Analysis of Wavelet Transform for Image Denoising with MSE

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ABSTRACT
A Great challenge is to obtain an efficient method for removing noise from the images. Noise can contaminate the image at time of capturing or transmission. The method of removing noise from image depends on the type of noise present in image. In this, different types of noise and analysis of noise removal techniques is presented. Here, result of applying various noise types to image and also results of applying various filters to those noisy images have been presented. Quantitative measure of comparison is provided by several quality parameters on the image. The parameters used are: Mean Square Error (MSE), Peak signal to noise ratio (PSNR), and Universal Image Quality Index. Whenever an image is reconstructed, the quality of reconstructed image is calculated in terms of various quality parameters. MSE is considered as one of the most reliable and widely used quality parameter however, we are using a new universal image quality index Q, which proves to be better than MSE. An improvisation of the same has also been proposed in this report. The noisy image is reconstructed by using wavelets on filtered image. The image is filtered using wiener filter i.e. frequency domain filtering followed by application of wavelets. The fact that the image reconstructed by this method is better than that reconstructed using other methods is proved to be true by examining the value of quality parameters MSE and PSNR. The value of MSE obtained by the above mentioned technique is found to be the smallest among all values of MSE obtained by other techniques i.e. the most favourable till now. Similarly the value of PSNR calculated by this technique is the highest obtained till now. Hence, we can say that the method adopted in this report to reconstruct an image from a noisy image is by far the best technique encountered till now.

Keywords
Image compression, wavelets, storage, etc.

1. INTRODUCTION
As the name suggests, Wavelets are small time limited waves having zero average value [3]. Different types of available wavelets are shown in Table. These wavelets are the basis function for wavelet analysis. Several families of wavelets that have proven to be especially useful are included in the wavelet toolbox [10]. The details of these wavelet Families have been shown below. ** Following wavelets in the last column of the table indicate a wavelet being a part of an infinite family of wavelets.

Sr. No	Mother wavelet family names	Abbreviations	Wavelets
1	Haar	Haar	
2	Daubechies	Db	db1 db2 db3 db4 db5 db6 db7 db8 db9 db10 db**
3	Symlets	Sym	sym2 sym3 sym4 sym5 sym6 sym7 sym8 sym**
4	Coiflets	Coif	coif1 coif2 coif3 coif4 coif5
5	BiorSplines	Bior	bior1.1 bior1.3 bior1.5 bior2.2 bior2.4 bior2.6 bior2.8 bior3.1 bior3.3 bior3.5 bior3.7 bior3.9 bior4.4 bior5.5 bior6.8
6	ReverseBior	Rbio	rbio1.1 rbio1.3 rbio1.5 rbio2.2 rbio2.4 rbio2.6 rbio2.8 rbio3.1 rbio3.3 rbio3.5 rbio3.7 rbio3.9 rbio4.4 rbio5.5 rbio6.8
7	Meyer	Meyr	
8	DMeyer	Dmey	
9	Gaussian	Gaus	gaus1 gaus2 gaus3 gaus4 gaus5gaus6 gaus7 gaus8 gaus**
10	Mexican_hat	Mexh	
11	Morlet	Morl	
12	Complex Gaussian	Gaus	cgau1cgau2cgau3cgau4 cgau5 cgau**
13	Shannon	Shan	shan1-1.5 shan1-1 shan1-0.5 shan1-0.1 shan2-3 shan**
14	Frequency B-Spline	Fbsp	fbsp1-1-1.5 fbsp1-1-1 fbsp1-1-0.5 fbsp2-1-1 fbsp2-1-0.5 fbsp2-1-0.1 fbsp**
15	Complex Morlet	Cmor	cmor1-1.5 cmor1-1 cmor1-0.5 cmor1-0.1 cmor**

The Discrete Wavelet Transform, which is based on sub-band coding, is found to yield a fast computation of Wavelet Transform [52][59]. It is easy to implement and reduces the computation time and resources required. The discrete wavelet transform uses filter banks for the construction of the multi-resolution time-frequency plane. The Discrete Wavelet Transform analyzes the signal at different frequency bands with different resolutions by decomposing the signal into an approximation and detail information.

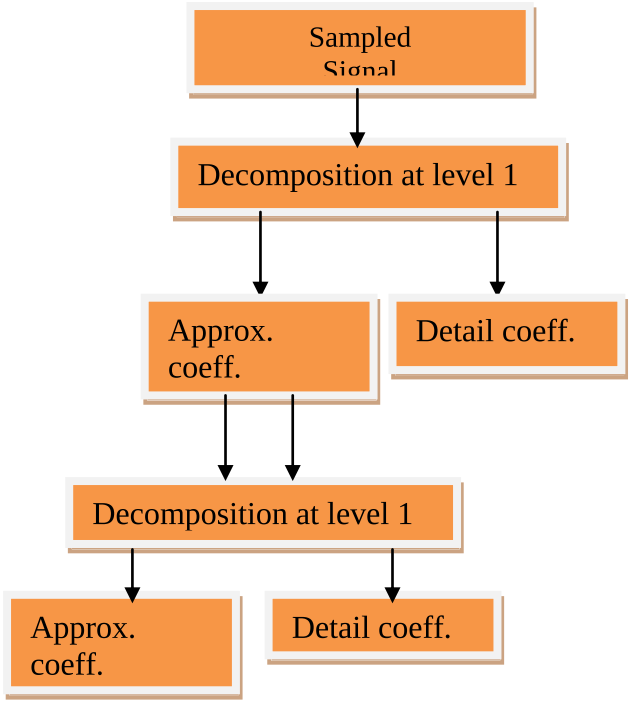

Fig 1: Flow of Wavelet - Multi-level Decomposition

The decomposition of the signal into different frequency bands obtained by successive high pass g[n] and low pass h[n] filtering of the time domain signal. The combination of high pass g[n] and low pass filter h[n] comprise a pair of analyzing filters The output of each filter contains half the frequency content, but an equal amount of samples as the input signal. The two outputs together contain the same frequency content as the input signal; however the amount of data is doubled. Therefore down sampling by a factor two, denoted by 2, is applied to the outputs of the filters in the analysis bank. Reconstruction of the original signal is possible using the synthesis filter bank. In the synthesis bank the signals are up sampled and passed through the filters g[n] and h[n]. The filters in the synthesis bank are based on the filters in the analysis bank.

2. LITERATURE SURVEY

Archana., et al. (2014) [1] proposed a theory based on image restoration methods. It explains digital image processing and describes 3 types of noise which are Gaussian, salt and pepper and speckle noise. Proliferation of Digital Images across the internet has given rise to more systematic and effective image restoration methods. Process of image restoration involves procuring noise free original image from a corrupted noisy image. This process of image restoration is crucial in many areas such as satellite imaging, astronomical image & medical imaging where degraded images need to be repaired. This paper provides a review of various Denoising Techniques in Image Restoration. The Denoising Techniques uses Linear and Non Linear Filters. It explains mean, median and adaptive filter in brief. The technique used for image restoration is Nearest Neighbour method along with Contrast and Saturation technique.

Atllas N., et al. (2014) [2] proposed a theory based on various techniques for reduction of speckle noise in ultrasound images. De-noising plays a very important role in the field of the biomedical image pre-processing. It is often done before the image data is to be analyzed. This paper presents a review of various techniques for reduction of speckle noise in ultrasound images. Speckle Noise is one of the most prominent noises seen in the ultrasound images and corrupts the visual quality of the image for further processing being multiplicative in nature. This paper demonstrates wavelet based techniques for improving visual image quality in ultrasound images and Denoising. With the help of variable window technique and region based processing; discrete wavelet transform technique provided better noise rejection in ultrasound images by removing the speckle noise.

Anutam., et al. (2014) [3] proposed a theory based on comparison of various wavelets at different decomposition levels. PSNR, MAE and MSE are the measures used for comparing image quality. Comparison of filters with wavelet based methods has also been carried out to De-noise image. Image Denoising is an important part of diverse image processing and computer vision problems. The important property of a good image de-noising model is that it should completely remove noise as far as possible as well as preserve edges. One of the most powerful and perspective approaches in this area is image de-noising using discrete wavelet transform (DWT). In this paper, comparison of various Wavelets at different decomposition levels has been done. As number of levels increased, Peak Signal to Noise Ratio (PSNR) of image gets decreased whereas Mean Absolute Error (MAE) and Mean Square Error (MSE) get increased. A comparison of filters and various wavelet based methods has also been carried out to de-noise the image. The simulation results reveal that wavelet based Bayes shrinkage method outperforms other methods.

Mandot M., et al. (2014) [4] proposed a theory based on pre-processing step of digital imaging, noise present in digital image and how filtering technique improves the quality of image and reduces noises in synthesis medical images. Now a day in regular emerging field of technology use of digital imaging grows. Digital image processing refers to processing of digital images by the digital computer to improve the quality of image and enhancing the image and their edges. DIP is vast area of work. This digital image processing is used in many fields like in photography, high security number plate recognition system and in medical field also. This paper mainly focuses on pre- processing step of digital imaging, noise present in digital image and how filtering technique improves the quality of image and reduces the noise in synthesis medical images. In this paper we take ultrasound medical images for pre-processing on digital image processing. So the input is ultrasound image for pre-processing. This paper describes type of noise and a new filtering technique for removing blurriness. Result is based on isualization and histogram of image.

Daway H., (2014) [5] proposed a theory based on a Mode Filter (MF) to reduce salt and pepper noise. The metrics for comparison used are PSNR, MSE, and IEF. A mode filter (MF) is proposed to remove high density salt & pepper noise from images. First stage in this algorithm the pixels with noise are detected and in the second stage each noisy pixel has been replaced by the mode value, after reduced range and estimate all noise value (0's and 255's) from the kernel. The proposed algorithm MF shows significantly better image quality than a simple median filter (SMF), adapted mean filter (AMF), Decision Based Algorithm (DBA) and Decision Based Unsymmetric Trimmed Median Filter (MDBUTMF). The proposed algorithm is examined with different gray image and it appears better Peak Signal-to-Noise Ratio (PSNR) and Image Enhancement Factor (IEF).

3. IMAGE DE-NOISE ALGORITHMS

The process adopted in filtering noisy image has been described with the help of block diagram and in detailed steps given below

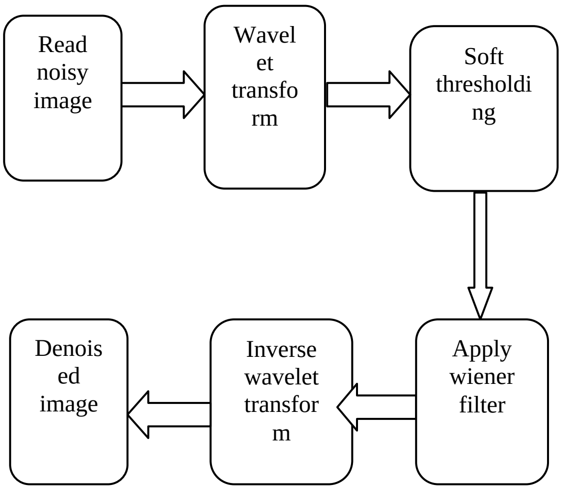

Fig 2: Process of proposed algorithm

Step 1:- Read the noisy image as input.

Read image from the hard disk with the help of inbuilt function. e.g.

I=imread('I.png');

Step 2:- Decide name of wavelet family.

Use any one wavelet from the various wavelets family (db1-45 and others).

Step 3:- Decide density of noise used by wiener filter, which should be >=0.01.

Use Numeric Value as a parameter to add noise density in the image.

Step 4:- Use odd size mask for low frequency sub-band.

Always use odd mask size like 3x3, 5x5, 7x7…etc for low frequency sub-band because odd size of mask has center value.

Step 5:- Use odd size mask for high frequency sub-band.

Always use odd mask size like 3x3, 5x5, 7x7…etc for high frequency sub-band because odd size of mask has center value.

Step 6:- Apply first level dwt (Single-level discrete 2-D wavelet transform)

The dwt2 command performs a single-level two-dimensional wavelet decomposition with respect to either a particular wavelet ('wname') or particular.wavelet decomposition filters (Lo_D and Hi_D) you specify.

[cA,cH,cV,cD] = dwt2(X,'wname') computes the approximation coefficients matrix cA and details coefficients matrices cH, cV, and cD (horizontal, vertical, and diagonal, respectively), obtained by wavelet decomposition of the input matrix X. The 'wname' string contains the wavelet name.

Step 7:- Apply second level dwt on output obtained in previous step

[AA,AB,AC,AD]=dwt2(cA,wname);

Step 8:- Apply soft thresholding i.e. remove noise from high frequency domain in dwt.

Apply first level soft-Thresolding in each block cH,cV and cD respectively than again apply second level soft-Thresolding in each block AB,AC and AD respectively.

Step 9:- Apply wiener filter.

2-D adaptive noise-removal filtering is a lowpass filter, a grayscale image that has been degraded by constant power additive noise. wiener2 uses a pixel-wise adaptive Wiener method based on statistics estimated from a local neighbor hood of each pixel.

Step 10:- Apply inverse dwt for second level.

The idwt2 command performs a single-level two-dimensional wavelet reconstruction with respect to either a particular wavelet ('wname', see wfilters for more information) or particular wavelet reconstruction filters (Lo_Rand Hi_R) that you specify.

Step 11:- Apply inverse dwt for first level.

Same process will be implemented for first level as mentioned in step 10.

Step 12:- Save denoised image.

Write image to graphics file. imwrite(A,filename,fmt) writes the image A to the file specified by filename in the format specified by fmt.

4. IMAGE DE-NOISE TOOL

Finally, the reconstructed (denoised) image is compared with the original image by means of quality parameters MSE and PSNR. These values help us estimate the extent of reconstruction.

When we click on button filter_Apply execution of proposed algorithms which is define in section 3 is start. In the process three different images have already stored on the hard disk first input image, second noisy image and third filtered image. For second phase of the tool click on quality button, browse window will be open and ask to import original image and filtered image once you import the images it will give the values of MSE and PSNR, to check the accuracy or for comparisons we need the value of MSE and PSNR for the input image and noise image which should be degraded.

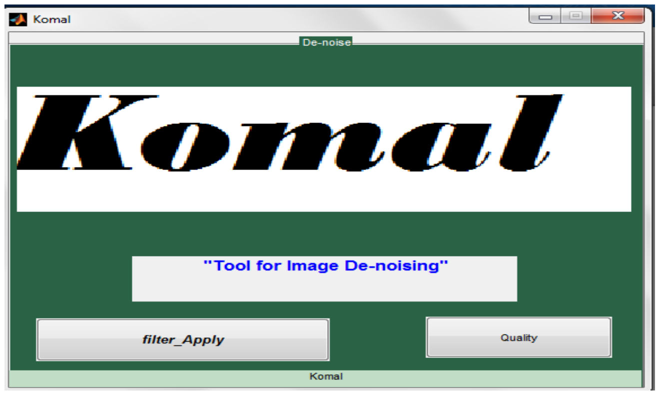

Fig 3: GUI

5. RESULT

Results are formulated and presented in form of Tables. First of all, the values of MSE and PSNR are calculated for order static filters, which come out to be unsatisfactory. Next, a new universal image quality index is used as a quality parameter and also histogram equalization is performed on images in order to improve value of new quality index. Later in this chapter, frequency domain filtering followed by application of wavelets is done and values of MSE and PSNR are recorded for the same. The values stored make it clear that which technique is best in process of noise removal and image reconstruction.

In the below there are two image first input image and second noisy image with gaussian noise. Our objective is to remove the noise from the second image and compare with first image that how much we are close to ideal image after the filtering.

Fig 4: Input Image Fig 5: Gaussian Noise

Table 1: MseAndPsnr Values For Gaussian Noise

Quality parameter	R component	G component	B component
MSE	237.0562	231.3223	228.8254
PSNR	24.3823	24.4886	24.5358

The values of parameters obtained above without proposed filter or wavelets and are un-favourable.

Table 2: Haar Wavelet Values For Gaussian Noise

Quality parameter	R component	G component	B component
MSE	140.5669	125.1484	122.8254
PSNR	26.6520	27.1565	27.2570

The values of parameters get improved than original values and are obtained by applied wavelets 'haar' with proposed filter.

Table 3:Db Wavelet Family Values For Gaussian Noise

Type of wavelet	Quality parameter	R component	G component	B component
db1	MSE	140.5669	125.1484	122.2878
	PSNR	26.6520	27.1565	27.2570
db2	MSE	210.5146	190.4105	185.0931
	PSNR	24.8980	25.3339	25.4569
db3	MSE	83.9162	75.1645	74.6778
	PSNR	28.8923	29.3707	29.3989
db4	MSE	121.7556	107.3875	105.2782
	PSNR	27.2759	27.8213	27.9074
db5	MSE	188.0450	168.8309	164.1483
	PSNR	25.3882	25.8563	25.9784
db6	MSE	259.9101	237.4373	230.6227
	PSNR	23.9826	24.3753	24.5018
db7	MSE	102.2316	90.1505	88.8765
	PSNR	28.0350	28.5811	28.6429
db8	MSE	165.2622	146.3788	143.5395
	PSNR	25.9491	26.4465	26.5611
db9	MSE	235.6039	214.1133	207.9701
	PSNR	24.4090	24.8244	24.9508
db10	MSE	122.0873	107.6079	105.5134
	PSNR	27.2641	27.8124	27.8977
db11	MSE	143.2268	126.8956	123.9108
	PSNR	26.5706	27.0963	27.1997
db12	MSE	211.6468	191.2495	185.8192
	PSNR	24.8747	25.3148	25.4399
db13	MSE	84.1956	75.3015	74.7942
	PSNR	28.8779	29.3628	29.3921
db14	MSE	122.1987	107.7193	105.5548
	PSNR	27.2601	27.8079	27.8960
db15	MSE	188.1893	168.9817	164.3236
	PSNR	25.3849	25.8524	25.9738
db16	MSE	260.1243	237.6087	230.7920
	PSNR	23.9790	24.3722	24.4986
db17	MSE	102.4274	90.3013	88.9943

	PSNR	28.0266	28.5739	28.6372
db18	MSE	165.3729	147.5488	143.7138
	PSNR	25.9462	26.4414	26.5558
db20	MSE	122.3034	107.7865	105.6301
	PSNR	27.2564	27.8052	27.8929
db23	MSE	84.3800	75.4640	74.9121
	PSNR	28.8684	29.3534	29.3853
db25	MSE	188.3420	169.1185	164.4809
	PSNR	25.3813	25.8489	25.9696
db33	MSE	84.4533	75.5588	75.0000
	PSNR	28.8646	29.3480	29.3802
db43	MSE	84.4647	75.6271	75.0906
	PSNR	28.8641	29.3440	29.3749

db3 gives the best and most appropriate values for both the parameters; hence, db3 is the best member of this wavelet family for noise removal.

Table 4: Symlet Wavelet Family Values For Gaussian Noise

Type of wavelet	Quality parameter	R component	G component	B component
sym1	**MSE**	**140.5669**	**125.1484**	**122.2878**
	PSNR	26.6520	27.1565	27.2570
sym2	MSE	210.5146	190.4105	185.0931
	PSNR	24.8980	25.3339	25.4569
sym3	MSE	83.9162	75.1645	74.6778
	PSNR	28.8923	29.3707	29.3989
sym4	MSE	121.7164	107.3763	105.2900
	PSNR	27.2773	27.8217	27.9069
sym5	MSE	188.0054	168.7083	164.0537
	PSNR	25.3891	25.8594	25.9809
sym6	MSE	259.9063	237.4498	230.5483
	PSNR	23.9826	24.3751	24.5032
sym7	MSE	102.1185	90.1621	88.9309
	PSNR	28.0398	28.5806	28.6403
sym8	MSE	165.3166	147.3756	143.5555
	PSNR	25.9476	26.4465	26.5606
sym9	MSE	235.6420	213.9995	207.8680
	PSNR	24.4083	24.8267	24.9529
sym10	MSE	122.1133	107.7315	105.5795
	PSNR	27.2632	27.8074	27.8950

Sym3 gives the best and most appropriate values for both the parameters; hence, sym3 is the best member of this wavelet family for noise removal.

Table 5:Dmey Wavelet Family Values For Gaussian Noise

Quality parameter	R component	G component	B component
MSE	143.9384	127.4469	124.4412
PSNR	26.5490	27.0775	27.1812

This table gives the values of MSE and PSNR, when discrete approximation of Meyer wavelet is applied to images.

Table 6:Coiflets Wavelet Family Values For Gaussian Noise

Type of wavelet	Quality parameter	R component	G component	B component
coif1	MSE	84.0741	75.2217	74.6900
	PSNR	28.8842	29.3674	29.3982
coif2	MSE	259.7075	237.1542	230.3654
	PSNR	23.9860	24.3805	24.5066
coif3	MSE	235.5327	213.9328	207.8173
	PSNR	24.4103	24.8280	24.9540
coif4	MSE	211.6738	191.1659	185.7459
	PSNR	24.8741	25.3167	25.4416
coif5	MSE	188.2761	168.9376	164.2740
	PSNR	25.3829	25.8535	25.9751

coif1 gives the best and most appropriate values for both the parameters; hence, coif1 is the best member of this wavelet family for noise removal.

Table 7:Biorthogonal Wavelet Family Values For Gaussian Noise

Type of wavelet	Quality parameter	R component	G component	B component
bior1.1	MSE	140.5669	125.1484	122.2878
	PSNR	26.6520	27.1565	27.2570
bior1.3	MSE	86.3121	77.2687	76.6436
	PSNR	28.7701	29.2508	29.2860
bior1.5	MSE	191.4449	171.7029	166.8391
	PSNR	25.3104	25.7830	25.9078
bior2.2	MSE	86.0207	77.1674	76.5723
	PSNR	28.7848	29.2565	29.2901
bior2.4	MSE	189.4208	170.2584	165.5348
	PSNR	25.3565	25.8197	25.9419
bior2.6	MSE	103.6923	91.4962	90.1308
	PSNR	27.9733	28.5168	28.5821

bior2.8	MSE	237.5998	215.9908	209.6995
	PSNR	24.3723	24.7865	24.9148
bior3.1	MSE	241.3863	220.7059	215.1474
	PSNR	24.3037	24.6927	24.8034
bior3.3	MSE	126.7134	112.2248	110.0205
	PSNR	27.1026	27.6299	27.7161
bior3.5	MSE	263.3599	240.6773	233.7175
	PSNR	23.9253	24.3165	24.4439
bior3.7	MSE	168.1115	150.0168	146.0518
	PSNR	25.8748	26.3694	26.4857
bior3.9	MSE	124.6271	109.9055	107.6667
	PSNR	27.1747	27.7206	27.8100
bior4.4	MSE	187.6905	168.6667	164.0198
	PSNR	25.3964	25.8605	25.9818
bior5.5	MSE	257.7441	235.3675	228.6164
	PSNR	24.0189	24.4133	24.5397
bior6.8	MSE	235.8277	214.3490	208.1427
	PSNR	24.4049	24.8196	24.9472

bior2.2 gives the best and most appropriate values for both the parameters; hence, bior2.2 is the best member of this wavelet family for noise removal.

Table 8 Reverse Biorthogonal Wavelet Family Values For Gaussian Noise

Type of wavelet	Quality parameter	R component	G component	B component
rbio1.1	MSE	140.5669	125.1484	122.2878
	PSNR	26.6520	27.1565	27.2570
rbio1.3	MSE	84.1810	75.5484	75.1166
	PSNR	28.8787	29.3485	29.3734
rbio1.5	MSE	188.6351	169.4591	164.7809
	PSNR	25.3746	25.8402	25.9617
rbio2.2	MSE	84.6084	75.4751	74.9051
	PSNR	28.8567	29.3528	29.3857
rbio2.4	MSE	186.1865	167.2532	162.6933
	PSNR	25.4313	25.8971	26.0171
rbio2.6	MSE	101.0028	89.0975	87.8802
	PSNR	28.0875	28.6321	28.6919
rbio2.8	MSE	233.8773	212.5610	206.4522
	PSNR	24.4409	24.8560	24.9826
rbio3.1	MSE	276.2658	246.3094	237.9069
	PSNR	23.7175	24.2160	24.3667
rbio3.3	MSE	124.0257	109.3075	107.0878
	PSNR	27.1957	27.7443	27.8334
rbio3.5	MSE	259.0130	236.4746	229.7383
	PSNR	23.9976	24.3930	24.5185
rbio3.7	MSE	164.2735	146.5617	142.8153
	PSNR	25.9751	26.4706	26.5831
rbio3.9	MSE	121.2549	107.0014	104.9318
	PSNR	27.2938	27.8369	27.9217
rbio4.4	MSE	188.3078	169.1083	164.4622
	PSNR	25.3821	25.8492	25.9701
rbio5.5	MSE	262.3553	239.6271	232.6387
	PSNR	23.9419	24.3354	24.4640
rbio6.8	MSE	235.3314	213.8630	207.6810
	PSNR	24.4140	24.8194	24.9568

rbio2.2 gives the best and most appropriate values for both the parameters; hence, rbio2.2 is the best member of this wavelet family for noise removal.

In the same manner experiment was complete with other noise e.g. salt and paper and Speckle Noise.

6. CONCLUSION

In the present work we discuss different noises like Gaussian, salt and pepper, and speckle noise along with their PDF. We also explained various spatial filtering techniques and various image De-noising performance parameters. It is concluded that filtering is important in order to reconstruct a good quality image from a noisy image and various parameters help to identify which filter is best for removing a particular noise. The ideal values for parameters are 0 for MSE, 100000 for PSNR (as high as possible).

Next, frequency domain filtering is applied on noisy images and then wavelets are applied. The result for MSE and PSNR are calculated and tabulated. The results make it clear that the output image obtained after wiener filter and wavelets gives the most suitable values for both the quality parameters i.e. MSE & PSNR. The results also reveal that thesome wavelets are independent of noise or work properly and others are not supported in MATLAB. This is also explained with the help of table given below. In Future, noise models, filters and performance parameters can be increased in number in order to obtain a much clear view, concerning decision regarding particular filter selection for a noise type.

Table 9:Relationships between Noise and Wavelet

Wavelets corresponding noise	Gaussian	Salt & pepper	Speckle
Haar	Y	Y	Y
Daubchies	Y	Y	Y
Symlet	Y	Y	Y
Dmey	Y	Y	Y
Coiflets	Y	Y	Y
Bior	Y	Y	Y
Rbio	Y	Y	Y
Morlet	N	N	N
Cgau	N	N	N
Shannon	N	N	N
Fbsp	N	N	N
Cmor	N	N	N
Mexh	N	N	N
Morl	N	N	N
Meyr	N	N	N

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