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Denoising of Medical Ultrasound Images using Wavelet Transform with Bilateral Filter

T.Joel, J. Yogapriya

Abstract--Medical image degradation contains a significant impact on image quality and therefore affects the human interpretation and also the accuracy of computer assisted diagnostics techniques, unfortunately ultrasound images are principally degraded by an intrinsic noise known as speckle noise. Therefore, de- speckle filtering may be pre-processing step in medical ultrasound images. During this paper we propose a new image de-noising technique is the combination of bilateral filter and wavelet transform. The main contribution of this paper is within the use of a new neighborhood relationship to develop a new multi-scale bilateral filter. Experimental outcomes validate the usefulness and also the correctness of the proposed filter in edge preservation and speckle noise reduction for medical ultrasound images.

Key Words: Bilateral filter, speckle, wavelet transform, ultrasound image.

I. INTRODUCTION

Medical ultrasound images are typically corrupted by noise in its acquisition and transmission. Thus, the poor image quality is one of the major drawbacks of the ultrasound image because of speckle noise. Furthermore, the main challenge in image de-noising is to remove such noise whereas conserving the necessary options and details. Therefore, the reduction of speckle is critical to enhance the standard of echo-graphic images and to facilitate its interpretation. A number of ways are created to reduce the speckle noise using various types of filter. De-speckling filter techniques is classified as single scale spatial filtering (linear, nonlinear, adaptive methods etc.). Multi-scale filtering is based on wavelet, curvelet, contourlet, etc. Mean filtering and gaussian filtering are the samples of linear ways that blur the sharp edges, destroy lines and suppress the details. The nonlinear filtering is used to avoid the downside. Bilateral filtering is one of the most samples of nonlinear filtering introduced by Tomasi et al. [1].

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* Correspondence Author
T.Joel*, Associate Professor, R.M.K. Engineering College, Gummidipoondi, Tamil Nadu, India.
J. Yogapriya, Programmer Analyst, Cognizant Technology Solutions

It extends the conception of mathematician on smoothing by weight the filter coefficient with their corresponding relative component intensities. The fundamental plan of bilateral filter is to exchange a pixel value worth in an image by a weighted sum of the pixels in local neighborhood whose weights depends upon each spatial distance and the intensity distance between central component and its neighbours in shot noise adaptive bilateral filter introduced by Phelippeau et al. [2]. Speckle noise reduction in medical ultrasound by adaptive median filter is introduced by Kaun et al. [4]. Median filter is one of the techniques for removing the speckle noise from the ultrasound image and it can be adjusted and applied with the ultrasound images. This local filter where n*n mask is applied over the entire image. A study of speckle noise reduction filters introduced by Kaur et al. [5]. Frost filter is a convolution filter, linear, used to remove the speckle noise from images. The kernel size of n x n then the middle pixel value is replaced by weighted sum of values of the neighborhood. Lee filter is an improved filter when compared to other filters in edge protection. It is based on speckle model and uses local statistical to preserve details. It performs smoothing operation but not for high variance. Image de-noising for speckle noise reduction in ultrasound images using DWT techniques introduced by Kaur et al. [5]. Weiner filter was adopted for filtering in the spectral domain. It is applied to an image adaptively, tailoring itself to the local image modification. It performs little smoothing where the variance is small. It produces better result than linear filtering.

II. PROPOSED METHOD

The proposed method based on the combination of bilateral filter and the wavelet transform is illustrated in figure. A basic theoretic overview of this tools, is presented in the next sections.

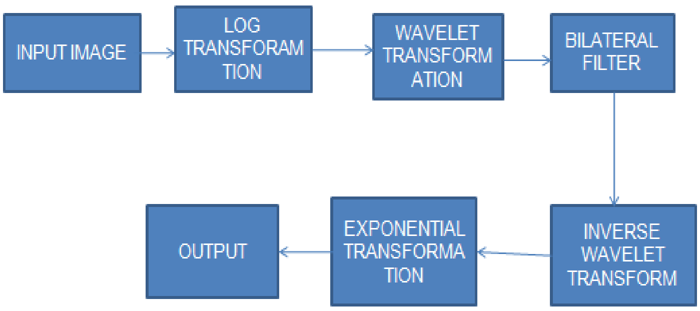

Fig 1 Block diagram of proposed method

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The input noisy image is modelled by log transformation. To the log transformed image wavelet transform is applied. The coefficients obtained from the transform is applied to the bilateral filter. Bilateral filter consists of domain filter and range filter. The use of domain filter is to suppression of noise and smoothening whereas range filter helps in preserving edges.

A. WAVELET TRANSFORM

The wavelet transform refers to the discrete wavelet transform [DWT] in which sampling of wavelet is done in a separate way and it is important to use DWT rather than Fourier transform as it has adjustable window size. Hence, scaling can be done in this and calculation time taken in DWT transform is very less as compared to Fourier transform in which time taken is more than Discrete wavelet transform. 1-D DWT is applied along the rows in order to perform 2-D wavelet decomposition, after that apply 1-D DWT along columns. This process results in four decomposed sub-band images referred to as high-high (HH), low-high (LH), low-low (LL) and high- low (HL). For multi resolution examination the LL band of previous level is again decomposed by Discrete Wavelet Transform [6].

B. BILATERAL FILTER

Bilateral filtering was presented by Tomasi and Manduchi [1]. It is accomplished by the combination of two gaussian filters. One filter works in intensity domain and the other filter works in spatial domain. It is a non-linear filter where the output is a weighted average of the input. The bilateral filter formulas are referred to ultrasound image de-noising using a combination of bilateral filtering and stationary wavelet transform introduced by Chin el al. [7]. The bilateral filter output for a pixel is defined as follows for an ultrasound image.

$$J_s = \frac{1}{K(s)} \sum_{p \in \Omega} (p - s) g(I_p - I_s) I_P$$

where K(S) is a normalization term.

$$K(s) = \sum_{p \in \Omega} f(p - s) g(I_p - I_s)$$

where g uses a gaussian in the intensity domain which characterizes the range filter and f uses a gaussian in the spatial domain which signifies the domain filter.

Mathematically domain filtering can be expressed as:

$$J_s = \frac{1}{K(s)} \sum_{p \in \Omega} (p - s) g(I_p - I_s) I_P$$

where

$$f(p - s) = exp^{-\frac{\|p-s\|^2}{2\sigma d^2}}$$

The spatial closeness between the neighborhood center and a nearby point is measured by f(p-s).

Range filtering is defined as follows

$$J(s) = \frac{1}{k_r(s)} \sum\nolimits_{p \in \Omega} g(I_p - I_s) I_P$$

where

g(Ip-Is) measures the photometric similarity between the center pixel and its nearby point p.

$$g(I_p - I_s) = exp^{-\frac{\|Ip-Is\|^2}{2\sigma d^2}}$$

Normalized constant in this case is

$$K_r(s) = \sum_{p \in \Omega} g(I_p - I_s)$$

III. PERFORMANCE METRICS

To show improvement in speckle reduction various parameters are measured in terms of Mean Square Error (MSE), Signal–to–Noise ratio (SNR) and Peak signal-to-noise ratio (PSNR). SNR is defined as

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

PSNR is defined as

$$PSNR = 10\, log_{10} \left(\frac{255^2}{MSE}\right)$$

MSE is defined as

$$MSE = \frac{1}{MxN} \sum_{j=1}^{M} \sum_{k=1}^{N} \left(X_{j,k} - X'_{j,k}\right)^2$$

Where

MxN = size of image

X = original image

X’ = reconstructed image

IV. RESULTS AND DISCUSSION

In this segment we performed several metrics to test the performance of the projected method and noisy medical ultrasound image.
To remove speckle noise from denoised images four filters [median, lee, frost, wiener] are compared with the proposed method of wavelet with bilateral filter.
Analysis of the result is done by measuring three quality metrics [MSE, SNR, PSNR]. Following tables shows comparative analysis of four filters.

Table 1: Results obtained for different filters

Metrics	Median	Lee	Frost	Weiner	Proposed Method
PSNR	26.56	27.81	26.76	26.85	**28.55**
SNR	16.51	17.76	16.71	16.80	**18.52**
MSE	0.351	0.348	0.426	0.435	**0.142**

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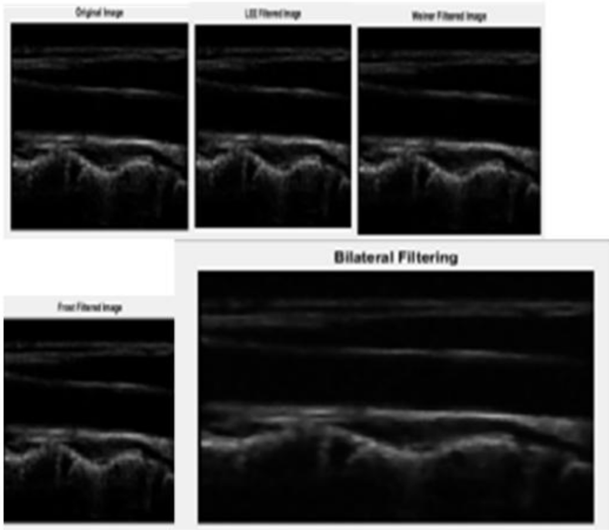

Fig 2 Output images of various filters

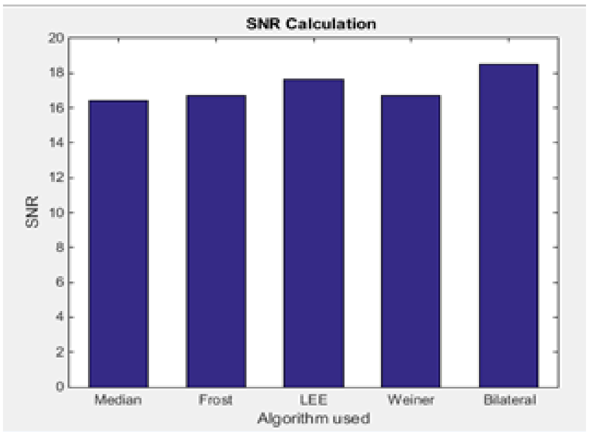

Fig 3 SNR calculation for various filters

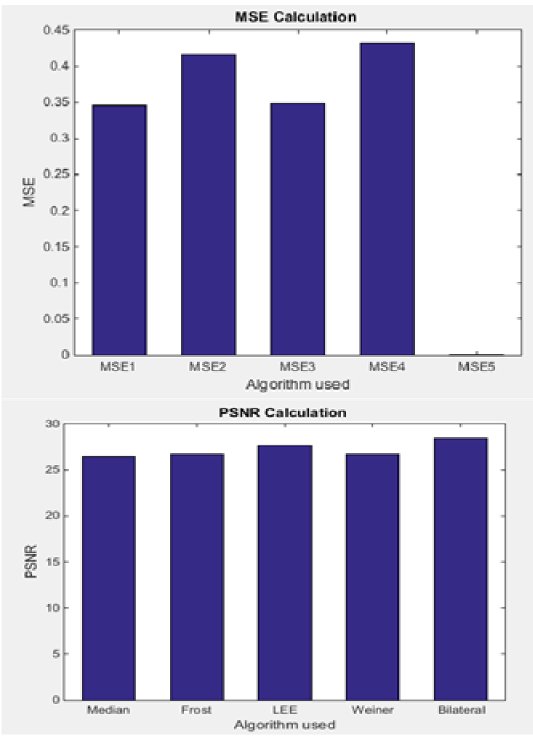

Fig 4 MSE and PSNR values of various filters

The performance of the proposed method was evaluated using various metrics. The input noise image is a spleen ultrasound image and was reconstructed using the proposed method and compared with median filter, frost filter, lee filter and wiener filter. Fig 3 shows SNR values of the proposed method is better when compared with median, frost, lee and wiener filter. Fig 3 shows MSE and PSNR values, which indicates the proposed wavelet transform with bilateral filter method shows improvement when compared with the other filters. Table 1 clearly indicates that the performance of the proposed method is better than the other filters. Fig 2 indicates the output image of the various filters with the proposed method. The output image obtained due to the proposed method provides a better noise suppression and edge preservation.

V. CONCLUSION

We established how a simple pre-processing step can significantly improve the denoising performance of the proposed method. The proposed method wavelet transform with bilateral filter shows better performance in terms of visual appearance as well as improvement in parameter values of SNR, PSNR and MSE when compared with median, frost, lee and wiener filter.

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AUTHORS PROFILE

Mr. T.Joel, M.E Associate Professor, R.M.K.Engineering College, Gumidipoondi, Tamil Nadu, India. tjl.ece@rmkec.ac.in

Ms. J. Yogapriya, M.E. Programmer Analyst, Cognizant Technology Solutions, Siruseri, Chennai Tamil Nadu, India. yogapriya.j@cognizant.com