



An Optimized Speckle Noise Reduction Filter for Ultrasound Image using SRAD

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Abstract-Noise is the major problem in the field of image processing. In Medical image such as Ultrasound image are contaminated by different types of noise. In diagnosis of diseases Ultrasonic devices are frequently used by healthcare professionals. The main problem during diagnosis is the distortion of visual signals obtained which is due to the consequence of the coherent nature of the wave transmitted. These distortions are termed as 'Speckle Noise'. In the presence of such noise it is difficult to diagnosis such image. So it is the most important preprocessing task. To acquire a better performance we state another method in SRAD filter that works efficiently to reduce noise an image without blurring the frontiers between different regions. To evaluate the performance we calculate the Signal to Noise Ratio, The Peak Signal to Noise Ratio, The Root Mean Square Error, The Edge Preservative Factor and also other image quality measurement criteria. This method gives the better result with comparison to existing the basic median filter.

Keywords: Anisotropic Diffusion, SRAD Ultrasound Image, Speckle Noise, Performance Evaluation, Multiplicative noise.

I. Introduction

Images are often contaminated by different types of noise such as Impulse noise, Gaussian noise, Speckle noise and mixed noise (Impulse and Gaussian) during the transmission, faulty memory location, coherence of waves or timing error. For medical images, the clarity of details and object visibility are important, whereas for image processing a high SNR is required because most of the image segmentation algorithms are very sensitive to noise [1]. Ultrasound image is widely used in the field of medical science. The common problem in Ultrasound image is speckle noise. Speckle is basically a form of multiplicative noise which makes the gray scale of pixels change violently, hide the subtle details and makes the imaging resolution descend greatly. Speckle [2] is not a noise in an image but noise-like variation in contrast. Speckle is basically a form of multiplicative noise. Which makes the grayscale of pixels change violently, hides the subtle details and makes the imaging resolution descend greatly. Ultrasound image have a high noise content and suffer poor contrast.. If the ultrasound image contaminated by noise then an efficient filtering is required to localize the desired object. In those case the filtering is most important. So we should use an optimized method to denoise an image very efficiently. For medical image we often faced Low Signal to Noise Ratio (SNR), Low Peak Signal to Noise Ratio (PSNR) , High Root Mean Square Error (RMSE) and Low Edge Preservative Factor (EPF) . But if the SNR is too small or the contrast too low it becomes very difficult to detect anatomical structures because tissue characterization fails [1]. For a visual analysis of medical images, the clarity of details and the object visibility are important, so high SNR ,PSNR & EPF are required because most of the image segmentation algorithms are very sensitive to noise [1]. In this paper we state an optimized filtering method to denoise an image properly that satisfies the image quality criteria. It reduce noise from an image with improve the SNR, PSNR, EPF and also other image quality measurement parameter.

II. Speckle Reducing Anisotropic Diffusion (SRAD)

Anisotropic Diffusion is a nonlinear smoothing filter [4] which uses a variable conductance term, that controls the contrast of the edges that influence the diffusion. This filter has the ability to preserve edges, while smoothing the rest of the image to reduce noise [5]. The anisotropic diffusion has been used by several researchers in image restoration [6] and image recovery [7]. SRAD [8] is an edge-sensitive Partial Differential Equation (PDE) anisotropic diffusion approach to reduce speckle noise in images. The anisotropic filtering in SRAD simplifies image features to improve image segmentation and smoothes the image in homogeneous area while preserving edges and enhances them. It reduces blocking artifacts by deleting small edges amplified by homomorphic filtering.

Given an intensity image $I_0(x,y)$ having finite power and non zero values over the image support Ω , the output image $I(x, y, t)$ is evolved according to the following PDE:

$$\begin{cases} \frac{\partial}{\partial t} I(x, y, t) = \text{div}(c(q) \cdot \nabla I(x, y, t)) \\ I(x, y, 0) = I_0(x, y), \quad \frac{\partial I(x, y, t)}{\partial \vec{n}} \cdot \partial \Omega = 0 \end{cases}$$

Where $\partial \Omega$ denotes the border of Ω , $\vec{n}$ is the outer normal to the $\partial \Omega$, and $C(\cdot)$ is the diffusion Coefficient. It is defined by

$$c(q) = \frac{1}{1 + [q^2(x, y, t) - q_0^2(t)] / [q_0^2(t)(1 + q_0^2(t))]}$$

Or,

$$c(q) = \exp \left\{ - \frac{[q^2(x, y, t) - q_0^2(t)]}{[q_0^2(t)(1 + q_0^2(t))]} \right\}$$

Where, $q(x, y, t)$ is the instantaneous coefficient of variation determined by

$$q(x, y, t) = \sqrt{\frac{(\frac{1}{2})(\|\nabla I\|/I)^2 - (\frac{1}{42})(\nabla^2 I/I)^2}{[1 + (1/4)(\nabla^2 I/I)^2]}}$$

And $q_0(t)$ is the speckle scale function. It is estimated using

$$q_0(t) = \sqrt{\frac{\text{var}[z(t)]}{\bar{z}(t)}}$$

Where, $\text{var}[z(t)]$ and $\bar{z}(t)$ are the intensity variance and mean over a homogeneous area at t , respectively.

III. Speckle Reduction Methodology

3.1 Theoretical Model

The Proposed Filter firstly detects noise in the image. Let I denote noisy image and for each pixel of I is represented by $I(x,y)$. A Sliding window of size 3×3 centered at $I(x, y)$ is defined as shown in **Figure 1**. An additional benefit of our proposed method is that it seeks to preserve detail while smoothing noise, something that the traditional SRAD filter does not do. At first we estimate that the center pixel of window is noise or not. To differ the noise and signal, we calculate the mean ($\bar{m}$) and standard deviation (d) of the window. If the pixel is between $\bar{m} - d$ and $\bar{m} + d$ then it is a signal otherwise noise and we will apply SRAD Filter on it that is shown in **Figure 2**.

$I(x-1, y-1)$	$I(x-1, y)$	$I(x+1, y+1)$
$I(x, y-1)$	$I(x, y)$	$I(x, y+1)$
$I(x+1, y-1)$	$I(x+1, y)$	$I(x+1, y+1)$

Figure 1: 3×3 Mask

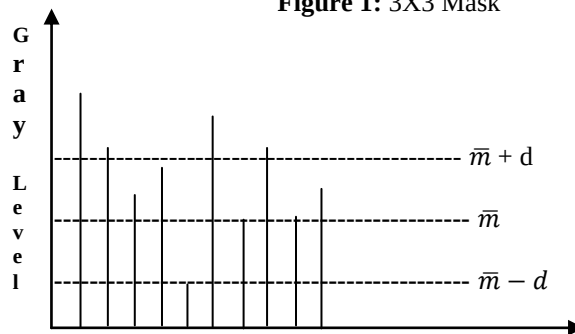


Figure 2: Graphical view of a window that shows the signal and noise label of a window.

To acquire a better performance we state another diffusion Coefficients that works efficiently for reducing the Speckle noise from Image without blurring the frontiers between different regions. It is define by

$$c(q) = \frac{1}{2} \left[1 - \frac{[q^2(x,y,t) - q_0^2(t)]\sqrt{3}}{[q_0^2(t)(1+q_0^2(t))]\sqrt{2}} \right]^2$$

3.2 ALGORITHM

1. Read an Image **I**.
2. Take a Sliding Window or Mask of size 3X3.
3. Calculate the Mean ($\bar{m}$) and Standard deviation (d) from M, And
 $A = \bar{m} - d$ $B = \bar{m} + d$
4. **IF** $A \leq I(x,y)$ and $I(x,y) \leq B$ **THEN**
 Result(x,y) = I(x,y)
- ELSE**
 Result(x, y) = div(c(q). $\nabla I(x, y, t)$)
5. Repeat the step 3 and 4 on Entire Image.
6. Display the Resultant Image.

IV. Evaluation Criteria

To validate the efficiency of this method we have defined some statistical criteria of image performance. Additionally to subjective visual evaluation, it is desirable to present quantitative measure. The parameters which are used in estimation of performance are SNR, PSNR, RMSE, EPF, RMSE_SNR, IFy, MSSIM.

Signal to Noise Ratio (SNR) [9]:

$$SNR = \left[\frac{\sum_{x=1}^M \sum_{y=1}^N f_2(x,y)^2}{\sum_{x=1}^M \sum_{y=1}^N (f_2(x,y) - f_1(x,y))^2} \right]$$

Peak Signal to Noise Ratio (PSNR) [9]:

$$PSNR = 10 \log \left[\frac{255^2}{MSE} \right]$$

Where,

$$MSE = \left[\frac{\sum_{x=1}^M \sum_{y=1}^N (f_1(x,y) - f_2(x,y))^2}{M * N} \right]$$

Edge Preservative Factor (EPF) [9] :

$$EPF = \frac{\Gamma(f_1 - \bar{f}_1, f_2 - \bar{f}_2)}{\sqrt{\Gamma(f_1 - \bar{f}_1, f_2 - \bar{f}_1) \cdot \Gamma(f_2 - \bar{f}_2, f_2 - \bar{f}_2)}}$$

Where,

$$\Gamma(s_1, s_2) = \sum_{i=1}^k s_1 \cdot s_2$$

Root Mean Square Error (RMSE) [9]:

$$RMSE = \sqrt{MSE}$$

Root Mean Square of Signal of Noise ratio (RMS_SNR) [10]:

$$RMS_SNR = \sqrt{\left[\frac{\sum_{x=1}^M \sum_{y=1}^N f_2(x,y)^2}{\sum_{x=1}^M \sum_{y=1}^N (f_2(x,y) - f_1(x,y))^2} \right]}$$

Ratio of Mean gray level or Capacity to preserve contrast (RM):

$$RM = \frac{\mu_2}{\mu_1}$$

Image Fidelity (IFy) [11]:

$$IFy = 1 - \frac{1}{SNR}$$

Where f1 means original Image, f2 means diffused Image and $\bar{f}_1$ & $\bar{f}_2$ represents the Mean of Original image and diffused image respectively. M×N is size of Image and x means row and y means columns.

Measuring Similarity between two image (MSSIM) [12][13] :

$$MSSIM(x, y) = \frac{1}{M} \sum_{j=1}^M SSIM(x_j, y_j)$$

$$SSIM(x, y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)}$$

Where,

$$\mu_x = \sum_{i=1}^N w_i x_i$$

$$\sigma_x = \sqrt{\sum_{i=1}^N w_i (x_i - \mu_x)^2}$$

$$\sigma_{xy} = \sum_{i=1}^N w_i (x_i - \mu_x) (y_i - \mu_y)$$

$$c_1 = (K_1 L)^2$$

$$c_2 = (K_2 L)^2$$

And

Where, L is the range of pixel values (255 for 8-bit grayscale images). And $K_1 \ll 1$ is a small constant and also $K_2 \ll 1$.

V. Experimental Result

To validate the efficiency of our proposed method, the simulation study has been carried out using MATLAB image processing Toolbox. One standard Medical image (Ultrasound Image) is selected for simulation study. Our Proposed algorithm has been applied to 2D ultrasound image with have been contaminated by multiplicative noise. Our proposed algorithm is compared with existing method which is shown in Table 1.

Table 1: Comparison of existing SRAD Filter and Proposed Method for Ultrasound image with Speckle noise.

Criteria	SRAD	Proposed Method
SNR	38.9853	43.8475
PSNR	73.7377	78.9856
RMSE	0.0431	0.0287
EPF	0.6084	0.7094
RMS_SNR	6.2438	6.6217
RM	0.9770	0.9846
IFy	0.9687	0.9813
MSSIM	1.0000	1.0000

Visual Comparisons are given bellow:

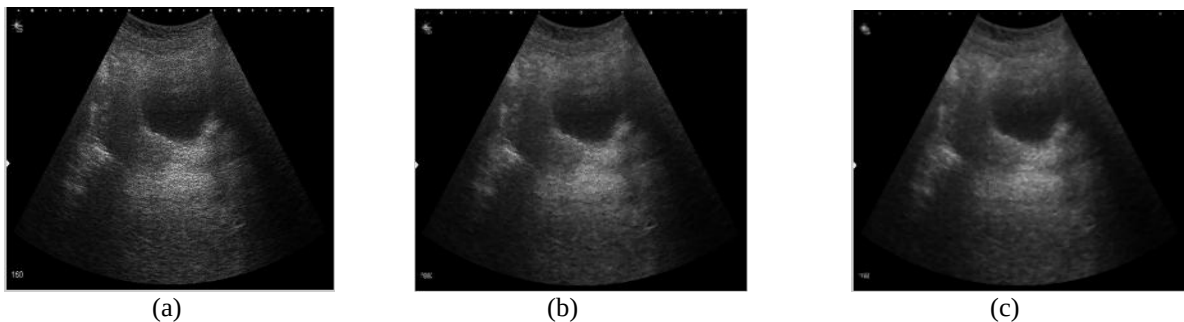


Figure 3: a) Original Noisy Image, b) Filtered Image using SRAD, c) Filtered Image using Proposed Method

VI. Conclusion

Image denoising has become a crucial step for correct diagnosis. The current need of healthcare industries is to preserve useful diagnostic information with minimum noise. In this paper, the proposed method's performance for denoising an image is evaluated both subjectively and objectively. The experimental results prove that the proposed method produces images which are cleaner and smoother and at the same time kept significant details, resulting in a clearer and appealing vision. The experimental result also shows that the proposed method restores the fine details, such as lines, frontiers and corners efficiently and shows better results when comparing with the basic median filter.

VII. References

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