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Image Noise Removal by Dual Threshold Median Filter for RVIN

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Abstract: *Removal of random valued impulse noise in digital images with edge preservation is one of the challenging tasks in digital image processing. For removal of impulse noise as well as preserve edge proposed a new filter that is Dual Threshold Median Filter (DTMF). The removal of impulse noise is done in two main stages, firstly, the detection of the impulse noise on the basis of maximum and minimum value of pixels in a 3X3 window. In the second stage, removal of impulse noise by using of median filter. In the filtering stage, the noise-free pixels remain unchanged in the low noise density, but in case of high noise density that is very difficult of identify the noisy pixel or edge of the image, this difficulty is remove by our proposed filter. The experimental outcome of our proposed filter is superior to the previous methods in terms of Peak Signal Noise Ratio and Mean Square Error of the different testing images, with different noise density level. The mathematical analysis describes that the analysis of the noisy pixels and use of noise-free pixels for the de - noising purpose provide better results and provides better visual quality of de-noised image.*
Keywords: *Dual Threshold, Random Valued Impulse Noise, Visual quality, Bluer*

I. Introduction

Digital images during the process of image acquisition or transmission have always been a very cumbersome task for researchers. In the field of image processing, digital images very often get corrupted by several kinds of noise during the process of image acquisition. The basic reasons are malfunctioning of pixels in camera sensors, faulty memory locations in hardware, or transmission in a noisy channel [1]. Images are often corrupted by the impulse noise, Gaussian noise, shot noise, speckle noise, etc. Preservation of image details and suppression of noise are the two important aspects of image processing. Impulse noise is of two types: fixed valued impulse noise and the random-valued impulse noise [2]. Here in this paper, we focus on random valued impulse noise. Random valued impulse noise generates impulses whose gray level value lie within a specific range. The random value impulse noise lies between 0 and 255 and it is very difficult to remove this noise. Salt and pepper noise is also known as fixed valued impulse noise producing two gray level values 0 and 255. Where 0 values belong to black and 255 belongs to white on the gray scale. It is generally reflected by pixels having minimum and maximum value in a gray scale image. Generally the basic idea behind image de-noising is the detection stage, which identifies the noisy and noise free pixels of the corrupted image, after that noise removal part removes the noise from the corrupted image under process while preserving the other important detail of image.

There are two types of filters in spatial domain: linear filter and non-linear filter. Linear filters are like wiener filter, mean filter. Here we propose a nonlinear median filter which removes random valued noise and preserves the edges of the image.

Initially standard median filter was used, but later on switching based median filters were developed which provides better results. Any other result oriented standard median filters were developed, like weighted median filter, SDROM filter [7], Centre weighted median filter [13], adaptive median filter, rank conditioned rank selection filter [11] and many other improved filters. The consequences of median filter also depend on the size of filtering window. Larger window has the great noise suppression capability, but image details (edges, corners, fine lines) preservation is limited, while a smaller window preserves the details but it will cause the reduction in noise suppression. Noise detection is a vital part of a filter, so it is necessary to detect whether the pixel is noisy or noise free. Only noisy pixels are subject to de-noising and noise free pixels remains untouched.

II. Noise Model

Two common types of the impulse noise are the Fixed-Valued Impulse Noise (FVIN), also known as Salt and-Pepper Noise (SPN), and the Random-Valued Impulse Noise (RVIN). They differ in the possible values which noisy pixels can take [5]. The FVIN is commonly modeled by

$$(Y_{ij}) = \left\{ \begin{array}{ll} X_{i,j} & \text{with probabilty} \quad p \\ (0,255) & \text{with probabilty} \quad 1-p \end{array} \right\} \ldots\ldots\ldots\ldots(1)$$

Where $X_{i,j}$ and $Y_{i,j}$ denote the intensity value of the original and corrupted images at coordinates (i,j) respectively and p is the noise density. This model implies that the pixels are randomly corrupted by two fixed extreme values, 0 and 255 (for 8-bit grey-scale images), with the same probability.

A model is considered as below:

$$(Y_{ij}) = \begin{cases} (0, m) & \text{with probabilty } p1 \\ X_{i,j} & \text{with probabilty } 1-p \\ (255-m, 255) & \text{with probabilty } p2 \end{cases} \quad \text{............(2)}$$

Where p = p1 + p2. We refer to this model as Random valued Impulse Noise (RVIN).

III. Related Work

1.1 Mean Filter (M.F)

A mean filter act on an image by smoothing it; that is, it reduces the intensity variation between adjacent pixels. The mean filter is nothing but a simple sliding window spatial filter that replaces the center value in the window with the average of all the neighboring pixel values including it. By doing this, it replaces pixels that are unrepresentative of their surroundings. It is implemented with a convolution mask, which provides a result that is a weighted sum of the values of a pixel and its neighbors. It is also called a linear filter. The mask or kernel is a square. Often a 3× 3 square kernel is used. If the coefficients of the mask sum up to one, then the average brightness of the image are not changed. If the coefficients sum to zero, the average brightness are lost, and it returns a dark image. The mean or average filter works on the shift-multiply-sum principle [11].

1.2 Median Filter

In the spatial domain the most basic nonlinear filter is the standard median filter (MF) [4]. Standard median filter replaces each pixel in the image by the median value of the corresponding filtering window. The standard median filter works effectively for low noise densities but at the cost of blurring the image.

Consider that the pixel values in a neighborhood are taken in to sequence M1, M2, M3……..Mn.

To estimate, the median value of pixels, first all pixels are sorted either in ascending or descending order. After sorting these pixels, the sequence will be Mi1≤Mi2≤Mi3≤................Min, in ascending order and Mi1 ≥ Mi2 ≥ Mi3 ≥ ....Min, in descending order.

Thus, mathematically median is expressed as:

$$\text{Median}(M) = \text{Med}\{Mi\}$$

$$= \begin{cases} Mi(n+1)/2, & \text{n is odd} \\ ½[Mi(n/2) + Mi(n/2)+1], & \text{n is even} \end{cases}$$

'n' is generally odd.

1.3 Adaptive Median Filter

S.Saudia, Justin Varghese, Krishnan Nallaperumal, Santhosh.P.Mathew, Angelin J Robin, S.Kavitha, Proposes a new adaptive 2D spatial filter operator for the restoration of salt & pepper impulse corrupted digital images name as -"Salt & Pepper Impulse Detection and Median based Regularization using Adaptive Median Filter", The Adaptive Impulse Filter effectively identifies the impulsive positions with a valid impulse noise detector and replaces them by a reliable signal determined from an appropriate neighborhood. Experimental results in terms of objective metrics and visual analysis show that the proposed algorithm performs better than many of the prominent median filtering techniques reported in terms of retaining the fidelity of even highly impulse corrupted images.

1.4 Signal-dependent rank ordered mean filter (SD-ROM)

It is an efficient nonlinear algorithm to suppress impulse noise from highly corrupted images while preserving image details and features [7]. This method is applicable to all impulse noise models, including fixed valued (equal height or salt and pepper) impulses and random valued (unequal height) impulses, covering the whole dynamic range. The filter effectively suppresses the noise, and preserves the details and edges without unnecessary increase in computational complexity.

1.5 Rank Conditioned Rank Selection Filter (RCRS)

The RCRS filters are proposed in the general structure of rank selection filters. The information utilized by RCRS filters is the ranks of selected input samples; hence the name rank conditioned rank selection filter [11]. The number of input sample rank used in this decision is referred to as the order of RCRS filter. The order ranges from zero to the number of samples in the observation window, giving the filters valuable flexibility. Low-order filters can give good performance and are relatively simple to optimize and implement.

1.6 Progressive Switching Median Filter (PSM)

It is a median-based progressive switching median (PSM) filter, proposed for the Removal of Impulse Noise from Highly Corrupted Images.[8] The filtering method is based on the following two main schemes: (1) Switching scheme : An impulse detection scheme is used before filtering, thus only a fraction of all the pixels will be subjected to filtering process and (2) Progressive methods : Both the impulse detection and the noise filtering procedures are progressively applied through a number of iterations. The main advantage of this method is that some impulse pixels located in the middle of large noise blotches can also be properly detected and filtered, which results in better restoration, especially for the cases where the images are highly corrupted.

1.7 Laplace Equation Based Adaptive Median Filter (LEAM)

Yiqiu Dong and Shufang Xu [5], proposed a new impulse detector which utilizes the differences between the current pixel and its neighbors aligned with four foremost directions. After impulse detection, the filter simply do not replace noisy pixels identified by outputs of median filter, but continue to make use of the information of the four directions to weight the pixels in the window so as to preserve the details of image.

1.8 Adaptive Dual Threshold Median Filter (ADTMF)

In Image De-noising by Dual Threshold Median Filtering for Random Valued Impulse Noise. The proposed method gives better PSNR values than other filters. The proposed filter has proved that it is very efficient for random valued impulse noise because practically noise is not uniform over the channel. We have used the concept of maximum and minimum threshold to detect both positive and negative noise. It produces very good PSNR and very small MSE for highly corrupted images, especially for more than 50% noise density. This method has the following advantages:

1) The median value is more accurate than other filters.
2) Two thresholds used and the threshold values can adaptively change according to the noise density.
3) It does require separate calculation for median value and threshold values, so it reduces the delay and enhance the processing speed of the filter with the help of parallel processing.

1.9 Fixed Threshold Dual Median Filter (FTDMF)

In this method dual median filtering is used for improving PSNR and reducing MSE values. This method is proposed for the removal of random valued noise from the gray scale images. The algorithm consists of two stages. In the first stage detection of noisy pixel is carried out and in second stage noisy pixel is replaced by median value using dual median filtering. The noisy pixels are detected with reference to three different conditions which results in effective detection. The experimental results show the proposed scheme performs better than other previous schemes.

However; further lessening in computational complexity is desired. Here we proposed a method with computational simplicity which makes it enable to restore images at faster rate.

IV. Proposed method

At present there are many de-noising techniques available for low level noise removal in images, but in case of high noise density removal is very difficult. In this paper, we will introduce a new method for gray scale image de-noising which is based on dual threshold median filtering. In our method we focus on removal of impulse noise in the image but also preserve the edges, with improved PSNR and reduced MSE at high density noisy image to 5% to 95%. There are many de-noising techniques have been proposed, several of them are application-dependent. In the field of image processing two main important stages are first is detection stage and the second is noise removal or enhancement stage. The proposed method provides an optimum result in 3x3 window size and also gives a better image details means that the losses of the image information is low and better image quality.

In the proposed method, simulate with the help of MATLAB, This whole phenomena is going on this steps first we take a gray scale image, then apply a random valued impulse noise (RVIN) of the targeted image, after that noisy pixels are detected using two dynamically calculated threshold. After the detection of noisy pixels they are subjected to de-noising process according to noise density level. The complete de-noising process can be divided in following number of steps:

Step-1:-

First select a gray scale image. Now apply our detection stage at all 3X3 windows. Now select any one frame and take the smallest size of filtering window that is 3X3.There are nine elements in filtering window. Now we exclude central pixel for 3X3 window. Now we have to calculate the maximum and minimum for remaining pixel. Now detect the pixel whether the pixel is noise or noise free. Now three conditions are arise i.e.

Filtering window of size 3x3

	Column 1	Column 2	Column 3
Row 1	A_1	A_2	A_3
Row 2	A_4	(C.P.) A_5	A_6
Row 3	A_7	A_8	A_9

A) Case A - If the value of the central pixel in a 3X3 window lies between the maximum and minimum value of current window then it is treated as noise free pixels.

B) Case B - If the value of central pixel is greater than the maximum or smaller than the minimum, then it is treated as noisy pixel.

C) Case C- If the value of target pixel equal to the minimum or the maximum then we will determine whether it is an edge or a noisy pixel. Then divide the window into three sub rows i.e. Central Row R2, Upper row R1 and lower Row R3 and calculate the sum of absolute difference between X_{ij} and its neighbors (R1, R2 and R3).

D) Case D- Determine the minimum value among 3 and its treated pivot point i.e. M. Now two conditions arise first is Min difference > Max difference then it is a noisy pixel otherwise it is an edge noise free.

Step-2:-

The image obtained in the previous step is again de-noised by calculating the median value again; the targeted pixel is replaced by this median value. Hence a better de-noised image is obtained with improved PSNR and reduced MSE.

Fig.1 shows the flow diagram of our proposed method is shown below.

V. Simulation And Results

The result of our proposed method for removal of random valued impulse noise is shown in this section. For simulation and results of our proposed algorithm we have to use MATLAB R2012b (8.0.0.783) software. Here we have applied our proposed algorithm on two very famous images in the digital image processing field for result calculation that are - first one is “Lena” and the second one is “Mandrill”. The size of both images is 256X256. The testing images are artificially corrupted by random valued impulse noise by using MATLAB and images are corrupted by different noise density levels, varying from 3% to 99 %. The performance of the proposed algorithm is tested for different color images. Basic configuration of our system is Manufacturer: Hewlett-Packard HP 4540s Processor: Intel (R) Core (TM) i5-3110M CPU @2.40 GHz with 4.00 GB (2.64 GB usable) RAM: System type: 64-bit Operating System. Simulation results also show less distortion at edges high gain in PSNR values over other algorithms. De-noising performances are quantitatively measured by PSNR and MSE defined by:

$$PSNR = 10\log_{10} \frac{(255)^2}{\mathrm{MSE}} \quad (3)$$

$$MSE = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(Y_{i,j} - Y_{i,j})}{m \times n} \quad (4)$$

Where MSE = Mean Square Error M, N are number of channels, length and width of image respectively. The values of Yi, j and Y' i, j are components of original and filtered vector pixels respectively. In this section we also calculate the processing time of our method.

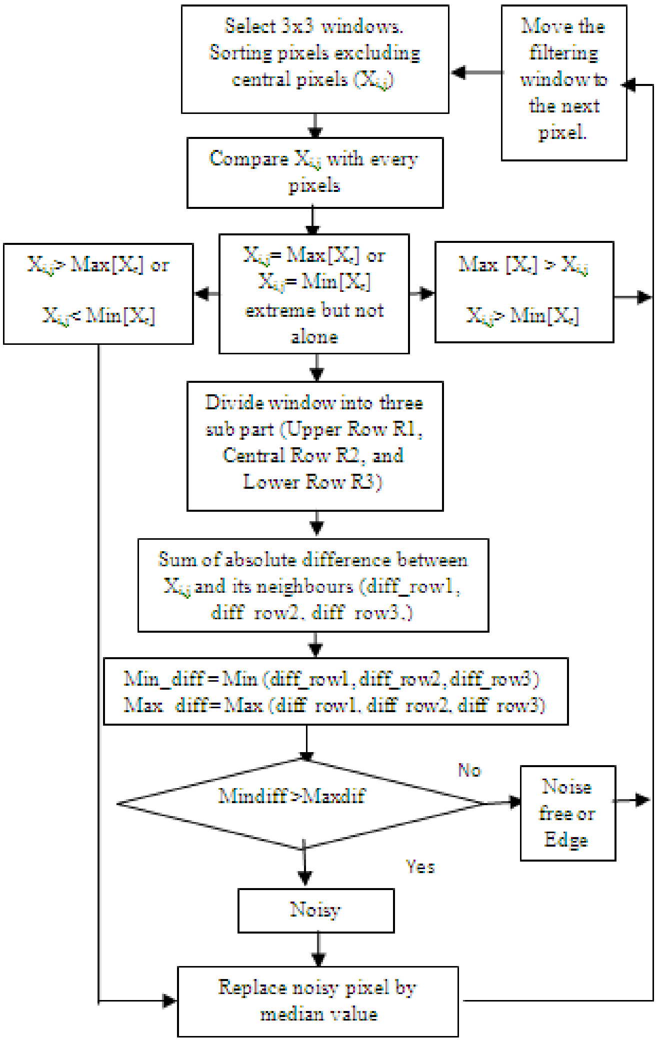


Fig. 1 – Flow Diagram of Proposed method

The results in the Table I show that the MSE of proposed method better at high density of noise. Table I shows the comparison of MSE values of different filters for "LENA" image. As the density of noise increasing, the response of the proposed filter becomes better as compared to the other filters like Median filter (MF) [3], Centre weighted median filter (CWM) [5] [14], Progressive switching median filter (PSMF) [11], Signal dependent rank order median filter (SDROM) [8] [13], Adaptive center weighted median filter (ACWM) [9] [10], Reverse Adaptive center weighted median filter (RACWM), Tristate median filter (TSM) [12]. Here we see that our proposed result is better than other filters. This table shows the comparison between different noise density 50% to 90%.

The results in the Table II show that the PSNR of proposed method better at high density of noise. Table II shows the comparison of PSNR values of different filters for "LENA" image. This table shows the comparison between different noise density 50% to 90%.

Table I: Comparison of MSE values of different filters for LEENA image

Different Methods	Noise density				
	50%	60%	70%	80%	90%
MF	2057.7	3919.5	6808.9	10071.1	14557.2
CWM	3258.9	5408.5	8376.8	11300	15243.3
PSM	650.25	1963.9	5048.5	9619	14914
IMF	264.9	493.1	1422.6	4009.4	10306
SDROM	2360.9	4396.2	7465.8	10791.4	14896.3
ACWM	2153.1	4009.4	6967.5	10071.1	14557.2
RACWM	540.8	1007.1	2056.2	4296.1	10071.1
TSM	3492	5930.3	9398.9	12678.8	16334
PA	**548.3**	**750**	**1052.1**	**1313.3**	**1650.3**

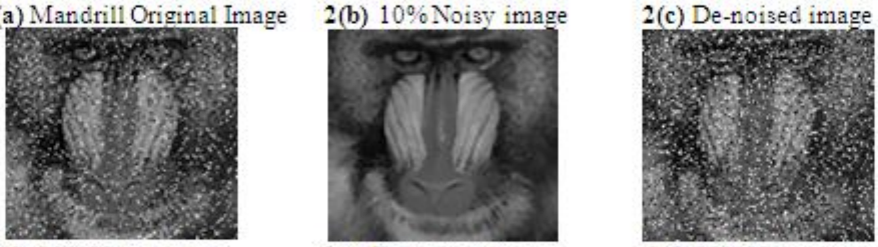
As the density of noise increasing, the response of the proposed filter becomes better as compare of other filters like Median filter, Centre weighted median filter, Progressive switching median filter, Signal dependent rank order median filter, Adaptive center weighted median filter, RACWM, Tri- state median filter.

Table II: Comparison of PSNR values of different filters for LENA IMAGE

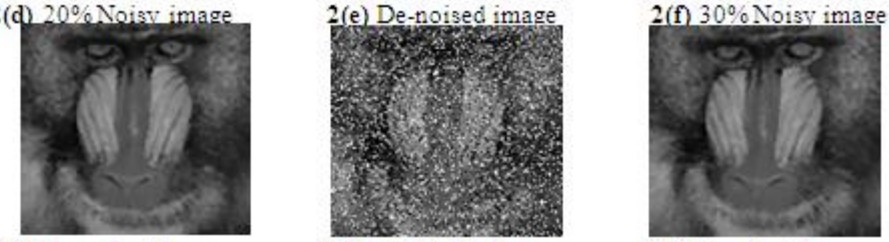
De-noising Methods	Noise density				
	50%	60%	70%	80%	90%
MF	14.734	13.34	12.6	10.23	8.9
CWM	19.57	17.38	15.55	14.09	12.09
PSMF	19.4425	12.2215	9.9653	8.1236	6.6092
IMF	23.89	21.2	16.59	12.1	8
SDROM	22.15	19.86	16.77	14.59	12.7
ACWM	14.8	12.1	9.7	8.1	6.5
RACWM	20.79	18.1	15	11.8	8.1
TSM	19.44	18.55	16.47	14.77	13.39
PA	**25.3627**	**23.9634**	**22.1029**	**20.8135**	**19.9419**

Here Table III shows the comparative analysis of MSE of different filters for "MANDRILL" image and the results clearly shows that the MSE of proposed filter is very less as compared to other filter.

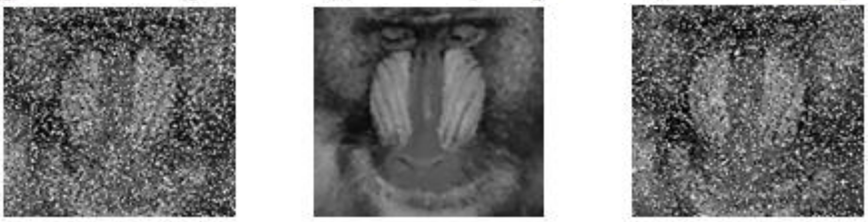
2(a) Mandrill Original Image 2(b) 10% Noisy image 2(c) De-noised image



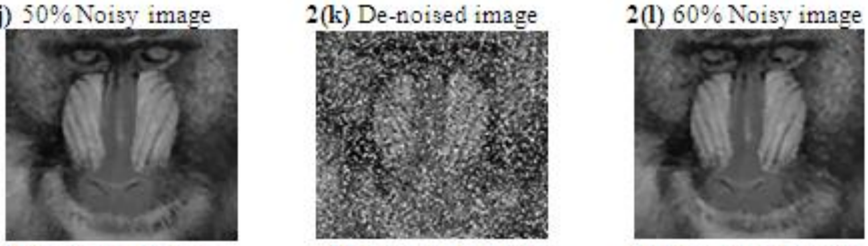
2(d) 20% Noisy image 2(e) De-noised image 2(f) 30% Noisy image



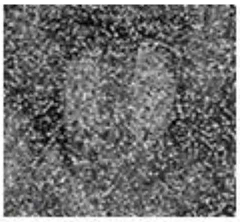
2(g) De-noised image 2(h) 40% Noisy image 2(i) De-noised image



2(j) 50% Noisy image 2(k) De-noised image 2(l) 60% Noisy image

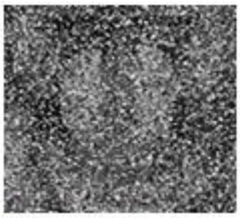


2(m) De-noised image 2(n) 70% Noisy image 2(o) De-noised image

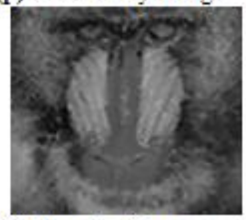


2(p) 80% Noisy image

2(q) De-noised image



2(r) 90% Noisy image



2(s) De-noised image

Fig.2. Mandrill Image

This method is tested on the "MANDRILL" image of size 256X256 shown in Fig. 2. The Fig. 2 (b), 1 (d), 1 (f), 1 (h), 1 (j), 1 (l) and 1 (n), 1 (p), 1 (r), shows the Mandrill image corrupted by 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% and 90% respectively, and figure 2 (c), 2 (e), 2 (g), 2 (i), 2 (k), 2 (m), 2 (o), 2 (q) 2 (s) show images De-noised by the proposed method.

Table III: Comparison of MSE values of different filters for MANDRILL image

Different Methods	Noise density				
	50%	60%	70%	80%	90%
MF	2203.3	3829	5285.4	9617.9	13585.6
CWM	3334.8	5285.4	7999.8	11042.8	14225.9
PSMF	729.6	1919	5165.1	8376.8	14557.2
IMF	264.9	493.1	1422.6	4009.4	10305.7
SDROM	2104.1	3918.1	6967.5	10071.1	14557.2
ACWM	2153.1	4009.4	6967.5	10071.1	14557.2
RACWM	620.9	984.1	1875.3	3741.8	8571.9
TSM	3573.3	5795.3	8975.9	12390.2	15598.4
PA	**270.0403**	**302.2**	**349.78**	**399.49**	**461.65**

We are clearly shown in figure 2 all color image noise removal. Figure 2 shows the visual perception of proposed method on mandrill image. Here we simulate our method not only in a high noise density, but a low noise density as well. We clearly see that no blur occurs in the higher de-noised images at 80% and 90% noise density. As we all know that if the PSNR value is increase the result of an algorithm is improved. PSNR improvement is not only a branch mark of image de-noised human and visual perception is also very important that's why when we talk about the image talks not only in the improvement of numbers but also focus on the image enhancement.

Table IV: Comparison of PSNR values of different filters for Mandrill image

Different Methods	Noise density				
	50%	60%	70%	80%	90%
MF	14.7	12.3	10.9	8.3	6.8
CWM	12.9	10.9	9.1	7.7	6.6
PSMF	19.5	15.3	11	8.9	6.5
IMF	23.9	21.2	16.6	12.1	8
SDROM	14.4	11.7	9.4	7.8	6.4
ACWM	14.8	12.1	9.7	8.1	6.5
RACWM	20.2	18.2	15.4	12.4	8.8
TSM	12.6	10.5	8.6	7.2	6.2
PA	**24.0143**	**23.4171**	**22.7571**	**22.0603**	**21.5301**

The result in the table IV shows the comparative analysis of PSNR of different filters for "MANDRILL" image.

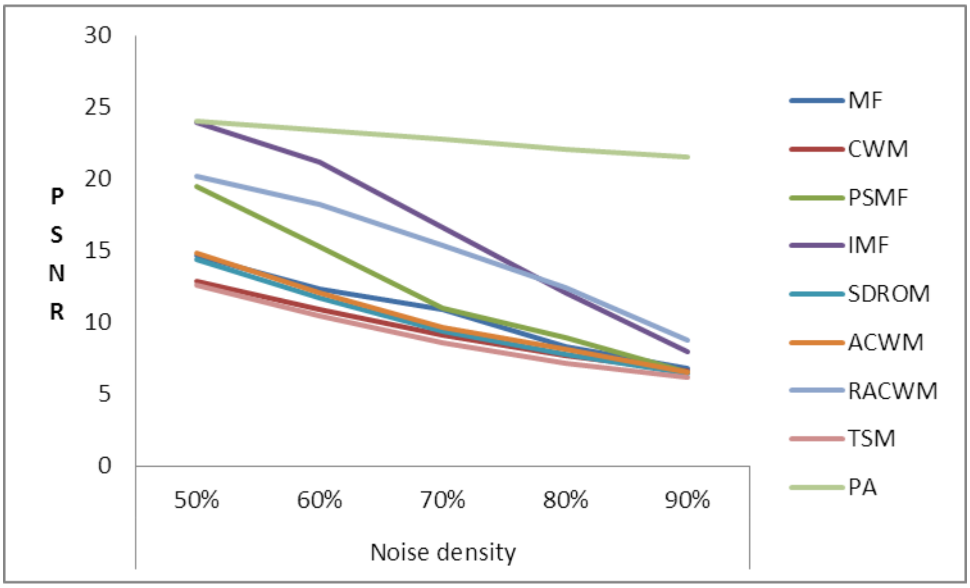


Fig.3. Graphical representation of PSNR of different filters at different noise density

The graphical representation of PSNR for Mandrill image of different filters likes MF, CWM, PSM, IMF, SD-ROM, ACWM, RACWM and TSM is shown in Fig.3. Here the results show that no filter, except the DTMF (dual Threshold Median Filter), produces better results the proposed filter for de-noising. DTMF only gives better results for 50% to 90% noise density and all other filters.

Where X-axis represents the different noise density between 50 to 90% and Y-axis represents the PSNR (dB) values of different filters.The PSNR of proposed method does not decrease very rapidly for high density noise like other filtering methods, in fact, as the noise density increases its our filter holds much better PSNR then other noise removal filters.

VI. Conclusion

The proposed method gives better PSNR values than other filters. The proposed filter has proved that it is very efficient for random valued impulse noise because practically noise is not uniform over the channel. We have used the concept of maximum and minimum threshold to detect both edges and noisy part of image. It produces good PSNR and reduced MSE for highly corrupted images, especially for more than 50% noise density. This method has the following advantages: The main advantage of our method that is two thresholds used and the threshold values can adaptively change according to the noise density of filtering window. Threshold values will be different for different noise density. Other de-noising methods have either single threshold value or threshold having constant value throughout the image irrespective of density of noise.

Our method shows good performance at different noise level. Also less complex sorting algorithm require because small number of elements are need to sort for the selection of minimum, maximum and median values. Finally our proposed method Dual Threshold Median Filter (DTMF) is all address of impulse noise removal for both low and high-density noise level with detail or edge preservation.

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References

[1]. Zhu Youlian, Huang Cheng, "An Improved Median Filtering Algorithm Combined with Average Filtering", IEEE, 2011 Third International Conference on Measuring Technology and Mechatronics Automation, 6-7 Jan. 2011, pp. 420 – 423.

[2]. Vikas Gupta and Abhishek Sharm "Image De-Noising by Enhanced MedianFiltering for High Density Noisy Images" Springer 2013 Fourth International Conference onSignal and Image Processing 2012 ICSIP. DOI: 10.1007/978-81-322-1000-9_55.

[3]. WANG Chang-you, YANG Fu-ping, GONG Hui, A new kind of adaptive weighted median filter algorithm, 2010 International Conference on Computer Application and System Modeling (ICCASM 2010).

[4]. Gonzalez R.C, Woods. R.E., Digital Image Processing, 3rd edition, Pearson Prentice Hall, 2009.

[5]. Shanmugavadivu P & Eliahim Jeevaraj P S, "Laplace Equation based Adaptive Median Filter for Highly Corrupted Images", International Conference on Computer Communication and Informatics (ICCCI -2012), 2012

[6]. T.-C. Lin, P.-T. Yu, , A new adaptive center weighted median filter for suppressing impulsive noise in images, Information Sciences 177 (2007) 1073–1087.

[7]. Xiaokai WANG, Feng LI, "Improved adaptive median filtering,"Computer Engineering and Applications, 2010, vol.46, no. 3,

pp.175-176. (in Chinese)

[8]. James C. Church, Yixin Chen, and Stephen V. Rice "A Spatial Median Filter for Noise Removal in Digital Images", Southeastcon, 2008.

[9]. Xiaoyin Xu, Eric L. Miller, Dongbin Chen and Mansoor Sarhadi "Adaptive two-pass rank order filter to remove impulse noise in highly corrupted images", IEEE Transactions on Image Processing, Vol. 13, No. 2, February 2004.

[10]. Guoping Qiu, " An improved Recursive Median Filtering Scheme for Image Processing", IEEE Trans. on Image Processing, Vol.5, No.4, pp. 646-648. l 1996.

[11]. T. Chen and H.Wu Adaptive impulse detection using centre-weighted median filters, Signal Processing Lett., vol.8, no. 1, pp. 13, Jan. 2001.

[12]. Z. Wang and D. Zhang, "Progressive switching median filter for the removal of impulse noise from highly corrupted images," IEEE Trans. on Circuits and Systems II: Analog and Digital Signal Processing, vol. 46, no. 1, pp. 78–80, 1999.

[13]. T. Chen, K.-K. Ma, and L.-H. Chen,"Tri-state median filter for image denoising," IEEE Trans. Image Processing, vol. 8, no. 12, pp. 1834–1838, 1999.

[14]. E. Abreu, S.K. Mitra, A signal-dependent rank ordered mean (SD-ROM) filter. A new approach for removal of impulses from highly corrupted images, in: Proceedings of IEEE ICASSP-95, Detroit, MI, 1995, pp. 2371–2374.

[15]. T. Song, M. Gabbouj, and Y. Neuvo, "Center weighted median filters: some properties and applications in image processing," Signal Processing, vol. 35, no. 3, pp. 213-229, 1994.

[16]. V. Jayaraj and D. Ebenezer, "A new switching-based median filtering scheme and algorithm for removal of high-density salt and pepper noise in image," EURASIP J. Adv. Signal Process., 2010

[17]. K. Aiswarya, V. Jayaraj, and D. Ebenezer, "A new and efficient algorithm for the removal of high density salt and pepper noise in images and videos," in Second Int. Conf. Computer Modeling and Simulation, 2010, pp. 409–413..

[18]. Manohar Koli and S.Balaji –"LITERATURE SURVEY ON IMPULSE NOISE," Journal (SIPIJ) Vol.4, No.5, October 2013 DOI.