International Journal of Electronics Signals and Systems

Volume 3 | Issue 3 Article 3

January 2014

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AN FPGA IMPLEMENTATION OF MODIFIED DECISION BASED UNSYMMETRICAL TRIMMED MEDIAN FILTER FOR THE REMOVAL OF SALT AND PEPPER NOISE IN DIGITAL IMAGES

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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. Images are often corrupted by impulse noise during acquisition and transmission; thus, an efficient noise suppression technique is required before subsequent image processing operations. Median filter (MF) is widely used in noise removal methods due to its denoising capability and computational efficiency. However, it is effective only for low noise densities. Extensive experimental results demonstrate that our method can obtain better performances in terms of both subjective and objective evaluations than denoising techniques. Especially, the proposed method can preserve edges very well while removing salt and pepper noise. Modified Decision Based Algorithm (MDBA), and Progressive Switched Median Filter (PSMF) shows better results at low and medium noise densities. At high noise densities, their performance is poor. A new algorithm to remove high-density salt and pepper noise using modified Decision Based Unsymmetric Trimmed Median Filter (DBUTMF) is proposed. The proposed algorithm replaces the noisy pixel by trimmed median. Since our algorithm is algorithmically simple, it is very suitable to be applied to many real-time applications and higher noise densities. 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. 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).

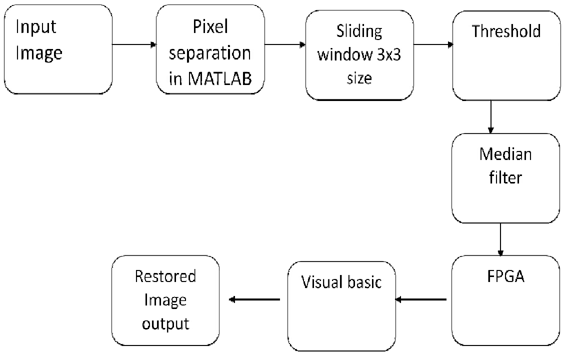
Index Terms-- *Median filter, salt and pepper noise, unsymmetrical trimmed median filter*

I. INTRODUCTION

Images are often corrupted by salt and pepper noise due to error in transmission of digital images. 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. The objective of noise removal is to eliminate the salt and pepper noise with minimum deformation caused to the image. The new algorithm has lower computation time when compared to other standard algorithms. Results of the algorithm is compared with various existing algorithms and it is proved that the new method has better visual appearance and quantitative measures at higher noise densities In this standard median filter will be effective only at low noise densities. The standard median (SM) filter is a simple nonlinear smoother that can suppress noise while retaining sharp sustained changes (edges) in signal values. It is particularly effective in reducing impulsive-type noise. In An adaptive median filter (AMF). The nonlinear mean filter cannot remove such positive and negative impulses simultaneously many switched median filters were proposed to detect and correct only the corrupted pixel. But at high noise densities the window size has to be increased which may lead to blurring the image. In switching median filter the major drawback is defining that a robust decision is difficult. Especially when the noise level is high.

To overcome the above drawback, Decision Based Algorithm (DBA) is proposed. In this, image is denoised by using a 3*3 window. Decision-based median filtering algorithm in which local image structures are used to estimate the original values of the noisy pixels.

In such case, neigh- boring pixel is used for replacement. This repeated replacement of neighboring pixel produces streaking effect. In order to avoid this drawback, Decision Based Unsymmetric Trimmed Median Filter (DBUTMF) is proposed. In case if the selected window contains all the values as 0s and 255s means then trimmed median value cannot be obtained, so this is also not an effective one. Due to these the algorithm does not give better results at very high noise density that is at 80% to 90.Due to this the proposed Modified Decision Based Un- symmetric Trimmed Median Filter (MDBUTMF) algorithm re- moves 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 above block diagram mainly consists of taking at 256/256 image and adding noise to it and converting a noise image into a matrix and then dividing a entire matrix into 3×3 siding window, after dividing that window the sliding window is applied with our MDBUTMF to eliminate the noise pixel. This is represented as 0 and 255 after the eliminating noise pixel by images convert into text format. The text format is converted into bit stream. which is compatible to a FPGA kit is used by Spartan 3E which consist of micro blaze processor which is 32 bit processor consisting of RISC(Reduced Instruction Set) architecture. The output of FPGA kit is visualized in visual basic where the noise less image is retrieved.

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. A fixed impulse noise detector using unsymmetrical trimmed variants for the removal of high density salt and pepper noise for corrupted gray scale image is proposed. The proposed algorithm utilizes an impulse detector based on the threshold value obtained by unsymmetrical trimmed variants to check, if the pixel is noisy or not. In this median value is used 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. For high noise densities it does not preserve the image information due to the elimination of outlier values. Unsymmetrical trimmed filter replaced the symmetrical counterpart. The trimming was not uniform as in the previous case; So for the removal of salt and pepper noise at high noise densities with edge preservation (MDBUTMF) Modified decision based unsymmetrical trimmed median filter is proposed.

III. PROPOSED ALGORITHM

The proposed Modified Decision Based Unsymmetric Trimmed Median Filter (MDBUTMF) and Salt and Pepper Noise Reduction Method avoid the above drawback even at high noise densities. The proposed method provides better Peak Signal-to-Noise Ratio (PSNR) than the existing methods. The proposed filter (MDBUTMF) replaces the noisy pixel by trimmed median value when some of the elements with values 0s and 255s are present in the selected window. If all the pixel values in the selected window are 0s and 255s means then the noisy pixel is replaced by mean value of all the elements present in that selected window.

The throughput of MDBUTMF is a noise removal image. 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

Step 1:

Select 2-D window of size 3×3. Assume that the pixel being processed is Pij.

Step 2:

If 0 < Pij < 255 then Pij is an uncorrupted pixel and its value is left unchanged. This is illustrated in Case iii) of Section IV.

Step 3:

If Pij=0 or Pij=255 then Pij is a corrupted pixel then two cases are possible as given in Case i) and ii).
Case i): If the selected window contains all the elements as 0's and 255's. Then replace Pij 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 Pij 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.

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:

$$\begin{pmatrix} 0 & 255 & 0 \\ 0 & <255> & 0 \\ 255 & 0 & 255 \end{pmatrix}$$

Where "255" is processing pixel, i.e., (Pij).

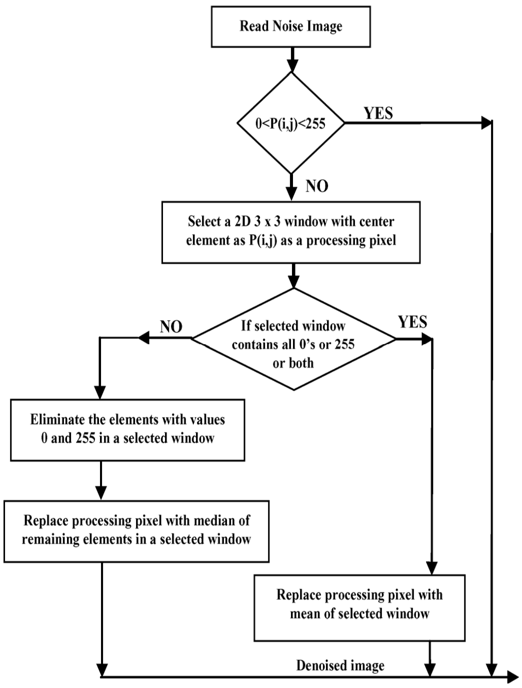


Fig 1. Flow chart of MDBUTMF.

Since all the elements surrounding (Pij) 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:

$$\begin{pmatrix} 78 & 90 & 0 \\ 120 & <0> & 255 \\ 97 & 255 & 73 \end{pmatrix}$$

Where "0" is processing pixel, i.e.,(Pij) . 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 Pij 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:

$$\begin{pmatrix} 43 & 67 & 70 \\ 55 & <90> & 79 \\ 85 & 81 & 66 \end{pmatrix}$$

Where "90" is processing pixel, i.e.,(Pij).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 gray scale and color images. The noise density (intensity) is varied from 10% to 90%. For implementing our algorithm, we have used MATLAB 7 on a 2.80 GHz Pentium R processor with 1 GB of RAM. The performances of the proposed algorithm are quantitatively measured by the Peak Signal to Noise Ratio (PSNR) and Image Enhancement Factor (IEF as defined in (1) and (3), respectively:

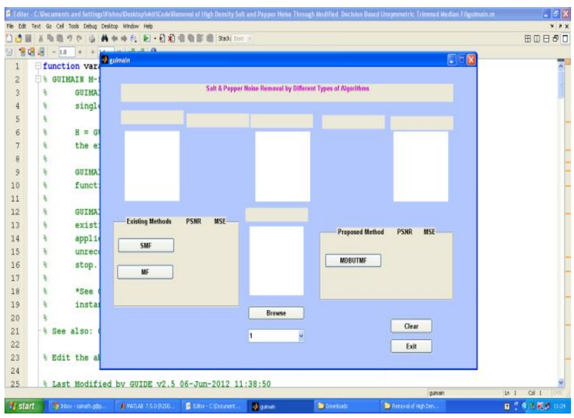


Table I

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

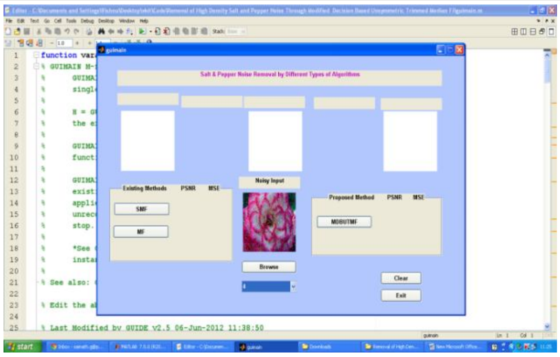
Noise Density	Median Filter	Switching Median Filter	MDBUTMF
1%	42.105	36.579	51.4779
2%	40.1528	36.2234	46.53315
3% 4% 5% MSE	39.2938 38.1312 37.4737	35.7106 35.2816 34.8293	46.1503 43.8922 41.9527
1% 2% 3% 4% 5%	4.0042 6.2776 7.6506 9.06 11.6336	14.2945 15.5146 17.4589 19.2718 21.3872	0.4626 1.4437 1.5779 2.65378 4.14771

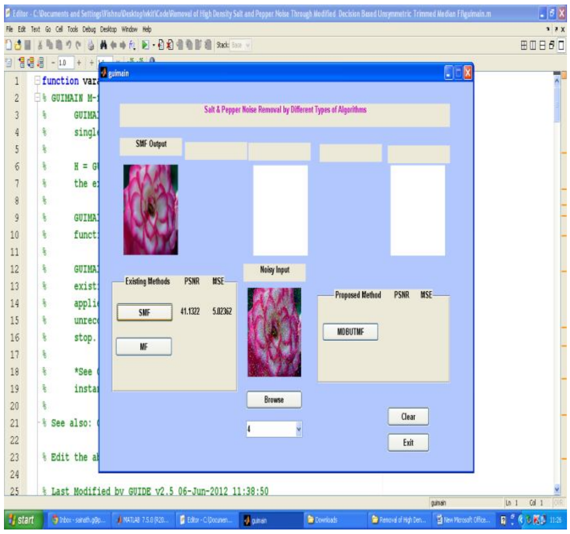
$$\text{PSNR in dB} = 10log10\left(\frac{255^2}{MSE}\right)$$

$$MSE = \sum_i \sum_j (Y(i,j) - \dot{Y}(i.j))^2 / M \times N$$

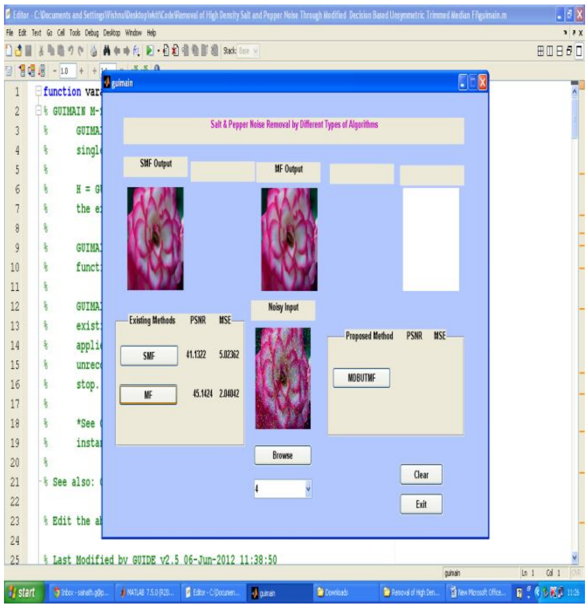
$$IEF = \frac{\sum_i \sum_j (\eta(i,j) - y_{(i,j)})^2}{\sum_i \sum_j (\hat{y}(i,j) - y_{(i,j)})^2}$$

Where MSE stands for mean square error, IEF stands for image enhancement factor, is size of the image, Y represents the original image, denotes the denoised image, and 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.



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.

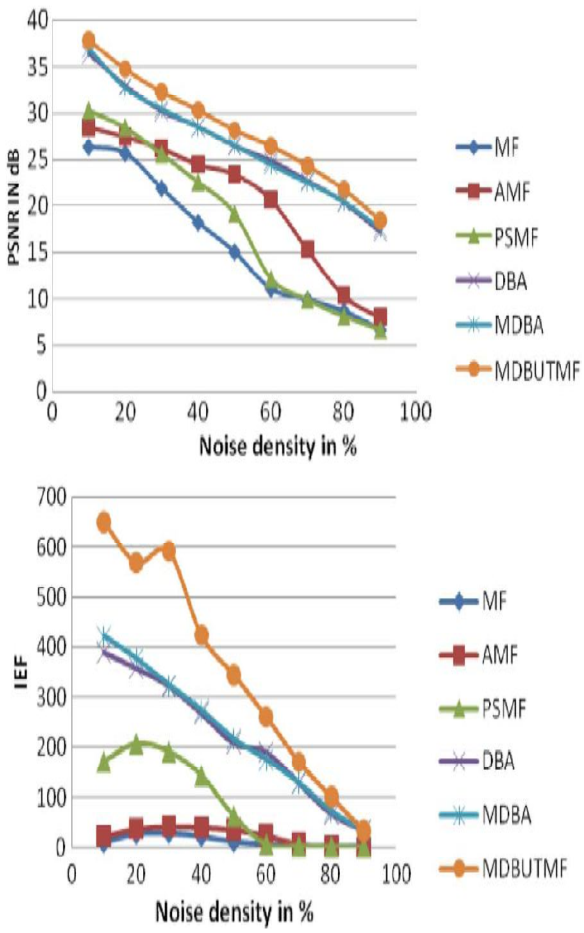
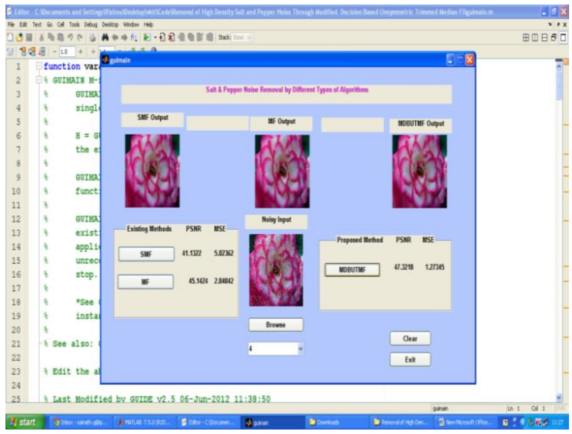


Fig 2. Comparison graph of PSNR and IEF at different noise densities for Lena image.

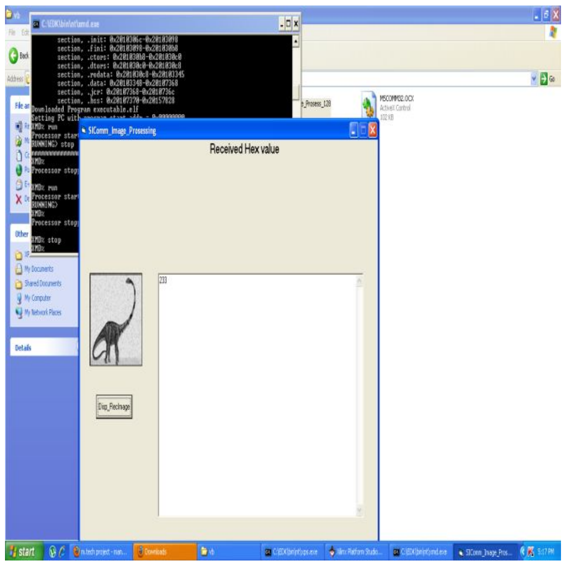
TABLE III
Comparison of PSNR Values of Different Test Images At Noise Density of 70%

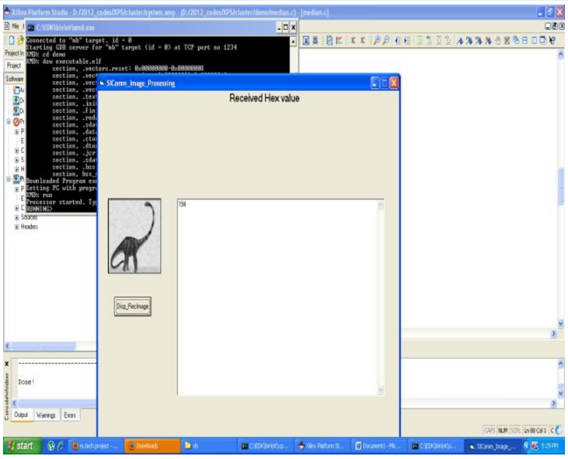
Test images	PSNR in dB					
	MF	AMF	PSMF	DBA	MDBA	MDBUTMF
Cameraman	9.46	13.93	9.47	20.84	19.97	22.52
Lena	9.93	15.25	9.84	22.64	22.47	24.30
Baboon	10.11	14.86	10.05	22.35	20.54	23.80

The 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. it can be observed that the performance of the proposed algorithm is better than the existing algorithms at high noise densities. Not all the elements in a selected 3 x 3 window is 255s or zeros at medium noise density. Hence, the proposed algorithm is almost same PSNR value against MDBUTMF at medium noise density. 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.





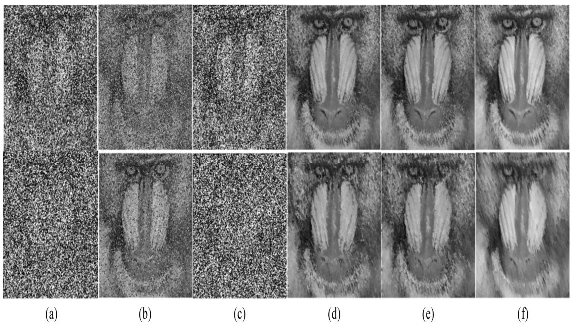


Fig. 3. Results of different algorithms for Baboon image. (a) Output of MF. (b) Output of AMF. (c) Output of PSMF. (d) Output of DBA. (e) Output of MDBA.(f) Output of MDBUTMF. Row 1 and Row 2 show processed results of various algorithms for image corrupted by 80% and 90% noise densities, respectively.

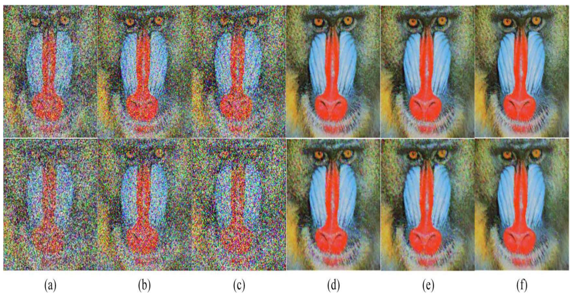


Fig. 4. Results of different algorithms for color Baboon image. (a) Output of MF. (b) Output of AMF. (c) Output of PSMF. (d) Output of DBA. (e) Output of MDBA. (f) Output of MDBUTMF. Rows 1 and 2 show processed results of various algorithms for color image corrupted by 70% and 80% noise densities, respectively.

VI. CONCLUSION

A new algorithm (MDBUTMF) is proposed which gives better performance in comparison with the existing non-linear filter like Standard Median Filter (SMF), Adaptive Median Filter (AMF), Decision Based Algorithm (DBA) Modified Decision Based Algorithm (MDBA), and Progressive Switched Median Filter (PSMF) algorithms. These existing impulse noise removal algorithms are 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 .Both visual and quantitative results are demonstrated and it is also applied to many real-time applications The proposed algorithm is effective for salt and pepper noise removal in images at high noise densities.

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