A SYSTEMATIC APPROACH FOR DESPECKLING OF MEDICAL ULTRASOUND IMAGES

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ABSTRACT

Ultrasound is a medical diagnostic technique that is widely used because of its low cost and capability of forming real time imaging. A major problem regarding ultrasound images is the corruption by speckle noise. In this paper, speckle noise is removed by the methods based on Hard Thresholding based on Curvelets and Spatial filtering techniques such as Sobel operator, prewitt operator, Lee filter, and NL-Mean filter. The methods are evaluated and compared in terms of filter assessment parameters namely, Signal to Noise ratio (SNR), Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE) and Correlation Coefficient (CC).

KEYWORDS: Ultrasound Imaging (US), Mean Square Error (MSE), Signal to Noise Ratio (SNR), Peak Signal to Noise Ratio (PSNR), Correlation Coefficient (CC), Despeckling

INTRODUCTION

Ultrasound is a commonly used diagnostic imaging modality for heart, liver, spleen, and lungs etc [4]. The main advantage of the ultrasound imaging is that it is quick, economic, relatively safe, and noninvasive and the machinery is highly portable and versatile. However, the main disadvantage of the ultrasound image is poor quality of images [1], due to speckle noise. Speckle is an inherent property of ultrasound images, and is modeled as spatial correlated multiplicative noise. The presence of speckle is undesirable since it degrades image quality and affects the tasks of diagnosis and human interpretation. As a result, speckle filtering is a critical method for feature extraction, analysis, and recognition in medical imagery measurements. Several techniques for removing the speckle noise [5] have been developed over a decade. The main purpose of the noise reduction technique is to remove speckle noise by retaining important features of the image. This paper is organized as follows: Section 2 elaborates Spatial Domain Filters. Section 3 discusses the Hard Thresholding based on Curvelets. Section 4 describes the Proposed Algorithm. In section 5 Results and Discussion and in the last, conclusion is made in section 6.

SPATIAL DOMAIN FILTERS

In this study, we have used the following spatial filters for speckle suppression in ultrasound images:

Sobel Operator

The Sobel operator [6] is based on convolving the image with a small, separable, and integer valued filter in horizontal and vertical direction and is therefore relatively inexpensive in terms of computations. The sobel operator performs a 2-D spatial gradient measurement on an image. Typically, it is used to find the approximate absolute gradient magnitude at each point in an input grayscale image. The sobel edge detector uses a pair of 3x3 convolution masks, one estimating the gradient in the x-direction (columns) and the other estimating in the y-direction (rows). A convolution mask is usually much smaller than the actual image. As, a result, the mask is slid over the image, manipulating a
square of pixels at a time.

**Prewitt Operator**

Prewitt operator [6] is similar to the Sobel operator and is used for detecting vertical and horizontal edges in images.

**Lee Filter**

Lee is used primarily to filter speckled data. The enhanced lee filter smooths the image data without removing edges or sharp features in the image. A simple lee filter is described by the following equation:

\[ y(i,j) = \frac{\bar{g}(ij) - \sigma(ij)}{\sigma_u^2} \left[ g(i,j) - \bar{g}(i,j) \right] \]  

(1)

Where \( g(i,j) \) is the sample image, \( \bar{g}(ij) \) is the local mean, \( \sigma(ij)^2 \) is the local variance, \( \sigma_u^2 \) is the variance of the sample image.

**NL-Mean Filter**

The approach of Non Local Means filtering is based on estimating each pixel intensity from the information provided from the entire image and hence it exploits the redundancy caused due to the presence of similar patterns and features in the image. In this method, the restored gray value of each pixel is obtained by the weighted average of the gray values of all pixels in the image. The weight assigned is proportional to the similarity between the local neighborhood of the pixel under consideration and the neighborhood corresponding to other pixels in the image.

The filters mentioned above smoothens the central pixel on the basis of its neighborhood pixel

**HARD THRESHOLDING BASED ON CURVELETS**

Hard Thresholding [29] sets any coefficient less than or equal to the threshold to zero. Hard thresholding is used to suppress the noise. Hard threshold is defined by:

\[ f(\tilde{c}_l) = \begin{cases} |\tilde{c}_l| \geq k\sigma_{\tilde{c}_l}/\sigma_{\tilde{c}_l} & \text{if } |\tilde{c}_l| \geq k\sigma_{\tilde{c}_l}/\sigma_{\tilde{c}_l} \\ 0 & \text{if } |\tilde{c}_l| < k\sigma_{\tilde{c}_l}/\sigma_{\tilde{c}_l} \end{cases} \]  

(2)

Where \( \sigma_{\tilde{c}_l} \) is the standard deviation (SD) of the original image, \( \tilde{c}_l \) is an approximation value for the SD of each curvelet coefficient for noise images, and \( k \) is a scale dependent value.

**PROPOSED ALGORITHM**

As digital image of Ultrasound of any body part is available, so no acquisition stage is implemented. However, the image with speckle noise is acquired. The acquired image is then resized to 256 x 256 pixels. The Proposed Filter is applied to the resized image and the Final denoised image is acquired.

**Step 1:** Consider the noisy input image i.e., ‘jpeg’.

**Step 2:** Resize the image to 256 x 256 pixels.

**Step 3:** Repeat steps 4 to 9 for each pixel in an image.

**Step 4:** Consider the current pixel as center pixel.
**Step 5:** Consider a linear array (proposed) and clear the values.

**Step 6:** Apply six filter masks by multiplying 0.33 to RGB values of all the pixels of a 3x3 square kernel.

**Step 7:** The proposed linear array is then updated by six different responses from the step 7.

**Step 8:** Apply arithmetic mean filter on all the values of the proposed linear array.

**Step 9:** Replace the value of the pixel under consideration with the result obtained from step 8.

**Step 10:** Calculate SNR, PSNR, MSE and CC.

**Step 11:** Output Image.

**RESULTS AND DISCUSSIONS**

The current work has used Proposed Algorithm as a smoothing filter for denoising purposes in the proposed algorithm. The results are compared qualitatively as well as quantitatively using Peak signal-to-Noise Ratio, Signal-to-Noise Ratio, and Mean Square Error as quality metrics.

![Comparison of Filters](image)

**Figure 1:** Comparison of Filters for a) US1 with, b) Sobel Operator, c) Prewitt Operator, d) Lee Filter, e) NL-Mean Filter, f) Curvelet Hard Thresholding, g) Proposed Filter

**Table 1:** Comparison of Results for Image Denosing

<table>
<thead>
<tr>
<th>Method</th>
<th>Quality Metrics</th>
<th>SNR</th>
<th>PSNR</th>
<th>MSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sobel</td>
<td></td>
<td>0.8129</td>
<td>56.962002</td>
<td>0.13088</td>
</tr>
<tr>
<td>Prewitt</td>
<td></td>
<td>0.1598</td>
<td>56.907551</td>
<td>0.13253</td>
</tr>
<tr>
<td>Lee</td>
<td></td>
<td>-1.5363</td>
<td>69.69483</td>
<td>0.00697</td>
</tr>
<tr>
<td>NL-Mean</td>
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<td>-3.284</td>
<td>63.599479</td>
<td>0.02838</td>
</tr>
<tr>
<td>Hard Thresholding</td>
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<td>-0.4400</td>
<td>82.35710</td>
<td>0.00037</td>
</tr>
<tr>
<td>Proposed Algorithm</td>
<td></td>
<td>1.57200</td>
<td>86.894611</td>
<td>0.00013</td>
</tr>
</tbody>
</table>

From the table 1, it can be verified that the MSE value for the proposed algorithm is the lowest, SNR and PSNR values for the proposed algorithm are the highest as compared to the other filters.

**CONCLUSIONS**

This paper presents the brief overview of the methods for ultrasound image denoising. In contrast to existing
speckle filters, the proposed algorithm offers many advantages including better accuracy and greater noise reduction. The proposed technique performs better than curvelet based hard thresholding and other speckle filters as that can be shown in terms of Lower MSE, Higher SNR & PSNR.

REFERENCES