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Speckle Noise Reduction in Ultrasound Images using IWD

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Abstract: *This paper implements Intelligent Water Drop (IWD) technique for removal of speckle noise from the ultrasound images. Noise is a factor that degrades the quality of images, so we need to use an efficient technique to remove the noise from the images. IWD algorithm removes the noise and also retains the useful information of the medical image. It improves the quality of an image. In this work, removal of speckle noise has been tested on 5 ultrasound images by using IWD technique. Moreover IWD technique has been compared with the median filter and wavelet denoising methods on the basis of the parameters namely Peak Signal to Noise Ratio (PSNR), Structural Similarity Index for Measuring image quality (SSIM), Coefficient of correlation (Coc) and Edge Preservation Index (EPI). The results show that the IWD technique is better than wavelet denoising and median filter for removal of speckle noise as well as edge preservation*

Index Terms: *speckle noise, wavelet filter, IWD, median filter and ultrasound images.*

I. INTRODUCTION

Noise is a factor that degrades the quality of images during the processing of images *e.g.* while we are acquiring the images or transmitting the images. So noise reduction is important for processing of images and for interpretation of images so that we can get the useful information from the images. There are many types of noises which get added in the images such as guassian noise, speckle noise, salt and pepper noise *etc.* Various types of noise removal techniques are used for removing these types of noises. One of the most important factor in noise removal technique is completely removing the noise as well as preserving the edges so that we can preserve the useful information of an image. Traditionally, two models are used *i.e.* linear model and nonlinear model. Linear model is used to remove the noise at a faster speed but it is not an efficient model for preserving edges where edges are discontinuities in an image. Non linear models are those which are used to remove the noise as well as preserve the edges efficiently.

In this paper, we present a method to reduce speckle noise which is generally seen in the ultrasound images. An image containing speckle noise produces bright and dark pixels because of the interference of waves in an unrealistic manner. Speckle noise can be removed by using median filters and wavelet transformation techniques. But in these techniques there is a trade-off between the PSNR (Peak to Signal Ratio) and Edge Preservation Index (EPI). In this work, for removal of speckle noise the IWD technique has been applied on 5 ultrasound images namely left kidney, right kidney, 3D feet/legs, liver and 3D ultrasound image and also preserve the edges in an efficient manner. The performance of IWD technique is determined by finding PSNR, EPI, SSIM and Coc. This paper is organized into eight sections. Overview of noise is given in first section. Introduction about the

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medical images is given in second section. The third, fourth and fifth sections give a brief overview of the different techniques *i.e.* median filter, wavelet filter and IWD technique to restore/ denoise the image. The different parameters used as performance metrics are explained in sixth section. Results and discussion of this research is presented in seventh section. The conclusion and the future scope are given in eighth section respectively.

II. MEDICAL IMAGES

The pictures or the images taken from the body parts of human beings are called Medical images. The Medical images are used by the doctors for diagnosis purposes or to examine the diseases occuring in human body. So it is very important to get the better visualization of medical images. Medical images can be acquired through MRI (Magnetic Resonance Imaging), CT (Computed Tomography) or through ultrasound waves. The images acquired through MRI provide better quality but takes long time for processing. CT provides good resolution in images but it is not good for patients because of harmful radiations radiated during processing. Ultrasound images are generally preferred because these can be quickly acquired in an economic and non surgical manner without ionizing radiations [1]. So ultrasound imaging is widely used but it has one major limitation *i.e.* there is presence of speckle noise due to interference of waves which degrade the quality of an image [2].

To remove the noise from the medical images by using various denoising techniques is called medical image processing. In this work, we have taken five ultrasound images to remove the speckle noise for the better visual quality of the images so that the doctors can examine the images for proper diagnosis.

III. MEDIAN FILTER

In a median filter, the pixels of an image containing noise are replaced with median value and neighbourhood of these pixels are arranged in a numerical order. These neighbourhood pixels make a window. Different shapes of window have been chosen for different type of images. Square shaped window is preferred for 2D images. Generally median filter operates on a window containing odd number of pixel values but if pixel values are even then median is taken by the average of two middle values. Median filtering is a non-linear technique that performs best with the impulse noise while retains sharp edges from an image. The output of median filter is calculated by taking median of the input values. The main disadvantage of median filter is that the computation time required to arrange the intensity value of each set is very long and they are very expensive [3].

IV. WAVELET FILTER

Discrete Wavelet Transform (DWT) is applied on an image and then hard and soft thresholding can be applied over the wavelet coefficients. DWT transforms function space of original image into a different domain [4]. Then to get the denoised image, Inverse DWT (IDWT) is applied on the image which includes the exponential transformation that is applied to reverse the logarithm function. In this way, the image is restored. But there is always a trade-off between noise removal and edge preservation. The noise present in an image generally reduces the resolution and brightness of an image. So wavelet filters are used to remove the

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noise from an image and also retain the useful information from an image.

V. IWD Technique

The main objective of the IWD Technique is to eliminate the noise and retain the useful information from the ultrasound images. Intelligent Water Drop (IWD) is a technique to restore the image. It depends on two things *i.e.* soil and velocity. Where the soil is more, the velocity of water is less and where the soil is less, velocity of water is more. In this concept, the soil indicates the noise in an image. To determine the quantity of noise present in an image, we need to determine the velocity of a pixel by adding some water drops in a pixel. If velocity of water is less in a particular pixel, then it will replace that pixel with the mean value to remove the noise and the same process is repeated for the whole image. In this way, it will restore the complete image. This technique is actually based on action and reactions of the water drops in a river or in an image [5].

In this work, the noise is reduced by using IWD in MATLAB, the algorithm of which is as follows:

Step 1: Capture the image by using any device like camera, scanner or any other.

Step 2: Speckle noise is added into an original image.

Step 3: Wavelet transform is applied on an image.

Step 4: Determine the coefficients of IWD *i.e.* soil and velocity.
Velocity is updated while moving from pixel i to pixel j.

$$vel^{IWD}(w+1) = vel^{IWD}(w) + \frac{r_v}{s_v + t_v . soil^2(i,j)}$$

Where vel^{IWD} (w+1) = updated velocity
Velocity is updated by using parameters *i.e.* $r_v = 1$, $s_v = 0.01$ and $t_v = 1$.
Soil and velocity are the dynamic parameters and N_{iwd} *i.e.* no. of water drops which indicates the set of positive integers are the static parameters.

Step 5: Calculate the mean value.

Step 6: Replace the least value of velocity with the mean value.

Step 7: A single pixel of an image is restored.

Step 8: Repeat this process for the whole image.

Step 9: An image is restored.

VI. RELATED PARAMETERS

The performance of denoising techniques are determined and compared in terms of various performance metrics, which are discussed below:-

1. Peak Signal to Noise Ratio (PSNR): It is defined as the ratio of signal power to noise power. It basically provides the gray value difference between resulting image (Denoised image) and original image.
Mathematically:

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

Where MSE is Mean Square Error

The higher the value of PSNR, the quality of reconstructed image becomes better.

2. Coefficient of Correlation (Coc): It is used for checking the quality of denoised image.

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Mathematically:

$$\text{Coc} = \frac{\sum(g-\bar{g}).(\hat{g}-\bar{\hat{g}})}{\sqrt{\sum(\Delta g-\overline{\Delta g})^2 . \sum(\Delta g-\overline{\Delta \hat{g}})}}$$

Where $\bar{g}$ is mean of original image, $\bar{\hat{g}}$ is mean of denoised image, g is the original image and Δg is change in original image. $\hat{g}$ is the denoised image and $\overline{\Delta \hat{g}}$ is the mean of change in denoised image.

Lower is the value of Coc, better is the quality of the reconstructed image.

3. Structural Similarity Index (SSIM): This parameter measures the similarity between two images. This parameter compares the degraded image with the reference image *i.e.* non degraded image. This performance metric is a better measure to determine the image quality than PSNR and MSE (Mean Square Error). It provides the better human eye perception of images. Mathematically:

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

Where,

μ_x, μ_y= average of x, average of y

σ_x, σ_y= variance of x, variance of y

σ_{xy} = covariance of x and y

$c_1 = (k_1 \times l)^2$, $c_2 = (k_2 \times l)^2$

where l is dynamic range of pixel value.

$k_1 = 0.01$, $k_2 = 0.03$

Higher the value of SSIM, more is similarity between two images.

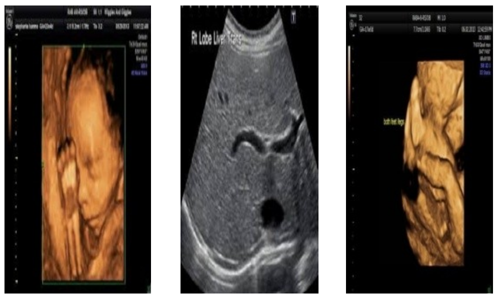
4. Edge Preservation Index (EPI): Edge Preservation Index indicates how many edges are preserved from an image. Mathematically:

$$EPI = x/y$$

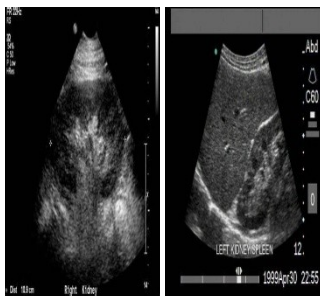
Where x is number of edges and y is number of edges preserved. Lower the value of EPI, better the preservation of edges.

VII. EXPERIMENTAL RESULTS AND DISCUSSION

In this work, 5 ultrasound images *i.e.* 3D ultrasound image, Liver, 3D feet/legs, Right kidney and Left kidney has been taken as shown in Fig.1. Then different filtering techniques namely Median filter, Wavelet filter and IWD technique has been implemented on these 5 ultrasound images as shown in Fig. 3, 4, 5, 6 and 7. The values of parameters after applying the above mentioned filters have also been tabulated in Table 1 to 5.



(a) (b) (c)



(d) (e)

Fig1: Original ultrasound images: (a) 3D (b) Liver (c) 3D limbs or both feet/legs image (d) Right kidney (e) Left kidney.

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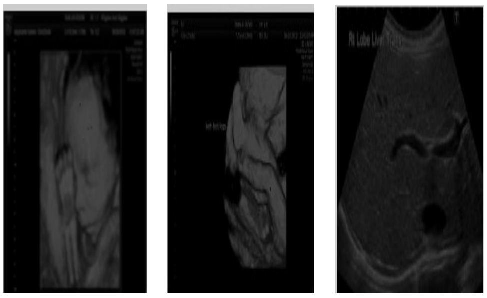

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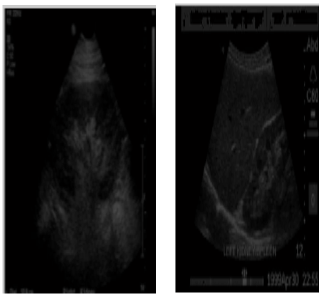
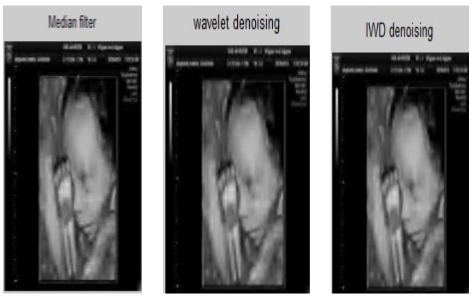


(d) (e)

Fig 2: After adding speckle noise to images of Fig 1

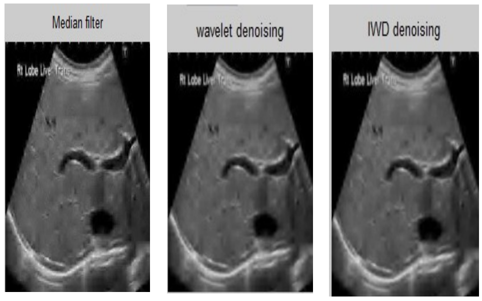


(a) (b) (c)

Fig 3: Results after applying (a) median filter (b) wavelet denoising (c) IWD to 3D ultrasound image

Table 1: PSNR, SSIM, EPI, Coc results of 3D ultrasound images

Method / Parameter	Median Filter	Wavelet denoising	IWD
PSNR	33.5832	33.1077	41.3708
Coc	0.997284	0.998838	0.999345
SSIM	0.0632098	0.0641516	0.424228
EPI	0.76614	0.681638	0.60805

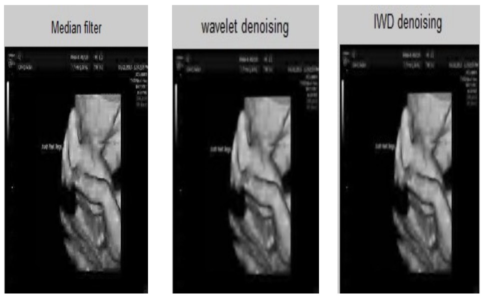


(a) (b) (c)

Fig 4: Results after applying (a) median filter (b) wavelet denoising (c) IWD to liver

Table 2: PSNR, SSIM, EPI, Coc results of liver ultrasound image.

Method / Parameter	Median Filter	Wavelet denoising	IWD
PSNR	29.9073	32.2983	40.7143
Coc	0.99484	0.997978	0.998746
SSIM	0.0837839	0.083858	0.289987
EPI	1.21457	1.03903	0.571164



(a) (b) (c)

Fig 5: Results after applying (a) median filter (b) wavelet denoising (c) IWD to both feet/legs or 3D limbs.

Table 3: PSNR, SSIM, EPI, Coc results of 3D both feet/ legs ultrasound image.

Method / Parameter	Median Filter	Wavelet denoising	IWD
PSNR	25.1326	33.16	40.2483
Coc	0.989133	0.997294	0.999088
SSIM	0.0390545	0.0411081	0.48081
EPI	0.796124	0.714971	0.50379

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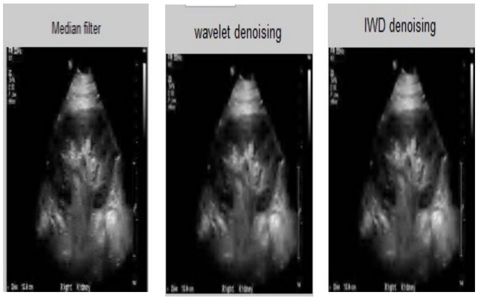
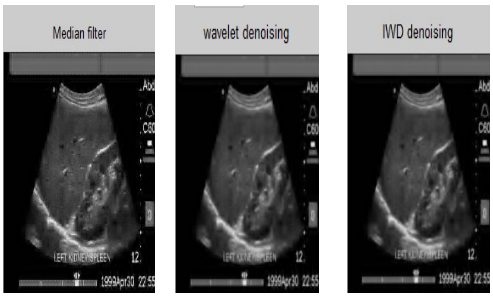


(a) (b) (c)

Fig 6: Results after applying (a) median filter (b) wavelet denoising (c) IWD to right kidney.

Table 4: PSNR, SSIM, EPI, Coc results of right kidney ultrasound image.

Method / Parameter	Median Filter	Wavelet denoising	IWD
PSNR	29.4955	34.7351	39.2856
Coc	0.987894	0.99483	0.998266
SSIM	0.0270865	0.0274326	0.313406
EPI	0.600005	0.554465	0.43741



(a) (b) (c)

Fig 7: Results after applying (a) median filter (b) wavelet denoising (c) IWD to left kidney

Table 5: PSNR, SSIM, EPI, Coc results of left kidney images

Method / Parameter	Median Filter	Wavelet denoising	IWD
PSNR	26.9345	33.1593	36.0529
Coc	0.985666	0.992674	0.996369
SSIM	0.0286595	0.0294504	0.267206
EPI	0.391446	0.324667	0.266409

From the simulation results, it is observed that IWD technique provides higher values of PSNR, SSIM and lower values of EPI which improves the quality of an image. But it provides higher value of Coc which should be less to get better quality image. The Median filter provides lower Coc value but other parameters namely PSNR, SSIM and EPI are not as good as with IWD technique and wavelet filter. Wavelet filters are better than Median filters on the basis of the parameters used in this work except Coc parameter. From the simulation results, we can say that IWD technique is better for the removal of speckle noise as well as edge preservation in ultrasound images. Further, IWD technique provides best results in 3D images out of 5 ultrasound images that have been taken in this work.

VIII. CONCLUSION AND FUTURE SCOPE

Removal of noise from an image is an important task in image processing. Many denoising methods fail to preserve the edges of an image. So we are not able to get the useful information from the image. But in medical applications edge preservation is an important task so as to preserve the useful information for diagnosis purposes. Our conducted experiments show that Intelligent Water Drop (IWD) technique provides higher PSNR values, higher SSIM and lower EPI values than median filter and wavelet denoising methods which in turn improve the quality of an image. Hence IWD technique provides better noise removal as well as edge preservation than median and wavelet transform techniques. So IWD overall provides better utilities than median filter and wavelet denoising methods in the applications such as medical where edge preservation is required along with noise removal.

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In the present work, we have implemented only one optimization algorithm over 5 ultrasound images *i.e.* 3D images, right kidney, left kidney, 3D feet/legs and liver. The results are encouraging for PSNR, SSIM and EPI. In future, work can be extended to improve Coc also by hybridising the present technique with other denoising technique.

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