An Efficient New Edge Preserving Technique for Removal of Salt and Pepper Noise

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***Abstract*—This paper proposes an efficient procedure for removal of salt and pepper noises from the noisy images on the basis of their local edge preserving filters. This algorithm consists of two major stages. In the first stage, the maximum and minimum pixel value in the the corrupted image is used to select noisy pixels or noise free pixels and then in second stage, local edge preserving filters are used on the basis of noisy pixel detected and the nature of its neighboring pixels in the selected window. Comparing the obtained results with other computationally simple noise removal techniques, our proposed algorithm gives much better qualitative and quantitative performance. Due to its simplicity and low computational cost, our method is suitable for its application in many real time situations.**

***Index Terms*—Edge Preserving, Median Filter, Noise Detection, Salt and Pepper Noise.**

I. Introduction

During the signal encoding and transmission, when the signals passes through the noisy transmission lines or is contaminated by electronic induction noises the main reason for degradation of signal like images is the influence of salt and pepper noise. Salt and Pepper noise is a common type of image noise and many image denoising methods have been carried out for the restoration of images corrupted by impulse noise [1]-[2]. Some of the methods uses median filter [2] or its modified version to implement the denoising process. Drawback with this method is that they modify both the noisy and noise free pixels during the restoration of images. However, when the noise level is more than $50\%-60\%$, it fails to preserve the details of the original image and the image got smeared. Though there are techniques [5]-[12] in literature which avoid the damage on noise free pixels by employing image filter with an impulse detector and try to preserve the details of the image but the performance were not significant.

In [5], a detail preserving filter is proposed based on the soft switching median (SWM) filter. After detection of corrupted pixels, the process employ the rank-ordered mean filter (ROM) to remove the corrupted pixels. In [6], a specified regularization method is applied for edge preservation and noise suppression. Many denoising techinques [8]-[12] have been proposed which uses fixed size window and makes the algorithm computationaly less complex. In [8], a new impulse detector (NID) for switching median filter was proposed. NID used the minimum absolute value of four convolutions which are obtained by using one-dimensional Laplacian operators to detect noisy pixels. The differential rank impulse detector (DRID), presented in [9], implemented the impulse detector based on comparison of signal samples within a narrow rank window by both rank and absolute value. In [10], a simple fuzzy impulse detector (SFID) was proposed to remove the impulse noise. An alpha-trimmed mean method was presented in [11] which uses the alpha-trimmed mean in impulse detection and the noisy pixels predicted by a linear combination of its original value and median of its local window. In [12], again a denoising based (DBA) algorithm was presented which predicts the noisy pixel with the help of median of current window and its neighbouring pixels value.

The main contribution in this paper is that we have proposed a two phase novel edge preserving algorithm which modifies only noisy pixels. Use of fixed size window like [8]-[12] for locating noisy pixels and its processing adds additional advantage of being simple and efficient. Simulation results after carrying out extensive experiments shows that our proposed algorithm can obtain better performance both quantitatively and qualitatively when compared with other noise removal techniques [8]-[12] mentioned in literature.

The remaining part of this paper is organized as follows. Section II describes the impulse noise model to detect the noisy pixels in the image. Section III explains our efficient edge preserving denoising scheme. Section IV discuss about the experimental results and comparisions whereas conclusion remarks are mentioned in section V.

II. Impulse Noise Model

In this paper, we have considered an 8-bit grayscale image I. Let O be the corrupted image with $O(i,j)$ be the gray value at pixel (i,j) and P be a window centered at (i,j). We focus only on the detection and denoising of fixed value impulse noise, namely "Salt and Pepper noise". Salt and Pepper noise is characterized by the appearance of black and white dots in the image, and its characteristic is that some of the original pixel values are retained and only some of the pixels are corrupted by noise. The corrupted pixel either chooses a value closer to 0 (Pepper noise) or to a value closer to 255 (Salt noise). We assume here the following noise model:

$$O(i,j) = \begin{cases} R(i,j), & \text{with probability } r \\ I(i,j), & \text{with probability } 1-r \end{cases} \quad (1)$$

where $R(i,j)$ is the noisy image with pixel value of 0 and 255 only and $I(i,j)$ are the pixels of original image with pixels range $(0,255)$, where r is the noise ratio. In this paper, the noise has been added synthetically on the test images by assigning the pixel value 0 and 255 randomly.

III. Proposed Algorithm

Let $P(i,j)$ denote the current pixel at coordinates (i,j) and X denote its pixel value in the window P chosen. For each pixel in an image, we define a 3×3 window centered on X at first.

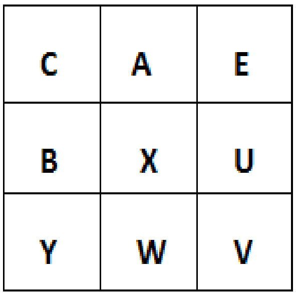

Fig. 1. Pixels present in current Window.

For simplicity we have assumed, let C, A, E, B, P, U, Y, W, V and X represents the intensity values of pixels $P(i-1,j-1)$, $P(i-1,j)$, $P(i+1,j+1)$, $P(i,j-1)$, $P(i,j+1)$, $P(i+1,j)$,$P(i+1,j+1)$ and $P(i,j)$ respectively, as shown in Figure 1. We have employed the raster scanning method that is why detection of $P(i,j)$ i.e. X as a corrupted pixel guarantees that the pixels C, A, E, and B are either original pixels or retrieved (pixels which were detected in stage 1 and made noise free in stage 2) pixel which implies that the present window contains either of the U,V,W and Y as corrupted pixels. Thus, it could be one or more than one set of corrupted pixels in the window on the basis of the number of corrupted pixels and its position. Thus a total of 16 different set of windows can be formed which are as follows.

No Error: U,V,W,Y all good.
Single Error: U corrupted or V corrupted or W corrupted or Y corrupted.
Double Error: UV corrupted , UW corrupted , UY corrupted , VW corrupted , VY corrupted or WY corrupted.
Triple Error: UVW corrupted or UWY corrupted or VWY corrupted or UVY corrupted.
Four Error: U, V, W, Y all corrupted.

TABLE I
GRADIENT CALCULATION AND PIXEL PREDICTION FOR SINGLE ERROR WINDOW.
CP - Corrupted Pixel, DoS - Direction of Gradient

C P	DoS	Gradient Calculation	Pixel Prediction
U	dv	2*$\mid A-W \mid$	A/2 + W/2
	dh	$\mid C-E \mid + \mid Y-V \mid$	B
	d45	2*$\mid Y-E \mid$	Y/2 + E/2
	d135	2*$\mid C-V \mid$	C/2 + V/2
V	dv	2*$\mid A-W \mid$	A/2 + W/2
	dh	2*$\mid B-U \mid$	B/2 + U/2
	d45	$\mid Y-E \mid$	Y/2 + E/2
	d135	$\mid B-W \mid + \mid A-U \mid$	C
W	dv	$\mid C-Y \mid + \mid E-V \mid$	A
	dh	2*$\mid B-U \mid$	B/2 + U/2
	d45	2*$\mid Y-E \mid$	Y/2 + E/2
	d135	2*$\mid C-V \mid$	C/2 + V/2
Y	dv	2*$\mid A-W \mid$	A/2 + W/2
	dh	2*$\mid B-U \mid$	B/2 + U/2
	d45	$\mid U-W \mid + \mid A-B \mid$	Y
	d135	2*$\mid C-V \mid$	C/2 + V/2

TABLE II
GRADIENT CALCULATION AND PIXEL PREDICTION FOR DOUBLE ERROR WINDOW

UV	dv	2*$\mid A-W \mid$	A/2 + W/2
	dh	2*$\mid C-E \mid$	C/2 + E/2
	d45	2*$\mid Y-E \mid$	Y/2 + E/2
	d135	$\mid B-W \mid + \mid C-W \mid$	C
UW	dv	$\mid Y-C \mid + \mid E-V \mid$	A
	dh	$\mid C-E \mid + \mid Y-V \mid$	B
	d45	2*$\mid Y-E \mid$	Y/2 + E/2
	d135	2*$\mid C-V \mid$	C/2 + V/2
UY	dv	2*$\mid A-W \mid$	A/2 + W/2
	dh	2*$\mid C-E \mid$	B
	d45	$\mid A-B \mid + \mid U-W \mid$	E
	d135	2*$\mid C-V \mid$	C/2 + V/2
VW	dv	2*$\mid Y-C \mid$	A
	dh	2*$\mid B-U \mid$	B/2 + U/2
	d45	2*$\mid E-Y \mid$	Y/2 + E/2
	d135	$\mid B-U \mid + \mid C-U \mid$	C
VY	dv	2*$\mid A-W \mid$	A/2 + W/2
	dh	2*$\mid B-U \mid$	B/2 + U/2
	d45	$\mid A-B \mid + \mid U-W \mid$	A/2+B/2
	d135	$\mid B-W \mid + \mid A-U \mid$	C
WY	dv	2*$\mid E-V \mid$	E/2 + V/2
	dh	2*$\mid B-U \mid$	B/2 + U/2
	d45	$\mid A-B \mid + \mid U-W \mid$	E
	d135	2*$\mid C-V \mid$	C/2 + V/2

Removal of Noise from corrupted pixels

1) For each noisy pixel (detected in stage 1 with pixel values 0 or 255) X, its window type (out of the 16 different sets mentioned above) is decided on the basis of its neighboring pixel values which comprises both original and corrupted pixels.
2) Then for each set of window, gradient d_h, d_v , d_{45} and d_{135} are estimated with the help of original pixels and estimated noise free pixels present in windows.
3) The centered corrupted pixel for that window is calculated corresponding to the minimum gradient value among d_h, d_v , d_{45} and d_{135} for that particular set of window.

TABLE III
GRADIENT CALCULATION AND PIXEL PREDICTION FOR TRIPLE ERROR WINDOW.

C P	DoS	Gradient Calculation	Pixel Prediction
UVW	dv	2*$\mid C-Y \mid$	Y/2 + C/2
	dh	2*$\mid C-E \mid$	C/2 + E/2
	d45	2*$\mid Y-E \mid$	Y/2 + E/2
	d135	$\mid C-A \mid + \mid C-B \mid$	C/2 + A/2
UVY	dv	$\mid A-W \mid$	A/2 + W/2
	dh	$\mid C-E \mid$	C/2 + E/2
	d45	$\mid B-A \mid$	B/2 + A/2
	d135	$\mid B-W \mid$	B/2 + W/2
UWY	dv	$\mid V-E \mid$	E/2 + V/2
	dh	$\mid C-E \mid$	C/2 + E/2
	d45	$\mid B-A \mid$	A/2 + B/2
	d135	$\mid C-V \mid$	C/2+V/2
VWY	dv	$\mid B-C \mid + \mid V-E \mid$	A
	dh	$\mid B-U \mid + \mid C-E \mid$	B/2 + U/2
	d45	2*$\mid A-B \mid$	A/2 + B/2
	d135	2*$\mid A-U \mid$	A/2 + U/2

4) In case of four errors, the center pixel is calculated using the value of rest (C, A, E and B) of the noise free pixels in the window as shown in equation 3, where $\tilde{X}$ is the pixel value to be predicted.

$$\tilde{X}(i,j) = \begin{cases} min(A,B), & \text{if C} \geq \text{max(A,B)} \\ max(A,B), & \text{if C} \leq \text{min(A,B)} \\ (A+B+C+E)/4, & \text{otherwise} \end{cases} \qquad (2)$$

5) In this way, all the corrupted pixels are predicted using the equations for all different window set as shown in Table I, Table II and Table III repectively.

IV. Simulation results

In order to demostrate the performance of the proposed denoising algorithm we have conducted extensive experiments with some other image denoising techniques for salt and pepper noises mentioned in literature. In order to validate the objective performance, PSNR (Peak Signal to Noise Ratio) values of proposed algorithm along with some other denoising techniques like Median Filter [2], NID [8], DRID [9], SFID [10], ATMBM [11] and DBA[12] respectively has been tabulated in Table IV. The proposed algorithm was tested on 6 well known 512×512 8-bit gray scale images: Lena, Boat, Plane, Couple, Goldhill and Pepper as shown in Figure 2. In order to show the powerful nature of proposed algorithm this was again tested on Lena for wider range of noise ratio as low as 1% to as high as 90% which is tabulated in Table V. The beauty of this proposed algorithm can be shown by its ability to remove noises effectively even for 80% ,90% noise ratio as shown in Figure 3, which also validates the better subjective or visual quality of the restored images by our algorithm.

Fig. 2. Test Images (.pgm) of size 512×512

TABLE IV
PSNR COMPARISON OF THE RESTORED TEST IMAGES BY DIFFERENT METHODS FOR 20% NOISE RATIO.

Methods	Lena	Plane	Couple	Goldhill	Peppers
MF[2]	31.00	29.80	27.56	29.19	31.00
NID[8]	34.03	30.32	29.95	32.18	33.37
DRID[9]	36.22	34.87	31.49	33.22	35.39
SFID[10]	37.55	36.06	32.97	35.21	35.26
ATM[11]	37.42	35.24	32.21	33.87	35.32
DBA[12]	37.49	36.16	33.78	35.41	36.94
Proposed	**38.81**	**38.13**	**35.78**	**36.55**	**38.55**

V. Conclusion

In this paper, an efficient two stage denoising algorithm for removing salt and pepper noise has been proposed, which solves the purpose of edge preservation along with noise removal from the noisy images. The experimental results conclude that our proposed algorithm performs much better than other state of art in literature either which are of same computational cost or have employed somewhat alike prediction scheme, in terms of both subjective and objective quality. The most significant characteristic of this algorithm is its ability to remove the wide range of the noises i.e. from 1% to 90% effectively and it can be seen in the graph of Figure 4.

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TABLE V
COMPARATIVE RESULT WHILE RESTORATION OF LENA FOR WIDE RANGE OF NOISE RATIO IN TERMS OF PSNR

	1%	10%	20%	30%	40%	50%	60%	70%	80%	90%
Median Filter[2]	33.63	32.58	31.00	29.27	27.40	24.41	21.06	17.03	12.95	8.95
NID[8]	42.25	37.46	34.03	31.00	28.72	26.42	23.98	21.95	18.72	13.18
DRID[9]	42.73	39.11	36.22	33.92	32.15	29.94	27.53	24.07	17.84	11.33
SFID[10]	53.07	41.66	37.55	33.97	30.50	26.46	22.61	18.43	14.53	10.38
ATMBM[11]	47.28	41.56	37.42	34.47	31.10	27.03	23.21	19.09	15.21	11.16
DBA[12]	53.07	41.67	37.49	35.40	34.04	**32.31**	30.47	28.34	26.10	**23.72**
Proposed Method	**54.03**	**42.82**	**39.02**	**36.43**	**34.05**	31.97	**30.64**	**28.78**	**26.13**	23.48

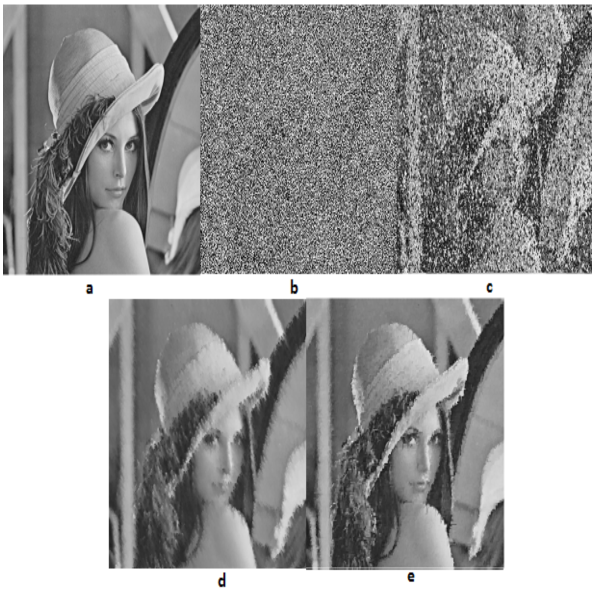

Fig. 3. VISUAL COMPARISON OF THE RESTORED TEST IMAGE LENA BY LATEST BEST METHOD (a) Original Image, (b) Noisy Image with noise level 90% (c) Restored Image by Median Filter [2], (d) Restored Image by DBA [12], (e) Image restored by Proposed Algorithm.

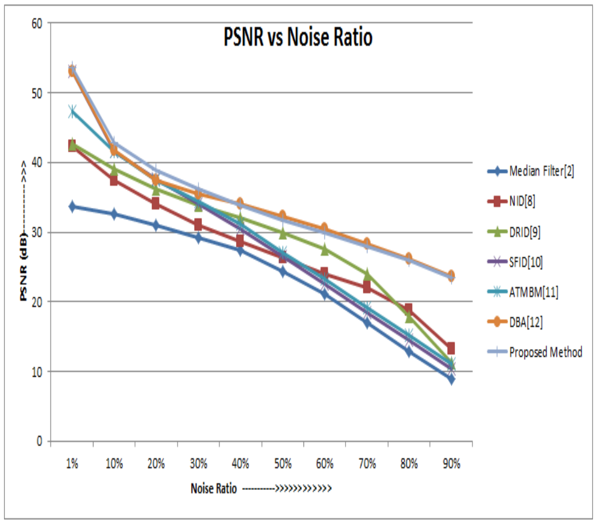

Fig. 4. PSNR COMPARISON OF THE RESTORED LENA IMAGE BY DIFFERENT METHODS FOR NOISE RATIO 1% TO 90% NOISE RATIO.

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