Removal of Impulse Noise using Noise Adaptive Fuzzy Switching Median Filter

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ABSTRACT
This paper presents a novel method for the removal of random valued impulse noise. The proposed method consists of two stage detection where the noisy pixels are detected followed by filtering which replaces only the noisy pixels. The filtering process is a recursive process where the preprocessed pixels are also considered. Each and every pixel is processed and can restore images which are highly corrupted up to 60% noise density with improved PSNR value and low value of MSE. The image clarity is maintained with improved visual quality.

Keywords: Fuzzy Reasoning, Directional Filter, PSNR values, MSE values

1. INTRODUCTION
The field of digital image processing refers to processing digital image by means of a digital computer. It encompasses processes that extract attributes from images including the recognition of individual objects. The areas of applications of digital image processing are varied. They are used in medical fields like Xray, MRI images. It is used in astronomical researches and video in television.

Before any processing is done images must be first restored. Images may be corrupted by noise during image acquisition and transmission. There are different types of noises depending upon the camera sensors and the atmospheric interferences. Hence the first and foremost step before any image processing procedure is the restoration of the image by removal of noises in the images.

Image noise is the random variation of brightness or color information in images produced by the sensor and circuitry of a scanner or digital camera. Image noise is generally regarded as an undesirable by-product of image capture. The proposed method concentrates on image denoising where impulse noises in images are removed. Impulse noise is found in situations where quick transients such as faulty switching, take place during imaging, due to transmission errors, malfunctioning pixel elements in the camera sensors, faulty memory locations, and timing errors in analog-to-digital conversion. An important characteristic of this type of noise is that only part of the pixels are corrupted and the rest are noise-free. Impulse noise is classified as fixed value impulse noise and random value impulse noise. Random valued impulse noise follows uniform distribution. It takes any value in the dynamic range of a gray scale image between maximum pixel value (255) and minimum pixel value (0) (for 8-bit gray scale image).

The median filter is the basic nonlinear filter for removing impulse noise. It has good noise suppression ability and high computational efficiency but it is prone to damage such important details as thin lines and sharp corners since it replaces every pixel by the median value of its neighbouring pixels.

The recent methods which are effective in the removal of random valued impulse noise are a new directional weighted median filter for removal of random valued impulse noise(DWMF)[5], an efficient denoising chip for the removal of impulse noise(EDRIN)[4] and robust detection technique for removing random valued impulse noise (RDRIN)[3]. The DWMF uses directional weighted filters which is effective in removing very low noise densities whereas EDRIN has proved better restoration capability. Compared to the aforesaid methods RDRIN can remove higher noise densities.

The proposed method consists of teo stage detection along with two stage filtering. The undetected pixels in the first stage of detection are given as the input to the second stage of detection. The noise adaptive fuzzy switching median filter is used as the first stage of filtering where only the noisy pixels are considered for the replacement with the median of noise free pixels whereas the second stage of filtering is the directional filter which is used to preserve the edges and fine details.

2. TWO STAGE NOISE DETECTION
The intensity of the noisy pixel will be distinct from its nearest surrounding pixels. Based on this criterion the proposed method focuses on noisy pixel detection. A two stage noise detection is proposed here where the undetected noisy pixels from the first stage are passed as input to the second stage of noise detection.

The input images considered are mainly of 256 x 256 or 512 x 512 pixels. The image size can vary as desired. Consider ‘x’ to be the input image. In the first stage of noise detection a 11 x 11 window is selected as for small window sizes the intensity of noise free pixels are less when high noise density is considered. Hence the aforesaid window size is assumed.

The absolute differences of the central pixel from its neighbouring pixels is given as

$$d(k,l) = |x(k,l) - x(i,j)| \qquad -N \le k,l \le N \qquad (1)$$

where (2N + 1) x (2N +1) is the window size. A tuning parameter t1 is added and subtracted to these difference values given as

$$f = |d_{kl} \pm t1| \quad \forall \quad |d_{kl} \pm t1| \le t2 \qquad (2)$$

where t2 is the second tuning parameter.

Two arrays obtained as $[d_{kl} + t1]$ and $[d_{kl} - t1]$ are stored in a single array. The values in this array which are less than t2 is passed to f. The noise mask is created as

$$S_{i,j} = \begin{cases} 0 & \text{if size}(f) \leq t3 \\ 1 & \text{otherwise} \end{cases} \quad (3)$$

where t3 is the third tuning parameter. $S_{ij} = 0$ denotes noisy pixels whereas $S_{ij} = 1$ denotes noise free pixels. The process is recursive where the pre-processed pixels are considered.

The undetected noisy pixels from the first stage of detection are passed to the next detection stage. In the next detection stage the window size is set to 5 x 5 and the same procedure is carried out as in the first detection stage with change in the values of tuning parameter given in table 1.

Table 1. Tuning parameters for different detection stages

	Sliding Window Size	Tuning Parameters		
		t1	t2	t3
1st stage	11	14	12	24
2nd stage	5	1	25	6

3. RECOVERY PROCESS

Two stages of filtering are used. The first stage of filtering involves the noise adaptive fuzzy switching median filter where only noisy pixels are replaced using fuzzy reasoning.

Initially the window size is set to 3 x 3. The number of noise free pixels in the window is counted. If the count <1 the window size is increases until this condition is satisfied. The maximum window size is selected as 9 x 9. Then find the median of the noise free pixels in the selected window which is given as

$$M(i,j) = \text{median}\{x(i+m, j+n)\} \quad \text{with } S(i+m, j+n) = 1 \quad (4)$$

If window size have reached 9 x 9 and the count < 1 then set the window size to 3 x 3 and take the median of the pre-processed pixels which is given as

$$M(i,j) = \text{median}\{x(i-1, j-1), x(i, j-1), x(i-1, j+1), x(i-1, j)\} \quad (5)$$

The absolute luminance difference in the window is found as

$$d(i+k, j+l) = |x(i+k, j+l) - x(i,j)| \quad \text{with } (i+k, j+l) \neq (i,j) \quad (6)$$

The local information which is the maximum absolute luminance difference is given as

$$D(i,j) = \max\{d(i+k, j+l)\} \quad (7)$$

Fuzzy reasoning is applied to the extracted local information D(i,j).The fuzzy set adopted is defined by the fuzzy membership function F(i,j)

$$F(i,j) = \begin{cases} 0 & : \quad D(i,j) < T1 \\ \frac{D(i,j) - T1}{T2 - T1} & : \quad T1 \leq D(i,j) < T2 \\ 1 & : \quad D(i,j) \geq T2 \end{cases} \quad (8)$$

For optimum performance the two predefined thresholds T1 and T2 are set to 10 and 30. The restoration term is given as

$$Y(i,j) = [1 - F(i,j)] * x(i,j) + F(i,j) * M(i,j) \quad (9)$$

The process is recursive. The filtered output of the first stage is passed to the second filtering stage.

In the second filtering stage the absolute difference of the central pixel from the four directional pixels in a 5 x 5 window is taken and stored in four sets. The set giving the directional differences is given as

$$S_k = \{D_k - x(i,j)\} \qquad k = 1,2,3,4 \quad (10)$$

The four directions are

$$\begin{aligned} D_1 &= \{(-2,-2), (-1,-1), (0,0), (1,1), (2,2)\} \\ D_2 &= \{(0,-2), (0,-1), (0,0), (0,1), (0,2)\} \\ D_3 &= \{(2,-2), (1,-1), (0,0), (-1,1), (-2,2)\} \\ D_4 &= \{(-2,0), (-1,0), (0,0), (1,0), (2,0)\} \end{aligned} \quad (11)$$

where (0,0) is the central pixel position. Then the sum of the four directional differences are found as

$$\text{sum}_k = \text{sum}(S_k) \qquad k = 1,2,3,4 \quad (12)$$

Minimum among the sum are found and the median of the minimum directional difference is found. Only noise free pixels and pre-processed pixels in the concerned direction are considered for taking median.

$$L = \min(\text{sum}_k) \qquad k = 1,2,3,4 \quad (13)$$

$$M(i,j) = \text{median}\{L\} \quad (14)$$

The absolute luminance difference in the window is found using the equation (6) followed by the calculation of local information which is the maximum absolute luminance difference given in equation (7). Next the equation (8) is used to find the fuzzy membership function and finally the restoration term is given as in equation (9). In the second stage also the processes is recursive along with pixel by pixel evaluation.

4. RESULTS AND DISCUSISION

The threshold values are optimized to get better restoration. The proposed method restores highly corrupted images with noise densities as high as 60% with improved PSNR values.

The tuning parameters are optimized to yield good result for all noise densities. Hence the fixed values of the tuning parameters give consistent PSNR values and also MSE value is much reduced.

(a) (b)

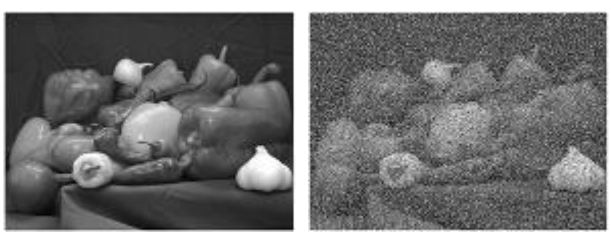
(c) (d)

(e) (f)

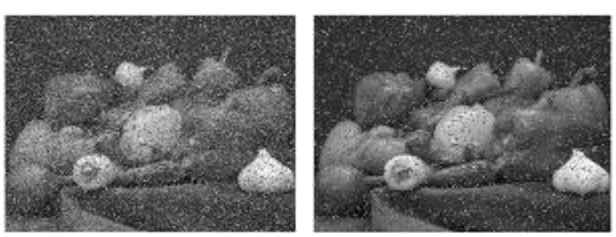
Figure 1. Results for different methods and the proposed method for 60% corrupted 'lena' image (a) original image (b) noisy image (c) DWMF (d) EDRIN (e) RDRIN (f) Proposed method

The proposed method is compared with the existing methods. Three different test images are used and the corresponding PSNR values and the MSE values are compared. It can be seen that in the proposed method the PSNR values are consistent and gives good PSNR for highly corrupted noise with better image quality.

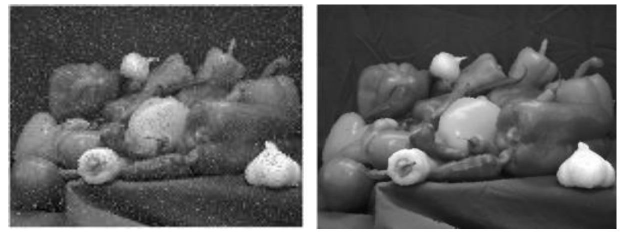
The noise mask is used for processing only the noisy pixels whereas retaining the noise free pixels. Pixel by pixel processing enables better image restoration and visual quality.



(a) (b)



(c) (d)



(e) (f)

Figure 2. Results for different methods and the proposed method for 50% corrupted 'peppers' image (a) original image (b) noisy image (c) DWMF (d) EDRIN (e) RDRIN (f) Proposed method

The PSNR values and MSE values of the existing methods for different test images for varying noise densities are compared with the proposed method and given in the Table 2 to 5.

Table 2. Comparison of PSNR values of proposed technique with existing techniques for 512x512 lena image

Noise Density	DWMF	EDRIN	RDRIN	Proposed Method
30	18.1087	25.5235	26.5900	30.1799
40	16.1872	22.4067	23.3969	29.5786
50	14.7031	19.8100	20.5384	28.7990
60	13.3538	17.4319	18.0601	27.6059
70	12.3060	15.4260	15.7887	25.9309

Table 3. Comparison of PSNR values of proposed technique with existing techniques for 384x512 peppers image

Noise Density	DWMF	EDRIN	RDRIN	Proposed Method
30	18.1818	25.5927	27.0006	33.9014
40	15.9346	22.2179	23.1923	33.0055
50	14.1109	19.0566	20.0746	31.6128
60	12.6763	16.5281	17.2199	30.2138
70	11.4586	14.3798	14.7532	27.2174

Table 4. Comparison of MSE values of proposed technique with existing techniques for 512x512 lena image

Noise Density	DWMF	EDRIN	RDRIN	Proposed Method
30	1005.1	182.2764	142.5855	62.3867
40	1564.4	373.6041	297.4327	71.6505

50	2201.8	679.3297	574.4358	85.7386
60	3004	1174.6	1016.4	112.8477
70	3823.7	1864.1	1714.8	165.9563

The mean square error value (MSE) of the proposed method is comparatively less to the previous methods. It implies that the false and missed detections are less increasing the percentage of right detection. The rate of increase in wrong detection is less than the existing methods and this helps in better restoration of images that are highly corrupted.

The rate of increase in wrong detection depends on the tuning parameters and hence the tuning parameters along with the window size selection are optimized for better results.

Table 5 Comparison of MSE values of proposed technique with existing techniques for 384x512 peppers image

Noise Density	DWMF	EDRIN	RDRIN	Proposed Method
30	988.3335	179.3965	129.7239	26.4814
40	1658.2	390.2002	311.7806	32.5482
50	2523.4	808.0132	639.1722	44.8543
60	3511.2	1446.3	1233.4	61.9017
70	4647.5	2371.9	2176.5	123.4067

5. CONCLUSION

Image denoising is an effective and primitive step in any kind of digital image processing where the image is restored from the added noises and clarity is maintained. The previous methods concentrates on image filtering using median filters, adaptive median filters where whole of the pixels including the noise free pixels are considered. It can remove only very low noise densities.

The paper presents a two stage detection and filtering mechanism where only the noisy pixels are replaced while the noise free pixels are retained. The proposed method works well for highly corrupted images with noise densities as high as 60 % with better PSNR value and improved visual quality. The algorithm can be applied to color images as well with good results.

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7. REFERENCES

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