Random Valued Impulse Noise Removal Using Region Based Detection Approach

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***Abstract*—Removal of random valued noisy pixel is extremely challenging when the noise density is above 50%. The existing filters are generally not capable of eliminating such noise when density is above 70%. In this paper a region wise density based detection algorithm for random valued impulse noise has been proposed. On the basis of the intensity values, the pixels of a particular window are sorted and then stored into four regions. The higher density based region is considered for stepwise detection of noisy pixels. As a result of this detection scheme a maximum of 75% of noisy pixels can be detected. For this purpose this paper proposes a unique noise removal algorithm. It was experimentally proved that the proposed algorithm not only performs exceptionally when it comes to visual qualitative judgment of standard images but also this filter combination outsmarts the existing algorithm in terms of MSE, PSNR and SSIM comparison even up to 70% noise density level.**

Keywords-random valued inpulse noise; image filtering; region based; detection

I. INTRODUCTION

Random valued impulse noise removal is a stringent task. This type of noise is introduced in the digital images through transmission and acquisition [1]. A significant characteristic of this type of noise is that only fractions of the pixels are degraded [2]. A variety of filters [4-22] are being proposed in past years to remove random valued impulse noise. The main motive of using these filters is to detect and reduce the noise as well as preserving the image information. Median filters were rapidly used to remove this type of noise. Author in [3] introduced a median filter which was able to contain noise up to some level. It was a good filter, which preserved edges greatly. But this filter was not fulty effective as noiseless pixels also got changed during restoration. Successively some other median filters were proposed [4-6]. These filters provided noise restoration to a medium level but they were not so effective for the same reason, so the image got blurred and edges were modified. Afterwards a variety of condition based filters were introduced. But those filters failed to restore the noise effectively. Author in [7] introduced a two phase swap filter which was able to preserve details at a low noise density. A tri state median filter that used a standard median and center weighted median filter to detect the noise but was not able to preserve minute details at medium noise densities was proposed in [8]. In [9], author proposed another adaptive center weighted median filter which sighted a slight improvement in preserving details but that also in lower noise densities. Author in [10] introduced a filter which was able to preserve minute details at medium noise density. Though the detection cabability was not that impressive. To enhance its capability a generic programming filter was proposed in [11]. This filter had a two stage cascading detector which enchanced the detection rate. A new dimension in the filtering is introduced in [12]. This was a PDE based technique which used anisotropic diffusion to filter impulsive noise. The method performed better than the previous disscussed schemes. In 2012 ROR [13] (robust outlyingness ratio) was proposed. This filter first calucated a robust outlyingness ratio to find out the impulsive pixels then by the ROR value the pixels are divide into four clusters. It was followed by a two stage detection process. Use of fuzzy filters had also shown great result. In 2013 a robust direction based detector [14] was proposed which used standard deviation based detection procedure to filter the noise. Afterwards, TDWM [15] was proposed. This filter used directional threshold based approach to remove noise. This filter was good at medium noise density level. Recently, a new detection method was introduced in [16]. This method used standard deviation and threshold concept together to approximate neighborhood pixels. This filter was successful at 60% noise density but failed once the noise was higher than that. So, removal of impulse at higher noise density was still a task to be achieved. In this paper, a two-step, region based, detection and removal method is introduced. This method generated improved results in higher noise densities. The rest of the paper is organized as follows. Proposed methodology is discussed in Section II. Computer-generated results and comparisons with recent filters are presented in Section III. Finally future challenges and conclusion are discussed in Section IV.

II. PROPOSED METHODOLOGY

Let $x_{i,j}$ for (i,j) Є A ≡ {1,2,3,…M} × {1,2,3,……N} be the intensity of the pixel at pixel location (i,j) of a random valued corrupted M×N image X. Simultaneously a same size binary flag image F has been generated taking all values of the pixels $f_{i,j} = 1$.

A. Noise Detection Part

A 5× 5 window (W) has been created taking center pixel in $x_{i,j}$ the image X. A set {S} is formed taking all the elements of the window and the elements are put in increasing order.

S= {s1, s2, s3, s4, ……., s25} $\forall$ s1 ≤ s2 ≤ s3 ≤ ……≤ s25

Four subsets S1, S2, S3, S4 are also formed like below.

S1= { si : 0 ≤ si ≤ 60 } $\forall$ i = 1,2,3,4,…..,25

S2= { si : 61 ≤ si ≤ 120 } $\forall$ i = 1,2,3,4,…..,25

S3= { si : 121 ≤ si ≤ 180 } $\forall$ i = 1,2,3,4,…..,25

S4= { si : 181 ≤ si ≤ 255 } $\forall$ i = 1,2,3,4,…..,25

Now n(S1), n(S2), n(S3), n(S4) are calculated.

Examining Max n(Si) $\forall$ i= 1,2,3,4 the following steps are followed:

if n(S1) is Max

$$m = \frac{s_6 + s_7 + s_8}{3}$$

else if n(S2) is Max

$$m = \frac{s_9 + s_{10} + s_{11}}{3}$$

else if n(S3) is Max

$$m = \frac{s_{12} + s_{13} + s_{14}}{3}$$

else

$$m = \frac{s_{17} + s_{18} + s_{19}}{3}$$

Hence standard deviation (σ) is calculated taking all the elements of W with equation no 1.

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2} \quad (1)$$

if $\left|x_{i,j} - m\right| \le \sigma$ then

$x_{i,j}$ is considered as a undisturbed pixel

else

noisy pixel and simultaneously pixel of the binary image F is replaced by 0 i.e $f_{i,j} = 0$.

After completing the above process the updated binary flag image F1 is generated.

The above algorithm is based on maximum no of elements of the four subsets. Here it is considered that the undisturbed pixels will increase the no of elements in the corresponding subsets. Here S is a set of elements in increasing order. The undisturbed pixels will take their positions 6,7,8 for S1, 9,10,11 for S2, 12,13,14 for S3 and 17,18,19 for S4 respectively. As the aforementioned algorithm is not sufficient to find out the disturbed elements above 75%, for final detection and filtering, next algorithms are followed.

B. Noise Removal Part

The image X (M×N) and the binary flag image F1 (M×N) are taken for further operation. Here $x_{i,j}$ and $f_{i,j}$ are considered a pixel value at the location i, j in the images X and F1.

if ($f_{i,j}$ == 0) then

replace $x_{i,j} = 0$.

Completing the above process image X1 (M×N) is generated.

1) Algorithm 1

if ($x_{i,j}$ == 0) then

use SCMMF [17] algorithm for removal process.

Completing all the steps same size image X6 (M×N) is generated

2) Algorithm 2

A 3×3 matrix from image X6 is created taking $x_{i,j}$ as center. Here $x_{i,j}$ and $f_{i,j}$ are considered a pixel value at the location i,j in the images X6 and F1.

if ($f_{i,j}$ == 1) then

Let A = {x : x ≠ 0}

Let B = { y : y = $\left|x_{i,j} - x\right| \ge \sigma$}

if (n(B)≥5) then

replace $x_{i,j} = \frac{\sum y}{n(B)}$

Completing all the steps a final same size output image X7 (M×N) is generated.

III. RESULT AND ANALYSIS

This method is evaluated using MATLAB 7.12 (R2011a) in a 2.8-GHz CPU with 2 GB RAM. To check the effeteness of the proposed algorithm, random Matlab images are used. Noise density is varied from 30% to 70%. The quality analysis of the proposed algorithm is shown in Figure 1.

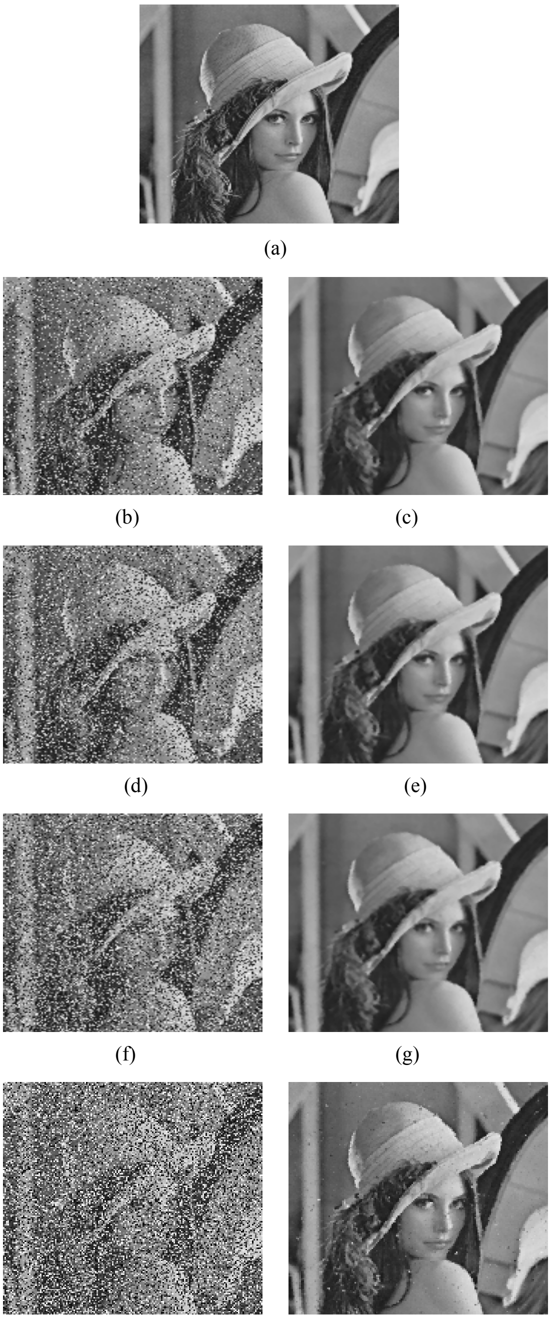


Fig. 1. Result of proposed filters on Lena image (a) Original Image (b) 30% noise corrupted image (c) proposed filter output (30%) (d) 40% noise corrupted image (e) proposed filter output (40%) (f) 50% noise corrupted image (g) proposed filter output (50%) (h) 60% noise corrupted image (i) proposed filter output (60%)

Numeric analysis of the proposed method is quantified by Mean Square Error (MSE), Peak Signal-to-Noise Ratio (PSNR), Structural Similarity Index Measurement (SSIM) [18] and Mean Structural Similarity Index Measurement (MSSIM) as clarified in (2), (3), (4), and (5) respectively:

$$\text{MSE}=\left(\sum_{M,N}\frac{\left(O(m,n)-\hat{O}(m,n)\right)^2}{M\times N}\right) \quad (2)$$

where,

O = Original Image

$\hat{O}$ = De-noised image

M= Number of rows

N= Number of columns

$$PSNR=10\log_{10}\frac{255^2}{MSE} \quad (3)$$

$$SSIM(x,y)=\frac{(2\mu_x\mu_y+C_1)(2\sigma_{xy}+C_2)}{(\mu_x^2+\mu_y^2+C_1)(\sigma_x^2+\sigma_y^2+C_2)} \quad (4)$$

$$MSSIM(x,y)=\frac{1}{M}\sum_{m=1}^{M}SSIM(x_m,y_m) \quad (5)$$

where μ_x and μ_y are the means of image x and image y respectively. The standard deviation of image x and image y is denoted by σ_x and σ_y respectively. C_1, C_2 are the constants σ_{xy} is the co-variance of x and y, given by :

$$\mu_x=\frac{1}{N}\sum_{i=1}^{N}x_i$$

$$\sigma_x=\left[\frac{1}{N-1}\sum_{i=i}^{N}(x_i-\mu_x)^2\right]^{\frac{1}{2}}$$

$$\sigma_{xy}=\left(\frac{1}{N-1}\sum_{i=i}^{N}(x_i-\mu_x)\right)$$

The comparison of PSNR values of the proposed algorithm with respect to known filters is represented in Table I. At high noise density level i.e. 40-60% the proposed method obviously outperforms the existing filters. Table II represents the PSNR values of different images at 70% noise density. Figure 2 states the perceptible results at images Lena, Gold Hill and Cameraman at 70% noise density level. MSSIM is used to evaluate the structural symmetry of Lena image at varying noise densities, shown in Figure 4. The PSNR values of the popular images like Lena, Cameraman and Gold Hill at 70% noise density with respect to the proposed method are discussed in Table II. From the qualitative, numeric and structural analysis it is obvious that the performance of the proposed method produced superior performance than other recent filters especially at high noise density levels. Figure 3 reflects the comparison of the proposed filter with other various filters by the graph of MSE against the noise density 30%-60% for the Lena image.

TABLE I. COMPARISON OF PSNR VALUES OF DIFFERENT FILTERS FOR LENA IMAGE AT VARIOUS NOISE DENSITIES

Image	Filters	30%	40%	50%	60%
Lena	LUO	30.29	28.27	26.23	24.21
	GP	31.87	28.42	24.86	21.68
	NSDD	30.86	28.35	26.39	24.08
	ROR	24.93	21.51	18.69	15.61
	RDD	26.14	22.98	19.99	16.72
	TDWM	28.02	26.85	25.88	25.00
	[16]	30.68	29.41	27.41	25.10
	Proposed	**29.80**	**29.45**	**28.64**	**28.49**

TABLE II. PSNR FOR DIFFERENT IMAGES FOR PROPOSED METHOD AT 70% NOISE DENSITY

PSNR		
Lena	**Gold Hill**	**Cameraman**
26.10	26.37	25.47

(a) (b) (c)

Fig. 2. Result of different images by proposed filter at 70% noise density (a) Lena (b) Gold-hill (c) Cameraman.

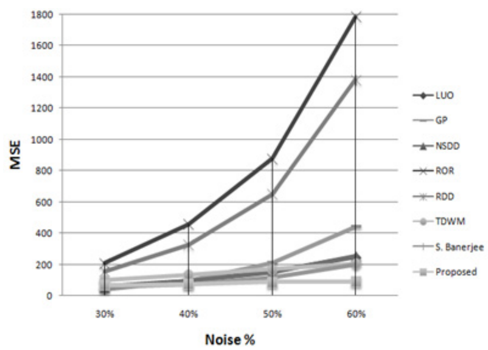
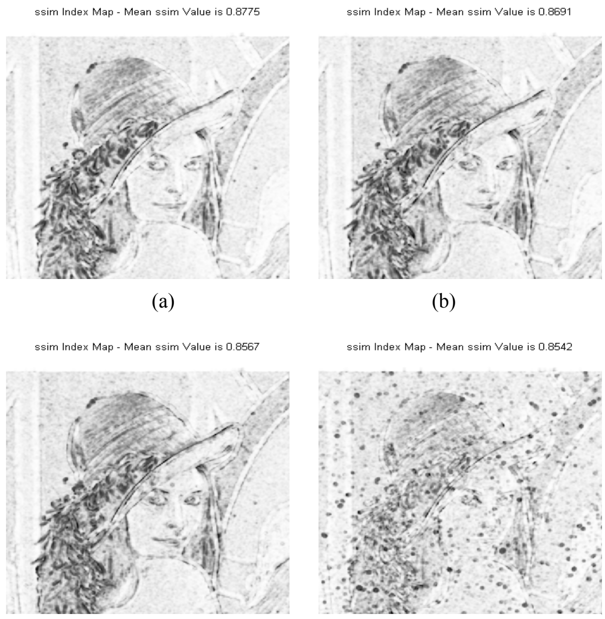


Fig. 3. Comparison graph of MSE at different noise densities for Lena Image.

IV. CONCLUSIONS

This paper takes into account both traditional and avant-garde random valued impulsive noise removal filter techniques. The studied filters LUO, GP, NSDD, ROR, RDD, TDWM are chiefly explored and a comparative study with special emphasis at high noise density level is presented. Earlier contributions in this area of work are revised, re-embellished and produced in a more comprehensive but simplified manner that would make this work understandable even to people with general science background. This work focuses on the existing renowned filters and also on the latest findings. It was observed that the usage of those filters was not up to the mark at high density noise levels. This work is an attempt to bridge that gap by introducing the modified filters.



(a) (b)

(c) (d)

Fig. 4. SSIM Index map (MSSIM) of Lena image at noise density: (a) 30% (MSSIM=0.8775), (b) 40% (MSSIM=0.8691), (c) 50% (MSSIM=0.8567), (d) 60% (MSSIM= 0.8542).

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