\sum_{j-0}^{N-1}(Y_j)^2\right]$$

For no smoothing filter output is the only mean intensity value (Im).

C. Kaun Filter:

It was developed by Kaun, Nathan and Kurlander in 1987. It is a local linear minimum mean square error filter under multiplicative noise. It is more advanced than Lee filter in a factor as it has no approximation involved. It transforms the multiplicative speckle model into the additive linear form[12]. Weighted function W for Kuan filter is given by equation (5).

$$W = \frac{\left(1 - \frac{Cu}{Ci}\right)}{1 + Cu} \quad (5)$$

Where,

Cu = estimated noise variation coefficient.

$Cu = \sqrt{\frac{1}{ENL}}$, ENL = equivalent noise looks.

Ci = variation coefficient of image.

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$$Ci = {}^{S}/_{Im}$$

S = Standard deviation of Im.

IV. PERFORMANCE ANALYSIS PARAMETER

To analyze the speckle reduction methods various performance parameters are used and compared such as Peak Signal-to-Noise Ratio (PSNR), Mean Square Error (MSE), and Mean Absolute Error (MAE).

A. Peak Signal to Noise Ratio (PSNR)

PSNR is defined from RMSE. It is the ratio between the original and a denoised image. The higher PSNR the better is the quality of the compressed or reconstructed image. For 256 gray levels, PSNR is defined as (6)[13]

$$\mathrm{PSNR} = 10\log_{10}\frac{255^2}{\mathrm{MSE}} \tag{6}$$

B. Mean Square Error (MSE)

It is the mean squared difference between the original image and the degraded image, MSE is defined as (7)[14]

$$\mathrm{MSE} = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}[f(x,y) - f'(x,y)]^2 \tag{7}$$

C. Mean Absolute Error (MAE)

It is the mean absolute error between two images being compared. MAE is defined as (8)[15]

$$\mathrm{MAE}(I_{filt}, I_{ref}) = \frac{1}{XY}\sum_{i=1}^{Y}\sum_{j=1}^{X}|I_{filt}(i,j) - I_{ref}(i,j)| \tag{8}$$

Where, I_{filt}, I_{ref} are filtered and original image of size (X×Y)

V. RESULTS AND DISCUSSIONS

In this project three spatial filters Frost, Lee, and Kaun are used to remove speckle noise from an ultrasound fetus image. For analysis, speckle noise were added and the performance was analyzed based on Peak Signal to Ratio (PSNR), Mean Absolute error (MAE) and Mean Squared Error (MSE). The response of Frost filter was appreciable than other filters.

Fig. 2. Original Image

Fig. 3. Frost Filter

Fig. 4. Kaun Filter

Fig. 5. Lee Filter

Figure 2 shows the original image, Figure 3 to 5 shows the filtered output obtained using Frost Filter, Kaun Filter, Lee Filter.

Table 1. SHOWS THE PERFORMANCE ANALYSIS PARAMETERS OF FILTERS USED

Filter	PSNR	MAE	MSE
Kaun	16.576	18.771	733.607
Lee	18.578	18.541	776.402
Frost	20.653	18.376	714.17

The above table shows the performance comparison of the three filters. It shows that Frost filter has marginally higher PSNR value and a good MSE compared to the other two filters.

VI. CONCLUSION

The performance of denoising algorithms is measured using quantitative performance measures such as PSNR, MAE and MSE as well as in term of visual quality of the images. Many of the methods fail to remove speckle noise present in the ultrasound medical images, since the information about the variance of the noise shall not be identified by the methods. Performance of three filters is tested with ultrasound fetal image, computational results shows that Frost filter performed better than other two filters.

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