Comparison of Filters for Despeckle With Improved Speckle Reducing Antiscopic Diffusion Filter for Ultrasound Images


Abstract: ---- Due to the presence of speckle noise leads to the poor quality of the US images. The presence of speckle noise makes it difficult to understand the information contain in the US image hence filtering of US image is required to improve the image quality. The paper gives us the comparison of different filters techniques (linear filter (lf), Anisotropic Diffusion(AD), Nonlinear filter kuwahara(Kuwa), median filter(med), hybrid median filter(hmed), Lee Filter &kaun, frost filter, Wavelet based speckle reduction methods, speckle reducing anisotropic diffusion filter (srad), improved srad(Israd), 65 texture feature, image intensity normalization, 15 image quantitative metrics and image quality evaluation. It is observed that the Israd, improves the image quality of liver, kidney, uterus, live mass ultrasound images.

I. INTRODUCTION

In recent years there is a lot of advancement and progress in image processing however, a lot of factors in the image quality, hinders the automated image analysis [1], and diseases evaluation [2]. This includes artifacts by image acquisition instrumentations, transmission errors, coding artifacts, which will degrade the image quality and induce noise in ultrasound image. Cancer is the most deadly disease in both men and women there are several types of cancer like lung cancer, Prostrate cancer, Breast Cancer, Uterus Cancer etc these diseases can cause of death. Hence diagnosis of the cancer in the early stages is crucial. Ultrasound imaging is a widely used technology for diagnosing and treatment of cancer. Noninvasive methods used to diagnose cancer still have limitations. Detection techniques are currently based primarily on physical examination. Ultrasound image segmentation is an important problem in medical image analysis and visualization. Because these images contain strong speckle noise and attenuation artifacts [3], it is difficult to automatically segment these images to detect interested objects in the correct position and orientation. The Fig. 1 gives the flowchart analysis of ultrasound image analysis used in the paper to compare 10 different filtering techniques

II. SPECKLE FILTERS

In this section, 10 image despeckle filtering methods are presented as follows: (a) linear filter,(b) Anisotropic

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Fig. 1 – Flowchart analysis of the for ultrasound Image analysis

In order to analysis the performance of the different filters 50 ultra sound images of liver, uterus, breast, and kidney.
Diffusion (c) nonlinear filter kuwahara, (d) median filter, (e) hybrid median filter, (f) Lee Filter & kaun, and (g) frost filter (h) Wavelet based speckle reduction methods (i) speckle reducing anisotropic diffusion filter (srad), (j) improved srad.

(a) Linear despeckle filter

This filter uses 1st order statistics mean, variance of neighboring pixel that is described by the multiplicative noise model [4, 5, 26]. The algorithms based on the equations given below:

\[ f_{ij} = \bar{g} + k_{ij}(g_{ij} - \bar{g}) \]

\[ g_{ij}, k_{ij} \text{is a weighting factor, where } k \in [0, 1], \text{ and } i, j \text{ are the pixel coordinates. The factor } k_{ij} \text{ is a function of the local statistics in a moving window and is defined by the equation:} \]

\[ k_{ij} = \frac{1 - g^{-2} \sigma^2}{\sigma^2 + \sigma_n^2} \]

The values of moving window and \( \sigma_n^2 \) represent the variance of the moving window and \( \sigma_n^2 \) the variance of noise in the whole image. The noise variance can be calculated from the logarithmically compressed image by computing the average noise variance over a number of windows with dimensions considerably larger than the filtering window. The moving window size for the despeckle filter in this study was 5 x 5 and the number of iterations applied to each image was two. The filter is the most appropriate in increasing the optical perception evaluation in ultrasound images and videos, while the mean and the median values are preserved in ultrasound images [5] and videos [19] by increasing the optical perception evaluation. The filter decreases the variance of speckle noise in the image, improves statistical and texture features extraction, increases the classification accuracy and the overall image quality of the image by enhancing edges [4].

(b) Anisotropic diffusion filter

Perona and Malik [31] introduced the following function, \( d_{ij,t} = f(|\nabla g|) \), that smoothed the original image while trying to preserve brightness discontinuities:

\[ \frac{dg_{ij,t}}{dt} = div(dg_{ij,t} \nabla g_{ij,t}) = \left[ \frac{d}{dt} g_{ij,t} \frac{d}{dt} g_{ij,t} \right] + \left[ \frac{d}{dt} g_{ij,t} \frac{d}{dt} g_{ij,t} \right] \]

Where \( |\nabla g| \), is the gradient magnitude, and \( d(|\nabla g|) \), is an edge stopping function, which is chosen to satisfy \( d \rightarrow 0 \) when \( |\nabla g| \rightarrow \infty \) so that the diffusion is stopped across edges. This function, called the diffusion coefficient, \( cd(|\nabla g|) \), is a monotonically decreasing function of the gradient magnitude, \(|\nabla g|\) yielding intra-region smoothing, and not inter-region smoothing [4, 17, 27, 31] by impeding diffusion at image edges. A basic anisotropic partial-differential equation is given in (5). Two different diffusion coefficients were proposed in [31], as follows:

\[ cd(|\nabla g|) = \frac{1}{1 + (\frac{|\nabla g|}{K})^2} \text{ and } cd(|\nabla g|) = \frac{2|\nabla g|}{1 + (\frac{|\nabla g|}{K1})^2} \]

where K and K1, are positive gradient threshold parameters, known as diffusion or flow constants [31]. In this work we used the first diffusion coefficient in (6) as it was found to perform better in our images 4, 5.

(c) Nonlinear despeckle filter

The kuwahara is an 1D filter operating in a 5x5 pixel neighborhood searching for the most homogenous neighborhood area around each pixel [4, 28]. The algorithm based on the equations given below:

\[ k_{ij} = \frac{1 - g^{-2} \sigma^2}{\sigma^2 + \sigma_n^2} \]

The values of moving window and \( \sigma_n^2 \) represent the variance of the moving window and \( \sigma_n^2 \) the variance of noise in the whole image. The noise variance can be calculated from the logarithmically compressed image by computing the average noise variance over a number of windows with dimensions considerably larger than the filtering window. The moving window size for the despeckle filter kuwahara was set to two. The kuwahara filter can be used to improve the classification accuracy of different organs and tissues and to enhance edges, thus also improving the optical perception evaluation [3].

(d) Median, hybrid medianspeckle filters

The median filter [4, 5] is a median filter applied over windows of size 5x5. This is an extension of the filter hmedian, which was introduced in [30] and later used in [4, 5] and it computes the median of the outputs generated by median filtering with three different windows (cross shape window, x-shape window and normal window). The moving window size for the despeckle filter median and hmedian was for both filters 5x5 pixels, while the number of iterations applied to each image was three and two respectively. The median filter is well suited for improving the optical perception evaluation but repeated application destroys the image edges. The filter hmedian preserves the edges and...
increases the optical perception evaluation. It can thus be used to preserve and enhance edges of various organs in ultrasound images [3,4].

(f) Lee Filter and Kaun
The Lee filter is designed to eliminate speckle noise while preserving edges and point features in radar imagery. Based on a linear speckle noise model and the minimum mean square error (MMSE) design approach. Lee filter form an output image by computing a linear combination of the center pixel intensity in a filter window with the average intensity of the window. Kaun and Lee filter have the same formulation although signal model assumption and derivations are different. These two filters achieve a balance between straightforward averaging in homogeneous regions and identity filter where edges and point features exist. This balance depends on the coefficient of variation inside the moving window.

(g) Frost Filter
Frost achieves a balance between averaging and all pass filter by forming an exponentially shaped filter kernel. The response of the filter varies locally with the coefficient of variation.

(h) Wavelet based speckle reduction methods
The wavelet based speckle reduction method usually includes (1) logarithmic transformation (2) wavelet transformation (3) modification of noisy coefficient using shrinkage function (4) invert wavelet transform and (5) exponential transformation. This method can be classified into three groups

1. Thresholding methods - The wavelet coefficients smaller than the predefined threshold are regarded as contributed by noise and then removed [19],[20]. The thresholding techniques have difficulty in determining an appropriate threshold.
2. Bayesian estimation methods - This Method approximates the noise free signal based on the distribution model of noise free signal and that of noise [21]-[23]. Thus, reasonable distribution models are crucial to the successful application of these techniques to medical ultrasound imaging.
3. Coefficients correlation methods - This is an undecimated or over complete wavelet domain denoising method which utilizes the correlation of useful wavelet coefficients across scales [24]. However this method does not rely on the exact prior knowledge of the noise distribution and this method is more flexible and robust compared to other wavelet based methods.

III. PROPOSED FILTER IMPROVED SPECKLE REDUCING ANISOTROPIC DIFFUSION FILTER (ISRAD)
Due to noise and speckles in the ultrasound B mode and elastographic images, noise filtering and edge enhancement are required. There are several fundamental requirements of noise filtering methods for medical images. One, it should not lose the important information of object boundaries and detailed structures. Two, it should efficiently remove noise in the homogeneous regions and finally, it should enhance morphological definition by sharpening discontinuities. The Speckle Reducing Anisotropic Diffusion (SRAD) filter (Yongjian Yu and T. Scott Acton, 2002) meets these requirements of noise filters and also improves the image quality significantly while preserving the important boundary information and hence, in present study, speckle reducing anisotropic diffusion filtering of real elastography and ultrasound B mode images is done to reduce noise and speckles. Segmentation is required to separate the tumor region from its background. Improved Speckle reducing anisotropic diffusion proposed is Based on setting the diffusion coefficient in the diffusion equation using the local frame gradient and the frame Laplacian. The Israd filter uses two seemingly different methods, namely the Lee [26] and the Frost diffusion filters [27]. In [33], a more general updated function for the output image is presented, by extending the PDE versions of the despeckle filter as:

\[ f_{ij} = g_{ij} + \frac{1}{\eta_s} d \psi(c_{srad}(\nabla g)) \nabla g_{ij} \]

where \( \eta_s \) is the size of the filtering window. The diffusion coefficient for the speckle anisotropic diffusion, \( c_{srad}(\nabla g) \) is given in [33] as:
It is required that $c_{\text{rad}}(\nabla g) \geq 0$. The above instantaneous coefficient of variation combines a normalized gradient magnitude operator and a normalized Laplacian operator to act like an edge detector. High relative gradient magnitude and low relative Laplacian indicates an edge. The Israd filter utilizes speckle reducing anisotropic diffusion according to (12) with the diffusion coefficient, $c_{\text{rad}}(\nabla g)$ in (13) [33]. The coefficient of variation for the Israd filter can be selected from 0.01 up to 0.1 and the number of iterations from 1 to 200. In this study the number of iterations applied to each image, was set to 30, while the coefficient of variation was 0.02. As it was observed during the processing the Israd filter may be used to improve the overall image quality. It was furthermore observed to improve the quality of video encoding as well reducing the bandwidth required for transmitting the filtered ultrasound image over a 3G wireless network [32].

Results and conclusion

Table 1: statistical features

<table>
<thead>
<tr>
<th>Original</th>
<th>Large dep</th>
<th>Average dep</th>
<th>Difference dep</th>
<th>Low</th>
<th>High</th>
<th>Rel Error</th>
<th>ME</th>
<th>SE</th>
<th>RMSE</th>
<th>SAE</th>
<th>MAX</th>
<th>SSD</th>
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<tbody>
<tr>
<td>Median</td>
<td>23.36</td>
<td>22.62</td>
<td>33.28</td>
<td>34.67</td>
<td>35.87</td>
<td>35.17</td>
<td>24.53</td>
<td>24.53</td>
<td>26.32</td>
<td>24.15</td>
<td>22.75</td>
<td>36.34</td>
</tr>
<tr>
<td>Mean</td>
<td>23.36</td>
<td>22.62</td>
<td>33.28</td>
<td>34.67</td>
<td>35.17</td>
<td>35.17</td>
<td>24.53</td>
<td>24.53</td>
<td>26.32</td>
<td>24.15</td>
<td>22.75</td>
<td>36.34</td>
</tr>
<tr>
<td>Vol. Std</td>
<td>0.81</td>
<td>0.82</td>
<td>1.009</td>
<td>1.109</td>
<td>1.184</td>
<td>1.184</td>
<td>2.149</td>
<td>2.149</td>
<td>2.78</td>
<td>1.28</td>
<td>1.28</td>
<td>1.84</td>
</tr>
<tr>
<td>Skewness</td>
<td>1.813</td>
<td>1.814</td>
<td>1.808</td>
<td>1.38</td>
<td>1.38</td>
<td>1.38</td>
<td>2.149</td>
<td>2.149</td>
<td>2.78</td>
<td>1.28</td>
<td>1.28</td>
<td>1.84</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>3.772</td>
<td>3.772</td>
<td>3.078</td>
<td>3.417</td>
<td>3.054</td>
<td>3.054</td>
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<td>4.5</td>
<td>4.7</td>
<td>5.7</td>
<td>5.7</td>
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</tr>
</tbody>
</table>

Table 2: Spatial gray level dependence matrices

Table 3: Gray level difference statistics

Table 4: Gray level difference statistics

Fig 1: Ultra sound image of kidney
observed from Table 1 that almost all filters preserve the median and reduce the variance. Furthermore, it is also observed that when the Israd filters are applied to the ROI of image, they increase contrast, H1 and angular sum, but lower roughness while at the same time they preserve the rest of the features. The results of this study can also be favorably compared with the results presented in [5,12], where similar texture features values were computed for Kidney.

Table 5: Image Quality

Table 5 tabulates selected image quality metrics between original and despeckled images when filtering is applied on the entire image and when applied in an ROI (− /−). For all filters investigated, when filtering was applied on the entire image or in an ROI the geometric average error (GAE) was 0. This can be attributed to the fact that the information between the original and the processed images remains unchanged. The quality metrics LMSE, and NAE showed a similar performance as the MSE and RMSE whereas for the Israd filter, smaller values of the same metrics were observed.

REFERENCES


[48] K. Potter, D.J. Green, C.J. Reed, R.J. Woodman, et al.,