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A NOVEL AND EFFICIENT METHOD FOR REDUCTION DEGRADATION CAUSED BY HIGH DENSITY IMPULSIVE NOISE IN DIGITAL IMAGES

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Abstract- Salt and pepper noise is the most common type of impulsive noise. In this paper, a novel technique is presented for detecting and removing of impulsive noise. In this technique, the significant parts of image information are not changed. In the proposed algorithm, several rotations and transposes of the noisy image are processed. The algorithm uses the mean or median values of the pixels in Von Neumann neighborhood of the processed pixel. Several experiments are done on different grayscales and color test image corrupted with different percent's of noise. The results show the considerable superiority of the proposed method (up to 2 dB in PSNR values) compared with the reported state of the art methods in the field.

Keywords: Noise Removal, Impulse Noise Detector, Image Enhancement.

I. INTRODUCTION

Digital images as the output of different digital cameras and scanners suffer somewhat from different kinds of noise. One of the common types of noise is impulsive noise, in which the difference between current pixels value as its neighboring pixels values are very high. Impulse noise reduction from corrupted images plays an important role in various applications of image processing applications such as image segmentation, object detection, edge detection, compression, etc.

Usually a nonlinear filter such as various kinds of median filtering has been used for noise reduction. In [1], a hybrid method based on Cellular Automata (CA) and fuzzy logic called Fuzzy Cellular Automata (FCA) in two steps is used. In [2], a modified decision based unsymmetrical trimmed median filter algorithm for the restoration of gray scale, and color images that are highly corrupted by salt and pepper noise is proposed and tested against different grayscale and color images and it gives better Peak Signal-to-Noise Ratio (PSNR) and Image Enhancement Factor (IEF).

In [3] a method for increase the performance of an ear verification system is proposed, where at first, in a pre-processing step using hybrid-denoising method, the noises are removed from ear images and then the next step these enhanced images are used for verification system. In [4], a two-step method for reduction of impulse noise is presented. At the first step, impulse noise is detected using ANFIS, and at the second step the corrupted noise pixel replaced with new value based on ANN.

Reference [5] proposes an Adaptive Neuro-Fuzzy Inference System (ANFIS) based impulse detection method for the restoration of images corrupted by impulse noise. In [6], describes the application of Cellular Automata (CA) to various image-processing tasks such as denoising and feature detection. Then, the proposed algorithm for detecting and removing of noise is discussed. Simulation results including comparison of them with the related work are presented in section III. Section IV concludes the paper.

II. PROPOSED FILTER

In this paper, an effective method for the removal of impulsive noise from images with three innovations is proposed. Several experiments are done on various noisy images with more than 30% noise density and the results show the superiority of the proposed method over existing state of the art methods and its ability to enhance the quality of grayscale or color noisy images compared with related works.

A. Detection and Removal of Impulsive Noise

In the first step of the proposed algorithm, the noisy image is scanned and processed pixel by pixel. If the current pixel value is not equal to the highest intensity value (255) or the lowest intensity value (0), its value is not be changed, else the current pixel is identified as a noisy pixel and a 3×3 window (centered in the position of current pixel) is considered.

To correct the existing noise levels in the window, if the number of zero or 255 values in the window is greater than four then the values of noisy pixels are replaced by the median value of the values of non-noisy pixels in the window. Else, the values of noisy pixels are replaced by the mean value of the values of non-noisy pixels in the window. Finally, assuming that P_{ij} is the current pixel's value in the noisy image, using Equation (1) for Von Neumann neighborhood, the P_{ij} is corrected as:

$$P_{i,j} = \frac{1}{4}\left[P_{i-1,j} + P_{i+1,j} + P_{i,j-1} + P_{i,j+1} \right] \quad (1)$$

B. Improving the Performance of Noisy Pixel's Detection and Removal Algorithm

The noise detection and removal algorithm is done on the noisy image pixel by pixel and in a row-wised scan from the first pixel of the first row to last pixel of the last row. The results of algorithm are saved in corresponding matrix. Because in noise detection and removal algorithm, in each step, the current pixel value is changed, after a few steps, the changed values are entered to the window and caused error for detecting and removing processes. In this section, we propose an idea to overcome this problem.

The noisy image is rotated 90 degrees clockwise and noise detecting and removing processes are resumed. The result is stored in a new matrix. This matrix is rotated 90 degrees counterclockwise to return to state corresponding to the original image. Rotation of noisy image is repeated with angles 180 & 270 degrees in a clockwise direction and then results are saved in matrixes and those matrixes are rotated 180 and 270 degrees counterclockwise to return to the state corresponding to the original image.

Therefor we have four two-dimensional matrixes for noisy image. These four matrixes are called as M_k, k = 1, 2, 3, 4. To get more detailed information, transpose of the noisy image is calculated and the above process for four rotations are done on it and herewith another four matrixes are created. For these four matrixes, the transpose matrixes are calculated to return to state corresponding to original image. These four matrixes are called as M_k, k = 5, 6, 7, 8.

Finally we have eight matrixes as M_k, k = 1, 2, … , 8. To form the improved image, value of each pixel position of (i,j) is replaced by median value of the corresponding values of eight matrixes $M_k(i,j)$, k = 1,2,…,8.

$$Denoised\_Image(i,j) = \underset{k}{median}\left[M_k(i,j)\right] \quad (2)$$

Figure 1 shows the structure of the second stage of the proposed algorithm.

C. Optimization of Proposed Algorithm Using Rotation and Transpose Calculation of the Noisy Image

The steps of the optimization of the proposed algorithm are illustrated as follows.

Step 1- In each stage, values of M_k (i, j) are sorted in ascending order.

$$S = \underset{k}{sort}\left[M_k(i,j)\right], \quad k = 1,2,\ldots,8 \quad (3)$$

Step 2- For each matrix M_k, a two-dimensional window of 3×3, centered at M_k (i, j) is selected. (Therefore, eight windows are created).

Step 3- Median values for all eight windows is calculated and named as *Med*.

Step 4- Based on mean value of *Med* a decision is made as:
If $Med \le S(1)$ then $T_{corrected} = S(1)$;
Else if $S(1) < Med \le S(2)$ then $T_{corrected} = S(2)$;
Else if $S(2) < Med \le S(3)$ then $T_{corrected} = S(3)$;
Else if $S(3) < Med \le S(4)$ then $T_{corrected} = S(4)$;
Else if $S(4) < Med \le S(5)$ then $T_{corrected} = Med$;
Else if $S(5) < Med \le S(6)$ then $T_{corrected} = S(5)$;
Else if $S(6) < Med \le S(7)$ then $T_{corrected} = S(6)$;
Else if $S(7) < Med \le S(8)$ then $T_{corrected} = S(7)$;
Else if $S(8) < Med$ then $T_{corrected} = S(8)$;
End if

Step 5- $T_{corrected}$ value for the current pixel is considered.

Step 6- First step to fifth step are repeated for all elements of matrixes.

III. SIMULATION RESULTS

In this paper, the proposed algorithm is compared with the several methods for detecting and removing of impulse noise such as FCA [1], ANFISFWS [3], NNANFIS [4], NNDMF [5], SNFF [6], FSF [7], IFCF [8], FIRE [9], FF [10], PSMF [11], SDROMF [12], SWMF [13], IRF [14], CWMF [15], SMF [16], TCA [17], GLAM [18], BDND [19], OSC [20], FSM [21], EEP [22], SAWM [23], CNDSM [24], NAFSM [25], NAGM [26], DNLM [27], CWM (7x7) [28], TSM (3x3) [29], LUM [30], MED (3x3), MED (5x5), MED (7x7), ATMAV [31], FSB [32], HAF [33], AWFM [34], SFCF [35], EIFCF [36], MIFCF [36], FIRE [37], FMF [38], DSFIRE [39], PWLFIRE [40], FIDRM [41].

Subjective performance of the proposed algorithm and reported pervious works are illustrated in Figures 2 and 3 for 256-gray-level Baboon and Peppers images with 80% and 50% impulse noise density. Restoration performance is quantitatively evaluated by Peak Signal-To-Noise Ratio (PSNR) and Mean Structural Similarity (MSSIM) [42], which are defined as:

$$PSNR = 10\,log_{10}\left(\frac{D^2}{MSE}\right) \quad (4)$$

$$MSE = \frac{\sum_{i=1}^{N}\sum_{j=1}^{M}\left(\left(P(i,j) - Q(i,j)\right)\right)^2}{M \times N} \quad (5)$$

$$MSSIM\left(p_k, q_k\right) = \frac{\sum_{k=1}^{B} SSIM\left(p_k, q_k\right)}{B} \quad (6)$$

$$SSIM\left(p_k, q_k\right) = \frac{\left(2\mu_{p_k}\mu_{q_k} + C_1\right)\left(2\sigma_{p_k q_k} + C_2\right)}{\left(\mu_{p_k}^2 + \mu_{q_k}^2 + C_1\right)\left(\sigma_{p_k}^2 + \sigma_{q_k}^2 + C_2\right)} \quad (7)$$

where, D is the dynamic range of the pixel intensities (255 for 8-bit gray-level images). M and N are the sizes of the images, P and Q denote the original image and the filtered image, respectively. P_k and Q_k are the image contents at the kth local window in the original and filtered images, B is the total number of local windows in the image. μ_{pk} and μ_{qk} are the mean intensity of P_k and Q_k, σ_{pk} and σ_{qk} are the standard deviation of P_k and Q_k, σ_{pkqk} is the covariance between P_k and Q_k, $C_1=(k_1D)^2$ and $C_2=(k_2D)^2$ are small constants to stabilize $SSIM$ using the following parameter settings, K_1 = 0.01 and K_1 = 0.03 [42].

The comparison between the performances of the proposed algorithm and the related works are compared in Table 1 for different density values for impulse noise. Table 1 results are depicted in Figure 4. As Figure 4 shows our proposed algorithm's performance is better than other works. The PSNR values of the enhanced images resulted from the proposed algorithm are about 2 dB higher than those of other methods.

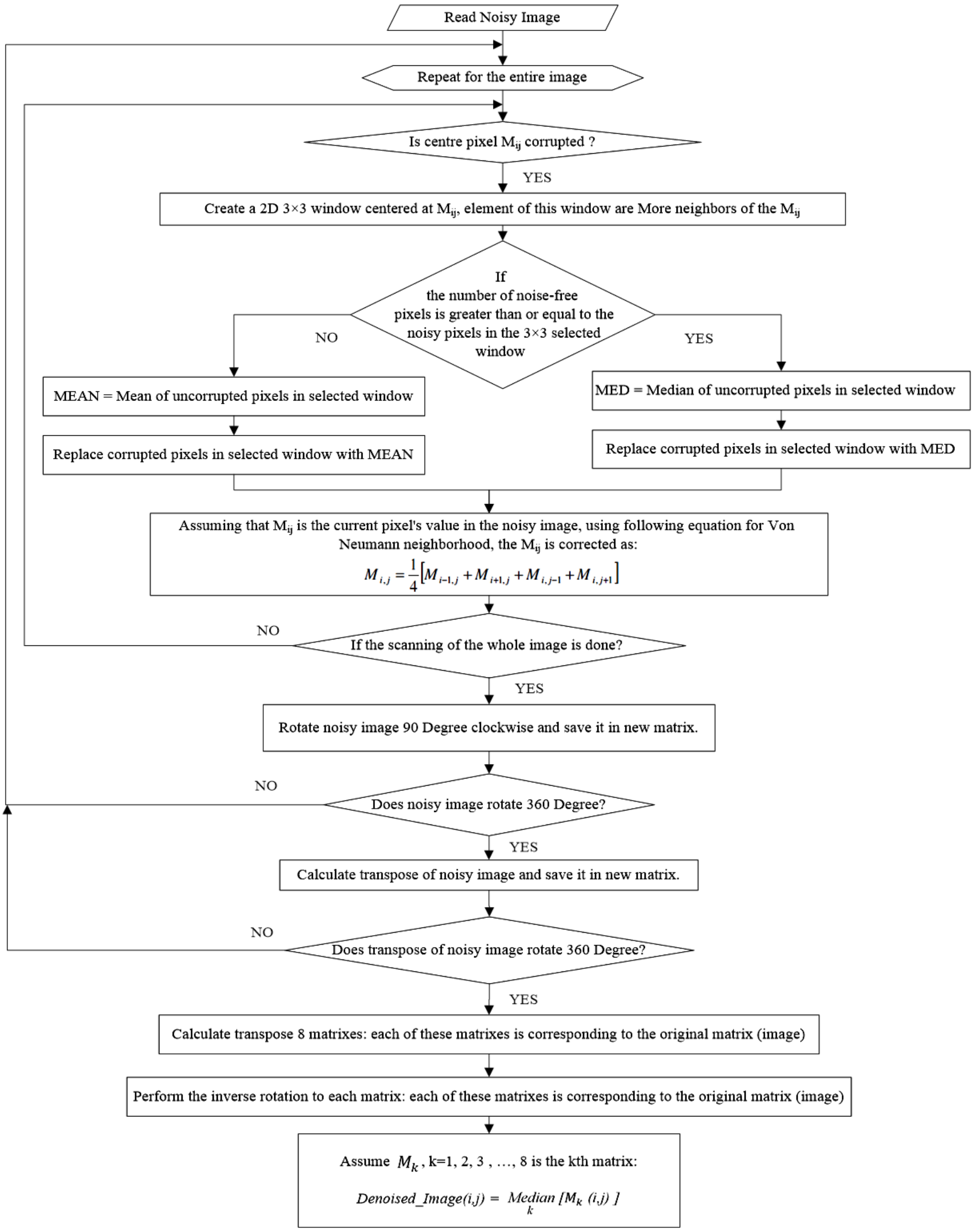

Figure 1. Structure of the second stage of the proposed algorithm

Figures 5 and 6 show MSSIM values of all the evaluated filters operating on the corrupted images Lena and Baboon, respectively. Obviously, the proposed filter produces higher MSSIM values than the other filters at the various noise ratios. In addition to the previous experiments, where only impulse noise was considered, we also compared our method for other noise situations in Table 2. The first experiment (case 1) shows the numerical results for images corrupted with impulse noise.

In the second experiment (case 2), we illustrate the filtering performance for images corrupted with a mixture of Gaussian noise and impulse noise. In this case the proposed method filters out the impulse noise but leaves the Gaussian noise, so that a Gaussian denoising filter can be applied afterwards. The simulation results show that, for the Image corrupted by hybrid impulsive and Gaussian noise, the proposed algorithm is better than the other algorithms, which are compared with that.

IV. CONCLUSIONS

In this paper a novel method, which is much better than the all comparable methods for detecting and removing of impulse noise (from images) is proposed. Subjective and objective evaluations (MSSIM and PSNR) on different images with different noise densities show the superiority of the proposed method over the related recent works in the field. The enhanced images resulted from the proposed algorithm has PSNR values which are about 2dB higher than those of other methods.

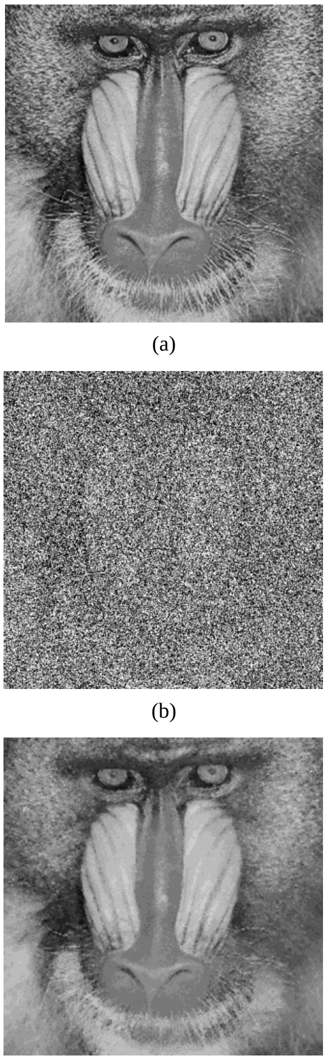

Figure 2. Results of proposed filter for Baboon image. (a) Original image Lena, (b) noisy image with 80% impulse noise, and (c) Output of proposed filter

Figure 3. Comparison of the enhanced images for the Peppers by impulse noise density of 50%

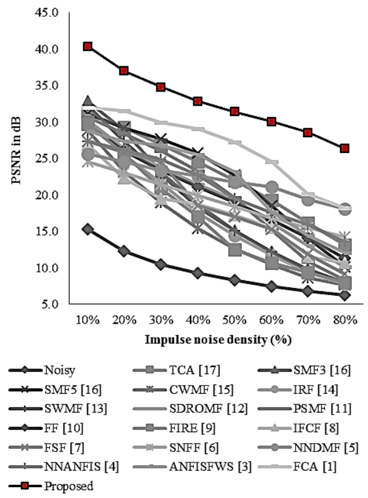

Figure 4. Comparison graph of PSNR at different noise densities for Peppers image

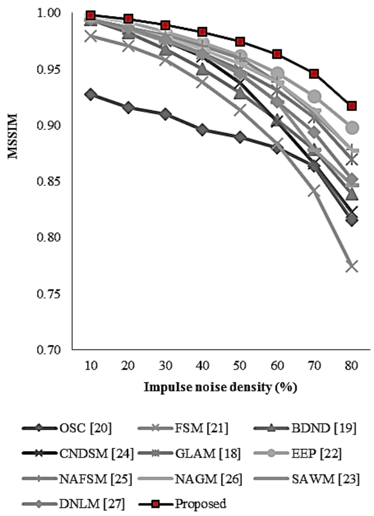

Figure 5. Restoration results in MSSIM of the various filters operating on the image (512×512) Lena

Table 1. Restoration results in PSNR (dB) of the various filters operating on the (512×512) Peppers test images corrupted impulse noise.

Methods	Noise ratio							
	10%	20%	30%	40%	50%	60%	70%	80%
Noisy	15.3	12.3	10.5	9.3	8.3	7.5	6.8	6.3
TCA [17]	31.1	29.3	26.9	24.6	22.0	19.3	16.2	13.2
SMF3 [16]	32.8	28.8	23.2	18.7	15.1	12.2	9.8	8.0
SMF5 [16]	31.1	29.2	27.7	25.7	22.7	18.5	14.1	10.2
CWMF [15]	28.9	23.3	19.0	15.4	12.6	10.5	8.6	7.7
IRF [14]	30.3	25.5	21.7	17.6	14.5	11.8	9.4	7.8
SWMF [13]	32.3	27.4	22.8	18.3	15.1	12.2	9.7	8.0
SDROMF [12]	30.3	26.4	23.8	21.4	19.4	16.2	13.1	10.2
PSMF [11]	30.7	28.4	26.1	23.3	19.6	15.2	10.9	8.3
FF [10]	29.6	26.1	23.4	21.1	19.0	16.6	14.1	11.3
FIRE [9]	29.7	25.6	20.9	17.0	12.5	10.7	9.4	8.0
IFCF [8]	26.9	22.3	19.5	18.7	17.2	15.5	11.5	10.7
FSF [7]	27.4	25.8	24.6	18.5	17.0	15.3	11.9	9.2
SNFF [6]	24.5	23.1	21.4	19.9	18.4	16.8	15.5	14.2
NNDMF [5]	25.6	24.6	23.4	22.6	21.8	21.1	19.4	18.1
NNANFIS [4]	27.3	26.2	24.9	22.7	19.5	17.6	15.9	13.6
ANFISFWS [3]	28.7	27.3	26.8	25.5	23.2	17.7	14.4	12.1
FCA [1]	32.0	31.5	29.9	29.1	27.2	24.6	20.1	18.2
Proposed	40.4	37.0	34.8	32.9	31.4	30.1	28.5	26.4

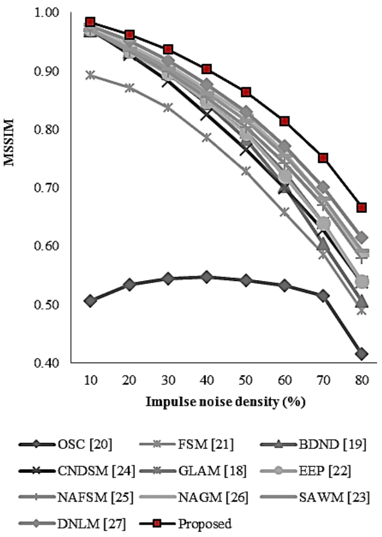

Figure 6. Restoration results in MSSIM of the various filters operating on the image (512×512) Baboon

Table 2. PSNR results for the (256 × 256) Lena image for different impulse noise cases with Case 1- impulse noise, Case 2- Gaussian noise with $\sigma = 5$ mixed with Impulse noise

Methods	Case 1			Case 2		
	5%	20%	30%	5%	20%	30%
CWM (3x3) [28]	33.0	27.3	23.5	31.0	27.1	23.4
CWM (7x7) [28]	29.4	26.7	26.1	28.7	29.6	25.6
TSM (3x3) [29]	34.7	27.7	23.8	31.6	28.2	24.1
TSM (7x7) [29]	32.7	26.6	23.9	30.6	27.3	23.8
LUM [30]	32.7	26.9	23.8	30.9	26.9	23.8
MED (3x3)	29.7	26.9	23.8	29.1	26.9	23.9
MED (5x5)	27.3	26.5	26.1	27.2	26.8	25.9
MED (7x7)	25.8	25.3	25.2	25.7	25.4	25.0
ATMAV [31]	20.3	21.7	21.3	27.8	26.9	26.3
FSB [32]	29.4	26.9	23.1	29.2	26.9	23.7
HAF [33]	28.6	24.5	22.0	28.9	28.4	27.5
AWFM [34]	29.6	27.4	26.3	30.2	29.7	28.3
SFCF [35]	29.3	25.0	21.2	28.8	24.9	21.7
EIFCF [36]	29.5	26.9	24.3	29.0	26.6	24.0
MIFCF [36]	29.7	26.3	23.1	29.4	25.7	22.8
IFCF [36]	29.6	26.9	24.3	29.2	26.6	24.2
FIRE [37]	31.8	24.3	20.4	30.0	24.0	20.4
FMF [38]	33.9	27.8	23.4	32.0	27.7	23.9
DSFIRE [39]	23.6	22.6	21.5	23.5	23.1	21.9
PWLFIRE [40]	35.2	24.0	29.5	32.2	23.6	19.5
FIDRM [41]	40.7	33.9	31.8	35.3	32.8	31.0
Proposed	41.2	34.4	32.5	40.2	33.8	31.6

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BIOGRAPHIES

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