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A NOVEL DENOISING TECHNIQUE FOR MIXED NOISE REMOVAL FROM GRAYSCALE AND COLOR IMAGES

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ABSTRACT

The real-time images acquired from cameras, CCTV, medical image scanners like Magnetic Resonance Imaging (MRI), Computerized Tomography (CT), Ultrasound (US) and X-ray etc., are often corrupted by noise. This noise may be a mixture of two or more noise types. In recent years, researchers concentrate on developing a denoising filter to suppress the mixed noises to improve the quality of the image. A novel algorithm that uses absolute difference, mean and median for the removal of mixed noise in image has been proposed in this article. The proposed filter is tested with the images induced by two types of noise mixed (Salt and Pepper and Gaussian noise) and three types of noise mixed (Gaussian, Salt and Pepper and Speckle noise) images. The performance of the proposed algorithm is compared with existing Fuzzy Based Filter (FBF), and Median Weiner Bilateral Filter (MWBF) algorithms. The test images used in this research work are Lena image, Iris eye images and medical images in grayscale Joint Photographic Experts Group (JPEG) format and also with the color images in four different image formats with mixed noise level ranging from 0.01 to 0.10. The experimented results show that the proposed algorithm yields better performance than the algorithms mentioned above. Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE) are the metrics used in this comparative analysis.

Keywords: *Image Denoising, Mixed noise removal, Mean, Median, Absolute Difference, PSNR, MSE*

1. INTRODUCTION

Image denoising is the process of removing or suppressing the noise to enhance the quality of the image and is an essential preprocessing step before undergoing segmentation, object detection and image analysis. The noise is an unwanted disturbance in the image induced during acquisition and transmission that destroys the fine details. In real time, images have been corrupted by two or more types of noises. Hence, it becomes essential to develop a denoising algorithm that can suppress the mixed noise from the image. The chief objective of this research study is to remove or suppress mixed multiple noises treated in image and to enhance their quality for future processing.

1.1 Noise Types

The Salt and Pepper (SP) noise will take a gray level value either minimal (0) or maximal (255) intensity. Hence, it is also called as fixed impulse noise [1]. The sharp and sudden disturbance in the image signal is the cause of salt and pepper noise degradation. Generally, this type of noise will affect only a small number of image pixels that are randomly corrupted by either 0 or 255. The Salt and Pepper noise is viewed as white and dark dots in the image. [2].

Gaussian Noise is also called additive noise [3]. In this noisy image, each pixel intensity value is the sum of the true pixel value and a random Gaussian distributed noise value. Hence, it is evenly distributed over the signal [4]. The scale of Gaussian noise is independent at each pixel and independent of the signal intensity. Every pixel in the image will be changed from its original value by using a small amount [5].

Speckle noise is caused by coherent processing of backscattered signals from multiple distributed targets [6]. This noise is generated by

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multiplying a random value with pixel values of the image. Hence, it is known as multiplicative noise. It can be expressed as $J = I + n*I$. Where, J is the speckle noise distribution image, I is the input image and n is the uniform noise image with mean 0 and variance v [7].

The mixed noise discussed in this article is the combination of above specified three types of noise.

1.2 Mixed Noise

When two or more types of noise are induced one after the other in the same image then it is known as mixed noise. The suggested technique is tested with the images corrupted by two /three noise mixed types.

1.2.1 Type I mixed noise(two noise types mixed)

When two types of noise are induced in the same image then such type of mixed noise comes under this category. Figure 1 shows the process of inducing the two types of noise (Salt and Pepper and Gaussian noise) in an image in the same order to form a mixed noisy image.

Figure 1: The Steps Of Inducing Two Noise Types Mixed

1.2.2 Type II mixed noise (three noise types mixed)

In this type, three types of noise are induced in the same image. This research work concentrates on introducing Salt and Pepper, Gaussian and Speckle noise in an image to form this type of mixed noisy image. The two combinations of these three types of noise are discussed in this research.

Mixed noise combination I

In this combination, the original image is induced with Gaussian noise, Speckle noise and Salt and pepper noise in the same image and in the same order to get a mixed noise image. The steps of inducing this mixed noise combination using Lena image are shown in figure 2.

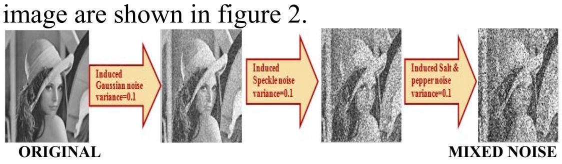

Figure 2: The Steps Of Inducing Combination I

Mixed noise combination II

In this combination, the original image is induced with Salt and Pepper noise, Gaussian and Speckle noise in the same image and in the same order to get a mixed noise image. The steps of inducing this mixed noise combination using Lena image are shown in figure 3.

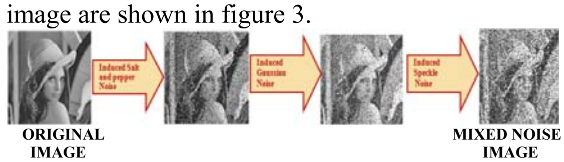

Figure 3: The Steps Of Inducing Combination I

2. LITERATURE REVIEW

Hybrid denoising method [8] has been used for the removal of multiple noises (Gaussian and impulse noise) in medical images. In this article, a hybridization of wavelet filter and Center weighted median filter has been designed. Wavelet transformation is applied on the noisy images to produce wavelet coefficients. Soft threshold technique is used on the coefficients and an inverse wavelet transformation is done to obtain a denoised image. This denoised image still contains some artifacts which are reduced by applying Center Weighted Median (CWM) filter.

An improved Weighted Encoding with Sparse Nonlocal Regularization (WESNR)[9] has been proposed to remove mixed impulse noise and Gaussian noise. In this approach, a decision based algorithm is applied to the noisy image to obtain an initialized image which reduces the artifacts and blurring The weighted encoding is used to suppress the impulse noise from the above output image and sparse nonlocal regularization is used to suppress the additive white Gaussian noise.

Remya Soman et al [10] introduced a novel approach for mixed noise (Gaussian noise and impulse noise) removal. In this technique, Robust Outlyingness Ratio (ROR) statistics is combined with Adaptive Center Weighted Median (ACWMF) and Detail Preserving Variational Method (DPVM). In this approach, the ROR statistic is used to classify the pixels into different clusters. This cluster undergoes course and fine stage of noise detection using ACWMF. The noise detected in the previous stage is removed using DPVM. The final stage of filtering is done by means of Non Local Mean filter.

An efficient fuzzy based filter (FBF) [11] has been introduced to suppress mixed noise from the images. The mixed noise addressed in this article is the combination of Salt and Pepper noise and Gaussian noise. In this proposed filter, a fuzzy flag is calculated for each processing pixel using the membership function. For a noise free pixel, the fuzzy flag is set to zero and the processing pixel is left unchanged. If the flag is set to one, then the processing pixel is replaced by the median value of the neighbor pixels. For all other fuzzy flag value

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that lies between zero and one, the processing pixel value is replaced by a linear combination of processing pixel value and median value. This algorithm suppresses the noise as well as the fine structures and sharp intensity edges are preserved.

Sandeep Kumar et al[12] introduced a special filter which is a combination of Median filter, Wiener filter and Bilateral filter to suppress the mixed noise. A mixed noise image is generated by adding Gaussian noise with Speckle noise and Salt and Pepper noise. This mixed noise is passed as input to a special filter. In this special filter, the noisy image is first sent to the median filter. Then, the resultant image is passed as input to Wiener filter. The output obtained from Wiener filter is then passed into the Bilateral filter in order to get the denoised image.

Though there are several denoising technique have been suggested in the literature some of the techniques fails to retain the edges and fine details while suppressing the noise when the noise density is high. In the proposed technique, double filtering is done using mean and median concept that helps to suppress the noise efficiently. The fine structure and sharp edges are preserved even at high noise level induced in the test images.

3. PROPOSED ALGORITHM

The proposed algorithm is an enhanced technique on the research work carried out in [13] that helps to suppress the noise from the mixed noise image. The mixed noise induced image is taken as input to the proposed filter. In this algorithm, the 5x5 window has been selected such that P(i,j) is the processing pixel. The 5x5 mask for proposed filter is given in figure 1a. The intensity values for the pixel location A1, A2, B1, B2, C1, C2, D1 and D2 are taken into consideration for finding the absolute difference. The mean M1 and M2 are calculated for the pixels which are having the minimum absolute difference between the pixels (A1-A2, B1-B2) and (C1-C2, D1-D2). Then, the P(i,j) is replaced by the mean of M1, M2 and P(i,j). Simultaneously the previous pixel P(i-1,j) is replaced by the median of the pixels(W, X,Y, Z) in the 3x3 window as shown in figure 1b. The above process is repeated for the entire image. The denoised image is obtained as a result of suppressing the mixed noise using the proposed algorithm. This processing step of the algorithm is shown below.

		D1		
		B1		
C1	A1	P(i,j)	A2	C2
		B2		
		D2		

a.The 5x5 mask

	W	
Z	P(i-1,j)	X
	Y	

b. The 3x3 mask

Figure 4: The MXN Mask Used For Proposed Filter

3.1 Algorithm

Step 1: Read a mixed noisy image.
Step 2: Initialize the window size as 5 (W=5) Assume the center element as the processing pixel P(i,j).
Step 3:Compute the mean (M1) for the pixels which are having the minimum absolute difference between the pixels (A1-A2, B1-B2).
Step 4: Compute the mean (M2) for the pixels which are having the minimum absolute difference between the pixels (C1-C2, D1-D2).
Step 5: Replace the central pixel P(i,j) with the mean of M1, M2 and P(i,j).
Step 6: Replace the previously processed pixel P(i-1,j) with the median of pixels (W,X,Y,Z).
Step 7: Repeat the steps from 3 to 6 until all the pixels are processed in the given image.

4. IMPLEMENTATION OF PROPOSED ALGORITHM

The denoising algorithm proposed in this article has been implemented along with existing filters such as FBF [11], and MWBF [12] using Matlab. The inputs to these algorithms are the above specified type I and type II mixed noise induced images. These algorithms are tested with the standard Lena image of size 512x512, Iris images of size 640x480 from CASIA-Irisv3 database. The performance of the algorithms are also tested with medical images like B-mode US images of size 538x340 from http://splab.cz/en/download/databaze/ultrasound,MRI standard knee images of 256x256 size and CT Dental scanned images with the 512x512 size which are taken from the DICOM sample dataset and sample color images with four different image format are used as test images.

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5. PERFORMANCE METRICS

The performance of the noise reduction techniques are commonly measured in terms of Mean Square Error (MSE)[14,15,16,17] and Peak Signal to Noise Ratio (PSNR)[14,15][17].

5.1 Mean Square Error (MSE)

Mean Square Error (MSE) is the commonly used image quality metrics. Let the noisy image be g(x, y), filtered image be f̂(x, y) and original noise-free image be f (x, y). The discrete spatial coordinates of the digital images are represented by x and y. Let M × N pixels be the size of the image. The MSE is defined in the equation (1).

$$MSE = \frac{1}{M \times N} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} \left[f(x,y) - \hat{f}(x,y) \right]^2 \quad (1)$$

5.2 Peak Signal To Noise Ratio (PSNR)

Peak Signal to Noise Ratio (PSNR) is used to measure an objective difference between two images. The reconstructed image quality is estimated with respect to an original image. If the reconstructed image has higher PSNR value, then it is judged better. Both the original image and denoised image should be of the same size. The PSNR is measured in dB. The PSNR is defined in the equation (2).

$$PSNR = 10 \log_{10} \frac{255^2}{MSE} \quad (2)$$

6. EXPERIMENTAL RESULTS

In this research, the proposed technique is compared with FBF [11] existing filter for the suppression of type I (Salt and Pepper and Gaussian noise) mixed noise. The order of noise types induced in the input image and existing filter [11] are same. The Standard Lena image and 50 Iris images in grayscale JPEG format are used as the test images and their performance is analyzed. The original image, type I noise image with noise level 0.10 and the denoised image obtained by proposed filter and FBF [11] are shown in figure 5. Though the experiment has been carried out for mixed noise level ranging from 0.01 to 0.10, table 1 and 2 shows the result of every 2% increment in the noise level starting from 0.02 to 0.10 for Lena and Iris images respectively.

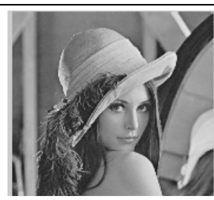
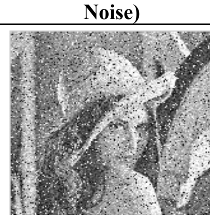
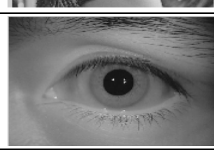
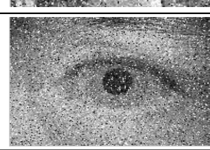
IMAGE	ORIGINAL IMAGE	TYPE I MIXED NOISE (Salt and Pepper, Gaussian Noise)	DENOISED IMAGES	
			FBF[11]	PROPOSED METHOD
LENA IMAGE				
IRIS IMAGE				

Figure 5: Result Of Grayscale JPEG Images With Type I Mixed Noise

Table 1: Comparison Using Lena Image With Type I Mixed Noise.

S.NO	NOISE LEVEL	METRICS	FBF[11]	PROPOSED METHOD
1	0.02	PSNR	25.31	**27.38**
		MSE	191.23	**118.71**
2	0.04	PSNR	23.68	**25.18**
		MSE	278.03	**197.47**
3	0.06	PSNR	21.89	**22.93**
		MSE	420.41	**331.55**
4	0.08	PSNR	20.24	**20.96**
		MSE	615.73	**520.99**
5	0.10	PSNR	18.81	**19.36**
		MSE	854.89	**752.48**

Table 2: Comparison Using Average Of 50 Iris Images With Type I Mixed Noise.

S.NO	NOISE LEVEL	METRICS	FBF[11]	PROPOSED METHOD
1	0.02	PSNR	25.76	**29.46**
		MSE	172.47	**73.62**
2	0.04	PSNR	24.00	**26.27**
		MSE	258.79	**153.54**
3	0.06	PSNR	22.12	**23.56**
		MSE	398.77	**286.71**
4	0.08	PSNR	20.41	**21.38**
		MSE	592.01	**472.90**
5	0.10	PSNR	18.89	**19.61**
		MSE	839.48	**711.51**

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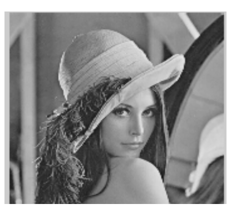
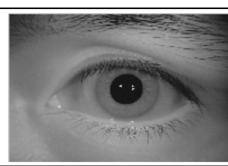
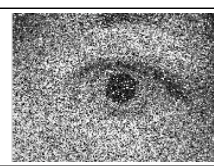
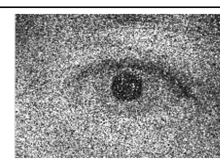
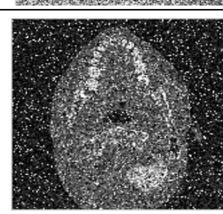
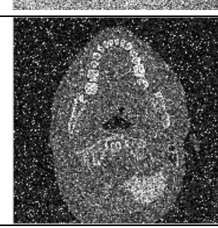
The proposed algorithm is also tested with type II mixed noise (salt and Pepper, Gaussian and speckle noise) and compared with FBF[11] and MWBF[12] existing filters for the suppression of three types of noise mixed in order to analyze the stability of the algorithm. The mixed noise combination I is the same order of noise types induced in the MWBF [12]. Mixed noise combination II is the same order of first two noise types (Salt and Pepper, Gaussian noise) specified in FBF [11] and Speckle noise is added at the end. The FBF[11], MWBF[12] and the proposed method are tested with type II mixed noise with various noise level ranging from 0.01 to 0.10 induced noisy images such as the standard Lena and 200 Iris images and also tested with medical images like US, MRI and CT each of 25 in grayscale JPEG images as well as sample color images in Joint Photographic Experts Group (JPEG), Portable Network Graphics (PNG), Tag Image File Format (TIFF) and Bitmap (BMP) format.

The original images and corresponding two combinations of type II mixed noise induced grayscale and color images in JPEG format with noise level 0.10 are shown in figure 6 and 7. The resultant denoised grayscale and color images of proposed approach and existing filters are shown in figures from 8 to11. Though the experiments have been carried out for mixed noise level ranging from 0.01 to 0.10 the tables from 3 to 7 show the result of grayscale JPEG for every 2% increment in the noise level starting from 0.02 to 0.10. The tables from 8 to 11 show the result using color images in four different image formats for noise level 0.02 and 0.10. The PSNR and MSE values of the proposed algorithm are compared with the HBF [11] and MWBF [12] existing filter for the test images used in this research.

The performance of proposed filter and FBF [11] with type I mixed noise using Lena and Iris images is plotted in the graph in terms of PSNR values and their results are shown in figure 12.a and 12.b.

IMAGE	ORIGINAL IMAGE	MIXED NOISE INDUCED IMAGE	
		COMBINATION I (GAUSSIAN, SPECKLE, SALT & PEPPER)	COMBINATION II (SALT & PEPPER, GAUSSIAN, SPECKLE)
LENA IMAGE			
IRIS IMAGE			
CT IMAGE			

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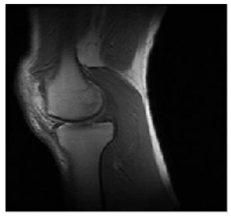
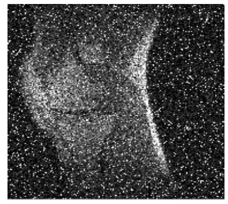
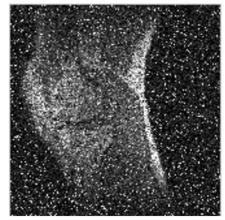
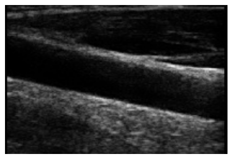
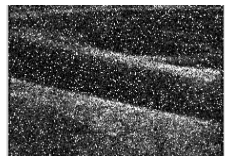
MRI IMAGE			
US IMAGE			

Figure 6: Original And Type II Mixed Noise Grayscale JPEG Images

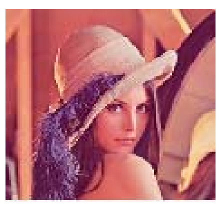
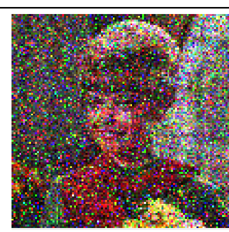
COLOR IMAGE	**ORIGINAL IMAGE**	**MIXED NOISE INDUCED IMAGE**	
		COMBINATION I (GAUSSIAN, SPECKLE, SALT & PEPPER)	**COMBINATION II (SALT & PEPPER, GAUSSIAN, SPECKLE)**
LENA IMAGE			
HOUSE IMAGE			
PEPPER IMAGE			
GIRL IMAGE			

Figure 7: Original And Type II Mixed Noise Color JPEG Images

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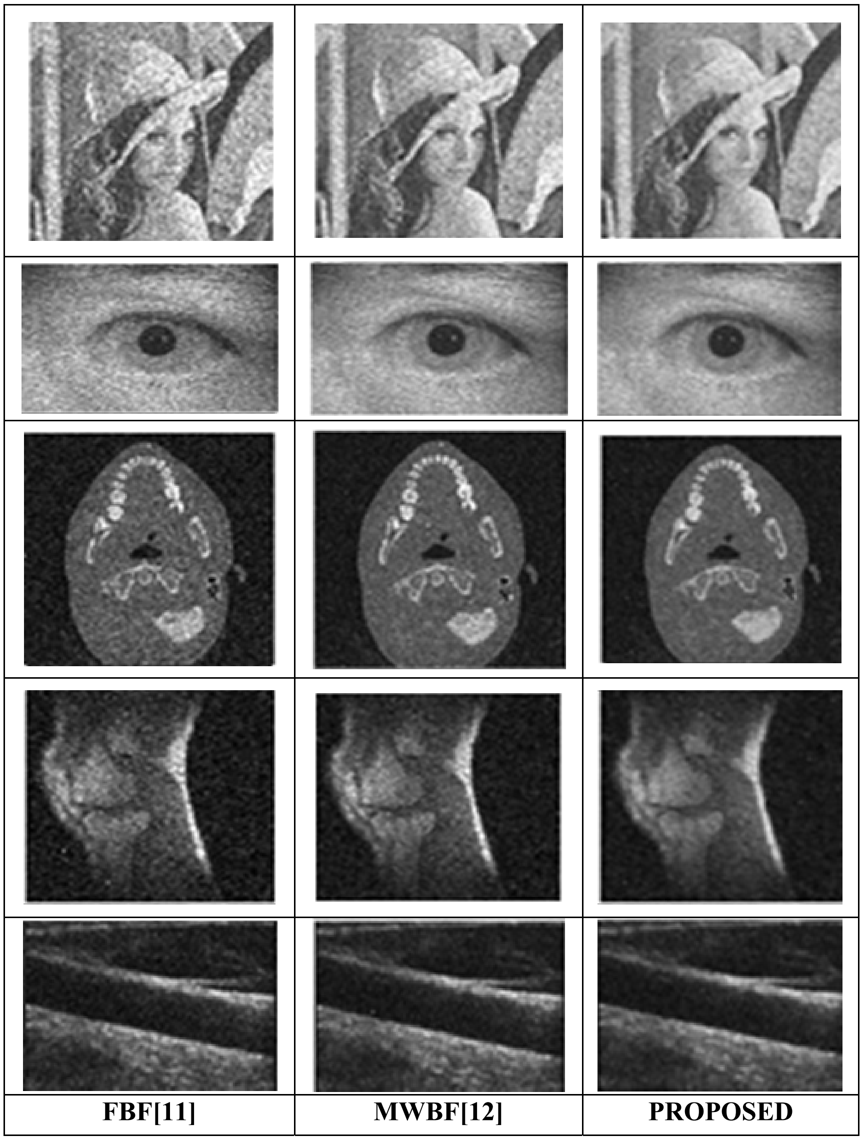

Figure 8: Result Of Grayscale Jpeg Images With Type Ii Mixed Noise Combination I

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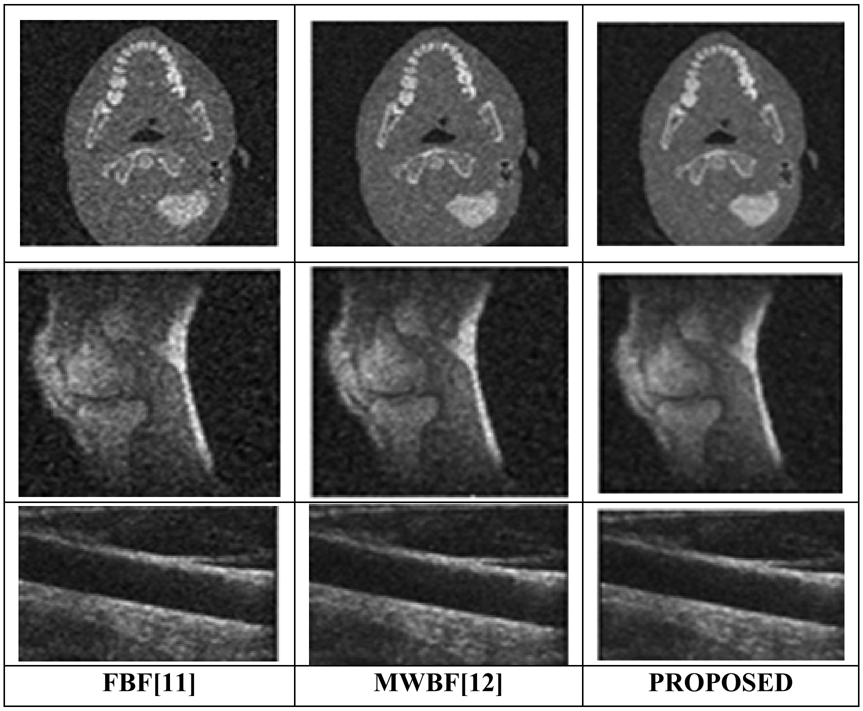

Figure 9: Result Of Grayscale JPEG Images With Type II Mixed Noise Combination II

Figure 10: Result Of Color JPEG Images With Type II Mixed Noise Combination I

Figure 11: Result Of Color JPEG Images With Type II Mixed Noise Combination II

Table 3: Comparison Of Algorithms Using Lena Grayscale Image With Type II Mixed Noise

S.NO	MIXED NOISE TYPE	NOISE LEVEL	METRICS	FBF[11]	MWBF[12]	PROPOSED METHOD
1	COMBINATION I	0.02	**PSNR**	23.76	24.27	**27.09**
			MSE	273.24	248.22	**126.83**
	COMBINATION II	0.02	**PSNR**	23.32	24.27	**27.04**
			MSE	268.84	242.99	**128.27**
2	COMBINATION I	0.04	**PSNR**	21.53	22.62	**24.99**
			MSE	457.15	355.69	**205.92**
	COMBINATION II	0.04	**PSNR**	21.61	22.68	**25.01**
			MSE	448.36	350.68	**205.05**
3	COMBINATION I	0.06	**PSNR**	19.56	20.98	**23.01**
			MSE	718.16	518.15	**324.97**
	COMBINATION II	0.06	**PSNR**	19.77	21.11	**23.20**
			MSE	685.11	503.36	**310.96**
4	COMBINATION I	0.08	**PSNR**	18.02	19.47	**21.23**
			MSE	1024.25	734.30	**489.27**
	COMBINATION II	0.08	**PSNR**	18.16	19.64	**21.42**
			MSE	991.75	706.01	**468.85**
5	COMBINATION I	0.10	**PSNR**	16.59	18.04	**19.69**
			MSE	1423.38	1006.12	**698.32**
	COMBINATION II	0.10	**PSNR**	16.94	18.42	**20.02**
			MSE	1315.22	941.56	**645.79**

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Table 4: Comparison Of Algorithms Using Average Of 200 Iris Grayscale Images With Type II Mixed Noise

S.NO	MIXED NOISE TYPE	NOISE LEVEL	METRICS	FBF[11]	MWBF[12]	PROPOSED METHOD
1	COMBINATION I	0.02	**PSNR**	24.36	26.83	**29.15**
			MSE	239.14	135.48	**80.09**
	COMBINATION II	0.02	**PSNR**	24.38	26.85	**29.14**
			MSE	237.35	134.98	**77.68**
2	COMBINATION I	0.04	**PSNR**	22.00	24.31	**26.26**
			MSE	411.64	241.36	**154.31**
	COMBINATION II	0.04	**PSNR**	22.06	24.37	**26.52**
			MSE	416.00	238.13	**148.35**
3	COMBINATION I	0.06	**PSNR**	19.92	22.02	**23.69**
			MSE	663.80	408.25	**278.52**
	COMBINATION II	0.06	**PSNR**	20.07	22.17	**23.89**
			MSE	640.63	394.65	**263.51**
4	COMBINATION I	0.08	**PSNR**	18.15	20.08	**21.56**
			MSE	998.70	638.24	**454.86**
	COMBINATION II	0.08	**PSNR**	18.40	20.34	**21.87**
			MSE	939.50	602.06	**420.82**
5	COMBINATION I	0.10	**PSNR**	16.65	18.43	**19.81**
			MSE	1412.04	932.66	**680.53**
	COMBINATION II	0.10	**PSNR**	17.01	18.81	**20.24**
			MSE	1294.55	854.58	**595.73**

Table 5: Comparison Of Algorithms Using Average Of 25 CT Grayscale Images With Type II Mixed Noise

S.NO	MIXED NOISE TYPE	NOISE LEVEL	METRICS	FBF[11]	MWBF[12]	PROPOSED METHOD
1	COMBINATION I	0.02	**PSNR**	25.05	24.38	**26.58**
			MSE	203.43	237.22	**143.09**
	COMBINATION II	0.02	**PSNR**	25.02	24.36	**26.53**
			MSE	204.54	238.16	**144.46**
2	COMBINATION I	0.04	**PSNR**	23.24	23.13	**24.79**
			MSE	308.22	316.49	**215.94**
	COMBINATION II	0.04	**PSNR**	23.18	23.07	**24.69**
			MSE	312.45	320.60	**220.76**
3	COMBINATION I	0.06	**PSNR**	21.46	21.69	**22.95**
			MSE	464.99	440.86	**330.00**
	COMBINATION II	0.06	**PSNR**	21.40	21.60	**22.81**
			MSE	471.61	449.89	**340.18**
4	COMBINATION I	0.08	**PSNR**	19.81	20.24	**21.23**
			MSE	679.62	615.74	**489.57**
	COMBINATION II	0.08	**PSNR**	19.76	20.14	**21.07**
			MSE	687.99	630.26	**508.02**
5	COMBINATION I	0.10	**PSNR**	18.32	18.88	**19.70**
			MSE	956.65	841.86	**697.44**
	COMBINATION II	0.10	**PSNR**	18.29	18.78	**19.53**
			MSE	963.73	861.54	**724.64**

Table 6: Comparison Of Algorithms Using Average Of 25 MRI Grayscale Images With Type II Mixed Noise

S.NO	MIXED NOISE TYPE	NOISE LEVEL	METRICS	FBF[11]	MWBF[12]	PROPOSED METHOD
1	COMBINATION I	0.02	**PSNR**	25.48	26.37	**28.42**
			MSE	184.84	150.80	**94.09**
	COMBINATION II	0.02	**PSNR**	25.48	26.35	**28.36**
			MSE	184.76	151.56	**95.32**
2	COMBINATION I	0.04	**PSNR**	23.58	24.54	**26.01**
			MSE	285.25	228.79	**163.24**

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	COMBINATION II	0.04	**PSNR**	23.53	24.47	**25.89**
			MSE	288.82	232.65	**167.72**
3	COMBINATION I	0.06	**PSNR**	21.72	22.68	**23.74**
			MSE	438.39	351.16	**275.12**
	COMBINATION II	0.06	**PSNR**	21.65	22.54	**23.59**
			MSE	445.22	362.46	**284.91**
4	COMBINATION I	0.08	**PSNR**	20.04	20.96	**21.77**
			MSE	645.11	521.08	**432.35**
	COMBINATION II	0.08	**PSNR**	19.98	20.80	**21.61**
			MSE	653.87	540.90	**449.14**
5	COMBINATION I	0.10	**PSNR**	18.51	19.39	**20.09**
			MSE	916.25	749.26	**636.94**
	COMBINATION II	0.10	**PSNR**	18.47	19.29	**19.90**
			MSE	924.29	766.27	**664.73**

Table 7: Comparison Of Algorithms Using Average Of 25 US Grayscale Images With Type II Mixed Noise

S.NO	MIXED NOISE TYPE	NOISE LEVEL	METRICS	FBF[11]	MWBF[12]	PROPOSED METHOD
1	COMBINATION I	0.02	**PSNR**	25.49	25.67	**27.94**
			MSE	183.60	176.73	**104.55**
	COMBINATION II	0.02	**PSNR**	25.46	25.63	**27.90**
			MSE	184.85	178.26	**105.47**
2	COMBINATION I	0.04	**PSNR**	23.51	24.02	**25.58**
			MSE	289.89	257.91	**180.18**
	COMBINATION II	0.04	**PSNR**	23.47	23.94	**25.45**
			MSE	292.65	262.65	**185.31**
3	COMBINATION I	0.06	**PSNR**	21.66	22.30	**23.42**
			MSE	443.64	382.96	**296.12**
	COMBINATION II	0.06	**PSNR**	21.60	22.18	**23.25**
			MSE	450.17	393.71	**307.85**
4	COMBINATION I	0.08	**PSNR**	19.98	20.69	**21.56**
			MSE	652.88	555.70	**454.56**
	COMBINATION II	0.08	**PSNR**	19.92	20.55	**21.35**
			MSE	664.05	575.01	**477.44**
5	COMBINATION I	0.10	**PSNR**	18.47	19.22	**19.93**
			MSE	925.03	777.77	**661.00**
	COMBINATION II	0.10	**PSNR**	18.43	19.08	**19.71**
			MSE	933.09	804.01	**695.18**

Table 8: Comparison Of Algorithms Using RGB Color JPEG Images With Type II Mixed Noise

S.NO	COLOR IMAGE	MIXED NOISE TYPE	NOISE LEVEL	METRICS	FBF[11]	MWBF[12]	PROPOSED METHOD
1	LENA IMAGE	COMBINATION I	0.02	**PSNR**	23.09	22.45	**25.08**
				MSE	319.37	370.12	**201.80**
			0.10	**PSNR**	16.65	17.83	**19.46**
				MSE	1406.04	1072.34	**737.06**
		COMBINATION II	0.02	**PSNR**	23.10	22.42	**25.05**
				MSE	319.65	372.87	**203.41**
			0.10	**PSNR**	16.97	18.10	**19.68**
				MSE	1305.47	1006.47	**699.67**
2	HOUSE IMAGE	COMBINATION I	0.02	**PSNR**	23.23	23.42	**26.54**
				MSE	309.38	296.04	**144.31**
			0.10	**PSNR**	16.54	18.13	**19.71**
				MSE	1441.71	999.92	**695.63**
		COMBINATION II	0.02	**PSNR**	23.28	23.46	**26.50**
				MSE	305.60	293.16	**145.45**
			0.10	**PSNR**	16.85	18.47	**20.10**
				MSE	1343.64	925.57	**637.47**
3	PEPPERS IMAGE	COMBINATION I	0.02	**PSNR**	23.47	22.23	**25.51**
				MSE	292.23	388.41	**182.99**
			0.10	**PSNR**	16.89	17.75	**19.53**
				MSE	1331.52	1091.48	**724.87**

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		COMBINATION II	0.02	**PSNR**	23.54	22.22	**25.57**
				MSE	287.80	389.67	**180.50**
			0.10	**PSNR**	17.16	17.97	**19.69**
				MSE	1251.15	1036.39	**698.46**
4	GIRL IMAGE	COMBINATION I	0.02	**PSNR**	24.91	25.16	**27.26**
				MSE	209.88	198.42	**122.19**
			0.10	**PSNR**	18.16	19.06	**19.91**
				MSE	994.84	807.56	**664.11**
		COMBINATION II	0.02	**PSNR**	24.91	25.11	**27.23**
				MSE	210.16	200.37	**122.98**
			0.10	**PSNR**	18.17	18.99	**19.82**
				MSE	998.43	820.53	**678.30**

Table 9: Comparison Of Algorithms Using RGB Color PNG Images With Type II Mixed Noise

S.NO	**COLOR IMAGES**	**MIXED NOISE TYPE**	**NOISE LEVEL**	**METRICS**	**FBF[11]**	**MWBF[12]**	**PROPOSED METHOD**
1	LENA IMAGE	COMBINATION I	0.02	**PSNR**	23.57	24.16	**26.77**
				MSE	286.01	249.23	**136.60**
			0.10	**PSNR**	16.89	18.37	**20.04**
				MSE	1328.77	944.31	**644.07**
		COMBINATION II	0.02	**PSNR**	23.60	24.19	**26.73**
				MSE	284.40	248.07	**137.91**
			0.10	**PSNR**	17.12	18.62	**20.27**
				MSE	1259.42	893.66	**611.58**
2	HOUSE IMAGE	COMBINATION I	0.02	**PSNR**	23.21	23.07	**26.54**
				MSE	310.44	321.66	**144.14**
			0.10	**PSNR**	16.49	18.01	**19.65**
				MSE	1458.03	1027.92	**704.83**
		COMBINATION II	0.02	**PSNR**	23.24	23.06	**26.57**
				MSE	308.29	321.45	**143.10**
			0.10	**PSNR**	16.80	18.39	**20.00**
				MSE	1357.98	942.66	**649.69**
3	PEPPERS IMAGE	COMBINATION I	0.02	**PSNR**	23.62	23.52	**26.74**
				MSE	282.50	289.04	**137.75**
			0.10	**PSNR**	16.90	18.17	**19.90**
				MSE	1303.16	991.76	**664.40**
		COMBINATION II	0.02	**PSNR**	23.64	23.51	**26.76**
				MSE	281.42	289.98	**137.18**
			0.10	**PSNR**	17.20	18.39	**20.11**
				MSE	1239.5	942.24	**633.80**
4	GIRL IMAGE	COMBINATION I	0.02	**PSNR**	24.62	24.72	**26.77**
				MSE	224.45	219.32	**136.67**
			0.10	**PSNR**	18.04	18.91	**19.78**
				MSE	1020.1	836.41	**683.72**
		COMBINATION II	0.02	**PSNR**	24.64	24.78	**26.73**
				MSE	223.29	216.14	**138.01**
			0.10	**PSNR**	18.14	18.89	**19.74**
				MSE	998.83	838.61	**689.07**

Table 10: Comparison Of Algorithms Using RGB Color TIFF Images With Type II Mixed Noise

S.NO	**COLOR IMAGES**	**MIXED NOISE TYPE**	**NOISE LEVEL**	**METRICS**	**FBF[11]**	**MWBF[12]**	**PROPOSED METHOD**
1	LENA IMAGE	COMBINATION I	0.02	**PSNR**	23.60	24.15	**26.77**
				MSE	283.91	249.62	**136.72**
			0.10	**PSNR**	16.90	18.36	**20.01**
				MSE	1326.59	949.00	**649.93**
		COMBINATION II	0.02	**PSNR**	23.59	24.16	**26.76**
				MSE	284.62	249.29	**137.10**
			0.10	**PSNR**	17.11	18.62	**20.27**
				MSE	1264.07	892.57	**611.02**
2	HOUSE IMAGE	COMBINATION I	0.02	**PSNR**	23.20	23.11	**26.57**
				MSE	311.48	317.92	**143.32**
			0.10	**PSNR**	16.53	18.04	**19.70**
				MSE	1446.22	1021.57	**696.02**

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		COMBINATION II	0.02	PSNR	23.20	23.10	**26.53**
				MSE	311.00	318.43	**144.49**
			0.10	PSNR	16.88	18.43	**20.05**
				MSE	1335.13	934.32	**643.09**
3	PEPPERS IMAGE	COMBINATION I	0.02	PSNR	23.62	23.52	**26.77**
				MSE	282.28	289.07	**136.93**
			0.10	PSNR	16.97	18.19	**19.91**
				MSE	1305.45	986.99	**663.30**
		COMBINATION II	0.02	PSNR	23.65	23.53	**26.74**
				MSE	280.72	288.57	**137.88**
			0.10	PSNR	17.20	18.40	**20.08**
				MSE	1238.69	939.57	**638.21**
4	GIRL IMAGE	COMBINATION I	0.02	PSNR	24.61	24.76	**26.74**
				MSE	224.77	217.42	**137.80**
			0.10	PSNR	18.07	18.95	**19.83**
				MSE	1014.98	827.45	**676.74**
		COMBINATION II	0.02	PSNR	24.67	24.79	**26.73**
				MSE	221.77	216.01	**138.04**
			0.10	PSNR	18.10	18.88	**19.68**
				MSE	1007.38	842.22	**699.23**

Table 11. Comparison Of Algorithms Using RGB Color BMP Images With Type II Mixed Noise

S.NO	COLOR IMAGES	MIXED NOISE TYPE	NOISE LEVEL	METRICS	FBF[11]	MWBF[12]	PROPOSED METHOD
1	LENA IMAGE	COMBINATION I	0.02	PSNR	23.57	24.17	**26.76**
				MSE	286.92	249.01	**137.19**
			0.10	PSNR	16.91	17.83	**20.05**
				MSE	1325.93	1072.34	**642.17**
		COMBINATION II	0.02	PSNR	23.60	24.18	**26.77**
				MSE	283.80	248.21	**136.90**
			0.10	PSNR	17.10	18.60	**20.23**
				MSE	1268.38	897.77	**616.02**
2	HOUSE IMAGE	COMBINATION I	0.02	PSNR	23.22	23.11	**26.57**
				MSE	310.32	317.83	**141.18**
			0.10	PSNR	16.48	17.99	**19.68**
				MSE	1462.93	1034.07	**699.95**
		COMBINATION II	0.02	PSNR	23.24	23.11	**26.64**
				MSE	308.15	318.02	**140.80**
			0.10	PSNR	16.81	18.30	**19.97**
				MSE	1356.14	962.18	**655.40**
3	PEPPERS IMAGE	COMBINATION I	0.02	PSNR	23.63	23.51	**26.77**
				MSE	281.63	290.09	**136.70**
			0.10	PSNR	16.97	18.18	**19.89**
				MSE	1306.79	988.66	**667.03**
		COMBINATION II	0.02	PSNR	23.65	23.52	**26.75**
				MSE	280.71	289.18	**137.61**
			0.10	PSNR	17.22	18.42	**20.13**
				MSE	1232.17	935.25	**631.06**
4	GIRL IMAGE	COMBINATION I	0.02	PSNR	24.64	24.74	**26.75**
				MSE	223.57	217.64	**137.36**
			0.10	PSNR	18.07	18.96	**19.81**
				MSE	1014.99	826.71	**679.04**
		COMBINATION II	0.02	PSNR	24.66	24.78	**26.74**
				MSE	222.76	216.31	**137.64**
			0.10	PSNR	18.13	18.92	**19.75**
				MSE	998.92	833.54	**688.77**

Similarly, the results of the proposed algorithm, FBF [11] and MWBF [12] with type II mixed noise for the tested images are shown in figures from 13 to 17. This graph shows that the proposed filter performs better than the other existing filter induced with type I and II mixed noise in terms of PSNR value and the proposed technique remain stable for both combinations of type II mixed noise.

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6.1 Comparison Of Proposed Technique With Existing Filters

The FBF [11] previous work have tested only with four sample grayscale JPEG images, and the MWBF [12] have used a single customized 'Azeleza' white color JPEG flower image as test image in the literature.

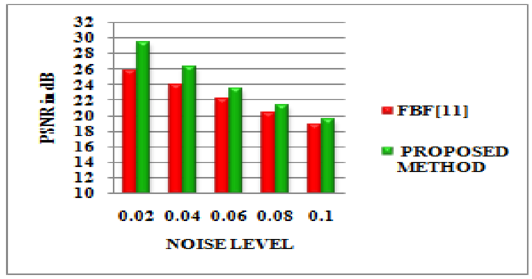
In the current research work, the proposed technique and the existing filter FBF [11] and MWBF [12] have been tested with standard Lena image and the 200 Iris eye biological images in JPEG grayscale images and also with color images with sample of four different image formats namely JPEG, TIFF, PNG and BMP. An attempt have been made test the robustness of the proposed technique using 25 JPEG grayscale images of different medical image modality such as Ultrasound, MRI and CT.

Irrespective of noise density the average PSNR and MSE values for proposed and FBF [11] have been calculated. The proposed technique when compared with FBF [11] shows an increase of 5.35% and 8.18% PSNR score and decrease of 18.60% and 24.91% with respect to MSE score for two noise type mixed Lena and Iris test images.

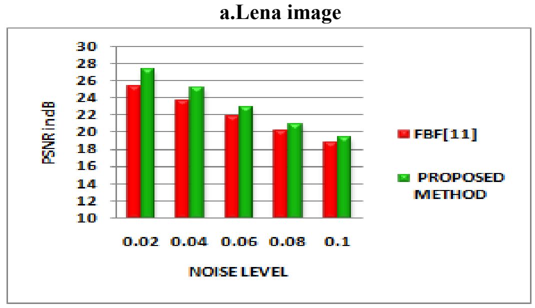
The average PSNR and MSE values for Proposed and MWBF [12] irrespective of noise density for three types of noise mixed is calculated. The proposed method when compared with MWBF [12] shows a significant increase of 10.09%, 7.88%, 6.40%, 5.34%,and 5.84% PSNR score for combination I noise type and 9.96%, 8.10%, 6.19%, 5.20% and 5.64 % PSNR score for combination II noise type. Significant decrease of 35.53%, 30.04%, 23.49%, 19.93%, 21.14% MSE for combination I noise type and 35.91%, 32.29%, 22.49%, 19.09%, 19.98% MSE for combination II noise type using Lena, Iris, CT, MRI and US images.

Similarly, it also shows a significant increase in PSNR and decrease in MSE for sample color images using four different image formats.

According to metrics, the denoising technique which shows a higher PSNR value and lower MSE value is the better denoising technique. The result obtained is the evident that the proposed algorithm performs better than FBF [11] and MWBF [12] existing filters in the literature for the two / three noise type mixed combination ranging from 0.01 to 0.10 levels in terms of metrics as well as by visual appearance of the denoisied image.

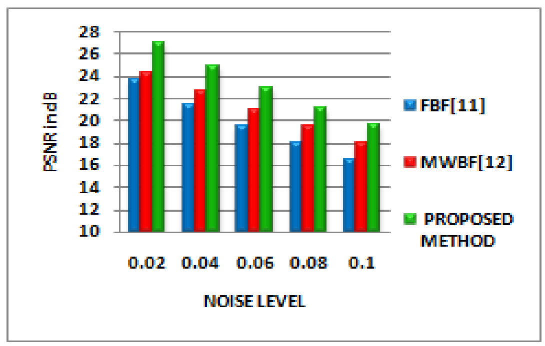


a.Lena image

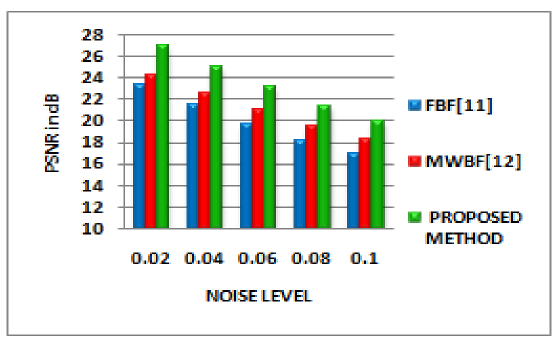


b.Iris image

Figure 12: Comparison Graph Of PSNR With Type I Mixed Noise.



a. Combination I



b. Combination II

Figure 13: Comparison Graph Of PSNR For Lena Image With Type II Mixed Noise

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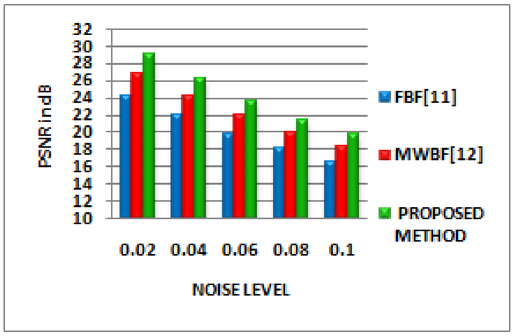
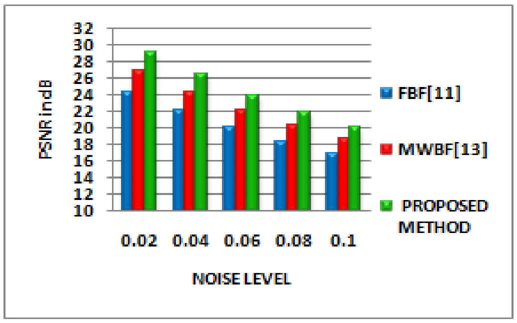
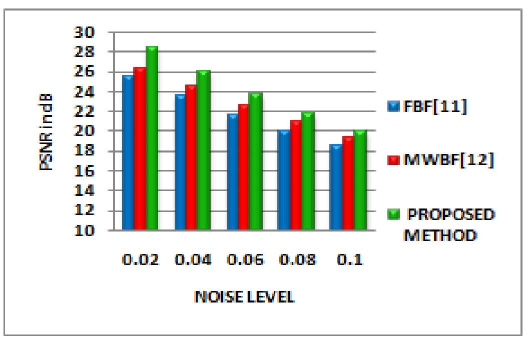


a. **Combination I**

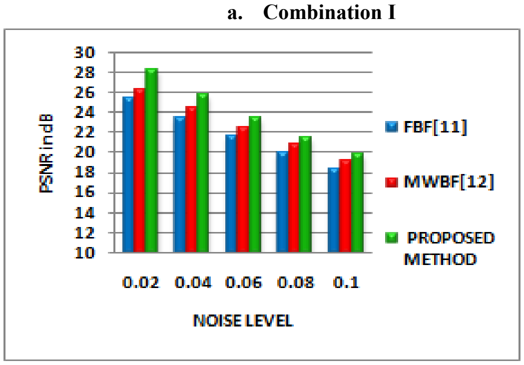


b. **Combination II**

Figure 14: Comparison Graph Of Average PSNR For 200 Iris Image With Type II Mixed Noise

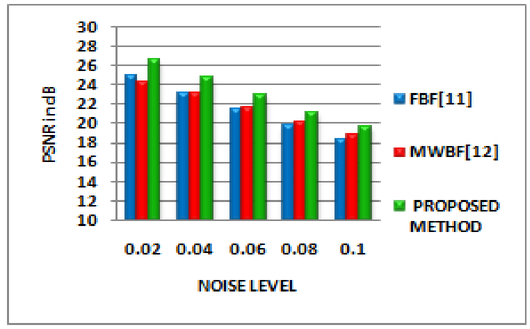


a. **Combination I**

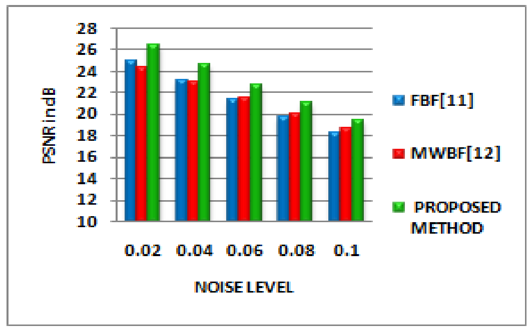


b. Combination II

Figure 15: Comparison Graph Of Average PSNR For 25 MRI Images With Type II Mixed Noise

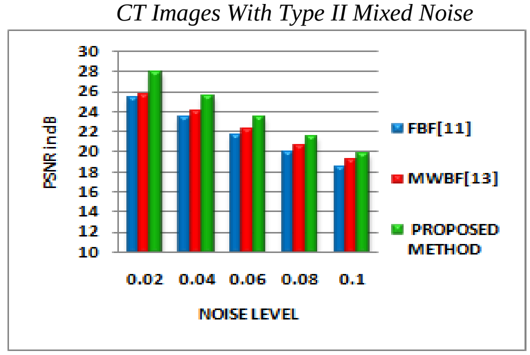


a.Combination I

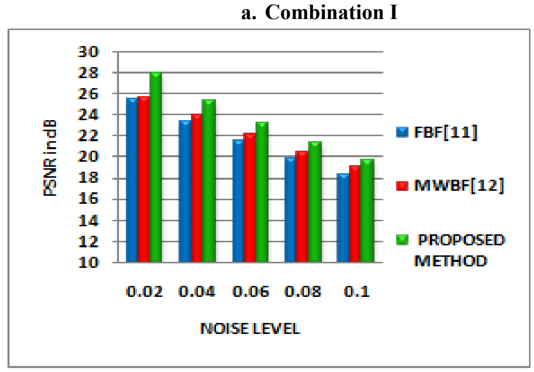


b. Combination II

Figure 16: Comparison Graph Of Average PSNR For 25 CT Images With Type II Mixed Noise



a. Combination I



b. Combination II

Figure 17: Comparison Graph Of Average PSNR For 25 US Images With Type II Mixed Noise

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6. CONCLUSION

An experimental comparative analysis of the proposed technique with existing filters induced with two and three types of noise mixed images is conducted on standard Lena image, Iris images, medical images in JPEG grayscale and color images in four different image formats. The quality of the denoised image evaluated using PSNR and MSE parameters. It is evident from the obtained results that the proposed denoising technique is superior for two/three types of noise mixed in the specified combination when compared with the other existing filters used in this study.

In this research work, the noises are introduced artificially to test the performance of the denoising techniques whereas in real time for example latent finger print images can have noise already present. In such cases, the noises are to be identified first and suitable filter or combination of filters to be suggested for removing those noises. The future work is to test the suggested denoising approach with mixed noise induced in video images and also focus on the introduction of other noise type(s) to determine the robustness of the proposed algorithm and also to test the proposed technique with real time images that have noise already present in it.

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