# Survey on Non Linear Noise Removal Techniques for Salt and Pepper Noise in Digital Images

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**Abstract**—*The main cause of the image quality degradation is noise. Noise makes it difficult for the observer to discriminate the fine details of the image. There are various types of noises which can corrupt the image. Noise can appear on the images due to faulty memory locations, during transmission, during image acquisition, due to timing errors in the digitization process etc. Image denoising becomes the necessity to enhance the image quality without any loss of image information. The numerous researchers have presented various techniques to remove salt and pepper noise from digital images. A Survey of various such techniques is presented in this paper.*

**Keywords**— *Impulse Noise, Salt and Pepper Noise, Non Linear Filters, Image Denoising, PSNR, IEF and MSE.*

## I. Introduction

Digital Image Processing is an active research area in the field of signal processing, biomedical instrumentation, intelligent transportation systems such as automatic number plate recognition, medical imaging, criminology etc. For better image processing it is necessary to have an image that is free from any kind of degradation. During acquisition and transmission of image signal, impulse noise can appear on the image and can degrade the image quality. Impulse noise has a property that only a part of the pixels are corrupted with noise and remaining pixels are noise free. Impulse noise is of two types: Salt and Pepper Noise and Random Valued Noise [1]. The image pixels that are corrupted by random valued impulse noise can take any value in the range of [0,255] for the grayscale images. Salt and pepper noise is one where the noisy pixels can take either the maximum or minimum value in a dynamic range i.e. the corrupted pixels will appear either as white or black pixels in case of grayscale images.

$$y_{ij} = \begin{cases} 0 \text{ or } 255 & \text{with probability } p \\ x_{ij} & \text{with probability } 1-p \end{cases} \quad \text{...(i)}$$

Where $y_{ij}$ represents the noisy image pixel, $p$ is the probability of salt and pepper noise and $x_{ij}$ is the uncorrupted image pixel with probability *1-p*.

The main sources of salt and pepper noise are faulty memory locations used for storage, malfunctioning of pixel elements in camera sensors and timing errors in digitization process i.e.
timing errors while converting analog signal to digital signal. To enhance image quality for better understanding of the fine details of image, it is necessary to suppress such type of impulse noise from the digital images while retaining the important features of image and is called denoising of image. The purpose of image denoising to estimate the original image from the corrupted image. Image Denoising is an important pre-processing task in various digital image processing applications such as optical character recognition (OCR), medical imaging, intelligent transportation system, biomedical imaging, criminology etc.

## II. Noise Removal Techniques

Non linear filters gives best results for removal of salt and pepper noise from digital images. Non linear filters are those in which the output response is not a linear function of input. Non linear filters are mostly used for removal of non Gaussian noise from digital images. Various non linear filters are discussed below:

### 1. Standard Median Filter

The output of non linear filters is dependent on the ordering of the pixels contained in image under the filter window. The most common type of non linear filter is Median Filter (MF) [2]. Median Filter replaces the value of the processing pixel with the median value of its neighbourhood pixels in window. Median filters are very popular because of their simplicity and better results at low noise densities up to 50%. But as the noise density increases the performance of MF decreases. If the window size is increased, the output image gets blurred.

## 2. Decision based Algorithm

Decision based algorithm is a fast and efficient algorithm than standard median filter [3][4]. DBA first detects the noisy pixels in the corrupted image. It decides whether the processing pixel is noisy or noise free by checking its value. If the value of the processing pixel lies between the maximum or minimum value in the dynamic range, then it is noise free pixel otherwise the processing pixel is corrupted by salt or pepper noise. If the processing pixel is noise free, then it is left unchanged. If the processing pixel is corrupted by salt and pepper noise, it is replaced by the median value of neighbourhood pixels in the 3x3 window surrounding the processing pixel.

The advantage of decision based algorithm is that it does not modify the uncorrupted pixels and only changes the corrupted pixel.

The major disadvantage of decision based algorithm is that at higher noise densities the calculated median value can be noisy.

## 3. Decision based Unsymmetrical Trimmed Median Filter

To overcome the drawback of DBA, Decision based Unsymmetrical Trimmed Median Filter (DBUTMF) was proposed [5]. The algorithm first detects the noisy pixels from the corrupted image by checking the value of pixels. If the value of processing pixel lies between the maximum and minimum value, then it is noise free pixel otherwise the pixel is corrupted. If the processing pixel is noise free, it is left unchanged. Otherwise the processing pixel is changed by the median of neighbourhood pixels in 3x3 window surrounding the processing pixel, but before calculating median value the corrupted pixels are removed from the window. It is unsymmetrical filter because only the corrupted pixels are trimmed from window before calculating the median value.

DBUTMF has a problem that at higher noise densities the window can have all corrupted pixels. So in this case, the algorithm will not work as expected.

## 4. Modified Decision based Unsymmetrical Trimmed Median Filter

Modified Decision based Unsymmetrical Trimmed Median Filter (MDBUTMF) overcomes the drawback of DBUTMF [6]. MDBUTMF first detects the noisy pixels and then modifies the corrupted pixels. MDBUTMF uses a window of size 3x3 around the processing pixels. The three cases that can occur are illustrated below:

Case 4.1*:* If the processing pixel is corrupted i.e. either 0 or 255, and all the neighbourhood pixels in window are not corrupted, then MDBUTMF calculates the unsymmetrical trimmed median value to replace the processing pixel.

Case 4.2*:* If the processing pixel is corrupted i.e. either 0 or 255, and all the neighbourhood pixels in window are corrupted, then MDBUTMF calculates the mean of the all pixels in window to replace the processing pixel. In this case median is not calculated, because median itself will be noisy.

Case 4.3*:* If the processing pixel is noise free, then it is left unchanged.

Results shows that this filter performs better than other existing algorithms upto a noise density of 90%.

## 5. Iterative Unsymmetrical Trimmed Midpoint-Median Filter

Iterative Unsymmetrical Trimmed Midpoint-Median Filter (IUTMMF) algorithm [7] was developed for the efficient restoration of gray scale images that are corrupted by salt and pepper noise. This algorithm is implemented in two phases. In the first phase midpoint-median filter is applied on the noisy image iteratively two times. In the second phase, modified decision based mean median filter (MDBMMF) is applied on the output of first phase.

### 5.1 First Phase

In this phase value of every pixel is checked and a window of size 3x3 is taken around

processing pixel. The three case that can occur are illustrated below:
Case 5.1.1*:* If the processing pixel is noise free, then the pixel value is not changed.

Case 5.1.2*:* If the processing pixel is noisy and all the neighbouring pixels in window are not noisy, then two cases are considered:
Case 5.1.2.1*:* If the number of noise free pixels in window is greater than 4, then take the median of the noise free pixels to replace the noisy pixel.
Case 5.1.2.2: If the number of noise free pixels in window are less than 5, then take the midpoint mean of the noise free pixels to replace the noisy pixel.

*Case 5.1.3:* If the processing pixel is noisy and all the neighbouring pixels in window are noisy, then the pixel value is not changed and left for processing in second iteration.

**5.2 Second Phase**
The output of first phase is supplied as input to this phase. The value of every pixel is checked and a window of size 3x3 around the processing pixel is used. The three different cases that can occur are illustrated below:
*Case 5.2.1:* If the processing pixel is noise free, then it is left unchanged.

Case 5.2.2*:* If the processing pixel is corrupted i.e. either 0 or 255, and all the neighbourhood pixels in window are not corrupted, then it calculates the unsymmetrical trimmed median value to replace the processing pixel.

Case 5.2.3*:* If the processing pixel is corrupted i.e. either 0 or 255, and all the neighbourhood pixels in window are corrupted, then it calculates the mean of the all pixels in window to replace the processing pixel.
Results shows that this filter out performs other existing algorithms upto a noise density of 95%.

## III. RESULTS AND ANALYSIS

Various algorithms described in Section II has been applied on standard grayscale image of size 512x512 and implemented using Matlab 7.0. For quantitative analysis three metrics are used:

1. *Peak Signal to Noise Ratio (PSNR):* PSNR is an engineering term for the ratio between the maximum possible power of the signal and power of corrupting noise that affects the fidelity of its representation. PSNR is expressed in terms of logarithmic decibel scale.

$$PSNR=10\ log_{10}\frac{255^2}{MSE} \qquad ...(ii)$$

2. *Image Enhancement factor(IEF):* IEF is the ratio of squared error between noisy image and original image and squared error between denoised image and original image.

$$IEF=\frac{\sum\sum(n(i,j)-Y(i,j))^2}{\sum\sum(Y'(i,j)-Y(i,j))^2} \qquad ...(iii)$$

3. *Mean Square Error(MSE):* MSE measures the average of squares of the errors. The error is the amount by which the value implied by the estimator differs from the quantity to be estimated.

$$MSE=\frac{\sum\sum(Y(i,j)-Y'(i,j))^2}{M*N} \qquad ...(iv)$$

In the above relations, M*N is the size of image, Y denotes the original Image, Y' denotes the denoised image and n is the noisy image.
Quantitative analysis is done by varying the noise density from 10% to 95% and the various parameters i.e. PSNR, IEF and MSE is calculated and the results are discussed in Table I, Table II and Table III and Fig.1, Fig.2 and Fig.3 for PSNR, IEF and MSE respectively.

TABLE I
PERFORMANCE COMPARISON OF PSNR AT VARIOUS NOISE DENSITIES FOR LENA IMAGE

| PSNR( dB) | | | | | |
|---|---|---|---|---|---|
| **Noise Level** | **MF** | **DBA** | **DBUTMF** | **MDBUTMF** | **IUTMMF** |
| 10% | 32.08 | 40.84 | 42.85 | 42.85 | 42.85 |
| 20% | 28.98 | 33 | 39.24 | 39.28 | 39.26 |
| 30% | 23.64 | 26.11 | 36.65 | 36.68 | 36.76 |
| 40% | 19.04 | 20.91 | 33.91 | 34.73 | 35.05 |
| 50% | 15.32 | 16.84 | 29.6 | 32.05 | 33.41 |


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| | | | | | |
|---|---|---|---|---|---|
| 60% | 12.35 | 13.49 | 24.37 | 28.8 | 32.05 |
| 70% | 10.08 | 10.96 | 19.02 | 24.65 | 30.47 |
| 80% | 8.19 | 8.81 | 14.08 | 20.24 | 28.71 |
| 90% | 6.68 | 6.9 | 9.5 | 15.9 | 26.1 |
| 95% | 6.03 | 6.17 | 7.43 | 13.9 | 23.59 |

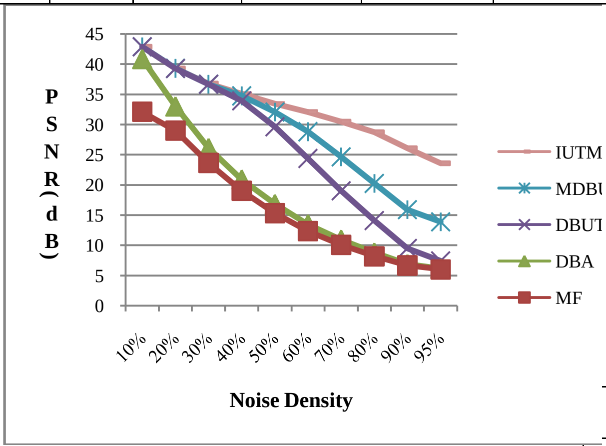



Fig. 1 A line chart of PSNR vs Noise Density.

TABLE II
PERFORMANCE COMPARISON OF IEF AT VARIOUS NOISE DENSITIES FOR LENA IMAGE

| IEF | | | | | |
|---|---|---|---|---|---|
| **Noise Level** | **MF** | **DBA** | **DBUTMF** | **MDBUTMF** | **IUTMMF** |
| 10% | 57.86 | 345.62 | 548.9 | 548.94 | 548.8 |
| 20% | 44.94 | 113.64 | 477.16 | 482.11 | 479.3 |
| 30% | 19.71 | 34.73 | 392.8 | 396 | 403 |
| 40% | 9 | 13.9 | 278.8 | 336.8 | 362.5 |
| 50% | 4.8 | 6.8 | 129.6 | 227.5 | 310.5 |
| 60% | 2.8 | 3.8 | 46.68 | 129.2 | 273.8 |
| 70% | 2 | 2.47 | 15.83 | 57.8 | 220.7 |
| 80% | 1.49 | 1.72 | 5.7 | 23.94 | 168.8 |
| 90% | 1.18 | 1.27 | 2.29 | 10 | 103.9 |
| 95% | 1.08 | 1.11 | 1.4 | 6.62 | 61.6 |

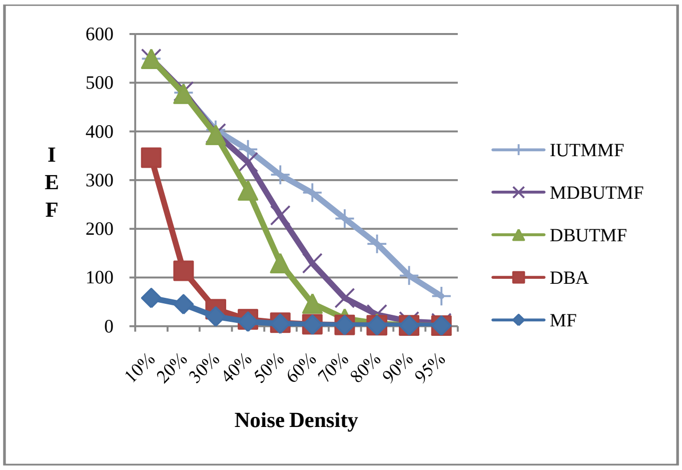



Fig. 2 A line chart of IEF vs Noise Density.

TABLE III
PERFORMANCE COMPARISON OF MSE AT VARIOUS NOISE DENSITIES FOR LENA IMAGE

| MSE | | | | | |
|---|---|---|---|---|---|
| **Noise Level** | **MF** | **DBA** | **DBUTMF** | **MDBUTMF** | **IUTMMF** |
| 10% | 32.22 | 5.39 | 3.39 | 3.39 | 3.4 |
| 20% | 82.81 | 32.75 | 7.8 | 7.7 | 7.7 |
| 30% | 282.1 | 160.1 | 14.16 | 14 | 13.8 |
| 40% | 821 | 530.9 | 26.61 | 22 | 20.4 |
| 50% | 1921 | 1355 | 71 | 40.8 | 29.8 |
| 60% | 3861 | 2927 | 239 | 86 | 40.8 |
| 70% | 6466 | 5249 | 819 | 224 | 58.8 |
| 80% | 9926 | 8607 | 2558 | 618 | 90 |
| 90% | 14068 | 13112 | 7264 | 1653 | 161 |
| 95% | 16331 | 15800 | 11838 | 2656 | 286 |

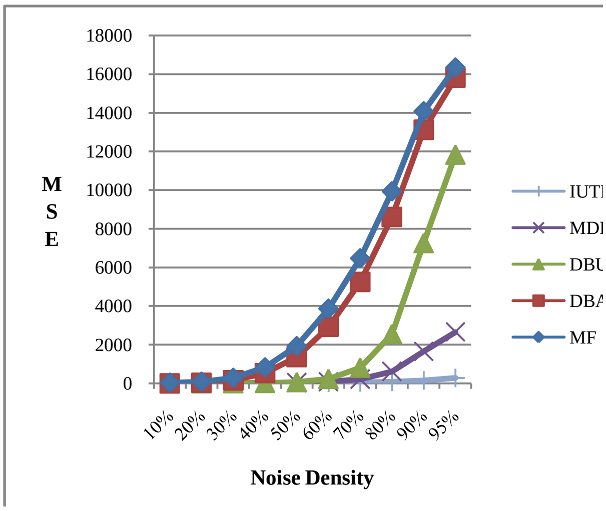
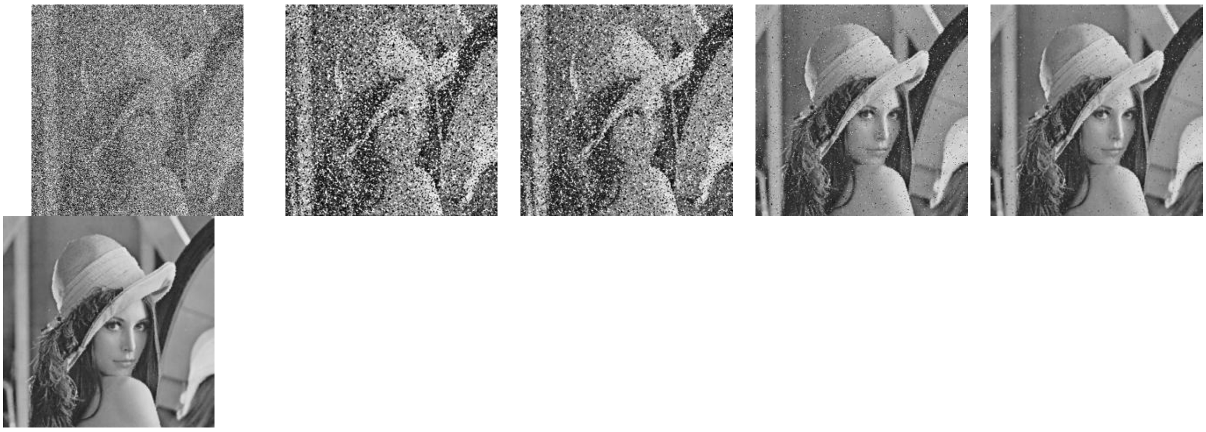



Fig. 3 A line chart of MSE vs Noise Density.

Qualitative analysis of the various algorithms is shown below in Fig.4 at noise density of 70% for Lena.png image of size 512x512.



(A) (B) (C) (D) (E)

(F)

Fig. 4 Result for Lena.png image of size 512*512 at 70% noise density (A) Noisy Image (B) MF Output (C) DBA Output (D) DBUTMF Output (E) MDBUTMF Output (F) IUTMMF Output.

## IV. Conclusions

In this paper, authors have reviewed the various non linear filters used for removal of high density salt and pepper noise from grayscale images. Various algorithms such as MF, DBA, DBUTMF, MDBUTMF and IUTMMF are discussed above in section II of this paper. The results obtained from the implementation of above said algorithms are compared in terms of PSNR, IEF and MSE and discussed in Section III. From the results it can be concluded that the IUTMMF out performs the various other algorithms even at the noise densities up to 95%. It can be concluded from the survey that Iterative Unsymmetrical Trimmed Midpoint-Median Filter gives best results than various other Filters.

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