RESEARCH ARTICLE OPEN ACCESS

A Comparative Performance Analysis of High Density Impulse Noise Removal Using Different Type Median Filters

Trapti Soni[1], Mrs.Vaishali Joshi[2]
Department of Computer Science and Engineering
R.G.P.V. Bhopal
Sanghavi Institute of Management & Science
Indore (M.P) - India

ABSTRACT
This paper focused on the review of some existing nonlinear filtering techniques for reduced impulse noise in different digital images. There are many filters are exists for removal of low density impulse noise, but in case of high density impulse noise filters are not perform very well. In this paper we compare different type of median filters and compare the efficient of the filters to remove impulse noise. Both type of analysis shown in this paper visual as well as quantities result also. For compare the efficiency of filters, we will check the PSNR and MSE values of different existing filters, with the help of chart we easily analysis for exiting filter performance. In this paper shows the different type filters literature, there are Median filter, Weighted Median Filter (WMF), Adaptive Weighted Median Filter (AWMF), Centre Weighted Median Filter (CWMF), Tri-State Median Filter (TSMF), Decision based unsymmetrical trimmed mean filter (DBUTMF), Modified Non-linear filter (MNF).
Keywords:- Impulse Noise, digital image, PSNR and MSE value.

I. INTRODUCTION

Digital image processing is the science of modifying digital images using a digital computer. Digital image technique and applications usually take an image as input and produced output. These outputs are a modified image, and encoded image etc [1]. Images are used in many fields for e.g. entertainment, remote sensing, medical image etc. Image processing refers to a set of procedures which aims at modifying the appearance and nature of an image in order to either enhance its pictorial information content for human interpretation or make it suitable enough for developing applications and autonomous machine perception. Digital image as a finite set of elements, each of which has a particular location and values, called picture elements, image elements, pels and pixels. Each pixel can be a single bit to represent either black or white. In facsimile a black and white image is scanned and converted into a rectangular array of dots called “pixels”. Each pixel is assigned a value 0 (for white) or 1 (for black) according to measured intensity [1].

There are different types of images such as Binary image, gray scale image, RGB image, CMY image and Indexed image. Binary image is formed due to the fact that each pixel is just black or white for which only one bit is required per pixel. Binary image is generally created by a gray scale image. In Gray scale image the range of pixels of this image type is between black to white, a total of 256 states are generally available with an 8-bits representation. Such images are useful for diagnostic photography using X-rays, images of printed works etc and are suitable for recognition of most of natural objects [1].

II. NOISE

Noise is unwanted information or signal presents in original signal or image. This is destroying the quality of image. For data transmission technique visual information is transmitted into channel. This visual information is corrupted in communication channel with noise. Noises are occurred an image different ways such as scanner, noisy sensor, channel error, lighting, camera, storage media etc. Impulse Noises are classifying into two main categories: Fixed valued impulse noise (salt and pepper noise) and random value impulse noise.

The salt and pepper type of noise are either salt (255) or pepper (0) and it also called the black and white spots on the images. Mathematically P is represent total noise density and salt & pepper noise have a noise density of p/2.

$$Y_{i,j} = \begin{cases} 0 \text{ or } 255, with\ probability\ \ P \\ X_{i,j}\ ,\ \ with\ probability\ 1 - P \end{cases} \quad \cdots$$

(1)

Where $Y_{i,j}$ represents the noisy image pixel, p is the total noise density of impulse noise and $Y_{i,j}$ is the uncorrupted image pixel. At times the salt noise and pepper noise may have different noise densities p_1 and p_2 and the total noise density will be

$P = p_1 + p_2$.

In case of random valued impulse noise, noise will take any gray level value from 0 to 225. During this case conjointly noise is at random distributed over the complete image and probability of prevalence of any gray level value as noise will be same. Mathematically represent random valued impulse noise is following [2].

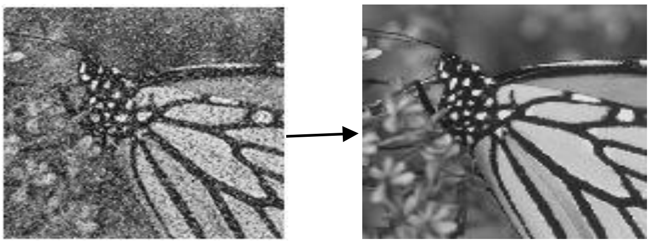
$$Y_{i,j} = \begin{cases} K_{i,j}\ ,\ \ with\ probability\ \ P \\ X_{i,j}\ ,\ \ with\ probability\ 1 - P \end{cases} \quad \cdots$$

(2)

Where $K_{i,j}$ is the gray level value of the noisy pixel.

III. NOISE DETECTION

The feature of impulse noise are that its value jumps to a 0 or 255 gray level value. We know that in each 3x3 window (W) have the nine pixel values. when we detected the noise in image then target window from the pixel value is check and compared with the centre pixel value, if it is equal to 0 or 255 gray level value in window, then it is a noisy pixel and this window is send to the next stage for noise removing, otherwise the centre pixel is noise free and it is left unchanged [3].



Noisy image Restored image

Fig 1: Image De-noising

A fundamental problem is to effectively remove noise from an image while keeping its fundamental structure constituting of edges, corners, etc., intact or retaining as much as possible the important signal features. This method is called “Image Denoising” [4].

IV. CLASSIFICATION OF FILTERING ALGORITHM

The purpose of denoising is to remove the noise while safe as much as possible original information of the image. The denoising of the image can be done in two ways:

Linear filtering and nonlinear filtering.

1. Linear Filters

In the case of linear filtering, the noise reduction algorithm is applied for all pixels of the image linearly without knowing about noisy pixel and non-noisy pixel. It is applied for noisy and non-noisy pixel so, linear filter algorithm destroy the non noisy pixel that is main disadvantage of linear filter. Linear filter are used band pass, high pass and low pass filter. Linear filter are tend to blurring sharp edges, black and white dot and in the presence of signal dependent noise perform poorly. Example for linear filters is mean, median and average filter etc. [5].

2. Non-Linear Filters

Nonlinear filters are applied on pixels surrounded by noisy pixels. The noise is removed without any attempts to explicitly identify it. Non linear filter a low pass filtering on groups of pixels with the assumption that the noise occupies the higher region of frequency spectrum. Linear filters, such as those used in band pass, high pass, and low pass, nonlinear filters are sometimes used also for removing very short wavelength, but high amplitude features from data. Image enhancement is the operation of taking a corrupted/noisy image and estimating the clean original image. Example for Nonlinear filter are median, min-max filter, centre weighted median filter etc. [5] [6].

V. LITERATURE SURVEY AND RELATED WORK

5.1 Median filter (M.F)

In 1989 A.K. Jain [7] introduced a "Fundamentals of Digital Image Processing". The proposed method median filter is used to remove salt and pepper noise in this paper. It is very simple to implement and very effective in removing impulse noise at low density levels. The median filter, especially with a larger window size destroys the image details due to its rank ordering process. It acts like a low pass filter which blocks all high frequency components of the image like edges and noise, thus blurs the image. As the noise density increases, the filtering window size is increased to have a sufficient number of encrypted pixels in the neighborhood. Depending upon the sliding window mask, there may be many variations of median filters. In this paper, Median filter with sliding window (3×3), (5×5) and (7×7) are reviewed. Applications of the median filter require caution because median filtering tends to remove image details such as thin lines and corners while reducing noise.

5.2 Weighted Median Filter (WMF)

In 1995,[8][9], R. K. Yang, L. Yin, M. Gabbouj, J. Astola, and Y. Neuvo, proposed a new method "Optimal weighted median filtering under structural constraints," weighted median filter is one of the branch of median filter . The operations involved in WMF are similar to SMF, except that WMF has weights associated with each of its filter element. these weights correspond to the number of sample duplications for the calculation of median value.[40] the successfulness of weighted median filter in preserving image details is highly dependent on the weighting coefficients, and the nature of the input image itself. Unfortunately, in practical situations, it is difficult to find the suitable weighting coefficients for this filter, and this filter requires high computational time when the weights are large. Some researchers, such as, proposed adaptive weighted median filters (AWMF), which is an extension to WMF. By using a fixed filter size *W h, w*, the weights of the filter will be adapted accordingly based on the local noise content.

5.3 Adaptive Weighted Median Filter (AWMF)

In 2008 Deng Xiuqin [12], proposed a new method "A new kind of weighted median filtering algorithm used for image Processing". This new algorithm first determines noisy pixel in image through noise detection, then adjusts the size of filtering window adaptively according to number of noise points in window, the pixel in the filtering window are grouped adaptively by certain rules and gives corresponding weight to each group of pixel according to similar it, and finally the noise detected are filtering treated by means of weighted median filtering algorithm

5.4 Center Weighted Median Filter (CWMF)

In sept 1991, [10] [11] S.-J. Ko and Y.-H. Lee, proposed a new method "Centre weighted median filters and their applications to image enhancement," for removal impulse noise. The Centre weighted median (CWM) filter is an extension of the weighted median filter, which gives more weight to centre values within the window. This CWM filter allows a degree of control of the smoothing behaviour 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 centre pixel of (2k+1) square window considered as test pixel. If centre 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 centre pixel is treated as corrupted pixel. Corrupted pixel is replaced by estimated value of median. Estimated value of median is calculated by sorting all elements of window in ascending order and taking median of elements from L th element to (N-L) th element. N is number of elements in an array.

5.5 Tri-State Median Filter (TSMF)

In Dec 1999, [13]Tao Chen, Kai-Kuang Ma, Li-Hui Chen proposed new method "Tristate Median Filter for Image Denoising" before applying filtering unconditionally, incorporates the Standard Median (SM) filter and Centre Weighted Median (CWM) filter into the noise detection framework to determine whether the pixel is corrupted. Noise detection is realized by an impulse detector, which takes the outputs from the SM and CWM filters and compares them with the origin or centre pixel value in order to make a tri-state decision. The switching logic is controlled by a threshold T and the output of TSM filter.

5.6 Decision based unsymmetrical trimmed mean filter (DBUTMF)

In 2013[14] K. Aiswarya, V. Jayaraj, and D. Ebenezer proposed a new method for "An improved decision based unsymmetric trimmed median filter for removal of high density salt and pepper noise". DBUTMF is a non linear filter that is overcome drawback of DBA .In DBUTM, detected noise in 3x3 window then corrupted pixel is replaced by a median value of the pixels. This median value is obtained by trimming impulse values from current window if they are present. It is unsymmetrical filter because only impulse values i.e. corrupted pixels are trimmed to obtain median of the window. The performance comparison shows that PSNR and IEF of DBUTM are greater than that for SMF, AMF and DBA. However, at very high noise density of the order of 80% to 90%, the number of corrupted pixels increases. So it happens that, all neighbouring pixels of central pixel are 0‟s or 255‟s or both of them, and then trimmed median cannot be obtained. So at high noise density this algorithm does not give better result.

5.7 Modified decision based unsymmetrical trimmed mean filter (MDBUTMF)

In 2011 [15] S. Esakkirajan, T. Veerakumar, Adabala N. Subramanyam, and C. H. Prem Chand proposed a new method for removal of high density salt and pepper noise (SNP) that is – "Removal of High Density Salt and Pepper Noise through Modified Decision Based Unsymmetrical Trimmed Median Filter". Modified Decision Based Unsymmetrical Trimmed Median Filter (MDBUTMF) is a non linear filter that can perform better in salt and pepper noise removal even under high noise densities. MDBUTMF is used for the noise detection and removal process in this thesis. The filtering process consists of initially detecting noisy pixels. Each and every pixel of the image is checked for the presence of salt and pepper noise. The processing pixel is checked whether it is noisy or noise free. That is, if the processing pixel lies between maximum and minimum gray level values (between 0 and 255) then it is noise free pixel, it is left unchanged. If the processing pixel takes the maximum or minimum gray level (0 or 255) then it is noisy pixel which is processed by MDBUTMF.MDBUTMF are better performances of high noise density as compared to DBUTMF, SMF, WMF, AWMF, CWMF, TSMF etc.

5.8 Modified Non-linear filter (MNF)

In 2013 Dr. G. Ramachandra Reddy, [16] A. Srinivas, M. Eswar Reddy and, T.Sunilkumar was proposed a new method "Removal of high density impulse noise through modified non linear filter". This method yields better results at very high noise density that is at 80% and 90% and gives better Peak Signal-to-Noise Ratio (PSNR). Modified Non-linear Filter algorithm processes the corrupted images by first detecting the noisy pixels in the image. To check processing pixel is noisy or noise free by verifying whether it lies between maximum and minimum grey level values then it is noise free pixel, else pixel is said to be corrupted. Only corrupted pixels are processed to replace with noise free pixel value, uncorrupted pixels are left unchanged. The logic behind this paper that is Alpha Trimmed Mean Filtering (ATMF) is symmetrical filter. As symmetric at either end even un-corrupted pixels are trimmed. This leads to loss of image details and blurring of the image. In order to overcome this drawback, an Un-symmetric Trimmed Median and Mean Filter are found. In this method, the selected 3 x 3 window elements which contain 0's or 255's or both are removed. Then the median or mean value of remaining pixels is taken. This median or mean value is replaced in corrupted pixel value.

VI. COMPARISON

In this paper eight existing filters are define each filter are many merits and demerits. For comparisons of existing filter we analysis that MF is used to remove image details such as thin lines and corners while reducing noise. It is used to remove noise in image for only low noise density .WMF are similar to SMF except that WMF has weights associated with each of its filter elements. It requires high computational time when the weights are large. CWMF is an extension of WMF which gives more weight to centre value within the window. It is allows a degree of control of the smoothing behaviour thought the weights in this technique. WMF adaptive impulse detection using centre weighted median rank order filtering algorithm. The main disadvantage of the switching median filter and decision based filter is that it is based on the predefined threshold. In order to overcome the disadvantages of these mentioned filtering techniques a two stage algorithm has been proposed. In this algorithm an adaptive median filter is used in first stage to classify the values of the noisy and noise free pixels and detail preserving regularization technique is used in second stage to preserve the details and edges as much as possible [17].AWMF is also an extension of WMF it is used a fixed filter size w the weight of the filter will be adopted accordingly based on the local noise content. TSMF is used to overcome drawback of WMF, CWMF and AWMF.DBUTMF is used to overcome the DBA, but this filter is not better result at high noise 80%-90% .MDBUTMF is removes the drawbacks of DBUTMF algorithm but some disadvantage are also include in this algorithm. MNF is better performance of remove low and high density of noise as compared to other existing filters.

The PSNR and MSE values of the MNF are compared to the existing other filter by wide range of noise density for baboon image are show in table1 and table2. Fig 2 show the different algorithms for baboon image at 60% noise density.

And in fig 3 show a graph for comparisons of different median based filter for reducing noise of corrupted baboon image of PSNR values. This graph help we easily analysis which filter performance is better.

The PSNR and MSE can be expressed as:

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

$$MSE = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\{X(i,j) - Y(i,j)\}^2}{m \times n}$$

Where,

PSNR= Peak Signal to Noise Ratio

MSE= Mean Square Error

X= Original signal

Y= Denoised image

m×n = size of image

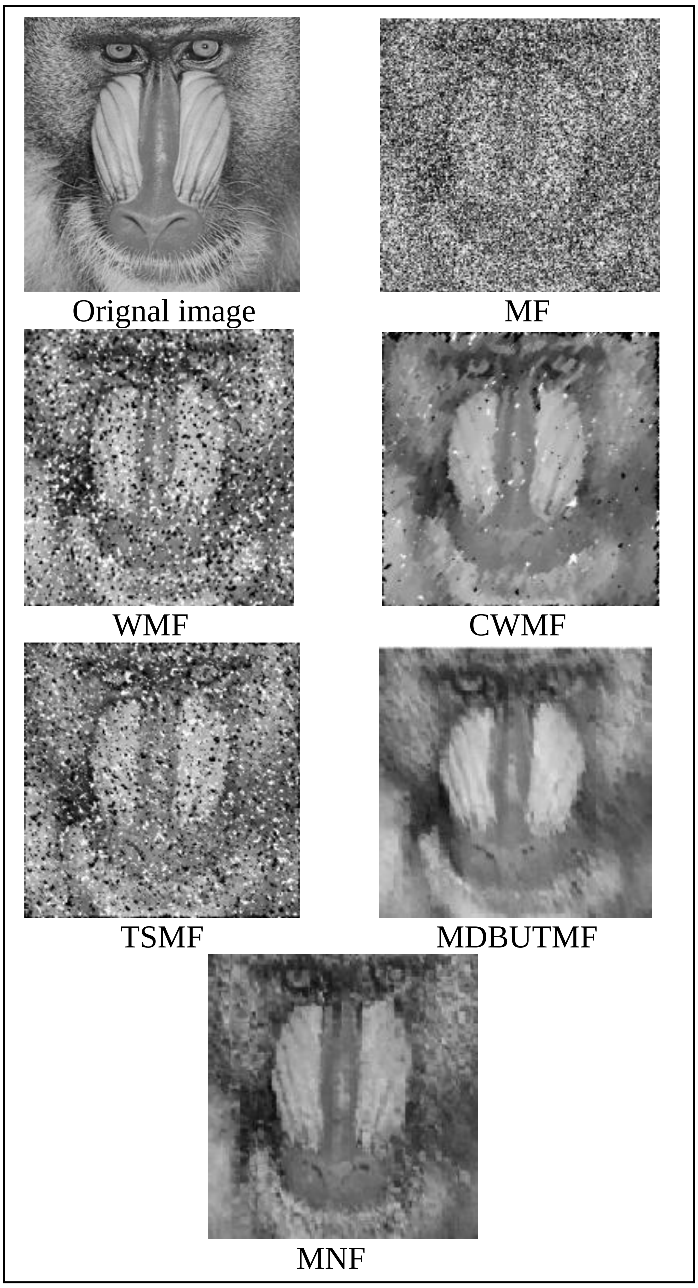


Fig 2: Result of different algorithms for baboon image at 60% noise density

Table 1. Comparison of MSE value of existing median filter for baboon image

NOISE DENSITY %	MF	WMF	CWMF	TSMF	MDBUTMF	MNF
10	195.9	312.9	159.8	69.2	35.5673	33.5948
20	200.2	385.1	400.2	210.1	70.8955	63.0983
30	265.1	400.6	632.8	346.1	105.7684	101.397
40	385.9	512.9	800.9	789.2	150.875	135.894
50	492.4	691.2	2.2e+003	1.7e+003	200.1543	180.036
60	595.1	800.8	4.1e+003	3.2e+003	300.453	234.462
70	1.42e+003	1500	6.1e+003	5.8e+003	390.453	302.654
80	4.52e+003	1.5e+003	8.2e+003	7.5e+003	480.4582	409.277
90	7.8e+003	7.4e+003	1.3e+004	1.4e+004	892.33	633.648

Table 2. Comparison of PSNR value of existing median filter for baboon image

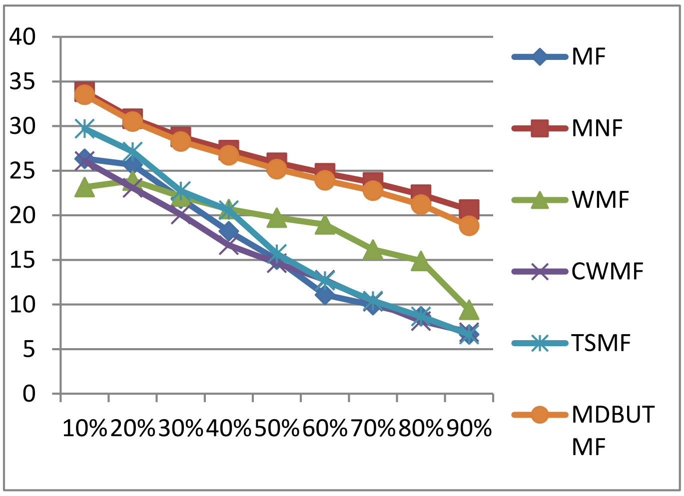


Fig 3: A comparison chart of different median-based filters for the reducing noise of corrupted baboon image of PSNR values.

Noise Density %	MF	WMF	CWMF	TSMF	MDB UTM F	MNF
10	26.34	23.17	26.09	29.72	33.59	33.85
20	25.66	23.89	23.08	27.14	30.51	30.83
30	21.86	22.10	20.1	22.73	28.28	28.79
40	18.21	20.70	16.66	20.57	26.73	27.31
50	15.04	19.73	14.64	15.68	25.18	25.89
60	11.08	18.98	12.77	12.67	23.92	24.72
70	9.93	16.16	10.31	10.43	22.76	23.69
80	8.68	14.89	8.15	8.66	21.20	22.32
90	6.65	9.42	6.90	6.65	18.82	20.65

.

VII. CONCLUSION

Conclude the impulse noise reduction is more valuable in traditional digital image processing. This review paper present existing reduction algorithms for impulse noise but they have several merits and demerits for noise reduction of corrupted image. For comparisons of several nonlinear filters MNF filter performance is better. This filter is quite effective in eliminative the impulse noise. Extensive simulation results verify its excellent impulse detection and detail preservation abilities by attaining the highest PSNR and lowest MSE values across a wide range of noise densities.

REFERENCES

[1] R. C. Gonzalez and R. E. Woods, Digital Image Processing. Pearson Education, Upper Saddle River, New Jersey,2007

[2] International Journal of Computer Applications (0975 – 8887) Volume 84 – No 8, December 2013 "An Improved Decision based Asymmetric Trimmed Median Filter for Removal of High Density Salt and Pepper Noise

[3] A Modified algorithm for Removal of Salt and Pepper Noise in Colour Images Venkatasubramanian Adhinarayanan1, S.P.Sheebha2, L. Sriraman3, T. N. Prabakar4, G. Seetharaman . 2012 Third International Conference on Intelligent Systems Modelling and Simulation.

[4] Jacques LévyVéhel, "Fraclab," www-rocq.inria.fr/fractales, May 2000

[5] IJCSET "comparative analysis of image denoising techniques", Monika pathak and sukhdev singh.multani mal modi collage, Patiala.

[6] IJITEE, ISSN: 2278-3075,volume-2,issue-4,"image denoising techniques a review paper ",kanika gupta ,s.k. gupta,march 2013

[7] A.K.Jain, Fundamentals of digital image processing. Prentice-Hall, 1989

[8] T. Chen and H. R. Wu, "Adaptive impulse detection using center weighted median filters," IEEE Signal Process.Lett., vol. 8, no. 1, pp. 1–3, Jan.2001

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

[10] S.-J. KO and Y.-H. Lee, "Center weighted median filters and their applications to image enhancement," IEEE Trans. Circuits Syst., vol. 38, no. 9,pp. 984-993,Sept. 1991

[11] Review of Impulse Noise Reduction Techniques Manohar Annappa Koli Research Scholar, Department of Computer Science Tumkur university

[12] DENG Xiuqin, XIONG and Yong PENG HONG,"A new kind of weighted median filtering algorithm used for image Processing," International Symposium on Information Science and Engineering., vol. 2, pp. 738-743, Dec. 20-22, 2008

[13] Tao Chen, Kai-Kuang Ma, Li-Hui Chen "TriSstate Median Filter for Image Denoising" IEEE Transactions on Image Processing, Vol. 8, No. 12, December 1999, pp 1834-1838

[14] 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

[15] W. K. Pratt, Digital Image Processing. New York: Wiley-Interscience, 1991

[16] Dr. G. Ramachandra Reddy, A. Srinivas, M. Eswar Reddy and, T.Sunilkumar "Removal of high density impulse noise through modified non linear filter"2013.

[17] IJPRET "comparative study on removal of high density salt and pepper noisethrough modified decision based unsymmetrical trimmed median filter", MR.PIYUSH A.DHANDE, 2014.

[18] "Digital Image Processing" R. C. Gonzalez and R. E. Woods, 2nd Ed., Englewood Cliffs, Nj: Prentice Hall, 2002

[19] A novel approach to noise reduction for impulse noise and Gaussian noise" P. Krishnapriya, Mr. S. Sanjeev Kumar, IJETAE, International Conference on Information Systems and Computing, vol.-3, January 2013

[20] Signal & image processing an international journal (SIIPIJ) vol.4, no.5, October 2013, "Literature survey on impulse noise reduction"manohar koli and s.balaji.

[21] IJAIEM volume 3,issue 3 march 2014, "Median filtering Frameworks and their Application to Image Enhancement"Kaveri A.P.1 and K.J.Amrutkar 21M.E. Student ,RMD SINHGAD WARJE 2Asst. Prof.

[22] "Removal of high density salt and pepper noise in images and vedio using denoising methods" IJCSMC, Vol. 2, Issue. 10, October 2013, pg.234 – 242Ramanaiah N1, Satish Kumar V2
(Department of ECE, MITS, Madanapalle, AP, India)

[23] A. Ben Hamza, P. Luque, J. Martinez, and R. Roman, "Removing noise and preserving details with relaxed median filters," J. Math. Image. Vision, vol. 11, no. 2, pp. 161–177, Oct. 1999.

[24] .David L. Donoho and Iain M. Johnstone., "Adapting to unknown smoothness via wavelet shrinkage", Journal of the American Statistical Association, vol.90, no432, pp.1200-1224, December 1995. National Laboratory, July 27, 2001.

[25] S. G. Mallat and W. L. Hwang, "Singularity detection and processing with wavelets," IEEE Trans. Inform. Theory, vol. 38, pp. 617–643, Mar. 1992.

[26] . D. L. Donoho, "De-noising by soft-thresholding", IEEE Trans. Information Theory, vol.41, no.3, pp.613-627, May1995. http://wwwstat.stanford.edu/~donoho/Reports/1992/denoisereleas e3.ps.Z

[27] Imola K. Fodor, Chandrika Kamath, "Denoising through wavelet shrinkage: An empirical study", Center for applied science computing Lawrence Livermore National Laboratory, July 27, 2001.

[28] R. Coifman and D. Donoho, "Translation invariant de-noising," in Lecture Notes in Statistics: Wavelets and Statistics, vol. New York: Springer-Verlag, pp. 125--150, 1995.

[29] R. Yang, L. Yin, M. Gabbouj, J. Astola, and Y. Neuvo, "Optimal weighted median filters understructural constraints," IEEE Trans. Signal Processing vol. 43, pp. 591–604, Mar. 1995.

[30] R. C. Hardie and K. E. Barner, "Rank conditioned rank selection filters for signal restoration," IEEE Trans. Image Processing, vol. 3, pp.192–206, Mar. 1994.

[31] Reginald L. Lagendijk, Jan Biemond, Iterative Identification and Restoration of Images, Kulwer Academic, Boston, 1991.

[32] T. Sreekanth Rao, P. Gangamohan, P. Nagarjuna Reddy, B. Prathyusha," Wavelet Based Image De-noising of Non-Logarithmic Transformed Data", IJCST, Vol. 2, SP I, Dec 2011, pp 213-215

[33] Scott E Umbaugh, Computer Vision and Image Processing, Prentice HallPTR, New Jersey, 1998.

[34] Langis Gagnon, "Wavelet Filtering of Speckle Noise-Some Numerical Results," Proceedings of the Conference Vision Interface 1999, TroisRiveres.

[35] 1/fnoise,"BrownianNoise,"http://classes.yale.edu/9900/math190a/OneOverF.html, 1999.

[36] David L. Donoho and Iain M. Johnstone, "Ideal spatial adaption via wavelet shrinkage", Biometrika, vol.81, pp 425-455, September 1994.

[37] P. E. Ng and K. K. Ma, "A switching median filter with boundary discriminative noise detection for extremely corrupted images," IEEE Trans. Image Process., vol. 15, no. 6, pp. 1506–1516, Jun. 2006.

[38] V. Strela. "Denoising via block Wiener filtering in wavelet domain". In 3rd European Congress of Mathematics, Barcelona, July 2000. BirkhäuserVerlag.

[39] H. Choi and R. G. Baraniuk, "Analysis of wavelet domain Wiener filters," in IEEE Int. Symp. Time-Frequency and Time-Scale Analysis, (Pittsburgh), Oct. 1998. http://citeseer.ist.psu.edu/article/choi98analysis.html

[40] H. Zhang, Aria Nosratinia, and R. O. Wells, Jr., "Image denoising via wavelet-domain spatially adaptive FIR Wiener filtering", in IEEE Proc. Int. Conf. Acoustic., Speech, Signal Processing, Istanbul, Turkey, June 2000.

[41] E. P. Simoncelli and E. H. Adelson. Noise removalvia Bayesian wavelet coring. In Third Int'l Conf on Image Proc, volume I, pages 379-382, Lausanne, September 1996. IEEE Signal Proc Society.

[42] H. A. Chipman, E. D. Kolaczyk, and R. E.McCulloch: 'Adaptive Bayesian wavelet shrinkage', J.Amer. Stat. Assoc., Vol. 92, No 440, Dec. 1997, pp.1413-1421.

[43] Marteen Jansen, Ph. D. Thesis in "Waveletthresholding and noise reduction" 2000.

[44] M. Lang, H. Guo, J.E. Odegard, and C.S. Burrus,"Nonlinear processing of a shift invariant DWT for noise reduction," SPIE, Mathematical Imaging: Wavelet Applications for Dual Use, April 1995.
[45] I. Cohen, S. Raz and D. Malah, Translationinvariantdenoising using the minimum description length criterion, Signal Processing, 75, 3, 201-223 (1999).
[46] "Salt and pepper noise reduction using MDBUTM filter with fuzzy based refinement", IJMIE, ISSN: 2249-0558, volume 2, issue 5, May 2012.
[47] Ashwni kumar and Priyadarshi kanungo,"First Order Neighborhood decision based Median filter," World Congress on Information and Communication Technologies., pp. 785-789, Oct. 30- Nov. 2, 2012