An Efficient Two step Algorithm for Despeckling the Ultrasound Image

Nageswari P, Rajan S, Manivel K

Abstract: The speckle noise presence in ultrasound images is a critical concern in medical image processing. It degrades the important features captured in an image and decreases the physician’s capacity to understand the image accurately. In recent years, numerous techniques have been proposed to de-noise the ultrasound images. In this paper, a new speckle noise removal algorithm has been proposed for medical ultrasound images. Based on the concepts of fuzzy logic and Coefficient of variation, the proposed algorithm first classifies the image area into three different regions such as homogeneous, edge and detail region. Next, average filter, median filter and an adaptive mean filter are employed to partition the unwanted noise from the pixels of different regions. Filter selection depends on the features of a region. The proposed algorithm develops image quality by removing maximum unwanted noise while protecting the important image details.

Index Terms: Ultrasound Image, Fuzzy Logic, Triangular Membership function, SpeckleNoise, Image Fuzzification

I. INTRODUCTION

The process of medical imaging is to capture the images of internal organs and soft structural tissues of the human body. Currently, different imaging modalities are available in medical field. Out of these modalities, ultrasound imaging is often considered because of its versatile, portable, non-invasive, real time imaging and relatively cost effective. On the other hand, the main drawback of medical ultrasound imaging is that, it intrinsically degrades with speckle noise. This drawback creates an opportunity for a physician to take a wrong decision about an image with speckle noise. Hence denoising has become an essential preprocessing task in medical image processing. Speckle noise that affects ultrasound images is a multiplicative noise which follows gamma distribution.

II. RELATED WORKS

Filters [1, 2] based on local statistics provide efficient denoising in homogeneous region however fail to protect the noisy pixels in edge region. Yonjian et al. [3] and Krissian et al.[4] proposed diffusion algorithms for speckle reducing in ultrasound images. Farzana et al. [7] proposed a de-speckling algorithm based on adaptive bilateral filtering. Of late, many researchers focus their interest to involve fuzzy techniques in medical image denoising process. It has the capability to handle the image with vagueness and ambiguity efficiently. Also it represents and manages the human facts as fuzzy if-then rules. Filters based on fuzzy logical system provide a good solution for classical logical system based filters [8].

Based on fuzzy techniques, Cheng et al. [9] found a new speckle noise reducing method, for synthetic radar images. In this method, for every pixel in the filtering window, fuzzy edges are calculated and fuzzy filtering is done by employing the weight contributions of adjacent pixels. However the main drawback of this method is that, it is appropriate only for homogeneous regions. Zhang et al. [10] presented a fuzzy logic and sub pixel fractional diffusion approach for de-speckling the ultrasound images. This approach employs Euler Lagrange equation and does the filtering in an iterative way which improves the image contrast. But there is a limitation for calculating the image Fuzzification for every iteration Binaee et al. [11] proposed an ultrasound image enhancement methodology by utilizing gradient for image classification and calculating non local mean for similar windows. Babu et al. [12] discussed an adaptive speckle reducing technique for ultrasound images. Initially, based on coefficient of variation, this technique classifies the image area into three different regions. Then the filtering is carried out by selecting appropriate filters. Based on discrete topological derivative, an ultrasound de-speckling algorithm is proposed by Damodaran et al. [13]. This algorithm reduces speckle noise proficiently but it consumes more time to improve the image contrast. Similarly, based on multi transducer architecture, a
An Efficient Two step Algorithm for Despeckling the Ultrasound Image

De-noising method is developed by Tsakalakis et al. [14]. This method employs a technique which combines spatial and frequency compounding with super solution de-speckling algorithm. The major disadvantage is, the image registration is required for the images which are captured from various sensors with dissimilar frequencies. Based on the concepts of fuzzy logic and Coefficient of variation, the proposed algorithm, first classifies the image area into three different regions such as homogeneous, edge and detail region. Next, Average Filter, Median Filter and an Adaptive Mean Filter are employed to breakdown the obnoxious noise from the pixels of different regions.

The paper is organized as follows: Section 2 describes the related work, their limitations and the objective of the paper. Section 3 discusses the proposed method; section 4 and 5 describes the simulation results and conclusion.

III. PROPOSED WORK

In the proposed method, the image areas are divided into three different regions and fuzzy membership function is employed to sketch the outer line among these regions.

Further the image is classified by using the coefficient of variation. Coefficient of variation is defined as the ratio of standard deviation and mean. A pixel with minimum value of coefficient of variation determines a homogeneous region pixel, maximum value of coefficient of variation denotes edge pixels and intermediate value corresponds to the detail region. Depending on this principle, the noisy pixels have been classified into three distinct regions namely homogeneous, edge and detail regions. Then a fuzzy triangular membership function has been employed to address the speckle noise fuzziness. It is utilized to describe fuzzy values of different image regions.

Let us consider the ultrasound image that degrades with speckle noise be \( I(y, z) \).

Then

\[
I(y, z) = N(y, z) \cdot M(y, z)
\]

Where, \( N(y,z) \) is the noise free image and \( M(y,z) \) is the multiplicative speckle noise. \( P \times Q \) is the dimensions of the image \( I(y,z) \). Where \( y=1...P \) and \( z=1...Q \).

The following equation defines the fuzzy membership value for each pixel of the image \( I(y, z) \).

\[
\mu_{low} = \begin{cases} \frac{n - \text{COV}}{n-1} & 1 \leq \text{COV} \leq p_1 \\ \text{min} \left( \frac{\text{COV} - p_1}{n-p_1}, \frac{p_1 - \text{COV}}{p_1-n} \right) & p_1 < \text{COV} < p_2 \\ \frac{\text{COV}}{m-n} & \text{otherwise} \end{cases}
\]

Where, \( y=1,...,P \), \( z=1,...,Q \).

Based on the principle of Coefficient of variation, the image pixels are separated into three different regions namely, homogeneous detail and edge region. Pixel belonging to the homogeneous region has low \( \text{COV} \) whereas high \( \text{COV} \) shows edge region and medium belonging to the detail region.

III. PROPOSED WORK

In the proposed method, the image areas are divided into three different regions and fuzzy membership function is employed to sketch the outer line among these regions.

Further the image is classified by using the coefficient of variation. Coefficient of variation is defined as the ratio of standard deviation and mean. A pixel with minimum value of coefficient of variation determines a homogeneous region pixel, maximum value of coefficient of variation denotes edge pixels and intermediate value corresponds to the detail region. Depending on this principle, the noisy pixels have been classified into three distinct regions namely homogeneous, edge and detail regions. Then a fuzzy triangular membership function has been employed to address the speckle noise fuzziness. It is utilized to describe fuzzy values of different image regions.

Let us consider the ultrasound image that degrades with speckle noise be \( I(y, z) \).

Then

\[
I(y, z) = N(y, z) \cdot M(y, z)
\]

Where, \( N(y,z) \) is the noise free image and \( M(y,z) \) is the multiplicative speckle noise. \( P \times Q \) is the dimensions of the image \( I(y,z) \). Where \( y=1...P \) and \( z=1...Q \).

The following equation defines the fuzzy membership value for each pixel of the image \( I(y, z) \).

\[
\mu_{low} = \begin{cases} \frac{n - \text{COV}}{n-1} & 1 \leq \text{COV} \leq p_1 \\ \text{min} \left( \frac{\text{COV} - p_1}{n-p_1}, \frac{p_1 - \text{COV}}{p_1-n} \right) & p_1 < \text{COV} < p_2 \\ \frac{\text{COV}}{m-n} & \text{otherwise} \end{cases}
\]

Where, \( y=1,...,P \), \( z=1,...,Q \).

Based on the principle of Coefficient of variation, the image pixels are separated into three different regions namely, homogeneous detail and edge region. Pixel belonging to the homogeneous region has low \( \text{COV} \) whereas high \( \text{COV} \) shows edge region and medium belonging to the detail region.

Figure 1 shows the fuzzy membership function for the image \( I(y, z) \).

The details of calculating threshold values are given below

\[
l = \min (\text{COV}_k)
\]

\[
m = \max (\text{COV}_k)
\]

\[
n = \text{middle} (\text{Unique} (\text{COV}_k))
\]

\[
p_1 = \text{average} (\text{COV}_{[l,n]})
\]

\[
p_2 = \text{average} (\text{COV}_{[n,m]})
\]

Figure 2 shows the flow diagram of the proposed method.

A. Algorithm:

1. Compute coefficient of variation employing 3x3 window in the region of each pixel of \( I(y,z) \)

2. Compute triangular membership function thresholds by using

\[
l = \min (\text{COV}_k)
\]

\[
m = \max (\text{COV}_k)
\]

\[
n = \text{middle} (\text{Unique} (\text{COV}_k))
\]

\[
p_1 = \text{average} (\text{COV}_{[l,n]})
\]

\[
p_2 = \text{average} (\text{COV}_{[n,m]})
\]

3. Isolate every pixel of image \( I \) into distinct region employing triangular function

\[
I(y, z) = \begin{cases} \mu_{low} = \frac{n - \text{COV}}{n-1} & 1 \leq \text{COV} \leq p_1 \\ \mu_{mid} = \text{min} \left( \frac{\text{COV} - p_1}{n-p_1}, \frac{p_1 - \text{COV}}{p_1-n} \right) & p_1 < \text{COV} < p_2 \\ \mu_{high} = \frac{\text{COV}}{m-n} & \text{otherwise} \end{cases}
\]

4. Employ suitable filter to denote each pixel of all three regions
The equation for median filter with moving window of size 3 x 3 is given as follows:

\[
D'(y, z) = Med (I(y + j, z + k))
\]  (5)

Where, \(-1 \leq (j, k) \leq 1\)

(iii) Adaptive Mean Filter:

Edge pixels are continuous and grouped in nature. Hence we have to assign larger weight to the co-efficient of neighboring pixel with the same magnitude. Alternatively, noisy pixels which have larger co-efficient are discontinuous and isolated in nature. On the basis of this study, an adaptive weighted mean filter is used for filtering the edge noisy pixels. Therefore we have to assign smaller weight to the co-efficient of neighboring pixel with different magnitude. For every neighboring pixel with different magnitude for every neighboring co-efficient, the weight value is given by

\[
w(j, k) = r(j, k) \times s(j, k)
\]

Where, \(s(j, k)\) and \(r(j, k)\) are the spatial and magnitude similarity respectively denoted as in [15].

The magnitude and spatial similarity is given by

\[
r(j, k) = e^{-\left(\frac{(I(y, z) - I(y + j, z + k))^2}{3}\right)}
\]  (7)

\[
s(j, k) = e^{-\left(\frac{(j + k)^2}{9}\right)}
\]

Where \(I(y, z)\) and \(I(y + i, z + k)\) are middle pixel and its adjacent pixel respectively in a 3 x 3 window and \(j, k \in [-1 to 1]\).

IV SIMULATION RESULTS:

The proposed speckle noise reducing method is implemented in MATLAB 14a and simulation results are presented. The performance is compared with Mean, Median, AMF, AWMF, LEE, ASSF, ANSF, ABF and Fuzzy Filter. For quantitative analysis, performance of different filters is compared in terms of Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR).

Mean Square Error (MSE) is defined as:

\[
MSE = \frac{\sum_{(x, y)} (X_{xy} - Y_{xy})^2}{MN}
\]  (8)

Peak Signal to Noise Ratio (PSNR) is defined as:

\[
PSNR = 10 \log_{10} \left( \frac{255^2}{MSE} \right)
\]  (9)
An Efficient Two step Algorithm for Despeckling the Ultrasound Image

Where, MSE is the mean square error between original image and filtered image.

To test effectiveness of the proposed methodology, real human liver ultrasound image has been considered. Figure 3 shows the residual images which are obtained by applying various denoising techniques on real liver image. It is obvious from these figures that mean and median filters are able to suppress considerable amount of noise but fails to protect the edge regions. AMF and AWMF creates lots of vagueness. During the process of denoising, filters introduced by M. Karama et.al and D. Kuan et.al removes the important structural details. Fuzzy filter produces no significant performance in terms of both edge preservation and noise suppression.

Table 1 Quantitative analysis of ultrasound liver image:

<table>
<thead>
<tr>
<th>Nois algorithm</th>
<th>Speckle noise (10%)</th>
<th>Speckle noise (20%)</th>
<th>Speckle noise (30%)</th>
<th>Speckle noise (40%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MSE</td>
<td>PSNR</td>
<td>MSE</td>
<td>PSNR</td>
</tr>
<tr>
<td>Average</td>
<td>128.563</td>
<td>21.574</td>
<td>134.324</td>
<td>20.743</td>
</tr>
<tr>
<td>AMF</td>
<td>115.684</td>
<td>27.547</td>
<td>121.854</td>
<td>24.547</td>
</tr>
<tr>
<td>Lee</td>
<td>110.164</td>
<td>29.814</td>
<td>116.634</td>
<td>27.891</td>
</tr>
<tr>
<td>ASSF</td>
<td>108.361</td>
<td>31.425</td>
<td>112.148</td>
<td>29.425</td>
</tr>
<tr>
<td>ANSF</td>
<td>102.482</td>
<td>33.432</td>
<td>106.872</td>
<td>31.432</td>
</tr>
<tr>
<td>ABF</td>
<td>98.564</td>
<td>34.896</td>
<td>101.634</td>
<td>33.896</td>
</tr>
<tr>
<td>Fuzzy filter</td>
<td>94.854</td>
<td>37.854</td>
<td>98.425</td>
<td>34.854</td>
</tr>
<tr>
<td>Proposed filter</td>
<td>87.238</td>
<td>38.532</td>
<td>92.387</td>
<td>35.532</td>
</tr>
</tbody>
</table>

Fig. 3 A noisy version of a human liver ultrasound image. Results filtered by (a) Mean, (b) Median, (c) AMF, (d) AWMF, (F) LEE, (g) ASSF, (h) ANSF, (i) ABF, (J) Fuzzy filter and (k) Proposed filter.

Tables 1, 2, 3 and 4 show the quantitative results of ultrasound liver, gall bladder, spleen and pancreas images between the existing techniques and proposed method. Highest value of PSNR and lowest value of MSE indicates the noise reducing capability of the proposed method. Finally, the proposed algorithm eliminates maximum amount of noise as well as protect the image structural details in all situations when compared to other existing state-of-the-art techniques.
Table: 2 Quantitative analysis of ultrasound gall bladder image:

<table>
<thead>
<tr>
<th>Noise algorithm</th>
<th>Speckle noise (10%) MSE</th>
<th>Speckle noise (20%) MSE</th>
<th>Speckle noise (30%) MSE</th>
<th>Speckle noise (40%) MSE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PSNR</td>
<td>PSNR</td>
<td>PSNR</td>
<td>PSNR</td>
</tr>
<tr>
<td>Average</td>
<td>129.352</td>
<td>22.325</td>
<td>135.244</td>
<td>21.223</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>141.528</td>
<td>19.364</td>
</tr>
<tr>
<td>Median</td>
<td>128.224</td>
<td>25.369</td>
<td>131.288</td>
<td>24.975</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>138.243</td>
<td>22.258</td>
</tr>
<tr>
<td>AMF</td>
<td>114.356</td>
<td>28.854</td>
<td>127.336</td>
<td>27.226</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>132.456</td>
<td>25.425</td>
</tr>
<tr>
<td>AWMF</td>
<td>113.244</td>
<td>30.253</td>
<td>120.852</td>
<td>29.572</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>126.864</td>
<td>26.841</td>
</tr>
<tr>
<td>Lee</td>
<td>111.521</td>
<td>32.251</td>
<td>118.344</td>
<td>28.698</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>121.856</td>
<td>27.235</td>
</tr>
<tr>
<td>ASSF</td>
<td>109.142</td>
<td>34.672</td>
<td>116.254</td>
<td>31.258</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>119.364</td>
<td>29.954</td>
</tr>
<tr>
<td>ANSF</td>
<td>105.436</td>
<td>36.549</td>
<td>112.522</td>
<td>35.422</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>118.668</td>
<td>33.437</td>
</tr>
<tr>
<td>ABF</td>
<td>102.452</td>
<td>37.292</td>
<td>108.532</td>
<td>36.691</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>112.569</td>
<td>34.534</td>
</tr>
<tr>
<td>Fuzzy filter</td>
<td>98.546</td>
<td>38.854</td>
<td>103.854</td>
<td>37.522</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>105.336</td>
<td>36.246</td>
</tr>
<tr>
<td>Proposed filter</td>
<td>91.543</td>
<td>39.235</td>
<td>96.528</td>
<td>38.532</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>98.736</td>
<td>37.836</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>110.256</td>
<td>34.823</td>
</tr>
</tbody>
</table>

V CONCLUSION

A new speckle denoising methodology for real abdomen images has been given in this paper. The proposed filter is based on the concept of fuzzy logic and coefficient of variation. Filtering process has been carried out in two steps, in step-1 Image region has been classified into three different regions and in step-2 appropriate filters have been employed. Both quantitatively and qualitatively results have been proved. Hence, we finalize that the proposed algorithm can proficiently denoising the abdomen ultrasound image and it too develops diagnostic outcomes of modality of ultrasound image.

REFERENCES


Authors Profile

Nageswari P was born in Namakkal, Tamilnadu. She received her Masters in mathematics from Periyar University, Tamilnadu, India, 2004 and 2006 respectively. She has been awarded Master of Philosophy in mathematics by Periyar University, Salem, Tamilnadu. Currently she is a Research scholar in the department of Mathematics, Erode Arts and Science College. Her research interests include ultrasound image processing and fuzzy set theory.

Rajan S is an Associate Professor of Mathematics at Erode Arts and Science College, Erode, Tamilnadu, India, having 25 years of teaching experience at both undergraduate and postgraduate levels. He received his MSc in 1984 from Madras University and PhD in 2005 from Bharathiar University, India. His areas of interest are computer algebra systems and applications of differential equations.

Manivel K was born in Namakkal, Tamilnadu. He received Master degree in Applied Electronics from Anna University of Technology Coimbatore, Tamilnadu, India, 2010. He has been awarded PhD, degree for his Research work in the area of image processing by Anna University, Chennai. He has held the position of Associate Professor and Researcher within the Centre for Electronics and Communication Engineering, Madhena Engineering College, Tamilnadu, India. His main research interests are in the areas of image processing, artificial intelligent techniques.
An Efficient Two step Algorithm for Despeckling the Ultrasound Image