DECISION BASED ADAPTIVE MEDIAN FILTER TO REMOVE BLOTCHES, SCRATCHES, STREAKS, STRIPES AND IMPULSE NOISE IN IMAGES

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ABSTRACT

In this paper, a novel decision based adaptive median filter to remove blotches, scratches, streaks, stripes and random valued impulse noise in images is presented. The proposed method is a two stage algorithm. In the first stage the noise candidates are detected using rank ordered absolute difference (ROAD) value. In the second stage the replacement is done by median of uncorrupted pixels in the filtering window. The filtering window is varied adaptively based on the number of uncorrupted pixels in the window. The visual and quantitative results show the proposed filter outperforms many of the standard filters in terms of different artifact removal with edge preservation.

***Index Terms*—** Adaptive median filter, Impulse noise, Rank ordered absolute difference

1. INTRODUCTION

Digital images are often corrupted by impulse noise due to transmission errors, malfunctioning of pixel elements in the camera sensors, faulty memory locations, timing errors in analog-to-digital conversion [1]. Impulse noise is characterized by replacing a portion of an image's pixel values with random values, leaving the remainder unchanged [2]. Random valued impulse noise takes any value in the dynamic range [0,255]. Various filtering techniques have been proposed for removing impulse noise in the literature. The goal of noise removal is to suppress the noise while preserving image details. It is well-known that linear filters could produce serious image blurring [3]. As a result, nonlinear filters [8-13] have been widely exploited due to their much improved filtering performance, in terms of impulse noise removal.

In addition to impulse noise there are other types of artifact that are common in old films and video sequences are namely, blotches, scratches, streaks and stripes [4]. Stripes are a model of lines interaction with the image. A common defect in old motion picture material is line scratches [4]. They are visible as narrow, bright or dark, vertical (or near-vertical) lines, which persist for many frames. The scratches are formed by the film material running against an object in the camera or projection equipment.

A streak [5] can be any sequence of pixels in the image which has been replaced with random values. In this case the entire rows or columns from the image are replaced with arbitrary sequence of values ranging from 0 to 255. In [5] simple algorithm has been proposed to remove streaks in digital images. The blotches [6] are regions of different, usually homogeneous gray levels that can be modeled as spatial local minima or maxima. Distortions of scratches look like a thin line of pixels of arbitrary shape with nearly equal gray level values. On the other hand, distortions of blotches look like a small coherent image area of pixels with very similar gray level values. The distortions of scratches and blotches can be well modeled as a burst of impulsive noise distortions [7].

Recently, [15] a new local image statistic called ROAD (Rank-Ordered Absolute Difference) has been proposed to identify the impulsive pixels, and incorporated it into a bilateral filter [14] designed to remove additive Gaussian noise. The result is a trilateral filter capable of removing mixed Gaussian and impulse noise. ROAD statistic is very high for impulse noise pixels and much lower for uncorrupted pixels. ROAD provides a measure of how close a pixel value is to its four most similar neighbors. But when the noise level is high, it blurs images seriously.

In order to amplify the differences between noisy pixels and noise-free pixels in ROAD so that the noise detection can be more accurate, a new statistic called ROLD [16] is introduced. It uses two-stage method to detect the noisy candidate pixels and utilize the edge-preserving regularization method in the second phase. This method removes random-valued impulse noise even for noise level as high as 60%. But the main draw back is that it requires high computational time.

To overcome these difficulties in this paper a two stage decision based algorithm to remove random valued impulse noise, blotches, scratches, streaks, and stripes is proposed. In the first stage it identifies the noisy pixels using ROAD statistics and in the second stage the detected noise value is replaced by adaptive median filter. The proposed method is simple, fast and efficient compare to the recently proposed technique. The proposed algorithm outperforms many of the existing algorithms in terms of noise removal and edge preservation.

2. PRINCIPLES OF ALGORITHM

The proposed algorithm is a decision based algorithm; the algorithm first detects the noisy pixels based on the rank ordered absolute difference between the center pixel and surrounding pixels. The ROAD value of the processing pixel is calculated by summing the first five absolute difference values in the sorted array. A binary image (B) is obtained by comparing the road value with a pre defined threshold value. This process is repeated for entire image. In the binary image B the value 0 corresponds to noisy pixel and value 1 correspond to noise free pixel.

In the correction stage, the corrupted pixel is replaced by the median of the uncorrupted pixels in the 3x3 filtering window. The window size is increased if the number of uncorrupted pixels is less than three. This processing is done for the entire image.

3. PROPOSED ALGORITHM

Let X be the corrupted image of size MxN and X (i,j) denote gray level at pixel location (i,j). Let S denotes the detection window of size WxW centered at X (i,j), where $W=2L_D+1$ and initially $L_D=1$. The pixels in the detection window are defined in equation (1)

$$S = X(i+k,j+l),\ -L_D \le k,l \le L_D \qquad (1)$$

The detection, filtering and illustration of the proposed algorithm is summarized as follows

3.1 Noise Detection

Step 1: A 3x3 detection window (S) centered at X(i,j) is applied to the corrupted image. The absolute difference (D) of all the pixel values with the center pixel is obtained using equation (2)

$$D = |X(i+k,j+l)-X(i,j)|,\ -L_D \le k,l \le L_D \qquad (2)$$

Step 2: The array D is sorted and the sum of five smallest absolute differences are calculated. This gives the ROAD value for the current pixel as shown in equation (3)

$$ROAD = \sum_{n=1}^{5} D(n) \qquad (3)$$

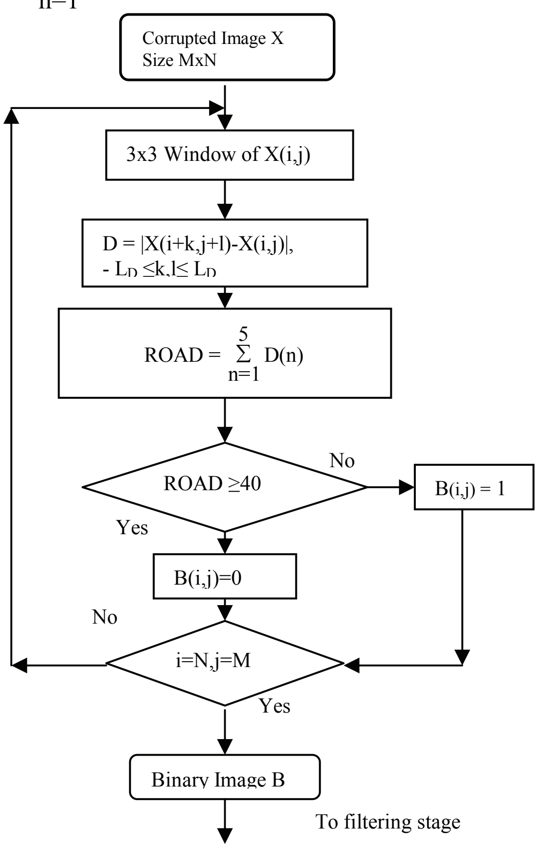

Figure 1. Flow chart of the noise detection stage

Step 3: The ROAD value of the current pixel is checked with a predefined threshold value. Based on the condition current pixel is detected as corrupted or uncorrupted. For optimum performance the threshold value is set as 40 for all images. The above steps are repeated for the entire image and a binary image (B) of size MxN is obtained using equation (4)

$$B = \begin{cases} 1, ROAD(i,j) < 40 \\ 0, ROAD(i,j) \ge 40 \end{cases} \qquad (4)$$

For better performance of PSNR and MAE, the predefined thresholds for absolute difference (D) and for ROAD value are selected as 5 and 40 respectively. Structure of the detection flow chart given in the figure (1)

3.2 Noise Filtering

Step 1:A WxW correction window centered at B(i,j) is applied to the flag image B,where $W=2L_C+1$and initially $L_C=1$. If B(i,j) =0, a resultant image R is obtained by multiplying the Binary image segment with noisy image segment by using equation (5),

$$R=X(i+k,j+l).B(i+k,j+l),\ -L_C \le k,l \le L_C \qquad (5)$$

Step 2: In R, number of non zero pixels are three and above, X(i, j) is replaced by median of non zero pixels in R. If number of non zero pixels is less than three, L_C is incremented by one and step 1 and step 2 are repeated. The same process is repeated for entire image.

3.3 Illustration

To illustrate the proposed algorithm, a 3x3 image segment from a Lena image corrupted by 40% random valued impulse noise is taken. The absolute difference (D) between center pixel and surrounding pixels are calculated and sorted. The first five values of the sorted array D is used to find the ROAD value of center pixel.

Original Segment

$$I = \begin{bmatrix} 166 & 168 & 167 \\ 163 & 173 & 157 \\ 164 & 168 & 159 \end{bmatrix}$$

Noisy Segment

$$X = \begin{bmatrix} 225 & 99 & 167 \\ 163 & 139 & 157 \\ 109 & 151 & 159 \end{bmatrix}$$

Absolute Difference Value

$$D = \begin{bmatrix} 86 & 40 & 28 \\ 24 & 0 & 18 \\ 30 & 12 & 20 \end{bmatrix}$$

Binary Image Segment

$$B = \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 1 \\ 0 & 1 & 1 \end{bmatrix}$$

Sort (D) = {0,12,18,20,24,28,30,40,86}

ROAD = 0+12+18+20+24=74

Since the ROAD value is greater than predefined threshold value (T=40), the Center pixel is considered as noisy candidate and B(i,j) set to 0. The resultant image R is obtained by multiplying the Binary image segment and noisy image segment.

$$R = \begin{bmatrix} 0 & 0 & 167 \\ 163 & 0 & 157 \\ 0 & 151 & 159 \end{bmatrix}$$

The center pixel is replaced by a median of the uncorrupted pixels in the R. i.e. Y(i,j) = median(167,163,157,151,159) = 159

4. RESULTS AND DISCUSSION

In this section, the performance of the proposed algorithm is tested for gray scale and color images of size 512 X 512 with standard algorithms for different types of degradations. The results are compared with well – known algorithms such as standard median filter (SMF)[1], adaptive median filter (AMF)[10], tri-state median filter (TF) and trilateral filter[15]. For color images the same algorithm is applied for all three channels. The resultant image is combined. The quantitative performance is compared in terms of peak signal to noise ratio (PSNR) and mean absolute error (MAE). Figure 2 shows the results for a cameraman image corrupted by blotches. The figure 2(f) clearly shows the proposed algorithm completely removes the blotches with edge preservation compared with other standard filters. The performance of the proposed algorithm is tested with other algorithm for a scratch corrupted bridge image as shown in figure 3. It can be observed from figure 3(f) the proposed algorithm removes the scratches without any trace as compared with other filters. The Pepper image is corrupted by horizontal and vertical streaking and tested with various filters as shown in figure 4. Compared to the other algorithms, the proposed algorithm completely removes the streaking with edge preservation. Figure 5 shows the results of the boat image degraded by stripes of one pixel thickness. Compared to the figure 5(d), the figure 5(f) removes the degradation more effectively with reduced blurring.

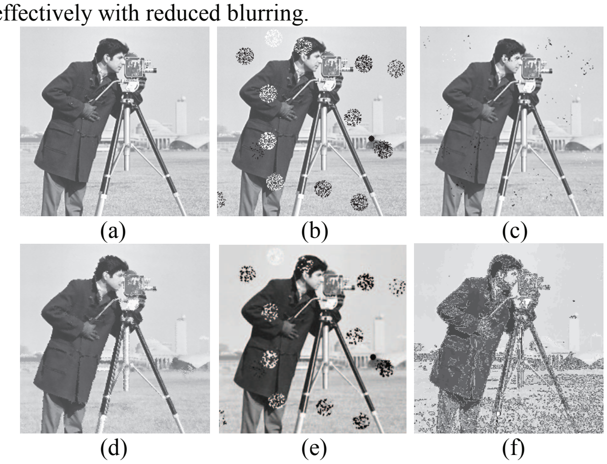

Figure 2. (a) Original image (b) Blotch corrupted Image. Restored image using (c) SMF (d) AMF (e) Trilateral (f) PA

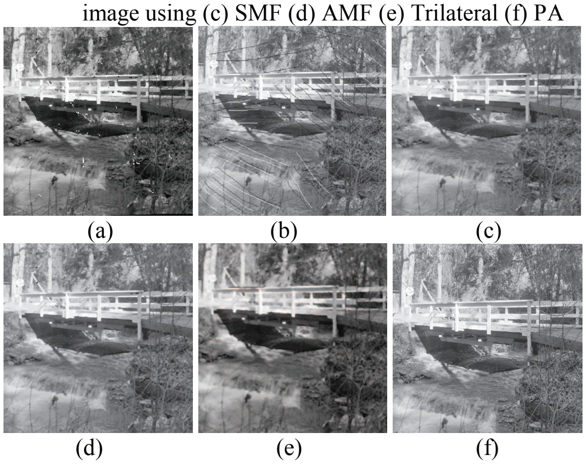

Figure 3. (a)Original image (b) Scratch corrupted Image. Restored image using(c) SMF (d) AMF (e) Trilateral (f) PA

In addition to the different types of degradations the proposed algorithm is also tested for Lena image corrupted by 40% random valued impulse noise. The restoration results is compared with standard filters namely tri-state median filter, adaptive median filter and trilateral filter. The figure 6 (f) clearly shows the proposed algorithm outperforms the existing algorithms in terms of noise removal and edge preservation. Table 1 and Table 2 shows the PSNR and MAE results of various filters for a Lena image corrupted by different noise densities. The PSNR and MAE results clearly show the superior performance of the proposed algorithm over other algorithms.

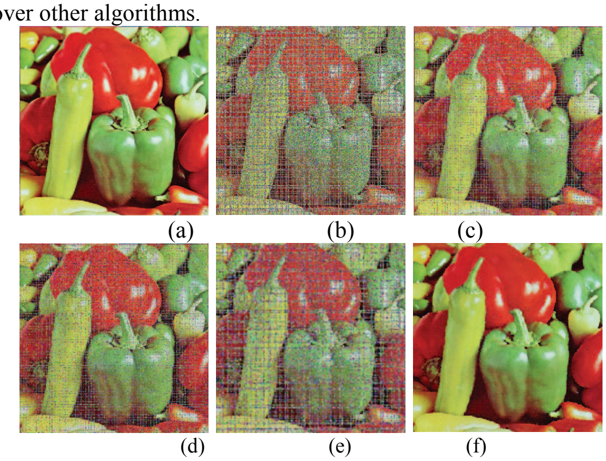

Figure 4. (a) Original image (b) Streaks Corrupted Image. Restored image using(c) SMF (d) AMF (e) Trilateral (f) PA

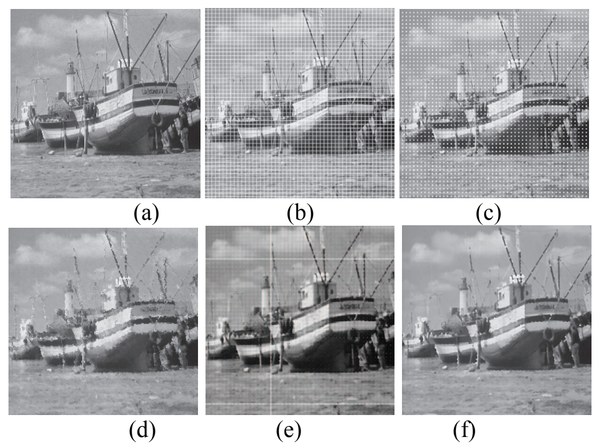

Figure 5. (a) Original image (b) Stripes Corrupted Image. Restored image using(c) SMF (d) AMF (e) Trilateral (f) PA

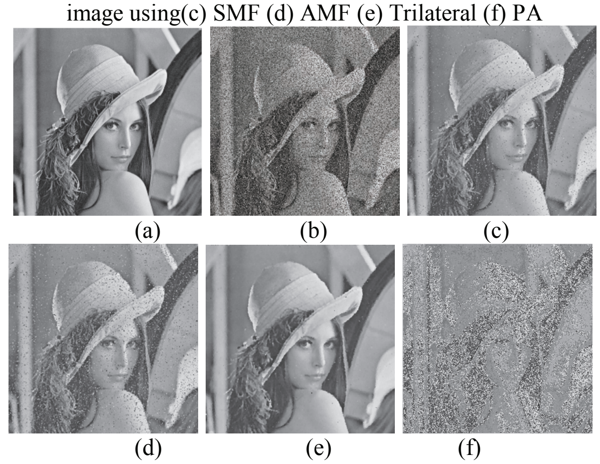

Figure 6. (a) Original image (b) streaks corrupted Image (RV40%). Restored image using(c) TF (d) AMF (e) Trilateral filter (f) PA

TABLE 1 COMPARATIVE PSNR VALUES OF VARIOUS FILTERS ON NOISY 'LENA' IMAGE

NOISE DENSITY	SMF	CWMF	ACWMF	Trilateral	PA
10	33.72	35.06	36.04	31.662	37.02
20	31.56	30.49	30.84	30.91	33.15
30	28.16	26.05	26.81	29.98	31.47
40	24.8	22.34	23.12	28.57	29.53
50	21.67	19.57	20.05	26.05	27.83
60	18.98	17.38	17.4	22.42	24.71
70	16.86	15.55	15.45	18.60	22.24
80	15.08	14.09	13.73	15.17	18.81
90	13.62	12.09	12.35	12.56	14.52

TABLE 2 COMPARATIVE MAE VALUES OF VARIOUS FILTERS ON NOISY 'LENA' IMAGE

NOISE DENSITY	SMF	CWMF	ACWMF	Trilateral	PA
10	2.79	1.73	0.71	4.06	1.56
20	3.39	2.61	1.82	4.32	2.01
30	4.52	4.42	3.52	4.68	2.56
40	6.57	7.59	6.45	5.29	3.38
50	9.98	12.21	10.88	6.59	4.41
60	15.28	18.19	17.48	9.72	7.21
70	22.03	25.54	25.17	16.42	9.1
80	30.24	34.07	34.86	28.05	15.38
90	39.55	42.92	45.53	43.75	31.34

4.1 Computation time

All the algorithms are simulated in MATLAB equipped in a Pentium dual core PC with 2 GB RAM. Table 3 shows the computation time of various algorithms for a Lena image corrupted by random valued impulse noise at 30% and 60% noise densities. It is can be observed that the proposed algorithm takes very less time compared to the existing standard algorithms.

TABLE 3 PROCESSING TIME DIFFERENT ALGORITHMS

Algorithm	Time (in seconds)	
	Noise Density 30%	Noise Density 60%
AMF	33.91	42.27
Tristate MF	24.12	24.36
Trilateral	34.31	34.41
Proposed Algorithm	15.69	22.45

5. CONCLUSION

In this paper, a new switching median filter based on rank ordered absolute differences between pixels is presented. The proposed filter shows a stable performance over a variety of gray scale and color images, provided that the threshold is chosen in the range of [35- 45] for all noise densities. The proposed algorithm is a simple algorithm to remove different types of degradations namely scratches, streaks, stripes and blotches. In addition to that the proposed algorithm is very effective in removing random valued impulse noise up to a noise density as high as 60%. It is compared with standard algorithms and the superior performance is demonstrated using qualitative and quantitative measures. The main advantage of the proposed algorithm is easy to implement in hardware and fast execution time.

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