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RESEARCH ARTICLE

Analysis of Image Noise Removal Methodologies for High Density Impulse Noise

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ABSTRACT: Image noise removal is most important pre-processing step of image processing. Filtering method is emphasized for all types of de-noising schemes used for noise removal. In this paper, we have study about the different methods based on non-linear filter to remove the impulse noise from images. Different image noise removal algorithms are studied and some parameters are compared in a wide range of noise density to study the results of different filters. Mathematical analysis shows the quality of some de-noising algorithms and compares those methods. Complexity of some techniques are very less; because small number of calculations required removing the noise.

Keywords: Impulse Noise, Median Filter, PSNR, MSE

1. INTRODUCTION

Digital Digital images are very important source of information but because of the noise generated due to flaws in the system (like imperfection in collection system, transmission medium and imaging system) makes it difficult to study an image for any purposes. Therefore noise filtering is the most important task that one has to do before image processing and hence noise filter plays a very important role in this process. There are two types of filter used for noise filtering they are-

1. Linear filter
2. Non linear filter

Linear [4] [5] filter basically finds the corrupted pixel and replace it with the average /mean of the neighboring uncorrupted pixels as shown below. In linear filter it is assumed that noise is impulse and it takes the value either X_{min} or X_{max} i.e. 255 or 0 thus in this case the corrupted pixel is replaced by mean value of its neighborhood pixels. Linear filter

suppresses high density of noise but also unable to preserve the details and leads to blurring of image therefore this filter is not used widely.
Non linear filter is also known as median filter it is the prominently used filter, it removes the noise by replacing every pixel with the median of its neighborhood pixel. Here median is the centre value of the neighborhood pixel i.e. half of the pixel value is above median value and half is below it and since the impulse will take the extreme values the median selected from the neighborhood pixel will give high possibilities of noise free pixel.

Table I. Filtering window of size 3x3

	Column 1	Column 2	Column 3
Row 1	A_1	A_2	A_3
Row 1	A_4	A_5	A_6
Row 3	A_7	A_8	A_9

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 two 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.

2. IMPULSE NOISE MODEL

Noise may be modeled as impulse noise [**13**][**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.

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

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.

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

3. DENOISING METHODS

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

3.1 Mean Filter:-

Mean filter are also called average filter and it is a linear filter. [4][5] It is good enough filter to remove smooth type noise like Gaussian noise. It filters the image by replacing the central pixel of filtering window with average or mean of all neighboring pixels. Then it slide filtering window to the next pixel and again calculates the average of neighbors 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

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

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

3.2 Median Filter:-

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

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

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

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

3.3 Weighted Median Filter:-

It [12] 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.

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

3.4 Linear Mean-Median Filter:-

Figure 1 shows the block diagram of LMMF; consist of noise prediction, detector and pre-filtering section. Two ROM filters are used for reconstruction of noisy pixels. Density Impulse Noise Prediction (p) is amount of noise which mixes on the original image Y(i,j), which is expressed in percent (%).The p data is used to determine the options. The output option for pre filtering depends upon the value of p, which is expressed as follows:-

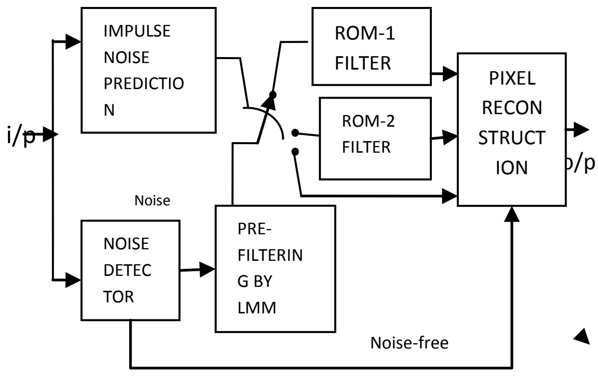


Figure 1.Block Diagram Representation of LMMF

For, p < 30%, output is forwarded for Pixel Reconstruction, for 30% < p < 70%, output is forwarded to ROM-2 and for p > 70%, output is forwarded to ROM-1. We predict the density of impulse noise by:

1. We make 2D index matrix $Y_n(i,j)$ with element value 0 or 1. $Y_n(i,j)$ is the corrupted image which is also the reference for $Y_n(i,j)$.
2. Determining the value of index 0 or 1 in each element matrix $Y_n(i,j)$:-

$$Yn(i,j) = \begin{cases} 1 & \text{if } Yn(i,j) \text{ is } 0 \text{ or } 255 \\ 0 & \text{if other} \end{cases} \ldots\ldots(8)$$

3. The percentage of the impulse noise prediction is obtained by calculating percentage of the average value of $f_d(x,y)$:

$$p = \frac{1}{NM}\sum_{x=1}^{N}\sum_{y=1}^{M} Yn(i,j) \ * 100\% \ldots\ldots(9)$$

Where M= no. of Rows of Image

N = no. of Column in image

Noise detector serves to detect the matrix elements of $Y_n(i,j)$ are the noisy pixel or not. Before the filtering process is conducted, we set the value of each element noise, where "salt or 255" on be replaced by "0". So that, $Y_n(i,j)$ only has one noise model, that is "pepper or 0". We design PRE filter by linear filter. Linear Filter (LF) is designed from the blend between of the median and the average values on the free- noise pixels.

4. SIMULATION & RESULTS

The simulations are carried out to assess the performance of the different filters and to compare them with the standard Median and adaptive filters. When the image is corrupted with impulse noise, the performance of the standard Median Filter (MF) [8], Signal Dependent rank order mean filter (SD-ROM) [11], Linear Mean-Median filter (LMMF) [7], Decision-based Algorithm (DBA) [6], Adaptive Switching Median Based Filter (ASMBF) [4]. are shown. The PSNR (Peak Signal to Noise Ratio) & MSE (Mean Square Error) is taken as the *performance measure*. Witch can represent by [2]

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

Where MSE (Mean square error), is

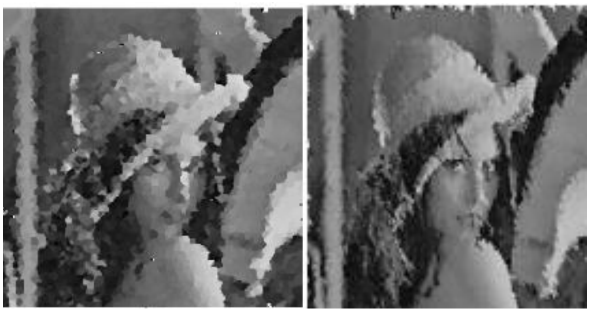
$$MSE = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\{Z(i,j) - A(i,j)\}^2}{m \times n} \ldots\ldots..(12)$$

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. Figure shows the output images of different filters like median filter and linear mean-median filter.

(a) Lena Image (b) Noisy Image



(c) De-noised Using WMF (d) De-noised using LMMF

Figure 2.De-noised images by different filters

5. CONCLUSION

In our research paper, we have presented impulse noise removal algorithms based on the Different median filters. The value is measured between mean and median values of the free- noise pixel that have been able to reduce impulse noise in the several variations of impulse noise density. Different methods having various filtering algorithms have the capability to reduce impulse noise across in varying ranges of noise from 10% up to 90%. The success of LMMF is to reduce impulse noise is measured using Qualitative and Quantitative parameters. Qualitative parameter is conducted by observation of visual quality. Meanwhile, quantitative parameter is measured by calculation of PSNR (Peak Signal to Noise Ratio) and MSE (Mean Square Error). LMMF has higher PSNR value than all other filters that indicates the De-noising results almost close to the original image quality. Overall, the qualitative or quantitative testing of our different methods shows significantly better image quality in different algorithms like MF, SD-ROM, DBA, and ASMBF. We can apply and develop some other methods in the sequence image filters to reduce impulse noise densities.

TABLE II. 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
SD-ROM	26.0	24.0	20.8	17.4	14.4	11.7	9.4	7.8	6.4
ASMBF	38.05	35.856	32.18	30.33	27.35	22.44	17.27	11.81	8.02
DBA	41.48	37.27	34.47	31.87	29.80	27.64	25.30	22.84	19.42
LMMF	42.93	39.38	37.11	34.97	33.34	31.37	29.41	26.77	23.55

TABLE III. 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
SD-ROM	163.3354	258.8692	540.8544	1183.26	2360.9	4396.2	7465.8	10791.4	14896.3
ASMBF	10.1878	16.8842	39.36229	60.26711	119.6962	370.7493	1219.215	4286.278	10258.42
DBA	4.624666	12.19215	23.23167	42.27468	68.08953	111.9645	191.9024	338.1274	743.1566
LMMF	3.311924	7.50033	12.6497	20.70524	30.13564	47.43297	74.48698	136.7982	287.1312

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