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Medical Image Denoising In The Wavelet Domain Using Haar And DB3 Filtering

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***ABSTRACT*:** *The Medical Images normally have a problem of high level components of noises. There are different techniques for producing medical images such as Magnetic Resonance Imaging(MRI) ,X-ray, Computed Tomography and Ultrasound, during this process noise is added that decreases the image quality and image analysis. Image denoising is an important task in image processing, use of wavelet transform impoves the quality of an image and reduces noise level. It works on Haar and Daubechies Transforms. Firstly the image is decomposed using Haar and Daubechies transforms, then the level of soft and hard threshold is selected for reducing the noise in the image and after that by calculating and comparing the PSNR of an image for every wavelet then assign the wavelet which gives more PSNR to the respective image. Haar transform decomposed the discrete signal into two subsignals of half its length.One subsignal is a running average or trend and other is running difference or fluctuation. Daubechies wavelet has set of scaling functions which are orthogonal. It is useful in noise removal as high frequency coefficient spectrum reflect all high frequency changes. Hard thresholding is a keep or kill procedure. Soft threshholding shrinks the coefficients above the threshold in absolute value.*

Keywords:*Db3,Haar,MSE,PSNR,threshold.*

I. INTRODUCTION

Medical image enhancement technologies have attracted much attention since advanced medical equipments were put into use in the medical field. Enhanced medical images are desired by a surgeon to assist diagnosis and interpretation because medical image qualities are often deteriorated by noise and other data acquisition devices, illumination conditions, etc. Our target of medical image enhancement are mainly to solve problems of the high level noise of a medical image. The noise present in the images may appear as additive or multiplicative components and the main purpose of denoising is to remove these noisy components while preserving the important signal as much as possible[1].In medical image enhancement there are many studies, mainly on grayscale transform and frequency domain transform. Frequency domain filtering can be used for periodic noise reduction and removal .

We proposed an approach which is used to enhance a medical image by using Haar and db3 wavelet transform, by selecting soft and hard thresholding level[2-5] and thus reducing the noise.In this paper, unwanted noisy components can be thresholded without affecting the significant features of the image. We calculate PSNR(Peak Signal To Noise Ratio)and MSE(Mean Square Error) by using these two orthogonal wavelets and then compare the resultants.

1.Introduction to wavelet transform

In most of the applications of image processing ,it is essential to analyse a digital signal. If the data will be transformed into any other domain then the structure and features of the signal may be better understood. There are several transforms available like Fourier transform, Hilbert transform, Wavelet transform, etc. The wavelet transform is better than fourier transform because it gives frequency representation of raw signal at any given interval of time, but fourier transform gives only the frequency- amplitude representation of the raw signal,but the time information is lost. So we cannot use the Fourier transform where we need time as well as frequency information at the same time.[2]

1.1 Haar wavelet

Haar wavelet is one of the oldest and simplest type of wavelet. The Haar Transform provides prototype for all other wavelet transforms. Like other wavelet transforms, the Haar Transform decomposes the discrete signal into two sub-signals of half its length. One sub-signal is a running average or trend and other sub-signal is running difference or fluctuation. The advantage of Haar wavelet is that it is fast, memory efficient and conceptually simple. The Mother Wavelet function is as: [1-2]
Haar mother wavelet:

$$\Psi(t) = \begin{cases} 1 & 0 \le t \le \frac{1}{2} \\ -1 & \frac{1}{2} \le t \le 1 \\ 0 & \text{otherwise} \end{cases} \qquad \textbf{(1)}$$

Its scaling function □ (t) can be described as:

$$\square(t) = \begin{cases} 1 & 0 \le t \le 1 \\ 0 & otherwise \end{cases} \qquad \textbf{(2)}$$

1.2 Daubechies Wavelet Db3

Daubechies wavelet is the first wavelet family which has set of scaling function which are orthogonal. This wavelet has finite vanishing moments. Daubechies wavelets have balanced frequency responses but non-linear phase responses. Daubechies wavelets are useful in compression and noise removal of audio signal processing because of its property of overlapping windows and the high frequency coefficient spectrum reflect all high frequency changes.[3]

II. INTRODUCTION TO DENOISING

De-noising plays a very important role in the field of the medical image pre-processing. It is often done before the image data is to be analyzed. Denoising is mainly used to remove the noise that is present and retains the significant information, regardless of the frequency contents of the signal. It is entirely different content and retains low frequency content. De-noising has to be performed to recover the useful information. In this process much attention is kept on, how well the edges are preserved and how much of the noise granularity has been removed[4-5] The main purpose of an image-denoising algorithm is to eliminate the unwanted noise level while preserving the important features of an image. In wavelet domain,the noise is uniformly spread throughout the coefficients while mostly the image information is concentrated in the few largest coefficients. The most important way of distinguishing information from noise in the wavelet domain consists of thresholding the wavelet coefficients. Mainly hard and soft thresholdings techniques are performed.

III. METHODOLOGY

In medical images many wavelets like db1,sym8,coif1, coif3 etc can be used for denoising of an medical image but we have used haar and daubechies db3(mallat) at certain level of soft and hard threshold and then decomposed and reconstructed the denoised image. PSNR values are calculated for comparing these two wavelets.

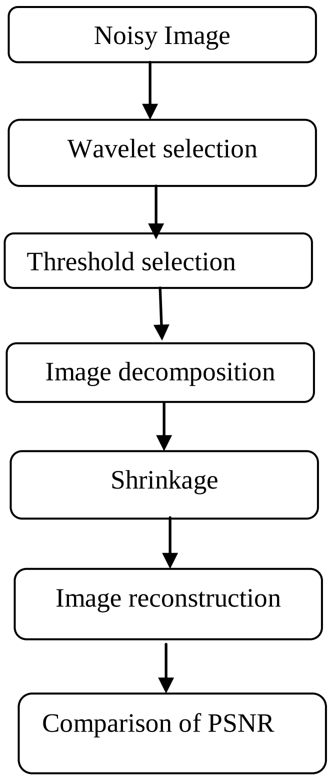


Fig.1 Flow chart of Medical Image Denoising

1.1 Decompositon of an image

In the orthogonal wavelet decomposition procedure, the generic step splits the approximation coefficients into two parts. After splitting we obtain a vector of approximation coefficients and a vector of detail coefficients, both at a coarser scale. The information lost between two successive approximations is captured in the detail coefficients. Then the next step consists of splitting the new approximation coefficient vector, successive details are never reanalyzed. In the corresponding wavelet packet situation, each detail coefficient vector is also decomposed into two parts using the same approach as in approximation vector splitting. This offers the richest analysis. The complete binary tree is produced in the one-dimensional case or a quaternary tree in the two-dimensional case. [8]

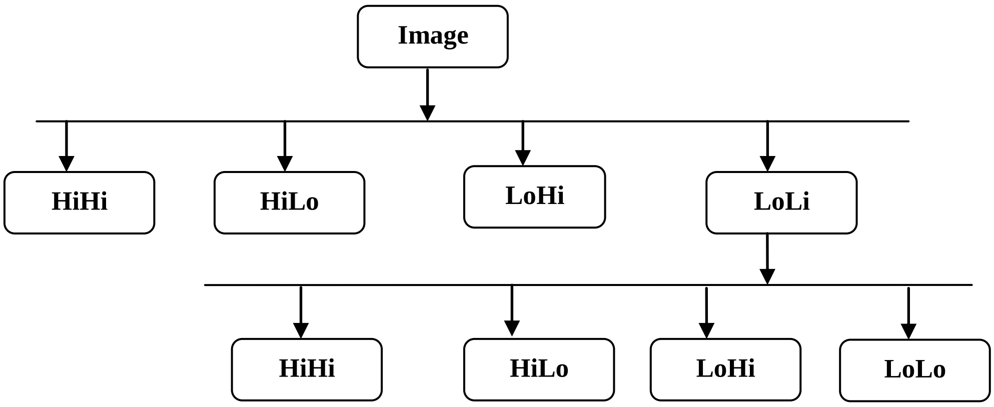


Fig.2 Image Decomposition using Wavelet Transform

LoLo = Horizontal low and Vertical low frequency component.
LoHo = Horizontal low and Vertical high frequency component.
HoLo = Horizontal high and Vertical low frequency component.
HoHo = Horizontal high and Vertical high frequency component.

1.2 Reconstruction of an Image

Opening the Noise Reduction subsystems shows the same wavelet blocks but with a soft or hard threshold is applied to the transformed signal bands. By attenuating the higher frequency bands, the high frequency noise is reduced. You can adjust the threshold levels to see the effects of attenuation on the denoising characteristics of the system [8-9].

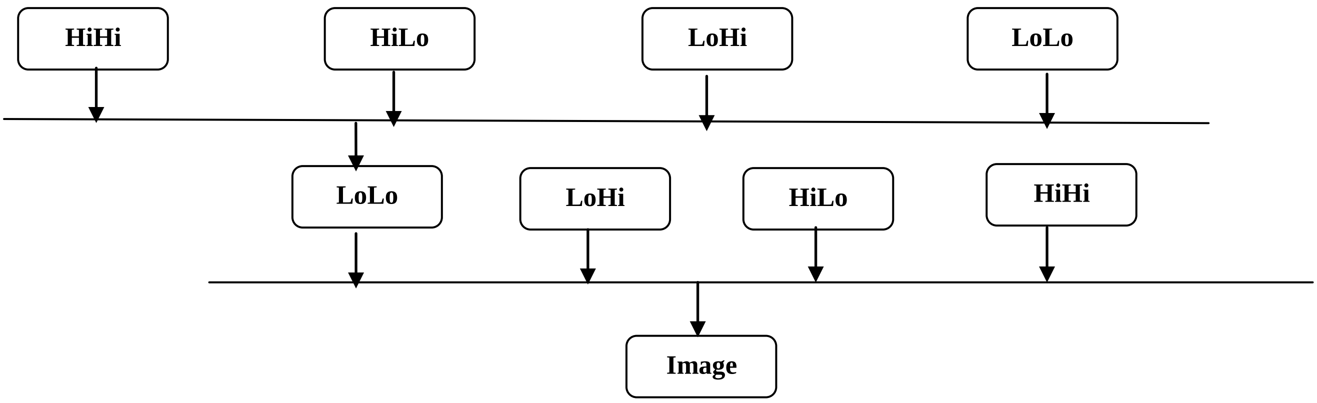


Fig.3 Image Reconstruction using Wavelet Transform

2 .Input Image

Experiments are conducted on several gray scale medical images like X -Ray,MRI,Ultrasound,CT scan of resolution 512×512, then speckle noise is added at different noise levels σ= .01, .02, .04.

3. Wavelet selection

We select a wavelet Haar or Db3. Haar transform decomposed the discrete signal into two subsignals half of its length. Daubechies wavelet has set of scaling functions which are orthogonal. It is useful in noise removal as high frequency coefficient spectrum reflect all high frequency changes.

4. Thresholding

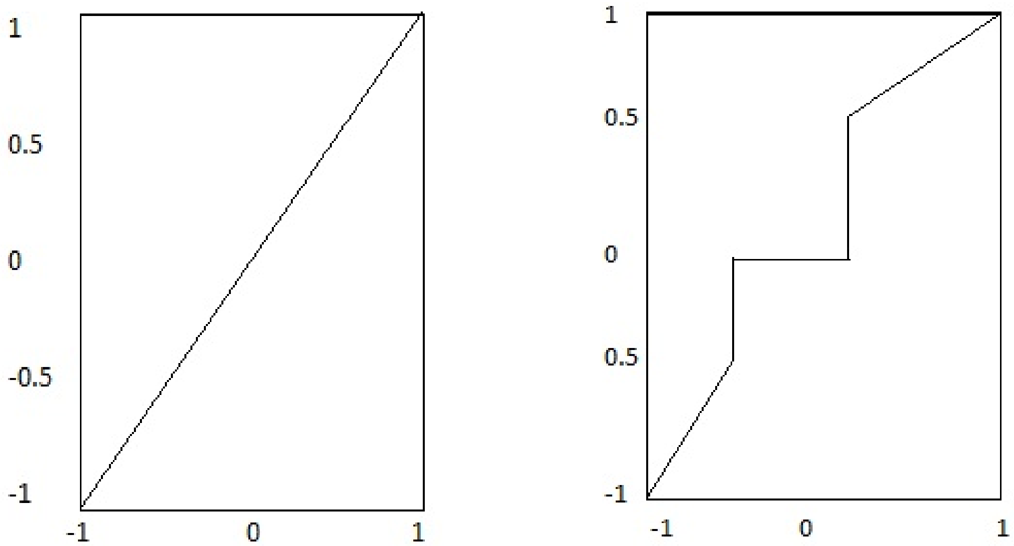
Thresholding is the simplest method of image denoising .In this from a gray scale image, thresholding can be used to create binary image. Thresholding is used to segment an image by setting all pixels whose intensity values are above a threshold to a foreground value and all the remaining pixels to a background value. Thresholding is mainly divided into two categories:

4.1 Hard Thresholding

Hard threshold is a "keep or kill" procedure and is more intuitively appealing. The transfer function of the Hard thresholding is shown in the figure. Hard thresholding may seem to be natural. Sometimes pure noise coefficients may pass the hard threshold and this thresholding method is mainly used in medical image processing.[6-7]

Hard thresholding can be defined as follow:

D(U, □)=U for all |D|> □ (3)
0 otherwise



Original signal Hard thresholded signal

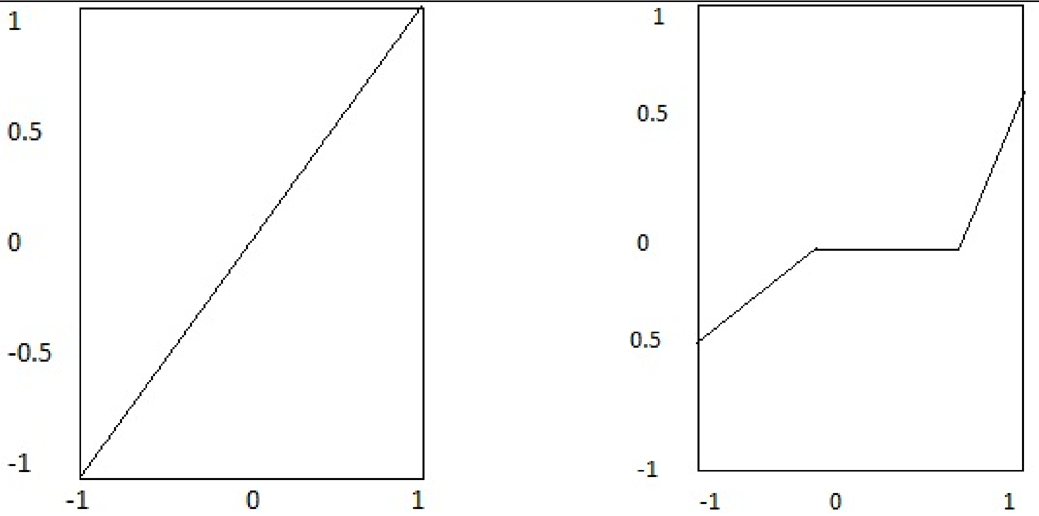
Fig .4 Original and Hard thresholded signal

4.2 Soft Thresholding

Soft threshold shrinks coefficients above the threshold in absolute value. The false structures in hard thresholding can be overcomed by soft thresholding. Now a days, wavelet based denoising methods have received a greater attention. Important features are characterized by large wavelet coefficient across scales in most of the timer scales.[6]

Soft thresholding can be defined as follow:

D (U, □) =sgn (U) max (0, |U|- □) (4)



Original signal Soft thresholded signal

Fig.5 Original and Soft thresholded signal

5 .Calculation of PSNR

PSNR values can be calculated by comparing two images one is original image and other is distorted image .The PSNR has been computed using the following formula:

$$\textbf{PSNR} = 10\log_{10}\left(\frac{R^2}{MSE}\right) \qquad \textbf{(5)}$$

Where R is the maximum fluctuation in the input image data type. For example, if the input image has a double-precision floating-point data type, then *R* is 1. If it has an 8-bit unsigned integer data type, *R* is 255, etc.

6. Wavelet based comparison of MSE

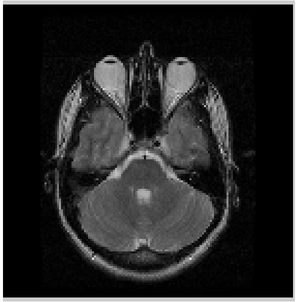
Mean Squared Error (MSE): One obvious way of measuring this similarity is to compute an error signal by subtracting the test signal from the reference, and then computing the average energy of the error signal. The mean-squared-error (MSE) is the simplest, and the most widely used for image quality measurement.

$$\textbf{MSE} = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(x(i,j) - y(i,j)\right)^2 \qquad \textbf{(6)}$$

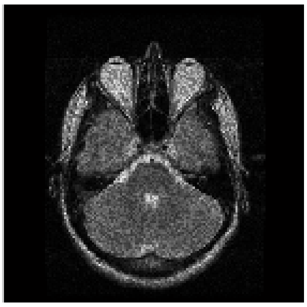
Where x (i, j) represents the original image and y(i , j) represents the denoised (modified) image and i and j are the pixel position of the M×N image.MSE is zero when x(i, j) = y(i, j) .

IV. EXPERIMENTAL RESULTS AND DISCUSSION

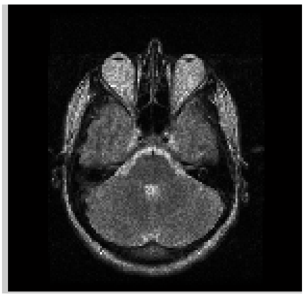
In this paper, experiments are conducted on four different gray scale medical images. Like, Ultrasound, MRI, X-Ray,CT scan of resolution 512□ 512 at different speckle noise levels, σ = .01,.02,04. Haar and db3 wavelet transforms are applied for denoising respectively. Different PSNR and MSE values are calculated at different level of speckle noise on each medical image at soft and hard thresholding levels by applying these Haar and db3 wavelets one after another and then comparison is made from the tables given below showing the PSNR values at each level which shows the better wavelet. It is clear from the tables below that db3 wavelet is better than haar wavelet for the purpose of denoising in the medical images .When speckle noise is added , σ = .01,.02,.04 in all type of image,PSNR is calculated. Denoising is performed at speckle noise σ=.01, on MRI images by using Haar and db3 wavelets at soft threshold, the best PSNR value is calculated that is 40.5521 db and 41.6880 db respectively.



(a)Original Image



(b)Noisy Image



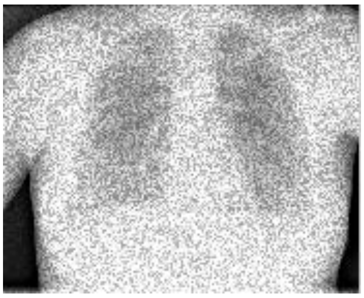
(c)Denoised Image

(d)Difference Image

Fig.6 Visual results of MRI image after computation by haar wavelet

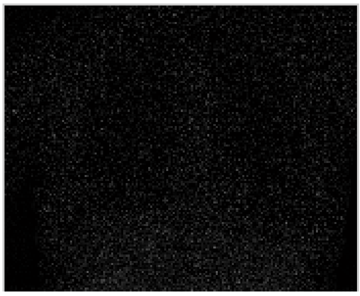
In this computation (a) is original mri image and (b) is image has speckle noise of level .04 and in (c) image is enhanced by soft thresholding using haar wavelet at one decomposition level and so PSNR is calculated 35.1736 db.(d) is the difference between original image and denoised image and the remaining noise in the image.

(e)Original Image



(f) Noisy Image

(g)Denoised Image



(h)Difference Image

Fig.7 Visual results of X-ray image calculated by db3 wavelet

In this computation (e) is original X ray image ,(f) is image is noisy having speckle noise .03 ,(g) is the image denoised at hard threshold by using db3 filter at first decomposition level and thus PSNR is computed

28.3919 db,(h) is the difference image ,remaining percentage of noise than the original image in the denoised image.

Table 1.PSNR values of different medical images after processing through haar wavelet

Image type	Type of threshold	Level of noise	SNR	MSE
MRI Image	HARD	□ = .01	39.1906	0.0208
		□ = .02	36.2338	0.0293
		□ = .04	33.2502	0.0414
	SOFT	□ = .01	40.5521	0.0175
		□ = .02	38.2208	0.0230
		□ = .04	35.1776	0.0328
Ultra sound Image	HARD	□ = .01	36.4263	0.0284
		□ = .02	33.6919	0.0390
		□ = .04	30.8570	0.0542
	SOFT	□ = .01	37.8652	0.0237
		□ = .02	35.6897	0.0305
		□ = .04	33.2628	0.0403
X ray Image	HARD	□ = .01	33.8997	0.0375
		□ = .02	31.0818	0.0521
		□ = .04	28.3093	0.0719
	SOFT	□ = .01	33.8669	0.0377
		□ = .02	31.1137	0.0518
		□ = .04	28.2746	0.0722
CT scan Image	HARD	□ = .01	35.9726	0.0296
		□ = .02	33.9120	0.0377
		□ = .04	31.6461	0.0489
	SOFT	□ = .01	35.5005	0.0312
		□ = .02	34.1565	0.0364
		□ = .04	32.3186	0.0450

Table 2.PSNR values of medical images after processing through db3 wavelet

Image type	Type of threshold	Level of noise	SNR	MSE
MRI Image	HARD	□ = .01	39.5221	0.0200
		□ = .02	36.4032	0.0287
		□ = .04	33.2896	0.0412
	SOFT	□ = .01	41.6880	0.0153
		□ = .02	38.8438	0.0214
		□ = .04	35.4287	0.0319
Ultra sound Image	HARD	□ = .01	36.8990	0.0269
		□ = .02	33.9569	0.0379
		□ = .04	31.0251	.0531
	SOFT	□ = .01	38.7189	0.0214
		□ = .02	36.2854	.0284
		□ = .04	33.6682	0.0385

X ray Image	HARD	□ = .01	34.0084	0.0372
		□ = .02	31.2532	0.0512
		□ = .04	28.3919	0.0714
	SOFT	□ = .01	33.9951	0.0372
		□ = .02	31.1902	0.0515
		□ = .04	28.4155	0.0712
CT scan Image	HARD	□ = .01	38.3518	0.0224
		□ = .02	35.6784	0.0307
		□ = .04	32.9149	0.423
	SOFT	□ = .01	38.8313	0.0211
		□ = .02	36.5162	0.0277
		□ = .04	33.9027	0.0375

V. CONCLUSION

In this paper,denoising of different medical images like,MRI,ultrasound,X-ray,CT scan is performed using haar and db3 wavelets at both soft and hard threshold levels and the peak signal-to-noise ratio(PSNR) is calculated. After denoising by these two wavelets,PSNR values are compared and it is found that db3 wavelet is more efficient than haar wavelet for removing the certain level of speckle noise in the medical images and also it enhances the visual quality of the medical images. It helps to select the best wavelet transform for the denoising of particular medical image and it will also help in effective diagnosis.

VI. FUTURE SCOPE

The above calculations are being performed on an image of resoltion 512□ 512 and work is beingdone to remove speckle noise of the images and future plan is to make it valuable for different resolution and for different size of images. Medical images corrupted by other noises like Gaussian or poisson can also be denoised and PSNR values can be enhanced.

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