An Unsymmetrical Iterative Trimmed Mean Median Filter for Color Image Enhancement

Shraddha Mishra[1], Mrs. Navdeep Kaur Saluja[2]

¹M.Tech Student, ²Assistant Professor

Computer Science Engineering, Infinity Management & Engineering College, Sagar(M.P.) India

Abstract--This paper presents a new method for the de-noising and enhancement of color images, when images are corrupted by color valued impulse noise (salt and pepper noise). This method gives a better output for salt and pepper impulse noise as compare to the other famous filters like Standard Median Filter (SMF), Decision Based Median Filter (DBMF) and Modified Decision Based Median Filter (MDBMF) and so on. According to this proposed algorithm the noisy pixel is replaced by trimmed mean value. Firstly, the color image is sub-divided into three parts, i.e. the Red, Green and Blue color pixel matrices, then these three matrices are checked for error. When previous pixel values, 0's and 255's are present in the particular window and all the pixel values are 0's and 255's then the noisy pixel is replaced by mean. Different color images are tested via proposed method. The experimental result shows better Peak Signal to Noise Ratio (PSNR) value, mean square error (MSE) and with better visual and human perception.

Index Terms-- Blurring, salt and pepper noise, RGB Format, Modified Nonlinear filter, Peak Signal to Noise Ratio and Image enhancement factor.

I. INTRODUCTION

Image noise is random variation of brightness or color information in images, and is usually an aspect of electronic noise. It can be produced by the sensor and circuitry of a scanner or digital camera. Image noise can also originate in film grain and in the unavoidable shot noise of an ideal photon detector. Image noise is an undesirable by-product of image capture that adds spurious and extraneous information. In the field of image processing, digital images are mainly corrupted by the impulse noise [1]. Impulse noise is usually characterized by some portion of image pixels that are corrupted, leaving the remaining pixels unchanged [2]. There are two types of impulse noise a i.e.

1) fixed-valued impulse noise and

2) randomly valued impulse noise. In this paper, fixed valued impulse noise removal technique is shown. Fixed valued impulse noise is also called salt-and-pepper noise or spike noise. An image containing salt-and-pepper noise will have dark pixels in bright regions and bright pixels in dark regions. The salt and pepper noise corrupted pixels of image take either maximum or minimum pixel value Salt and pepper noise. Fixed valued impulse noise are producing two color level values 0 and 255. In salt and pepper noise (sparse light and dark disturbances), pixels in the image are very different in color or intensity unlike their surrounding pixels. Salt and pepper degradation can be caused by sharp and sudden disturbance in the image signal. Generally this type of noise will only affect a small number of image pixels. When viewed, the image contains dark and white dots, hence the term salt and pepper noise [3]. Typical sources include flecks of dust inside the camera and overheated or faulty (Charge-coupled device) CCD elements.

There are various filetrs have been designed for denoising the color image from salt and pepper noise and the performance have been improved with each new development, So far, both mean and median filters have been a great approach in noise removal, The another filters such as standard median filter[4][5], vector median filter, adaptive vector median filter, decision based median filter, weighted median filter[9], centre weighted median filter[10], recusive weightded median filter[11], weiner filter, fuzzy filters have been designed for the same purpose. The performance of median filters also depends on the size of window of the filter. 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 noise or noise free. However, further reduction in computational complexity is enviable.

II. NOISE MODEL

Salt-and-pepper noise is one common noise type of digital image processing. The noisy image *y* can be modelled as-

$$(X_{ij}) = \begin{cases} Y_j \text{ with probabilty } & 1-p \\ Z_j \text{ with probabilty } & p \end{cases} \qquad 2.1$$

Where *j* is the 2D pixel position vector, *xj* is the *j*'th pixel value in the clean image *x* and *sj* the *j*'th pixel value in the noise image, which is usually an iid random process with the binary value range of *{*0, *v*max(255)*}* with *P*(*sj* = *v*max) = *q* for *q* € [0, 1]. Although in practice more noise types are present, in this paper we will work only the salt and pepper noise model. Impulse noise is modelled as salt-and-pepper noise. Pixels are randomly corrupted by two fixed values, 0 and 255 generated with the equal probability. We can mathematically represent salt-and-pepper impulse noise as:

$$N(x) = \begin{cases} 1-B & for \cdots x = W(i,j) \\ B & for \cdots x = 0\, or\, 255 \end{cases}. \qquad 2.2$$

Where $W_{i,j}$ is the color level value of the noisy pixel.

III. RELATED WORKS

Image noise is an unavoidable side-effect occurring as a result of image capture, more simply understood as inaudible, yet inevitable fluctuations. In a digital camera, if the light which enters the lens misaligns with the sensors, it will create image noise. Even if noise is not so obviously visible in a picture, some kind of image noise is bound to exist. Every type of electronic device receives and transmits some noise and sends it on to what it is creating.

Various types of filters have been developed for color image de-noising. Linear filter used to remove certain types of noise. Averaging or Gaussian filters are appropriate for this purpose. Linear filters also tend to blur sharp edges, destroy lines and other fine image details, and perform poorly in the presence of signal-dependent noise. An adaptive process of filter accomplished with the wiener function applies a Wiener filter (a type of linear filter) to an image adaptively, tailoring itself to the local image variance. If the variance is large, wiener performs little smoothing. If it is small, wiener performs more smoothing. This approach often produces better results than linear filtering, but not in high density noises. In recent years, a variety of nonlinear median type filters such as standard median filters, vector median filters, weighted median, rank conditioned rank selection, and relaxed median have been developed to overcome this shortcoming. The standard median filter is providing most consistence performance, but it fails in case of high density noisy image, image enhancement and original image preservation cannot b done properly. Adaptive median filter shows better result over SMF but in case of high density noise it cause image blurring. In order to avoid this problem, “switching” strategy is usually used. This method distinguishes noise

pixels from noise-free pixels. If a central pixel is considered to be noise, this pixel is replaced by the output of vector median filter (VMF) filter and if not, the pixel remains without change [6]. The following filters are constructed based on the same technique: the adaptive vector median filter (AVMF) [7], fast peer group filter (FPGF) [8], and vector lower–upper–middle smoother (VLUM). Recently, a new filter as modified switching median filter “MSMF” has been suggested [14]. This filter is actually an improved filter of AVMF, and it preserves thin lines, fine details, and image edges. Another filter known as Progressive Switching Median Filter [13] had been in work. This method uses two threshold values which are obtained using trial and error method. One of the exciting filter used in salt and pepper noise removal is signal-dependent rank ordered mean (SDROM) Filter [12]. In the above mentioned techniques, the blurring problems of images, edges destroying, and remaining of noise are not often resolve.

In order to overcome the problems of previous filers outputs, a new filter has been designed. In this filter, the color image is filtered for salt and pepper noise, the results are improved in comparison to other filters. The next section will show the proposed method.

IV. PROPOSED METHOD

In this filtering technique, at first the three primaries of a color image (R, G and B) are separated in three different matrices and each matrix is traced for error separately. Then, the error is replaced by the mean value of the neighbourhood pixels. Once, all the noisy pixels are denoised, the three matrices are mixed together to get the noise free original image.

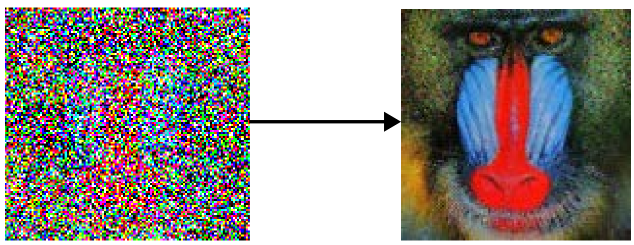


Fig.1 Image De-noising

ALGORITHM

Step 1: First a color image is taken and fixed valued impulse noises (Salt and Pepper noise) are added to this image.

Step 2: In second step, the noisy color image is separated in the three primaries (Red, Green and Blue) color image pixel matrices

Step 3: In the third step, all the pixels of the three different colors are examined whether they are lying in between 0 to 255 ranges or not. Here two cases arises.

Case 1 $X(ij) = 0<P(ij)<255$

$Y(ij) = 0<P(ij)<255$

$Z(ij) = 0<P(ij)<255$

Case 2 $X(ij) \neq 0<P(ij)<255$

$Y(ij) \neq 0<P(ij)<255$

$Z(ij) \neq 0<P(ij)<255$

Where X(ij), Y(ij) and Z(ij)is the image size of the red, green and blue respectively..

Case 1- If Pixels are lying between 0< P(ij)<255 then they are noise free and move to restoration image.

Case 2- If the pixels are not lying between in the range then they are moved to step 4.

Step 4: In the fourth step noisy pixels of step3 is taken as the targeted pixel W(ij) of a window of size 3 x3

Step 5: If the preferred window contains all elements as 0's and 255's. Then take the mean of all the 0's and 255's from the window and send to restoration image.Now find the median of the remaining pixels. Replace $W(ij)_j$ with the mean value. This noise free pixel is restored in de-noised image at the 7th step.

Step 6: Steps 3 to 5are repeated until all pixels in all the three basic color matrices are processed.

Step 7: Till now all the noisy pixels have been removed and the noise free pixels are restored in the respective color window. In the last step, the three basic color windows are combined together to get the noise free color image.

Hence a better de-noised image is obtained with improved PSNR and also shows a better image with very low blurring and improved visual and human perception.

V. RESULTS

In this section, the result of the proposed method for removal of fixed valued impulse noise is shown. For simulation of proposed method, MATLAB12.0 software is used. A 'Lena', 'Cameraman' and 'mandrill' image of size 256X256X3 has been taken as a reference image for testing purpose. The testing images are artificially corrupted by Salt and Pepper impulse noise by using MATLAB and images are corrupted by different noise density varying from 10 to 90 %. The performance of the proposed algorithm is tested for color scale image.

The quality of image can be quantitatively calculated by PSNR values.

The PSNR is expressed as:

$$PSNR = 10\log_{10} \frac{(255)^2}{\text{MSE}} \quad \ldots\ldots\ldots\ldots\ (1)$$

Where MSE (Mean Square Error) is

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

The PSNR values of the proposed algorithm are compared with other existing algorithms by variable noise density of 10% to 95%.

In the above table 1 and figure 2 shows the graphical comparison of proposed result on different noise density and different parameters. The parameters are peak signal to noise ratio, mean square error and time taken to run this algorithm. Now discuss the result comparison of proposed method with different previous method on 'Cameraman image'. In the below table 2 and table 3 shows the comparison of proposed method.

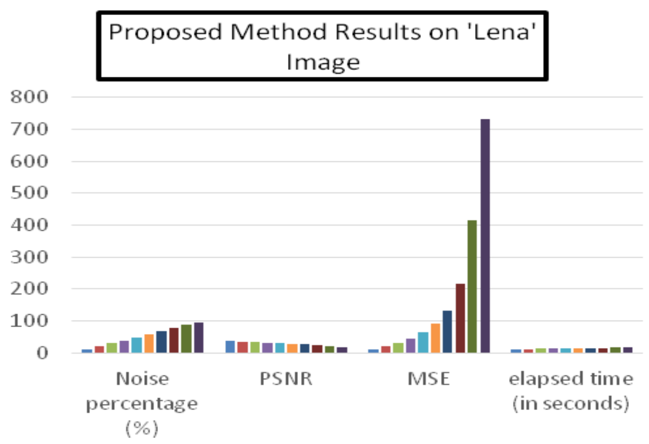


Fig. 2 Shows Graphical comparison of 'Lena image result '

Table 1 shows the comparison of PSNR values of different de-noising methods for color Lena image.

Noise percentage (%)	PSNR	MSE	elapsed time (in seconds)
10	38.2436	9.8849	9.83
20	35.1627	19.8890	12.28
30	33.3050	30.4582	13.27
40	31.4948	46.1731	13.63
50	30.0894	63.7848	14.87
60	28.4352	93.8486	15.40
70	26.9142	133.2787	15.21
80	24.8250	217.1904	15.57
90	22.0081	416.4509	16.60

Table 2 shows the comparison of MSE values of different de-noising methods for color 'Cameraman' image.

MSE						
ND(η) in %	MF	DBA	DBUTMF	MDBUTMF	Base Paper	Proposed filter
10	214.8	47.91	43.61	39.17	33.65	32.99
20	282.8	103.84	101.78	94.98	70.48	58.07
30	377.61	174.73	149.41	130.78	96.44	88.1
40	507.5	275.54	215.66	198.52	140.73	118.9
50	786.8	386.1	300.98	254.68	188.1	157.06
60	1294.	509.3	419.25	340.39	235.9	212.26

70	2208.	731.2	560.25	487.92	340.2	292.33
80	4377.	1059.	910.51	819.76	457.6	418.54
90	1034	1763.	1729.3	1442.57	643.2	712.4

In the above table 2 shows comparison of mean square error (MSE) of proposed filter at different noise density in between 10% to 90%. In the above table clearly see that MSE value of proposed filter is lower as compare to other previous filter. Mean square error (MSE) are try to as lower as possible.

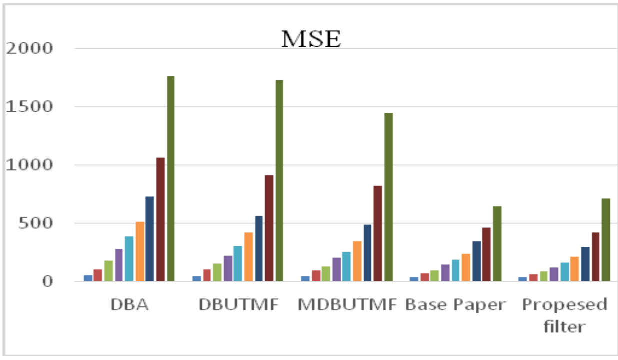


Fig. 3 Shows Graphical comparison of MSE 'Cameraman image result '

In the above figure 3 is the graphical representation of table 2 in which compare the **mean square error (MSE**) of proposed filter with different previous methods. In similar way compare the **peak signal to noise ratio (PSNR)** in the below table 3 and figure 4. In this table form of result compare the PSNR value of proposed filter and compare with different other filters, after that shows the graphical representation of PSNR of proposed method as compare to other method. PSNR value shows the improvement of restored image, therefor higher value of PSNR shows good result. In the below figure 4 and table 3 PSNR value of proposed filter is higher as compare to other previous filter.

TABLE 3- Comparison of PSNR values with varying noise densities result of various filters

31PSNR (dB)						
(η) in %	MF	DBA	DBUTMF	MDBUTMF	Base Paper	Proposed
10	24.84	.36	31.77	32.24	32.89	32.943
20	23.65	28	28.09	28.39	29.68	30.49
30	22.39	25.74	26.42	27	28.32	28.6
40	21.11	23.76	24.83	25.19	26.68	27.37
50	19.3	22.3	23.38	24.1	25.42	26.17
60	17.04	21.1	21.94	22.85	24.44	24.86
70	14.72	19.52	20.68	21.28	22.85	23.47
80	11.75	17.92	18.57	19.03	21.56	21.91
90	8.02	15.7	15.79	16.57	20.08	19.6

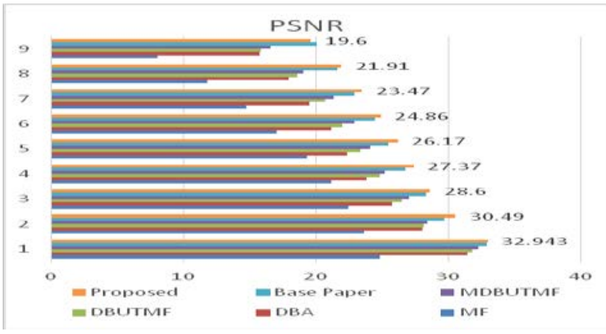
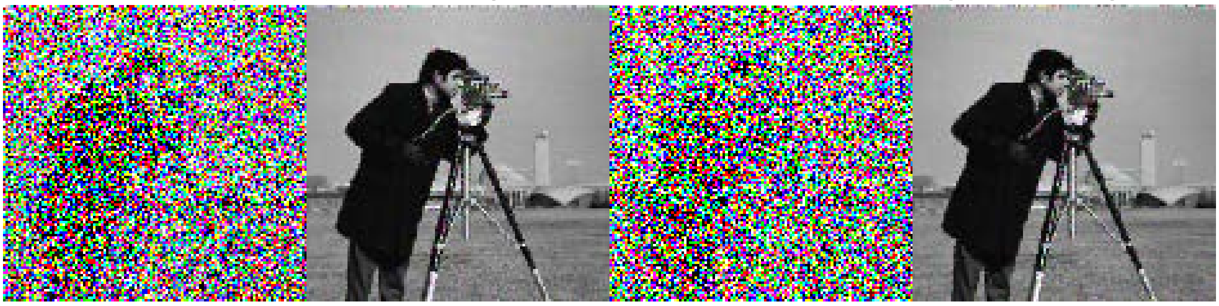


Fig.4 PSNR (dB) Vs Noise Density %

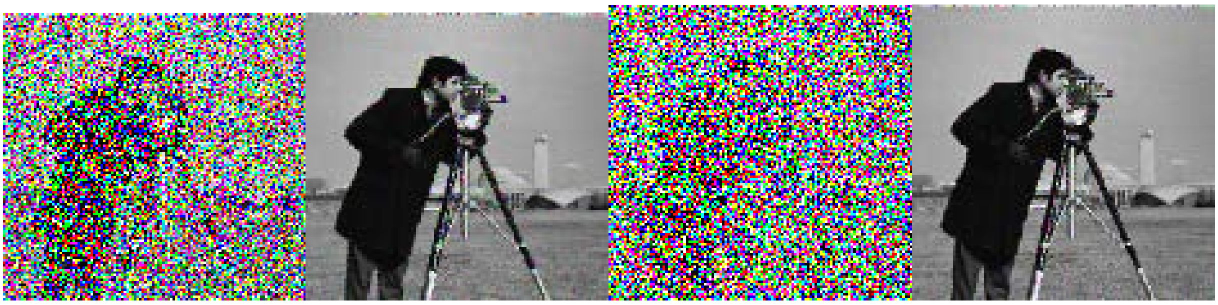
The proposed ALGORITHM shows a better result as compare to other existing algorithms at different noise densities as shown in Table-2 and table 3. The result of new method is better not only in terms of PSNR , but also show a good result in visual and human perception is also shown in the these shows the visual quality of the image. Graphical plots of PSNR values of different noise density compression with different filters against noise densities for Lena image is shown in Figure 1. Now shows the visual result of proposed color impulse removal using proposed filter and previous filters.

(a) Standard Noise free Camera man image (b) 10% noise density (c) restored image at10%

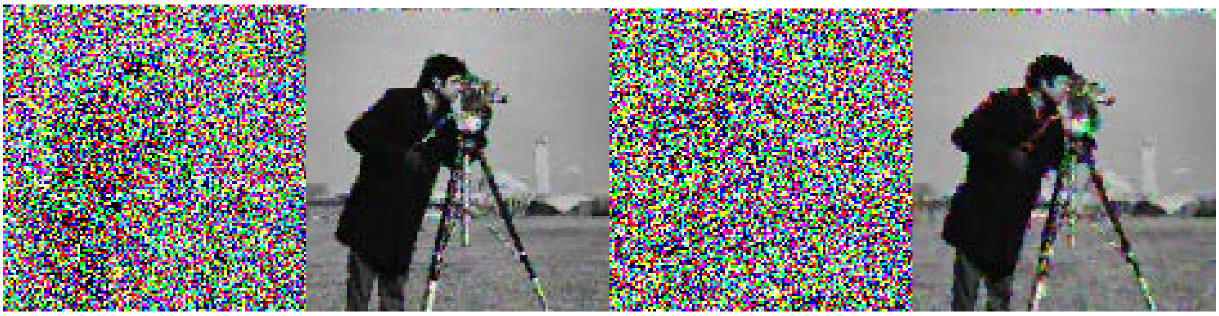
(d) 20% Noise density (e) restored image at 20% (f) 30% Noise density (g) restored image at 30%



(h) 40% Noise density (i) restored image at 40% (j) 50% Noise density (k) restored image at 50%

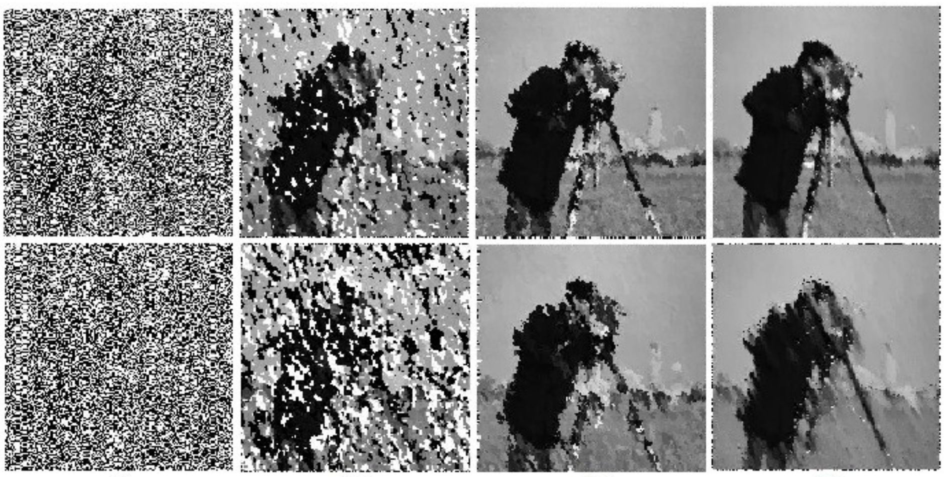


(l) 60% Noise density (m) restored image at 60% (n) 70% Noise density (o) restored image at 70%



(p) 80% Noise density (q) restored image at 80% (r) 90% Noise density (s) restored image at 90%

Fig. 5 (a –s) Shows the visual result of proposed method at different noise density between 10% to 90%



(a) (b) (c) (d)

(e) 80% noise density resorted (f) 90% noise density resorted

Fig. 6. Results of different filters for grayscale cameraman image (a) Noise corrupted image. (b) Output of MF. (c) Output of DBA. (d) Output of DBUTMF. Row 1 and row 2 show processed results of different filters for image corrupted by 80% and 90% noise densities respectively

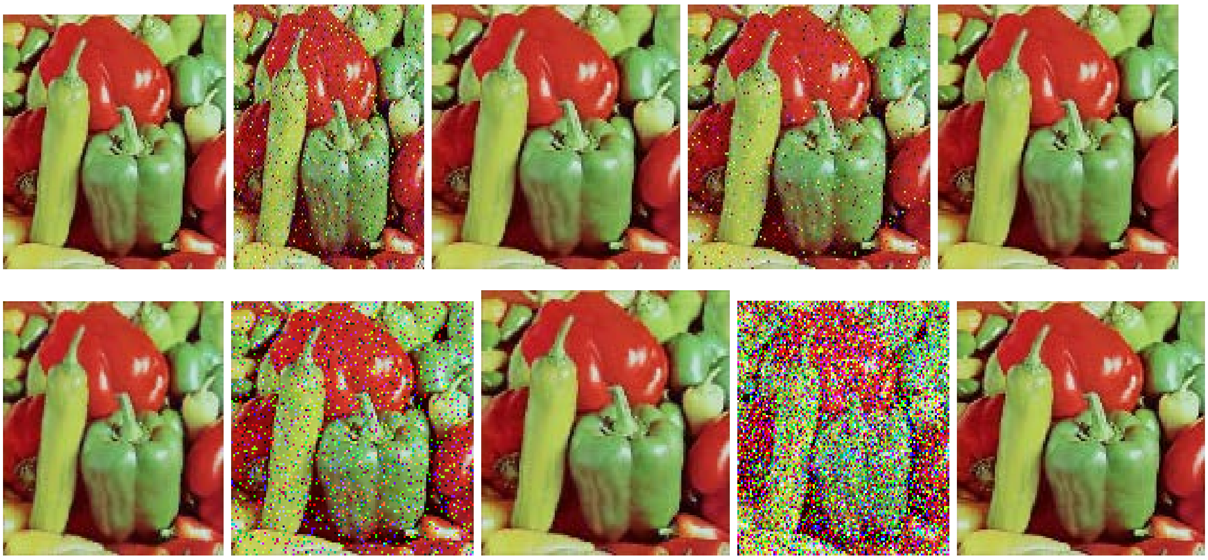


Fig. 7 (a –i) Shows the visual result of proposed method on 'Pepper Image' at different noise density between 3% to 20%

VI. CONCLUSION

A new algorithm has been proposed to deal with the salt and pepper noise at high noise density, which cause poor image quality, and is frequently enhanced in the PSNR. In this paper Improved Mean Filtering is used for enhancing the peak signal to noise ratio (PSNR). The performances of proposed filter shows better result in quantitative as well as the visual and human perception manners, as compared to other existing filters. Results reveal that the proposed filter exhibits better performance in comparison with SMF, WMF, AMF, DBA, RWM, SD ROM and PSMF filters in terms of higher PSNR. Indifference to AMF and other existing algorithms, the new algorithm uses a small 3x3 window having only eight neighbours of the corrupted pixel that have higher connection; this provides more edge information, more important to better edge preservation as well as more better human and visual perception. The new algorithm filter also shows reliable and stable performance across a different range of noise densities varying from 10% - 90%. The performance of the proposed method has been tested at low, medium and high noise densities on color scales. In fact at high noise density levels the new proposed algorithm gives better performance as compare with other existing de-noising

REFERENCES

[1]. Digital Image Processing, Rafael C. Gonzalez, Richard E. Woods, Prentice Hall, Upper Saddle River, New Jersey 07458.

[2]. Fundamentals of Digital Image Processing, S. Annadurai, R. Shammugalakshmi, Pearson Education India.

[3]. Castleman Kenneth R, *Digital Image Processing*, Prentice Hall, NewJersey, 1979

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

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

[6]. Langis Gagnon, “Wavelet Filtering of Speckle Noise-Some Numerical Results,” *Proceedings of the Conference Vision Interface* 1999, Trois Riveres.

[7]. 1/*f* noise, “Brownian Noise,”http ://classes .yale. edu/ 9900 /math190a/OneOverF.html, 1999.

[8]. Jacques Lévy Véhel, “Fraclab,” www-rocq.inria.fr/fractales, May 2000.

[9]. 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

[10]. 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.

[11]. 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.

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

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

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

[14]. 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.

[15]. V. Strela. “Denoising via block Wiener filtering in wavelet domain”. In 3rd European Congress of Mathematics, Barcelona, July 2000. Birkhäuser Verlag.

[16]. 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

[17]. 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.

[18]. S.Esakkirajan,T.Veerakumar, Adabala N. Subramanyam and C. H. PremChand. “Removal of High Density Salt and Pepper Noise Through Modified Decision Based Unsymmetric Trimmed Median Filter.” *IEEE Signal Processing Letters,* VOL. 18, NO. 5, MAY 2011.

[19]. T.Sunilkumar, A.Srinivas, M.Eswar Reddy and Dr. G.Ramachandren Reddy “Removal of high density impulse noise through modified non-linear filter” Journal of Theoretical and Applied Information Technology.. Vol. 47 No.2, 20th January 2013 ISSN: 1992-8645, E-ISSN: 1817-3195.

[20]. S. Zhang and M. A. Karim, “A new impulse detector for switching median filters,” *IEEE Signal Process. Lett.*, vol. 9, no. 11, pp. 360–363, Nov. 2002.

[21]. Hossein Hosseini and Farokh Marvasti “Fast restoration of natural images corrupted by high-density impulse noise”. *Springer-EURASIP Journal on Image and Video Processing* 2013, 2013:15.

[22]. H. Hwang and R. A. Hadded, “Adaptive median filter: New algorithms and results,” *IEEE Trans. Image Process.*, vol. 4, no. 4, pp. 499–502, Apr. 1995.

[23]. K. Aiswarya, 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

[24]. T.A. Nodes and N.C. Gallagher, Jr., “The output distribution of median type filters,” IEEE Trans. Communication., 32(5): 532-541, 1984.

[25]. 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. .

[26]. J. Astola and P. Kuosmaneen, *Fundamentals of Nonlinear Digital Filtering*. Boca Raton, FL: CRC, 199J. Clerk Maxwell, *A Treatise on Electricity and Magnetism*, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[27]. T.Sunilkumar, A.Srinivas, M.Eswar Reddy and Dr. G.Ramachandren Reddy “Removal of high density impulse noise through modified non-linear filter” Journal of Theoretical and Applied Information Technology.. Vol. 47 No.2, 20th January 2013 ISSN: 1992-8645, E-ISSN: 1817-3195.

[28]. Lal, Shyam; Kumar, Sanjeev and Chandra, Mahesh. "Removal of High Density Salt & Pepper Noise through Super Mean Filter for Natural Images", International Journal of Computer Science Issues (IJCSI).

[29]. Pattnaik, Ashutosh, Sharad Agarwal, and Subhasis Chand. "A New and Efficient Method for Removal of High Density Salt and Pepper Noise through Cascade Decision based Filtering Algorithm", Procedia Technology, 2012.

[30]. T. Veerakumar. "Salt and pepper noise removal in video using adaptive decision based median filter", 2011 International Conference on Multimedia Signal Processing and Communication Technologies, 12/2011.

[31]. Ashraf Aboshosha. "Image denoising based on spatial filters, an analytical study", 2009 International Conference on Computer Engineering & Systems, 12/2009.

[32]. V.R. Vijaykumar. "Detail preserving median based filter for impulse noise removal in digital images", 2008 9th International Conference on Signal Processing.

[33]. Singh, Ravindra Kumar; Chaudhari, Narendra S. and Saxena, Kanak. "Probabilistic Selection of QoS Paths for Improving Survivability in MPLS Networks", Communications & Network, 2013.

[34]. Shan, Jianhua, and Liangliang Zhu. "A Local Similarity Pattern for Removal of Random Valued Impulse Noise", Journal of Multimedia, 2014.

[35]. Hanji, Geeta, M. V. Latte, and Yi Xie. "A new threshold-based median filtering technique for salt and pepper noise removal", Second International Conference on Digital Image Processing, 2010.

[36]. Bhabesh Deka. "A linear prediction based switching median filter for the removal of salt and pepper noise from highly corrupted image", 2012 2nd National Conference on Computational Intelligence and Signal Processing (CISP), 03/2012

[37]. Hadhoud, Marwa M. A.; Eladawy, Mohamed I. and Farag, Ahmed. "Left Ventricle Cavity Segmentation from Cardiac Cine MRI", International Journal of Computer Science Issues (IJCSI).

[38]. Chih-Yuan Lien. "An Efficient Denoising Approach for Random-Valued Impulse Noise in Digital Images", 2011 Second International Conference on Innovations in Bio-inspired Computing and Applications.

[39]. Chen, Pei-Yin, Chih-Yuan Lien, and Hsu-Ming Chuang. "A Low-Cost VLSI Implementation for Efficient Removal of Impulse Noise", IEEE Transactions on Very Large Scale Integration (VLSI) Systems, 2010.

[40]. Hsu, Chun-Lung, Chen-Wei Lan, Yu-Chih Lo, and Yu-Sheng Huang. "Adaptive De-noising Filter Algorithm for CMOS Image Sensor Testing Applications", 2010 IEEE 25th International Symposium on Defect and Fault Tolerance in VLSI Systems, 2010.

[41]. Deivalakshmi, S., S. Sarath, and P. Palanisamy. "Detection and removal of Salt and Pepper noise in images by improved median filter", 2011 IEEE Recent Advances in Intelligent Computational Systems, 2011.

[42]. T. Yahagi. "A Random-valued Impulse Noise Detector Using Level Detection", 2005 IEEE International Symposium on Circuits and Systems, 2005

[43]. Joshi, Sunil; Jadon, R. S. and Jain, R. C. "Sequential Pattern Mining Using Formal language Tools", International Journal of Computer Science Issues (IJCSI), 2012.

[44]. Bai, Tian, Jieqing Tan, Min Hu, and Yan Wang. "A novel algorithm for removal of salt and pepper noise using continued fractions interpolation", Signal Processing, 2014.

[45]. Veerakumar, T., S. Esakkirajan, and Ila Vennila. "An efficient approach to remove random valued impulse noise in images", 2012 International Conference on Recent Trends in Information Technology, 2012.

[46]. K. S. Srinivasan. "A New Fast and Efficient Decision-Based Algorithm for Removal of High-Density Impulse Noises", IEEE Signal Processing Letters, 3/2007

[47]. Hsieh, Mu-Hsien, Fan-Chieh Cheng, Mon-Chau Shie, and Shanq-Jang Ruan. "Fast and efficient median filter for removing 1–99% levels of salt-and-pepper noise in images", Engineering Applications of Artificial Intelligence, 2013.

[48]. Nair, Madhu S., and P. M. Ameera Mol. "An Efficient Adaptive Weighted Switching Median Filter for Removing High Density Impulse Noise", Journal of The Institution of Engineers (India) Series B, 2014.

[49]. Jafar Ramadhan Mohammed. "An Improved Median Filter Based on Efficient Noise Detection for High Quality Image Restoration", 2008 Second Asia International Conference on Modelling & Simulation (AMS).

[50]. Debananda Padhi, Sucharita Padhi, Bratati Mohanty "Order Statistic Filters for removing Salt-and-Pepper Noise of Images: A Comparative Study", International Journal of Advanced Research in Computer Science andSoftware.