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Analysis of Image Filtering With Detail Preservation Methodologies for Impulse Noise Removal

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***Abstract* – The concept of this paper is to study of various image noise removal methods and provide simple but efficient method of image de-noising to improve the performance and to provide reduction in the complexity of implementation. This paper shows the different techniques in different domains to remove the noise and produce better results with small window size. The image details preservation is also better with small window. Our purpose is to find approach is to remove as much as impulse noise possible with preservation of fine details of image. Extensive simulations and comparisons are done with competent schemes. The results show better noise removal capability along with fine image details preservation of images corrupted with noise impulses.**

***Keywords* – Edge Preservation, Impulse Noise, Median Filter, PSNR, MSE.**

I. Introduction

In the field of Image processing, during the transmission and acquisition, images are corrupted by the different type of noise. Because of the noise, quality of image is reduced and other features like edge sharpness and pattern recognition are also badly affected. There may be noise of Gaussian type noise, impulse type noise, shot noise or salt and pepper noise.

The impulse noise has generally two types: fixed value impulse noise and random value impulse noise. The fixed value impulse noise is also known as salt and pepper noise. It is generally reflected by pixels having minimum and value in gray scale image. The random value impulse noise is random in nature and it is very difficult to remove this noise. To remove the effect of noise, we have several process of image de-noising. But removal of noise and restoration of original image causes blurring the edges of image. Impulse noise causes random black and white dots on the image so impulse noise reduction is very important phenomena of image processing. The basic idea of image de-noising has two parts:

1) Detection of noise, and
2) Removal of noise.

Detection of noise **[5]** determines that the image is corrupted by noise or not, and noise removal part remove the noise from the image while preserving the other important detail of image. Filters **[3]** are better option to remove the noise from the image because they are easy to implement on hardware. The filters can be divided in two types: linear filter and non-linear filter. Linear filters are like average filter or called averaging low pass filter. But linear filter tends to blur edges and other details of image, which may reduce the accuracy of output. On the other hand non-linear type filter like median filter has better results than linear filter because median filter remove the impulse noise without edge blurring.

The standard median filter **[3]** mostly used because of its good performance and preservation of image details. The performance of median filter also depends on the size of window of filter. Smaller window preserve the details but it will cause the reduction in noise suppression. Larger window has great noise reduction capability but image details (edges, corners, fine lines) preservation is limited. With the improvement in the standard median filters, **[9]** there were so many filters has designed like weighted median filter, center weighted median filter, adaptive median filter, rank order median filter and many other improved filters. Different filters uses different sorting algorithm like merge sort, quick sort, heap sort to sort the elements of window. Some techniques focused on noise detection, so there are different techniques to find out that the pixel is noisy or noiseless, so that only noisy pixel will be replaced by the median value and noiseless pixel will be unaffected. These techniques reduce the processing time and also improve the quality of image.

In the proposed algorithm we have improved the technique of noise detection by improving the threshold value. We have used threshold values (maximum and minimum), so there is easy to detect the random valued impulse noise. We also reduce the complexity of calculation because the threshold values and median value are calculating simultaneously.

This paper is organized as follows. In section II noise model for different types of noise is defined. Section III gives the classification of various image de-noising methods. Finally, section IV gives the conclusions of the work.

II. Impulse Noise Model

Noise may be modeled as impulse noise [**3**][**5**] having either minimum or maximum value on image pixels. This noise can be further divide in two types i.e. fixed value impulse noise (Salt or pepper noise) and Random value impulse noise. The pixels corrupted by any of the fixed valued impulse noise (0 or 255). The corrupted pixels take either 0(black) or 255 (white) with equal probability distribution.

$$N(x) = \begin{cases} B/2 & \text{for} \cdots x = 0 \\ 1 - B & \text{for} \cdots x = W(i, j) \\ B/2 & \text{for} \cdots x = 255 \end{cases} \quad \ldots\ldots\ldots(1)$$

Here B= Noise density,

N(x) = probability density function,
W(i,j) = intensity value,
X(i,j) = Noisy pixel.

The pixels corrupted by random value impulse noise will be having the B as combined probability of black and white spots unlike the salt & pepper noise.

$$N(x) = \begin{cases} 1-B & \text{for} \cdots x = W(i,j) \\ B & \text{for} \cdots x = 0 \text{ or } 255 \end{cases} \quad ......(2)$$

III. De-noising Methods

Filters used for image noise removal can be dividing in two categories, linear filters and non-linear filters.

A. Mean Filter:-

Mean filter are average filter is a linear filter. [4][5] It is appropriate filter to remove smooth type noise like Gaussian noise. It filters the image by replacing the central pixel of filtering window with average of all neighboring pixels. Then it moves filtering window to the next pixel and again calculates the average for replacement. This process repeated for whole image by sliding the filtering window from pixels to pixels. The operation of mean filter can be represented as

$$\text{Mean}\{W_i......W_N\} = 1/N \sum_{i=1}^{N} W_i \quad ....(3)$$

W_1.........W_N are pixels in filtering window. N is No. of pixels in filtering window. This linear operation causes blurring into the image and reduces the visual quality of image. This reduces the performance of mean filter.

B. Median Filter:-

The drawback of linear filters can be overcome by non-linear filter. The most common type of non-linear filter is median filter. [8] Median filter has edge preserving quality during the noise reduction. It used NxN size of filtering window for noise removal, where N is odd. This NxN matrix contains N^2 element. Median filter operation first sorts all the elements of filtering window, than it select the central element of that sorted sequence called median value. The central pixel of filtering window will than replaced with this median value. [2]The function of median operation can be written as

$$\text{Median}(W) = \text{Med}\{Wi\}$$

$$= \begin{cases} Wi(n+1)/2, & \text{n is odd} \\ ½[Wi(n/2) + Wi(n/2)+1], & \text{n is even} \end{cases} \quad ....(4)$$

Where W1, W2, W3 ………... WN is the sequence of neighbour pixels. First all the elements are sorted in ascending or descending order like $Wi1 \le Wi2 \le Wi3 \le$....................WiN, than take the central element to replace with central pixel. Median filter has good performance to remove Impulse noise.

C. Weighted Median Filter:-

It [7] has two stages to remove noise. One is noise detection and then noise removal. First it assigns different weights to different pixels in filtering window on some predefined order. Then it calculates average of all neighboring pixels inside the window.

$$\text{Avg}\{A(i,j)\} = 1/9 \sum_{k=-1}^{1} \sum_{r=-1}^{1} 1Y(i+k, j+r) \quad ......(10)$$

Where k,,r = -1, 0, 1
Central pixel = Y(i,j)
If Min{A(i,j)} = Y(i,j) or Max{A(i,j)} = Y(i,j).

Then central pixel will be considered as noisy. Then we modified filtering window and remove the noise by checking similarity between central pixel and neighboring pixels

D. A Novel Edge Preserving Filter:-

This algorithm [8] suggests first to find the noisy pixels and filter the noisy pixel to provide a noise free image with preserved edges.

Here we select a window of size WxW (where W is an odd number) with centre X(i,j). Now, firstly it is checked whether X(i,j) is noisy or noise free. On detection of x(i,j), if the outcome is noise free then the pixel remain unaltered and if the outcome of X(i,j) is noisy then it has to go through various process for the correction of pixel . Basic criteria for noisy and noise free channels are as follows-

$$X(i,j) = \begin{cases} \text{noise free} & \text{if } 0 < X(i,j) < 1; \\ \text{noisy} & \text{if } X(i,j) = 0 \text{ or } X(i,j) = 1; \end{cases} \quad ......(5)$$

The adaptive median of the noisy pixel is calculated, which is as follows-

$$X_{i,j} = Nr_{i,j} \quad ......(6)$$

Where Nr(i,j) has min.{ND(r)}

The pixel from the window closest to the adaptive median is replaced with the noisy pixel and to perform this, the absolute difference of Adm (Adaptive Median) with all the neighbor of $X(i,j)$ is calculated, for window w^2-1 (neighborhood differences) ND(r) is calculated.

$$N_d(r) = A_{dm} - Nr_{i,j} \quad ....(7)$$

Where Nr(i,j) is the rth neighbor of $X(i,j)$ and r=1,2,3,4,….. ,k^2 -1. Now two cases arise based on which noise is removes as follows-

Case 1: There are all zeros and all ones or mixed noise. Now, in this window all the pixels are noisy, therefore it cannot be exchanged with any noise free pixel, so the size of the window is increased by the next order. For e.g. if the size of window is 5X5 then it is increased to 7X7. Now, the increased value closest to the Adm is used. And again if all the pixels in window are zero then the window size is further increases.

Case2: In this case the window contains both types of pixels i.e. noisy and noise free. Then the noisy pixels are considered and altered with the noise free pixels. This removes the noise as well as preserves the edges.

E. Detail Preserving Filter:-

This filter is based on Soft Switching Median (SWM) which filters the image to attenuate noise while keeping the details of the images preserved so that after filtering the image is not blurred or distorted. In order to preserve the edges and fine details from the extrema found by min-max algorithm. The filtering process is summarized as follows:-

Impulse Noise Detection- In this, a sliding window centered on x_{ij} is employed to detect the extrema for corrupted pixels.

First rearranging the input samples X_r of window WxW in ascending order, then we compare X(i,j) with each element of window and then extreme test can be expressed as

$X(i,j) = N;\ \text{if}\ X(i,j) > \max[X_r]\ \text{or}\ X(i,j) < \min[X_r];$

(N is corrupted pixel)

$X(i,j) = N';\ \text{if}\ X(i,j) = \max[X_r]\ \text{or}\ X(i,j) = \min[X_r];$

x_i (N' is noisy candidate)

$X(i,j) = S;\ \text{Else};$

(S is noise free pixel)

Edge and Smooth Region Detection- In order to identify the edges and fine detailed from the noise candidates, the sub window is introduced in the proposed algorithm. In the sliding window can be divided into four one-dimensional sub-window i.e horizontal, vertical, main diagonal and auxiliary direction window.

In each sub-window, the sum of absolute value of difference between X(i,j) and the other pixel is denoted as m1,m2,m3 and m4 respectively.

$$m = \min\left[m_1, m_2, m_3, m_4\right]$$

Here, we employ T as a threshold, if m is greater than the threshold, the noise candidate will be considered corrupted pixel as the following expression

$$X(i,j) = \begin{cases} N & \text{if } m > T; \\ S & \text{Else}; \end{cases} \quad \ldots\ldots\ldots\ldots(8)$$

Impulse Noise Filter - Both noisy and noise free pixels are identified. This filter adopts the Rank Ordered Mean (ROM) Filter to remove the noise effects.

Let ROM denotes the median value of X_r and $Z(i,j)$ denotes the output of filter which is expressed as follows

$$Z(i,j) = \begin{cases} ROM & \text{if } X(i,j) \in N; \\ X(i,j) & \text{if } X(i,j) \in S; \end{cases} \quad \ldots\ldots\ldots\ldots(9)$$

IV. Simulation & Result

The simulations are carried out to assess the performance of the improved median filters and to compare the same with the standard Median and adaptive filters. The image is corrupted with impulse noise, the performance of the standard Median Filter (MF) [8], Novel Edge Preserving Filter (NEPF) [9], Detail Preserving Filter (DPF) [10] and Linear Mean Median

Table I: Comparison result of PSNR value (decibel) of the Lena image

Methods	Noise density *(P)* in % for Lena Image								
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
MF	28.7	26.4	22.6	18.3	15.0	12.2	9.8	8.1	6.5
DPF	36.24	34.17	32.05	29.05	24.42	19.37	15.17	11.45	8.97
NEPF	34.01	31.08	29.58	28.73	28.04	27.61	27.04	26.15	23.73
LMMF	42.93	39.38	37.11	34.97	33.34	31.37	29.41	26.77	23.55

Table II: Comparison result of MSE value of the Lena image

Methods	Noise density *(P)* in % for Lena Image								
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
MF	87.71631	148.9637	357.339	961.7902	2056.271	3918.144	6808.953	10071.18	14557.28
DPF	15.4554	24.89318	40.55836	80.92456	235.0068	751.762	1977.335	4656.723	8242.906
NEPF	25.82738	50.70845	71.62759	87.11248	102.1128	112.7406	128.5525	157.7903	275.4738
LMMF	3.311924	7.50033	12.6497	20.70524	30.13564	47.43297	74.48698	136.7982	287.1312

Filter (LMMF) [1] are shown. The PSNR (Peak Signal to Noise Ratio) & MSE (Mean Square Error) is taken as the *performance measure*. Witch can represent by [2]

$$PSNR = 10\log_{10}\frac{(255)^2}{MSE} \quad \ldots\ldots\ldots\ldots(11)$$

Where MSE (Mean square error), is

$$MSE = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\{Z(i,j) - A(i,j)\}^2}{m \times n} \quad \ldots\ldots\ldots(12)$$

Z (I, j) = De-noised Image

A (I, j) = Original Image

For the better noise removal performance, the MSE values should be very small and PSNR should be as high as possible. The figure 1 shows the results of different de-noised algorithms [1][8][9][10] on image corrupted by impulse noise.

(a) Original Lena Image (b) Noisy Lena Image

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(c) De-noised by DPF


(d) De-noised by NEPF


(e) De-noised by LMMF

Fig.1. Lena Image Denoised by Different Filters

V. Conclusion

Performance analysis of de-noising algorithms is measured by peak signal-to-noise ratio (PSNR), mean square error (M.S.E) as well as in terms of visual quality of the images. Different densities of noise are added to test image for the evaluation of PSNR. Like the other improvement in the De-noising techniques, they remove the noise more efficiently than previous techniques. Our aim of study different techniques is to find an effective de-noising technique which is best suitable with small window size. The small window has good image details preservation. The mathematical analysis shows that the quality of image is better in adaptive and edge preserving filters than the average filter and other standard median filter.

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