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Edge Preserving Denoising Techniques Using DWT and NHA Methods

[1]Chaitra B T, [2]Ajay Betur P

[1]M.Tech (DECS), [2]Assistant Professor
Department of E&C,
JNNCE, Shimoga, Karnataka, India

***Abstract*— Wavelet Transform also has a localized nature like DCT both in space and time. In this method, the edge preservation of images is an important fact. Thus, it gives better results than DCT. There are many types of wavelet domain filters. Among different types of wavelet filters, Discrete Wavelet Transform (DWT) gives better results for image denoising. It obtains high PSNR value than DCT technique, because it reduces blocking artifacts in images. White Gaussian noise of zero mean can be removed by using frequency analysis method of high resolution. The noise component cannot be easily remove from original image component while using processing technique DCT due to sidelobes are observed in the images. Thus, 2D non-harmonic analysis (2D NHA) technique that is used for reducing noise in images. It is a frequency analysis technique of high resolution which increases noise reduction accuracy due to its sidelobe reducing quality. The NHA denoising method obtain increased PSNR value than DCT and DWT techniques.**

***Index Terms*— *Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), Non Harmonic Analysis (NHA)*, Steepest Descent Method, PSNR.**

I. INTRODUCTION

In this digitized world, images are important in applications like advanced cameras, medical image processing, communication fields etc. Generally, data sets of images are consisted by noise. Corrupted instruments, data acquisitions problems are reasons for corruption of data. Therefore, image denoising play a vital role in image processing technology. It decreases corruption from images of interest. Image denoising can be defined as the technology of dividing an image into many segments such as, sets of pixels. Image processing uses many denoising techniques to reduce noise from digital image. There are several kinds of noise[7] which are contaminated in clean images. They are amplifier, impulsive, speckle, poison noises etc.

Image denoising techniques has three main basic approaches, spatial, transform domain, wavelet domain thresholding filters. The categories of image denoising techniques are shown in figure 1.

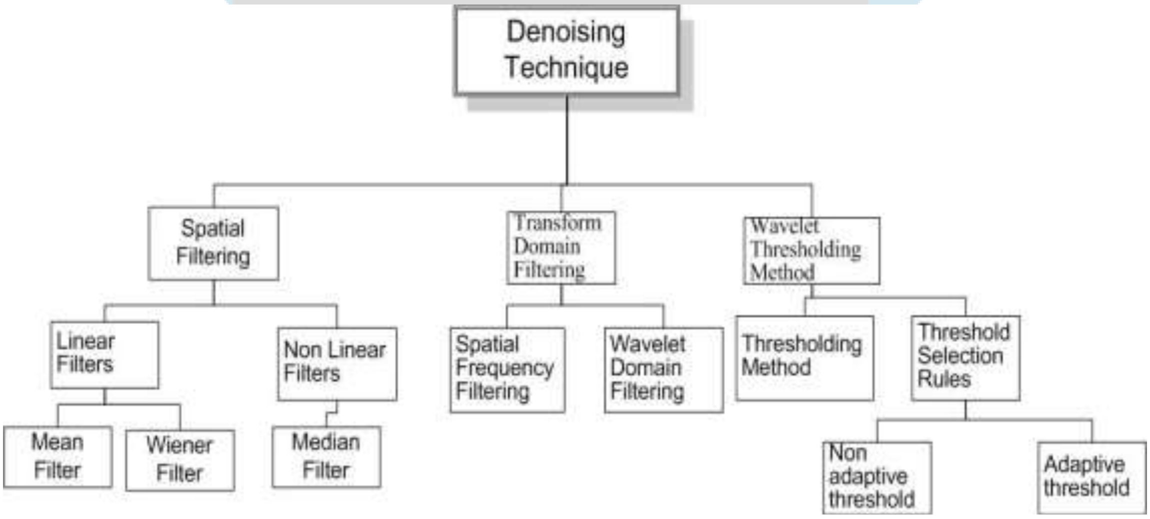

Figure 1: Classification of denoising techniques

Filtering approaches have following objectives:

a. Suppression of the noise in all regions.
b. Preservation of edges.
c. Providing better image quality.

A. Discrete Cosine Transform (DCT)

Regularly the advanced pictures would displaying once on screen promptly then afterward they are caught. There need aid two representable sorts to advanced picture that is spatial area or frequency area. Spatial area pictures can be understands through human eyes, yet frequency area utilizes the spatial area analysis. Normally, human eyes need aid a greater amount touchy through those medium. Furthermore low spatial area, and the picture offers with more spatial frequency which cannot be easily understand. Discrete Cosine Transformation (DCT) is a spatial filter [6]. They have wide variety of applications in the fields of science, in compression of images, etc.

II. IMPLEMENTATION METHODS

Discrete wavelet transform (DWT) and Non harmonic analysis (NHA) method are the two denoising techniques which are proposed to remove noise from the picture.

A. Discrete wavelet transform (DWT)

DWT is a kind of filtering which comes under wavelet domain. It has many advantages over DCT. It gives a non iterative along with different kinds of representing a signal because it resembles the basis disintegration. DWT exhibits some of the properties which helps in commotion reduction in pictures are sparsity, edge clustering and detection, and also multiresolution. In processing of picture, the removal of commotion is the major feature. The process of reduction of commotion from the corrupted picture is known as denoising. The coefficients resulted by the DWT are used to erase annoying components.

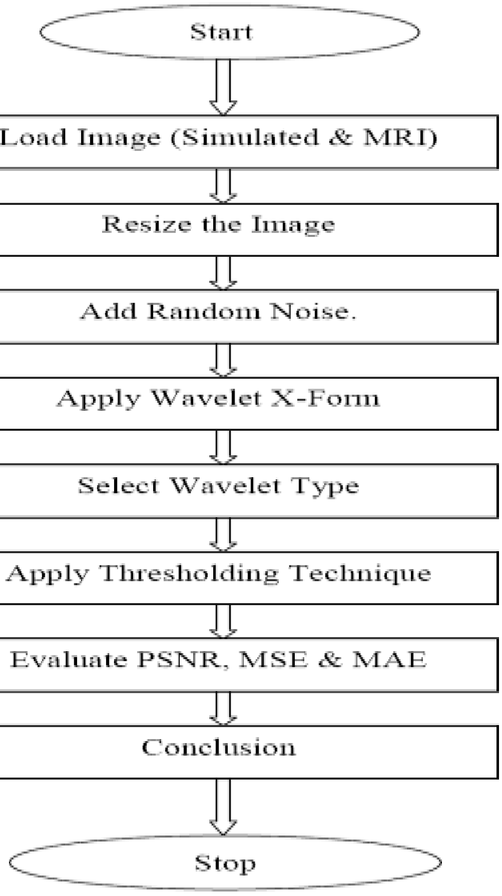

Figure 2: Flow chart of DWT technique

Figure 2 shows the DWT algorithm [5]. The steps are as follows:

a) Select the picture
b) Selected picture must be resized to 256x256. If we take more sized pictures like 512x512, then it consumes time for implementation. If lesser sized pictures are selected then there will be less implementation time.
c) Adding commotions to the selected picture.
d) Apply DWT.
e) Choose the better decomposition level. Then corrupted picture is divided into subbands or components.
f) Apply the better threshold method. Later apply the inverse transform to get the reconstructed picture.

Many applications uses wavelet transform and it plays an vital role in denoising pictures. Continuous wavelete transforms is a kind of wavelet filtering which indicates frequencytime technique. Normally, WT partition the picture into high and low components. The frequency resemble between one picture and selecting wavelete function is expressed by coefficients of wavelet which can be calculated by convolving a signal with scaled wavelete aspect.

Generally, the WT can be executed along a filtre bank. Because it segments the picture in to sub pictures with regarding to the different frequencies. During decomposition, picture is divided into ortonormal functions of wavelet domain. DWT of signal delivers a non-excess rebuilding, which gives better spatial and phantom confinement of signal arrangement, contrasted and other multi-scale portrayal, for example, gaussian also laplacian pyramid. The consequence of the DWT is a multilevel decay, in which

the signal is deteriorated in guess and detail coefficients at each level. This is made through a procedure that is identical to LPF and HPF.
The wavelet change is presented for the timefrequency examination of transient persistent signs, and after that stretched out to the hypothesis of multi-determination wavelet change utilizing FIR channel estimate. This oversaw utilizing the dyadic type of CWT. In dyadic frame, the scaling capacity is picked as energy of two.
y(t) is the signal divided into high also low frequency parts. The reconstruction of y(t) can be estimated as:

$$y(t) = \sum_{i=1}^{N}\left[\sum_{d=-\infty}^{\infty} D_i(d)C_{i,d}(t) + \sum_{d=-\infty}^{\infty} A_l(d)\emptyset_{l,d}(t)\right] \quad (1)$$

Such that, $C_{i,d}(t)$ indicates analysis of discrete wavelet, $\emptyset_{l,d}(t)$ indicates scaling, $D_i(d)$ and 2^i, $A_l(d)$ indicates detailed and approximated signals 2^l, $D_i(d)$ and $A_l(d)$ are attained by applying scaling also wavelete filters[4] :

$$h(j) = 2^{\frac{-1}{2}}\left(\emptyset(t), \emptyset(2t-j)\right) \quad (2)$$

$$g(j) = 2^{\frac{-1}{2}}\left(C(t), \emptyset(2t-j)\right) \quad (3)$$

$$g(j) = (-1)^j h(1-j) \quad (4)$$

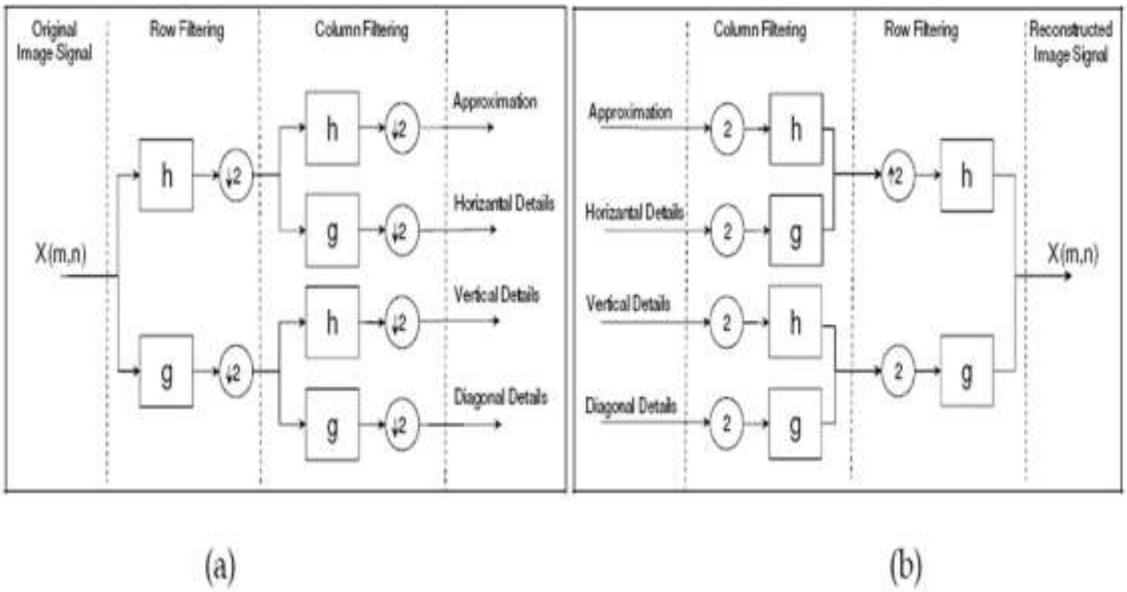

Figure 3*:* 2-D DWT decomposition and reconstruction of input picture

↓2 as indicated in fig 3 represent the down sample. ↑2 represents the up sample. The decomposition of picture by 2-d DWT is known as subband coding. LPF and HPF indicates the signal approximation and more frequency components. The input picture is examined as columns and rows in case of 2-D signals. DWT initially filtered out rows and columns of input picture as like 1-D. 2 D DWT decomposition and reconstruction of input picture as illustrated in fig 3. Fig 3(a) indicates the decomposition of picture using 2-D DWT. Fig 3(b) indicates the reconstruction of the input picture. The picture is decomposed into diagonal, horizontal, vertical and approximations details. After decomposition, we obtain the reconstructed picture by up sampling.

B. Non Harmonic Analysis (NHA) Technique

In transform domain, the multipoint techniques are depends on thresholding by using orthogonal transforms. Generally, DFT and DCT techniques are commonly known as orthogonal transforms. The accuracy of signal based on analysis window size. If the period is larger than the analysis window then the analysis of signal cannot be done. Thus, sidelobes are obtained in results of using a DCT technique[1]. This is because of the signal of input image in analysis window do not has an integer period value. To overcome the above-said problem, the frequency analysis method is used known as non harmonic analysis (NHA) tecnique.
NHA method have been used in various fields and obtains better results. This method provides frequency as line spectrum so sidelobes suppression can be observed in the results. It increases accuracy of signal thresholding. DCT uses large analysis window but NHA uses small analysis window compared to DCT. So NHA method obtains better results than DCT. NHA method makes difference in the segments of clean signal and corrupted signal due to it treats frequency as spectrum of line.

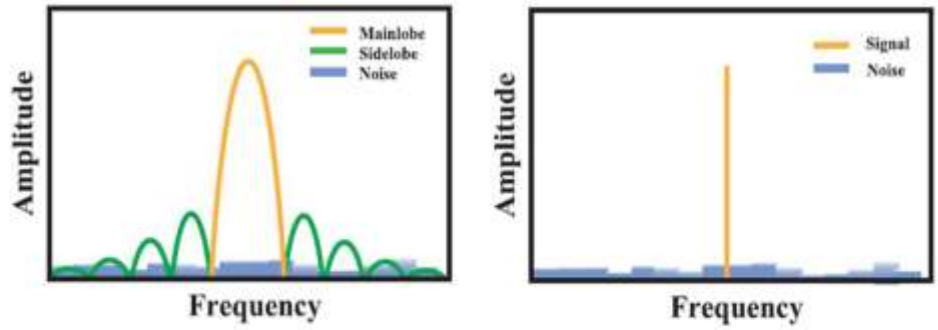

Figure 4: Difference between analysis of DFT or DCT and NHA technique

Figure 4 illustrates the difference between the analysis of DFT and NHA techniques [2]. Hence, NHA is superior than DCT. NHA is best suited for thresholding techniques. Furthermore, while analyzing non stationarity of signals, it results in distortion of signal. Therefore, sidelobes are observed in pictures.
For the frequency analysis, the Fourier transform can be expressed as below:

$$F(x) = \frac{1}{L}\int_0^L f(t)e^{-2\pi f t}\,dt \qquad (5)$$

where L indicates analysis window length. Fourier coefficients can be determine by solving the equation (5). In this analysis window L, fourier transform which can be used for analysis of completely periodic signal. Hence, results of analysis of completely periodic signal dependent on L, along with errors are observed in non-harmonic signal analysis. Like fourier transform, NHA method also calculates the coefficients of fourier transform. The NHA method estimates the Fourier coefficients by using the least squares method.

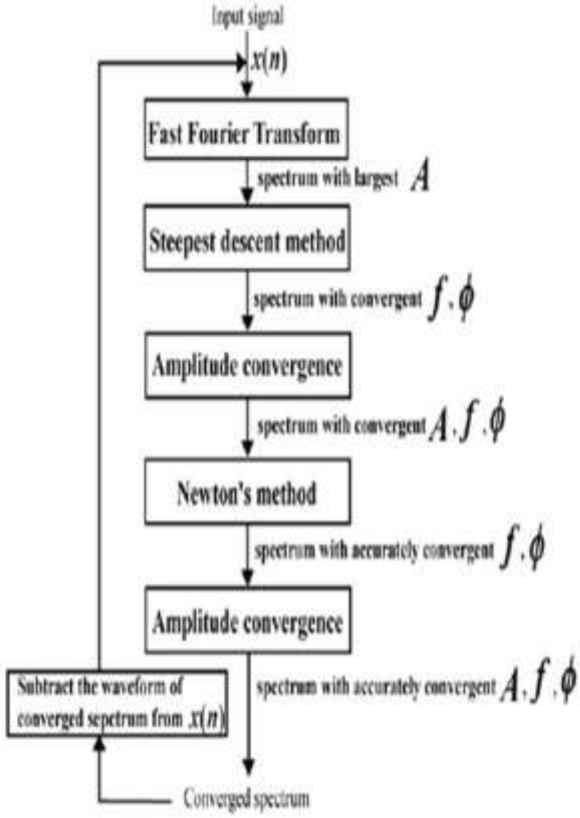

Figure 5: Flow chart of NHA algorithm

The signal model for 2D NHA can be given as below:

$$O(p_1, p_2) = \hat{B}\cos\left(2\pi\left(\frac{\hat{f}_i}{\hat{f}_{is}}p_1 + \frac{\hat{f}_j}{\hat{f}_{js}}p_2 + \hat{\psi}\right)\right) \qquad (6)$$

Where, p_1, p_2 are the pixel numbers, sampling frequencies are $\hat{f}_{is}$ and $\hat{f}_{js}$. In this, the spatial dimensions are x and y. For reducing the sum of comparisons between 2-D signal model $\hat{B}$ and the input signal O, initial phase $\hat{\psi}$, frequencies $\hat{f}_i$ and $\hat{f}_j$ and parameter $\hat{B}$ need to be calculated as:

$$F(\hat{B}, \hat{f}_i, \hat{f}_j, \hat{\psi}) = \frac{1}{P_1 P_2} \sum_{p_1=0}^{P_1-1} \sum_{p_2=0}^{P_2-1} \{O(p_1, p_2) - \hat{O}(p_1, p_2)\}^2 \quad (7)$$

The initial values are obtained by DCT when utilizing the nonlinear equations. From this initial values, the optimal solution for NHA technique which are acquired by the method of steepest descent [3].
The parameter B also a initial phase Ψ can be introduced on implementing the methods of less mean squares. This method is applied to comparison of signal between the sinusoidal wave and analyzed signal. Yet steepest descent technique depends on frame length. Thus it finds hard to implement the signal analysis that does not has a simple structure of harmonic frequency. This is due to frequencies which depends on the length of frame that are utilized for harmonic group frequencies, likewise DCT. Generally, lesser frequency variations cannot be easily observed. Furthermore, we have to apply the process of non linear equation to equation 5.

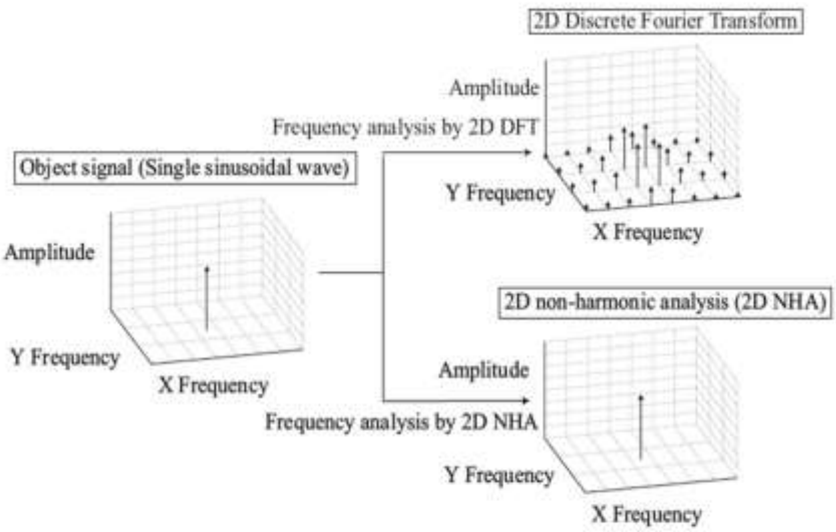

Figure 6: Comparison between DFT and NHA frequency resolution

Figure 6 illustrates the frequency resolution differences of 2D DFT method and 2D NHA method. It is clear from this figure that side lobes occur in 2D FFT, but not in 2D NHA. Hence, NHA method do not consider sidelobe and suppress the influence of noise.

III. RESULTS AND DISCUSSIONS

The section describes execution of proposed methods. In previous section, we have explained about the algorithms of proposed methods. In this section, the comparison of different denoised methods have been explained. We have used Matlab 2015 software to implement the algorithms and we have used graphical user interface that is (GUI) to represent the output of each denoising methods.
The two performance parameters are used to calculate for the many pictures. They are ratio of peak signal to noise that is PSNR along with mean square error that is MSE.

1. *Peak signal to noise ratio*: The ratio of maximal possible of signal power and exploiting commotion power which influence the integrity of picture is known as PSNR. It can be measured in dB which is calculated as follows:

$$PSNR = 10 \log (255 - MSE)^2 \quad (8)$$

2. *Mean Square Error*: The mean of pixel errors all over the picture is known as MSE. It can be calculated as follows:

$$MSE = \frac{1}{N} \sum_{j=0}^{N-1} (X_j - \hat{X}_j)^2 \quad (9)$$

As we said earlier, we have used Matlab software to for implementation and GUI for representation of output.

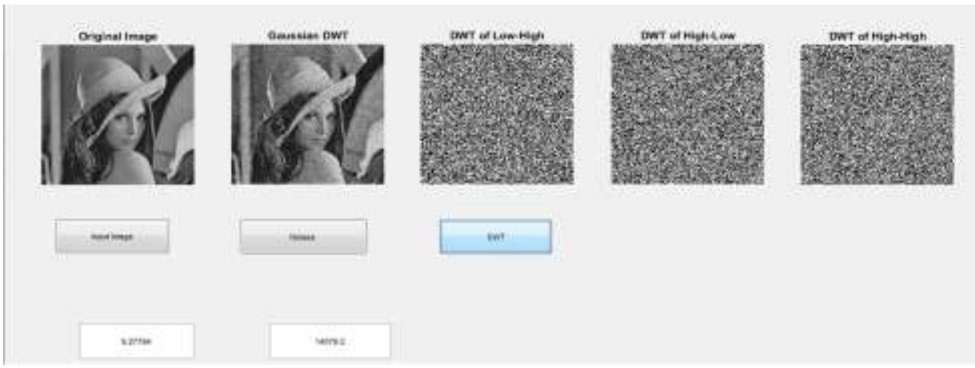

Figure 7(a): Image denoising using DWT for gaussian noise

Figure 7 shows the GUI representation of implementation of DWT. The first pushbutton is for input image. The second pushbutton is for adding noises to the input image. The third pushbutton is for applying DWT to the noisy images. The corresponding performance parameters values PSNR and MSE are shown in PSNR and MSE buttons.
We have to select the input image. Then we need to add the noises to input image. Here we selected 3 kinds of commotions- gaussian noise, poisson noise also speckle noise.
Figure 7(a) shows the gaussian noise removal by DWT technique. The image is decomposed into four subbands, low low component, high low component, low high component along with high high component. PSNR value calculated is 9.27794dB and MSE value is 14079.2.

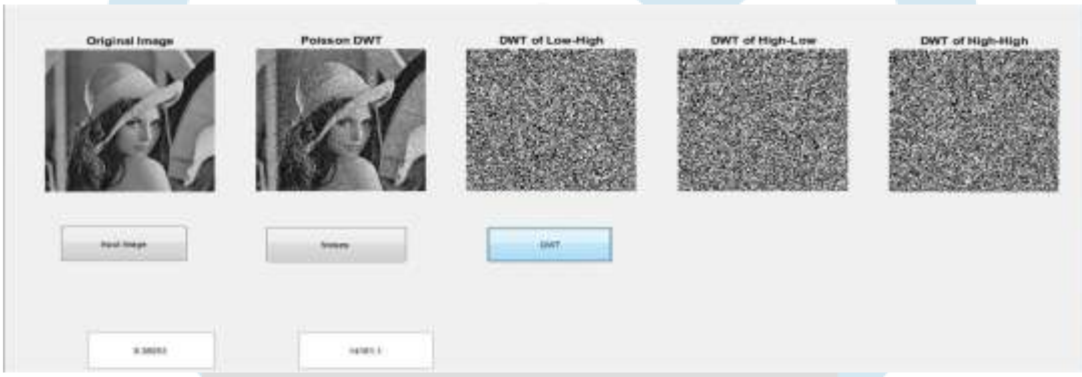

Figure 7 (b): Image denoising using DWT for poisson noise

Figure 7(b) shows the poisson noise removal by DWT technique with PSNR value 9.36053dB and MSE value 141611.1.

Figure 7(c): Image denoising using DWT for speckle noise

Figure 7(c) shows the speckle noise removal by DWT technique with PSNR value 14645dB and MSE value 14183.

Figure 7(d): Image denoising using NHA technique

Figure 7(d) shows the gaussian , poisson and speckle noise removal by NHA method with PSNR value for Gaussian noise is 58.5744dB and MSE value 4.55. The noise removal of poisson noise with PSNR value is 56.5571dB and MSE value is 7.24. The speckle noise removal by NHA method with PSNR value 38.833dB and MSE value 428.7. By using NHA method, the reconstruction of input image is obtained with PSNR value 72.3988dB and MSE value 8.43459.
We have implemented three methods for removing noise from images. The performance parameters ratio of peak signal to noise (PSNR) along with mean square error (MSE) gives image quality. If image have higher PSNR value, then the image quality is better. The table 1 gives the comparison of three different denoising techniques that is DCT, DWT and NHA methods. We have used different images with adding three noises gaussian noise, poisson noise and speckle noise.
For each denoising method, we calculated PSNR and MSE values. NHA method attained higher PSNR value and MSE value, then the image quality is better when using NHA method than state-of-art methods.

Table 1: Comparison of Proposed methods

Images	Noises	DCT		DWT		NHA	
		PSNR	MSE	PSNR	MSE	PSNR	MSE
Lenna	Gaussian	1.84236	14009.6	1.8928	13957.4	58.675	4.445
	Poisson	1.96321	14216.9	1.9625	14046	54.137	12.64
	Speckle	2.07299	14882.6	14458.7	14045	38.612	450.99
Barbara	Gaussian	3.22012	17125.3	3.3145	16917.2	56.057	8.122
	Poisson	3.25652	17284.5	3.3447	16993.7	52.711	17.551
	Speckle	3.25271	17965.6	17390.8	16998.1	36.864	674.58
Cameraman	Gaussian	2.07812	18931.6	2.8415	18288.8	58.014	5.1758
	Poisson	2.76321	19136.3	2.9208	18405.9	52.565	18.1511
	Speckle	2.79624	20067.8	18922.1	18405.9	36.836	678.92
Building	Gaussian	1.37654	15441.6	1.3750	15367.6	62.940	1.665
	Poisson	1.44123	15572.6	1.4478	15476.3	49.038	40.89
	Speckle	1.63633	16105.4	15836.2	15476.3	37.322	606.965
Bird	Gaussian	5.65786	11871.4	6.5279	9781.85	58.596	4.58702
	Poisson	5.67521	12044.8	6.5976	9838.66	51.338	24.077
	Speckle	5.89116	12609.3	10189	9838.66	41.252	245.574
Brain MRI	Gaussian	9.91179	60831.1	8.9084	5265.48	58.923	4.19889
	Poisson	9.93906	61712.9	8.9621	5318.39	55.689	8.84056
	Speckle	10.0674	64282.5	5549.8	5318.39	43.854	134.896
OCT eye scan	Gaussian	8.75393	53982.7	10.3412	5516.34	60.996	2.60519
	Poisson	8.79865	54793.3	10.3826	5570.31	56.921	6.67514
	Speckle	9.03901	58162.1	5758.01	5584.92	44.368	119.851
MRI image	Gaussian	3.51096	25588.4	4.19973	21942.9	57.581	5.71926
	Poisson	3.61128	25182.4	4.27577	21652.4	37.878	534.053
	Speckle	3.86285	24165.1	20744.3	21652.4	33.114	1600.72

IV. CONCLUSION

In this work, image denoising with edge preserving techniques DWT and NHA are implemented.
Discrete Cosine Transform (DCT) is spatial filtering technique. DCT shows better performance at average bit rates. The main limitation of DCT is its considers only spatial pixels correlation within the individual 2D block. But it neglects the pixels correlation of adjoining blocks. Decorrelation of blocks can not be done at border when applying DCT to the corrupted pictures.

DCT attains lower PSNR value, hence the image quality is low. Discrete Wavelet Transform (DWT) is wavelet transforming technique. DWT shows better performance at less bit rates. The more usage of neither wavelet basis functions nor wavelet domain filters results in blurring around boundaries of pictures. Thus, DWT is superior than DCT technique so that DWT degrades blocking artifacts. DWT attains slightly higher PSNR value than DCT technique, hence the image quality is better than DCT denoising technique.

Non harmonic analysis (NHA) technique is new preprocessing technique. NHA is superior than DCT, because of reduction of sidelobe. For experiment, we have used different images, NHA attains higher PSNR values for each image. Hence NHA is better method than DWT in this context. Hence the image quality is better when using NHA method than the state-of-art methods. It has better image quality for medical images. Hence, NHA denoising method is best suited for medical image processing.

The proposed methods DWT and NHA methods obtained better results. These two methods are edge preserving denoising techniques. In future study, we can consider segmentation method for better results. And also we can study application of DWT technique for medical image processing.

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