Speckle Noise Reduction in Ultrasound Images: Performance Analysis and Comparison

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***Abstract*--- In digital image processing image is corrupted by various types of noise. But medical image is usually corrupted by speckle noise. So image de-noising is very essential exercise of diagnose. We compare different filter for de-noising the noise from the image. The speckle noise is multiplicative noise, which is difficult to remove. However, there are various filters available which can remove multiplicative noise. We compare our results for mean filter, median filter, Gaussian filter and bilateral filter. Mean filter and median filter are general filter which can be used for the reduction of any type of noise. Gaussian filter is basically used for Gaussian noise but here for comparison purpose we use this filter. Bilateral filter is non linear filter that preserves edges and use to remove additive noise. So, we use this filter using homomorphic approach. Bilateral filter has been shown work well than other smoothing filters like mean, median and Gaussian filters.**

Keywords: Bilateral filter, Ultrasound images, speckle, median, mean

I. INTRODUCTION

Speckle phenomena affect all coherent imaging systems including systems using laser, SAR and medical imaging techniques. Visual information plays an important role in almost all areas of our life. Today, much of this information is represented and processed digitally [7]. Noise is the undesired information that degrades the image.There is different sources of noise that may contaminate any digital image and degrade the quality. The overall noise characteristics in an image depends on many factors, namely type of sensor, pixel dimensions, temperature, exposure time, and speed of the sensor Image de-noising refers to the recovery of a digital image that has been contaminated by noise. Image de-noising is used to remove the noise while retaining the important signal features. The purpose of image de-noising is to estimate the original image from the noisy data. Low image quality is an obstacle for an effective feature extraction, analysis, recognition and quantitative measurements. Therefore, there is a fundamental need of noise reduction from medical images.

Ultrasound imaging is widely used in the field of medicine. It is used for imaging soft tissues in organs like liver, kidney, spleen, heart, brain etc. Ultrasound images are inexpensive, harmless to human body. Ultrasound images are also suffered from one noise that is speckle noise. Speckle noise is one of the major sources of noise. Speckle noise is an inherent property of medical ultrasound imaging, and it generally tends to reduce the image resolution and contrast, thereby reducing the diagnostic value of this imaging modality [7]. Noise removal methods also remove some useful information from the image which makes the image unusable for feature extraction and analysis.

Noise can be additive and can be multiplicative. The additive noise refers to an unwanted signal that gets added into some relevant signal. Multiplicative noise refers to an unwanted signal that gets multiplied into some relevant signal during capture, transmission, or other processing. Multiplicative noise is difficult to remove as compared to additive noise [9]. Noise characteristics for ultrasound images are: Sensor type, Exposure time, Temperature, ISO sensor speed. Several methods have been proposed in the past for removing speckle noise from ultrasound imaging. In this paper a comparative analysis of the performance of various filtering methods for ultrasound image de-noising is presented. This paper is organized as follows. Section II describes the proposed method of comparative study. Section III introduces the image material. The results are illustrated in section IV. Finally section V concludes the paper.

II. METHODS

The speckle noise in an ultrasound image is generated by the fact that there are a number of elementary scatters within each resolution cell of the image that reflects the incident wave back towards the ultrasound sensor. The backscattered coherent waves with different phases undergo constructive and deconstructive interference in a random manner. The resulting image is corrupted by a random granular pattern, called speckle noise [9]. In proposed method, first speckle noise is added into ultrasound image and then an image is decomposed into its frequency components. In one dimensional signal and image shows that one approximation sub band and one detail sub band at each scale of the decomposition. There will be four sub bands for two dimensional images at each scale. The analysis and synthesis filter form a perfect reconstruction filter bank. Performance measurements in ultrasound images are Peak signal to noise ratio (PSNR). PSNR is computed as follows:-

$$PSNR = 10log_{10}\left[\frac{255\times255}{MSE}\right]$$

There are following filters used for image smoothing:

A. Mean filter

Mean filter is simple and smoothing filters. It replaces the pixel value by mean (average) of its neighbours. But the problem with this filter is it blurs the image, resolves simple noise and no detail of the image is preserved [1].

B. Median filter

To overcome the problem of mean filter we are using median filter. It is also image smoothing filter. It replaces the pixel value by median of its neighbours. The variance in neighbouring value does not influence mean. It sort values and find the middle one. It is good filter to remove strong noise but it preserves some details [1].

C. Bilateral filter

It is convolution filter. The idea underlying bilateral filtering is to do in the range of an image what traditional filters do in its domain. Two pixels can be close to one another, that is, they occupy nearby spatial location, or they can be similar to one another, that is, have nearby values, possibly in a perceptually meaningful fashion.The main reason of taking this filter is that it only smooth regions but does not smooth edges. Bilateral filter smooth image but preserve edges. It operates both in domain and range of the image. Bilateral filter gives better performance when we are taking log of it because it is use for additive noise [6]. The algorithmic idea of bilateral filter is it smooth as usual in the domain of the image e.g. Gaussian and it does not smooth when pixels are not similar e.g. edges.

The bilateral filter is defined as follows:-

$$\hat{X}[k,l] = \frac{\sum_{(i,j)\epsilon N\,(k,l)} w[k,l,i,j]y[i,j]}{\sum_{(i,j)\epsilon N\,(k,l)} w[k,l,i,j]}$$

Weight is computed as follows:-

$$w_{BL}[k,l,i,j] = exp\left\{-\frac{(y[k,l]-y[i,j])^2}{2\sigma_r^2}\right\}.f\left(\sqrt{(k-i)^2+(l-j)^2}\right)$$

Where, function f takes the geometric distance into account and it is monotonically non-increasing. If may take many forms, such as a Gaussian, a box function, a constant and more.

The domain and range parameters σ_d and σ_r control the Behavior of weights. The bilateral filter is used in the Proposed algorithm since it is non iterative and simple

D. Gaussian Filter

Gaussian filter is a filter whose impulse response is a Gaussian function. Gaussian filters are designed to give no overshoot to a step function input while minimizing the rise and fall time. This behavior is closely connected to the fact that the Gaussian filter has the minimum possible group delay. Mathematically, a Gaussian filter modifies the input image by convolution with a Gaussian function. The Gaussian smoothing operator is a 2-D convolution operator that is used to `blur' images and remove detail and noise.

MATERIALS

A. Images

We use two sets of images gathered from ultrasound image datasets. Since the size of speckle noise in these data is not known, in order to compare the results of de-noising by different methods, we use these data as reference data assuming they are clean and without speckle noise [8].

B. Noisy Images

In order to generate speckle noisy image, we apply the multiplicative speckle noise on the ultrasound image in which S is the noise-free ultrasound image and η is uniformly distributed random noise with mean 0 and variance υ.Speckle Noise is represented as below:-

I=S*N

IV. EXPERIMENTAL RESULTS

In experimental results the performance of bilateral filter comes superior to other smoothing filters. I have taken first logarithmic of bilateral then apply bilateral filter on it.

TABLE I.
Comparison of Standard Deviations of Different De-noising Filters for Test T1 Image Corrupted by Speckle Noise

	PSNR			
Standard deviation	***Mean Filter***	***Median Filter***	***Gaussian Filter***	***Bilateral Filter***
0.1	33.3949	32.9770	32.0695	36.8698
0.2	32.1375	30.5043	29.1969	36.2290
0.3	31.1214	28.8700	27.4840	35.1675
0.4	30.3741	27.7596	26.2635	34.0217
0.5	29.6233	26.7771	25.2759	32.6687
0.6	29.0475	26.0266	24.4933	31.3493
0.7	28.5758	25.4490	23.8561	30.1980
0.8	28.0192	24.7858	23.2509	28.9490
0.9	27.7307	24.4032	22.7905	27.9685

Fig. 1 Comparison of different filters

In the above table there is different filters used for taking PSNR values of standard variance from .01 to .09.From this table bilateral filter shows better results and performance.By taking variance .03,.04…..09 PSNR values are coming lower and shows effect on image detail.

Fig. (1) Original Ultrasound image

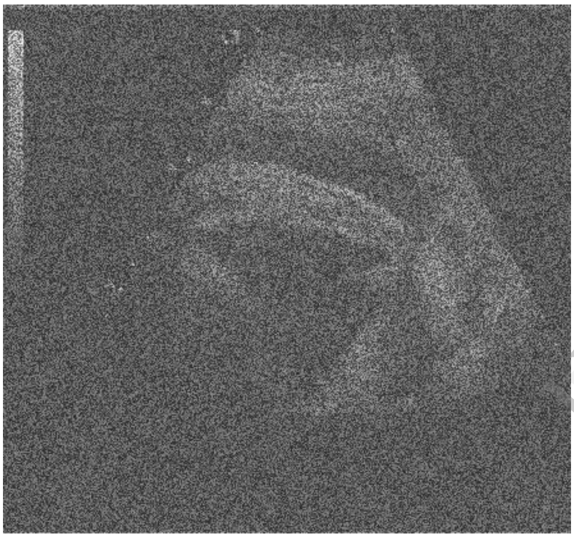

Fig.(2) Noisy image with variance 0.01

Fig.(3) Mean Filter with variance 0.01 on test image T1

Fig. (4) Median Filter with variance 0.01 on test image T1

Fig.(5) Gaussian Filter with variance 0.01 on test image T1

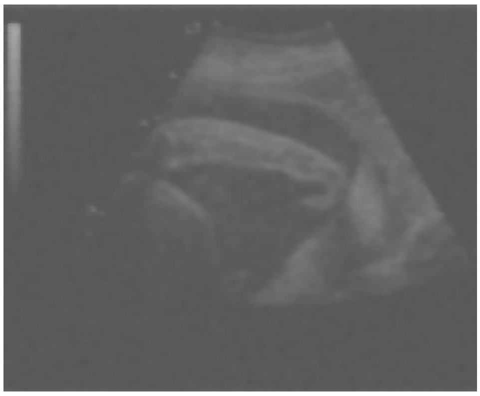

Fig.(6) Bilateral Filter with variance 0.01 on test image T1

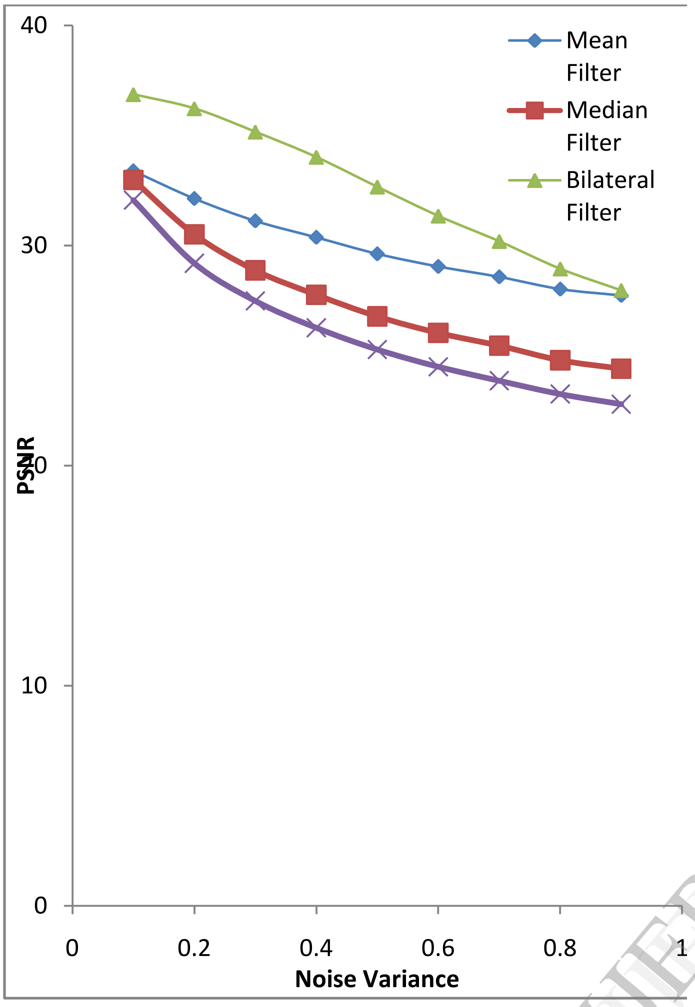

Fig.(7) Graphical comparison of different filters

V. CONCLUSION

In this paper, we experimented various methods for speckle noise reduction like Mean, Median, Gaussian and Bilateral filtering methods and seen that speckle noise reduced as shown in results above. The technique of de-speckling is used as to convert multiplicative noise into additive noise. So this we propose work a de-speckling method using bilateral filter in ultrasound images to reduce speckle and this is used for reducing additive noise. To provide better performance of bilateral filter we are taking logarithmic of it. The different performance analyses are experimented on ultrasound images with filtering methods. The performance analyses are calculated by PSNR values. The results show that bilateral filter gives better results and performance than others filter. So the future work is to get more optimum result with bilateral filter for reducing speckle noise by preserving edges and getting more useful information of ultrasound images.

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