

Experimental Investigations of Median Filter to Suppress Impulse Noise from Images

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ABSTRACT: Impulse noise suppression and detail preservations are important features of image processing filter. The application of median filter results in good compromise between the said contradictory goals. In this paper, the median filtering is applied to low, medium and high detail images that are corrupted by five different categories of impulse noise. The performance of a median filter is evaluated based on subjective and objective analysis

KEYWORDS: Image Processing, Impulse Noise, Salt & Pepper Noise, Mean, Geometric Mean, Harmonic Mean and Median Filter.

I. INTRODUCTION

Images are distorted by impulse noise due to faulty sensors and channel transmission errors. It is essential and vital to restore the corrupted pixels to assist the subsequent image processing operations. The impulse noise thinly corrupts the portion of pixels to relatively high or low levels compared to its neighbouring pixels. The corrupted pixels are restored via filtering process. The filters are traditionally classified into linear and non-linear based on the mathematical properties of the filtering function. The performance of a linear filter is found to be unsatisfactory for the restoration of images corrupted by impulse noise [3]. The linear filter has the tendency of blurring the edges. The examples of linear filter are average filter [1], geometric mean filter [1] and harmonic mean filter [1].

The median filter is considered as an optimum likelihood estimator for impulse noise suppression. The median filter was introduced in 1974 by J W Tukey under the name “running median” for smoothing of discrete data[2].The median filter was gone through many phases of development since its first introduction. The significant amount of work has been undertaken in developing the properties of median filter.

Gallagher and Wise [3] have shown that certain signal structure called root signals are invariant to median filtering. The root signal represents the pass band of a filter. The root signal comprises constant neighbourhood, region of monotonically rising or falling points and edges. The root signals forms the basic descriptor of a deterministic property of median filter.

The output distribution and output moments are the basic descriptor of statistical property [4]. The statistical property tells about noise attenuation capability of a median filter. The output variance is a measure of the noise attenuation capability of a filter.

The goal of [4] is to cast some light on edge preserving and noise attenuation capability of a median filter. Alan Conrad Bovik [5] has presented a probabilistic analysis of streaking effect observed in median filtering. The streaking effects are identified as runs of equal or nearly equal values which creat visual impression that have no visual correlation.

Based on the extensive survey it has been observed that, the relevance of median filter in suppressing different categories of impulse noise still remain an untouched area. The impulse noise exists in five different categories which are modelled in section 2. The potential of a median filter against noise suppression and edge preservation is checked for low, medium and high detail image.

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II. NOISE MODELS

The five different models of impulse noise are considered for examining the performance of a median filter. Each of the models is described in detail as follows.

Noise Model 1

The noise is modeled as salt and pepper noise. The pixels are randomly corrupted by two extreme values 0 and 255 with equal probability. The probability density function is defined as

$$f(x) = \begin{cases} \frac{P}{2} & \text{for } x = 0. \\ 1 - P & \text{for } x = s(i,j) \\ \frac{P}{2} & \text{for } x = 255 \end{cases}$$

Where P is noise density and s(i,j) is intensity value of the pixel at (i,j).

Noise Model 2

The noise is similar to model 1 except that each pixel might be corrupted by either 'pepper' noise or 'salt' noise with unequal probabilities. The probability density function is defined as

$$f(x) = \begin{cases} \frac{P_1}{2} & \text{for } x = 0. \\ 1 - P & \text{for } x = s(i,j) \\ \frac{P_2}{2} & \text{for } x = 255 \end{cases}$$

Where $P = P_1 + P_2$, and $P_1 \neq P_2$. P_1 and P_2 are density of pepper and salt noise respectively.

Noise Model 3

The impulse noise could be more realistically modeled by two fixed ranges that at both the ends with a length m each respectively. For example, if $m=10$ the noise will be equally likely be any values in the range [0,9] or [246 255]. The probability density function is given by

$$f(x) = \begin{cases} \frac{P}{2m} & \text{for } 0 \leq x < m. \\ 1 - P & \text{for } x = s(i,j) \\ \frac{P}{2m} & \text{for } (255 - m) < x \leq 255. \end{cases}$$

Noise Model 4

The noise model 4 is similar to model 3, except that the density of low intensity impulse noise and high intensity impulse noise are unequal. The probability density function is given by

$$f(x) = \begin{cases} \frac{P_1}{m} & \text{for } 0 \leq x < m. \\ 1 - P & \text{for } x = s(i,j) \\ \frac{P_2}{m} & \text{for } (255 - m) < x \leq 255. \end{cases}$$

Noise Model 5

The impulse noise in model 5 is modeled as random valued impulse noise. The pixels are randomly corrupted by any values between 0 and 255. The probability density function is defined as

$$f(x) = \begin{cases} P & \text{for } x \in [0, 255] \\ 1 - P & \text{for } x = s(i,j) \end{cases}$$

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III. MEDIAN FILTER

The median filter exploits the rank order information of the input data to effectively remove the impulse noise. The median filtering is accomplished by moving a mask over an image and calculating its response at each stage by ordering the pixels in the filtering window. The median filter replaces each pixel by median value of data within the filtering window. The median filtering is illustrated in algorithm presented in figure1.

Consider a set of identically distributed random variable x_i , where $i \in \{1, 2, 3, \dots, n\}$. If the random variables are arranged in an ascending or descending order of a magnitude such that $x_{(1)} < x_{(2)} < x_{(3)} < x_{(4)} < x_{(5)} < x_{(6)} \dots \dots \dots < x_{(n)}$

$$Y = \text{median} \{ x_{(1)} < x_{(2)} < x_{(3)} \dots \dots < x_{(n)} \} \quad (1)$$

```
for(i=1:M)
for(j=1:N)
B(1:3,1:3)=O(i-1:i+1,j-1:j+1)
Y(i,j)=med(B(:))
end
end
```

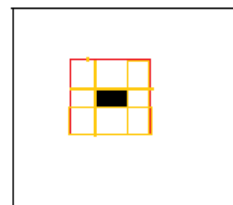


Figure 1: Median Filtering

IV. EXPERIMENTAL RESULTS

The restoration performance of a median filter is quantified using peak signal to noise ratio according to equation 3. The extensive simulations are conducted using low, medium and high detail images corrupted by five different cases of impulse noise.

$$MSE(x, z) = \frac{1}{N \times N} \sum_{i,j}^N (x(i, j) - z(i, j))^2 \quad (2)$$

$$PSNR(x, z) = 10 * \log_{10} \left(\frac{255 * 255}{MSE(x, z)} \right) \quad (3)$$

The images are categorized into low, medium and high detail based on the number of edge pixels. The low, medium and high detail image respectively comprises less, medium and large number of edges in the image. The test image that belongs to low, medium and high detail are cameraman, penguin and presentation image respectively.

The visual results of mean, geometric mean, harmonic mean and median filter are displayed in figure 2 to 6. The objective results are documented in table 1 to 5. Figure 7 to 9 graphically illustrates the quantitative performance comparison in terms of, peak signal to noise ratio. Consistently, the median filter outperforms than mean, geometric mean and harmonic mean filter over a wide range of noise densities. On the contrary, the performance of a median filter starts to drop from 20% noise density onwards. This is mainly due to corrupted pixel density increases in the filtering window.

Further, the table 6 illustrates the computation of variance about a region R_1 . The region R_1 is characterized by intensities values [156 153 155 158 156 159 154 156 160] and the corresponding intensities values in the noisy and restored image using mean, geometric mean, harmonic mean and median filter are [255 255 0 158 0 159 154 0 160], [172 162 178 155 155 121 145 146 181], [156 157 165 156 0 0 157 0 0], [156 0 0 171 0 0 0 0 212] and [157 158 159 157 158 160 156 158 159]. From the variance table, the median filter achieves greater attenuation of noise.

The intensity profile of an original image, image corrupted by 20% impulse noise and the image restored using mean and median filter are shown in figure 10 to 13. The intensity profiles clearly indicate that the median filter is robust against edge preservation.

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Table 1: PSNR performance on (a) Low Detail Image (b) Medium Detail Image (c) High Detail Image corrupted by salt and pepper noise with equal probability.

Noise Density	Peak Signal to Noise Ratio				
	NPSNR	MF	GMF	HMF	MF
10%	15.03	21.71	9.82	9.81	26.3
20%	12.10	19.24	7.64	7.65	24.60
30%	10.30	17.46	6.74	6.64	21.38

(a)

Noise Density	Peak Signal to Noise Ratio				
	NPSNR	MF	GMF	HMF	MF
10%	14.77	21.88	8.01	8.09	28.42
20%	11.61	18.75	5.98	5.95	25.63
30%	9.87	16.71	4.96	4.99	21.67

(b)

Noise Density	Peak Signal to Noise Ratio				
	NPSNR	MF	GMF	HMF	MF
10%	15.10	22.69	10.03	10.02	30.45
20%	12.15	19.88	7.84	7.91	27.22
30%	10.35	17.87	6.86	6.86	23.03

(c)

Table 2: PSNR performance on (a) Low Detail Image (b) Medium Detail Image (c) High Detail Image corrupted by a total density 10% and 20 % comprising different densities of salt and pepper noise.

Noise Density		Peak Signal to Noise Ratio				
Peppe	salt	NPSNR	MF	GMF	HMF	MF
4%	6%	15.99	22.3	10.5	10.38	24.46
6%	4%	15.15	21.7	9.23	9.13	26.34
5%	15%	15.05	21.7	5.59	5.59	26.38
15%	5%	12.32	18.8	6.76	6.66	23.31

(a)

Noise Density		Peak Signal to Noise Ratio				
Pepper	salt	NPSNR	MF	GMF	HMF	MF
4%	6%	15.63	22.55	8.94	8.9	29.2
6%	4%	14.42	21.50	7.49	7.56	28.8
5%	15%	12.09	18.64	8.08	3.88	24.5
15%	5%	9.94	16.87	5.01	5.03	21.5

(b)

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Noise Density		Peak Signal to Noise Ratio				
Peppe	salt	NPSNR	MF	GMF	HMF	MF
4%	6%	16.10	23.6	10.68	9.56	30.6
6%	4%	15.25	22.8	9.43	10.78	30.2
5%	15%	11.83	18.5	9.97	9.98	24.6
15%	5%	13.95	19.5	6.8	6.8	22.8

(c)

Table 3: PSNR performance on (a) Low Detail Image (b) Medium Detail Image (c) High Detail Image corrupted by 20 % total density comprising different range of low intensity and high intensity impulse with equal probability.

Noise Range		Peak Signal to Noise Ratio				
Low Intensity	High Intensity	NPSNR	MF	GMF	HMF	MF
[0 9]	[246 255]	12.34	19.40	12.89	11.34	23.68
[0 49]	[206 255]	13.35	19.86	16.65	14.60	24.72

(a)

Noise Range		Peak Signal to Noise Ratio				
Low Intensity	High Intensity	NPSNR	MF	GMF	HMF	MF
[0 9]	[246 255]	11.86	18.94	14.42	7.08	25.58
[0 49]	[206 255]	12.88	19.55	14.59	10.22	26.17

(b)

Noise Range		Peak Signal to Noise Ratio				
Low Intensity	High Intensity	NPSNR	MF	GMF	HMF	MF
[0 9]	[246 255]	12.31	19.99	13.06	9.27	27.56
[0 49]	[206 255]	13.44	20.69	17.06	12.50	27.22

(c)

Table 4: PSNR performance on (a) Low Detail Image (b) Medium Detail Image (c) High Detail Image corrupted by 5% low and 15% high intensity impulse in different range.

Noise Range		Peak Signal to Noise Ratio				
Low Intensity	High Intensity	NPSNR	MF	GMF	HMF	MF
[0 9]	[246 255]	12.13	18.36	11.19	11.19	23.09
[0 49]	[206 255]	13.11	18.98	14.90	14.90	23.16

(a)

Noise Range		Peak Signal to Noise Ratio				
Low Intensity	High Intensity	NPSNR	MF	GMF	HMF	MF
[0 9]	[246 255]	12.33	18.87	13.92	9.35	23.74
[0 49]	[206 255]	13.26	17.50	14.35	12.57	24.87

(b)

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Noise Range		Peak Signal to Noise Ratio				
Low Intensity	High Intensity	NPSNR	MF	GMF	HMF	MF
[0 9]	[246 255]	12.04	18.15	15.91	11.56	24.77
[0 49]	[206 255]	13.25	19.64	19.20	15.14	25.55

(c)

Table 5: PSNR performance on (a) Low Detail Image (b) Medium Detail Image (c) High Detail Image corrupted by different densities in the range [0 255].

Noise Density	Peak Signal to Noise Ratio				
	NPSNR	MF	GMF	HMF	MF
10%	18.34	23.13	21.55	17.5	26.37
20%	15.35	20.18	19.1	15.28	25.3
30%	13.61	19	17.5	13.98	22.9
40%	12.44	17.56	16.33	12.92	20.88
50%	11.40	16.16	15.1	11.91	18.28

(a)

Noise Density	Peak Signal to Noise Ratio				
	NPSNR	MF	GMF	HMF	MF
10%	17.43	23.03	19.8	15.45	28.85
20%	14.55	20.31	17.11	12.9	26.14
30%	12.67	17.96	15.11	11.71	23.03
40%	11.5	16.32	13.77	10.38	20.05
50%	10.48	14.79	12.5	9.56	17.09

(b)

Noise Density	Peak Signal to Noise Ratio				
	NPSNR	MF	GMF	HMF	MF
10%	18.43	24.78	22.61	18.29	30.42
20%	15.49	21.81	19.80	15.56	27.89
30%	13.76	19.73	17.73	14.11	25.02
40%	12.44	17.89	16.21	12.91	22.29
50%	11.56	16.67	15.17	12.12	19.34

(c)

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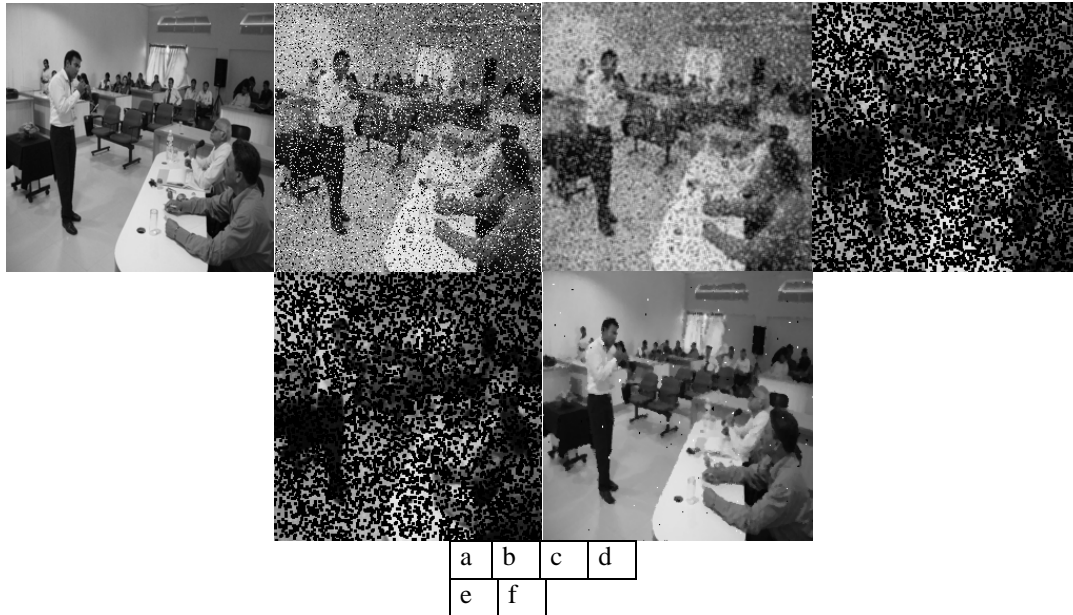


Figure 2: a)Original Image. b)Image Corrupted by 20% salt & Pepper noise. c-f) Restored Image Using Mean,Geometric Mean,Harmonic Mean & Median Filter.

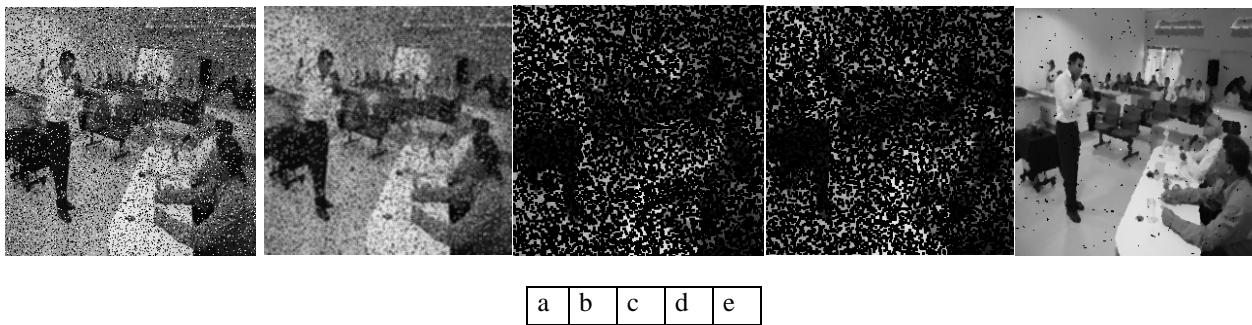


Figure 3:a-e)Image Corrupted by 15% salt & 5% Pepper noise. b-e) Restored Image Using Mean,Geometric Mean,Harmonic Mean & Median Filter.

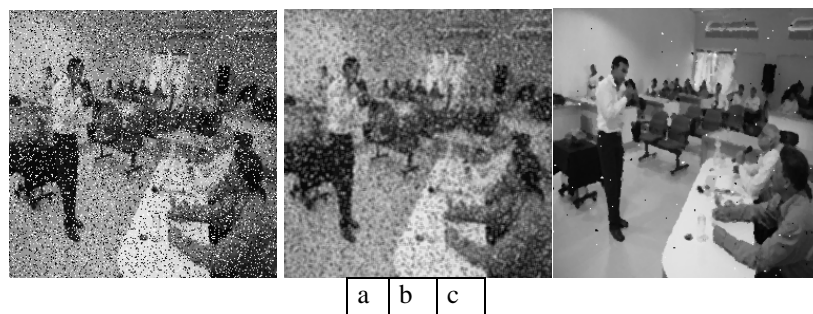


Figure 4: a) Image Corrupted by 20% low and high intensity impulse noise in the range [0 9] and [246 255]. b-c) Restored Image using mean and Median Filter

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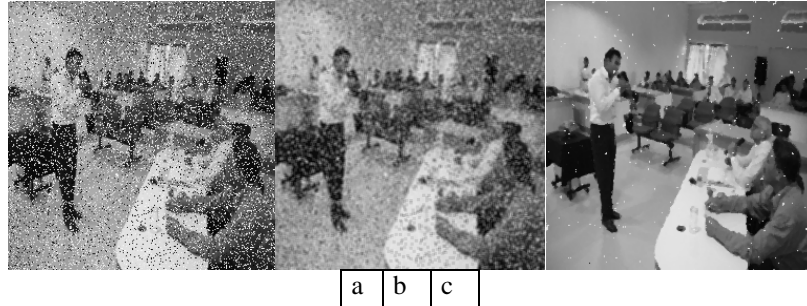


Figure 5: a) Image Corrupted by 5% low and 15% high intensity impulse noise in the range [0 49] and [206 255]. b-c) Restored Image using mean and Median Filter.

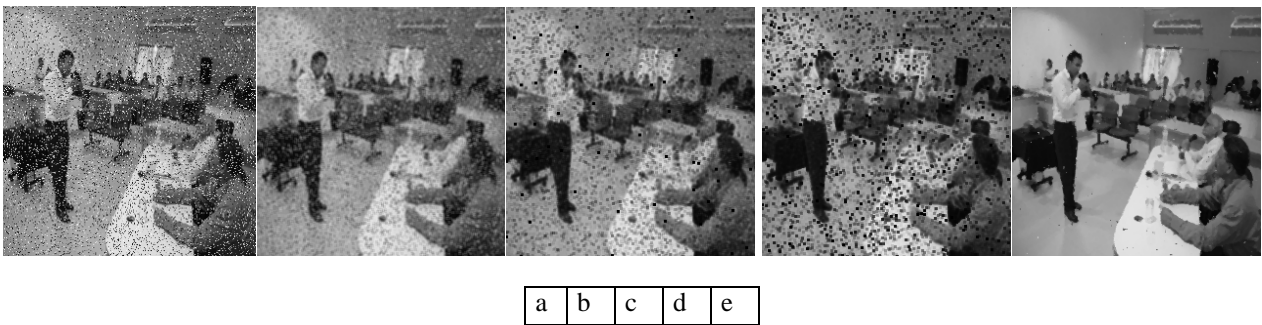


Figure 6: a)Image Corrupted by 20% random valued impulse noise. b-e) Restored Image Using Mean,Geometric Mean,Harmonic Mean & Median Filter.

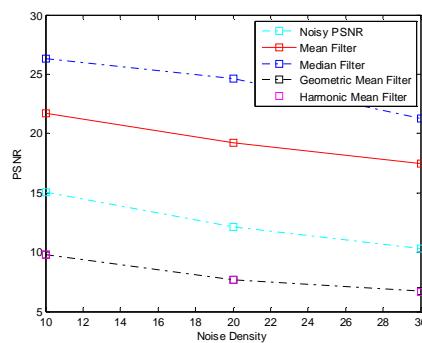


Figure 7: PSNR Performance Assessment for Low Detail Image corrupted by salt and pepper noise.

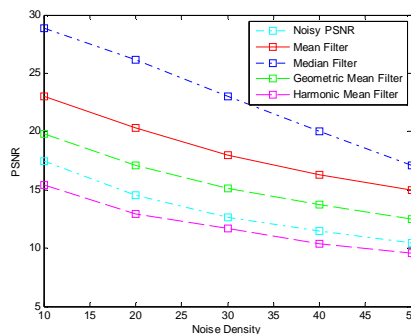


Figure 8: PSNR Performance Assessment for Medium Detail Image corrupted by impulse noise in the range [0 255].

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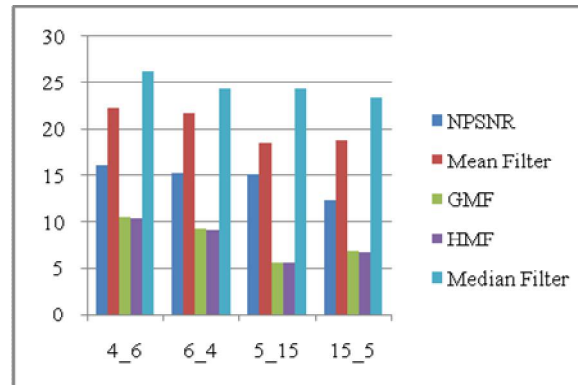


Figure 9: PSNR Performance Assessment of Low Detail Image corrupted by impulse noise with different densities of salt & pepper noise.

Table 6: Variance Table.

Region	V_o	V_n	Restored Image			
			Mean	GM	HM	Median
R_1	4.3	1062	265	695	828	1.5

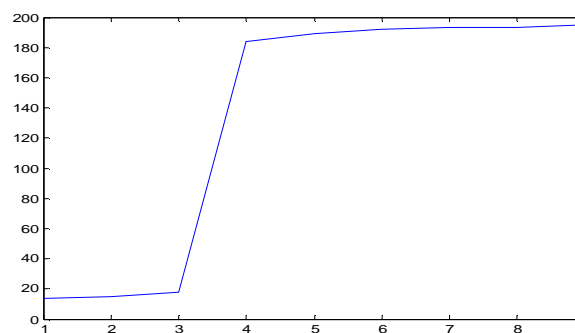


Figure 10: Intensity Profile of an Original Image at location (37,112)

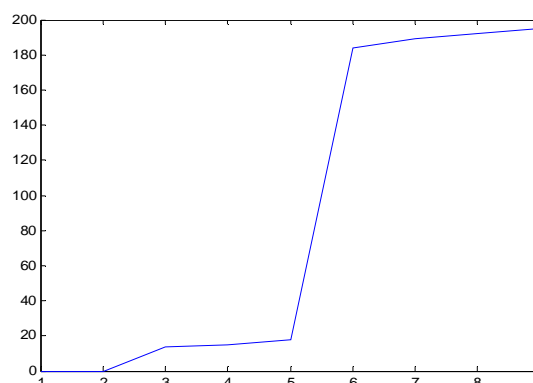


Figure 11: Intensity Profile of an Image Corrupted by 20% Impulse Noise at location (37,112).

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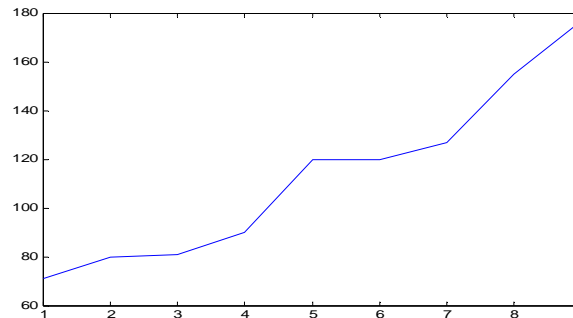


Figure 12: Intensity Profile of an Image Restored using Mean Filter at location (37,112)

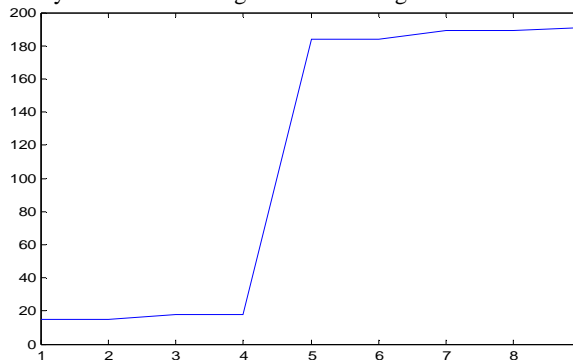


Figure 13: Intensity Profile of a Image Restored using Median Filter at location (37,112).

V. CONCLUSION

In this paper, the potential of a median filter is investigated for five different cases of impulse noise using low, medium and high detail image. The attenuation of noise is achieved by reduction in variance of a region. In this regard the median filter reduces considerable amount of noise. The edge profile of a mean and median filter illustrates that, the mean filter modifies step edges to ramp while the median filter preserves the edges. This fact reveals that the median filter is robust against edge preservation. Further, the geometric and harmonic mean filters lose its significance when applied to images corrupted by impulse noise of any density. The simulation results reveals that the restored images are not as good as noisy image. Accordingly both the filters are not to be used in its original form to suppress impulse noise in images. Therefore an effort can be made towards optimization of geometric and harmonic mean filters.

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BIOGRAPHY



Vishwanath Gouda R Malipatil is working as an Assistant Professor at BLDEA's VP Dr PGHCET Bijapur. He earned his B.E in Electronics & Communication from AIET Gulbarga and M.Tech in Communication Systems from PDA college of Engg & Technology Gulbarga. He is currently pursuing PhD at VTU Belgaum. His research work includes Image Processing, Error Control Coding, Effective utilization of seepage water for Agriculture & Efficient utilization of uncultivated land for Agriculture and teaching area includes Information Theory and Coding, Digital Communication, Optical Fiber communication for UG and PG students.



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