# High Density Noise Removal: A Review

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***Abstract-*** *Noise removal is one of the biggest challenges in the field of image processing. Impulse noise removal is one of the most necessary and important preprocessing step in digital image processing. Several median based techniques are reported in literature for different noise models. Each of them has their advantages and limitations. Most of the filters are good at noise suppression but their performance decreases in terms of edge preservation. In the review paper , various algorithms for removal of fixed valued impulse noise and their performance under different noise conditions and for various fixed valued noise models is discussed. That is why, review of noise models are essential in the study of image denoising techniques. In this paper, we express a brief overview of various noise models. These noise models can be selected by analysis of their origin. In this way, we present a complete and quantitative analysis of noise models available in digital images.*

***Keywords:-*** Switching median filter; Image denoising; Impulse noise detection; nonlinear filter , Noise model, Probability density function, Power spectral density (PDF), Digital images.

## I. INTRODUCTION

Many Practical developments, of considerable interest in the field of image denoising, need continuous and uniform review of relevant noise theory. Behalf of this, many researchers have addressed literature survey of given practical as well as theoretical aspects.

Although all literatures address the noise in imaging system usually presents during image acquisition, coding, transmission, and processing steps. This noise appearance disturbs the original information in voice, image and video signal. In this sense some questions arises in researches mind, how much original signal is corrupted?, how we can reconstruct the signal?, which noise model is associated in the noisy image. However time to time we have to need the reinforcement learning of theoretical and practical ideas of entilt noises present in digital images. Here, we are trying to present the solution of all these problems through the review of noise models. In this paper, the literature survey is based on statistical concepts of noise theory. We start with noise and the roll of noise in image distortion. Noise is random signal. It is used to destroy most of the part of image information. Image distortion is most pleasance problems in image processing. Image distorted due to various types of noise such as Gaussian noise, Poisson noise, Speckle noise, Salt and Pepper noise and many more are fundamental noise types in case of digital images. These noises may be came from a noise sources present in the vicinity of image capturing devices, faulty memory location or may be introduced due to imperfection/inaccuracy in the image capturing devices like cameras, misaligned lenses, weak focal length, scattering andother adverse conditions may be present in the atmosphere. This makes careful and in-depth study of noise and noise models are essential ingredient in image denoising. This leads to selection of proper noise model for image denoising systems [1-3].

The rest of the paper is structured as follows. The proposed algorithms and its different cases are described in section II. Simulation results are presented in section III. Finally conclusions are drawn in section IV.

## II. LITERATURE REVIEW

A lot of work has been done for the removal of fixed valued impulse noise from images. The median filter and its variants are used extensively for noise removal. Some of the significant works reported in literature is discussed.

Pei-Eng Ng and Kai-Kuan Ma [2] proposed a boundary discriminative noise detection technique for removing impulse noise. The filtration process consists of two stages namely impulse detection to find the processing pixel as corrupted or uncorrupted and then filtration of the corrupted pixel as the second step. The proposed algorithm is applied to each pixel of noisy image to identify whether it is corrupted or not. In order to determine whether the current pixel is corrupted or not, this algorithm first classifies the pixels of the processing window as lower intensity impulse noise, uncorrupted pixels, higher intensity impulse noise. The pixel is considered as uncorrupted pixel if it belongs to uncorrupted pixel group. If it does not belong to uncorrupted pixel group then it is assumed to be noise and filtration process takes place. The success of this algorithm is mainly due to two boundaries that distinguish these three groups. This filtration technique is very useful for denoising heavily corrupted images. Four noise models are considered for performance evaluation. But this technique does not work on noise model 5 (NM5). Also large window size leads to more computational time.

Zhou Wang and David Zhang [3] proposed a scheme called progressive switching median filter. This algorithm is used to restore images which are corrupted by salt & pepper noise. This method also comprises of two steps of impulse detection and then filtration of only the corrupted pixels. In this technique the impulse detector and the noise filter are applied progressively in iterative manners. The noisy pixels processed in the current iteration are utilized to help in processing of the other pixels in the subsequent iterations. The main advantage of this technique is that some impulse noise which is located in the middle of large noise blotches is detected and thus it can be filtered. This filter shows significant result at very high noise densities. This filter is used to remove salt & pepper noise only. It does not work on other four noise models.

Ashwin Thakur, Vipul Agrawal, Yogeshwar Khandagre, Alok Duby [4] proposed an approach for removal of high density salt and pepper noise through modified decision based asymmetric trimmed median filter. As all other methods available for noise removal, this process also first checks the pixel for corrupted or uncorrupted and then performs filtration process on the corrupted pixels and uncorrupted pixels are kept intact. In this technique the pixel under consideration is checked for corrupted or uncorrupted. If the value of the pixel lies between maximum and minimum gray value then it is considered as noise free pixels. On contrary, if the value of pixel is maximum or minimum gray value then it is treated as noisy pixel and hence filtered by proposed scheme. If the current pixel is 0 or 255 and all other pixels in the scanning window also have value as 0 and 255, then the current pixel is replaced by mean of the selected window. If the window contains elements apart from 0's and 255's then 0's and 255's are eliminated and median is computed of the remaining pixels and current pixel is replaced by that median value. This algorithm performs satisfactorily for removing low and medium density salt and pepper noise. This filter cannot remove noise from images which are corrupted by other noise models.

Suman Shrestha [5] proposed adaptive decision based median filtering algorithm which is the combination of adaptive median filter and decision based filter. In this technique, if the median is an impulse then window size is increased by 2 in both horizontal and vertical directions and adaptive median algorithm is repeated to find out if the median is again an impulse value. If it is again an impulse then the algorithm is repeated such a number of times unless window reaches its maximum value otherwise pixel value is replaced by left neighborhood value as it is done for decision based algorithm. This technique outperforms other existing techniques at high noise density as it prevents image blurring whereas at low noise density many other techniques shows significant improvement. Noise from images which are corrupted by salt & pepper noise can only be removed. This algorithm is not suitable for other noise models.

Raymond H. Chang, Chung-Wa Ho, and Mila Nikolova [6] proposed a scheme in which filtering of noisy pixel is done adaptive median filter and next step is to restore image using some special regularization method to preserve edge details. This method performs similar to other detection techniques at low noise density but when the noise density is high, then this technique proves to be more effective because high noise level leads to the formation of noise patches and they may be considered as noise free pixels, this reduces the performance of noise detection algorithm whereas this technique provides better results due to the high accuracy of detection technique and edge preserving property. Salt and pepper noise with high noise density are corrected with the implementation of this algorithm. But this technique does not perform for removal of all other noise models reported in literature.

K. S. Srinivasan and D. Ebenezer [7] proposed a decision based algorithm (DBA) for removal of impulse noise in which a 3 by 3 window is taken for processing. If the current pixel under consideration has value either 0 or 255 then only it is processed otherwise it is kept unchanged. But this algorithm produces streaking effects due to the replacement with neighboring pixels. This algorithm is also implemented for removal of salt and pepper noise (i.e NM1) only. Other types of noise cannot be removed with this filter.
K.Aiswarya ,V.Jayaraj and D.Ebenezer [8] proposed another technique called a new and efficient algorithm for the removal of high density salt and pepper noise from images and videos (DBUTM) which is the modification of decision based algorithm in which if a window contains elements of intensity 0 and 255 then those values are eliminated and median is calculated for the remaining values. This filter gives better results than DBA because impulses are not considered. But this technique is also useful for removing salt and pepper noise only.

## NOISE MODELS

There are five types of noise models reported in the literature. They are as follows:-

1) **Noise Model 1:** In this noise model, the pixels are corrupted by two fixed extreme values, 0 (minimum) and 255 (maximum) with equal probability.
2) **Noise Model 2:** In this model, pixels are corrupted with either "pepper" noise (i.e. 0) or "salt" noise (i.e. 255) with unequal probabilities.

3) **Noise Model 3:** Instead of two fixed values, impulse noise takes two fixed ranges that appear at both ends with a length of m each. If m is 10, noise will equal likely be any values in the range [0, 9] or [246,255].
4) **Noise Model 4:** Noise model 4 is similar to noise model 3, but the probability of occurrence of these ranges in image is unequal.
5) **Noise Model 5:** In this model, noise takes four equally separated intensity levels. The probability of noise taking all these four values is equal. Here the gray values of noise are 15, 25, 225 and 250.

Impulse noise gets added to any image in the form of above mentioned models.

**1. Gaussian Noise Model**

It is also called as electronic noise because it arises in amplifiers or detectors. Gaussian noise caused by natural sources such as thermal vibration of atoms and discrete nature of radiation of warm objects [5].

Gaussian noise generally disturbs the gray values in digital images. That is why Gaussian noise model essentially designed and characteristics by its PDF or normalizes histogram with respect to
gray value. This is given as

$$P(g) = \sqrt{\frac{1}{2\pi\sigma^2}} e^{-\frac{(g-\mu)^2}{2\sigma^2}}$$

Where g = gray value, σ = standard deviation and μ= mean. Generally Gaussian noise mathematical model represents the correct approximation of real world scenarios. In this noise model, the mean value is zero, variance is 0.1 and 256 gray levels in terms of its PDF, which is shown in Fig. 1.

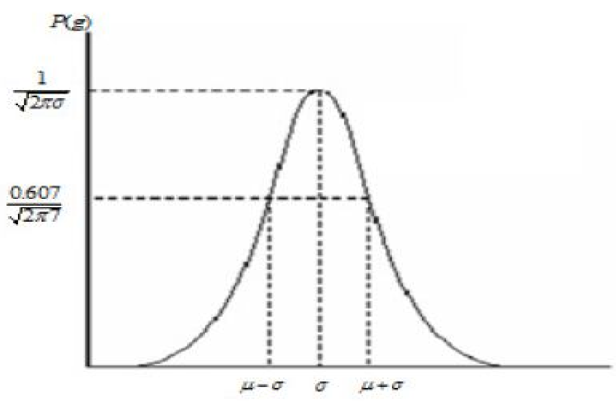



Figure 1 PDF of Gaussian noise

Due to this equal randomness the normalized Gaussian noise curve look like in bell shaped. The PDF of this noise model shows that 70% to 90% noisy pixel values of degraded image in between □□□□□and □□□□□. The shape of normalized histogram is almost same in spectral domain.

**2. White Noise**

Noise is essentially identified by the noise power. Noise power spectrum is constant in white noise. This noise power is equivalent to power spectral density function. The statement "Gaussian noise is often white noise" is incorrect [4]. However neither gaussian property implies the white sense. The range of total noise power is -_to +_ available in white noise in frequency domain. That means ideally noise power is infinite in white noise. This fact is fully true because the light emits from the sun has all the frequency components. In white noise, correlation is not possible because of every pixel values are different from their neighbours. That is why autocorrelation is zero. So that image pixel values are normally disturb positively due to white noise. This is also called data drop noise because statistically its drop the original data values. This noise is also referred as salt and pepper noise. However the image is not fully corrupted by salt and pepper noise instead of some pixel values are changed in the image. Although in noisy image, there is a possibilities of some neighbours does not changed [13-14]. This noise is seen in data transmission. Image pixel values are replaced by corrupted pixel values either maximum 'or' minimum pixel value i.e., 255 'or' 0 respectively, if number of bits are 8 for transmission. Let us consider 3x3 image matrices which are shown in the Fig. 3. Suppose the central value of matrices is corrupted by Pepper noise. Therefore, this central value i.e., 212 is given in Fig. 3 is replaced by value zero. In this connection, we can say that, this noise is inserted dead pixels either dark or bright. So in a salt and pepper noise, progressively dark pixel values are present in bright region and vice versa [15].

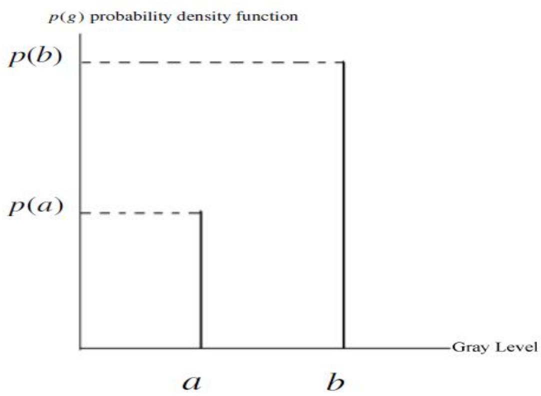
| | | |
|---|---|---|
| 254 | 207 | 210 |
| 97 | 212 | 32 |
| 62 | 106 | 20 |

→

| | | |
|---|---|---|
| 254 | 207 | 210 |
| 97 | 0 | 32 |
| 62 | 106 | 20 |

Figure 3 The central pixel value is corrupted by Pepper noise

Inserted dead pixel in the picture is due to errors in analog to digital conversion and errors in bit transmission. The percentagewise estimation of noisy pixels, directly determine from pixel metrics. The PDF of this noise is shown in the Fig. 4.




$$P(g) = \begin{cases} Pa \text{ for } g = a \\ Pb \text{ for } g = b \\ 0 \text{ otherwise} \end{cases}$$

Fig. 4 shows the PDF of Salt and Pepper noise,

if mean is zero and variance is 0.05. Here we will meet two spike one is for bright region (where gray level is less) called 'region a' and another one is dark region (where gray level is large) called 'region b', we have clearly seen here the PDF values are minimum and maximum in 'region a' and 'region b', respectively [16]. Salt and Pepper noise generally corrupted the digital image by malfunctioning of pixel elements in camera sensors, faluty memory space in storage, errors in digitization process and many more.

**Periodic Noise**

This noise is generated from electronics interferences, especially in power signal during image acquisition. This noise has special characteristics like spatially dependent and sinusoidal in nature at multiples of specific frequency. It's appears in form of conjugate spots in frequency domain. It can be conveniently removed by using a narrow band reject filter or notch filter.

**Speckle Noise**

This noise is multiplicative noise. Their appearance is seen in coherent imaging system such as laser, radar and acoustics etc, Speckle noise can exist similar in an image as Gaussian noise. Its probability density function follows gamma distribution, which is shown in Fig. 6 and given as in equation (8) [17-19].

$$F(g) = \frac{g^{\alpha-1} e^{\frac{-g}{a}}}{\alpha - 1! a^{\alpha}}$$

Figure: Lena image of speckle noise with variance 0.04

## IV. DENOISING OF IMAGES

Denoising of any image means suppression of effect of noise so that the resultant image becomes acceptable. There are two basic approaches for denoising of images. Spatial filtering methods and transform domain filtering methods. Spatial domain techniques work directly on image pixels whereas transform domain techniques are based on modifying Fourier or wavelet transform of image. Several denoising techniques are available for removal of fixed valued impulse noise due to their efficiency in noise reduction and ease of implementation. Standard median filter (SMF) is widely used due to its simplicity and noise removing capability. But this filter proves to be effective at low noise density because as noise density increases the edges of the image are not preserved [9]. This drawback was overcome by the introduction of several other techniques for the removal of salt and pepper noise. In center weighted median filter (CWM) [10], the center pixel is assigned a particular weight; this means that center pixel is repeated a number of times which is defined as a weight and then it is processed. CWM preserves more details at the expense of less noise suppression. Adaptive median filter (AMF) technique uses the approach in which window size changes adaptively for the removal of impulse noise. But this technique at high noise density leads to blurring of images due to large window size [15]. Then switching mechanism was incorporated in the filtering process so that only corrupted pixels gets filtered and uncorrupted pixels remains intact. These are called switching median filters. The performance of these filters depends on the accuracy of impulse detection schemes. The filtration scheme with min-max window [16] compares the pixel under processing window with the brightest and darkest pixels in the window and utilizes the difference value to determine the current pixel as corrupted or uncorrupted. The max filter which represents

100th percentile is used to find the brightest point in the image. The min filter is used to find the darkest point in the image. Threshold based switching median filter utilizes a suitable threshold for detection of impulse noise. Many other techniques are also available for the removal of impulse noise.
The performance of the filtration algorithms are measured in terms of visual quality and quantitatively. The objective quantitative measure used for evaluating the image restoration performance is peak signal to noise ratio (PSNR), defined as

$$\mathrm{PSNR} = 10log_{10}\left(\frac{255^2}{MSE}\right)\ dB$$

Where mean square error is

$$\mathrm{MSE} = \frac{1}{\mathrm{MN}}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(y_{i,j} - s_{i,j}\right)^2$$

## V. FUTURE SCOPE OF WORK

All the techniques available for removal of fixed valued impulse noise have their own advantages and limitations. Most of the techniques available are able to remove noise corrupted by noise model 1 and noise model 2. Very few techniques work on noise model 3 & 4. Some are able to remove noise effectively from highly corrupted images while some are good for images with low noise level. Some techniques remove noise but cause loss of information. Thus denoising techniques which can restore images to best possible extent are always required. Thus attempts can be made to modify some of the existing techniques so that they can perform better on existing models and can be implemented for other noise models after modifications.

## VI. EXPECTED OUTCOME

Modifications in the current techniques or by combining various techniques will result in more effective technique for image restoration. Result can be measured by visual appreciation and quantitatively in terms of increased peak signal to noise ratio (PSNR) and low mean square error (MSE). Also less number of miss detection (MD) and false alarm (FA) shows the effectiveness of good denoising technique.

## VII. CONCLUSION

In this paper we reviewed various impulse noise removal techniques reported in the literature used for the removal of fixed valued impulse noise. Most of the techniques are result of modifications in basic switching median filter. We also discussed the types of noise models by which image gets corrupted. Some of the techniques are best suited for denoising images but compromises on edge preservation. Most of the techniques are implemented for removal of salt and pepper noise only. Some methods are good at low noise density and causes blurring of images when noise content in the image is high. Thus various algorithms for the removal of fixed value impulse noise under different noise conditions and on different noise models were studied. Most of the techniques perform satisfactorily for noise model 1 and noise model 2 but their performance decreases for other noise models, Also results varies under different noise .conditions. Some are more effective for heavily corrupted images while other filters are convincing at low noise density only. Some algorithms provide a tradeoff between noise removal and edge sustentation i.e. removes noise while compromising with the details of the image. Thus noise removal is always an active field of research with the requirements of more and more efficient techniques which can restore images corrupted by impulse noise to the best possible extent.

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