Review of Impulse Noise Reduction Techniques

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***Abstract*– This Paper presents survey of impulse noise reduction techniques. In this paper around ten most popular techniques are implemented and compared. Results of all algorithms are analyzed and efficiency of algorithms is calculated. Algorithms are tested using different types of images i.e. MRI, space, Television images etc. This survey provides complete knowledge of noise reduction techniques and also it helps researchers in selecting best impulse noise reduction algorithm.**

Keyword- Impulse Noise, Adaptive Median Filter, Image Enhancement and Noise Detection.

I. INTRODUCTION

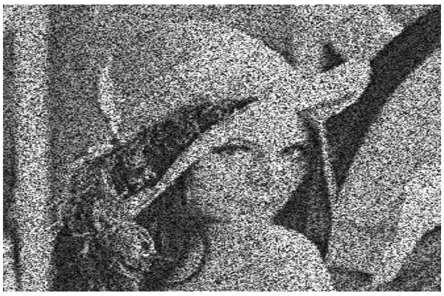
Images processing algorithms are designed to handle different problem domains. Efficiency of every algorithm is depending on the quality of input images. To enhance the quality of images various images enhancement or restoration techniques are use. Images enhancement techniques vary for different type's noise. Noise is any unwanted signal present in original signal. In Noise we have different noise types generated from different sources for example Impulse noise, Gaussian noise and speckle noise etc. Impulse Noise produces small dots or dark spots on an image. Where as Gaussian noise increases or decreases the brightness of image and speckle noise produce big patches. Impulse and Gaussian noise are distributed uniformly but speckle noise is non uniform noise. Main cause of impulse noise is error in camera sensors or transmission cables.

Noise reductions are basically classified into two types 1) linear techniques and 2) Non linear techniques. In linear techniques noise reduction formula is applied for all pixels of image linearly without classifying pixel into noisy and non noisy pixels. Draw back of linear algorithms is it damages the non noisy pixels because algorithm is applied for both noisy and non noisy pixels. Examples for linear filters are average, mean, median filters etc. Non linear Noise reduction is a two step process 1) noise detection and 2) noise replacement [1-14]. In first step, location of noise is detected and in second step, detected noisy pixels are replaced by estimated value. In literature so many algorithms are proposed but with low noise condition (up to 50% noise ratio), such algorithms works well but in high noise conditions performance of these algorithms is poor. To improve the range of noise reduction non linear techniques, MMF (Min-Max Median Filter) [1], CWMF (Center Weighted Media Filter)[2], AMF (Adaptive Median Filter) [3], PSMF (Progressive Switching Median Filter) [4], TMF(Tri-state Median Filter)[5] and DBA (Decision Based Algorithm) [6] algorithms are proposed.

The drawback of these algorithms is that as soon as noise ratio increases time required to process noise also increases and takes too much time that is not suitable for real world application. To process real time videos very high speed algorithms are required.

(a) Original Image.

(b) Original image with 30% Impulse Noise.



(c) Original image with 30% Speckle Noise.

(d) Original image with 30% Gaussian Noise.

Fig 1 Different types of Noise Images

II. PERFORMANCE MEASUREMENT

Performances of algorithms are measured by calculating PNSR (Peak signal to Noise Ratio) and SNRI (Signal to Noise Ratio Improvement).

Peak signal to Noise Ratio (PNSR):

It is measured in decibel (dB) and for gray scale image it is defined as:

$$MSE = \frac{\sum_I \sum_j (Xij - Rij)^2}{(M \times N)} \quad (1)$$

$$PSNR = 10\log 10 \times \frac{255x255}{MSE} \quad (2)$$

Where

X	-	Original Image.
R	-	Restored Image
M x N	-	Size of Image.
MAE	-	Mean Absolute Error.
MSE	-	Mean Square Error.
PSNR	-	Peak Signal to Noise Ratio.

The higher the PNSR in the restored image the better is its quality.

Signal to Noise Ratio Improvement (SNRI):

SNRI in dB is defined as the difference between the signal to noise ratio (SNR) of the restored image in dB and SNR of noisy image in dB. i.e.

SNRI (dB) = SNR of the restored image - SNR of noisy image.

Where,

$$\text{SNR of restored image} = 10\log 10 \times \frac{\sum_I \sum_j Xij^2}{\sum_I \sum_j (Xij - Rij)^2} \quad (3)$$

$$\text{SNR of Noisy image} = 10\log 10 \times \frac{\sum_I \sum_j Xij^2}{\sum_I \sum_j (Xij - Nij)^2} \quad (4)$$

Where, Nij is Noisy Image Pixel.

The higher value of SNRI reflects the better visual and restoration performance.

III. LINEAR FILTES

A. Average Filter:

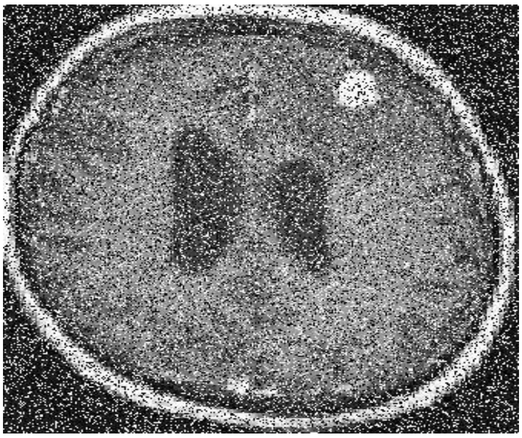
In average filter a square window of size 2k+1 is used. Here value of k changes from 1 to n. Window size (2k+1) is taken only because window width and height must be odd so that we get exactly central pixel (k+1, k+1). Using window original image is scanned row wise and column wise. Each time of scan value of central pixel of window is replaced by the average value of its neighboring pixels comes within the window.

B. Mean Filter

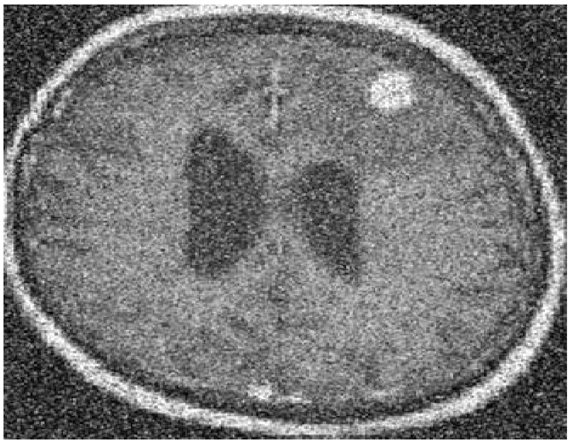
Working of Mean Filter is same as Average filter but here central pixel value is replace by the mean value of its neighboring pixels comes within the window.

C. Median Filter

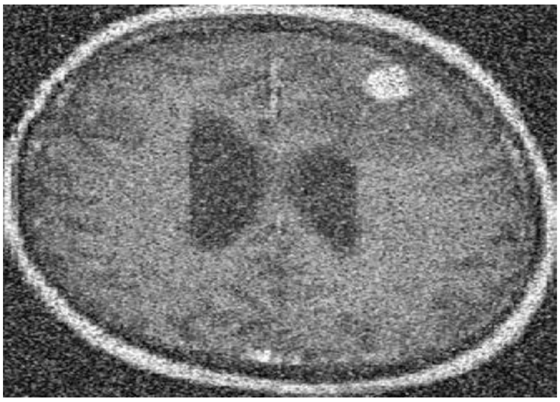
Working of Median Filter is same as Average filter but here central pixel value is replace by the median value of its neighboring pixels comes within the window.



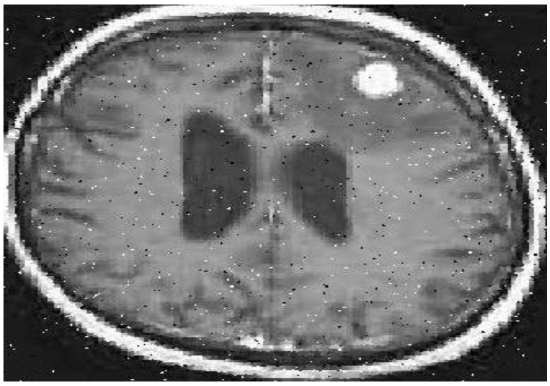
(a) Original Image



(b) Average Filter

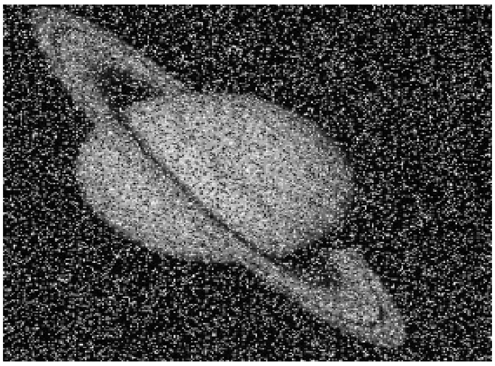
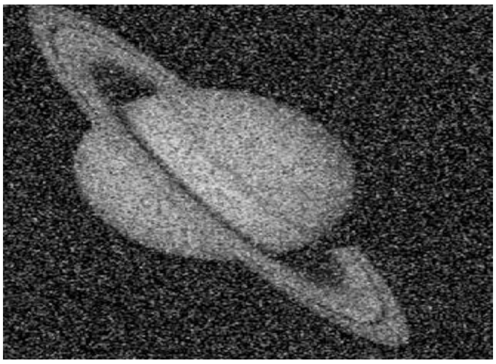


(c) Mean Filter

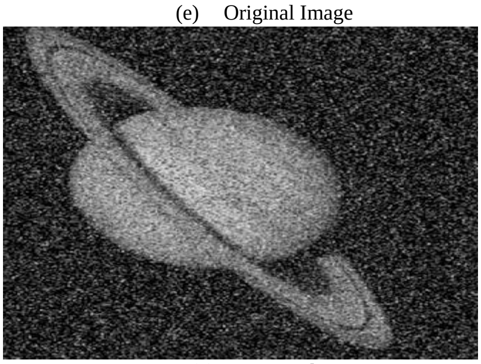
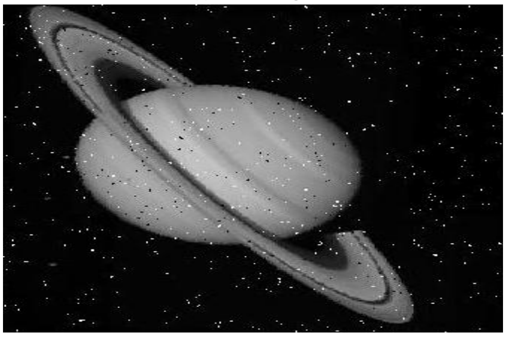


(d) Median filter

Fig 2. Outputs of (512x512) MRI Brain Image.

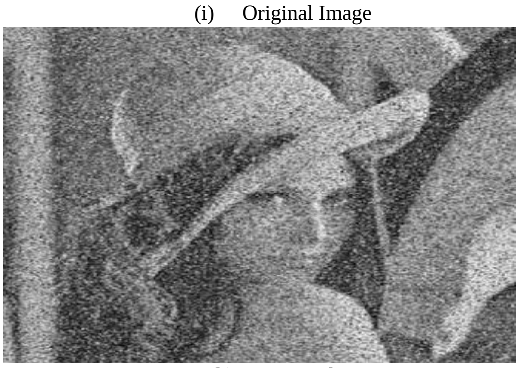
(e) Original Image (f) Average Filter

(g) Mean Filter (h) Median filter

Fig 3. Outputs of (512x512) Space Saturn Image.


(i) Original Image (j) Average Filter




(k) Mean Filter (l) Median filter

Fig 4. Outputs of (512x512) Television Lena Image.

TABLE I COMPARISON OF PSNR

Noise Ratio	MRI Brain Image			Satellite Saturn Image			Television Lena Image		
	Avg Filter	Mean Filter	Median Filter	Avg Filter	Mean Filter	Median Filter	Avg Filter	Mean Filter	Median Filter
10	22.54	22.51	31.20	21.89	21.90	37.66	24.30	24.27	37.40
20	19.71	19.58	27.12	18.00	17.99	30.15	21.08	21.05	30.91
30	17.72	17.70	22.58	15.53	15.47	22.73	18.96	18.95	24.33
40	16.16	16.14	18.30	13.60	13.60	17.74	17.42	17.42	19.29
50	14.86	14.91	14.70	12.06	12.07	13.84	16.19	16.18	15.43
60	13.81	13.83	11.82	10.74	10.76	10.74	15.12	15.14	12.40
70	12.85	12.84	09.62	09.64	09.64	08.37	14.24	14.15	10.05
80	11.95	12.01	07.75	08.63	08.60	06.47	13.39	13.40	08.14
90	11.21	11.22	06.30	07.80	07.75	04.93	12.65	12.71	06.62
AVG	15.64	15.63	16.59	13.09	13.08	16.95	17.03	17.03	18.28

TABLE II COMPARISON OF SNRI

Noise Ratio	MRI Brain Image			Satellite Saturn Image			Television Lena Image		
	Avg Filter	Mean Filter	Median Filter	Avg Filter	Mean Filter	Median Filter	Avg Filter	Mean Filter	Median Filter
10	7.01	7.00	16.09	7.47	7.51	23.93	8.29	8.32	21.88
20	7.00	6.94	15.00	6.40	6.38	19.42	8.01	8.01	18.42
30	6.67	6.66	12.22	5.46	5.44	13.74	7.60	7.60	13.57
40	6.25	6.25	09.19	4.58	4.59	09.95	7.23	7.25	09.82
50	5.82	5.89	06.56	3.81	3.81	06.97	6.92	6.90	06.96
60	5.47	5.47	04.54	3.05	3.06	04.59	6.60	6.62	04.81
70	5.06	5.08	03.11	2.38	2.36	02.81	6.33	6.25	03.31
80	4.65	4.71	01.97	1.69	1.66	01.38	6.00	6.02	02.19
90	4.32	4.34	01.23	1.10	1.05	00.22	5.72	5.78	01.47
AVG	5.80	5.81	7.76	3.99	3.98	9.22	6.96	6.97	9.15

IV. NON LINEAR FILTERS

A. Min-Max Median Filter:

Min-Max filter (MMF)[1] is conditional non linear filter. In this filter (3x3) window is use for scanning the image left to right and top to bottom. The center pixel of window (2, 2) is considered as a test pixel. If test pixel is less than minimum value present in rest of pixel in window and greater than maximum value present in rest of pixel in window. Then center pixel is treated as corrupted pixel and its value is replaced by median value of pixels present in window otherwise pixel is non corrupted pixel kept pixel value unchanged.

B. Center Weighted Median Filter:

The Center weighted median (CWM) filter [2] is an extension of the weighted median filter, which gives more weight to center values within the window. This CWM filter allows a degree of control of the smoothing behavior through the weights that can be set, and therefore, it is a promising image enhancement technique. These approaches involve a preliminary identification of corrupted pixels in an effort to prevent alteration of true pixel values. In CWM center pixel of (2k+1) square window considered as test pixel. If center pixel (k+1,k+1) less than minimum value present in rest of pixel in window and greater than maximum value present in rest of pixel in window then center pixel is treated as corrupted pixel. Corrupted pixel is replaced by estimated value of median. Estimated value of median is calculated by sorting all element of window in ascending order and taking median of elements from Lth element to (N-L)th element . N is number of elements present in an array.

C. Adaptive Median Filter:

The adaptive median filter (AMF) [3] is non linear conditional filter. It uses varying window size to noise reduction. Size of window increases until correct value of median is calculated and noise pixel is replaced with its calculated median value. In this filter two conditions are used one to detect corrupted pixels and second one is to check correctness of median value. If test pixel is less than minimum value present in rest of pixel in window and greater than maximum value present in rest of pixel in window then center pixel is treated as corrupted pixel. If calculated median value is less than minimum value present in window and greater than maximum value present in window then median value is treated as corrupted value. If calculated median is corrupted then increase the window size and recalculate the median value until we get correct median value or else window size reach maximum limit.

D. Progressive Switching Median Filter:

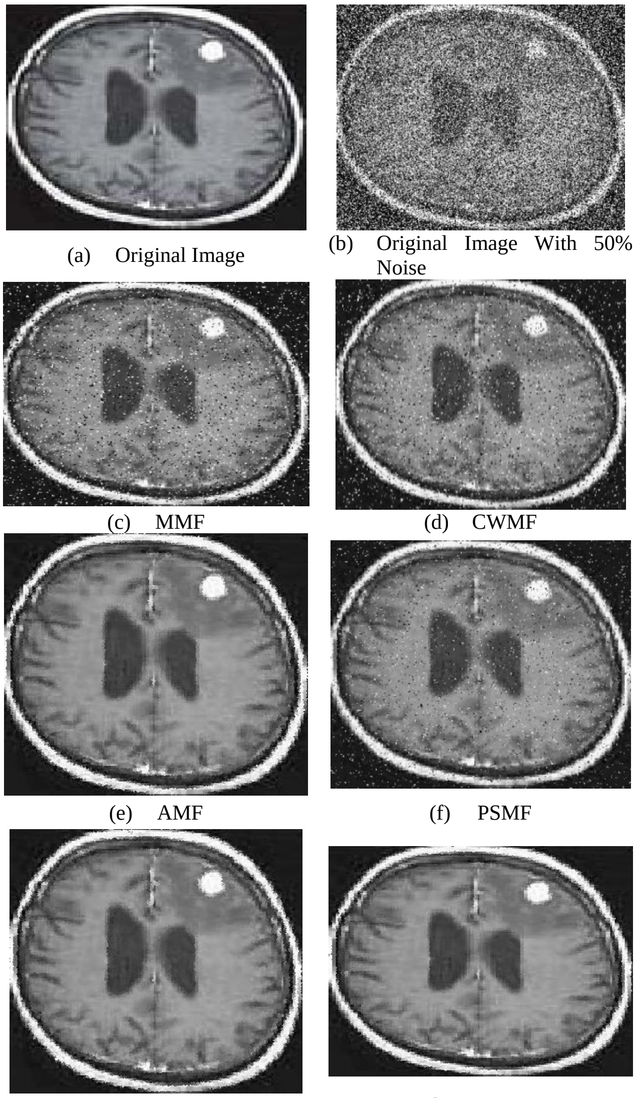
The Progressive median filter (PMF) [4] is a two phase algorithm. In phase one noise pixels are identified using fixed size window (3x3). If test pixel is less than minimum value present in rest of pixel in window and greater than maximum value present in rest of pixel in window then center pixel is treated as corrupted pixel. In second phase prior knowledge of noisy pixels are used and noise pixels are replaced by estimated median value. Here median value is calculated same as in AMF without considering the corrupted pixel present in window. If calculated median value is less than minimum value present in window and greater than maximum value present in window then median value is treated as corrupted value. If calculated median is corrupted then increase the window size and recalculate the median value until we get correct median value or else window size reach maximum limit.

E. Tri-state Median Filter:

The Tri-State Median filter (TSMF) [5] is a two phase algorithm. In phase one noise pixels are identified using standard median filter. In second phase prior knowledge of noisy pixels are used and noise pixels are replaced by Center weighted median filter.

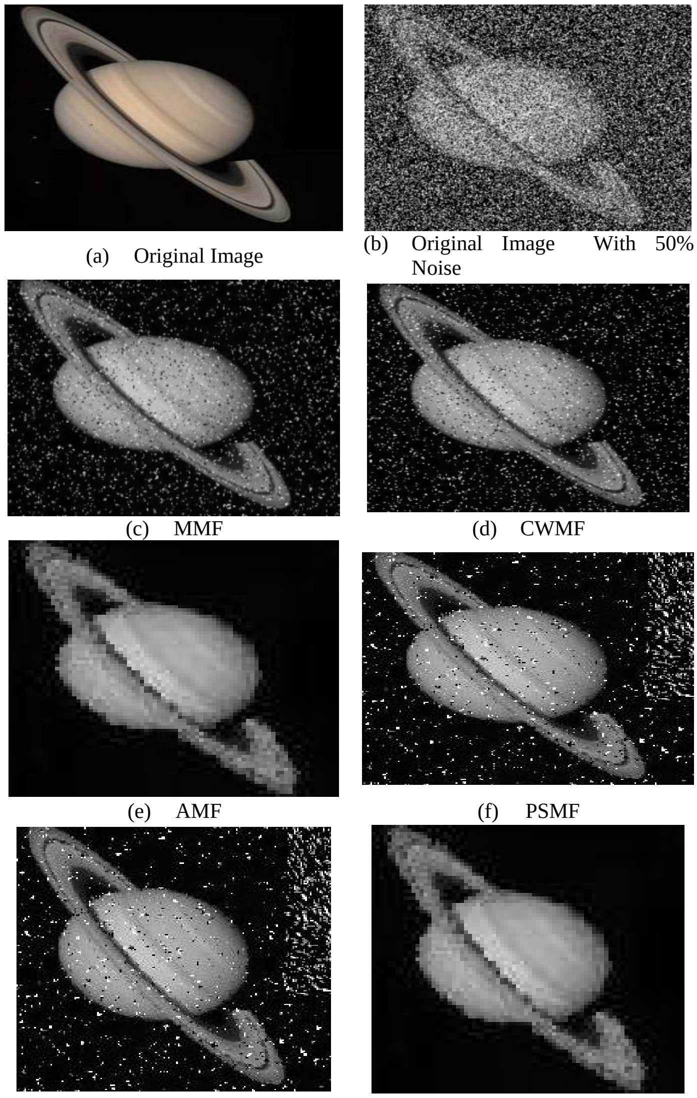
F. Decision Based Algorithm:

The Decision-Based median filter (PMF) [6] is a two phase algorithm. In phase one noise pixels are identified using fixed size window (3X3). In second phase prior knowledge of noisy pixels are used and noise pixels are replaced by middle value of sorted window pixels. In this time complexity of algorithm is analyzed.



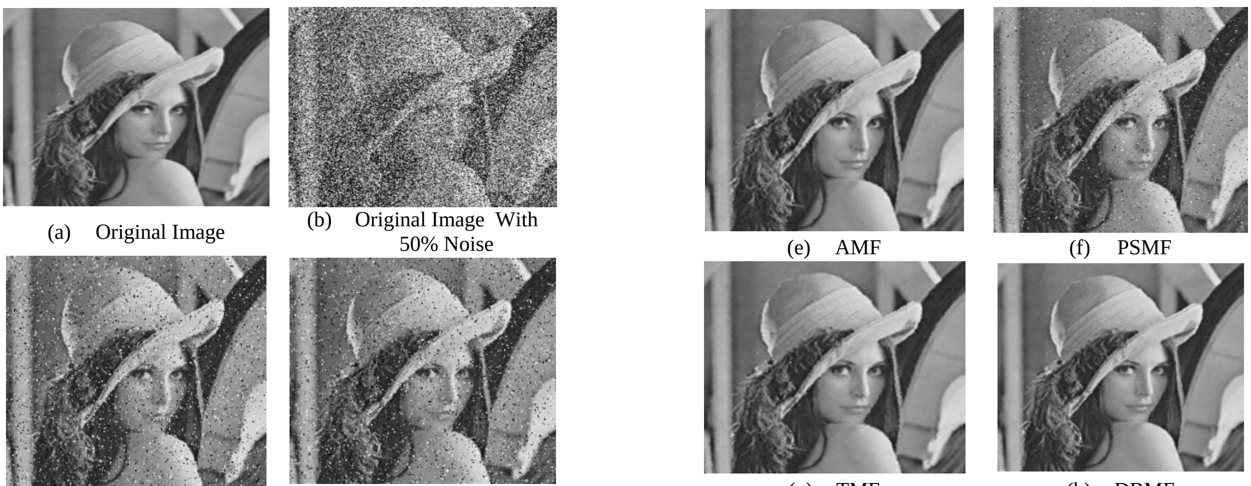
(a) Original Image
(b) Original Image With 50% Noise
(c) MMF
(d) CWMF
(e) AMF
(f) PSMF
(g) TMF
(h) DBMF

Fig 5. Outputs of (512x512) MRI Brain Image.



(a) Original Image
(b) Original Image With 50% Noise
(c) MMF
(d) CWMF
(e) AMF
(f) PSMF
(g) TMF
(h) DBMF

Fig 6. Outputs of (512x512) Space Saturn Image.



(a) Original Image
(b) Original Image With 50% Noise
(c) MMF
(d) CWMF
(e) AMF
(f) PSMF
(g) TMF
(h) DBMF

Fig 7. Outputs of (512x512) Television Lena Image.

TABLE I COMPARISON OF PSNR

Noise Ratio	MRI Brain Image					
	MMF	CWMF	AMF	PSMF	TMF	DBMF
10	32.17	31.95	31.97	28.31	22.50	31.66
20	28.69	28.62	30.27	27.66	22.44	31.43
30	23.81	23.96	28.49	25.38	22.32	30.00
40	19.56	19.46	27.28	22.07	22.18	28.76
50	15.95	15.96	26.01	18.59	22.08	27.19
60	12.94	12.85	24.71	15.38	21.80	26.17
70	10.42	10.37	23.32	12.71	21.09	24.99
80	08.30	08.32	21.02	10.20	20.07	23.79
90	06.51	06.56	17.22	08.11	16.96	21.89
AVG	17.59	17.56	25.58	18.71	21.27	27.32

TABLE II COMPARISON OF SNRI

Noise Ratio	MRI Brain Image					
	MMF	CWMF	AMF	PSMF	TMF	DBMF
10	54.79	54.57	54.60	50.93	45.12	54.29
20	51.31	51.25	52.89	50.28	45.06	54.05
30	46.44	46.58	51.12	48.01	44.95	52.62
40	42.18	42.08	49.90	44.70	44.81	51.39
50	38.58	38.59	48.63	41.21	44.70	49.81
60	35.56	35.48	47.34	38.01	44.42	48.79
70	33.05	32.99	45.95	35.34	43.72	47.61
80	30.93	30.94	43.65	32.83	42.70	46.41
90	29.13	29.18	39.84	30.73	39.59	44.52
AVG	40.21	40.18	48.21	41.33	43.89	49.94

TABLE III COMPARISON OF TIME

Noise Ratio	MRI Brain Image					
	MMF	CWMF	AMF	PSMF	TMF	DBMF
10	16.91	1.69	26.60	060.20	11.50	17.70
20	16.18	1.56	23.85	041.03	09.75	16.62
30	16.13	1.57	23.32	038.67	08.91	17.22
40	16.44	1.57	23.48	043.61	08.35	15.89
50	16.90	1.59	24.98	049.68	07.86	16.80
60	17.47	1.90	27.59	061.08	07.76	18.30
70	18.11	1.71	33.12	060.16	08.50	20.50
80	18.79	1.58	44.64	051.85	14.43	25.60
90	19.50	1.57	71.67	196.09	25.61	42.47
AVG	17.38	1.63	33.25	66.93	11.40	21.23

TABLE IV COMPARISON OF PSNR

Noise Ratio	Satellite Saturn Image					
	MMF	CWMF	AMF	PSMF	TMF	DBMF
10	38.35	38.34	29.27	27.83	26.89	23.38
20	31.51	31.09	25.59	23.46	25.03	20.16
30	23.70	23.72	23.07	20.48	22.69	18.53
40	18.60	18.39	20.90	17.82	20.89	17.28
50	14.40	14.53	19.50	15.42	19.45	16.38
60	11.52	11.45	18.35	12.90	18.07	15.53
70	08.97	08.96	17.10	10.46	16.96	14.83
80	06.91	06.88	15.85	08.31	15.74	14.19
90	05.17	05.18	13.19	06.37	13.06	13.64
AVG	17.68	17.61	20.31	15.89	19.86	17.10

TABLE V COMPARISON OF SNR

Noise Ratio	Satellite Saturn Image					
	MMF	CWMF	AMF	PSMF	TMF	DBMF
10	52.35	52.33	43.27	41.83	40.88	37.90
20	45.51	45.09	39.59	37.46	39.03	34.69
30	37.70	37.72	37.07	34.47	36.69	33.05
40	32.59	32.39	34.90	31.82	34.89	31.80
50	28.39	28.53	33.50	29.41	33.45	30.90
60	25.52	25.45	32.34	26.90	32.07	30.06
70	22.97	22.95	31.09	24.46	30.95	29.36
80	20.91	20.88	29.85	22.30	29.74	28.72
90	19.17	19.18	27.19	20.37	27.06	28.16
AVG	31.67	31.61	34.31	29.89	33.86	31.62

TABLE VI COMPARISON OF TIME

Noise Ratio	Satellite Saturn Image					
	MMF	CWMF	AMF	PSMF	TMF	DBMF
10	17.29	1.68	65.90	179.97	35.73	139.43
20	16.70	1.60	49.65	128.81	25.53	132.07
30	15.49	1.58	47.75	124.95	21.35	125.76
40	15.51	1.61	46.68	120.71	19.26	120.34
50	15.72	1.66	45.73	121.81	18.04	116.13
60	16.15	1.60	47.51	133.01	17.52	110.62
70	16.69	1.59	51.87	127.64	18.05	107.11
80	17.24	1.59	60.83	119.33	21.51	105.72
90	17.85	1.70	83.41	271.25	31.19	121.72
AVG	16.51	1.62	55.48	147.49	23.13	119.87

TABLE VII COMPARISON OF PSNR

Noise Ratio	Television Lena Image					
	MMF	CWMF	AMF	PSMF	TMF	DBMF
10	41.71	42.10	42.65	41.41	27.81	44.10
20	33.64	32.55	39.07	35.13	27.50	41.24
30	26.02	25.68	36.73	29.69	27.26	38.68
40	20.70	20.82	34.45	24.58	27.04	36.65
50	16.75	16.69	32.36	20.09	26.59	34.78
60	13.45	13.48	30.62	16.19	26.16	33.23
70	10.88	10.93	28.64	13.35	25.56	31.62
80	08.70	08.77	25.28	10.69	23.89	29.65
90	06.96	06.96	19.53	08.58	19.25	26.87
AVG	19.86	19.77	32.14	22.19	25.67	35.20

TABLE VIII COMPARISON OF SNR

Noise Ratio	Television Lena Image					
	MMF	CWMF	AMF	PSMF	TMF	DBMF
10	65.57	65.95	66.50	65.26	51.66	67.95
20	57.49	56.40	62.92	58.98	51.35	65.09
30	49.88	49.54	60.58	53.54	51.11	62.54
40	44.55	44.67	58.30	48.44	50.89	60.50
50	40.60	40.54	56.21	43.94	50.44	58.63
60	37.30	37.33	54.47	40.04	50.01	57.08
70	34.73	34.78	52.49	37.20	49.41	55.47
80	32.55	32.62	49.13	34.54	47.74	53.51
90	30.81	30.81	43.38	32.43	43.10	50.72
AVG	43.72	43.62	55.99	46.04	49.52	59.05

TABLE IX COMPARISON OF TIME

Noise Ratio	Television Lena Image					
	MMF	CWMF	AMF	PSMF	TMF	DBMF
10	16.00	1.54	19.95	024.66	7.17	12.25
20	13.59	1.64	19.89	026.65	6.89	12.93
30	14.15	1.63	20.44	033.07	5.98	13.97
40	15.96	1.65	21.62	036.89	5.62	16.18
50	17.26	1.68	23.60	044.44	5.46	19.31
60	16.22	1.98	26.76	061.06	5.68	18.31
70	17.36	1.65	32.32	060.69	6.97	20.37
80	17.11	1.66	43.48	048.21	12.18	25.53
90	17.88	1.76	70.68	184.30	24.83	41.82
AVG	16.17	1.68	30.97	57.77	8.97	20.07

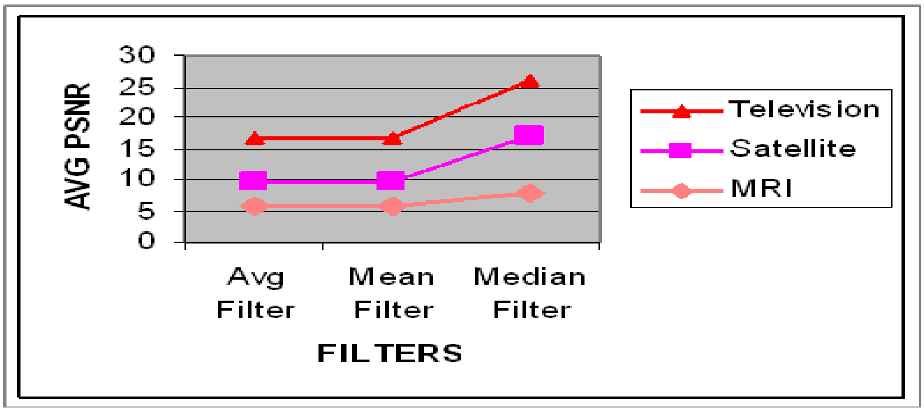


Fig 8. Comparison of Linear Filter PNSR.

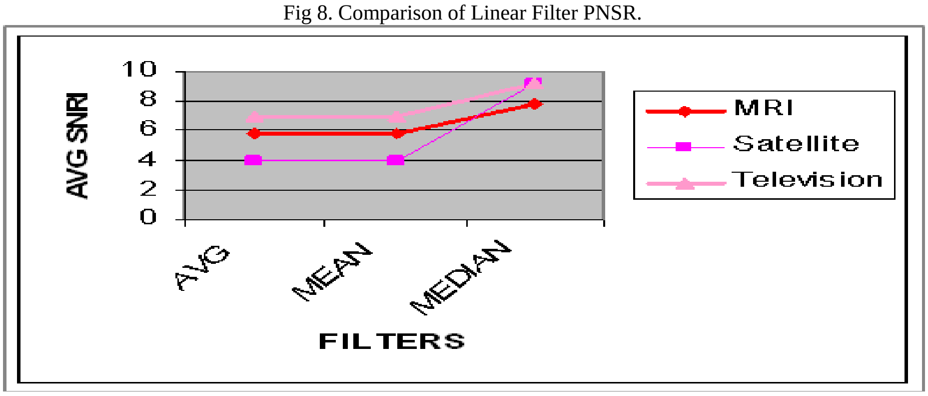


Fig 9. Comparison of Linear Filter SNRI

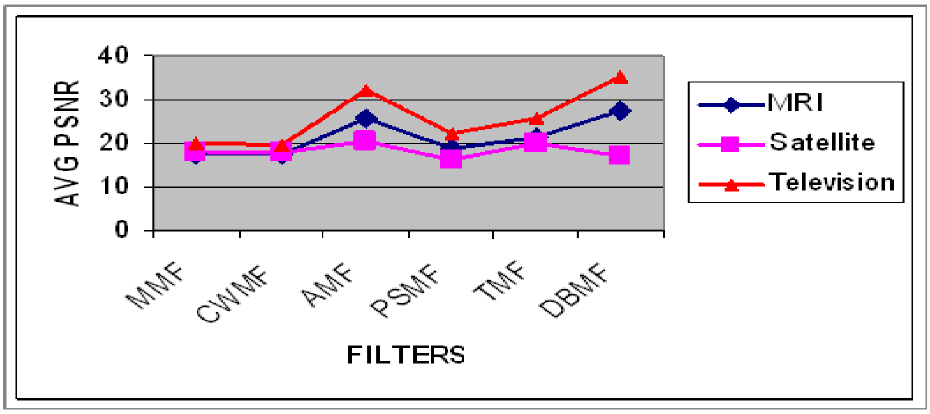


Fig 10. Comparison of Non Linear PNSR

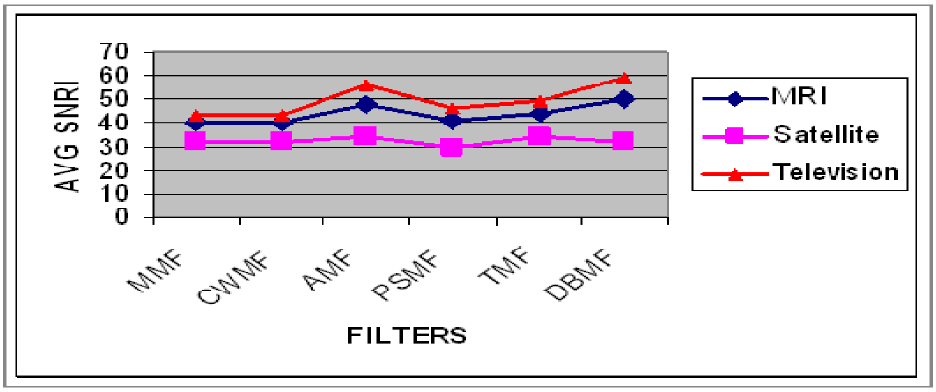


Fig 11. Comparison of Non Linear SNRI

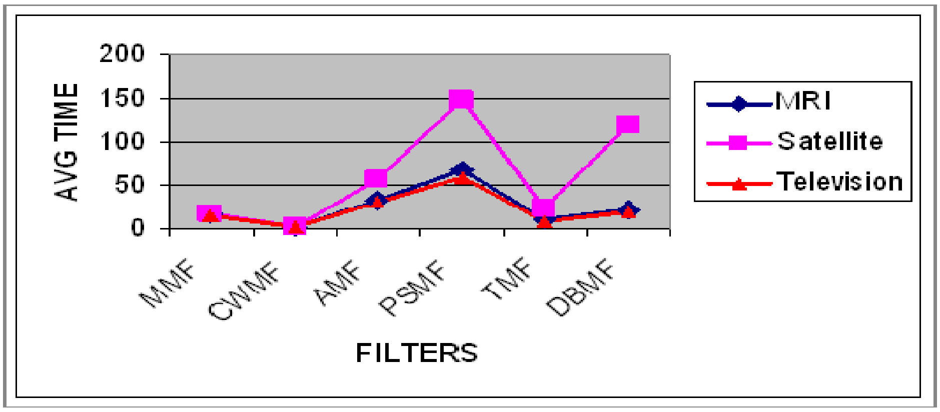


Fig 12. Comparison of Non Linear TIME.

V. CONCLUSION

In this paper a different linear and non linear algorithms for impulse noise detection are compared and analyzed. In analysis it is found that processing MRI images are more complicated than the space images. The space images are complicated than the television images. In linear algorithm median filter efficiency (PSNR and SNR) is more compared to the average and the mean filter. Hence median filter is prepared in almost all non linear algorithms.

In Non linear filters compared to other filters DBMF and AMF process high PNSR. DBMF and PSMF process high SNR. CWMF, MDF, TMF and DBMF take less execution time. Hence Overall performance of DBMF is better than other algorithms.

Draw Backs of existing systems

- Existing systems uses fixed or different window size for detection of impulse noise. No algorithm is exist which can automatically calculate the required window size.
- Existing systems not provides consistent output in both low and high noise conditions. Only few algorithms efficiently handles high noise condition i.e. noise ratio more than 50%.
- Exist systems are not well suited for real time applications because of there time consuming nature.

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