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Comparative Analysis of Saptial Filtering Techniques in Ultrasound Images

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***Abstract*-This paper gives the knowledge about the various filter techniques applied in the speckle noise removal from ultrasound fetal images. In many despeckling filters available in speckle reduction, some are best suited in ultrasound speckle noise images. The despeckle image evaluation quality measurements RMSE AND PSNR are compared to the ultrasound images in despeckling for the spatial domain filter.**

Keywords- Speckle Noise, Spatial Filters, Ultrasound Fetal Images

I. Introduction

The common characteristics of the medical images like as unknown noise, poor image contrast, in homogeneity, weak boundaries and unrelated parts will affect the content of the medical images. This problem rectified by pre-processing techniques. The pre-processing are fundamental steps in the medical image processing to produce better image quality for segmentation and feature extractions. The pre-processing steps deal with image enhancement, noise and special mark removal.

II. Preprocessing Steps

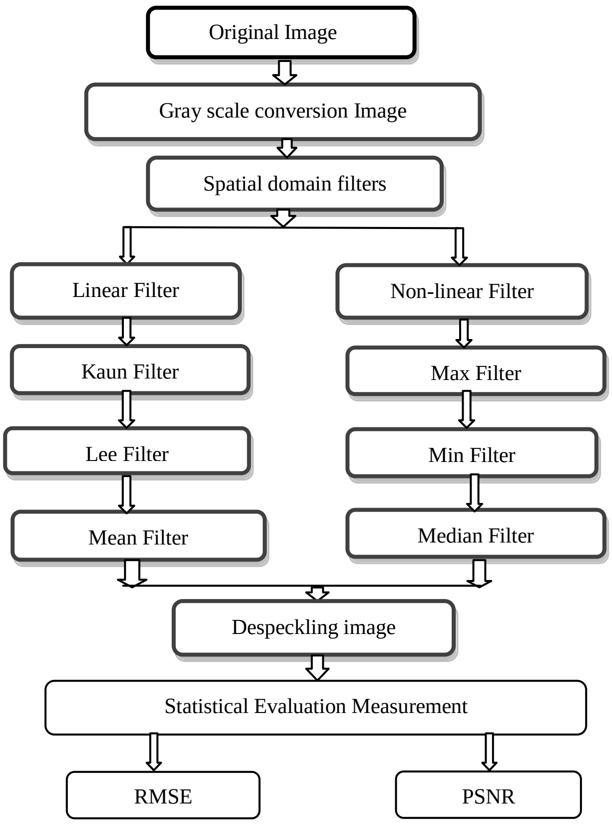

Figure 1. Flow of Pre-Processing Steps

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III. SPECKLE NOISE

Ultrasound machine uses high frequency sound waves to acquire pictures. The coherent nature of ultrasound imaging, results in the formation of a multiplicative noise called speckle noise. Speckle noise appears as a granular pattern which varies depending upon the type of biological tissue. The interference of backscattered signals result in speckle noise and its apparent resolution is beyond the functionalities of the imaging system. Noise content is usually stronger than the microstructure of tissue parenchyma and reduces the visibility and masks the tissue under investigation [1].

IV. NEED FOR FILTERING

Therefore, the main challenge in despeckling is to filter the noise content without affecting the microstructures and edges. Speckle is a form of multiplicative noise that affects the quality of ultrasound images. In ultrasound imaging the tissue under examination is a sound absorbing medium containing scatters. The inhomogeneity of the tissue and the small size of image detail than the wavelength of the ultrasound results in the scattering of signals and lead to the formation of a granular pattern called speckle noise. Better image quality helps in easy and accurate diagnostic decision making. The widespread use of ultrasound imaging necessitates the need for developing despeckling filters for reducing noise [1].

1. Linear Filtering

Linear filtering using mean filter, Lee filter, and Kaun filters are discussed on in this chapter III. Further, the process image denoising is illustrated considering the implementations.

A. Mean Filter

A spatial mean filter in which all coefficients are equal is called a box filter. These types of filters are used for blurring and for noise reduction. The output of such a linear smoothing filter is simply the average of the pixels in the neighborhood of the pixel mask. By replacing the value of every pixel in an image by the average of the gray levels in the neighborhood of the filter mask, the process results in an image with reduced sharp transitions in gray levels [2] is given equation in (1).

$$\mathrm{f(x,y)} = \frac{1}{\mathrm{mn}}\sum \mathrm{(s,t)} \epsilon\, \mathrm{S_{XY}}\, \mathrm{g(s,t)} \tag{1}$$

Here, f(x,y)is the denoise image and g(s,t) is the original image.

B. Lee Filter

This lee based is based on the approach. It depends upon the variance. If variance over an area is low or constant then the smoothing will occurs. If the variance is high then the smoothing will not be performed. The lee filter assumes that speckle noise is multiplicative. Than the SAR image can be approximated by a linear model [2] given the equation in (2),

$$Y_{ij} = \bar{K} + W^{*}(C - \bar{K}) \tag{2}$$

Where, $\mathrm{Y_{ij}}$is the gray scale value of the pixel at (i, j) after filtering. If there is no smoothing, the filter will output, only the mean intensity value $\mathrm{\bar{K}}$of the kernel K, otherwise, the difference between the centre pixels C and $\mathrm{\bar{K}}$ is calculated and multiplied with a weighting function W given equation in (3).

$$W = \frac{\sigma_K^2}{(\sigma_K^2 - \sigma^2)} \tag{3}$$

and then summed with $\bar{K}$, where σ_K^2 is the variance of the pixel values within the kernel given equation in (4).

$$\sigma_K^2 = \frac{1}{M^2}\sum_{u,v=0}^{M-1}(K_{uv} - \bar{K}) \tag{4}$$

Where, M x M is the size of the kernel and K_{uv} is the pixel value within the kernel at indices u and v, $\bar{K}$ is the mean intensity value of kernel. The parameter σ^2 is the variance of the image X. The main disadvantage of Lee filter is that it tends to ignore speckle noise in the areas closest to edges and lines.

C. Kaun Filter

The Kuan filter is better than Lee filter it does not make an approximation on the noise variance within filter window. It just simplifies to convert the multiplicative noise model in to additive linear form. But it depends on the ENL from an image to determine a weighting function W gives in [2] an equation (5) to perform filtering.

$$W = \frac{(1 - \frac{C_u}{C_i})}{(1 + C_u)} \tag{5}$$

The weighting function is computed from noise variation coefficient of an image, Cu gives in equation (6),

$$C_u = \sqrt{1/ENL} \tag{6}$$

Where, ENL is the Equivalent No of Looks in equation (7).

$$ENL = \left(\frac{\bar{K}}{\sigma_k}\right) \quad (7)$$

The σ_k is the standard deviation of the kernel and $\bar{K}$ is the mean intensity valueof the kernel. The only disadvantage of the Kuan filter is that the ENL parameter needs to be computed.

D. Performance On Linear Filters

These filters are good for removing noise that is speckle noise nature. The Linear filters find applications where a small region in the image is concentrated. Besides, implementation of such filters is easy, fast, and cost effective. It can be observed from the output of the images that the filtered images are blurred.

The ultrasound fetal abnormal images are downloaded to the different website, and images have the size of 215 × 215. The image acquisition is the preprocessing step and it converts to the gray scale level normally, it is used a gray scale image of 256 grey levels, which means a high computational cost because all possible pixel pairs must be taken into account. The Linear filters are applying to the every image and its resultant images to the stored.

TABLE I. COMPARISON OF EVALUATION MEASURE IN LINEAR FILTER TECHNIQUES

FILTERS	EVALUATION MEASURES	KAUN FILTER	LEE FILTER	MEAN FILTER
IMAGE 1	***RMSE***	7.7802	5.8750	6.1652
	PSNR	30.311	32.7506	32.3318
IMAGE 2	***RMSE***	9.3343	6.9803	7.4129
	PSNR	28.7292	31.2533	30.7311
IMAGE 3	***RMSE***	5.4073	4.7833	4.7911
	PSNR	33.4713	34.5362	34.5221
IMAGE 4	***RMSE***	12.3216	7.3152	9.2786
	PSNR	26.3174	30.8463	28.7812
IMAGE 5	***RMSE***	9.2069	6.8873	7.2555
	PSNR	28.8485	31.3699	30.9125
IMAGE 6	***RMSE***	10.7824	10.3297	10.3573
	PSNR	27.4765	27.8491	27.8258
AVERAGE	***RMSE***	9.1388	7.0285	7.5434
	PSNR	29.1923	31.4342	30.8507

It is observed from the (Table 1) list of the images and its evaluation measurements. The Kaun, Lee, Mean filters are Linear speckle noise removal filter techniques. It is observed the Fig 2 is the overall performance of RMSE and PSNR values based on the comparison of different linear filter techniques. The Fig 3 is the resultant images for the different Linear filtering methods.

E. Comparison of Non Linear Filters

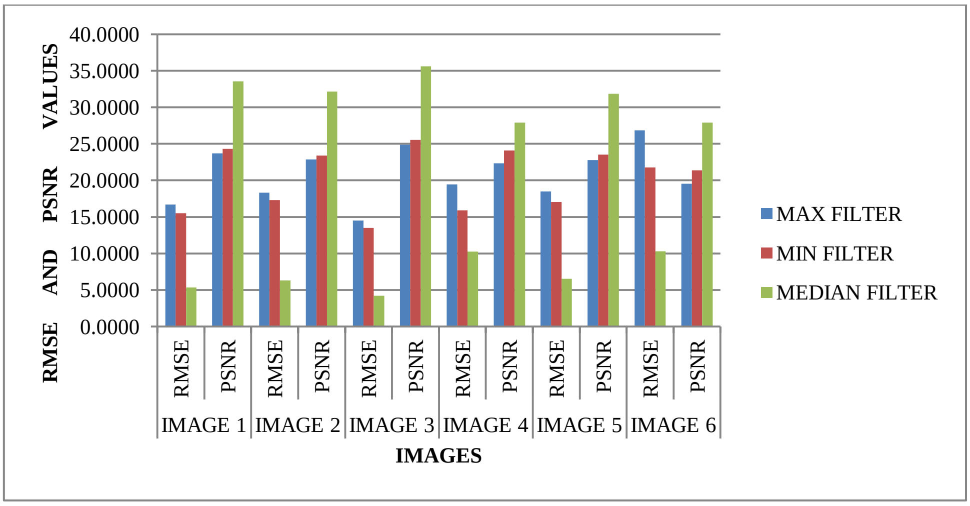

Figure 2. Overall Non Linear Filter Performances Based On Rmse And Psnr Values

F. Experimental results for non linear filters

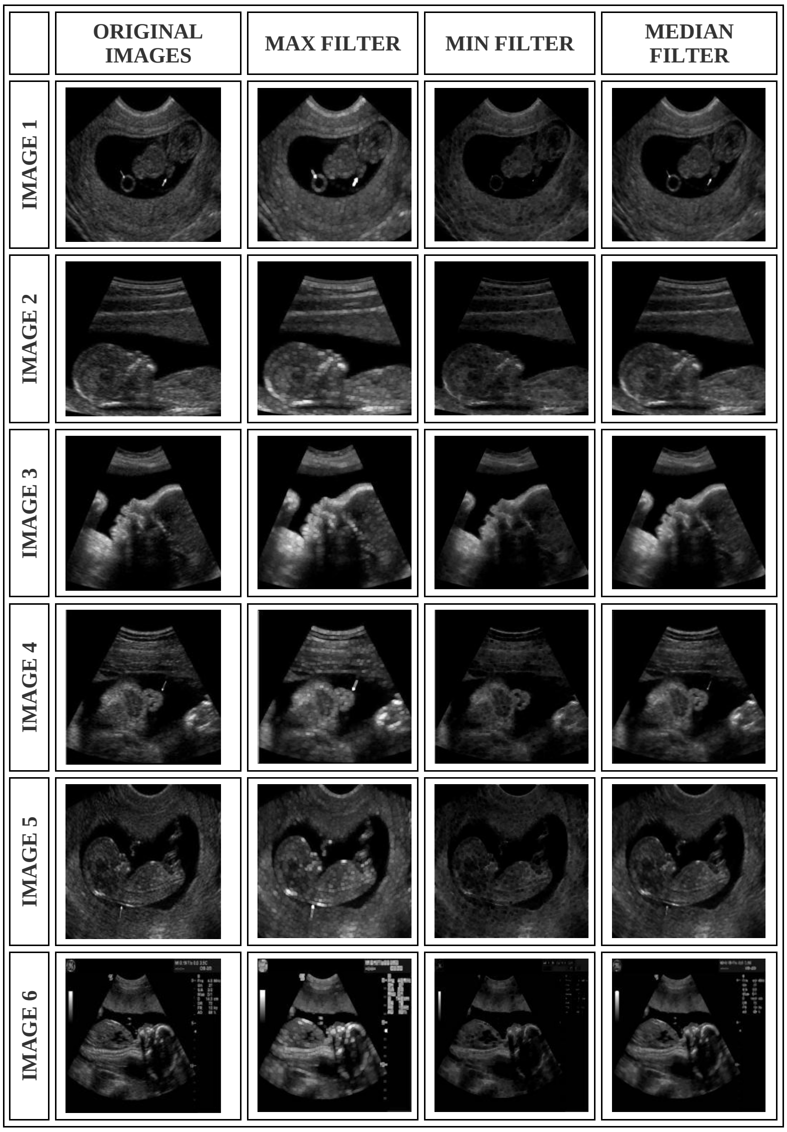

Figure 3. Resultant Images For Different Non Linear Filtering Methods

2. Non-Linear Filters

Non Linear filtering using Median filter, Max filter, and Min filter are discussed in this chapter. Further, the process image denoising is illustrated considering Matlab implementations.

A. Median Filter

Median filter is a Non-Linear filtering technique for speckle noise reduction. It works best with salt and pepper noise while retaining sharp edges in an image. This filter sorts the surrounding pixel values in the window to an orderly set and replaces the center pixel value with the middle value [3] in equation (8).

$$f(x,y) = median \sum (s,t) \epsilon S_{XY} \{g(s,t)\} \qquad (8)$$

Where Sxy represents the set of coordinates in a rectangular sub image window, centered at point (x, y), and Median represents the Median value of the window.

B. Max Filter

Max filter is located the brightest point in an image.it is a 100th percentile filter [3] in equation is, (9).

$$g(x,y) = max \{f(x+a, y+b) \qquad (9)$$

Here $g(x,y)$ is the denoise image and f(x+a, y+b) is the original image, and a, b values are ranges from -1, 0, +1.

C. Min Filter

Min filter is located the darkest point in an image. It is a 0th percentile filter [3] in equation is, (10).

$$g(\mathrm{x}, y) = min\{f(x + a, y + b)\} \tag{10}$$

Here $g(x, y)$ is the denoise image and f(x+a, y+b) is the original image, and a, b values are ranges from -1, 0, +1.

D. Comparison of nonlinear filter

It is observed from the (Table 2) list of the images and its evaluation measurements. The Max, Min, and Median filters are the nonlinear speckle noise removal techniques. It observed the Fig 4 is the overall performance of RMSE and PSNR values based on the comparison of different nonlinear filter techniques. The Fig 5 is the resultant images for the different nonlinear filtering methods.

TABLE II. COMPARISON OF EVALUATION MEASURE IN NON LINEAR FILTER TECHNIQUES

FILTERS	EVALUATION MEASURES	MAX FILTER	MIN FILTER	MEDIAN FILTER
IMAGE 1	*RMSE*	16.6797	15.5006	5.3509
	PSNR	23.687	24.3238	33.5621
IMAGE 2	*RMSE*	18.3125	17.2904	6.3050
	PSNR	22.8758	23.3747	32.137
IMAGE 3	*RMSE*	14.5005	13.4993	4.2279
	PSNR	24.9032	25.5246	35.6084
IMAGE 4	*RMSE*	19.4358	15.9046	10.2720
	PSNR	22.3587	24.1004	27.8977
IMAGE 5	*RMSE*	18.4828	17.0311	6.5249
	PSNR	22.7954	23.5059	31.8394
IMAGE 6	*RMSE*	26.8448	21.7844	10.2865
	PSNR	19.5536	21.3679	27.8854
AVERAGE	*RMSE*	19.0427	16.8351	7.1612
	PSNR	22.6956	23.6996	31.4883

E. Comparison Of Non Linear Filters

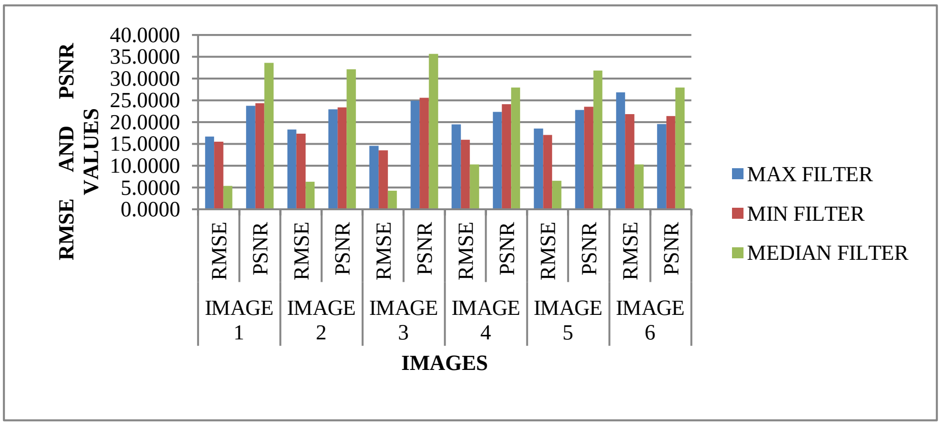

Figure 4. Overall Non Linear Filter Performances Based On Rmse And Psnr Values

F. *Experimental Results For Non Linear Filters*

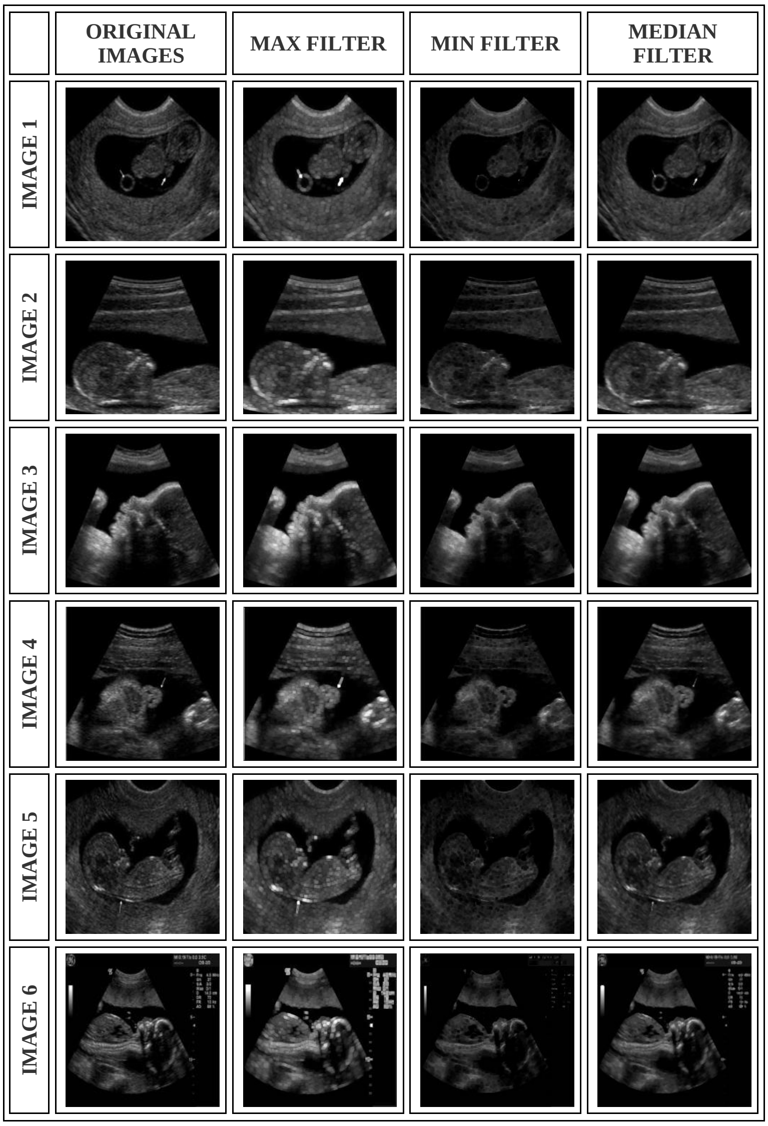

Figure 5. Resultant Images For Different Non Linear Filtering Methods

V. ENHANCEMENT AND RESULTS

A. *Estimation of Statistical Parameters*

The parameters which are used in estimation of performance are Root Mean Square Error (RMSE), and Peak Signal to Noise Ratio (PSNR).

B. *Estimation of RMSE*

The root-mean-square deviation (RMSD) or root-mean-square error (RMSE) is a frequently used measure of the differences between values predicted by a model or an estimator and the values actually observed. The RMSD of an estimator with respect to the estimated parameter is defined as the square root of the mean square error [3]. The formula is (11),

$$\mathrm{RMSE} = \sqrt{\frac{1}{\mathrm{MN}}\sum_{\mathrm{i}=1}^{\mathrm{M}}\sum_{\mathrm{j}=1}^{\mathrm{N}}(\mathrm{x}(\mathrm{i},\mathrm{j}) - \mathrm{x1}(\mathrm{i},\mathrm{j}))^2} \tag{11}$$

Here, $\mathbf{x}(\mathbf{i},\mathbf{j})$ is the original image, $\mathbf{x1}(\mathbf{i},\mathbf{j})$ is the denoise image.

C. *Estimation of PSNR*

It is an assessment parameter to measure the performance of the speckle noise removal method. The PSNR is higher for a good quality image and lower for a poor quality image [3] in equation (12),

$$\mathrm{PSNR} = 10\log_{10}\left(\frac{255*255}{\mathrm{MSE}}\right) \tag{12}$$

Here, *MSE (*Mean Square Error) is used to find the total amount of difference between two images The formula is (13),

$$\mathrm{MSE} = \frac{1}{\mathrm{MN}} \sum_{i=1}^{M} \sum_{j=1}^{N} (x(i,j) - x1(i,j))^2 \tag{13}$$

Here, $x(i,j)$ is the original image, $x1(i,j)$ is the denoise image.

D. Overall Linear And Non Linear Filters Performances

The enhancement preprocessing performs on the speckle noise removal for the ultrasound fetal images. The statistical evaluation measurements (Table 1 and Table 2) is calculated from the denoise images for the Linear and Non Linear filtering techniques. The Lee filter is the high PSNR value it is the best of the Linear despeckle filtering. The Max, Min, and Median are the non-linear filters have high RMSE values, and less PSNR values. The Median filter is the high PSNR value it is the best of the nonlinear despeckling filter. It observed the (Fig 6).is the overall performance for the Median filter is the best speckle noise removal filtering technique.

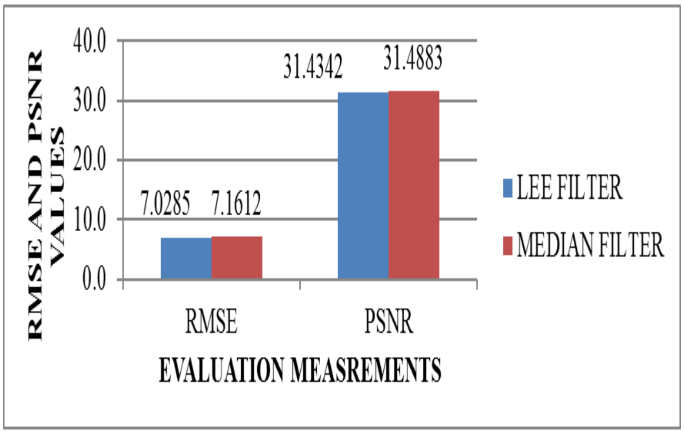

Figure 6. Overall Comparisons Of Lee And Median Filters

VI. Conclusion

This paper gives the knowledge about the various filter techniques applied in the speckle noise removal from ultrasound fetal images. In many despeckling filters available in speckle reduction, some are best suited in ultrasound speckle noise images. The despeckle image evaluation quality measurements RMSE and PSNR are compared to the ultrasound images in despeckling for the spatial domain filter. PSNR algorithm gives better performance than the other algorithm.

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