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Comparative Study of Different Levels of Discrete Wavelet Transform With Filters for Removal of Speckle Noise

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Abstract –

The medical images or ultrasound images are widely used in medical fields for different purposes. In medical images the quality of images effected due to addition of noise. Speckle noise effects the image by which images gets blurs or degradation occurs in the quality of image at receiver side. Speckle noise makes the image indistinct or unclear which is not easy to see clearly. There are many technique by which quality of speckle noise effected images can be increased .The comparative study is done by applying different levels of discrete wavelet transform and also the performance of this different levels are compared with filters specially the wiener filter. The PSNR of these different levels of discrete wavelet transform and also the PSNR of these different levels with wiener filters are calculated. The Comparative study shows that better PSNR value is obtained by addition of filters with discrete wavelet transform.

Keywords- Leena images; speckle noise; wiener filter; dwt; wavelet transform

I. INTRODUCTION

In medical field the noise is very common problem existing from long time and still research is in progress. In digital image processing the occurrence of noise during image transmission and image acquisition. There is two types of noise that is multiplicative noise and additive noise. Additive noise is easy to remove while multiplicative noise is hard to remove. According to the nature of the noise different methods can be applied to remove the noise. Speckle noise is different type of noise in the coherent imaging of objects.[2].Speckle noise for resolution objects often multiplicative in nature and it occurs whenever the surface roughness of the object or object image is the order of the wavelength of the incident wave that is whenever photo digitization is done by optical scanners ,chances of speckle noise to occur increases because the order of wavelength of incident radiation and roughness of paper resembles. Mathematically it can be defined as

$$v(x,y)=u(x,y)s(x,y)+\eta(x,y) \quad .....(1)$$

where s(x,y) represents speckle noise intensity,u(x,y) is speckle noise and η(x,y) represents white Gaussian noise[1].

The noise may or may not signal dependent and it may be correlated or uncorrelated. The two important classes of noise are defined further.

Additive noise: If the noise generation takes place from the sensors is called white Gaussian noise. This noise is additive in nature which can be represented by following equation

$$g(x,y)=f(x,y)+\eta(x,y) \quad .....(2)$$

where g(x,y) represents resulted image,f(x,y) is original image,η (x,y) is Gaussian noise.

Multiplicative noise: The noise from photographic plate which is grainless in nature is essentially multiplicative noise. The speckle noise in synthetic aperture radar and in ultrasound images is also multiplicative in nature which can be defined as:

$g(x,y)=f(x,y)\times\eta(x,y)$.....(3)

Where η (x,y) represents multiplicative noise.

The main aim of image denoising methods is that remove as much as possible noise while retaining important signal features as much as possible. Ultrasonic images are widely used medical images which is mainly corrupted by the speckle noise which is unwanted or unattractive because it degraded the quality of images and due to this problem in individual interpretation and diagnosis. According to this speckle filtering is pre-processing central step for extraction of features and recognition from medical imagery[1][3][4].

II. Image Denoising Techniques:

There are many available filters for speckle noise reduction,some have better visual interpretations while others gives good smoothing capabilities. The good filters for removal of this noise is wiener filter, lee filter, kuan filter and frost filters. These filters are based on spatial type filtering in a square moving window which is known as kerne. This works on central pixels as well as surrounding pixels. The filter window size may vary from 3 by 3 to 33 by 33.The only condition is that size of window must be odd. If large size of window is taken the important information must be lost due to over smoothing and if the window size is less or too small then also it will not give desired or good results. Mostly preferred windows are of size 3 by 3 or 7 by 7 as it gives better results[9].

A. Median filter

This filters works on centre pixel means. In this the window moves through image pixel by pixel and then replacing each value with the median value of neighboring pixel. The way pattern is seen of neighbors is called window. Which slides on pixels that is pixel by pixel over the entire image. The median value can be calculated by first sorting all values of pixels from window into numerical order and then value of considered pixel can be replaced by middle pixel value. This technique is non linear filtering technique specially removes salt and pepper noise. This filtering is effective in strong spike components and characteristics to be preserved are edges. The disadvantage of this filter is that it takes extra computation time which is needed to sort the value of intensity of each set [5].

B. Wiener filter

This filter is also known as least mean square filter. This filter is proposed in 1942 and it is applied adaptively on the image according to the value of variance. It minimize the mean square error in inverse filtering process and in noise smoothing. In this linear estimation is done of the original image.[10]. If the value of variance is small it performs smoothly. If the value of variance is large wiener filter performs less smoothly. This type of approach gives better results as comparison to the linear filters. The expression for wiener filter is as follows:

$f(u,v)=H(u,v)*H(u,v)_2+S_n(u,v)Sf(u,v)G(u,v)$.....(4)

Where $H(u,v)_2$ called degradation function and H(u,v)* called conjugate complex. G(u,v) called degraded image. Functions Sf(u,v) and Sn(u,v) are called power spectra of original image and the noise effected image. [6].

III. Discrete Wavelet Transform Technique

There are many techniques used to reduce the effect of speckle noise by using the wavelets. Here the technique used is known as Discrete Wavelet Transform(DWT). In DWT technique first the image is divided into four different parts HH,HL,LH and LL. Where the HH,HL,LH are detailed part and LL which is known asapproximation part.

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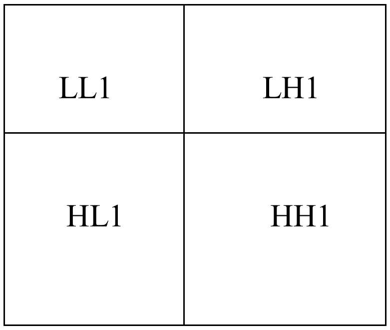


FIG1: Single level thresholding decompostion by using DWT[10].

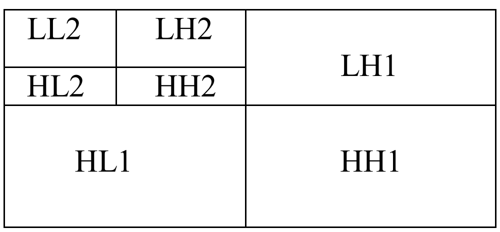


FIG2: Two level thresholding decomposition by using DWT [10].

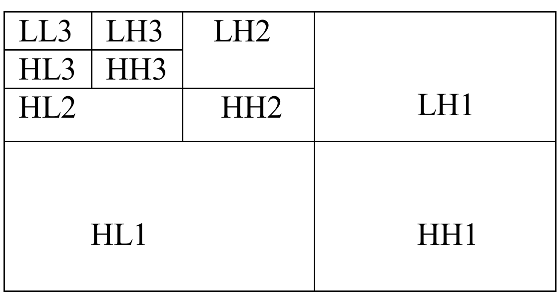
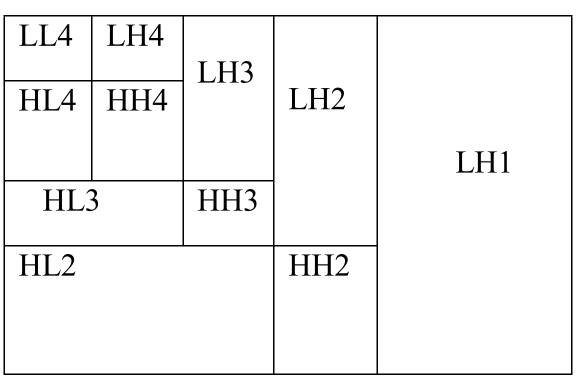


FIG: Three level thresholding decomposition by using DWT[10].

Discrete wavelet transform level 4 shown as follows:



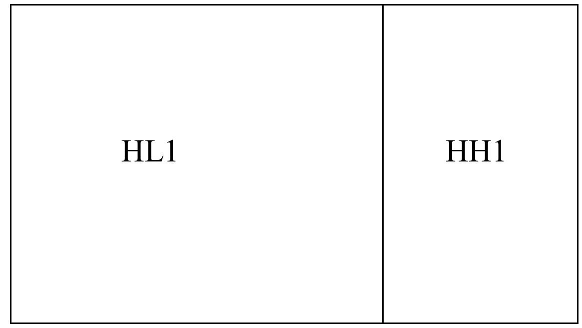


FIG4. Four level thresholding decomposition by using DWT [10].

DWT is used to decrease the speckle noise from the image. The main three steps are described below:

1. Calculate the DWT of the input noisy image.

2. Threshold the wavelet coefficients.
3. Calculate the IDWT to get the denoised image. There are mainly two types of thresholding is used. Soft thresholding and hard thresholding . Soft thresholding is used to delete the high frequency components in which the speckle noise takes place but some needed information is also lost. Soft thresholding function can be described as follows: $n2(w)=(w-sgn(w)T)I(|w|>T)$
Where sgn(x) called as sign function of x. The soft thresholding is preferred over hard thresholding technique.
Hard thresholding deletes or reduces the low frequency components but it also loses some needed information. The hard thresholding can be described as the following equation represents: $n1(w)=wI(|w|>T)$
Where w represents wavelet coefficient, T represents threshold [1][3][11]. In this research work the different levels of DWT techniques are compared as well as these different levels of DWT with the addition of wiener filter is also calculated and compared. The different value of PSNR is obtained with the different standard deviations. In figure LH represents low- high,

HH representshigh- high, HL representshigh-low and LL represents low-low frequency bands.

STEPS OF DWT METHODOLOGY:

1. Load the input image with size [m n]. Where m=n=128,256,512,1024.

2. Add noise into input image by using matlab command or function imnoise.

3. Apply homomorphic filtering or log transformation to the input noisy image.

g(x,y)=f(x,y).η (x,y)

where f(x,y)= original image.

η (x,y)= noise corrupted image.

Now apply homomorphic filtering on above equation:

Log g(x,y)=log[f(x,y).η (x,y)]

z(x,y)=log f(x,y)+logη (x,y).

4. Decompose the image into detail part and approximation part.

5. Calculate the variance of each sub band by using following equations:

Var=median(median(HH)',1) /0.6745

This method is also known as median absolute deviation method given by David l.donoho.

6. Threshold each sub band by the following equation:

Threshold=c*MAD-Q/2

Where MAD can be calculated by step 5.

c=Decomposition of wavelet at different levels.

Q=abs(M-I)

Where M mean is calculated by applying wiener filtering on each sub band on [3 3] or [7 7] window and I is calculated by taking positive value of each sub band.

7. Take inverse discrete wavelet transform of modified wavelet coefficient .

8. Apply wiener filtering on denoised image to get improved results.

9.Take the exponential of output to get final denoised or noise free image.

10. Finally calculate PSNR of denoised image by following equations:

MSE=∑∑(f(x,y)-f'(x,y))/MN

PSNR=10*log10(255*255)/MSE

IV. Results and Conclusion:

Table 1:PSNR value of [3 3] window table using haar family wavelet :

σ / level	0.1	0.2	0.3	0.4	0.5
Level1 DWT	31.263	30.027	29.433	29.052	28.766
Level2 DWT	31.295	30.031	29.434	29.053	28.774
Level3 DWT	31.297	30.048	29.450	29.063	28.782
Level4 DWT	31.298	30.063	29.464	29.073	28.789

Table 1 shows the PSNR value of different levels of discrete wavelet transform by using window [3 3]. The value of PSNR can be obtained from window [5 5] and window [7 7]. But window [3 3] has better results as comparison to these windows. So standard window [3 3] is preferred.

Table2:PSNR value of [3 3] window table of wiener and median filters:

σ / Filters	0.1	0.2	0.3	0.4	0.5
Wiener	30.703	28.320	26.775	25.678	24.834
Median	28.380	26.403	25.159	24.117	23.393

In the above tables the result of standard window [3 3] using haar family wavelet is shown.In the first table the different value of PSNR is obtained with different level of discrete wavelet transform. If the high amount of noise that is with variance 0.5 is added then the level 1 and level 4 shows better PSNR value than others. If the added noise of variance 0.2 then level 2 shows better results than others. If the added noise of variance 0.1 then level 1 shows good results than other levels.

In table 2 the PSNR value of wiener fiter and median filter is compared . The wiener filter gives best PSNR value than median filters as well as other filters. Now the different levels of DWT and wiener filter is combined together the results will be shown in following table:

Table 3: PSNR value of [3 3] window of haar family wavelet for combined different levels of DWT and wiener filter is shown as follows:

σ / DWT +wiener	0.1	0.2	0.3	0.4	0.5
Level 1	34.294	32.702	31.691	30.961	30.432
Level 2	34.298	32.703	31.703	30.985	30.501
Level 3	34.312	32.707	31.732	31.003	30.521
Level 4	34.315	32.730	31.735	31.017	30.543

Compare the table 1 and table 3. A high value of PSNR is obtained in combined method of discrete wavelet transform and wiener filter. A gain of upto 2 to 3 db is obtained in PSNR value. At level 4 highest value of PSNR is observed with variance 0.1, 0.2, 0.3, 0.4 and 0.5. When standard deviation is 0.1, 0.2, 0.3, 0.4 and 0.5 then the highest value observed are 34.315, 32.730, 31.735 and 30.543 respectively in DWT with wiener filteringbecause wiener filter explores a prior knowledge about the noise. In DWT level 4 shows maximum PSNR but low PSNR as compared to DWT with wiener filtering, because in the absence of wiener filter there is no prior knowledge of noise. Thus DWT with wiener filter shows better results than wiener filter,median filter and all other filters. If only DWT technique is used then PSNR value obtained is less than this combined method PSNR.

A. Image result for wiener filter [3 3] window:

(a) Input image leena (b) Noisy image(σ=0.02) (c)Weiner filtered image.

In the above case when speckle noise of standard deviation 0.02 is added then image(a) becomes the image(b) and in image(c) wiener filtering is done and it gives the image clear and least blurred. The value of PSNR obtained here is **28.1056** that is it shows how much image gets denoised.

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B. Results for median filter using window [3 3] with standard deviation(s.d) 0.02:

(a) Input image leena (b) Noisy image(σ=0.02) (c) Median filtered image.

In the above case when speckle noise of standard deviation 0.02 is added then image(a) becomes the image(b) and in image(c) median filtering is done and it gives the image clear and least blurred. The value of PSNR obtained here is **26.4036** that is it shows how much image gets denoised.

C. Results for DWT(level4) using window [3 3] with standard deviation(s.d) 0.02:

(a) Input image leena (b) Noisy image(σ=0.02) (c) DWT (level 4) filtered image.

In the above case when speckle noise of standard deviation 0.02 is added then image(a) becomes the image(b) and in image(c) DWT is done and it gives the image clear and least blurred. The value of PSNR obtained here is **30.063** that is it shows how much image gets denoised.

D. Results for DWT(level 4) with wiener filter using window [3 3] with standard deviation(s.d) 0.02:

(a) Input image leena (b) Noisy image(σ=0.02) (c) DWT (level 4) with wiener filtered image.

In the above case when speckle noise of standard deviation 0.02 is added then image(a) becomes the image(b) and in image(c) DWT with wiener filtering is done and it gives the image clear and least blurred. The value of PSNR obtained here is **32.730** that is it shows how much image gets denoised

E. Results for DWT(level 4) with wiener filter using window [3 3] with standard deviation(s.d) 0.01

(a) Input image leena (b) Noisy image(σ=0.01) (c) DWT (level 4) with wiener filtered image.

In the above case when speckle noise of standard deviation 0.01 is added then image(a) becomes the image(b) and in image(c) wiener filtering is done and it gives the image clear and least blurred. The value of PSNR obtained here is **34.315** that is it shows how much image gets denoised. This is the best result observed in DWT with wiener filtering.

Conclusion:

In this research work different types of filters and different level of DWT techniques are compared. Traditional filters are such as wiener filter, homomorphic wiener filter ,median filter and homomorphic median filters. These filters are used to denoise the effected image. Wiener filter has the best performance as comparison to the median filter. Also the comparison between different levels of only DWT technique and combined DWT with wiener filtering technique is done. From the tables it has been observed that DWT technique is better than wiener filtering and DWT with wiener filtering technique is better than DWT technique. Because this combined technique gives the best PSNR value from all other techniques used in this research work.

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