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A Hybrid Approach of Impulsive Noise Detection and Filter Using Adaptive Windows

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ABSTRACT

Digital Image processing involves changing the nature of an image in order to improve its pictorial information for human interpretation. Images are suffered from various types of the noises due to various reasons. Removal of noise from the images is very necessary before carrying out certain operation on them. So to image restoration is very important area of image processing. Impulse noise is basically introduced due to the bit error in transmission, faulty memory locations or timing errors in analog-to-digital conversion and also introduced during image acquisition stage. There are different kinds of impulse noise which depends upon the noise value and based upon this, impulse noise could be categorized as Salt and Pepper Noise (SNP), random valued noise (RVN) and universal impulse noise. A wide variety of existing algorithms are there having their own assumptions, views, merits and demerits and still the search of more efficient and better algorithm is a tricky challenge for the researchers. The major objectives of the present work is to propose an efficient, and growing length window, multiple scanning algorithm where noisy pixels will be trimmed and processing pixel will be replaced by the median value of the remaining noise free window for de-noising high density salt and pepper noise. Our proposed algorithm utilizes two different windows viz. Simplified window and Full window to determine whether a pixel is noisy or noise free. The simplified window is used in case of low noise density, otherwise full window is used. Besides, if in the selected window 90% or more pixels are corrupted then in such situation mean is used to replace the noisy pixels value else noisy pixel is replaced by the median value of the window. In this approach, only the disturbed pixels are treated and thus, they are detected first depending upon the minimum (0) and maximum (255) value. If the current pixel lies between maximum and minimum value, then it is not processed by the proposed filter. The proposed algorithm is effectual for salt and pepper noise elimination from images at low, medium and high noise densities and it processes mutually together on gray scale and color images. It provides quality results in terms of Mean Square Error (MSE), Peak Signal-to-Noise Ratio (PSNR.Structure Similarity Index measure (SSIM), and Image Enhancement Factor (IEF).

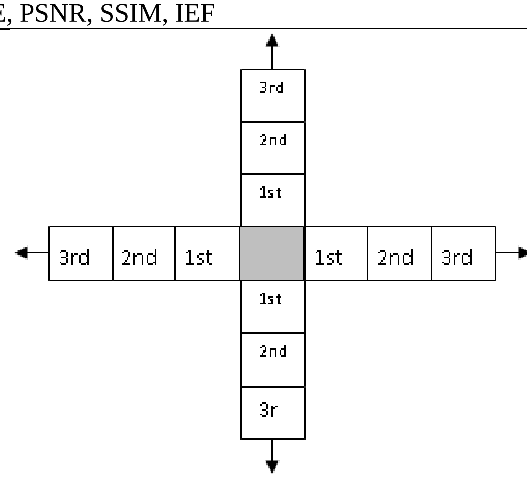
***Keywords* –** Impulse Noise, Simplified Window, Full Window, MSE, PSNR, SSIM, IEF

I. INTRODUCTION

1.1 Window

Our proposed algorithm utilizes two different windows viz. Simplified window and Full window to determine whether a pixel is noisy or noise free.

(i) Simplified window: For an image with low noise density simplified window is employed as in this case searching the diagonal sides of awindow is not required while the noise free pixels can be searched from horizontal and vertical lines.



(ii) Full window: In case noise densityin an image is high (ND > 50%) full window is used and the noisy pixel is replaced by the median of remaining elements of full window.

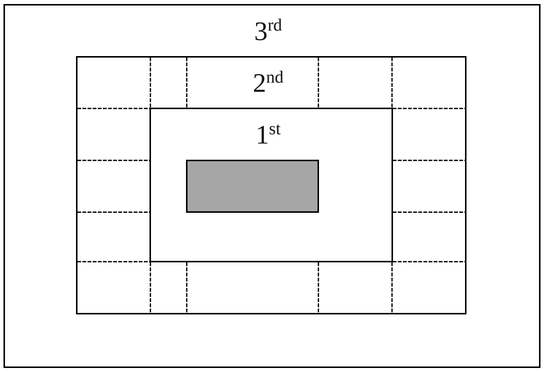


Fig. Full Window

1.2 Flowchart and algorithm

The algorithms based on growing window dimension as the probability of finding noise-free pixel increases when the window size is increased.
Unlike decision based algorithms the proposed algorithm consists of two stages first of Noise detections and then image restoration.

Window Selection: Estimated noise probability and the probability of being uncorrupted is $\tilde{p}$ and $1-\tilde{p}$. Therefore, by the applying binomial distribution, the predictable noise-free pixel is $(w^2-1)(1-\tilde{p})$ inside a window dimension of $w \times w$.
Through simulations the optimal value of the uncorrupted pixels in the neighborhood of the pixel under consideration comes out to be 5. Because of which the window size is obtained as the smallest odd integer greater than $\sqrt{1+\frac{5}{1-p}}$.
It has been observed that lower number of uncorrupted pixel in the pixel's neighborhood increases the detection error and higher number results in bigger window which further affects the detection accuracy as the pixels involved have less correlation with the central pixel.

Step 1: The first footstep in the proposed 2-phase method is to determine the impulse values in image, N_{min} and N_{max} and then construct the set of doubtful pixels. For this reason, proposed method present a straight forward rule, mentioned in Eq. (4.2).

$$\Omega_I = \{(i,j) | \tilde{x}_{i,j} = N_{min})(\tilde{x}_{i,j} = N_{max})\} \qquad (1.2)$$

Where symbol ∨ in (4.2) denotes logical OR. The set Ω_I contain the indices of doubtful or suspicious pixels.
Step 2: Calculate rate of suspicious pixels that is noise density $\tilde{p}$ and set window size w up to the least odd integer more than $\sqrt{1+\frac{5}{1-p}}$.

Step 3: Now, compute pixel's count $d_{i,j}^{min}$ and $d_{i,j}^{max}$ within the neighborhood of the pixel on coordinate (i,j) through grey values up to N_{min} and N_{max}, correspondingly.

Step 4: Prepare datasets of uncorrupted pixels using N_{min}, N_{max}, w, $d_{i,j}^{min}$ and $d_{i,j}^{max}$, respectively. The datasets for this purpose are given below in Eq.(1.3) and Eq.(1.4).

$$\Omega_{D1} = \{((i,j | d_{i,j}^{min} + d_{i,j}^{max} = w^2))\} \qquad (1.3)$$

$$\Omega_{D2} = \left\{ \begin{array}{c} \left(i,j \,\middle|\, (\tilde{x}_{i,j} = N_{min}) \wedge \left(d_{i,j}^{max} < \frac{d_{i,j}^{min}}{3} \right) \right) \vee \\ \left((\tilde{x}_{i,j} = N_{max}) \wedge \left(d_{i,j}^{min} < \frac{d_{i,j}^{min}}{3} \right) \right) \end{array} \right\}$$

(1.4)

symbol ∧ is logical AND.
Where ∩ along with ∪ denotes the intersection and union operations and $\bar{A}$ meant for the complement set of A.
From equations (1.3)-(1.4) entail that the pixel by means of impulse value is regarded as noise-free if:

(1) Each and every one of its surrounding pixels contain values identical to the impulse values,
(2) The greater part of its surrounding pixels is liable to individual of the impulse values,
(3) It enriches in this inclination
(4)

Step 5: Prepare set of corrupted pixels from uncorrupted datasets.

$$\Omega = \Omega_I \cap (\overline{\Omega_{D1}} \cup \overline{\Omega_{D2}}) \qquad (1.5)$$

Step 6: Set Mask matrix M for noisy image. Set 0 for noisy pixel and 1 for uncorrupted pixel in mask M.

$$M_{i,j} = \begin{cases} 0 \text{ if } (i,j) \in \Omega \\ 1 \text{ if } (i,j) \notin \Omega \end{cases} \qquad (1.6)$$

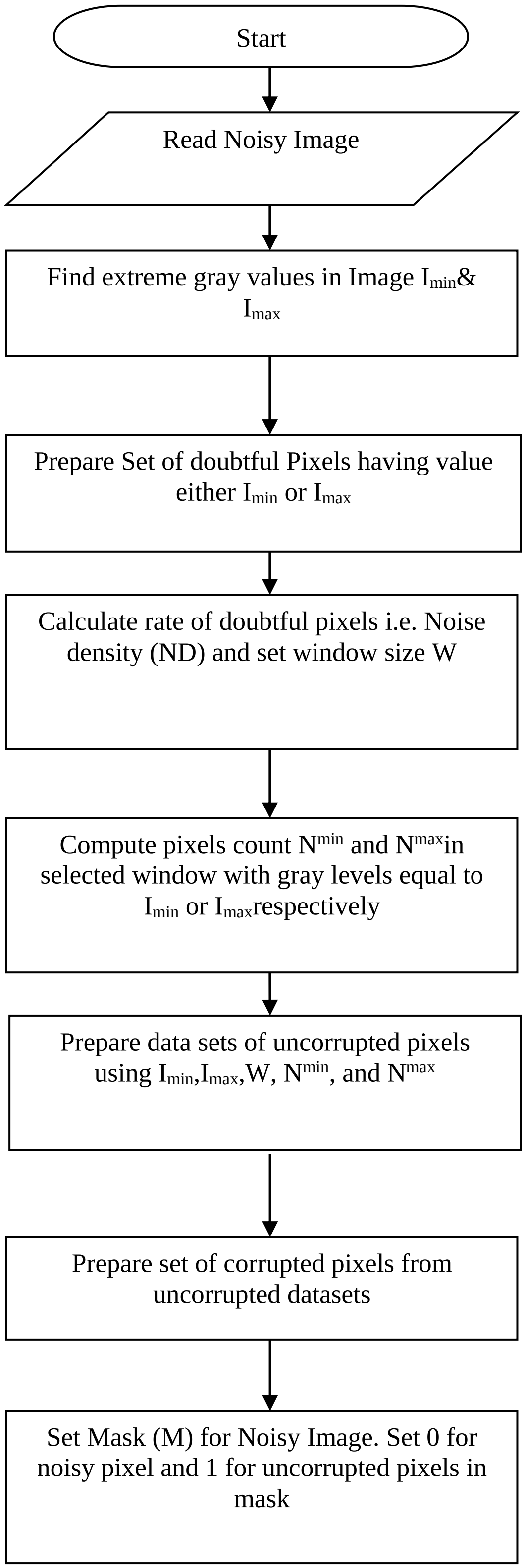


Fig. 4.5 Flow chart of impulse detector

II. TABLES, FIGURES AND EQUATIONS

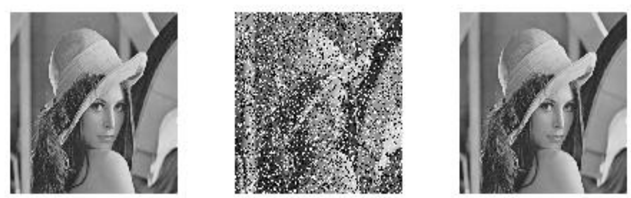
2.1Performance of Proposed Filter for Gray Scale Test Images

(a) (b) (c)

Fig. 2.1 Simulation Results of Lena Gray Scale Image at 10% Noise Density. (a) Original Image (b) Noisy Image (c) Denoised Image

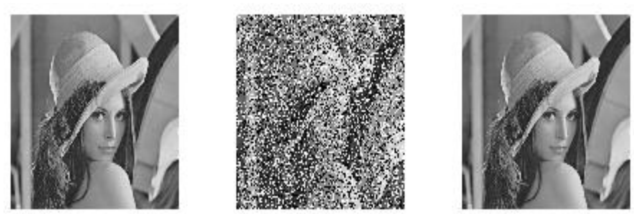
(a) (b) (c)

Fig. 2.2 Simulation Results of Lena Gray Scale Image at 20% Noise Density. (a) Original Image (b) Noisy Image (c) Denoised Image



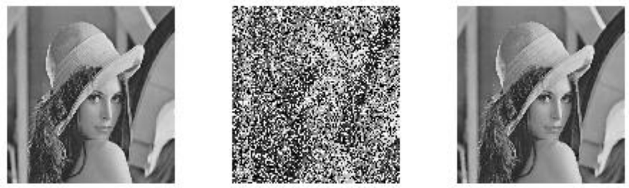
(a) (b) (c)

Fig. 2.3 Simulation Results of Lena Gray Scale Image at 30% Noise Density. (a) Original Image (b) Noisy Image (c) Denoised Image



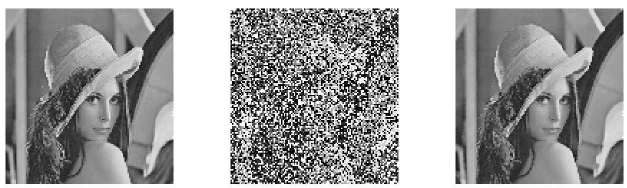
(a) (b) (c)

Fig 2.4 Simulation Results of Lena Gray Scale Image at 40% Noise Density. (a) Original Image (b) Noisy Image (c) Denoised Image



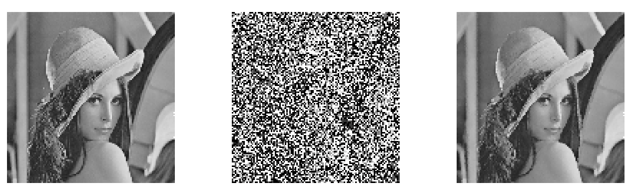
(a) (b) (c)

Fig 2.5 Simulation Results of Lena Gray Scale Image at 50% Noise Density. (a) Original Image (b) Noisy Image (c) Denoised Image



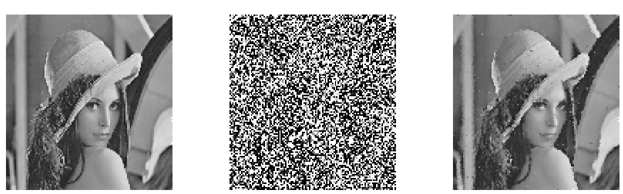
(a) (b) (c)

Fig 2.6 Simulation Results of Lena Gray Scale Image at 60% Noise Density. (a) Original Image (b) Noisy Image (c) Denoised Image



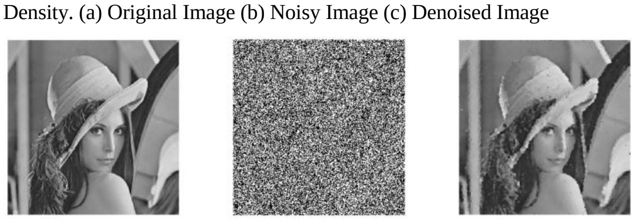
(a) (b) (c)

Fig 2.7 Simulation Results of Lena Gray Scale Image at 70% Noise Density. (a) Original Image (b) Noisy Image (c) Denoised Image



(a) (b) (c)

Fig 2.8 Simulation Results of Lena Gray Scale Image at 80% Noise Density. (a) Original Image (b) Noisy Image (c) Denoised Image



(a) (b) (c)

Fig 2.9 Simulation Results of Lena Gray Scale Image at 90% Noise Density. (a) Original Image (b) Noisy Image (c) Denoised Image

2.2 Performance of Proposed Filter for Color Test Images

(a) (b) (c)

Fig. 2.10 Simulation Results of Lena Color Image at 10% Noise Density. (a) Original Image (b) Noisy Image (c) Denoised Image

(a) (b) (c)

Fig. 2.11 Simulation Results of Lena Color Image at 20% Noise Density. (a) Original Image (b) Noisy Image (c) Denoised Image

(a) (b) (c)

Fig. 2.13 Simulation Results of Lena Color Image at 30% Noise Density. (a) Original Image (b) Noisy Image (c) Denoised Image

(a) (b) (c)

Fig. 2.14 Simulation Results of Lena Color Image at 40% Noise Density. (a) Original Image (b) Noisy Image (c) Denoised Image

(a) (b) (c)

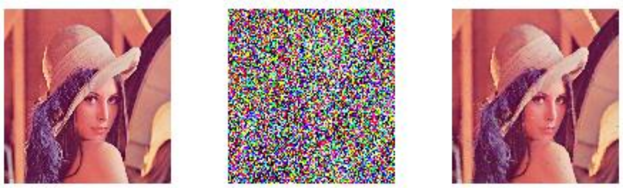
Fig. 2.14 Simulation Results of Lena Color Image at 50% Noise Density. (a) Original Image (b) Noisy Image (c) Denoised Image

(a) (b) (c)

Fig. 2.15 Simulation Results of Lena Color Image at 60% Noise Density. (a) Original Image (b) Noisy Image (c) Denoised Image

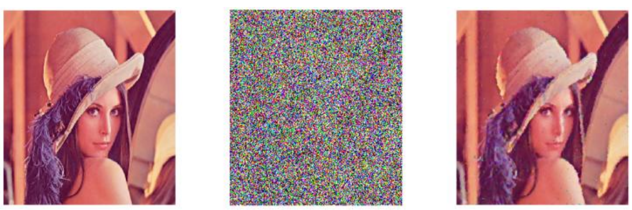
(a) (b) (c)

Fig. 2.16 Simulation Results of Lena Color Image at 70% Noise Density. (a) Original Image (b) Noisy Image (c) Denoised Image



(a) (b) (c)

Fig. 2.17 Simulation Results of Lena Color Image at 80% Noise Density. (a) Original Image (b) Noisy Image (c) Denoised Image



(a) (b) (c)

Fig. 2.18 Simulation Results of Lena Color Image at 90% Noise Density. (a) Original Image (b) Noisy Image (c) Denoised Image

2.3 Comparison of Results with Some Existing Filters

Noise Density (%)	Proposed Method	EWA [11]
10	47.74	42.49
20	44.18	39.11
30	41.99	37.15
40	40.29	35.61
50	39.03	34.22
60	37.72	32.81
70	36.68	31.30
80	35.59	29.68
90	34.24	26.89

Comparison of PSNR Values of Proposed Algorithm with EWA Algorithm for Lena Grey-Scale Image at Different Noise Densities

III. EQUATIONS

$$PSNR(dB) = 10log_{10}\left(\frac{255^2}{\frac{1}{M\times N}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}(X-Y)^2}\right) \quad (3.1)$$

$$IEF = \frac{E[N(i,j)-X(i,j)]^2}{E[Y(i,j)-N(i,j)]^2} \quad (3.2)$$

$$SSIM = \frac{(2\bar{x}\bar{y}+C1)(2\sigma_{xy}+C2)}{((\bar{x})^2+(\bar{y}^2)+C1)(\sigma_x{}^2+\sigma_y{}^2+C2)} \quad (3.3)$$

Where X(i,j) is the original image, N(i,j) is the noisy image and Y(i,j) is the denoised image. $\bar{x}$, $\bar{y}$ and σ represents the mean intensity of original image, mean intensity of denoised image and standard deviation, C_1 and C_2 are the constants and σ_{OD} is the covariance and are given as:

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

$$\bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_i$$

$$\sigma_x{}^2 = \frac{1}{N-1}\sum_{i=1}^{N}(x-\bar{x})^2$$

$$\sigma_y{}^2 = \frac{1}{N-1}\sum_{i=1}^{N}(y-\bar{y})^2$$

$$\sigma_{xy} = \frac{1}{N-1}\sum_{i=1}^{N}(x-\bar{x})(y-\bar{y})$$

SSIM value closer to 1 represents the better quality of the restored image.

$$IQI = Crr(x,y) \times L(x,y) \times C(x,y) \quad (3.4)$$

Where, Crr(x, y) is correlation between the original image and denoised image, L(x, y) is luminous distortion between the images and C(x, y) is the contrast distortion. The minimum value of IQI can be -1 and its maximum value can be 1. The more the value is close to 1, better will be the quality of restored image. The performance of the gray scale images of the proposed filter is evaluated in terms of BER, MSE, PSNR, IEF and SSIM.

For the color images, it first of all separates the three different layers and then performs filtering on each layer separately and finally combines the three outputs to get the final output color image.

IV. CONCLUSIONS

The proposed algorithm is effectual for salt and pepper noise elimination from images at low, medium and high noise densities and it processes mutually together on gray scale and color images. It provides quality results in terms of Mean Square Error (MSE), Peak Signal-to-Noise Ratio (PSNR), Structure Similarity Index measure (SSIM), andImage Enhancement Factor (IEF).
In case of very high noise densities like 90% or more, it makes the images blochy i.e. there is mapping of different gray levels onto themselves. This is due to the reason that in worst case we are using the mean of the pixels for replacing the central kernel value. But at such high noise densities, even after the processing in the two stages, the number of corrupted pixels is quite high. So, when we are going to take the mean of these pixels which are mostly the corrupted values i.e. black and white pixels then the mean of these is obviously comes out to be gray which makes the image blochy.
In the proposed work, trouble of image denoising is considered and emphasis is given on a balanced impulse noise detection and image restoration process. It has been compared with EWA technique in terms of PSNR. Proposed method has been tested at low and high noise intensities going together grey scale as well as color images. Still at high intensity of noise the proposed technique outperforms other methods. Experimental results are also taken in terms of SSIM, IEF and MSE. Together visual and qualitative results are established.

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