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A SURVEY ON FILTERING METHODS IN ULTRASOUND MEDICAL IMAGES

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ABSTRACT. *Digital image acquisition and process techniques plays necessary role in clinical designation. Medical pictures are usually corrupted by noise throughout their acquisition and transmission. Removing noise from the medical image remains a difficult task for researchers. Ultrasound imaging is widely used for imaging modalities like anti electron Emission picturing (PET), CAT (CT) and resonance Imaging (MRI) because of its non invasive nature, portable, accurate, harmless to the kith and kin and capability of forming real time imaging. The presence of signal dependant noise referred to as speckle degrades the utility of ultrasound imaging. The purpose of speckle reduction is to add the visualisation of the image and it is the pre-processing step for segmentation, feature extraction and registration. various method have been proposed for speckle reduction in ultrasound imaging. The scope of this paper is to administer an outline regarding despeckling techniques in ultrasound medical imaging.*

Keywords: *speckle noise, speckle filters, SNR, PSNR, MSE, CNR, SSIM*

1. **Introduction.** Ultrasound imaging plays major role in medical imaging to its non-invasive nature, accurate, low cost, capability of the real time imaging, harmless to the kith and kin and continued improvement in image quality [1] and [2]. It is used for imaging soft tissues in organs like spleen, uterus, liver, heart, kidney, brain etc. Speckle [3] is found in ultrasound imaging and alternative coherent imaging modalities. Two basic models of noise are Additive and Multiplicative. Additive noise is systematic and can be modelled, hence can be removed easily but multiplicative noise is image dependent, it is hard to model and hence cannot be removed easily. This work gives the analysis of such filters over different variance with the qualitative measurement of quality metrics such as SNR, PSNR, ASNR, FOM, CNR, SSIM, MSE [1]. In this work eight filters and seven different quality metrics are used for five variance values. This work is arranged in the paper as following. Section II describes algorithms for speckle filters. Section III contains

quality metrics details. Section IV discusses on the result analysis and section V concludes the discussion.

2. **Speckling filtering** Basically speckle filters can be classified as scalar (mean and median) and adaptive filters (Lee, Frost, Kuan etc). Both types of filter use a moving window [5]. The main difference between them is that the adaptive filters usually include a multiplicative model and the use of the local statistics. The Frost filter is an adaptive filter, and convolves the pixel values within a fixed size window with an adaptive exponential impulse response. The Lee filter performs a linear combination of the observed intensity and the local average intensity value within the fixed window [6]. In this section some of them are explained with their respective algorithms.

A. *Median Filter*

In median filter operation centre pixel is replaced by the median value of all pixels and hence produces less blurring and it preserves the edges.

Algorithm: 1. Take a 3 × 3 (or 5×5 etc.) region centered around the pixel (i, j).

2. Sort the intensity values of the pixels in the region into ascending order.

3. Select the middle value as the new value of pixel (i, j).

B. *Frost Filter*

Frost filter reduces speckle noise and preserves important image features at the edges.

Algorithm: K = e (- B * S)

Where B = D * (LV / LM * LM)

S : Absolute value of the pixel distance from the centre pixel to its neighbors in the filter window

D : Exponential damping factor (input parameter),

LM : Local mean of filter window

LV : Local variance of filter window.

The resulting gray-level value of the filtered pixel is R = (P1 * K1 + P2 * K2 + ... + Pn * Kn) / (K1 + K2 + .. + Kn)

Where P1,P2,...Pn are gray levels of each pixel in the filter window. K1,K2,...Kn are weights (as defined above) for each pixel. C

C. *Lee Filter*

Lee filter reduces speckle noise by applying spatial filter to each pixel.

Algorithm: Lm + K * (PC - M * LM)

Where, K(weighting function)= M * L / ((LM *LM * MV) (M * M * LV))

Where = 1/NLooks

PC : Centre pixel value of window

LM : Local mean of filter window LV : Local variance of filter window

M : Multiplicative noise mean

MV : Multiplicative noise variance

Nlooks : Number of looks

D. *Weiner Filter*

It reduces noise from image by comparing desired noiseless image. Weiner filter works on the basis of computation of local image variance.

$$f(u,v) = \left[\frac{H(u,v)^*}{H(u,v)^2 + \left[\frac{Sn(u,v)}{Sf(u,v)}\right]}\right] G(u,v)$$

Where, H(u,v) = Degradation function

G(u,v) = Degraded image

S_n (u ,v) = Power spectra of noise

S_f(u,v) = Power spectra of original image.

E. *Kuan Filter*

Applies a spatial filter to each pixel in an image, filtering the data based on local statistics of the centered pixel value.

Algorithm: The resulting filtered pixel value is:

R = PC * K + LM * (1 - K)

Where, CU = 1 / sqrt (NLooks) : Noise variation coefficient

CI = sqrt (LV) / LM : Image variation coefficient

K = (1 - ((CU * CU) / (CI * CI))) / (1 + (CU * CU))

PC : Centre pixel value of window

LM : Local mean of filter window

LV : Local variance of filter window

Nlooks : Number of looks

F. *Enhanced Lee Filter*

The enhanced Lee filter is an altered version of the Lee filter reducing the speckle noise effectively by preserving image sharpness and detail.

Algorithm: Value of smoothed centre pixel:LM for CI <= CU

LM * K + PC * (1 - K) for CU < CI < Cmax

PC for CI >= Cmax

where PC : Center pixel value of window

LM : Local mean of filter window

SD : Standard deviation in filter window

Nlooks : Number of looks

D : Damping factor

CU = 1 / square root (NLooks)(Noise variation coef.)

Cmax=srt(1+2/NLooks)(Max.noise variation coef.)

CI = SD / LM(Image variation coefficient)

K = e(- D (Ci - CU) / (Cmax - CI))

G. Enhanced Frost Filter

Algorithm: $W(x,y) = e^{-kfunc(C_I(x',y'))|(x,y)|}$
Where $func(C_I(x',y'))$ is a hyperbolic function of $C_I(x',y')$ defined as follows.

$$func(C_I) = \begin{cases} 0 & for\ C_I(x',y') < C_B \\ \frac{[C_I(x',y'-C_B]}{[C_{max}-C_I(x',y')]} & for C_B \le C_I(x',y') \le C_{max} \\ \infty & for\ C_I(x',y') > C_{max} \end{cases}$$

H. Gamma Map Filter

Based on the application of maximum a posteriori (MAP) approach, which required the a priori knowledge of the probability density function (PDF) of the image.

Algorithm:

$$U(x',y') = \begin{cases} I'(x',y') & C_I(x',y') < \\ \frac{(\alpha-L-1)(x',y')+\sqrt{I^2(x',y')(\alpha-L-1)+4\alpha L I'(x',y')}}{[C_{max}-C_I(x',y')]} & for C_B \\ I(x',y') & for\ C_I(x',y') \end{cases}$$

Where L is the number of looks,

$C_{max}(x',y') = \sqrt{2C_B}$

And $\alpha = \frac{1+C_B{}^2}{C_I{}^2(x',y')-C_B{}^2}$

3. Quality Metrics. For the quantitative assessment FIVE quality metrics are used on both noisy and filtered images. Quality metrics that are used in this work are signal to noise ratio (SNR), peak signal-to noise ratio (PSNR), contrast-to-noise ratio (CNR), structural similarity (SSIM), edge-region mean square error (MSE). These are explained in following sections.

A. SNR

This is fundamental parameter to measure level of noise. It is widely used. It is the ratio of mean to the standard deviation of pixel amplitudes in an image. Image having maximum speckle noise has SNR 1.91. There is indirect proportion between speckle noise and SNR [14]

$$SNR = 10 \log_{10} \frac{\sigma_g{}^2}{\sigma_e{}^2}$$

B. PSNR:

PSNR is defined from RMSE and quantifies the ratio between the possible power of a signal and the power of corrupting noise [15]. For a gray level image with 256 gray levels, PSNR is defined as,

$$PSNR = 20log_{10}(\frac{255}{RMSE})$$

Where, $RMSE = \sqrt{MSE}$

$$MSE(I_{filt}, I_{ref}) = \frac{1}{XY}\sum_{i=1}^{Y}\sum_{j=1}^{X}\left(I_{filt}(i,j) - I_{ref}(i,j)\right)^2$$

C. APSNR:

C. CNR

This metric operates on a single image and exploits levels of contrast between two different regions of images [8]. One region is a region of interest (ROI) and the other can be a part of the background. This metric is calculated as

$$CNR = \frac{|\mu 1 - \mu 2|}{\sqrt{\sigma 1^2 + \sigma 2^2}}$$

where , µ1 and $\sigma 1$ are mean and variance of ROI and µ2 and $\sigma 2$ are mean and variance of background.

D. SSIM:

Index is another metric for measuring the similarity between two images. This metric has much better consistency with the qualitative appearance of the image [1]

$$SSIM = \frac{1}{M}\sum \frac{(2\mu 1\mu 2 + C1)(2\sigma_{1,2} + C_2)}{(\mu_1{}^2 + \mu_2{}^2 + C_1)(\sigma_1{}^2 + \sigma_2{}^2 + C_2)}$$

between them. SSIM has value between 0 and 1, when it is equal to 1 images are structurally equal.

E. MSE:

This measures the average absolute difference between images [17].

$$MSE(IE_{filt}, IE_{ref}) = \frac{1}{XY}\sum_{i=1}^{Y}\sum_{j=1}^{X}\left(IE_{filt}(i,j) - (i,j)\right)^2$$

Where IE_{filt} and IE_{ref} are edges of filtered and reference images respectively. The edge region MSE measures the average differences in edge regions.

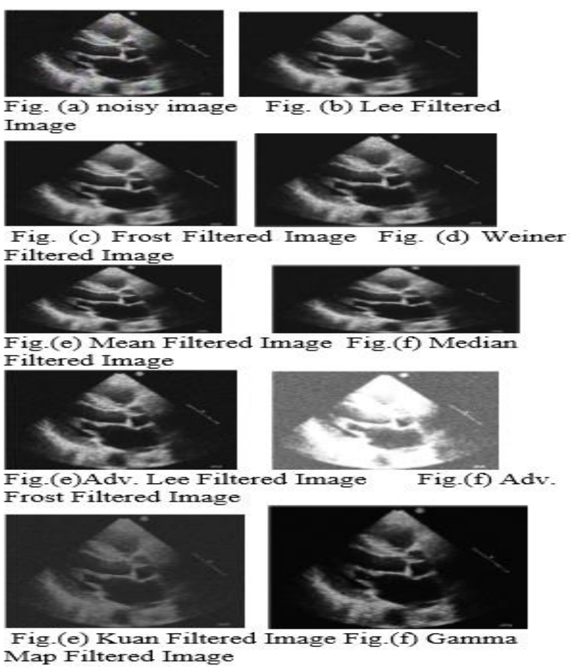

Fig. (a) noisy image Fig. (b) Lee Filtered Image

Fig. (c) Frost Filtered Image Fig. (d) Weiner Filtered Image

Fig.(e) Mean Filtered Image Fig.(f) Median Filtered Image

Fig.(e)Adv. Lee Filtered Image Fig.(f) Adv. Frost Filtered Image

Fig.(e) Kuan Filtered Image Fig.(f) Gamma Map Filtered Image

4. Experimental Results and Analysis. To remove speckle noise from echo images nine filters (Lee, Frost, mean, Median, Kuan, Advanced Lee and Frost, Gamma Map and Wiener) are used in this work. This filtering is done for the values of variances (0.02). Results are shown in following figures.

Result analysis is done by measuring five quality metrics (SNR, PSNR,CNR,SSIM, MSE.) Following tables shows comparative analysis of nine filters for different variance value.

Table 1. Quality metrics readings for speckle variance 0.02

QUALITY METRICS	SNR	PSNR	CNR	SSIM	MSE
Mean	14.06	22.71	0.04	0.78	635.7
Median	17.15	25.69	0.02	0.74	222.1
Lee	18.59	26.08	0.02	0.77	211.3
Frost	17.15	24.72	0.02	0.74	279.4
Kuan	6.17	14.68	0.33	0.6	368.8
Adv.lee	17.15	25.04	0.02	0.73	234.1
adv.frost	0.032	6.43	1.42	0.04	188.7
Weiner	18.58	29.19	0.02	0.77	178.5
GMap	0.032	6.43	1.4	0.04	190.9

5. Conclusion. This filter work the speckle noise with the nine completely different filters. Filtering analysis is completed by exploitation the five completely different quality metrics for the variance values. As speckle variance will increase noise additionally will increase. For higher values of speckle variance filter performance reduces slightly. Adaptive filters corresponding to Lee, Frost, Advanced Lee and Frost and wiener provides a lot of acceptable results.

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