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An Efficient Two step Algorithm for Despeckling the Ultrasound Image

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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. This algorithm modifies the image through partial differential equation. Rudin et al. [5] introduced a new technique which replaced the multiplicative noise model into additive Gaussian noise. This technique executes well only for additive noise model. Coll et al. [6] presented a non- local pattern for ultrasound images based on patches. This pattern is mainly introduced for de-noising the image with white Gaussian noise and it produced good results when compared with other art filters. 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.

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Similarly, based on multi transducer architecture, a de-noising method is developed by Tsakalakis et al. [14]. This method employed 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

$$I(y, z) = N(y, z).M(y, z) \qquad (1)$$

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 $y=1 \ldots P$ and $z= 1 \ldots Q$.

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

$$I(y,z)=\begin{cases}\mu_{Homo}=\dfrac{n-COV}{n-l} & l\le COV\le p_1,\\ \mu_{Detail}=\max\left(\min\left(\dfrac{COV-p_1}{n-p_1},\dfrac{p_1-COV}{p_2-n}\right),0\right) & p_1\le COV\le p_2\\ \mu_{Edge}=\dfrac{COV-n}{m-n} & otherwise\end{cases} \qquad (2)$$

Where, $y = 1\ldots\ldots P$, $z= 1\ldots\ldots Q$

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 COV whereas high COV shows edge region and medium belonging to the detail region.

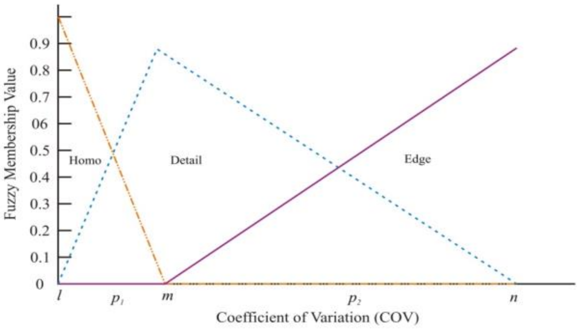


Fig. 1 Triangular Memership Function

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

The details of calculating threshold values are given below

$l = min(COV_k)$
$m = max(COV_k)$
$n = middle(Unique(COV_k))$
$p_1 = average(COV_{[l, n]})$
$p_2 = average(COV_{[n, m]})$

Where, $k \in PxQ$, single (COV_k) represents, if its applied to a vector, then the outcome would include no monotonous value. $[l, n]$, $[n, m]$ denote the range. $COV_{[l, n]}$ represents all value of COV among thresholds l and n. Similarly $COV_{[n, m]}$ represents all values of COV among thresholds n and 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 (COV_k)
   m= max (COV_k)
   n= middle (Unique (COV_k))
   p₁= average ($COV_{[l, n]}$)
   p₂= average ($COV_{[n,m]}$)
   Where, $k \in PxQ$
3. Isolate every pixel of image I into distinct region employing triangular function

$$I(y,z)=\begin{cases}\mu_{Homo}=\dfrac{n-COV}{n-l} & l\le COV\le p_1,\\ \mu_{Detail}=\max\left(\min\left(\dfrac{COV-p_1}{n-p_1},\dfrac{p_1-COV}{p_2-n}\right),0\right) & p_1\le COV\le p_2\\ \mu_{Edge}=\dfrac{COV-n}{m-n} & otherwise\end{cases} \qquad (3)$$

4. Employ suitable filter to denote each pixel of all three regions

$$D'(y,z)=\begin{cases}\vartheta_1 & I(y,z)\in\mu_{Homo}\\ \vartheta_2 & I(y,z)\in\mu_{Detail}\\ \vartheta_3 & I(y,z)\in\mu_{Edge}\end{cases} \qquad (3)$$

Where,

$$\vartheta_1 = \frac{1}{q}\sum_{j=-1}^{1}\sum_{k=-1}^{1} I(y+j,z+k)$$

$$\vartheta_2 = median(\pm(y+j,z+k))$$ Where, $-1\leq (j,k) \leq 1$

$$\vartheta_3 = \frac{\sum_{j=-1}^{1}\sum_{k=-1}^{1} W(i,j)\times I(y+j,z+k)}{\sum_{j=-1}^{1}\sum_{k=-1}^{1} W(i,j)}$$

5. Obtain the De-noised Image *D'(y,z).*

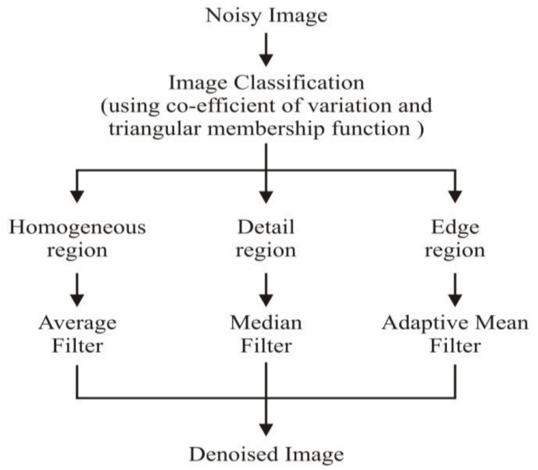


Fig. 2 Flow diagram of the proposed method

B. Adaptive Speckle De-Noising:

To obtain a de-noised image, an appropriate filter will be employed on every pixel of the image H which is classified into homogeneous, edge and detail region pixels. Generally, the noise effect in homogeneous region is very low when compared to edge or detail region. Hence an average filter is enough to remove noise in homogeneous region. For detail region we need to preserve the structural details. Therefore, a structural preserving non-linear filter, median filter would be used for filtering the detail region. In edge region, there is a chance to have both affected and non affected edges. Thus, an efficient filter would be required for denoising the noisy edge pixels to protect edges without distressing the original image content.

(i)Average Filter for Homogeneous Region:

D'(y, z), the new restored pixel value after processing the homogeneous region pixels with average filter, is given by

$$D'(y,z) = \frac{1}{9}\sum_{j=-1}^{1}\sum_{k=-1}^{1} I(y+j,z+k) \qquad (4)$$

(ii) MEDIAN FILTER FOR DETAIL REGION:

Median filter has the capacity to eliminate noise while protecting detail regions. Hence, we have utilized this filter to deal with detail region.

The equation for median filter with moving window of size 3 x 3 is given as follows:

$$D'(y,z) = Med(I(y+j,z+k)) \qquad (5)$$

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

$$D'(y,z) = \frac{\sum_{j=-1}^{1}\sum_{k=-1}^{1} w(j,k)\times I(y+j,z+k)}{\sum_{j=-1}^{1}\sum_{k=-1}^{1} w(j,k)} \qquad (6)$$

$$w(j,k) = r(j,k)\times s(j,k)$$

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

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

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

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

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:

$$MSE = \frac{\sum_{ij}(r_{ij} - x_{ij})^2}{MN} \qquad (8)$$

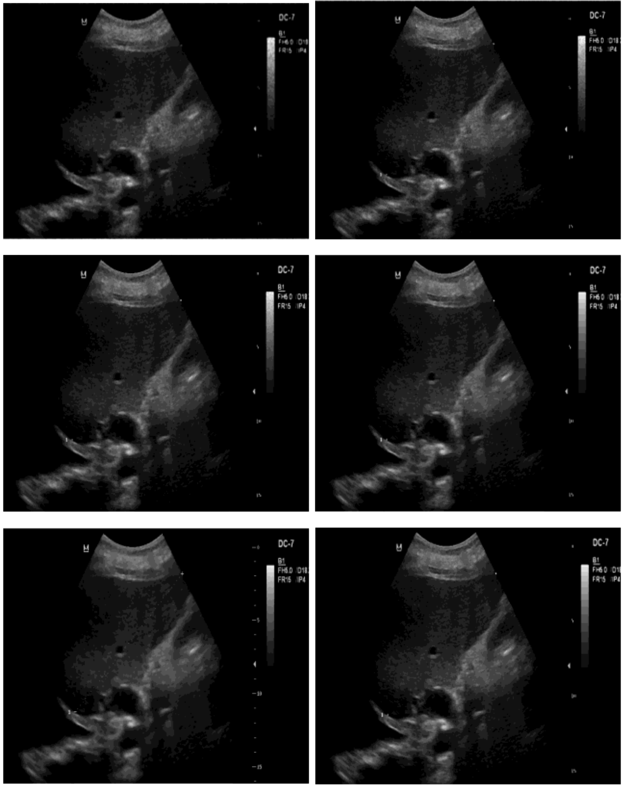
Peak Signal to Noise Ratio (PSNR) is defined as:

PSNR= $$PSNR = 10\log_{10}\left[\frac{255^2}{MSE}\right] \qquad (9)$$

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.



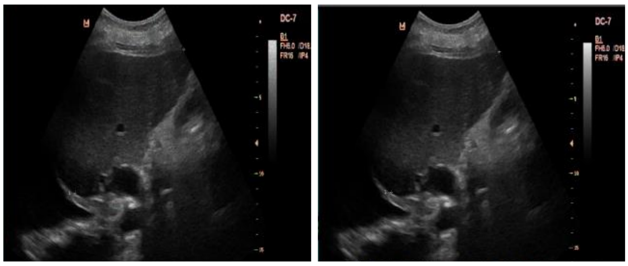


Fig.3 A noisy version of a human liver ultrasound image. Results filtered by (a) Mean, (b) Median, (c) AMF, (d) AWMF, (F) LEE, (g) ASSF, (h) ANSF, (i) ABF, (J) Fuzzy filter and (k) Proposed filter.

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: 1 Quantitative analysis of ultrasound liver image:

Nois algorithm	Speckle noise (10%)		Speckle noise (20%)		Speckle noise (30%)		Speckle noise (40%)	
	MSE	PSNR	MSE	PSNR	MSE	PSNR	MSE	PSNR
Average	128.563	21.574	134.324	20.743	138.528	19.584	145.782	17.362
Median	127.533	26.948	129.335	23.948	136.243	22.683	136.983	19.566
AMF	115.684	27.547	121.854	24.547	128.225	25.852	132.582	21.254
AWMF	112.805	28.365	118.520	26.365	122.569	26.523	127.832	23.226
Lee	110.164	29.814	116.634	27.891	119.234	27.412	123.748	24.263
ASSF	108.361	31.425	112.148	29.425	115.674	29.122	121.962	27.856
ANSF	102.482	33.432	106.872	31.432	112.336	31.326	119.783	29.845
ABF	98.564	34.896	101.634	33.896	108.568	32.258	115.543	31.482
Fuzzy filter	94.854	37.854	98.425	34.854	107.213	34.245	113.869	32.268
Proposed filter	87.238	38.532	92.387	35.532	105.873	35.842	111.852	34.665

Table: 2 Quantitative analysis of ultrasound gall bladder image:

Noise algorithm	Speckle noise (10%)		Speckle noise (20%)		Speckle noise (30%)		Speckle noise (40%)	
	MSE	PSNR	MSE	PSNR	MSE	PSNR	MSE	PSNR
Average	129.352	22.325	135.244	21.223	141.528	19.364	148.963	18.922
Median	128.224	25.369	131.288	24.975	138.243	22.258	142.862	21.655
AMF	114.356	28.854	127.336	27.226	132.456	25.425	138.965	23.346
AWMF	113.244	30.253	120.852	29.572	126.864	26.841	133.569	24.822
Lee	111.521	32.251	118.344	28.698	121.856	27.235	126.853	25.544
ASSF	109.142	34.672	116.254	31.258	119.364	29.954	122.582	27.622
ANSF	105.436	36.549	112.522	35.422	118.668	33.437	120.834	31.411
ABF	102.452	37.292	108.532	36.691	112.569	34.534	116.425	32.558
Fuzzy filter	98.546	38.854	103.854	37.522	105.336	36.246	112.544	33.452
roposed filter	91.543	39.235	96.528	38.532	98.736	37.836	110.256	34.823

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-1image 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 proposed algorithm can proficiently denoising the abdomen ultrasound image and it too develops diagnostic outcomes of modality of ultrasound image.

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