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Removal of High Density Salt and Pepper Noise along with Edge Preservation Technique

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ABSTRACT: *Linear and nonlinear filters have been proposed earlier for the removal of impulse noise; however this often brings about blurring which results in distorted edges and poor quality. Therefore the necessity to preserve the edges and fine details during filtering is the challenge faced by researchers today. A new non-linear 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 consists of two phases. In the first phase, the noise corrupted pixels is detected based on direction index based impulse detector. In the second phase, the detected pixels are filtered using unsymmetric trimmed median filter. Simulation results demonstrate that the proposed algorithm is better than traditional median-based filters and is particularly effective for the cases where the images are very highly corrupted.*

Keywords : *direction index based impulse detector,impulse noise, median-based filter, gray scale image, unsymmetric trimmed median filter*

I. INTRODUCTION

Images are often corrupted by impulse noise due to bit errors in transmission or introduced during the image acquisition stage. So impulse removal algorithms are essential for image restoration to precede reliable digital images through varied image processing applications. 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 pioneer impulse filtering algorithms based on linear operations like the Mean filter smoothened image details while removing noise and so non-linear operators emerged successfully to deal the non-linear characteristics of impulses.

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, when the noise level is over 50% the edge details of the original image will not be preserved by standard median filter [1]. As an improvement did numerous offshoots of median filter evolved in the form of Adaptive Median Filter (AMF), switching median filters [2], [3], Decision–based algorithm[4], [5], Decision Based Unsymmetric Trimmed Median Filter (DBUTMF) [6] and Modified Decision Based Unsymmetric Trimmed Median Filter (MDBUTMF) [7].

These algorithms do not give better results at very high noise density that is at 80% to 90%. 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. Therefore the necessity to preserve the edges and fine details during filtering is the challenge faced by researchers today [8].A new algorithm for the restoration of gray scale and color images that are highly corrupted by salt and pepper noise is proposed in this chapter.

The organization of this paper is as follows. The direction index based impulse detector [9] is formulatedin Section II. Section III describes unsymmetric trimmed median filtering. Section IVdescribes about the proposed algorithm. Section V briefly illustrates the proposed algorithm. SectionVI reports a number of experimental results to demonstrate the performance of the new filter. Finally, conclusions are drawn in Section VII.

II. DIRECTION INDEX BASED IMPULSE DETECTION

The method is usually based on the following two assumptions: 1) a noise-free image consists of locally smoothly varying areas separated by edges and 2) a noise pixel takes a gray value substantially larger or smaller than those of its neighbors. Let x(i,j) represent the pixel values at position (i, j) in the corrupted image. The input image is first convolved with a set of convolution kernels. Here, four one-dimensional Laplacian operators as shown in Fig.1 and Fig.2 are used, each of which is sensitive to edges in a different orientation. Then, the minimum absolute value of these four convolutions (denoted as r(i,j)) is used for impulse detection, which can be represented as

$$r(i,j)=\min(|x(i,j)\otimes K_p|) \quad : p=1 \text{ to } 4 \qquad (1)$$

Where K_p is the p^{th} kernel, and ⊗ denotes a convolution operation.

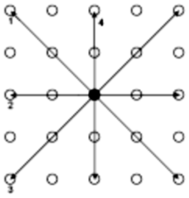

Fig.1 Directions used for impulse detection.

-1	0	0	0	0
0	-1	0	0	0
0	0	4	0	0
0	0	0	-1	0
0	0	0	0	-1

0	0	0	0	0
0	0	0	0	0
-1	-1	4	-1	-1
0	0	0	0	0
0	0	0	0	0

0	0	0	0	-1
0	0	0	-1	0
0	0	4	0	0
0	-1	0	0	0
-1	0	0	0	0

0	0	-1	0	0
0	0	-1	0	0
0	0	4	0	0
0	0	-1	0	0
0	0	-1	0	0

Fig.2 Four 5×5 convolution kernels.

The value of r(i,j) detects impulses due to the following reasons:

1. r(i,j) is large when the current pixel is an isolated impulse because the four convolutions are large and almost the same.
2. r(i,j) is small when the current pixel is a noise-free flat-region pixel because the four convolutions are close to zero.
3. r(i,j) is small also when the current pixel is an edge (including thin line) pixel because one of the convolutions is very small (close to zero) although the other three might be large.

So, we can compare r(i,j) with a threshold value T to determine whether a pixel is corrupted, i.e.,

$$\alpha(i,j) = \begin{cases} 1, & r(i,j) > T \\ 0, & r(i,j) \leq T \end{cases} \quad (2)$$

Obviously, the threshold affects the performance of impulse detection. It is not easy to derive an optimal threshold through analytical formulation. But we can determine a reasonable threshold using computer simulations.

III. UNSYMMETRIC TRIMMED MEDIAN FILTER

After impulse detection using direction index method, we need to replace the noisy pixels by a value equal to or close to its original value. For this purpose, instead of replacing the pixel by either mean or median, we make use of the information obtained in detection process. The word “unsymmetric” refers to replacing only the noisy pixels in the image leaving the uncorrupted pixels unprocessed. “Trimming” refers to removing the noisy pixels from the selected window in the filtering stage. Filtering using unsymmetric trimmed median filter involves three possible cases as given in case i), ii) and iii).

Case i): If the selected window contains all corrupted pixels, then the processing pixel is replaced by the mean value of the remaining pixels in the window.

Case ii): If the selected window contains corrupted pixel as the processing one and not all other pixels are corrupted, then the corrupted pixels are removed and from the remaining elements median is calculated. The test pixel is replaced with this median value.

Case iii): If the processing pixel of the selected window is a noise free pixel, then it is left unprocessed.

IV. PROPOSED ALGORITHM

The proposed non-linear algorithm consists of two steps. In the first step, the detection of impulse corrupted pixels is done based on direction index method. In the second step, the corrupted pixels that are detected using the direction index are filtered using unsymmetric trimmed median filter.

The steps of the proposed algorithm are elucidatedasfollows.

Step 1): Select a 2D 5×5 window. Assume that the center pixel is located at (i,j)

*Step 2):*The matrix is then convolved with four convolution kernels shown above.

*Step 3):*Then the minimum absolute value is taken as r(i,j)

$$r(i,j)=\min(|x_{ij} \otimes K_p|) \quad :p=1 \text{ to } 4$$

*Step 4):*Compare r(i,j) with a threshold T to determine whether a pixel is corrupted or not and assign the value of α(i,j) as below

$$\alpha(i,j) = \begin{cases} 1, & r(i,j) > T \quad \ldots \quad \text{Noisy pixel} \\ 0, & r(i,j) \leq \text{T} \quad \ldots \text{ Noiseless pixel} \end{cases}$$

*Step 5):*Repeat steps 1 to 4 until the whole image is processed.

*Step 6):*Again read the image and select a 2D 3×3 window. Assume that the pixel being processed is P(i,j).

*Step 7):*If α(i,j) = 0, then the uncorrupted pixel P(i,j) is left unchanged.

*Step 8):*If α(i,j) = 1, then P(i,j) is a corrupted pixel and two cases are possible as given in Case i) and ii).

Case i): If the selected 3×3 window contains all corrupted pixels, then replace P(i,j) with mean value of the elements in the window.

*Caseii):*If the selected window contains not all elements as corrupted pixels, then corrupted pixels are removed and from the remaining elements, median value is calculated and replace P(i,j) with that value.

*Step 9):*Repeat steps 6 to 8 until all the pixels in the entire image are processed.

The pictorial representation of each case of the proposed algorithm is shown in Fig. 3.The detailed description of each case of theflow chart shown in Fig.3 isillustratedthroughanexamplein SectionV.

V. ILLUSTRATION OF PROPOSED ALGORITHM

The Each and every pixel of the image is checked for the presenceof salt and pepper noise.

a. Illustration of Part I

Different cases are illustrated in thisSection for 2D 5×5 window.

Case i): If the selected window contains salt/pepper noise as the processing pixel and all other pixelsare flat pixels, then all the four convolutions (here 889, 837, 882, 847) will be large and hence r(min) = 837 will also be large. Thus α(i,j) = 1.

$$\text{Window1} = \begin{bmatrix} 27 & 42 & 0 & 38 & 54 \\ 41 & 36 & 48 & 45 & 40 \\ 47 & 32 & (255) & 34 & 18 \\ 56 & 29 & 62 & 50 & 32 \\ 45 & 43 & 73 & 28 & 25 \end{bmatrix}$$

Case ii): If all the pixels are flat pixels, then all the convolution values (here 89, 37, 82, 47) will be definitely small. Hence r(min)=37 is small and α(i,j) = 0, a noiseless pixel.

$$\text{Window2} = \begin{bmatrix} 27 & 42 & 0 & 38 & 54 \\ 41 & 36 & 48 & 45 & 40 \\ 47 & 32 & (55) & 34 & 18 \\ 56 & 29 & 62 & 50 & 32 \\ 45 & 43 & 73 & 28 & 25 \end{bmatrix}$$

Case iii): If the processing pixel is an edge pixel, then only one of the convolution values (here 356, 356, 356, 0) i.e., in the direction of the edge will be small. Though r(min) becomes small and hence α(i,j) = 0, a noiseless pixel. Thus edge preservation is done and the blurring of the image is avoided.

$$\text{Window3} = \begin{bmatrix} 2 & 2 & 180 & 180 & 180 \\ 2 & 2 & 180 & 180 & 180 \\ 2 & 2 & (180) & 180 & 180 \\ 2 & 2 & 180 & 180 & 180 \\ 2 & 2 & 180 & 180 & 180 \end{bmatrix}$$

5.2 Illustration of Part II

Different cases are illustrated in this section for 2D 3×3window.

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

$$\begin{bmatrix} 0 & 255 & 0 \\ 0 & (255) & 255 \\ 255 & 0 & 255 \end{bmatrix}$$

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 mean=170).

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

$$\begin{bmatrix} 78 & 90 & 0 \\ 120 & (0) & 255 \\ 97 & 255 & 73 \end{bmatrix}$$

Now eliminate the salt and pepper noise from the selected window. 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 and replace P(i,j)by 90.

Case iii): If the selected window contains a noise free pixel as a processing pixel, it does not require further processing and left unchanged.

VI. RESULTS AND DISCUSSION

The performance of the proposed algorithm is tested with different grayscale and color images. The noise density (intensity)is varied from 10% to 90%. Denoising performances are quantitatively measured by the PSNR and IEF as definedin(3)and (5), respectively:

$$\mathrm{PSNR(in\ dB)} = 10\log\left(\frac{255^2}{\mathrm{MSE}}\right) \quad (3)$$

$$\mathrm{MSE} = \frac{\sum_i \sum_j \left(\mathrm{Y}(i,j) - \hat{\mathrm{Y}}(i,j)\right)^2}{\mathrm{M} \times \mathrm{N}} \quad (4)$$

$$\mathrm{IEF} = \frac{\sum_i \sum_j \left(\eta(i,j) - \mathrm{Y}(i,j)\right)^2}{\sum_i \sum_j \left(\hat{\mathrm{Y}}(i,j) - \mathrm{Y}(i,j)\right)^2} \quad (5)$$

where PSNR stands for Peak Signal to Noise Ratio, MSE stands for mean square error, IEF stands for image enhancement factor, M×N is size of the image, Y represents the original image, $\hat{\mathrm{Y}}$ denotes the denoised image, η represents the noisy image.

TABLE.1 COMPARISION OF PSNR VALUES WITH EXISTING ALGORITHMS AT DIFFERENT NOISE DENSITIES FOR LENA IMAGE

NOISE %	MF	PSMF	DBA	MDBA	MBUTMF	PROPOSED
10	26.3400	30.2200	36.4000	36.9400	37.9100	38.2139
20	25.6600	28.3900	32.9000	32.6900	34.7800	35.8992
30	21.8600	25.5200	30.1500	30.4100	32.2900	34.3503

40	18.2100	22.4900	28.4900	28.4900	30.3200	33.0125
50	15.0400	19.1300	26.4100	26.5200	28.1800	31.6963
60	11.0800	12.1000	24.8300	24.4100	26.4300	30.3036
70	9.9300	9.8400	22.6400	22.4700	24.3000	28.4608
80	8.6800	8.0200	20.3200	20.4400	21.7000	26.0236
90	6.6500	6.5700	17.1400	17.5600	18.4000	23.2516

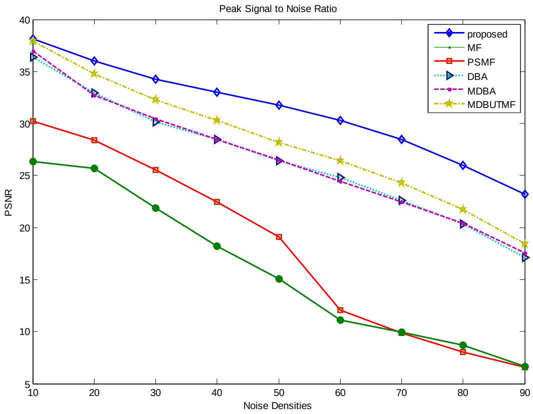

Fig.3. Comparison graph of PSNR with existing algorithms at different noise densities for Lena image.

The PSNR 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. A plot of PSNR against noise densities for Lena image is shown in Fig.3.From the Table II, it is clear that the proposed algorithm gives better PSNR values irrespective of the natureof the input image.

The qualitative analysis of the proposed algorithm againstthe existing algorithms at different noise densities for Cameraman image is shown in Fig. 4. In this figure, thefirst column represents the processed image using MF at 80% and 90% noisedensities. Subsequent columns represent the processed imagesfor PSMF, DBA, MDBA, MDBUTMF and proposed algorithm.

TABLE.2.COMPARISION OF PSNR VALUES WITH EXISTING ALGORITHMS FOR DIFFERENT TEST IMAGES AT 70% NOISE DENSITY

TEST IMAGES	MF	PSMF	DBA	MDBA	MBUTMF	PROPOSED
CAMERAMAN	9.46	9.47	20.84	19.97	22.52	34.4769
LENA	9.93	9.84	22.64	22.47	24.30	28.4608
BABOON	10.11	10.05	22.35	20.54	23.80	26.0484

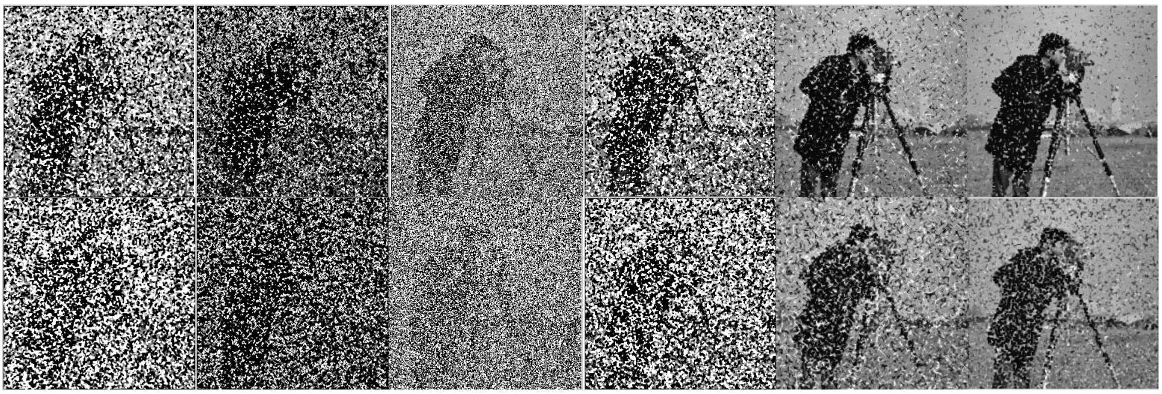

Fig.4. Results of different algorithms for Baboon image. (a) Output of MF. (b) Output of PSMF. (c) Output of DBA. (d) Output of MDBA. (e) Output of MDBUTMF. (f) Output of Proposed Algorithm. Row 1 and Row 2 show processed results of various algorithms for image corrupted by 80% and 90% noise densities, respectively.

VII. CONCLUSION

A new algorithm for the restoration of gray scale, and colour images that are highly corrupted by salt and pepper noise is proposed in this project. The proposed algorithm consists of two steps. In the first step, direction index based impulse detector completely makes use of the impulse characteristics and pixel information aligned in the four directions to detect the noise. In the second step, the corrupted pixels detected using the direction index is filtered using unsymmetric trimmed median filter. The performance of the algorithm has been tested at low, medium and high noise densities on gray-scale images. Both visual and quantitative results are demonstrated. The proposed algorithm offers high value of PSNR and a low MSE at higher noise densities and thus performing better than other filters in both subjective (image clarity) and objective (PSNR) evaluations.

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