An Improved Method to Remove Salt and Pepper Noise in Noisy Images

Jinder Kaur, Gurwinder Kaur, Ashwani Kumar

ECE Section, Yadavindra College of Engineering, Punjabi University Guru Kashi Campus,
Talwandi Sabo-151302, Punjab, India

*Corresponding author

doi: https://doi.org/10.21467/proceedings.114.23

Abstract

In the field of image processing, removal of noise from Gray scale as well as RGB images is an ambitious task. The important function of noise removal algorithm is to eliminate noise from a noisy image. The salt and pepper noise (SPN) is frequently arising into Gray scale and RGB images while capturing, acquiring and transmitting over the insecure several communication mechanisms. In past, the numerous noise removal methods have been introduced to extract the noise from images adulterated with SPN. The proposed work introduces the SPN removal algorithm for Gray scale at low along with high density noise (10\% to 90\%). According to the different conditions of proposed algorithm, the noisy pixel is reconstructed by Winsorized mean or mean value of all pixels except the centre pixel which are present in the processing window. The noise from an image can be removed by using the proposed algorithm without degrading the quality of image. The performance evaluation of proposed and modified decision based unsymmetric median filter (MDBUTMF) is done on the basis of different performance parameters such as Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), Image Enhancement Factor (IEF) and Structure Similarity Index Measurement (SSIM).

Keywords: Noise removal, Salt and Pepper Noise (SPN), Winsorized Mean

1 Introduction

Noise in image arises due to numerous reasons such as environment condition and the performance of image sensor. The quality of the sensing element also affects the digital image. The interferences of channel also corrupt the digital image during transmission [1]. Noise is unwanted information in an image which degrades the quality of image. Image noise is a irregular change of color information and image intensity. The uniform noise, Gaussian noise, salt and pepper noise (SPN), Rayleigh noise, gamma noise, speckle noise and Poisson noise are common types of noise, which can be added in the image during transmission or reception. The memory cell failure, synchronization error existing in image transmission, sharp and sudden disturbances in image signal, misfunctioning of camera sensor cells, digitization process are different reasons for generation of salt and pepper in the digital image. The SPN is also called as impulse noise, spike noise or shot noise. SPN consists of both arbitrary existence of black and white Gray level, while impulse noise consists of only random occurrence of white intensity levels. In the representation of an 8-bit image, the salt noise is represented by the pixel value ‘255’ and pepper noise is represented by ‘0’ [2].

In the image processing field, the SPN removal is taken as a common area of research. There are many traditional mean or median filters which are used to remove SPN from Gray scale and RGB images [3,4,5]. A progressive switching median filter (PSMF) based on switching scheme and progressive method have been proposed which is very effective to remove SPN from the images extremely contaminated with noise [6]. A two-phase scheme is also used to remove noise as high as 90%, in which adaptive median filter is used to recognize the noisy pixels and special regularization method is used to restore corrupted pixels. This method has advantage that it preserves the edge information during denoising process [7]. A novel

Proceedings DOI: 10.21467/proceedings.114; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-947843-8-8

two stage noise adaptive fuzzy switching median (NAFSM) filter and decision based on inverse distance weighted interpolation (DBIDWI) algorithm, were also presented to identify noisy pixels and then filtering action is applied to remove noise from them [8,3]. A method based on modified decision based unsymmetric trimmed median filter (MDBUTMF) was presented which was used to eliminate SPN from Gray scale and colored images. In this noise removal method, processing pixel was reconstructed with trimmed median value when selecting window consists all pixels between 0 and 255 and processing pixel replace by mean value when selected window consists 0 or 255 or combination of both 0 and 255. If the processing pixel is observed as non-noisy then it remains unchanged [9]. As the SPN introduce sharp and sudden disturbances in magnetic resonance images (MRI) and mammogram images, so the median filter and different tri-state non-linear values-based algorithm was used to eliminate high density SPN in that images [10, 11]. An adaptive median filter and two-level wavelet decompositions (AMF-WT) algorithm is also used to denoise the high frequency components in noisy images [12]. An adaptive right mean filter was also proposed and this algorithm was outperformed by MDBUTMF, DBA and NAFSMF algorithms at all noise densities except 80% and 90% densities [13]. There are different types of algorithms which have been developed to eliminate the SPN at several levels of noise density. But it has been observed from the study that the research related to the removal of SPN in image is not yet limited. In this work, an algorithm based on the Winsorized mean operation is proposed which can be used to denoise the Gray scale and RGB images at low along with at high density noise (10% to 90%).

The remaining part of the paper is divided into four sections. The Section 2 elaborates the SPN noise removal algorithm which is used to reduce the noise from image. Section 3 describes the results of presented algorithm and also elaborates the performance evaluation based on different performance parameters. Section 4 described the conclusion as well as future scope of the presented work.

2 Methodology of Proposed Algorithm

In this algorithm, the Winsorized mean operation is used to the eliminate the SPN from the noisy (corrupted) images. The non-linear operations are used by median and mean filters, which provide the good results for elimination of SPN from an image. The SPN removal is very easy, if the pixel values are very near to the mean or median value. For this reason, Winsorized mean operation is utilized to remove noisy pixels. Winsorized mean operation, the 1D array is sorted into ascending or descending order. Then from the sorted 1D array, the largest and smallest neighbouring values are reconstructed by observation. After the replacement of the values, a simple arithmetic mean formula is utilized to evaluate the Winsorized mean from the remaining highest and lowest values. It is expressed by as follows:

$$\text{Winsorised mean} = \frac{x_n + ...x_{n+1} + x_{n+2} + ...x_n}{N} \qquad (1)$$

Where n represents the largest and smallest value to be replaced nearby observation to it in an array. N represents the total number of data values.

The various steps of proposed algorithm are shown in figure 1. Initially, the centre element of the processing window is examined, whether it contains noise or it is noise free. If it holds the low (0's) and high (255's) pixel value and the centre pixel in the processing window is noisy, if it lies between low (0's) and high (255's) pixels value and left unaltered. Noisy pixel is reconstructed by using proposed algorithm. The various steps of proposed algorithm are given below:

Step 1: Select a $2D$ processing window of size 3×3. The $P(i, j)$ is considered as centre pixel in processing window.

Step 2: Examine whether the centre pixel in the processing window contains noise or it is noise free.

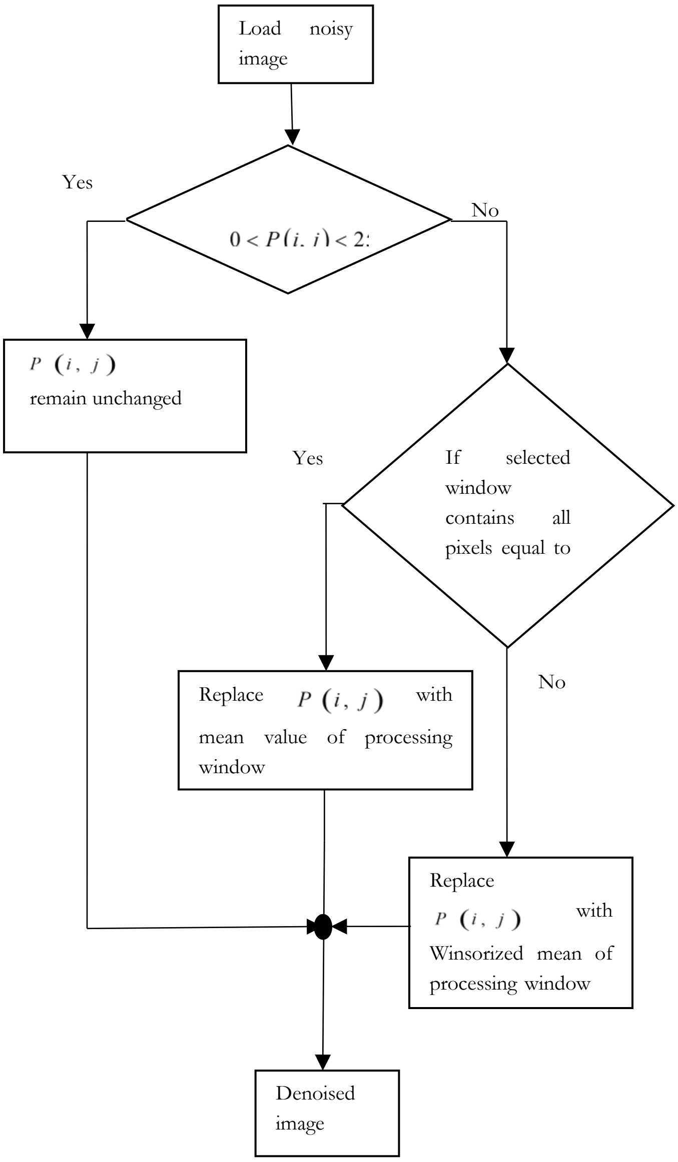


Fig. 1. Flow Diagram of Winsorized mean based algorithm

Step 3: If centre pixel $P(i, j)$ has the value 0's or 255's or both, then it is considered a noisy pixel. If the pixel value of $P(i, j)$ varies between 0 to 255, then it is considered a noise free pixel.

Step 4: The noisy pixel is reconstructed from an image as follows:

Case 1: If centre pixel $P(i, j)$ and entire pixels of the processing window contain all the values between 0 to 255. Find out the Winsorized mean of the processing window except the pixels having values 0's and 255's. The centre pixel $P(i, j)$ is reconstructed by Winsorized mean.

For example: If the centre pixel holds the value either 0 or 255 and some pixels from the present processing window around the centre pixel are also noisy, then convert the matrix into 1D array and this array is sorted in descending order as shown below:

$$\begin{bmatrix} 50 & 0 & 255 \\ 94 & (0) & 255 \\ 97 & 163 & 127 \end{bmatrix}$$

Unsorted array: $[50 \quad 0 \quad 255 \quad 94 \quad 0 \quad 255 \quad 97 \quad 163 \quad 127]$

Sorted array: $[255 \quad 255 \quad 163 \quad 127 \quad 97 \quad 94 \quad 50 \quad 0 \quad 0]$

Eliminate the 0's and 255's from the processing window and after elimination of noisy pixels from the processing window, sorted elements are only noise free pixels. Hence 1D array now becomes $[163 \quad 127 \quad 97 \quad 94 \quad 50]$. The largest value in 1D array is 163 and smallest value is 50. The arithmetic mean of the largest and smallest value in the 1D array is calculated. Then the centre pixel $P(i, j)$ is reconstructed with Winsorized mean i.e. 106.

Case 2: The centre pixel $P(i, j)$ as well as other pixels inside the processing window are having the pixel values 0's or 255's and the combination of both. Then $P(i, j)$ is reconstructed by the mean of all pixels except $P(i, j)$ in the processing window.

For example: In the following selected window, the '0' is representing centre element of processing window $P(i, j)$ and the remaining elements in the selected window around $P(i, j)$ are also 0's and 255's.

$$\begin{bmatrix} 0 & 255 & 255 \\ 255 & (0) & 255 \\ 0 & 255 & 0 \end{bmatrix}$$

The centre pixel is preferred to be reconstructed by mean value. Because the median of this type of processing window is either 0 or 255, which is again considered as noisy pixel. So, the centre pixel $P(i, j)$ is reconstructed by mean value i.e. 141.

Step 5: If pixel values of the centre pixel $P(i, j)$ and all other pixels of processing window are lies between 0 to 255, Then the processing window is examined as noise free.

For example: As shown in the following processing window, the centre pixel has value 177 which lies between 0 255. Then the value of the centre pixel remains unchanged i.e. it will be 177.

$$\begin{bmatrix} 55 & 70 & 67 \\ 88 & 177 & 89 \\ 103 & 58 & 0 \end{bmatrix}$$

Step 6: To denoise the whole image, the steps from 1 to 5 are repeated.

3 Results of Proposed Algorithm

3.1 Performance Parameters

The performance evaluation of the proposed algorithm with existing technique named as modified decision based unsymmetric median filter (MDBUTMF) is done. For this evaluation, different parameters are used like Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), Image Enhancement Factor (IEF) and Structure Similarity Index Measurement (SSIM). The details of these parameters are given below:

3.2 Mean Square Error (MSE):

Mean square error (MSE) is accumulative square error between the noise free and original test image [14]. It can be calculated as:

$$MSE = \frac{1}{mn}\sum_{0}^{m-1}\sum_{0}^{n-1}\left\| f(i,j) - g(i,j)\right\|^2 \qquad (2)$$

Where f represents the original test image, g represents the noise free image and $m \times n$ expresses the dimensions of image.

3.3 Peak Signal to Noise Ratio (PSNR):

The quality of the image can be indicated by Peak signal to noise ratio (PSNR). It is calculated from the mean square error of the original and denoised image. Mathematically, it can be calculated by using following formula:

$$PSNR = 10\log_{10}\left(\frac{MAX_I^2}{\sqrt{MSE}}\right) = 20\log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \quad (3)$$

Where MAX_I represents the maximum pixel value of image. When image pixels are expressed using 8 bit per sample. then MAX_I is 255 and MSE represent cumulative square error between denoised and original image [15].

3.4 Structure Similarity Index Measurement (SSIM):

Structure similarity index is represented as the average square difference between the estimated value and actual value. The resemblance between two images with same capture is measured by SSIM. If both images resembled with each other, then SSIM measurement index is equal to unity. SSIM measurement index evaluates on several windows of an image. It is evaluated as follows:

$$SSIM = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \qquad (4)$$

Where μ_x the average of x window, μ_y the average of y window, σ_x^2 the variance of x, σ_y^2 the variance of window y and σ_{xy} the co variance of x and y window [16].

3.5 Image Enhancement Factor (IEF):

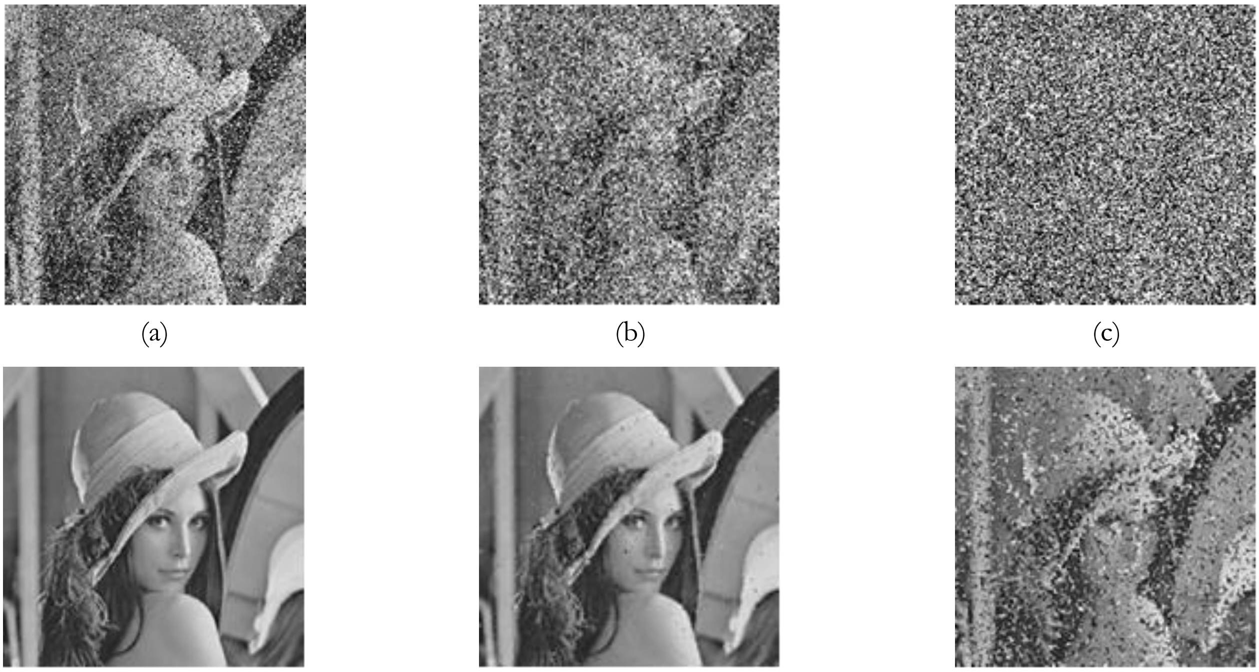
The improvement in the image quality is represented by Image enhancement factor. It is also used to highlight the image information. It can be calculated by using following formula:

$$IEF = \frac{\sum_i\sum_j\left[\eta(i,j) - \Upsilon(i,j)\right]^2}{\sum_i\sum_j\left[\hat{\Upsilon}(i,j) - \Upsilon(i,j)\right]^2} \qquad (5)$$

Where $\hat{\Upsilon}$ indicates the noise free image, Υ indicates the original test image and η represent the noisy image [16].

4 Results

The performance evaluation of the proposed algorithm is done by implementing the algorithm on standard test images such as Lena and Mandrill [17, 18], which are contaminated with SPN having 10% to 90% densities. The Lena and Mandrill image contaminated with SPN at different noise density levels i.e., 30%, 60% and 90% respectively are shown in figures 2 (a)-(c) and 4 (a)-(c) respectively. The noise from these images is removed with the proposed algorithm and the output images are shown in figures 2 (d)-(f) and 4 (d)-(f). The table 1 and 2 illustrate the quantitative performance of the proposed and MDBUTMF algorithm in terms of PSNR, IEF, MSE and SSIM for Lena and Mandrill image. This is well observed from the table 1, Lena image has low MSE and high PSNR, SSIM and IEF in comparison to the MDBUTMF algorithm. The quantitative analysis of different performance parameters for Lena image at different levels of noise density i.e., 10% to 90% are shown in figure 3 (a)-(d). A higher PSNR and low MSE in case of the proposed algorithm indicates the better image quality as compared to the MDBUTMF algorithm.



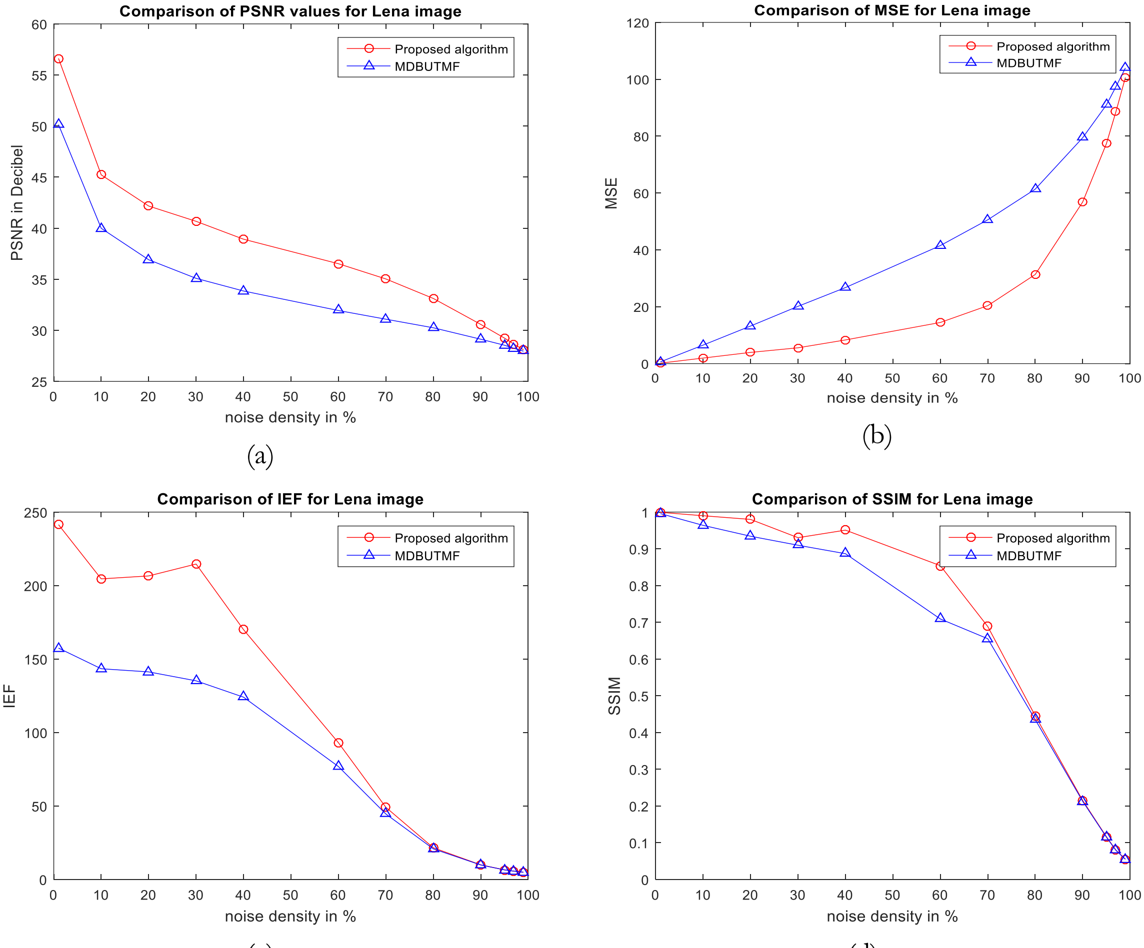
(a) (b) (c)

(d) (e) (f)

Fig.2. Lena image [17] corrupted with (a) 30% noise density (b) 60% noise density (c) 90% noise density and (d)-(f) denoised image with the proposed algorithm at 30%, 60% and 90% noise densities respectively

TABLE I. COMPARISON OF PSNR, MSE, IEF AND SSIM VALUE AT DIFFERENT LEVELS OF NOISE DENSITY FOR LENA IMAGE

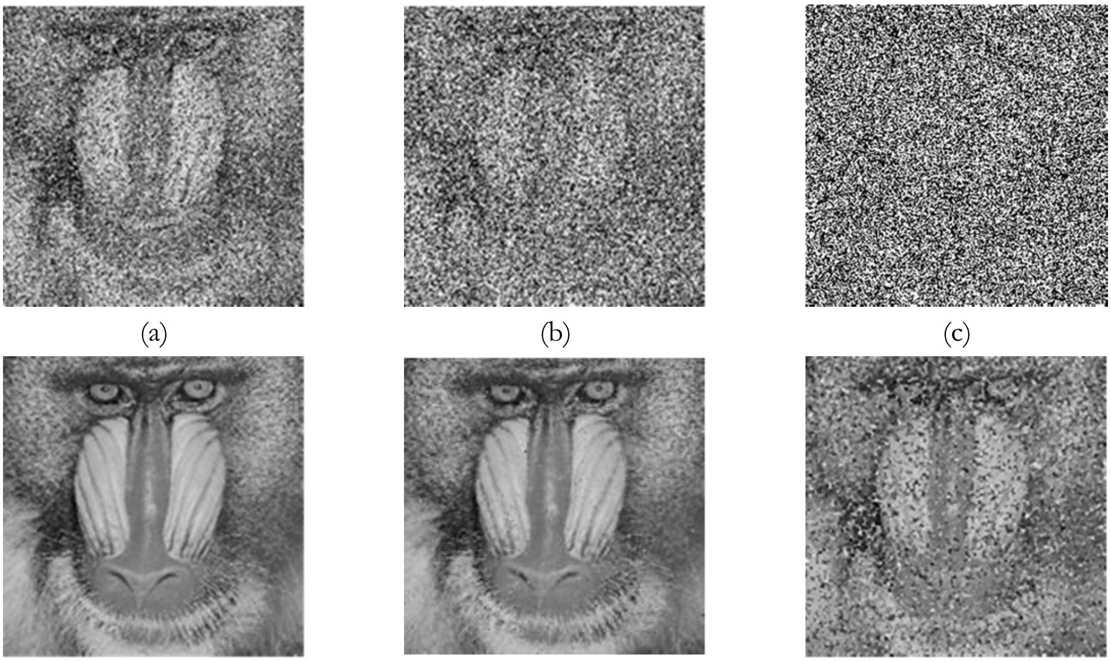
Lena	**PSNR**		**MSE**		**IEF**		**SSIM**	
Noise density	***MDBUTMF***	***Proposed***	***MDBUTMF***	***Proposed***	***MDBUTMF***	***Proposed***	***MDBUTMF***	***Proposed***
10%	39.99	45.22	6.51	1.95	143.37	204.54	0.9638	0.9900
20%	36.91	42.17	13.22	3.94	141.23	206.54	0.9342	0.9800
30%	35.09	40.23	20.14	6.15	135.15	194.44	0.9097	0.9675
40%	33.85	38.92	26.74	8.32	124.03	169.98	0.8867	0.9508
60%	31.94	36.52	41.51	14.47	76.82	93.02	0.7990	0.8541
70%	31.09	35.03	50.58	20.38	44.52	49.06	0.6552	0.6883
80%	30.25	33.12	61.35	31.64	20.79	21.52	0.4350	0.4455
90%	29.13	30.58	79.43	56.83	9.81	9.91	0.2127	0.2149



(a) (b)

(c) (d)

Fig.3. Comparison of performance parameters for Lena image at different levels of noise density



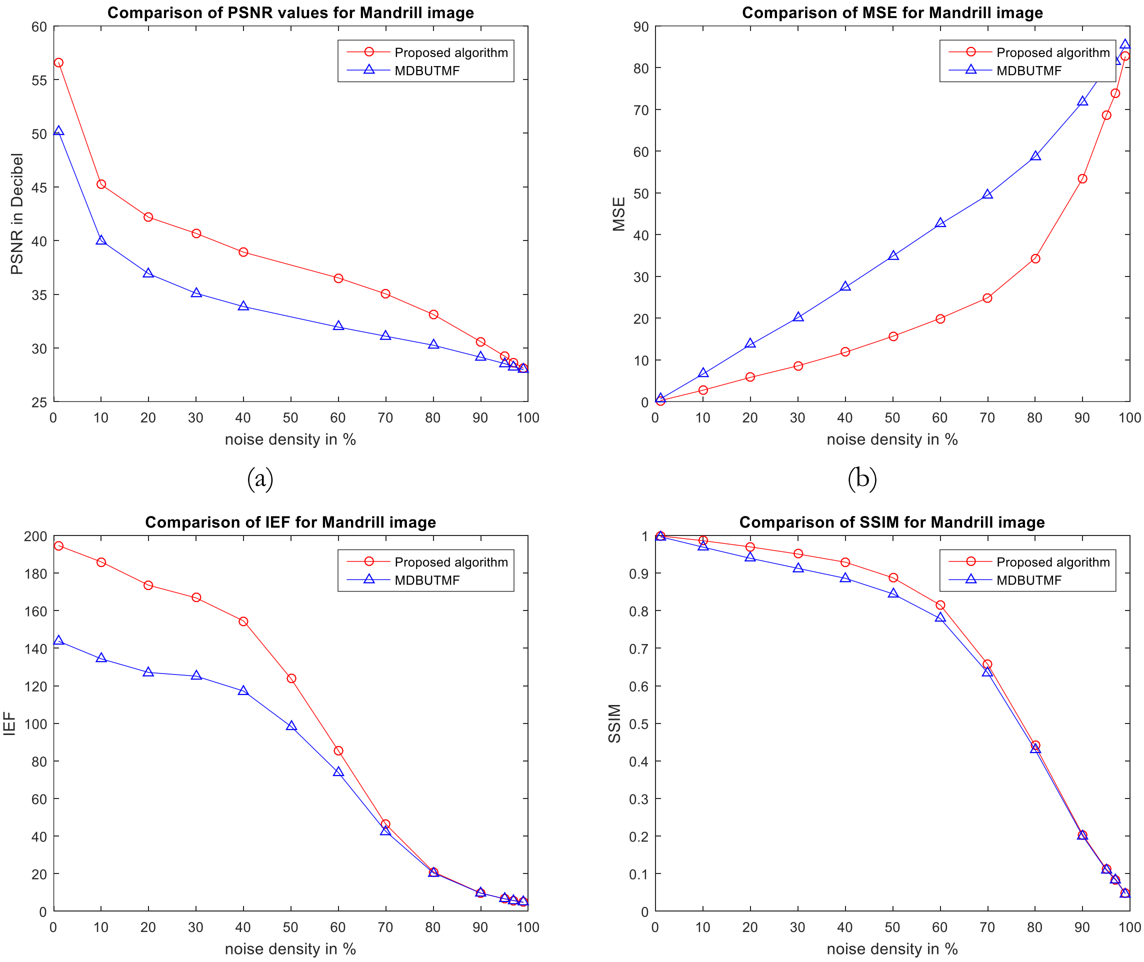
(a) (b) (c)

(d) (e) (f)

Fig. 4. Mandrill image [18] corrupted with (a) 30% noise density (b) 60% noise density (c) 90% noise density and (d)-(f) denoised image with the proposed algorithm at 30%, 60% and 90% noise densities respectively

TABLE II. COMPARISON OF PSNR, MSE, IEF AND SSIM AT DIFFERENT LEVELS OF NOISE DENSITY FOR MANDRILL IMAGE

Mandrill Image	**PSNR**		**MSE**		**IEF**		**SSIM**	
Noise density	***MDBUTMF***	***Proposed***	***MDBUTMF***	***Proposed***	***MDBUTMF***	***Proposed***	***MDBUTMF***	***Proposed***
10%	38.53	40.97	9.11	5.19	48.19	54.09	0.9617	0.9718
20%	35.32	37.69	19.09	11.06	46.50	52.88	0.9234	0.9423
30%	33.54	35.86	28.74	16.84	43.48	48.85	0.8801	0.9039
40%	32.33	34.62	38.01	22.41	43.78	48.34	0.8395	0.8660
60%	31.34	33.61	47.66	28.26	40.33	44.21	0.7865	0.8118
70%	30.47	32.63	58.25	35.48	34.83	37.43	0.7110	0.7329
80%	29.64	31.52	70.48	45.72	25.76	26.96	0.5851	0.5993
90%	29.01	30.52	81.56	57.59	16.91	17.27	0.4114	0.4167



(a) (b)

(c) (d)

Fig. 5. Comparison of performance parameters for Mandrill image at different levels of noise density

The performance evaluation of the proposed algorithm is also done for Mandrill image which is corrupted by low along with high density noise and quantitative analysis of Mandrill image is shown in table 2. The quantitative analysis of different performance parameters for Mandrill image are shown in figure 5 (a)-(d) at different levels of noise density i.e., 10% to 90%. At low noise density i.e., 30%, When the test images i.e., Lena and Mandrill are denoised by MDBUTMF algorithm, the value of IEF is 135.15 and 43.78 respectively. For the proposed algorithm, the value of IEF is 194.44 and 48.85 respectively. At medium noise density i.e., 60%, the test images produced the value of IEF is 93.02 and 37.43 respectively for the proposed algorithm, which is greater than the IEF value in case of MDBUTMF algorithm. The value of IEF is 9.81 and 16.91 respectively, when noise removal is done by MDBUTMF algorithm at noise density of 90%. But the value of IEF is 9.91 and 17.27 respectively, when noise removal is done by proposed algorithm. The noise free and high-quality images are produced by the proposed algorithm in comparison to MDBUTMF algorithm. From the tables 1 and 2, it is clear that after the denoising operation, the SPN is reduced from both images i.e., Lena and Mandrill. A Winsorized mean based algorithm have produced the denoised image. In both images, the PSNR value is high, it means both images have better image quality after denoising process and less information is lost. The proposed algorithm produces the less value of MSE for both test images, as compared to the MDBUTMF. The value of SSIM is low, when image is denoised by using MDBUTMF algorithm, while it is high, when image is denoised by the proposed algorithm. The greater SSIM value shows that the denoised images clearly resembles with their original images respectively after denoising process.

The proposed algorithm has been shown better performance on all the quantitative performance parameters named as PSNR, MSE, IEF and SSIM. To reduce SPN, the proposed algorithm performs better because it produces good quality of image and highlights important information.

5 Conclusion

In this proposed algorithm, Winsorized mean operation is used for the elimination of the SPN from noisy images. The performance of the proposed algorithm has been evaluated for the Gray scale images i.e., Lena and Mandrill. This algorithm gives better performance in comparison to MDBUTMF algorithm in terms of PSNR, MSE, IEF and SSIM. It is more effective for noise removal from the digital images contaminated with SPN at various levels of noise densities varies from 10% to 90%. This algorithm produces better image quality and less mean square error as compared to the MDBUTMF. As seen in this work, the proposed algorithm has been implemented successfully over the MDBUTMF algorithm to eliminate the SPN at various levels of noise density. The image denoising has very good scope in different fields like commercial, medical and in radar field. By keeping in view, the numerous applications in image processing field, improvement in the image filtering algorithm is the demand of today's scenario. In the future perspective, this technique is improved by using artificial intelligence or genetic algorithms.

References

[1] V. Rani, "A brief study of various noise model and filtering techniques,"Journal of global research in computer science, vol. 4, no. 4, pp. 166–171, 2013.

[2] R. Jain, R. Kasturi, and B. G. Schunck,Machine vision. McGraw-hillNew York, 1995, vol. 5.

[3] J. Azzeh, B. Zahran, and Z. Alqadi, "Salt and pepper noise: Effectsand removal,"JOIV: International Journal on Informatics Visualization,vol. 2, no. 4, pp. 252–256, 2018.

[4] N. Goel and P. Aggarwal, "Enhanced modified decision-based un-symmetric trimmed adaptive neighborhood winsorized mean filter forremoving 1–99% levels of salt-and-pepper noise,"Iranian Journal ofScience and Technology, Transactions of Electrical Engineering, vol. 43,no. 3, pp. 459–468, 2019.

[5] N. Goel, H. Kaur, and J. Saxena, "Modified decision based unsymmetricadaptive neighborhood trimmed mean filter for removal of very highdensity salt and pepper noise,"Multimedia Tools and Applications,vol. 79, no. 27, pp. 19 739–19 768, 2020.

[6] Z. Wang and D. Zhang, “Progressive switching median filter for theremoval of impulse noise from highly corrupted images,”IEEE Transac-tions on Circuits and Systems II: Analog and Digital Signal Processing,vol. 46, no. 1, pp. 78–80, 1999.

[7] R. H. Chan, C.-W. Ho, and M. Nikolova, “Salt-and-pepper noise removalby median-type noise detectors and detail-preserving regularization,”IEEE Transactions on image processing, vol. 14, no. 10, pp. 1479–1485,2005.

[8] K. K. V. Toh and N. A. M. Isa, “Noise adaptive fuzzy switching me-dian filter for salt-and-pepper noise reduction,”IEEE signal processingletters, vol. 17, no. 3, pp. 281–284, 2009.

[9] S. Esakkirajan, T. Veerakumar, A. N. Subramanyam, and C. PremChand,“Removal of high density salt and pepper noise through modified deci-sion based unsymmetric trimmed median filter,”IEEE Signal processingletters, vol. 18, no. 5, pp. 287–290, 2011.

[10] H. M. Ali, “A new method to remove salt & pepper noise in magneticresonance images,” in2016 11th International Conference on ComputerEngineering & Systems (ICCES). IEEE, 2016, pp. 155–160.

[11] V. Ramachandran and V. Kishorebabu, “A tri-state filter for the removalof salt and pepper noise in mammogram images,”Journal of medicalsystems, vol. 43, no. 2, p. 40, 2019.

[12] Y. Qian, “Removing of salt-and-pepper noise in images based onadaptive median filtering and improved threshold function,” in2019Chinese Control And Decision Conference (CCDC).IEEE, 2019, pp.1431–1436.

[13] U. Erkan, L. G ̈okrem, and S. Engino ̆glu, “Adaptive right median filterfor salt-and-pepper noise removal,”Uluslararası M ̈uhendislik Aras ̧tırmave Gelis ̧tirme Dergisi, vol. 11, no. 2, pp. 542–550, 2019.

[14] R. C. Gonzalez, R. E. Woodset al., “Digital image processing,” 2002.

[15] U. Erkan, L. G ̈okrem, and S. Engino ̆glu, “Different applied median filterin salt and pepper noise,”Computers & Electrical Engineering, vol. 70,pp. 789–798, 2018.

[16] M. Wirth, M. Fraschini, M. Masek, and M. Bruynooghe, “Performanceevaluation in image processing,” 2006.

[17] M. Wakin. Standard test images @ONLINE. [Online]. Available:https://www.ece.rice.edu/ wakin/images/

[18] Dataset of512×512Grayscale Test Images. [Online]. Available:https://ccia.ugr.es/cvg/CG/base.htm