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# A New Hybrid Filtering Technique Based on Neighboring Pixels to Remove Impulse Noise from Digital Images

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***Abstract***

*This paper proposes a hybrid technique to remove impulse noise from digital images. In this approach the filtering operation is based on 3*3 neighborhood of pixel under consideration. During filtering, the properties of neighborhood are considered to check whether it is highly corrupted with noise, medium or only itself act as impulse. Based upon these properties a new hybrid technique has been proposed to process the pixel which further uses different schemes. The experiments have been performed at various noise levels on standard images as well as on real images. The results have been evaluated on the basis of metrics like Signal to noise ratio (SNR), Edge preservation index ( EPI), Structure similarity index measure (SSIM), Multi scale structure similarity index measure (MS-SSIM) and Peak signal to noise ratio ( PSNR). From the results, it has been observed that proposed technique has worked efficiently by preserving the edges and fine lines. To demonstrate the effectiveness of proposed technique, the results have also been compared with other well accepted denoising techniques*

***Keywords:*** *Impulse noise, Noise filtering, Median filter, Midpoint filter, Image restoration*

## 1. Introduction

Noise can enter in an image through a variety of sources. This noise has to be processed with any denoising algorithm that cancels the noise components while preserving the original image structures [17]. The noisy pixels which are corrupted by impulse noise can take either the maximum or the minimum values *i.e.,* 0 or 255 [9]. In the most of applications, the presence of noise in image leads to bad performance of subsequent image processing tasks which are strictly dependent on the success of denoising operation. However, this is a difficult problem in any image processing system because the restoration filter must not distort the useful information in the image and preserve image details and texture while removing the noise [18]. It is very necessary to remove noise in the images before applying any further image processing task such as image recognition, edge detection, image segmentation *etc.* The noise can be removed by using various existing filtering techniques. There are many transform domain techniques like image denoising using wavelet threshold [5], discrete fourier transform, discrete cosine transform (DCT), discrete wavelet transform (DWT), curvelet transform and many anisotropic diffusion based algorithms have been developed but the main drawback of these techniques is their computational complexity due to the transformation process and are not efficient for impulse noise reduction [16]. The spatial domain filters are widely used because of their simplicity. The linear filtering techniques are not capable to remove the impulse noise effectively on the other hand the non-linear filtering techniques are widely used to remove impulse noise such as the median filter [33]. Median filter is known for its capability to remove the salt and pepper noise. Median Filter replaces the value of a pixel by the median of the intensity levels in the neighborhood of that pixel.

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The main disadvantage of this filter is that it works very well at low noise densities. But at high noise densities, it blurs the image and does not remove noise [1]. The other extensions of median filter, the minimum and maximum filter , rank-ordered mean filter (ROMF) [4] , weighted median filter (WMF) [4], progressive switching median filter (PSMF) [2] and center weighted median filter (CWMF) [4] are very simple and computationally efficient to remove impulse noise from images. But their drawback is that they operate both noisy and no noisy pixels in same manner. The adaptive median of absolute deviation (MAD)-based threshold filter (AMTF) incorporates an adaptive threshold to MAD-based impulse filtering approach. But at higher noise densities the recursive filtering operation increases the complexity of the algorithm [33]. In switching median filter the threshold value is predefined based on which the decision is made. But, obtaining optimal decision is difficult, also it ignores the local features of the image and hence edge details are not preserved at higher noise densities [29].

In this paper the work has been organized as follows. Section 2 describes the related work done in area of denoising of image. Section 3 presents the proposed work. Section 4 represents methodology of proposed technique with example. Section 5 describes the image quality assessment metrics. Section 6 illustrates the results and analysis. In the last Section 7 conclusion of this work has been described.

## 2. Related Work

In 2001, Jun-Seon Kim *et al.,* [3] proposed a new adaptive 3-D median filtering method and compared it with conventional non-linear methods to remove impulse noise. This method improved the quality of image and reduced the computation time. In 2004, Remzi oten *et al.,* [7] examined Alpha-trimmed mean filter and also presented a new adaptive alpha trimmed filter. Here the impulse noise is trimmed on the basis of local decision. The experimental results demonstrate that the proposed filter is a very good alternative to the existing schemes. In 2005, Raymond H. Chan *et al.,* [9] presented a two phase scheme based on adaptive median filter and detail preserving regulation methods. The experimental results showed significant improvement up to high noise density. In 2007, Krishnan Nallaperumal *et al.,* [10] proposed two new adaptive filtering algorithms named the Iterative adaptive switching median filter (IASMF) and the Adaptive threshold based median filter (ATMF) to remove of salt & pepper noise from images. Experimental results demonstrate that the IASMF and ATMF yield intelligible patches-free restoration. Indu, S *et al.,* [12] proposed pixel restoring median filter (PRMF) to remove noise from images. The experimental results demonstrate that their proposed technique is simple and prevents blurring. It is also suitable for real time applications. Madhu S Nair *et al.,* [13] proposed an improved decision based algorithm to remove salt & pepper noise from gray scale and color images. The performance of algorithm has been evaluated on the basis of PSNR, SSIM and IEF. They observed that the proposed algorithm is faster and well capable for edge preservation. In 2008, Shariar Kaisar *et al.,* [14] proposed a tolerance based arithmetic mean filtering technique to remove salt & pepper noise from images. This technique provided better results than that of the existing mean and median filtering techniques. They analyses that the arithmetic mean filtering technique works better than that of the geometric and harmonic mean filtering techniques and their proposed filtering technique works better than the arithmetic mean filtering technique. In 2009, Y. Shih *et al.,* [15] presented a novel PDE filter method by using the convection diffusion equation. It has been compared with an isotropic nonlinear diffusion model which shows its effectiveness to remove noise without using the nonlinear smoothing kernel which needs extra cost. In 2010, Bogdan Smoka [17] proposed peer group switching filter based on the evaluation of the statistical properties of a sorted sequence of accumulated distances used for the calculation of the vector median. The performance of filter has been increased by introducing threshold scheme. Hadi Sadoghi Yazdi *et al.,* [18] proposed a Modified adaptive center weighted median (MACWM) filter .The performance of proposed filter has been compared with median filter, signal dependent rank order mean filter, tri state median filter, fast peer group filter, switching scheme I filter, PFM filter and adaptive center weighted median filter (ACWM) , fuzzy median filter. The results demonstrate that the proposed MACWM filter is superior to a number of other median based filters. In 2011, Doda Shekar *et al.,* [19] presented Decision based unsymmetric trimmed median filter which removes impulse noise at high noise densities and also capable to preserve edges and fine details. P. Syamala Jaya Sree *et al.,* [20] proposed a novel adaptive median based lifting filter for image to remove the salt and pepper noise. The results show the superiority of the proposed filter in terms of image quality as well as the time complexity. In 2012, Ashutosh *et al.,* [21] proposed a new and efficient cascade decision based filtering algorithm to remove salt and pepper noise at high densities. The effectiveness of proposed algorithm has been evaluated for different images and the results are compared with other filters. The proposed algorithm shows better performance in terms of PSNR, MSE and MAE. Chaitanya Ethina *et al.,* [22] proposed a new image restoration technique. The proposed algorithm removed high density salt and pepper noise using modified decision based unsymmetrical trimmed median filter (DBUTMF). The performance of proposed algorithm has been analyzed on low, median and high noise densities based on PSNR and MSE values. K.Vasanth *et al.,* [23] proposed a decision based algorithm (DBUTVF) using modified shear sorting which is based on snake like mesh. The experiments demonstrate that proposed algorithm efficiently suppress the noise up to 85% noise density. Again K.Vasanth *et al.,* [24] proposed a new decision based unsymmetrical trimmed midpoint algorithm (DBUTMPF) by calculating trimmed midpoint rather than median of the images that are corrupted by impulse noise. The proposed algorithm efficiently removed the salt and pepper noise by preserving the edges at high noise densities. P. Syamala Jayasree *et al.,* [25] discussed a novel algorithm for salt and pepper image noise cancelation using cardinal B-splines. The proposed method provided efficient results due to the continuity properties of the cardinal B-splines. Shyam Lal *et al.,* [26] proposed a super mean filter (SUMF) to remove high density salt & pepper noise from digital images. The proposed SUMF filter has provided better performance as compared to other many existing denoising techniques even at 95% noise density levels. V. Thirilogasundari *et al.,* [27] proposed an extrema filter based on switching median filter. They concluded that proposed algorithm can restore the images corrupted up to 90% noise density. In 2013, Bhabesh Deka [28] proposed a multi scale based adaptive median filter which is capable to remove salt and pepper noise from grayscale images. The performances of different switching based median filters has been evaluated and compared with the proposed technique. Experimental results showed that proposed technique outperforms some of the existing methods, both visually and quantitatively by preserving their textures, details and edges. E. Jebamalar Leavline *et al.,* [29] analyzed median filter as well as its variants to remove salt and pepper noise. Their experimental results showed that, among the methods compared, tri state median filter and switching median filter provide good visual results. On the other hand, standard median filter, adaptive median filter, weighted median filter lack in preserving edges. In 2014, U. Sahin *et al.,* [31] proposed a new local transition function based on fuzzy theory. The proposed method removed salt and pepper noise by showing consistent and stable performance across a wide range of noise densities. In 2015, Justin Varghese *et al.,* [32] proposed an adaptive switching non-local filter (ASNLF) for restoration of digital images which are corrupted by impulse noise when there are sufficient uncorrupted pixels in the local neighborhood of the corrupted pixel to be replaced then algorithm works in non-local mode. Otherwise, the algorithm replaces impulsive pixels with the median of the uncorrupted pixels. They concluded that the proposed algorithm shows improved performance over other algorithms. In 2016, Igor Djurovic [34] applied the block matching and 3D filtering (BM3D) scheme to improve the decision-based/adaptive median techniques. The experimental results demonstrate the effectiveness of proposed technique for both grayscale and colored images.

## 3. Proposed Technique

This section describes the proposed algorithm by breaking down into number of Cases and Schemes.

**Step-1**: Let Pxy is a pixel to be processed and W is its neighborhood window of size 3∗3 centered on it. If the value of Pxy lies between the 0 and 255 (where 0 and 255 are excluded) *i.e.*, if Pxy >0 and Pxy <255 then it is noise free pixel and left unaltered. Otherwise go to Step -2.

**Step-2**: If the processing pixel is noisy pixel then check for any other noisy pixel present in the neighbor of processing pixel in windows. If there is no any other noisy pixel in the window except processing pixel then go for Scheme- 4. Otherwise go to Step 3.

**Step 3**: The 3∗3 windows with noisy neighbor is further categorized in following cases:

**Case-I**: if selected window contains either all 0's or all 255's.

**Case-II**: if selected window contains only combination of both 0's and 255's.

**Case-III**: if selected window contains combination of some noisy pixels and non-noisy pixel values.

All the above cases discussed have been showed in Figure 1.

If selected window falls in Case-I, then follow Scheme-1.

If selected window falls in Case-II, then follow Scheme-2.

If selected window falls in Case-III, then follow Scheme-3.

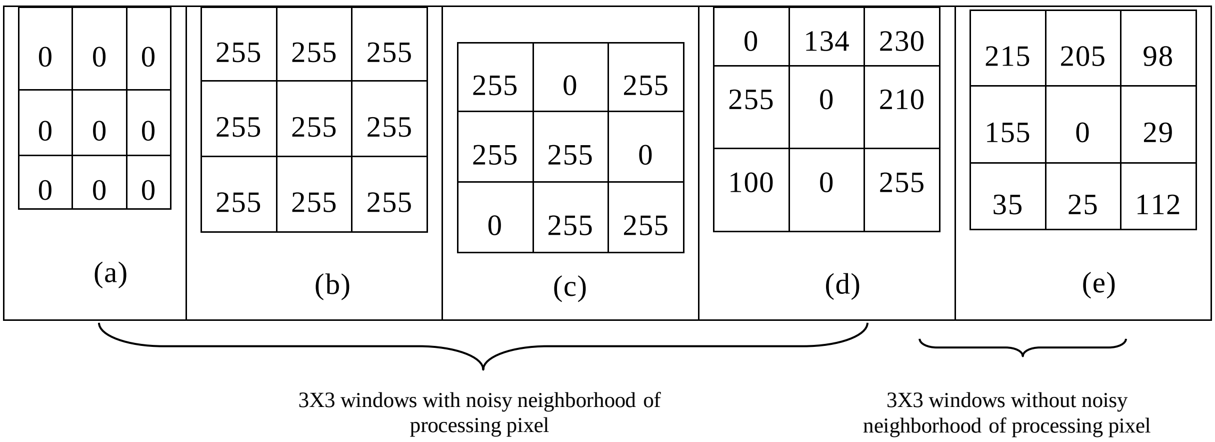



**Figure 1. (a), (b) Example of Case I; (c) Example of Case II; (d) Example of Case III of 3X3 Window with Noisy Neighbors of Processing Pixel; (e) Example of 3X3 Windows with No Any Noisy Neighbor of Processing Pixel**

### 3.1. Schemes:

The proposed hybrid technique is based on four schemes. As discussed in previous section, the processing windows are categorized in two ways *i.e.*, window with noisy neighbor and window without noisy neighbor. Hence the different types of schemes have been used to process different types of windows. The explanation of each scheme has been given as following:

**Scheme-1:**

This step is performed for case-I, in which selected window contains either all 0's or all 255's. .In this process the processing pixel is left unaltered. Here it is considered that if whole window contain 0's then it may be a white area in the image like teeth, white portion of eye *etc.* Hence it is not taken as impulse and kept unaltered. Similarly if whole window contain 255's then it may be a black area in the image like eye ball, hair etc. and hence it is also not taken as impulse and kept unaltered.

**Scheme-2:**

This step is followed in case-II i.e. if selected window contains only combination of both 0's and 255's as shown in Figure 1(c). These are both impulse values. In this case a midpoint of these values is calculated and the processing pixel is replaced with that midpoint *i.e.,* 128.

**Scheme-3:**

This scheme is performed for case-III, where selected window contains combination of some noisy pixels and non-noisy pixel values. The processing of this type of window further involves two steps.

**Trimming**:

Here all the pixel values of selected window are first sorted into ascending order. Then all the 0's and 255's are trimmed which are present in sorted array of pixel values to form a new trimmed array.

**Mid Point Calculation**:

After trimming the Midpoint of remaining pixels (trimmed array) is calculated and replaced with processing pixel.

Here it has been considered that presence of 0 and 255 results into inappropriate midpoint of the sorted array that is why trimming has been performed prior to midpoint calculation.

**Scheme-4:**

This scheme is performed when processing window does not contain noisy neighborhood as shown in Figure 1(e). Here first of all, the pixel values are sorted into ascending order. This sorted array does not contain any 0 or 255 except one noisy pixel. Then a median is calculated among all pixels (*i.e.,* of 8 elements) by removing noisy pixel. Then this median is replaced with noisy processing pixel. As median is chosen from neighboring pixels which may be an impulse, but in this case, median is calculated over that window which does not have pixel value 0 or 255. Hence there is very less chance to choose an impulse as a median to replace the processing pixel. It overcomes the drawback of median filter.

The performance of median filter normally degrades at higher noise densities, but in this work the median filter is applied only where neighborhood of processing window does not contain any 0 or 255, hence filter preserves fine details and edges.

## 4. Methodology

The proposed hybrid approach (PHA) has been described in Figure 2.

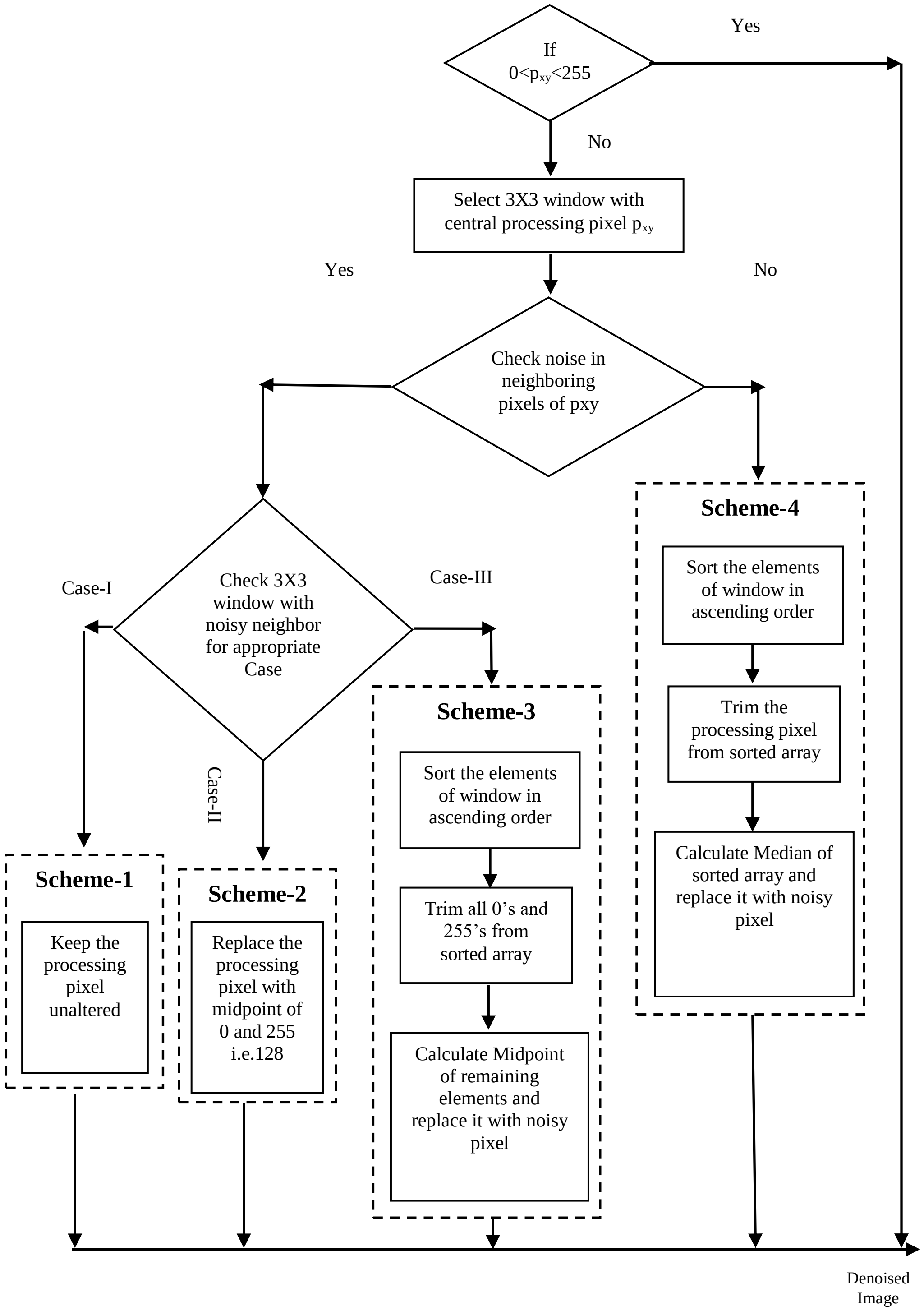



**Figure 2. Model of Proposed Technique**

### Illustration with example

Let us consider an example given in Figure 3. This 12∗12 pixel matrix contains total 22 corrupted pixels. Here only four 3∗3 windows *i.e.*, W1, W2, W3 and W4 have been considered to demonstrate the implementation of proposed technique.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 143 | 234 | 178 | 104 | 111 | 145 | 57 | 123 | 212 | 104 | 100 | 100 | |
| W1 | 134 | 165 | 173 | 101 | 106 | 189 | 43 | 176 | 207 | 101 | 104 | 123 | |
| | 126 | 0 | 179 | 103 | 118 | 212 | 90 | 159 | 199 | 103 | 105 | 176 | |
| | 136 | 178 | 182 | 123 | 125 | 245 | 123 | 102 | 213 | 123 | 104 | 159 | |
| | 106 | 100 | 189 | 172 | 0 | 0 | 0 | 109 | 189 | 172 | 101 | 102 | |
| W2 | 167 | 154 | 201 | 218 | 0 | 0 | 0 | 123 | 196 | 213 | 103 | 109 | |
| | 133 | 99 | 202 | 210 | 0 | 0 | 0 | 0 | 200 | 210 | 123 | 123 | |
| | 124 | 98 | 207 | 192 | 194 | 202 | 164 | 255 | 0 | 192 | 172 | 106 | W3 |
| | 167 | 102 | 211 | 178 | 0 | 255 | 255 | 149 | 56 | 178 | 213 | 167 | |
| | 187 | 158 | 156 | 78 | 255 | 0 | 0 | 123 | 189 | 78 | 210 | 133 | W4 |
| | 149 | 182 | 211 | 90 | 0 | 0 | 255 | 165 | 212 | 90 | 192 | 124 | |
| | 143 | 176 | 120 | 99 | 145 | 121 | 200 | 100 | 245 | 99 | 178 | 167 | |

**Figure 3. Illustration of Types of Windows**

**Processing of W1**: In this window there is not any other noisy pixel instead of processing pixel, hence according to proposed technique, Scheme- 4 is to be followed for processing of this noisy pixel.

Sorted array of W1: 0,126,134,136,165,173,178,179,182

Trimmed Array: 126,134,136, 165,173,178,179,182

Median: (165+173)/2= 169

Hence the processing pixel 0 will be replaced by 169

**Processing of W2**: In this window all pixel values are 0. Hence according to proposed technique, Scheme-1 is to be followed for processing of this noisy pixel *i.e.*, processing pixel will be kept unaltered.

**Processing of W3**: In this window there are some other noisy pixel surrounded to processing pixel. Hence according to proposed technique, this window falls in Case III and thus Scheme -3 has to be followed here.

Sorted Array:0,0,0,0,56,149,164,200,255,255

Trimmed Array: 56,149,164,200

Midpoint: (56+200)/2=128

Hence the processing pixel 255 will be replaced by 128

**Processing of W4**: in this window all pixels are corrupted with salt and pepper noise *i.e.*, window contains the combination of 0 and 255. Hence according to proposed technique, this window falls in Case II and thus Scheme-2 has to be followed here. Midpoint of 0 and 255 is 128.

Hence the processing pixel 0 will be replaced by 128.

## 5. Image Quality Assessment Metrics

### 5.1. Signal to Noise Ratio (SNR)

Signal to noise ratio is defined as the power ratio between a signal and the background noise [30].

$$SNR = \frac{P_{signal}}{P_{noise}} \tag{1}$$

Where p is average power.both noise and power must be measured at the same bandwidth.

### 5.2. Edge Preservation Index (EPI)

EPI is used to calculate edge preservation property of denoising technique. It is given as [11]:

$$EPI = \frac{\sum(\Delta I - \overline{\Delta I})\ \sum(\Delta F - \overline{\Delta F})}{\sqrt{\sum(\Delta I - \overline{\Delta I})^2 \sum(\Delta F - \overline{\Delta F})^2}} \tag{2}$$

Here ΔI and ΔF are high pass filtered versions of image I and F. If the EPI value is large, it means that more accurately edges have been preserved.

### 5.3. Structure Similarity Index Measure (SSIM)

It is the improvement over traditional methods like PSNR, MSE etc. This metric is calculated using different windows of an image. The general form of the SSIM index between signal x and y is defined as [8]:

$$SSIM(x,y) = [l(x,y)]^{\alpha}.[c(x,y)]^{\beta}.[s(x,y)]^{\gamma} \tag{3}$$

### 5.3. Multi-Scale Structure Similarity Index Measure (MS-SSIM)

Multi-scale method is a very convenient way to incorporate image details at different resolutions. It provides more flexibility than single scale approach in case of the variations of image resolution and viewing conditions. It provides better results than SSIM. In this method, distorted image is taken as input, the system iteratively applies a low pass filter and down samples the filtered image by a factor of 2. The overall MS-SSIM evaluation is obtained as following [6].

$$MSSSIM(x,y) = [l_m(x,y)]^{\alpha M}.\prod_{j=1}^{M}\left[c_j(x,y)\right]^{\beta j}\left[s_j(x,y)\right]^{\gamma j} \tag{4}$$

### 5.4. Peak Signal-to-Noise Ratio (PSNR)

The peak signal to noise ratio determines the ratio of the maximum grayscale value of the digital image to the power of noise that affects the image fidelity. It is defined by [30]:

$$PSNR = 10\ log_{10} \frac{(255)^2}{MSE} db \quad (5)$$

Where Mean square error (MSE) is the average squared difference between denoised restored image and original image

## 6. Results and Analysis

The implementation of proposed technique has been done in MATLAB software. The experiments of proposed technique have been done on some standard images including Lena, Barbara, Boats, Bridge, as well as on real images. In the experiments images are corrupted by salt and pepper noise with equal probability. The noise density is varied from 10% to 90%. In this paper Lena and Barbara image of size 512∗512 have been used to show comparative analysis on the basis of SNR, EPI, SSIM, MS-SSIM and PSNR. The experimental comparison of proposed technique is made with median filter (MF) [16], adaptive median filter (AMF), Decision based unsymmetrical trimmed median filter (DBUTMF) [19], Modified decision based un-symmetric trimmed median filter (MDBUTMF) [22] and Decision based un-symmetric trimmed midpoint filter (DBUTMPF) [24].

Table-1 illustrates the comparative analysis of various existing filters based on survey of literature. The performances of (PRMF) [12], An improved decision based algorithm [13], a novel adaptive median based lifting filter [20], extrema filter based on switching median filter [27], SUMF [25], cascade decision based filter [22], multi scale based adaptive median filter [28], Using cardinal B-splines [25], ASNLF [32], Improved decision-based/adaptive median using BM3D scheme [34] have been summarized in terms of PSNR and SSIM.

Table-2 demonstrates the results compiled with standard Lena image and Barbara image at 10% noise density. The value of SNR has been calculated to evaluate signal to noise ratio between original and restored image. The high SNR value shows the high quality of denoised image. The EPI has been calculated to check the edge preservation property of all filters. SSIM has been evaluated to check structural similarity between original image and denoised image. To incorporate the detail of image at different resolutions, the MS-SSIM has been calculated at level-5.

Similarly Table-3, Table-4, Table-5 and Table-6 lists the performance measurement parameters against different noise density of 30%, 50%, 70% and 90% respectively with Lena image and Barbara image. It has been observed that DBUTMF, MDBUTMF and DBUTMPF perform well at lower noise densities but as the noise density reaches up to 50% their performance abruptly falls down. As DBUTMPF suppresses much of noise but fails to preserve edges information. Hence from the values of metrics in the tables, it has been concluded that the proposed technique shows superiority among all other filters which are discussed in this paper.

**Table 1. Comparative Analysis of Existing Salt and Pepper Removal Techniques in Terms of PSNR and SSIM**

| Method | Year | Lena (512*512) | | |
|---|---|---|---|---|
| | | Noise Density | SSIM | PSNR |
| Indu S, *et al.*, [12] (PRMF) | 2007 | 40 | NA | 29.4 |
| | | 60 | NA | 26.9 |
| Madhu S. Nair [13] (An improved Decision based algorithm) | 2008 | 30 | 0.9888 | 30.79 |
| | | 60 | 0.952 | 24.95 |
| | | 90 | 0.812 | 19.20 |
| P. Syamala Jaya Sree *et al.*, [20] (a novel adaptive median based lifting filter) | 2011 | 10 | 0.9691 | 43.08 |
| | | 50 | 0.9284 | 33.22 |
| | | 70 | 0.7339 | 25.20 |
| V. Thirilogasundari *et al.*, [27] (extrema filter based on switching median filter) | 2012 | 10 | 0.99 | 38.38 |
| | | 50 | 0.96 | 33.09 |
| | | 90 | 0.74 | 24.04 |
| Shyam Lal *et al.*, [25] (SUMF) | 2012 | 10 | NA | 38.38 |
| | | 50 | NA | 28.31 |
| | | 90 | NA | 20.24 |
| Ashutosh Pattnaik *et al.*, [22] ( cascade decision based filter) | 2012 | 10 | NA | 41.87 |
| | | 50 | NA | 32.1 |
| | | 90 | NA | 24.61 |
| Bhabesh Deka *et. al.*, [28] (multiscale based adaptive median filter) | 2013 | 20 | 0.939 | 31.03 |
| | | 70 | 0.586 | 19.08 |
| | | 90 | 0.040 | 9.07 |
| P. Syamala Jayasree *et al.*, [25] (Using cardinal B-splines) | 2013 | 30 | 0.9619 | 35.89 |
| | | 50 | 0.9034 | 31.64 |
| | | 90 | 0.7246 | 25.48 |
| Justin Varghese *et al.*, [32] (ASNLF) | 2015 | 10 | 0.99 | 42.66 |
| | | 50 | 0.92 | 33.98 |
| | | 90 | 0.78 | 26.68 |
| Igor Djurovic [34] (Improved decision-based/adaptive median using BM3D scheme) | 2016 | 20 | NA | 33.49 |
| | | 60 | NA | 32.68 |
| | | 90 | NA | 27.74 |

NA – Not Available

**Table 2. Experimental Results of Various Filters on Lena Image and Barbara Image at 10% Noise Density**

| Filters | Lena image | | | | | Barbara Image | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | SNR | EPI | SSIM | MS-SSIM | PSNR | SNR | EPI | SSIM | MS-SSIM | PSNR |
| MF | 18.44 | 0.4987 | 0.9785 | 0.9885 | 33.92 | 11.39 | 0.2211 | 0.8982 | 0.9504 | 24.43 |
| AMF | 26.05 | 0.8023 | 0.9807 | 0.9886 | 42.38 | 19.70 | 0.9128 | 0.9861 | 0.9929 | 32.81 |
| DBUTMF | 27.17 | 0.8313 | 0.9808 | 0.9729 | 42.96 | 20.51 | 0.9260 | 0.9881 | 0.9940 | 33.59 |
| MDUTMEDF | 27.17 | 0.8823 | 0.9918 | 0.9901 | 44.02 | 20.41 | 0.9235 | 0.9882 | 0.9941 | 33.49 |
| DBUTMPF | 27.41 | 0.8840 | 0.9876 | 0.9905 | 41.80 | 20.83 | 0.9286 | 0.9901 | 0.9950 | 33.91 |
| **PHA** | **27.64** | **0.8896** | **0.9996** | **0.9999** | **44.85** | **21.68** | **0.9304** | **0.9989** | **0.9968** | **34.06** |

**Table 3. Experimental Results of Various Filters on Lena Image and Barbara Image at 30% Noise Density**

| Filters | Lena image | | | | | Barbara Image | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | SNR | EPI | SSIM | MS-SSIM | PSNR | SNR | EPI | SSIM | MS-SSIM | PSNR |
| MF | 9.40 | 0.1118 | 0.7540 | 0.8788 | 23.91 | 7.59 | 0.0843 | 0.7319 | 08603 | 20.64 |
| AMF | 21.20 | 0.6671 | 0.9762 | 0.9729 | 35.39 | 13.90 | 0.7042 | 0.9451 | 0.9717 | 27.01 |
| DBUTMF | 22.34 | 0.7100 | 0.9812 | 0.9814 | 37.50 | 15.12 | 0.7554 | 0.9564 | 0.9781 | 28.22 |
| MDUTMEDF | 22.45 | 0.7271 | 0.9814 | 0.9825 | 37.67 | 15.17 | 0.7578 | 0.9571 | 0.9786 | 28.25 |
| DBUTMPF | 22.83 | 0.7101 | 0.9901 | 0.9851 | 36.98 | 15.27 | 0.7729 | 0.9608 | 0.9801 | 28.49 |
| **PHA** | **23.01** | **0.7128** | **0.9910** | **0.9953** | **37.16** | **15.75** | **0.7804** | **0.9641** | **0.9843** | **28.93** |

**Table 4. Experimental Results of Various Filters on Lena Image and Barbara Image at 50% Noise Density**

| **Filters** | **Lena image** | | | | | **Barbara Image** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **SNR** | **EPI** | **SSIM** | **MS-SSIM** | **PSNR** | **SNR** | **EPI** | **SSIM** | **MS-SSIM** | **PSNR** |
| MF | 1.05 | 0.0360 | 0.2959 | 0.5235 | 15.24 | 1.56 | 0.0305 | 0.0344 | 0.5776 | 14.6 |
| AMF | 13.66 | 0.2900 | 0.9081 | 0.9510 | 27.58 | 10.07 | 0.4462 | 0.8532 | 0.9225 | 23.18 |
| DBUTMF | 15.52 | 0.3194 | 0.9450 | 0.9684 | 30.06 | 11.37 | 0.4911 | 0.8911 | 0.9450 | 25.45 |
| MDUTMEDF | 18.64 | 0.4649 | 0.9667 | 0.9716 | 32.95 | 12.06 | 0.5506 | 0.9052 | 0.9515 | 25.14 |
| DBUTMPF | 19.01 | 0.4670 | 0.9716 | 0.9718 | 33.36 | 12.84 | 0.5951 | 0.9106 | 0.9598 | 25.94 |
| PHA | **21.06** | **0.5903** | **0.9899** | **0.9861** | **33.47** | **13.03** | **0.6094** | **0.9211** | **0.9611** | **26.11** |

**Table 5. Experimental Results of Various Filters on Lena Image and Barbara Image at 70% Noise Density**

| **Filters** | **Lena image** | | | | | **Barbara Image** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **SNR** | **EPI** | **SSIM** | **MS-SSIM** | **PSNR** | **SNR** | **EPI** | **SSIM** | **MS-SSIM** | **PSNR** |
| **MF** | -4.26 | 0.014 | 0.0857 | 0.2298 | 9.88 | -3.47 | 0.0105 | 0.1092 | 0.2762 | 9.57 |
| **AMF** | 2.48 | 0.0536 | 0.3979 | 0.5920 | 17.18 | 2.73 | 0.1204 | 0.4415 | 0.6393 | 15.84 |
| **DBUTMF** | 4.89 | 0.0632 | 0.5850 | 0.7792 | 19.01 | 4.70 | 0.1233 | 0.5974 | 0.7868 | 17.77 |
| **MDUTMEDF** | 10.24 | 0.1384 | 0.7628 | 0.8793 | 24.59 | 8.13 | 0.2365 | 0.7190 | 0.8542 | 21.2 |
| **DBUTMPF** | 11.04 | 0.1401 | 0.8229 | 0.9009 | 26.05 | 9.07 | 0.2765 | 0.7587 | 0.8775 | 22.31 |
| **PHA** | **12.09** | **0.1669** | **0.8232** | **0.9102** | **26.17** | **9.13** | **0.2849** | **0.7603** | **0.8782** | **22.44** |

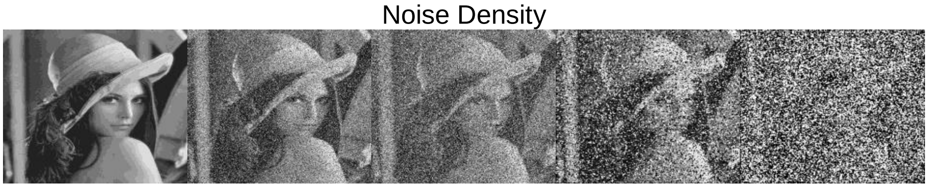
**Table 6. Experimental Results of Various Filters on Lena Image and Barbara Image at 90% Noise Density**

| Filters | Lena image | | | | | Barbara Image | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | SNR | EPI | SSIM | MS-SSIM | PSNR | SNR | EPI | SSIM | MS-SSIM | PSNR |
| **MF** | -7.63 | 0.0028 | 0.0206 | 0.0682 | 6.53 | -6.65 | 0.0031 | 0.0276 | 0.0857 | 6.38 |
| **AMF** | -5.68 | 0.0063 | 0.0514 | 0.1358 | 8.60 | -4.79 | 0.0157 | 0.0681 | 0.1716 | 8.31 |
| **DBUTMF** | -4.72 | 0.0088 | 0.1251 | 0.3213 | 9.46 | -3.90 | 0.0148 | 0.1579 | 0.3663 | 9.17 |
| **MDUTMEDF** | 1.40 | 0.0308 | 0.2455 | 0.4507 | 15.55 | 1.58 | 0.0370 | 0.2836 | 0.4974 | 14.63 |
| **DBUTMPF** | 2.07 | 0.0406 | 0.4438 | 0.6201 | 17.45 | 3.15 | 0.0515 | 0.3994 | 0.5885 | 16.10 |
| **PHA** | **7.45** | **0.0951** | **0.7417** | **0.7260** | **21.99** | **6.29** | **0.1428** | **0.5918** | **0.7718** | **19.35** |

To demonstrate the visual performance of proposed hybrid technique, the processed images are shown in Figure 4. The proposed method achieves a significantly high SNR, EPI and PSNR value at low and medium noise densities and this is mainly based on processing of noisy pixel by considering its neighbors which leads to the efficient noise removal and edge preservation of image. The SSIM and MS-SSIM values are also very near to 1 at low to medium noise densities which show that the denoised image is identical to original image. At higher noise densities the proposed method also provides better results than other well accepted techniques in literature. It has been analyzed that the use of different types of schemes to process noisy pixel provides the flexibility to process different types of image like pattern based, texture based and smooth images corrupted with less, medium or high noise density which leads to better restored images. Figure 5, 6, 7, 8 and 9 show the comparison of proposed technique with other denoising techniques on the basis of SNR, EPI, SSIM, MS-SSIM and PSNR respectively on Barbara and Lena image. The performance of all metrics and the subjective visual qualities of proposed method shows remarkable results after the images are being processed.

10% 30% 50% 70% 90%

Noise Density



Median Filter (MF)

Adaptive Median Filter (AMF)

DBUTMF

MDBUTMF

DBUTMPF

Proposed Hybrid Technique

**Figure 4. Visual Results of MF, AMF, DBUTMF, MDBUTMF, DBUTMPF and Proposed Hybrid Technique at Various Noise Densities**

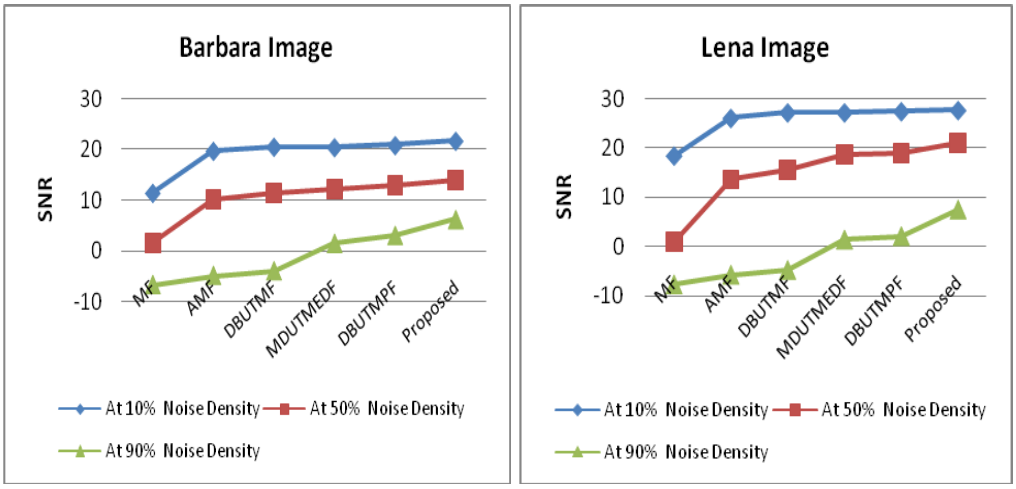



**Figure 5. Comparison of SNR at Various Noise Densities.**

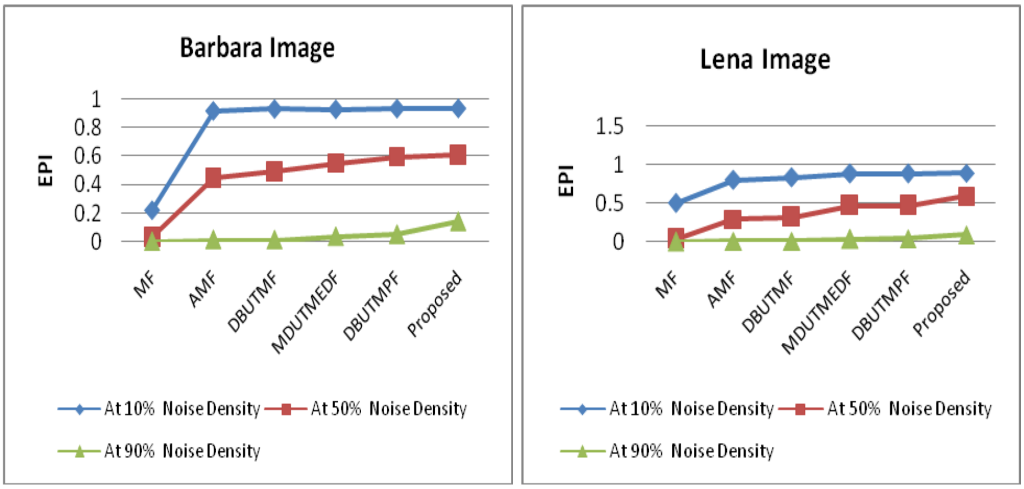



**Figure 6. Comparison of EPI at Various Noise Densities**

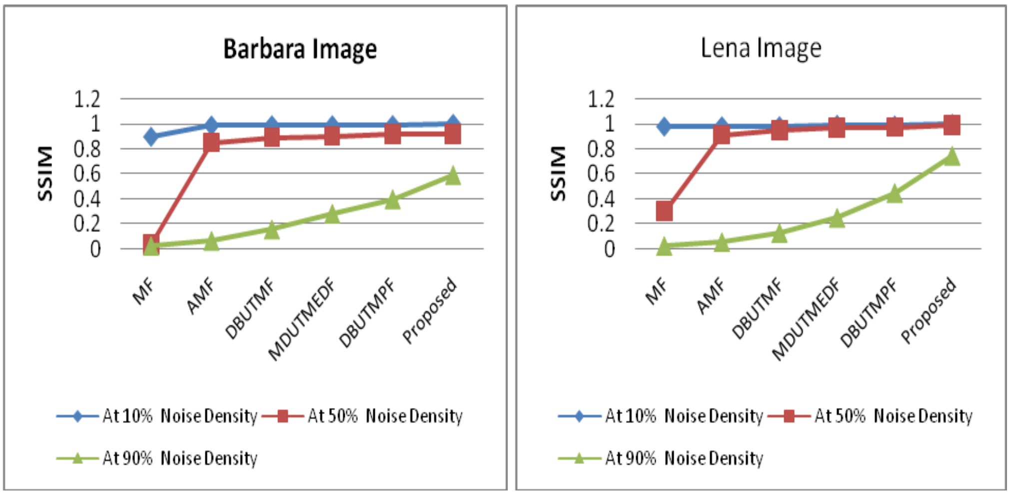



**Figure 7. Comparison of SSIM at Various Noise Densities**

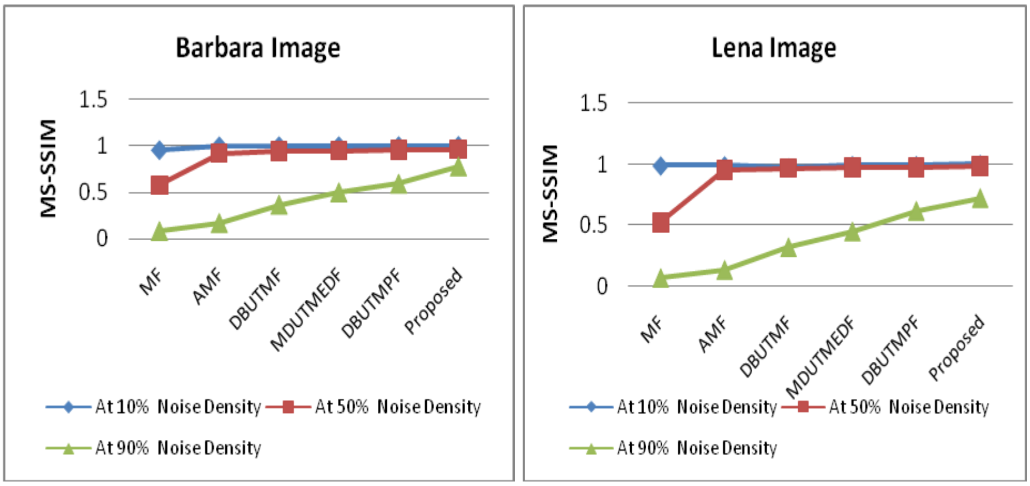



**Figure 8. Comparison of SSIM at Various Noise Densities**

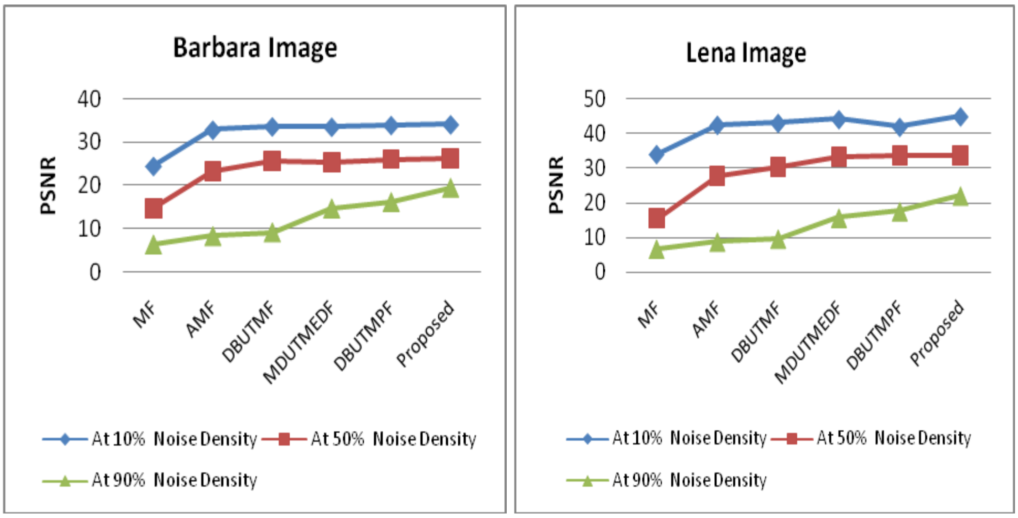



**Figure 9. Comparison of SSIM at Various Noise Densities**

## 6. Conclusion

In this paper a new hybrid technique is proposed to remove impulse noise from digital images, which gives better performance in comparison with other techniques. The proposed hybrid technique shows consistent and stable performance across a wide range of noise densities varying from 10% to 90%. The proposed hybrid technique uses multiple schemes to process the noisy pixel based on the properties of pixel under consideration, which enables efficient replacement of noisy pixel. The extensive experimental results included in this paper have demonstrated that the proposed technique is superior to a number of state-of-the-art impulse reduction filters in the literature.

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