Comparative Analysis of Spatial Filtering Techniques in Ultrasound Images

K Mohan  
Research Scholar  
Department of computer science  
Periyar University, Salem-636 011  
Tamilnadu, India  
tvmjagan@gmail.com

I Laurence Aroquiaraj  
Assistant Professor  
Department of computer science  
Periyar University, Salem-636 011  
Tamilnadu, India  
laurence.raj@gmail.com

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, inhomogeneity, 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
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).

\[ f(x,y) = \frac{1}{mn} \sum_{s,t} S_{xy} g(s,t) \]  

(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),

\[ Y_{ij} = \bar{K} + W^\ast(C - \bar{K}) \]  

(2)

Where, \( Y_{ij} \)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 \( \bar{K} \)of the kernel \( K \), otherwise, the difference between the centre pixels \( C \) and \( \bar{K} \) is calculated and multiplied with a weighting function \( W \) given equation in (3).

\[ W = \frac{\sigma^2_{\bar{K}}}{(\sigma^2_{\bar{K}} - \sigma^2)} \]  

(3)

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

\[ \sigma^2_{\bar{K}} = \frac{1}{M^2} \sum_{u,v=0}^{M-1} (K_{uv} - \bar{K})^2 \]  

(4)

Where, \( M \times M \) 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 \( \sigma^2 \) 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.

\[ W = \frac{(1-C_u)^2}{(1+C_u)^2} \]  

(5)

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

\[ C_u = \sqrt{\frac{\text{ENL}}{\text{ENL}}} \]  

(6)

Where, ENL is the Equivalent No of Looks in equation (7).
\[ ENL = \left( \frac{\bar{K}}{\sigma_k} \right) \]  

(7)

The \( \sigma_k \) is the standard deviation of the kernel and \( \bar{K} \) is the mean intensity value of 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>
<thead>
<tr>
<th>FILTERS</th>
<th>EVALUATION MEASURES</th>
<th>KAUN FILTER</th>
<th>LEE FILTER</th>
<th>MEAN FILTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMAGE 1</td>
<td>RMSE</td>
<td>7.7802</td>
<td>5.8750</td>
<td>6.1652</td>
</tr>
<tr>
<td></td>
<td>PSNR</td>
<td>30.311</td>
<td>32.7506</td>
<td>32.3318</td>
</tr>
<tr>
<td>IMAGE 2</td>
<td>RMSE</td>
<td>9.3343</td>
<td>6.9803</td>
<td>7.4129</td>
</tr>
<tr>
<td></td>
<td>PSNR</td>
<td>28.7292</td>
<td>31.2533</td>
<td>30.7311</td>
</tr>
<tr>
<td>IMAGE 3</td>
<td>RMSE</td>
<td>5.4073</td>
<td>4.7833</td>
<td>4.7911</td>
</tr>
<tr>
<td></td>
<td>PSNR</td>
<td>33.4713</td>
<td>34.5362</td>
<td>34.5221</td>
</tr>
<tr>
<td>IMAGE 4</td>
<td>RMSE</td>
<td>12.3216</td>
<td>7.3152</td>
<td>9.2786</td>
</tr>
<tr>
<td></td>
<td>PSNR</td>
<td>26.3174</td>
<td>30.8463</td>
<td>28.7812</td>
</tr>
<tr>
<td>IMAGE 5</td>
<td>RMSE</td>
<td>9.2069</td>
<td>6.8873</td>
<td>7.2555</td>
</tr>
<tr>
<td></td>
<td>PSNR</td>
<td>28.8485</td>
<td>31.3699</td>
<td>30.9125</td>
</tr>
<tr>
<td>IMAGE 6</td>
<td>RMSE</td>
<td>10.7824</td>
<td>10.3297</td>
<td>10.3573</td>
</tr>
<tr>
<td></td>
<td>PSNR</td>
<td>27.4765</td>
<td>27.8491</td>
<td>27.8258</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>RMSE</td>
<td>9.1388</td>
<td>7.0285</td>
<td>7.5434</td>
</tr>
<tr>
<td></td>
<td>PSNR</td>
<td>29.1923</td>
<td>31.4342</td>
<td>30.8507</td>
</tr>
</tbody>
</table>

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](image_url)
F. Experimental results for non linear filters

<table>
<thead>
<tr>
<th>ORIGINAL IMAGES</th>
<th>MAX FILTER</th>
<th>MIN FILTER</th>
<th>MEDIAN FILTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMAGE 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IMAGE 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IMAGE 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IMAGE 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IMAGE 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IMAGE 6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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).

\[
f(x, y) = \text{median} \left( \sum_{(s, t) \in S_{xy}} (g(s, t)) \right)
\]

Where \( S_{xy} \) 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).

\[
g(x, y) = \max \{ f(x + a, y + b) \}
\]

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).

\[ g(x, y) = \min\{f(x + a, y + b)\} \]  

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

E. Comparison Of Non Linear Filters

![Comparison Of Non Linear Filters](image)

Figure 4. Overall Non Linear Filter Performances Based On Rmse And Psnr Values
F. Experimental Results For Non Linear Filters

<table>
<thead>
<tr>
<th>ORIGINAL IMAGES</th>
<th>MAX FILTER</th>
<th>MIN FILTER</th>
<th>MEDIAN FILTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMAGE 1</td>
<td>IMAGE 2</td>
<td>IMAGE 3</td>
<td>IMAGE 4</td>
</tr>
<tr>
<td>IMAGE 5</td>
<td>IMAGE 6</td>
<td>IMAGE 1</td>
<td>IMAGE 2</td>
</tr>
</tbody>
</table>

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),

\[
RMSE = \sqrt{\frac{1}{MN} \sum_{m=1}^{M} \sum_{n=1}^{N} (x(i,j) - x1(i,j))^2}
\]  

(11)

Here, \(x(i,j)\) is the original image, \(x1(i,j)\) 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),

\[
PSNR = 10 \log_{10} \left( \frac{255^2 \times \text{MSE}}{255^2} \right)
\]  

(12)
Here, MSE (Mean Square Error) is used to find the total amount of difference between two images. The formula is (13),

\[ \text{MSE} = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} (x(i,j) - x_1(i,j))^2 \]  

(13)

Here, \( x(i,j) \) is the original image, \( x_1(i,j) \) 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](image)

### 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.

### REFERENCES


