A Novel Algorithm for Removing Impulse Noise From Highly Corrupted Image

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Abstract

Various switching-based median filter have been proposed in the literature for restoration of extremely corrupted images by impulsive noise (Salt and pepper noise). Progressive switching median filter (PSMF) and Boundary discriminative noise detection (BDND) median filter are some of these. It is well known that standard median filter(SMF) is not suitable for removing impulse noise from highly corrupted images. The poor efficiency of this filter is due to the fact that it is not able to discriminate the noisy pixel from noiseless pixel. The proposed method uses noise detection stage and then adaptive window shaped filtering stage for the restoration of images contaminated by impulse noise. The performance of the proposed method is demonstrated through computer simulation in comparison with the PSMF method and standard median filter.

Keywords: *Impulse Noise, Median Filter, Max-Min Filters, Morphological, Neighborhood.*

Introduction

Impulse noise is the main source of image degradation which occur during acquiring the image or transmitting through air. Hence restoring the corrupted image by suppressing the impulse noise is very crucial task in image processing field. Several non linear filters have been proposed for the restoration of images corrupted with impulse noise. Median filters and its variants are some of the early proposed method for removing the impulse noise[1-7].Later on different adaptive median filter[8-10] have also been proposed to restore the image corrupted with high density impulse noise. There advantage is that they can suppress the impulsive noise without edge blurring. In conventional median filter, the median operation is performed to each pixel unconditionally without considering whether a pixel is corrupted or uncorrupted which would inevitably alter the pixel values and remove signal detail of those uncorrupted pixel. Therefore a noise detection process to discriminate the uncorrupted pixel from the corrupted ones prior to applying non linear filtering is highly desirable. Therefore later methods[11] are usually of two stages, with impulse detector as first stage where corrupted pixel are detected and located where as impulse filter as second stage at which the corrupted pixel only are filtered and thus avoiding the modification of uncorrupted pixel. The scanned images, images stored in the memories, and transmitted images contain noise in the form of dark dots and white dots. This disturbance is caused due to the scanning process, memory fault, and error in transmission [12-13] The main drawback of standard median filter is that it is effective only for low noise densities and as the noise densities increases it starts exhibiting poor performance. Therefore a novel filter design is required for image processing which not only suppress the noise considerably but also preserve the high frequency content of image[14]

Objective of the Paper

For removing high density impulse noise, various algorithms have been proposed in the literature. It is well known that linear filtering techniques are not good for removing impulse noise because their performance is poor in removing high frequency noise and it also blurred the edges. There is a need to develop a filter which are not only effective in removing impulse noise but also preserve the edges or high frequency area of image. Therefore the use of nonlinear filtering techniques came into existence and a class of widely used non-linear digital filters is median filters and morphological filters. Both the filters are good to remove impulse noise as well as preserving the edges under low noise density condition. The median filter is the best known order statistic filter which work by replacing the central pixel value with the value obtained by computing the median of neighboring pixels. Median filter is well known to remove the impulse (Salt and pepper) noise while the max filter can remove the pepper noise efficiently, similarly min filter can easily remove the salt noise.

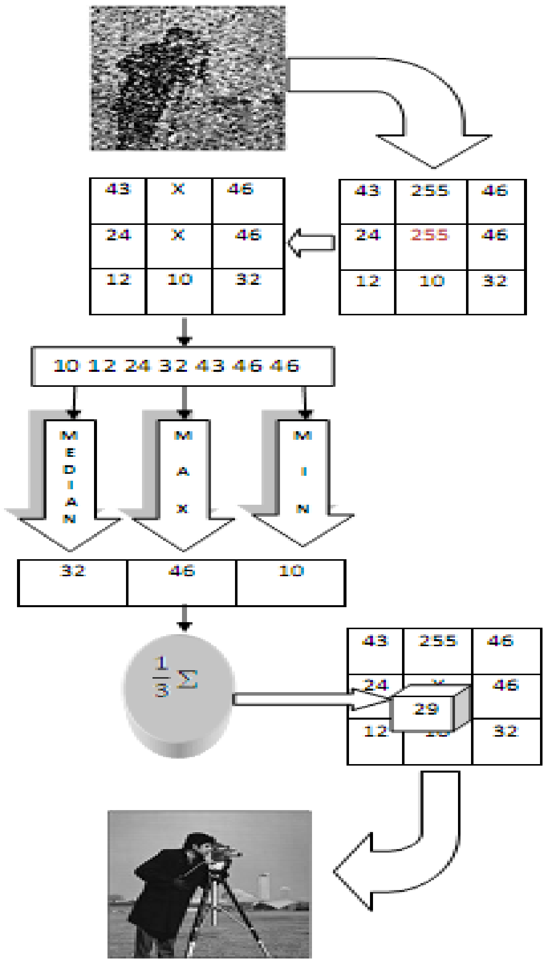
Impulse Noise Detection

For the proposed filter to work efficiently, an impulse noise detection stage prior to applying filtering technique[15,16] is much needed. impulse noise detection scheme detect whether the considered pixel is corrupted or uncorrupted pixel. Any pixel whose values changes drastically to 255(salt) or 0(pepper)or any other value which is much higher than its neighboring pixel values are considered as noisy pixels. Only the noisy pixel undergoes filtering operation and replaced with the new value, leaving the uncorrupted pixel intact.

The Proposed Filter

The pixel value of the image corrupted with impulse noise differs significantly from that of the neighborhood pixel. This type of noise can be removed in spatial domain. In spatial domain, median filter, max filter, min filter are non linear filter which are used to remove impulse noise. if we use these non linear filter in a modified way then we can achieve better impulsive noise suppression. Considering these entire thing, this hybrid filter is designed.

Block diagram of proposed filter is shown in Figure1, First a 3X3 window is run across the noisy image from left to right and top to bottom. The detection of corrupted or uncorrupted pixel is governed by checking whether the central pixel value of the selected window lies between the maximum and minimum values within the window. This is because the pixel corrupted by impulse noise can take maximum and minimum values in the range (0,255).if the value of considered pixel lie within this range then this is an uncorrupted pixel and left unchanged. But if the value of considered pixel doesn't lie within this range then it is a corrupted pixel and need filtering operation. This corrupted pixel is replaced with a new value obtained by applying three non linear operation, median operation,max operation,min operation in a modified shaped window. Since the Median filter reduces both salt and pepper noise while max and min filter remove pepper noise and salt noise respectively, therefore by applying all the three operation and then taking the average of all the three output gives a very effective noise removing algorithm. Modification of window shape as per the noise free pixel present in the selected window is described in section 5.



X - Pixel values which are noisy and hence not considered in processing

***Fig. 1:** Block diagram of proposed filter*

The Max, Median and Min filters are defined as

$$\hat{f}(x,y) = \max_{(s,t)\in S_{xy}} \{g(s,t)\}$$

$$\hat{f}(x,y) = \underset{(s,t)\in S_{xy}}{median}\{g(s,t)\}$$

$$\hat{f}(x,y) = \min_{(s,t)\in S_{xy}} \{g(s,t)\}$$

Where

$\hat{f}(x,y)$ = Restored Image

S_{xy} = Set of coordinate in rectangular window of size m x n, centered at point(x, y)

Modification Of Window Shape

In this proposed method the size and shape of window is very crucial.The size of window is chosen as odd dimension. It can be started from 3 x 3 and goes up to up to 9×9 dimension.Since through extensive experiment it is observed that 3×3 window gives better result than other dimension therefore, the size of the window is chosen as 3×3 size. The size of the window is fixed throughout the filter process. But it is a shape of the window that changes as per the number of uncorrupted pixel within the selected window.

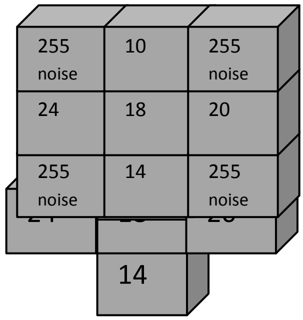


Figure 2 *Modification of Window shape*

As shown in Figure2 only the shape of the window is modified as per the uncorrupted pixel obtained within 3×3 window and therefore this shape is dependent upon the noise free pixels present in the neighborhood of the processing pixel. Depending on number of noise free pixel in a 3x3 window, a 3x3 window can take any shape out of possible 2^9 different possible shape.

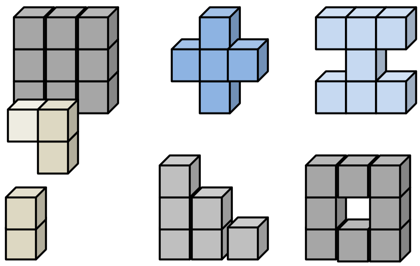


Figure 3: *Some possible shape of 3 X 3 Windows*

Steps of Algorithm

Step 1. Input the noisy image.
Step 2. Apply padding to avoid boundary problem .
Step 3. Run a 3x3 window .
Step 4. Detect the Impulse noise pixel.
Step 5. Modify the Shape of the window on the basis of neighboring corrupted pixel.

Step 6. If all the neighborhood pixels within the window are same (either 0 or 255), then retain the current pixel value intact.
Step 7. if central pixel is not corrupted then retain the pixel value intact.
Step 8. if the central pixel is noisy then processed it with the proposed filter.
Step 9. Replace the noisy pixel with the processed value.
Step 10. Repeat step 3 to step 9 untill the whole image is scanned.

Performance Parameter

In order to measure the efficiency of proposed filter, it is compared with Standard median filter (SMF) and Progressive switching median filter(PSMF) by computing the Mean Squared Error (MSE), Peak Signal-to-Noise Ratio (PSNR) and CPU execution time .

$$\text{MSE (no units)} = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\|g(x,y) - f(x,y)\|^2$$

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

Experimental Results

The proposed algorithm works on the basis of fixed size(3x3) but the adaptive shape window. The Cameraman image is taken as a test image and it is been corrupted to various percentages of impulse noise. Since the main objective of this algorithm is to suppress the noise and noise suppression can be identified by the parameter MSE. The proposed algorithm is tested for cameraman image corrupted with various noise percentages. Proposed algorithm is compared with the standard method which is given in IP tool box of Matlab and with PSMF method [17]. All the algorithm was implemented in MATLAB® Version 6.5 with system configuration of 3.0 GHz processor speed and 512 MB RAM.

The results were taken with the parameters like PSNR, MSE, and CPU Time which are shown in Table 1, Table 2 , Table 3 and Table 4. From Figure 3, Figure 4, and Figure 5, it is observed that the proposed algorithm outperforms the standard method and PSMF method algorithm.

Table 1: *PSNR comparison of Proposed, method and PSMF method*

Impulse Noise (in percentage)	PSNR for Cameraman Image (256 X 256)		
	PSNR for Proposed method	PSNR for standard method	PSNR for PSMF method
10	28.94	25.72	26.88
20	27.6	23.61	25.16
30	26.5	20.62	23.18
40	25.3	17.39	20.95
50	23.77	14.28	18.62
60	21.27	11.48	15.28
70	17.34	9.32	9.3
80	13.04	7.55	7.64
90	8.99	6.15	6.25

Table 2: *MSE Vs Impulse noise for cameraman Image*

Impulse Noise (in percentage)	MSE for Cameraman Image (256 X 256)	
	Noisy Image	Filtered Image
10	1984	81.64
20	4118.5	111.67
30	6167.8	143.16
40	8140.1	188.63
50	10055	268.65
60	12174	477.59
70	14217	1180.3
80	16042	3176.1
90	18184	8063.6

Table 3: *MSE comparison of Proposed, Standard and PSMF method*

Impulse Noise (in percentage)	MSE for Cameraman Image (256 X 256)		
	MSE for Proposed method	MSE for standard method	MSE for PSMF method
10	81.64	171.6	131.3
20	111.67	278.6	194.98
30	143.16	553.6	307.2
40	188.63	1167.3	514.13
50	268.65	2386.7	878.85
60	477.59	4548.8	1896.5
70	1180.3	7475.8	7507.2
80	3176.1	11245	11002
90	8063.6	15527	15172

Table 4: *CPU time comparison of Proposed, Standard method and PSMF method*

Impulse Noise (in percentage)	CPU time for Cameraman Image (256 X 256)		
	CPU time for Proposed method (in second)	CPU time for Standard method (in second)	CPU time for PSMF method (in second)
10	0.15	0.17	0.71
20	0.07	0.09	0.76
30	0.07	0.09	0.78
40	0.08	0.09	0.89
50	0.08	0.09	0.93
60	0.08	0.09	1.04
70	0.09	0.09	1.04
80	0.09	0.12	1,05
90	0.10	0.15	1.04

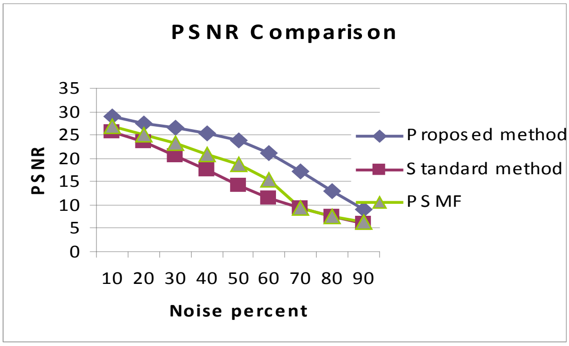


Figure 3: *PSNR Comparison for proposed, standard and PSMF method*

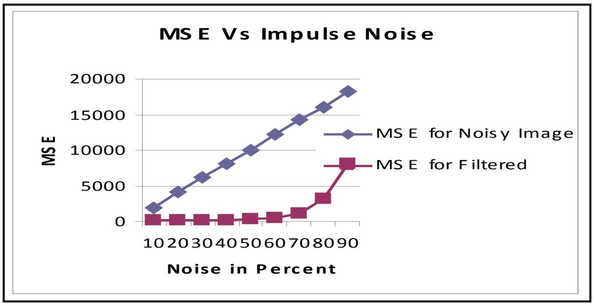


Figure 4: *MSE Vs Impulse Noise for cameraman (256 X 256) image*

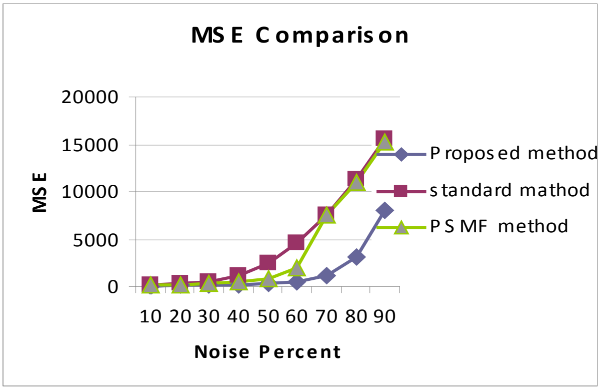
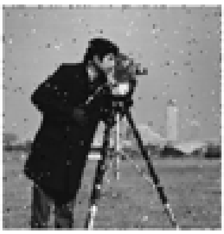
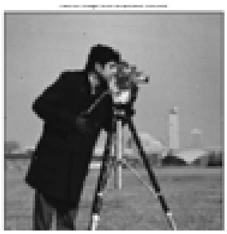


Figure 5: *MSE Vs Impulse Noise for cameraman (256 X 256) image*

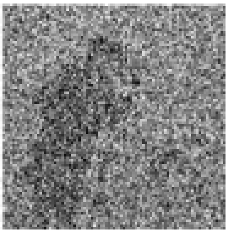
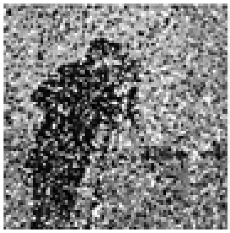
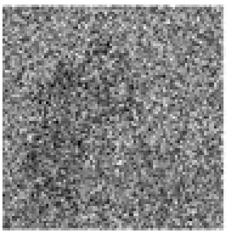
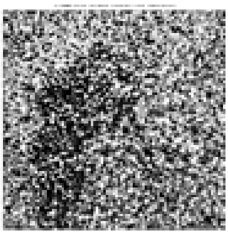
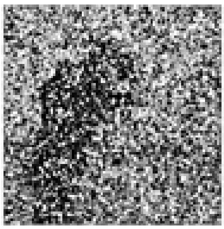
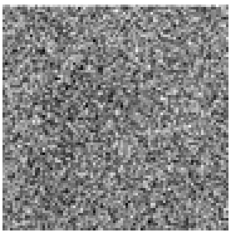
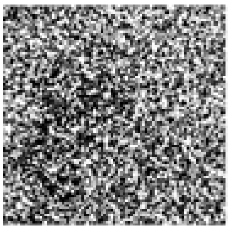
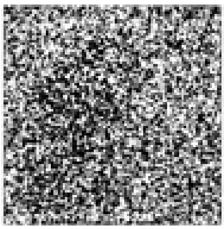
Proposed Filter Output For Various Noise Densities

Cameraman image is impregnated with impulse noise percentages of 10 to 90. The visual results obtained using the three algorithms are summarized in the Table 5. From these tables we can observe that the performance of proposed method for removing impulse noise is better than the Standard median method and PSMF method.

Table 5: *Visual Result of all the three method with different Impulse noise densities*

Original Image with Impulse Noise	Standard Median Method	PSMF Method	Proposed Method
Noise=10% 			
Noise=20% 			
Noise=30% 			
Noise=40% 			
Noise=50%			

Original Image	Standard Median Method	PSMF Method	Proposed Method
Noise=60% 			
Noise=70% 			
Noise=80% 			
Noise=90% 			

Conclusion

These are the results which are obtained by applying three different algorithms to the image corrupted by different impulse noise density. By these results it is evident that the restored images obtained after processing the noisy images using proposed algorithm is free from impulse noise to the maximum extent.

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