Removal of Salt and Pepper Noise through Modified PSM Filter

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ABSTRACT

In this paper, a new Modified Progressive Switching Median filtering algorithm is presented for the removal of salt and pepper noise from corrupted images. It sets a limit on the number of good pixel used in determine median and mean value and substitute to impulse pixel with the summation of its mean value and median value which is divide by 2.02, after that pass through Gaussian filter. This scheme can remove salt and pepper noise with a noise level as high as 90%. Experimental result shows that the proposed filter is superior over the traditional filter in maintaining higher PSNR (Peak Signal to Noise Ratio).

Keywords

Gaussian filter, Impulse Noise, IPSM, MATLAB, PSMF, PSNR

1. INTRODUCTION

Impulse Noise caused by malfunctioning pixel in camera sensors, faulty memory location in hardware or transmission in a noisy channel [1]. Impulse Noise also known as salt and pepper noise (respectively, random valued noise) and sparsely corrupts pixel to two intensity levels. The corrupted pixel is either set to a max value or zero value.

Applying of traditional median filter for removal of impulse noise gives relatively good response but analysis of different sources dedicated to median filtering shows, that the traditional manner filter has set of disadvantages.

- Signal weakening (object counters and edge are blurred in image).

- Affecting to non corrupted (good) image pixel.

Different modifications of median filter have been proposed to eliminate these disadvantages of median filtering. Now the Switching scheme attracts a high interest of many researches. This approach proves its efficiency for salt and pepper noise removal from digital image. The switching scheme approaches means splitting of noise removal procedure in to two main stages [2] [8].

a) Preliminarily detection of noise corrupted pixel of digital image in a progressively iterative manner.

b) Filtering of noise Impulse which has been detected in first stage, also in a progressively iterative manner.

Modified PSM filter with the algorithm of Impulse detector remains the same as proposed by Wang and Zhou [3]. However , unlike PSM in noise filtering , the proposed work set the minimum number of noise free pixels that need to be used in finding the median and mean value [4] and substitute the noisy pixel with summation of median value and mean value which is divided by 2.02 and after that pass through Gaussian filter.

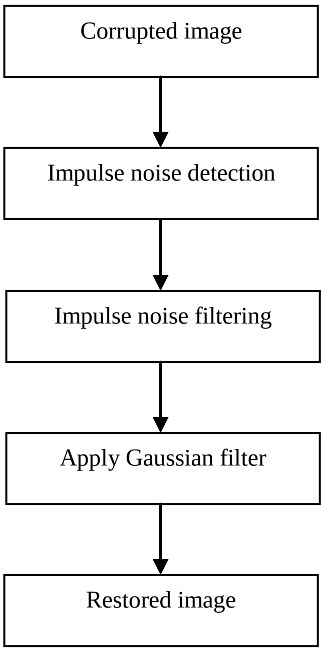


Figure 1: Flow chart of proposed method to reconstruct the Restored image

2. MODIFIED PSM FILTER

2.1 IMPULSE NOISE DETECTION

Using this detection algorithm, the median filter can avoid the replacement of noise-free pixel.

Steps:

[1] Three parameters have to be determined in impulse detection, which are the window size of median filter (W_D), number of iterations (N_D), and threshold value (T_D).

[2] For the best restoration: $N_D = 3$ [3] [5].

[3] Initially $N_I = 0$, Where N_I is the number of noisy pixels that have been detected. For each pixel $x_{(i,j)}$, a median filter with 3×3 window is used to find its corresponding median value.

$$m_{(i,j)} = Med\{\, x_{(i,j)} \mid i-1 \le i \le i+1, j-1 \le j \le j+1\} \qquad (1)$$

[4] The absolute difference between $m_{(i,j)}$ and $x_{(i,j)}$ is used to Determine whether the corresponding $x_{(i,j)}$ is an impulse or not. If it is an impulse, N_I is increased by 1, as given by:

$$N_I = N_I + 1\ if\ |m_{(i,j)} - x_{(i,j)}| \ge T_I \qquad (2)$$

Where the threshold [1] T_I is predefined as 40 [3].

[5] An estimation of the noise ratio, R_E is given by:

$$R_E = N_I / N \qquad (3)$$

Where N is the number of pixels in the image. This ratio is determined after all the pixels in the image have been filtered once.

[6] After that, W_D and T_D are determined based on R_E,

$$W_D = 3\ if\ R_E \le T_R \qquad (4)$$

Or,

$$W_D = 5\ if\ R_E > T_R \qquad (5)$$

$$T_D = a + b.R_E \qquad (6)$$

In order to find W_D and T_D, a rough estimation on noise ratio is determined by implementing Sun and Neuvo's switch I scheme [2]. According to Wang and Zhang's PSM [3], where T_R, a and b are defined as 25%, 65 and -50 respectively.

During impulse detection, two image sequences are produced. One is sequence of gray scale image $\{\{x^{(0)}_{(i,j)}\}\}$, $\{\{x^{(1)}_{(i,j)}\}\}$,…$\{\{x^{(n)}_{(i,j)}\}\}$. The other sequence is binary flag image sequence $\{\{f^{(0)}_{(i,j)}\}\}$,$\{\{f^{(1)}_{(i,j)}\}\}$,…$\{\{f^{(n)}_{(i,j)}\}\}$.

Where,

$\{\{x^{(0)}_{(i,j)}\}\}$, represent the pixel value at position (i, j) in the noisy image to be detected.

$\{\{x^{(n)}_{(i,j)}\}\}$, represents the pixel value at position (i, j) in the image after n-th iteration.

$\{\{f^{(n)}_{(i,j)}\}\} = 0$, represent good pixel at position (i, j).

$\{\{f^{(n)}_{(i,j)}\}\} = 1$, represent impulse pixel at position (i, j).

In the n-th iteration (n = 1, 2, ...), the median value $m^{(n-1))}_{(i,j)}$ for each pixel $x^{(n-1)}_{(i,j)}$ is determined with a median filter with W_D×W_D window size
.

$$m^{(n-1)}_{(i,j)} = Med\{\, x^{(n-1)}_{(i,j)} \} \qquad (7)$$

Where,

$$i = i - (W_D - 1)/2 \le i \le i + (W_D - 1)/2$$

$$j = j - (W_D - 1)/2 \le j \le j + (W_D - 1)/2$$

when the absolute difference of $x^{(n-1)}_{(i,j)}$ and $m^{(n-1)}_{(i,j)}$ exceeds the threshold T_D, the flag $f^{(n-1)}_{(i,j)}$ is set to '1'. Consequently, the processing pixel $x^{(n-1)}_{(i,j)}$ is substituted with the median pixel. Otherwise, both the flag and the processing pixel remain unchanged. This procedure is iterated for N_D times.

$$f^{(n)}_{(i,j)} = \{\, f^{(n-1)}_{(i,j)} \},\ if\ |x_{(i,j)} - m_{(i,j)}| < T_D \qquad (8)$$

Else ,

$$f^{(n)}_{(i,j)} = 1 \qquad (9)$$

And,

$$x^{(n)}_{(i,j)} = m^{(n-1)}_{(i,j)}\ \ if\ f^{(n)}_{(i,j)} \ne f^{(n-1)}_{(i,j)} \qquad (10)$$

Or,

$$x^{(n)}_{(i,j)} = x^{(n-1)}_{(i,j)}\ \ if\ f^{(n)}_{(i,j)} = f^{(n-1)}_{(i,j)} \qquad (11)$$

after N_D iteration , then two output images— $x^{(N_D)}_{(i,j)}$ and $f^{(N_D)}_{(i,j)}$ are obtained, but only $f^{(N_D)}_{(i,j)}$ is useful for our noise filtering algorithm [6].

2.2 Impulse noise filtering:

The noise filtering procedure also produces two image sequences, one is a sequence of gray scale image, $\{\{y^{(0)}_{(i,j)}\}\}$, $\{\{y^{(1)}_{(i,j)}\}\}$,…$\{\{y^{(n)}_{(i,j)}\}\}$. The other sequence is binary flag image sequence $\{\{g^{(0)}_{(i,j)}\}\}$,$\{\{g^{(1)}_{(i,j)}\}\}$,…$\{\{g^{(n)}_{(i,j)}\}\}$.

Where,

$\{\{y^{(0)}_{(i,j)}\}\}$, represent the pixel value at position (i, j) in the noisy image to be detected.

$\{\{y^{(n)}_{(i,j)}\}\}$, represents the pixel value at position (i, j) in the image after n-th iteration.

$\{\{g^{(n)}_{(i,j)}\}\} = 0$, represent good pixel at position (i, j).

$\{\{g^{(n)}_{(i,j)}\}\} = 1$, represent impulse pixel which should be filtered.

Initially, $$g^{(0)}_{(i,j)} = f^{(N_D)}_{(i,j)} \qquad (12)$$

In the n-th iteration (n = 1,2, ...), the medium value $m^{(n-1)}_{(i,j)}$ for each pixel $y^{(n-1)}_{(i,j)}$ is determined with a median filter [9] with W_F×W_F window size. According to Wang and Zhang's PSM [3], $W_F = 3$ is chosen for the best restoration. As in Wang and Zhang's PSM [3], the [10] median value $m^{(n-1)}_{(i,j)}$ is determined from only good pixels with $g^{(n-1)}_{(i,j)} = 0$ in the W_F×W_F window.

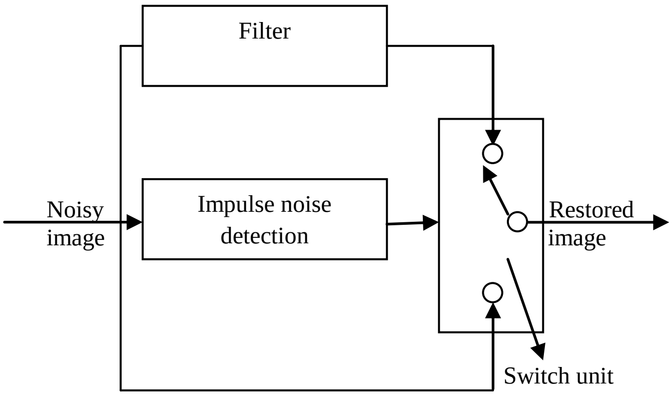


Figure 2: Switch scheme based framework

Proposed method:

Steps:

[1] In present work,,we set a limit to the number of good pixels that can be used to find the median value $m^{(n-1)}_{(i,j)}$ and mean value $\overline{m}^{(n-1)}_{(i,j)}$.

$$m^{(n-1)}_{(i,j)} = Med\{\, y^{(n-1)}_{(i,j)} \,\} \qquad (13)$$

$$\overline{m}^{(n-1)}_{(i,j)} = Mean\{\, y^{(n-1)}_{(i,j)}\} \qquad (14)$$

Where,

$$i = i - (W_F - 1)/2 \le i \le i + (W_F - 1)/2$$

$$j = j - (W_F - 1)/2 \le j \le j + (W_F - 1)/2$$

[2] Summation of equation (13) and equation (14) which is divided by 2.02 .After that, we substitute the impulse pixel with equation (15) as given below,

$$s^{(n-1)}_{(i,j)} = (\, m^{(n-1)}_{(i,j)} + \overline{m}^{(n-1)}_{(i,j)}\,) \,/\, 2.02 \qquad (15)$$

[3] $y^{(n)}_{(i,j)}$ is modified only when the pixel at (i, j) is an impulse and M is at least equal to G_P, where M denotes the total Number of good pixels with $g^{(n-1)}_{(i,j)} = 0$ in the $W_F \times W_F$ Window, and G_P denotes the number of good pixels that should be used in finding the corresponding median and Mean values, for best restoration Gp =5 [5].

$y^{(n)}_{(i,j)}$ defined as:

$$y^{(n)}_{(i,j)} = s^{(n-1)}_{(i,j)} \;\; if\; g^{(n-1)}_{(i,j)} = 1;\; M \ge G_P \qquad (16)$$

Else,

$$y^{(n)}_{(i,j)} = y^{(n-1)}_{(i,j)} \qquad (17)$$

[4] When either one of the criteria is not met, the noisy pixel is left unprocessed until further iterations to restore the noisy pixel. [11] The impulse pixel is considered as good pixel in the Subsequent iterations once it is modified as given by:

$$g^{(n)}_{(i,j)} = g^{(n-1)}_{(i,j)} \;\; if \;\; y^{(n)}_{(i,j)} = y^{(n-1)}_{(i,j)} \qquad (18)$$

Or,

$$g^{(n)}_{(i,j)} = 0 \;\; if \;\; y^{(n)}_{(i,j)} = s^{(n-1)}_{(i,j)} \qquad (19)$$

[5] Noise filtering procedure terminates after the N_F iteration With $\sum g^{(N_F)}_{(i,j)} = 0$, Only then, we obtained the restored output image $\{y^{(N_F)}_{(i,j)}\}$ and then pass through Gaussian filter [6].

3. RESULT AND DISCUSSION

Performances of algorithms are measured by calculating PNSR (Peak signal to Noise Ratio),

$$PSNR = 10\, log_{10}\, \{(255)2 \,/\, MSE\} \qquad (20)$$

Where, Mean Square Error (MSE) is given by,

$$MSE = 1 \,/\, N \sum \{y^{(N_F)}_{(i,j)} - x^{(0)}_{(i,j)}\}^2 \qquad (21)$$

Where N is the total number of pixels in the original image, $x^{(0)}_{(i,j)}$ is the pixel value at position (i, j) in the original image, And $y^{(N_F)}_{(i,j)}$ is the pixel value at position (i, j) in the filtered image.

Figure 3: Original standard Pirate image for simulation results

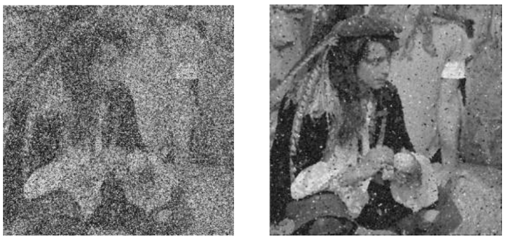


Figure 4: Result for Pirate image at 40% noise level (a) corrupted image (b) restored image

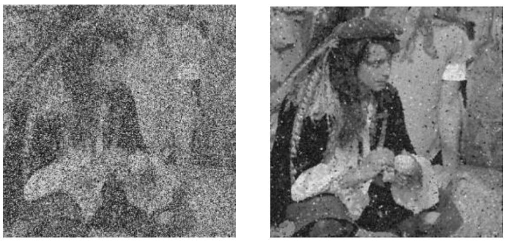


Figure 5: Result for Pirate image at 50% noise level (a) corrupted image (b) restored image

Table 1: Comparison of PSNR (dB) values for different images using Proposed Algorithm

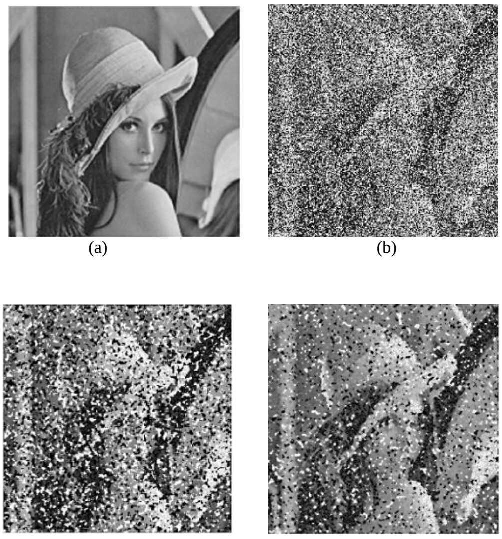
Image used	Noise percentage (%)					
	40	50	60	70	80	90
Rice	23.92	20.58	15.22	12.80	11.21	9.10
Pirate	24.52	21.36	15.27	12.72	10.70	9.02
Cameraman	21.82	19.42	14.65	12.30	10.07	8.52
Moon	24.80	20.71	16.81	12.98	8.55	6.80
Lena	22.95	21.22	15.88	13.25	10.98	9.01

Table 2: Estimated values of PSNR (dB) from different filters for 'LENA' (256×256) gray scale image

% NOISE	PSMF [3]	IPSMF [5]	PROPOSED
50	19.22	17.98	21.22
60	12.12	12.98	15.88
70	9.78	10.63	13.25
80	7.98	8.90	10.98
90	6.58	7.70	9.01

Table 3: Comparison of estimated values of PSNR(dB) of different gray scale images (256×256) at a noise (Impulse Noise) level of 80%

IMAGE	PSMF [3]	IPSMF [5]	PROPOSED
LENA	7.98	8.90	10.98
CAMERAMAN	7.59	8.86	10.07
RICE	8.21	9.26	11.21


(a) (b)

(c) (d)


(e)

Figure 6: a) Original image, b) Corrupted image by 60 % Impulse Noise, c) PSM filter [3], d) IPSM filter [5] e) Proposed filter

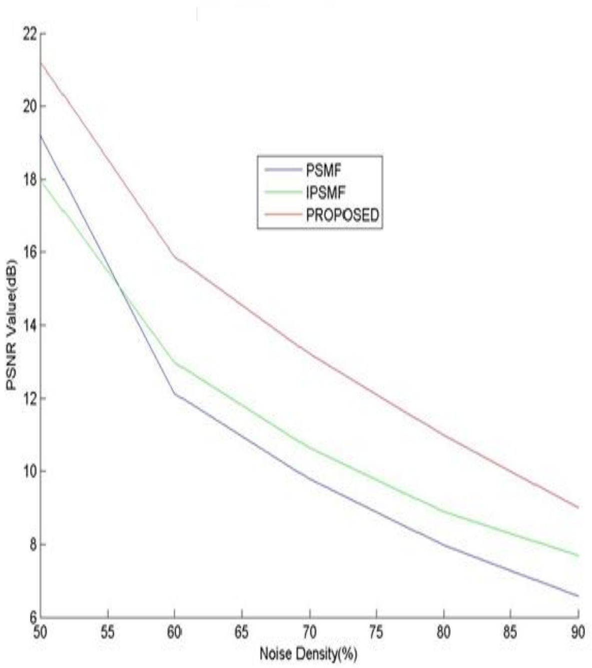


Figure 7: Plot PSNR Value of different filter over different noise density (%)

In our experiment, we introduced fixed amount of impulse noise [6] [7] in to original image 'Lena'.

Fig(6) ,show that our proposed filter has better restoration particularly for highly corrupted images.

Table(1), shows that proposed algorithm provide better result for different images from noise level as high as 90%.

4. CONCLUSION

The comparison of our proposed algorithm with the above mentioned techniques (Table (1)) show that our algorithm outperforms several techniques even at high noise levels. Table(1) show that noise level 40% to 90% for a different image ,PSNR shows that proposed filter provide better restored image. The proposed filter provides better PSNR values(Table (2) and (3)) for Lena image compared to PSM[3] or IPSM[5] filter at noise level as high as 90%.

The drawback with other methods introduced to handle high noise density fails as we increase the noise level. The main advantage of our algorithm is that its performance is not degraded with increasing noise level. It can easily handle high noise levels up to 90%.

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