Improving Signal to Noise Ratio of Low-Dose CT Image Using Wavelet Transform

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***Abstract*-Now-a-days, diagnosis of human diseases has become comparatively easier with the help of modern technology. Use of new technology provides more information about the patient condition and also patient's health can be monitored continuously. Early detection is a very important aspect in diagnosis. CT scanning is one such technique which is very effective and useful for early detection but the patient is exposed to harmful radiation when he/she undergoes CT scan. If the amount of radiation is reduced, the CT image quality decreases i.e. signal to noise ratio (SNR) decreases.**

Wavelet transform is a tool to analyzed signals and the entire set of wavelet share some common properties but each wavelet has certain unique properties of Image decomposition, de-noising and reconstruction which provides difference in PSNR.

In this paper, it is proposed to determine an analysis technique which will provide the required information from low-dose CT image, hence less harmful to the patient. Again in this paper an analysis is carried out on different low dose CT image using different wavelets. Images are decomposed, de-noised and reconstructed and then analyzed in terms of PSNR.

Keywords- Low-Dose CT, PSNR, Wavelet Transform.

I. INTRODUCTION

Image de -noising is very important in medical image processing. The first CT scan machine were invented in 1972 by Godfrey Newbold Hounsfield (EMI Central Laboratories) and Allan McLeod Cormack(Tuff University).Since

1972 CT technology is widely used in clinics and has become very important diagnosis method in Medical field. The word ‘Tomography’ is derived from Greek word ‘Tomos’ (slice or section) and ‘Graphein’ (to write). [3]

Medical images contain the information of vital organic tissues inside the human body and widely used for diagnosis of diseases and/or for surgical purpose. There are different technique for producing medical image such magnetic resonance imaging (MRI), X-ray Computed Tomography and Ultrasound. And the main objective of CT scan is to reconstruct the image from the set of projection. But the radiation used in CT scan is very harmful for human especially for children and pregnant women. Because of excessive radiation there may be possibility of developing cancer to the patient.[1]

Then in 1990 Naidich has proposed concept of low dose CT scan. According to him the amount radiation can be reduced by reducing current through the X-ray tube and keeping all other scanning parameter constant (like voltage). The relation between current in X-ray tube and radiation is linear .But if we reduce the radiation then there is decrease in Image Quality. The accuracy of diagnosis may also decreases because of decrease in image quality and there is a possibility of having difficulties in image analysis and post processing. Image de-noising is very important task in Image processing.

There are different methods used for de-noising the image and also used for improving the S/N ratio of CT images are Filter Back Projection [2], Statistical Iterative Reconstruction [3], Multiscale Wiener Filter [4], Wavelet transform etc**.**

In this paper, the CT image is de-noised using different wavelet like Biorthogonal, Daubechy, Haar, and Symlet and coiflet wavelet. By calculating and comparing PSNR of an image for every wavelet then assign the wavelet which gives more PSNR to the respective image and similar procedure for other images.

II. CT IMAGE AND CONCEPT OF LOW_DOSE CT

CT scan uses many X-rays to scan human body up to certain level of thickness. The main reason why X-rays are used in diagnosis because tissues and substances have different capacity to absorb X-rays. Some tissues are permeable to X-ray while others are impermeable. For example higher density tissue such as bones absorbed more X-ray therefore detector receives weak signal and it appears white on CT film while soft tissue like brain or kidney appears gray and cavities filled with air such as lung appears black. The signals from detector are then converted into electrical signals and then into digital signal by using analog to digital converter.

Radiation used in CT scan is directly proportional to the current through X-ray tube. Therefore low-dose CT scanning is nothing but scanning human body with low current through X-ray tube. Because of low-dose of radiation the harm caused by radiation is reduces, the expense to the bone by the patient reduces also cost of patient is reduces also it reduces damage to CT machine’s X-ray tube and increases the life of X-ray tube. [5, 6]

III. NOISE ANALYSIS

Noise is very important factor which reduces the quality of an image. The quality of CT image directly depends on radiation dose used in CT scan. The radiation dose is influenced by many factor such as X-ray tube current, X-ray tube voltage, beam energy, slice thickness, table speed and many more. If the image is very noisy then it will be very difficult to differtiate normal tissue and abnormal tissue and because of this there may be possibility having misdiagnosis. So image de-noising represents the crucial step in biomedical image processing. [7]

In this paper, we have taken different low-dose CT scan images of different part of body such brain, breast and Kidney. Then these images are processed with different types of wavelets like Biorthogonal, symlet, Coiflet, Daubechies and Haar and PSNR is calculated, PSNR is used to calculate the difference between two image that means how close two image are and PSNR is calculated as fallow,

$$PSNR = 10log10\frac{M.N.k^2}{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}(x(i\,,j) - x^\wedge(i\,,j))^2}$$

Where M and N are the number of pixels in each column and row respectively, x(i ,j) and x^(i ,j) are the gray value of original image and reconstructed image respectively at (i , j) and k is the maximum grey value.

IV. WAVELET DESCRIPTION

Wavelet has ability to examine signals simultaneously in both time and frequency domain. Any image decomposition using wavelet has two function that is wavelet function and scaling function. Wavelet function use to represent the high frequency component i.e. detail part of an image while scaling function use to represent the low frequency component i.e. smooth part of an image. In wavelet, one can uses a function which is termed as mother wavelet function and it's dilation and translation to generate a set of orthogonal basis function to represent signal. The wavelet transform analyzes signals at multiple scales by changing the width of the analysis window, and produces their scale-space representation. Wavelet is a mathematical tool that set data into different frequency component and then study each component with a resolution matched to its scale [8, 9].

There are many wavelets which are used for decomposition as well as for de-noising of images and signals. The important family of wavelet is Haar, daubechies, biorthogonal, coiflet, symlet and dmey. The description of this wavelet is given in the following section

A. Haar Wavelet

A Haar wavelet is one of the oldest and simplest type of wavelet. The Haar Transform provide prototype for all other wavelet transforms. Similar to other wavelet transforms, the Haar Transform decomposed 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.[10]. The Mother Wavelet function is as shown in fig.1

B. Daubechies Wavelet

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. [10] The Mother Wavelet function is as shown in fig.2

C. Symlet Wavelet

Symlet wavelet provides highest number of vanishing moment and it is compactly supported wavelet. By using symlet wavelet discrete and continuous wavelet transforms are also possible. [11] The Mother Wavelet function is as shown in fig.3

D. Coiflet Wavelet

Coiflet wavelets are compactly supported wavelet with highest number of vanishing moments for both phi and psi for a given support width. Discrete and continuous wavelet transform is possible with these [11]. The Mother Wavelet function is as shown in fig.4

E. Biorthogonal Wavelet

Biorthogonal Wavelet is families of compactly supported symmetrical wavelet. The symmetry of coefficients is often desirable because it result in linear phase of transfer function. Biorthogonal wavelet has two scaling function which generate different multiresolution analysis again it has two different wavelet function out of them one used for analysis and another used for synthesis.[12] The Mother Wavelet function is as shown in fig.5

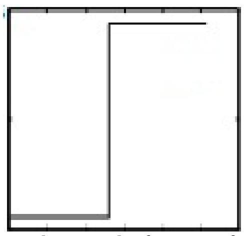

Fig1.Mother wavelet function of Haar Wavelet

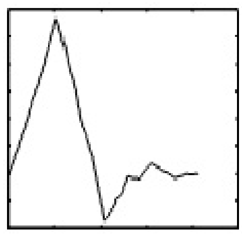

Fig.2 Mother Wavelet function of Daubechies Wavelet.

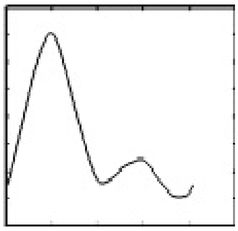

Fig.3 Mother Wavelet function of Symlet Wavelet

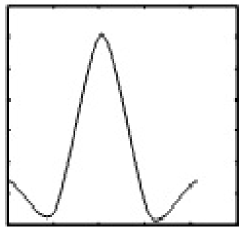

Fig.4 Mother Wavelet function of Coiflet Wavelet.

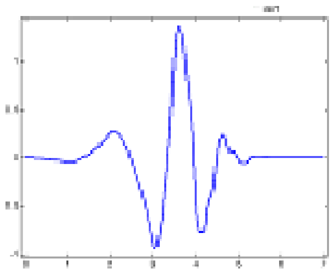

Fig.5 Mother Wavelet function of Biorthogonal Wavelet

V. FLOWCHART

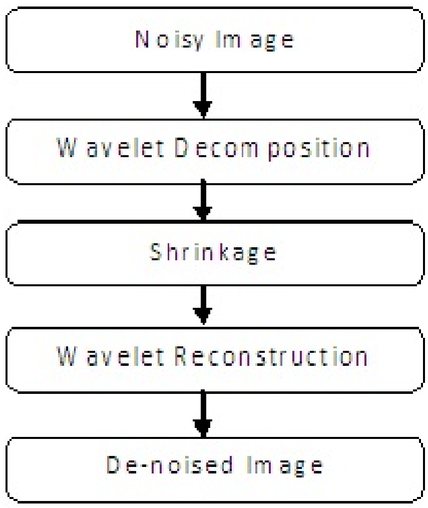

Fig.6 Flow chart of Wavelet De-noising

A. Decomposition

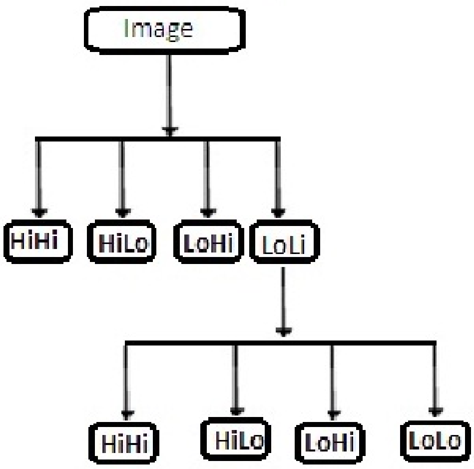

Fig.7 Image Decomposition using Wavelet Transform

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.

B. Reconstruction

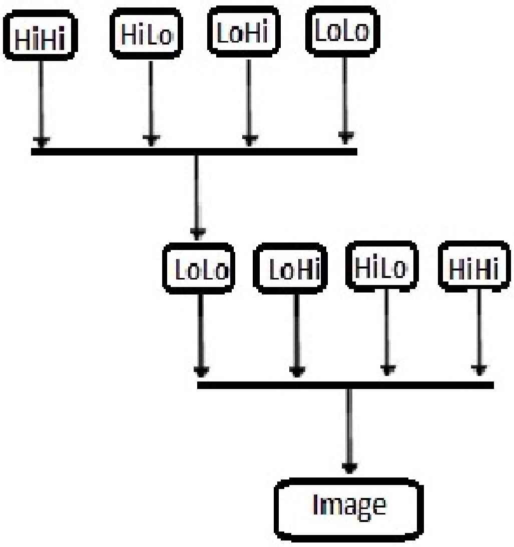

Fig.8 Image Reconstruction using Wavelet Transform

VI. Result and Discussion

In this paper, we have taken the CT image of 13 different patients out of them 5 CT images are of Brain of different patients. Similarly 4 CT images are of Beast and 4 CT images are of Kidneys of different patients. Then PSNR of each image is calculated and each image is in the JPEG format only.

The PSNR between normal dose CT image and low-dose CT image of Brain is 8.3307 and the PSNR between normal dose and wavelet based reconstructed low-dose CT image of Brain is 8.4802 that means there is improvement in PSNR by 0.1495 that is 14.95 percentage due processing using wavelets.
The PSNR between normal dose CT image and low-dose CT image of Breast is 12.6714 and the PSNR between normal dose and wavelet based reconstructed low-dose CT image of Brast is 12.7028 that means there is improvement in PSNR by 0.1314 that is 13.14 percentage due processing using wavelets.
The PSNR between normal dose CT image and low-dose CT image of Kidney is 11.4596 and the PSNR between normal dose and wavelet based reconstructed low-dose CT image of Kidney is 11.6005 that means there is improvement in PSNR by 0.1409 that is 14.09 percentage due processing using wavelets.
Table 1 shows the PSNR of CT images of Brain of different patient after processing through the different wavelets. From Table 1 it is clear that the Biorthogonal 3.7 wavelet gives the maximum PSNR for all the 5 CT image ofbrain as compared to the PSNR given by other wavelets.

Table 1. PSNR of CT images of brain after processing through different wavelet

Wavelet	**PSNR**				
	Brain (a)	**Brain (b)**	**Brain (c)**	**Brain (d)**	**Brain (e)**
Bior 1.3	24.2436	23.5694	38.3261	34.7678	35.0497
Bior 2.8	24.4393	23.6928	39.6759	36.0217	36.5665
Bior 3.7	24.4658	23.7660	41.5753	37.7139	38.2211
Bior 4.4	24.2593	23.5323	36.7481	33.4828	34.0762
Bior 6.8	24.3336	23.5727	37.2054	33.8710	34.5281
Coif 1	24.2392	23.5318	37.4153	34.0672	34.5750
Coif 2	24.2571	23.5423	37.1453	33.7615	34.3924
Coif 3	24.3105	23.5399	37.0613	33.7311	34.3704
Coif 4	24.2990	23.5491	36.9627	33.6321	34.3716
Haar	24.1705	23.5306	38.2667	34.7407	34.9657
Db 1	24.1705	23.5306	38.2667	34.7407	34.9657
Db 2	24.2557	23.5616	37.4263	34.0286	34.5230
Db 3	24.2323	23.5291	37.0736	33.7948	34.3522
Db 4	24.2736	23.5758	36.9261	33.6260	34.3040
Db 5	24.2868	23.5419	36.8151	33.5365	34.2123
Db 6	24.2700	23.5607	36.6773	33.3534	34.1296
Db 7	24.2779	23.5286	36.5849	33.3512	34.2530
Db 8	24.2989	23.5626	36.4340	33.2571	33.9827
Db 9	24.2851	23.5406	36.3092	33.1791	33.9185
Db 10	24.2913	23.5471	36.2208	33.1041	33.8519
Sym 1	24.1705	23.5306	38.2267	34.7407	34.9657
Sym 2	24.2557	23.5616	37.4263	34.0286	34.5230
Sym 3	24.2323	23.5291	37.0736	33.7948	34.3522
Sym 4	24.2805	23.5258	37.1341	33.7902	34.3974
Sym 5	24.2924	23.5657	37.0392	33.7267	34.3420
Sym 6	24.2718	23.5453	37.0673	33.7109	34.3280
Sym 7	24.2801	23.5569	36.9257	33.6522	34.3010

Table 2 shows the PSNR of CT images of Breast of different patient after processing through the different wavelets. From Table 2 it is clear that the Daubechies 10 wavelet gives the maximum PSNR for all the 4 CT image of breast as compared to the PSNR given by other wavelets

Table2. PSNR of CT image of breast after processing through different wavelets

Wavelet	**PSNR**			
	Breast (a)	**Breast (b)**	**Breast (c)**	**Breast (d)**
Bior 1.3	15.2260	20.0543	15.6251	22.2610
Bior 2.8	15.2442	20.0537	15.6279	22.3483
Bior 3.7	15.1717	20.0664	15.5928	22.3251
Bior 4.4	15.3043	20.0259	15.6954	22.2832
Bior 6.8	15.3073	20.0649	15.6781	22.2612
Coif 1	15.3122	20.0823	15.6704	22.2441
Coif 2	15.3055	20.0252	15.6731	22.2190
Coif 3	15.2901	20.1050	15.6797	22.2680
Coif 4	15.3025	20.1110	15.6817	22.2280
Haar	15.3025	20.1133	15.6787	22.2484
Db 1	15.3025	20.1133	15.6787	22.2484
Db 2	15.2706	20.0819	15.6672	22.2432
Db 3	15.3023	20.0668	15.6729	22.2637
Db 4	15.2953	20.1223	15.6820	22.2284
Db 5	15.2695	20.0517	15.6860	22.2683
Db 6	15.3098	20.0417	15.6832	22.2104
Db 7	15.3111	20.1115	15.6796	22.2804
Db 8	15.3027	20.0358	15.6939	22.2366
Db 9	15.2909	20.0672	15.6939	22.2612
Db 10	15.3210	20.1524	15.6988	22.3619
Sym 1	15.3025	20.1133	15.6787	22.2484
Sym 2	15.2706	20.0819	15.6672	22.2432
Sym 3	15.3023	20.0668	15.6729	22.2637
Sym 4	15.3033	20.1041	15.6830	22.2233
Sym 5	15.2809	20.0609	15.6777	22.2186
Sym 6	15.3025	20.0252	15.6810	22.2546
Sym 7	15.2776	20.1174	15.6858	22.2866

Similarly Table3 shows the PSNR of images of kidney after processing through different wavelets. For all the images of Kidney which we have taken, the biorthogonal 3.7 gives maximum PSNR for all images than PSNR of image process through other wavelets

Table3. PSNR of CT image of Kidney after processing through different wavelet

Wavelet	PSNR			
	Kidney (a)	Kidney (b)	Kidney (c)	Kidney (d)
Bior 1.3	23.7067	33.4196	35.7437	34.9918
Bior 2.8	23.8457	34.8259	37.0624	36.3399
Bior 3.7	23.8781	36.2438	38.6138	37.8748
Bior 4.4	23.7356	32.6832	34.6199	33.9017
Bior 6.8	23.7668	33.0640	34.9928	34.3100
Coif 1	23.7723	33.0189	35.1390	34.4114
Coif 2	23.7489	33.0064	34.8969	34.2698
Coif 3	23.7735	32.9447	34.8205	34.2035
Coif 4	23.7508	32.8822	34.6927	34.0966
Haar	23.6765	33.0790	35.5935	34.7237
Db 1	23.6765	33.0790	35.5935	34.7237
Db 2	23.7367	32.9788	35.0497	34.3577
Db 3	23.7312	32.9594	34.8964	34.2370
Db 4	23.7312	32.8490	34.7146	34.0612
Db 5	23.7703	32.7720	34.5916	33.9687
Db 6	23.7521	32.6798	34.4181	33.7843
Db 7	23.7893	32.6201	34.3342	33.4794
Db 8	23.7434	32.5262	34.2234	33.6330
Db 9	23.7492	32.4382	34.1383	33.8526
Db 10	23.7635	32.3569	34.0201	33.4671
Sym 1	23.6735	33.0790	34.5935	34.7237
Sym 2	23.6977	32.9288	35.3497	34.3577
Sym 3	23.7367	32.9594	34.8964	34.2370
Sym 4	23.7405	33.0181	34.9370	34.2703
Sym 5	23.7419	32.9455	34.8595	34.1806
Sym 6	23.7425	32.9722	34.8323	34.1682
Sym 7	23.7405	32.8969	34.7214	34.0661

VII. CONCLUSION

Using Wavelet Transform method one can get best suitable wavelet for particular image that means the wavelet which gives maximum PSNR for particular image. From experimental results, it is seen that the Biorthogonal 3.7 wavelet is best suitable wavelet for Brain CT images and the Daubechies 10 wavelet is best wavelet for Breast CT images. Again Biorthogonal 3.7 wavelet is best wavelet for Kidney .Thus, best quality of image with improved PSNR will be obtained along with reduction in the exposure of harmful radiation on the patient. This will also help in effective diagnosis. The combination of Wavelet Transform method with Wiener Filter Method or Adaptive Statistical Iterative Reconstruction Method may be helpful to improve the Quality of image further.

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