Removal of High Density Salt and Pepper Noise Through Modified Decision Based Unsymmetric Trimmed Median Filter

S. Esakkirajan, T. Veerakumar, Adabala N. Subramanyam, and C. H. PremChand

***Abstract*—A modified decision based unsymmetrical trimmed median filter algorithm for the restoration of gray scale, and color images that are highly corrupted by salt and pepper noise is proposed in this paper. The proposed algorithm replaces the noisy pixel by trimmed median value when other pixel values, 0's and 255's are present in the selected window and when all the pixel values are 0's and 255's then the noise pixel is replaced by mean value of all the elements present in the selected window. This proposed algorithm shows better results than the Standard Median Filter (MF), Decision Based Algorithm (DBA), Modified Decision Based Algorithm (MDBA), and Progressive Switched Median Filter (PSMF). The proposed algorithm is tested against different grayscale and color images and it gives better Peak Signal-to-Noise Ratio (PSNR) and Image Enhancement Factor (IEF).**

***Index Terms*—Median filter, salt and pepper noise, unsymmetrical trimmed median filter.**

I. Introduction

IMPULSE noise in images is present due to bit errors in transmission or introduced during the signal acquisition stage. There are two types of impulse noise, they are salt and pepper noise and random valued noise. Salt and pepper noise can corrupt the images where the corrupted pixel takes either maximum or minimum gray level. Several nonlinear filters have been proposed for restoration of images contaminated by salt and pepper noise. Among these standard median filter has been established as reliable method to remove the salt and pepper noise without damaging the edge details. However, the major drawback of standard Median Filter (MF) is that the filter is effective only at low noise densities [1]. When the noise level is over 50% the edge details of the original image will not be preserved by standard median filter. Adaptive Median Filter (AMF) [2] perform well at low noise densities. But at high noise densities the window size has to be increased which may lead to blurring the image. In switching median filter [3], [4] the decision is based on a pre-defined threshold value. The major drawback of this method is that defining a robust decision is difficult. Also these filters will not take into account the local features as a result of which details and edges may not be recovered satisfactorily, especially when the noise level is high.

To overcome the above drawback, Decision Based Algorithm (DBA) is proposed [5]. In this, image is denoised by using a 3 × 3 window. If the processing pixel value is 0 or 255 it is processed or else it is left unchanged. At high noise density the median value will be 0 or 255 which is noisy. In such case, neighboring pixel is used for replacement. This repeated replacement of neighboring pixel produces streaking effect [6]. In order to avoid this drawback, Decision Based Unsymmetric Trimmed Median Filter (DBUTMF) is proposed [7]. At high noise densities, if the selected window contains all 0's or 255's or both then, trimmed median value cannot be obtained. So this algorithm does not give better results at very high noise density that is at 80% to 90%. The proposed Modified Decision Based Unsymmetric Trimmed Median Filter (MDBUTMF) algorithm removes this drawback at high noise density and gives better Peak Signal-to-Noise Ratio (PSNR) and Image Enhancement Factor (IEF) values than the existing algorithm.

The rest of the paper is structured as follows. A brief introduction of unsymmertric trimmed median filter is given in Section II. Section III describes about the proposed algorithm and different cases of proposed algorithm. The detailed description of the proposed algorithm with an example is presented in Section IV. Simulation results with different images are presented in Section V. Finally conclusions are drawn in Section VI.

II. Unsymmetric Trimmed Median Filter

The idea behind a trimmed filter is to reject the noisy pixel from the selected 3 × 3 window. Alpha Trimmed Mean Filtering (ATMF) is a symmetrical filter where the trimming is symmetric at either end. In this procedure, even the uncorrupted pixels are also trimmed. This leads to loss of image details and blurring of the image. In order to overcome this drawback, an Unsymmetric Trimmed Median Filter (UTMF) is proposed. In this UTMF, the selected 3 × 3 window elements are arranged in either increasing or decreasing order. Then the pixel values 0's and 255's in the image (i.e., the pixel values responsible for the salt and pepper noise) are removed from the image. Then the median value of the remaining pixels is taken. This median value is used

Manuscript received December 07, 2010; revised February 05, 2011; accepted February 26, 2011. Date of publication March 03, 2011; date of current version March 10, 2011. The associate editor coordinating the review of this manuscript and approving it for publication was Prof. Dimitrios Androutsos.

S. Esakkirajan, A. N. Subramanyam and C. H. PremChand are with the Department of Instrumentation and Control Systems Engineering, PSG College of Technology, Coimbatore, India (e-mail: rajanesakki@yahoo.com; adabala.subbu@gmail.com; chennupati408@gmail.com).

T. Veerakumar is with the Department of Electronics and Communication Engineering, PSG College of Technology, Coimbatore, India (e-mail: tveerakumar@yahoo.co.in).

Color versions of one or more of the figures in this paper are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/LSP.2011.2122333

to replace the noisy pixel. This filter is called trimmed median filter because the pixel values 0's and 255's are removed from the selected window. This procedure removes noise in better way than the ATMF.

III. Proposed Algorithm

The proposed Modified Decision Based Unsymmetric Trimmed Median Filter (MDBUTMF) algorithm processes the corrupted images by first detecting the impulse noise. The processing pixel is checked whether it is noisy or noisy free. That is, if the processing pixel lies between maximum and minimum gray level values then it is noise free pixel, it is left unchanged. If the processing pixel takes the maximum or minimum gray level then it is noisy pixel which is processed by MDBUTMF. The steps of the MDBUTMF are elucidated as follows.

ALGORITHM

Step 1: Select 2-D window of size 3×3. Assume that the pixel being processed is P_{ij}.

Step 2: If $0 < P_{ij} < 255$ then P_{ij} is an uncorrupted pixel and its value is left unchanged. This is illustrated in Case iii) of Section IV.

Step 3: If $P_{ij} = 0$ or $P_{ij} = 255$ then P_{ij} is a corrupted pixel then two cases are possible as given in Case i) and ii).

Case i): If the selected window contain all the elements as 0's and 255's. Then replace P_{ij} with the mean of the element of window.

Case ii): If the selected window contains not all elements as 0's and 255's. Then eliminate 255's and 0's and find the median value of the remaining elements. Replace P_{ij} with the median value.

Step 4: Repeat steps 1 to 3 until all the pixels in the entire image are processed.

The pictorial representation of each case of the proposed algorithm is shown in Fig. 1.

The detailed description of each case of the flow chart shown in Fig. 1 is illustrated through an example in Section IV.

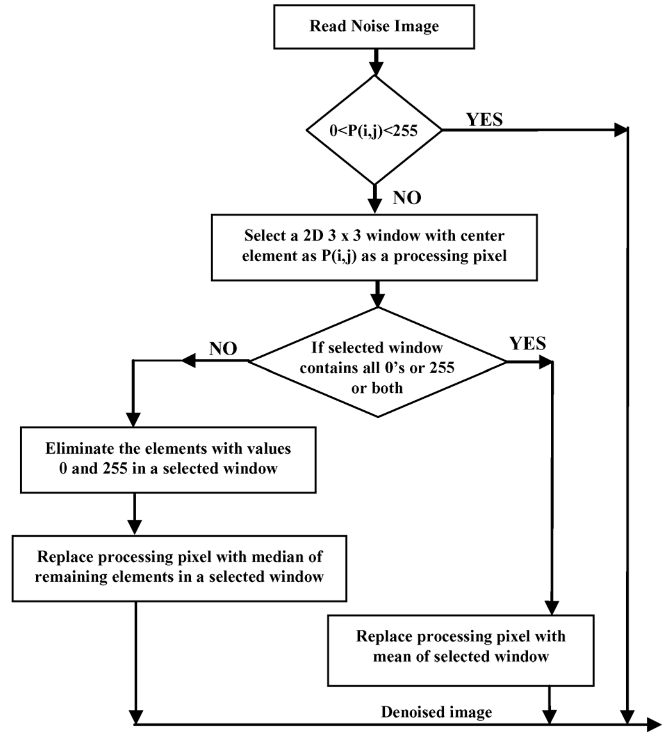


Fig. 1. Flow chart of MDBUTMF.

IV. Illustration of MDBUTMF Algorithm

Each and every pixel of the image is checked for the presence of salt and pepper noise. Different cases are illustrated in this Section. If the processing pixel is noisy and all other pixel values are either 0's or 255's is illustrated in Case i). If the processing pixel is noisy pixel that is 0 or 255 is illustrated in Case ii). If the processing pixel is not noisy pixel and its value lies between 0 and 255 is illustrated in Case iii).

Case i): If the selected window contains salt/pepper noise as processing pixel (i.e., 255/0 pixel value) and neighboring pixel values contains all pixels that adds salt and pepper noise to the image:

$$\begin{bmatrix} 0 & 255 & 0 \\ 0 & \langle 255 \rangle & 255 \\ 255 & 0 & 255 \end{bmatrix}$$

where "255" is processing pixel, i.e., (P_{ij}).

Since all the elements surrounding (P_{ij}) are 0's and 255's. If one takes the median value it will be either 0 or 255 which is again noisy. To solve this problem, the mean of the selected window is found and the processing pixel is replaced by the mean value. Here the mean value is 170. Replace the processing pixel by 170.

Case ii): If the selected window contains salt or pepper noise as processing pixel (i.e., 255/0 pixel value) and neighboring pixel values contains some pixels that adds salt (i.e., 255 pixel value) and pepper noise to the image:

$$\begin{bmatrix} 78 & 90 & 0 \\ 120 & \langle 0 \rangle & 255 \\ 97 & 255 & 73 \end{bmatrix}$$

where "0" is processing pixel, i.e., (P_{ij}).

Now eliminate the salt and pepper noise from the selected window. That is, elimination of 0's and 255's. The 1-D array of the above matrix is [78 90 0 120 0 255 97 255 73]. After elimination of 0's and 255's the pixel values in the selected window will be [78 90 120 97 73]. Here the median value is 90. Hence replace the processing pixel P_{ij} by 90.

Case iii): If the selected window contains a noise free pixel as a processing pixel, it does not require further processing. For example, if the processing pixel is 90 then it is noise free pixel:

$$\begin{bmatrix} 43 & 67 & 70 \\ 55 & \langle 90 \rangle & 79 \\ 85 & 81 & 66 \end{bmatrix}$$

where "90" is processing pixel, i.e., (P_{ij}).

Since "90" is a noise free pixel it does not require further processing.

V. Simulation Results

The performance of the proposed algorithm is tested with different grayscale and colour images. The noise density (intensity)

TABLE I
COMPARISON OF PSNR VALUES OF DIFFERENT ALGORITHMS FOR LENA IMAGE AT DIFFERENT NOISE DENSITIES

Noise in %	PSNR in dB					
	MF	AMF	PSMF	DBA	MDBA	MDBUTMF
10	26.34	28.43	30.22	36.4	36.94	37.91
20	25.66	27.40	28.39	32.9	32.69	34.78
30	21.86	26.11	25.52	30.15	30.41	32.29
40	18.21	24.40	22.49	28.49	28.49	30.32
50	15.04	23.36	19.13	26.41	26.52	28.18
60	11.08	20.60	12.10	24.83	24.41	26.43
70	9.93	15.25	9.84	22.64	22.47	24.30
80	8.68	10.31	8.02	20.32	20.44	21.70
90	6.65	7.93	6.57	17.14	17.56	18.40

TABLE II
COMPARISON OF IEF VALUES OF DIFFERENT ALGORITHMS FOR LENA IMAGE AT DIFFERENT NOISE DENSITIES

Noise Density in %	IEF					
	MF	AMF	PSMF	DBA	MDBA	MDBUTMF
10	10.36	23.20	171.63	390.67	422.58	648.98
20	28.17	37.76	207.31	358.91	377.42	568.43
30	30.02	42.57	190.92	322.89	324.74	590.83
40	23.12	40.98	143.49	268.49	275.24	424.18
50	11.72	36.11	62.98	208.77	217.18	345.13
60	6.73	25.21	6.61	190.70	175.89	261.66
70	3.31	7.89	3.28	128.58	129.65	171.69
80	2.00	2.91	1.98	67.42	73.24	101.72
90	1.37	1.31	1.37	33.85	33.33	34.23

is varied from 10% to 90%. Denoising performances are quantitatively measured by the PSNR and IEF as defined in (1) and (3), respectively:

$$PSNR\ in\ dB = 10\log_{10}\left(\frac{255^2}{MSE}\right) \tag{1}$$

$$MSE = \frac{\sum_i \sum_j \left(Y(i,j) - \hat{Y}(i,j)\right)^2}{M \times N} \tag{2}$$

$$IEF = \frac{\sum_i \sum_j (\eta(i,j) - Y(i,j))^2}{\sum_i \sum_j \left(\hat{Y}(i,j) - Y(i,j)\right)^2} \tag{3}$$

where MSE stands for mean square error, IEF stands for image enhancement factor, $M \times N$ is size of the image, Y represents the original image, $\hat{Y}$ denotes the denoised image, η represents the noisy image.

The PSNR and IEF values of the proposed algorithm are compared against the existing algorithms by varying the noise density from 10% to 90% and are shown in Table I and Table II. From the Tables I and II, it is observed that the performance of the proposed algorithm (MDBUTMF) is better than the existing algorithms at both low and high noise densities. A plot of PSNR and IEF against noise densities for Lena image is shown in Fig. 2.

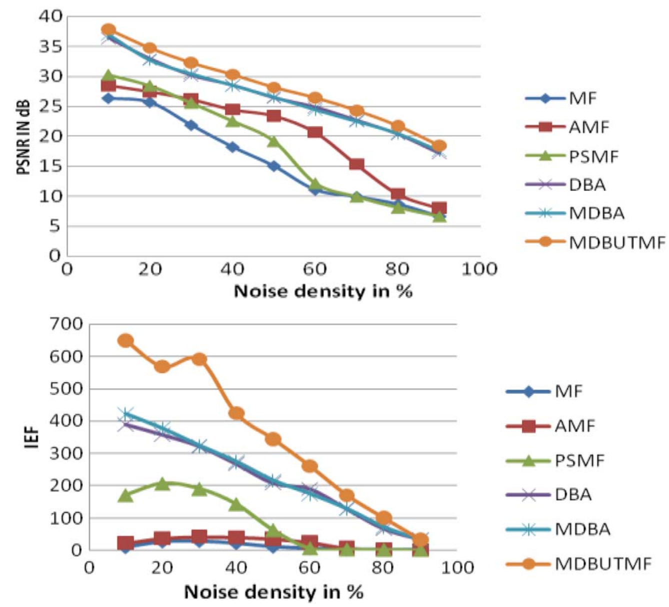


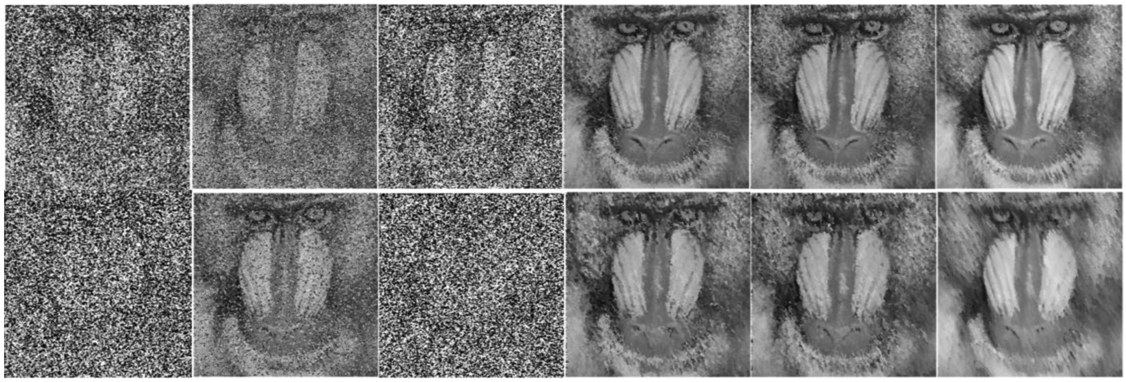
Fig. 2. Comparison graph of PSNR and IEF at different noise densities for Lena image.

TABLE III
COMPARISON OF PSNR VALUES OF DIFFERENT TEST IMAGES AT NOISE DENSITY OF 70%

Test images	PSNR in dB					
	MF	AMF	PSMF	DBA	MDBA	MDBUTMF
Cameraman	9.46	13.93	9.47	20.84	19.97	22.52
Lena	9.93	15.25	9.84	22.64	22.47	24.30
Baboon	10.11	14.86	10.05	22.35	20.54	23.80

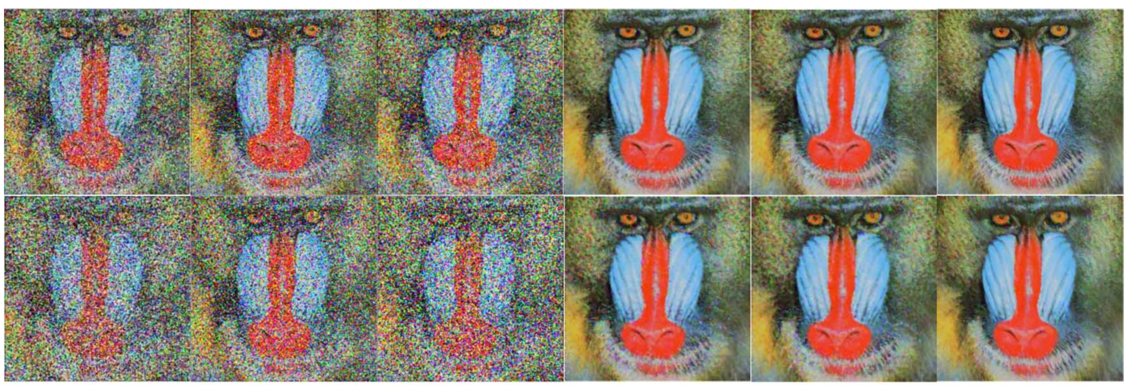
The qualitative analysis of the proposed algorithm against the existing algorithms at different noise densities for Baboon image is shown in Fig. 3. In this figure, the first column represents the processed image using MF at 80% and 90% noise densities. Subsequent columns represent the processed images for AMF, PSMF, DBA, MDBA and MDBUTMF. The proposed algorithm is tested against images namely Cameraman, Baboon and Lena. The images are corrupted by 70% "Salt and Pepper" noise. The PSNR values of these images using different algorithms are given in Table III. From the table, it is clear that the MDBUTMF gives better PSNR values irrespective of the nature of the input image.

The MDBUTMF is also used to process the color images that are corrupted by salt and pepper noise. The color image taken into account is Baboon. In Fig. 4, the first column represents the processed image using MF at 80% and 90% noise densities. Subsequent columns represent the processed images for PSMF, DBA, MDBA and MDBUTMF. From the figure, it is possible to observe that the quality of the restored image using proposed algorithm is better than the quality of the restored image using existing algorithms.



(a) (b) (c) (d) (e) (f)

Fig. 3. Results of different algorithms for Baboon image. (a) Output of MF. (b) Output of AMF. (c) Output of PSMF. (d) Output of DBA. (e) Output of MDBA. (f) Output of MDBUTMF. Row 1 and Row 2 show processed results of various algorithms for image corrupted by 80% and 90% noise densities, respectively.



(a) (b) (c) (d) (e) (f)

Fig. 4. Results of different algorithms for color Baboon image. (a) Output of MF. (b) Output of AMF. (c) Output of PSMF. (d) Output of DBA. (e) Output of MDBA. (f) Output of MDBUTMF. Rows 1 and 2 show processed results of various algorithms for color image corrupted by 70% and 80% noise densities, respectively.

VI. Conclusion

In this letter, a new algorithm (MDBUTMF) is proposed which gives better performance in comparison with MF, AMF and other existing noise removal algorithms in terms of PSNR and IEF. The performance of the algorithm has been tested at low, medium and high noise densities on both gray-scale and color images. Even at high noise density levels the MDBUTMF gives better results in comparison with other existing algorithms. Both visual and quantitative results are demonstrated. The proposed algorithm is effective for salt and pepper noise removal in images at high noise densities.

References

[1] J. Astola and P. Kuosmaneen, *Fundamentals of Nonlinear Digital Filtering*. Boca Raton, FL: CRC, 1997.

[2] 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.

[3] 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.

[4] 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.

[5] K. S. Srinivasan and D. Ebenezer, "A new fast and efficient decision based algorithm for removal of high density impulse noise," *IEEE Signal Process. Lett.*, vol. 14, no. 3, pp. 189–192, Mar. 2007.

[6] 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.

[7] 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.