

Sorted Min-Max-Mean Filter for Removal of High Density Impulse Noise

Deepti Kakkar, Neetu Sood, Prity Kumari*

Dr. B R Ambedkar National Institute of Technology
Jalandhar, Punjab, 144011, INDIA

*Corresponding Author

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Abstract: This paper presents an improved Sorted-Min-Max-Mean Filter (SM3F) algorithm for detection and removal of impulse noise from highly corrupted image. This method uses a single algorithm for detection and removal of impulse noise. Identification of the corrupted pixels is performed by local extrema intensity in grayscale range and these corrupted pixels are removed from the image by applying SM3F operation. The uncorrupted pixels retain its value while corrupted pixel's value will be changed by the mean value of noise-free pixels present within the selected window. Different images have been used to test the proposed method and it has been found better outcomes in terms of both quantitative measures and visual perception. For quantitative study of algorithm performance, Mean Square Error (MSE), Peak-Signal-to-Noise Ratio (PSNR) and image enhancement factor (IEF) have been used. Experimental observations show that the presented technique effectively removes high density impulse noise and also keeps the originality of pixel's value. The performance of proposed filter is tested by varying noise density from 10% to 90% and it is observed that for impulse noise having 90% noise density, the maximum PSNR value of 30.03 dB has been achieved indicating better performance of the SM3F algorithm even at 90% noise level. The proposed filter is simple and can be used for grayscale as well as color images for image restoration.

Keywords: Impulse noise, mean, noise removal, MSE, PSNR, IEF

1. Introduction

Noises in image can cause many problems like degradation of quality of image and loss of important information in image. Digital images are affected by various kinds of noises of which suppressing impulse noise in any image is a significant issue in Digital Image Processing (DIP) [1]. Salt & pepper noise (SPN) is another name for impulse noise. The salt or pepper noise appears with equal probability in any image. These noises are distributed over the complete image. Noises can be caused in an image when it is sent from one place to another place via electronics devices. Noise is also caused by sensor heat while capturing an image. Any abrupt change in the image pixel value can cause impulse noise. Removing impulse noise from an image is a challenging issue.

There are numerous techniques have been developed for noise reduction. They differ depending on the type of noise. Each technique has its own advantages, assumptions, and limitations. The aim of these techniques is to suppress noise while keeping the image information preserved and also at the same time maintains the edges. Here, techniques for impulse noise removal are considered and some techniques for removing impulse noise have been studied. Standard Median Filter (MF) [2] is the most commonly known technique for removing impulse noise. MF is a nonlinear order-statistic filter. In MF each pixel in reconstructed image equals to the median value of its nearest neighbours present in

original image. A square, sliding window is used to determine the size of neighbourhood. This window scans complete image pixel-by-pixel. MF has good denoising capability and computational efficiency, but to some limited noise level. It fails to preserve details at high noise level.

Conventional median filters don't check whether the current pixel is noisy or noise free and apply the median filter operation to each & every pixel. These filtering schemes produce images that have blurring effect, edges not preserved and resolution not retained due to miss-detection of noisy pixels as noise-free pixels and vice versa. Thus, the image information contributed from the noise free pixels is still filtered resulting in blurring the complete image and deteriorating the image quality. To solve this situation, the median filters approach are being accomplished in two stage way. Firstly, in order to take decision whether the pixel is noisy or noise free, an impulse noise detector is used. Secondly, noisy pixel is modified and noise free pixels remain unchanged. Numerous algorithms have been modified on the basis of MF to improve its performance. Some modifications of MF include, but not limited to, Adaptive Median Filters (AMF) [3]-[4], Weighted Median Filters (WMF) [5], Centre Weighted Median Filters (CWMF) [6], Adaptive Centre Weighted Median Filter (ACWMF) [7], Recursive Median Filters (RMF) [8] and Switching Median Filter (SMF) [9]. These modified filter approach have achieved better results than the traditional filters at low noise level. In AMF, the window size is adjusted to identify and remove the corrupted pixels according to the noise density. However, AMF leads to image blur and loss of details by increasing window size, and SMF too cause loss of image details because of lack of noise-free pixels in the high noise density, although it makes a great improvement in the efficiency and performance, compared to MF and AMF. In case of random noise, corrupted pixel value owns to the uncertainty and imprecision, many fuzzy MFs [10]-[11] have been presented for impulse removal, which are based on fuzzy logic. In case of fuzzy based filters, fuzzy logics are used to identify and estimate the corrupted pixels. The fuzzy filters can keep the details preserved very well while removing low-noise-level impulse noises. However, fuzzy filters don't provide satisfying output when images are highly corrupted.

In this paper, the corrupted pixel has been identified based on local maximum & minimum intensity in the grayscale range and then a new algorithm SM3F has been used to overcome impulse noise, keeping preserve the image information. The proposed algorithm has been applied to the noisy grayscale as well as to the RGB color image and the original image has been recovered efficiently.

2. Related Work

Recent advancement in digital image processing (DIP) and Impulse noise removal techniques develops several novel techniques to overcome the effect of impulse noise from digital images. Many noise detectors have been introduced to improve the performance of existing techniques. In this section a brief study of distinct impulse noise removal techniques has been made for last few years.

Chan, R.H. et al., (2005) [12] proposed a method to remove SPN in two phases. In 1st phase, an AMF is used for identification of corrupted pixels. In 2nd phase, a specialized regularization scheme is applied only to corrupted pixels in order to recover the original image. This scheme can remove SPN with a noise level up to 90%. Ng, P.E. et al., (2006) [13] proposed SMF with Boundary Discriminative Noise Detection (BDND) algorithm. Advantages of using BDND algorithms are that it works well with noise density up to 90%, and it is a real time application. But, the size of filtering window in BDND is limited. Srinivasan, K.S. et al., (2007) [14] proposed a Decision Based Algorithm (DBA) to address two problems namely blurring of images for large window sizes and poor noise removal for smaller window sizes, which are commonly encountered in MFs. This method uses a small 3×3 window having only neighbours of the noisy pixel that have higher correlation. DBA provides more edge details leading to better edge preservation and it has regular and stable performance for a wide range of noise densities. Ibrahim, H. et al., (2008) [15] introduced a hybrid of AMF with SMF. AMF framework has been used in order to enable the flexibility of the filter to change it size accordingly based on the approximation of local noise density. SMF framework has been used in order to speed up the process, because only corrupted pixels are filtered. Chen, P.Y. et al., (2008) [16] proposed two phase scheme for SPN removal and edge preservation. In first phase, an AMF is used for corrupted pixel detection and edge preservation. In second phase, the quality of reconstitution is improved using Non-Local Means algorithm. This scheme is simple and best suited for real time applications. However, despite its simplicity, this technique provides good results only when the noise density is low, and in case of high noise density all effective pixels will change. Toh, K.K.V. et al., (2010) [17] introduced an algorithm that utilizes histograms of corrupted images to detect noisy pixels. The filtering mechanism employs fuzzy logic to handle uncertainty in the extracted local information, caused by noise. This filtering algorithm is rather complex but has good performance and efficient processing time. Wang, C. et al., (2010) [18] presented an improved MF algorithm for images which are highly corrupted with SPN. First, by using Max-Min noise detector, each pixel is categorized either as image pixel or noisy pixel. After detection process, the noisy pixels are further classified into three classes as low, moderate, and high-density noises. Esakkirajan, S. et al., (2011) [19] proposed an algorithm, in which when the selected window contains other pixels either as '0' or '255' the corrupted pixel is modified with trimmed median value. When all the pixel values are '0' or '255' the corrupted pixel is modified with mean values Jafar, I.F. et al., (2013) [20] introduced a modified BDND filtering Algorithm. The modified BDND

applies two modifications to deal with the filtering issues of BDND. First, loosen the condition imposed on expanding the size of filtering window. Second, incorporate the spatial information of the pixels in the filtering process. Mu, W. et al., (2013) [21] presented an algorithm called Adaptive Window Multistage Median Filter for removing SPN. It uses multi-stage median filter detail preservation, extreme median filter to make judgment about presence of noise and threshold median filter for increasing performance on non-extreme noise. Kumar, J. et al., (2014) [22] presented a Modified DBA (MDBA) to overcome the limitation of DBA. The repeated replacement of noisy pixels with neighbourhood pixels causes streaks in images in case of DBA. MDBA ignores these streaks. In MDBA corrupted pixels are updated with median of asymmetric trimmed output. But for images which are highly corrupted, the pixels could be all 0's or all 255's or combination of both, and then replacement with trimmed median value is not possible. Bai, T. et al., (2014) [23] presented a method which uses a Local Mean and Variance based automatic Detector (LMVD) for noise detection and Newton-Thiele filter (NTF) for filtering process. NTF can be processed in two steps. In first step a 2-D grid is constructed using eight neighbouring pixels of the corrupted pixel. If the grid contains any corrupted pixel, a four-directional linear interpolation algorithm is applied to provide an estimate for that corrupted pixel. In second step the Newton–Thiele’s Rational Interpolation (NTRI) is constructed on the grid and the corrupted pixel’s value is substituted by NTRI on that grid. The NTF doesn’t require adjusting window size or other parameters. The proposed detector provides perfect detection performance. Zhang, P. et al., (2014) [24] proposed an Adaptive Weighted Mean (AWM) filter. In this, first adaptive window size is determined for each pixel by continuously increasing the window size until the minimum and the maximum values of two consecutive windows are equal respectively. Once it is completed, the current pixel is referred as noisy pixel if it is equal to either maximum or minimum value; otherwise it is referred as noise-free pixel. The noisy pixel is then modified with weighted mean of present window, while noise-free pixels remain unchanged. This filter has significantly low error detection rate and high restoration quality especially at high noise density. Ahmed, F. et al., (2014) [25] proposed a novel adaptive iterative fuzzy filter to restore images contaminated by impulse noise. This filtering, first detect the contaminated pixels using an adaptive fuzzy detector and second, after detection of contaminated pixels, it does denoising by using a weighted mean filter. It can retrieve meaningful details at noise level as high as 97%. Lin, P.H. et al., (2016) [26] proposed a very efficient method to restore highly corrupted images. This method comprises two modules: First, a noise-free pixel counter module in which both the number and the position of noise-free pixels has been detected in the noisy image, and second a morphological pixel dilation module, in which the dilatation operation of the noise-free pixels is iteratively executed based on morphological image processing to modify the neighbour noise pixels until a noise free image is constructed. The proposed method needs moderate execution time to achieve optimal impulse noise removal and higher PSNR values. Wang, Y. et al., (2016) [27] proposed an adaptive fuzzy based filter in which the noisy pixels are further classified into three categories as: uncorrupted pixel, less corrupted pixel, and highly corrupted pixel. In filtering process, a distance relevant filtering scheme is used to remove noise by making an assumption that pixels at a short distance tend to have alike values. The non-noise pixels are left unchanged; less corrupted pixel’s value is replaced by the weighted average value of its own value and the weighted mean; and highly corrupted pixel’s value is replaced by the weighted mean. Roy, A. et al., (2017) [28] introduced a filtering scheme to remove impulse noise of high-density from color images. In this, a non-causal linear prediction error along with deviation has been used for noise detection. The noisy pixels are processed by the adaptive vector median filter, whereas a noise-free pixel is updated by the weighted mean of noise-free pixels. However it achieves improved performance both fixed as well as random valued impulse noise, the computational complexity of detection procedure increases. Chen, Q.Q. et al., (2017) [29] proposed a noise-removal algorithm that can adapt to different pollution levels. By counting the number of closed grey level of pixels in neighborhood to detect the noisy pixels, the noise-detection process achieves high correct-detection and low false-alarm rates. Then, using the adaptive domain of Euler distance, the noise filtering process achieves excellent noise removal and good detail preservation.

3. The Proposed Scheme

To restore the original image from images highly corrupted by impulse noise with improved visual quality as well as with improved quantitative measures, a new algorithm has been proposed. A novel Sorted-Max-Min-Mean Filter (SM3F) algorithm has been proposed for high-density impulse noise removal. SM3F is a non-recursive algorithm, since evaluation of output image depends only on input image. Fig. 1 demonstrates the block diagram of the proposed methodology.



Fig. 1 - Proposed Methodology

The noise detection and removal process has considered in single algorithm. The algorithm description of proposed methodology is explained in Section 3.1 and the flow diagram is shown in Fig. 2.

3.1 Algorithm Description

The algorithm for the proposed SM3F filter has been described as follows:

Step 1: Take Noisy Image (I_{Noise})

Step 2: Noise Detection Condition

If $0 < P(i, j) < 255 \rightarrow$ Noise free Pixel

else if $P(i, j) = 0$ or $255 \rightarrow$ Pixel is noisy.

Step 3: Consider a window of size 3×3 with centre pixel as processing element.

Assume that the pixel being processed is $P(i, j)$.

Step 4: Apply Conditions

Case I: If $P(i, j)$ is a noise-free pixel then don't alter its value and go to step 7.

Case II: If $P(i, j)$ is a noisy pixel and contains all neighbouring pixels as either 0's or 255's then go to step 5.

Case III: If $P(i, j)$ is a noisy pixel and contains all neighbouring pixels as combinations of 0's and 255's then go to step 6.

Step 5: If $P(i, j)$ contains neighbouring pixels values as either 0's or 255's, then increase the window size by one. Consider $P(i, j)$ as Central processing pixel and go to step 4.

Step 6: If $P(i, j)$ contains neighbouring pixel values lying between '0' & '255' including '0' and '255' or both then calculate mean of noise-free pixels within that selected window. Replace $P(i, j)$ with calculated mean value and go to step 7.

Step 7: Image is restored.

Step 8: Repeat step 2 to step 7 for every pixel in I_{Noise} .

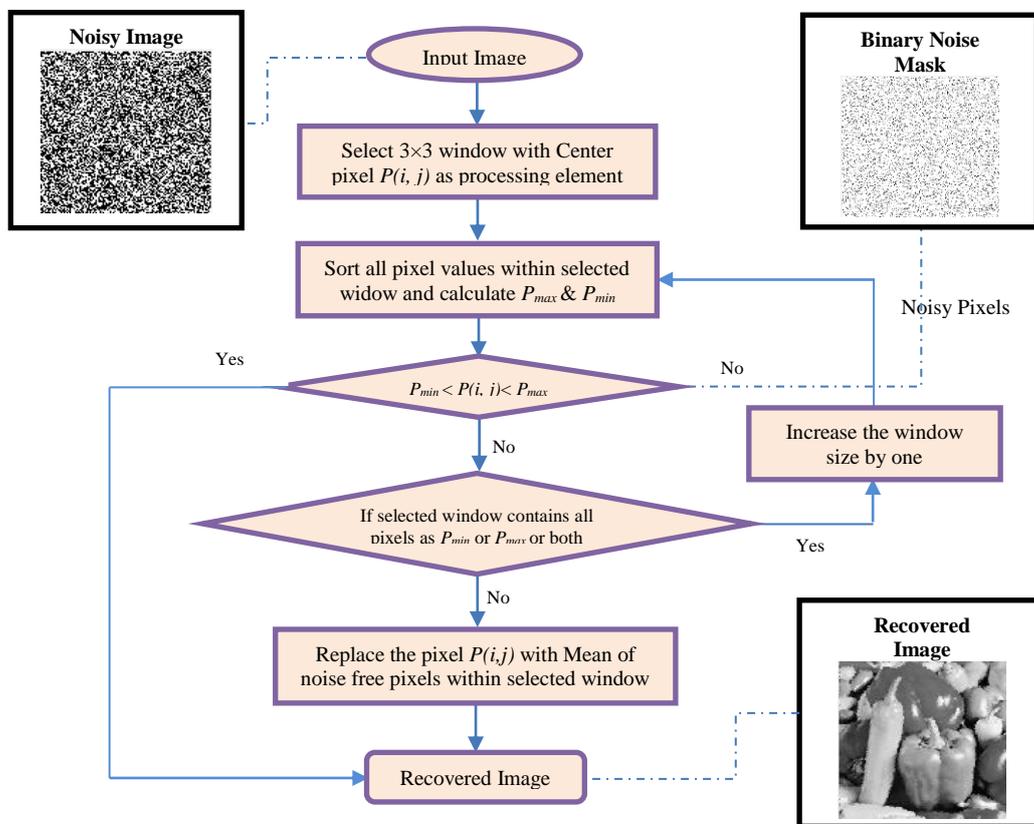


Fig. 2 - Flow Diagram of Proposed Methodology

3.2 Illustration of Proposed Methodology

Each pixel of input noisy image is checked for presence of impulse noise. In this section different cases of the flow diagram are illustrated with examples. Consider $P(i, j)$ as current processing pixel. If $P(i, j)$ is a noisy pixel with neighbouring pixel values lying between '0' and '255' including '0' and '255' or both has been illustrated in Case I. If $P(i, j)$ is a noisy with neighbouring pixel values as either '0' or '255' has been illustrated in Case II. If $P(i, j)$ is noise-free pixel and its value lies between '0' and '255' has been illustrated in case III.

Consider a 5×5 Noisy Image Matrix I_{Noisy} .

$$I_{Noisy} = \begin{bmatrix} 0 & 255 & 255 & 255 & 0 \\ 255 & 0 & 0 & 255 & 100 \\ 0 & 255 & 0 & 97 & 0 \\ 255 & 255 & 100 & 0 & 255 \\ 0 & 255 & 0 & 0 & 255 \end{bmatrix}$$

Case I: If selected window contains either '0' or '255' i.e. noisy pixel as processing pixel $P(i, j)$ and it has some neighbouring pixel that adds SPN to the image:

0	255	255	255	0
255	0	0	255	100
0	255	0	97	0
255	255	100	0	255
0	255	0	0	255

 \Rightarrow

$$\begin{bmatrix} 0 & 0 & 255 \\ 255 & \mathbf{0} & 97 \\ 255 & 100 & 0 \end{bmatrix} \Leftrightarrow \begin{bmatrix} 0 & 0 & 255 \\ 255 & \mathbf{98.5} & 97 \\ 255 & 100 & 0 \end{bmatrix}$$

Here '0' is processing pixel, i.e. $P(i, j)$. Now eliminate the SPN from selected window, i.e. eliminate 0's and 255's. The One Dimensional (1-D) array of above matrix after sorting is [0 0 0 0 97 100 255 255 255]. After elimination of 0's and 255's the selected window will contain [97 100]. The mean value of 97 & 100 is 98.5. Hence replace $P(i, j)$ by 98.5.

Case II: If selected window contains all the pixels as 0's or 255's including the processing pixel $P(i, j)$, i.e. all pixels within selected window are noisy:

0	255	255	255	0
255	0	0	255	100
0	255	0	97	0
255	255	100	0	255
0	255	0	0	255

 \Rightarrow

$$\begin{bmatrix} 0 & 255 & 255 \\ 255 & \mathbf{0} & 0 \\ 0 & 255 & 0 \end{bmatrix}$$

Here '0' is processing pixel, i.e. $P(i, j)$. Since all the elements surrounding $P(i, j)$ are 0's and 255's, increase the size of window to 5×5 .

$$\begin{bmatrix} - & - & - & - & - \\ - & 0 & 255 & 255 & 255 \\ - & 255 & \mathbf{0} & 0 & 255 \\ - & 0 & 255 & 0 & 97 \\ - & 255 & 255 & 100 & 0 \end{bmatrix} \Leftrightarrow \begin{bmatrix} - & - & - & - & - \\ - & 0 & 255 & 255 & 255 \\ - & 255 & \mathbf{98.5} & 0 & 255 \\ - & 0 & 255 & 0 & 97 \\ - & 255 & 255 & 100 & 0 \end{bmatrix}$$

The 1-D array of the above 5×5 matrix after sorting is [0 0 0 0 0 97 100 255 255 255 255 255 255 255 255]. Now eliminate 0's & 255's i.e. noisy pixel. After elimination of 0's and 255's the selected window will contain [97 100]. The mean value of 97 & 100 is 98.5. Hence replace $P(i, j)$ by 98.5.

Case III: If selected window contains a noise-free pixel as processing pixel, $P(i, j)$ then no further processing is required. Any pixel having value between '0' & '255' is noise-free pixel.



Here '100' is the processing pixel, i.e. $P(i, j)$. Since '100' is a noise free pixel it does not require further processing.

Each and every pixels of noisy image is checked and modified the value of corrupted pixels based on above illustration until a noise free image is recovered.

4. Performance Evaluation

This section demonstrates the visual results as well as quantitative analysis of the proposed scheme through simulation and comparison of the performance with several existing schemes. Various image quality parameters or metrics are calculated and analyzed using proposed method. Quality of an image is the characteristics that measure the recognized image degradation generally, compared to an original or ideal image. Image quality measurement can be classified as subjective quality assessment and objective quality assessment. Subjective image quality is a method of evolution of images by intelligibility, whereas objective image quality metrics calculate some statistical indices to specify the quality of recovered images. PSNR and MSE are two most commonly used parameters to illustrate the quality of reconstructed image.

4.1 Image Quantitative Measures Parameters

The image quality parameters provide some measures of closeness between two images by utilizing the difference in statistical distribution of pixel values. The proposed algorithm has been analyses using many grayscale as well as color standard images like Pepper, Aircraft, Candy, F16, Lena, Barbara, Baboon, Sailboat, etc. The noise density is increased from 10 to 90%. Parameters that are used for analysis are MSE, PSNR and IEF which are defined in subsequent sections as follows:

4.1.1 Mean Squared Error (MSE)

The MSE compares two images providing the quantitative similarity or error measurement between the two images. Low MSE value is required for effective results. For an original noise-free $m \times n$ grayscale image $Y(i, j)$ and its noisy approximations $\hat{Y}(i, j)$, the MSE is mathematically given as:

$$MSE = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [Y(i, j) - \hat{Y}(i, j)]^2 \tag{1}$$

4.1.2 Peak Signal to Noise Ratio (PSNR)

PSNR is generally employed as performance measure between original image and recovered image using a standard mathematical model and is most commonly used for measuring the quality of restoration. A higher value of PSNR generally represents higher quality reconstruction. The PSNR can be easily defined in terms MSE and mathematically it is given as:

$$PSNR \text{ (in dB)} = 10 * \log_{10} \left(\frac{MAX^2}{MSE} \right) \tag{2}$$

Where, MAX is the maximum pixel value possible in grayscale image. For an 8-bit image MAX is equal to '255'. For color images the image is transformed into a different color space (for e.g. RGB color space), in this case the definition of PSNR is same but it is considered for every channels.

4.1.3 Image Enhancement Factor (IEF)

IEF is another parameter to evaluate the image quality after restoration. Higher the value of IEF better will be the quality of restored image [31]. Mathematically IEF is defined as:

$$IEF = \frac{\sum_{i=0}^{m-1} \sum_{j=0}^{n-1} (I(i,j) - Y(i,j))^2}{\sum_{i=0}^{m-1} \sum_{j=0}^{n-1} (\hat{Y}(i,j) - Y(i,j))^2} \quad (3)$$

Where, Y is the Original Image, \hat{Y} = Recovered Image, I = Noisy Image, and $m \times n$ = Size of Grayscale Image

4.2 Simulation Results

The aim of Image Restoration or Noise Removal techniques is to efficiently restore the original image from any corrupted image, so that the interpretability or visual perception for human viewers can be improved. Noise removal also provides better input than other automated image processing methods. The performance of proposed algorithm has been tested for different grayscale as well as color images.

The performances of proposed method is quantitatively measured in terms of MSE, PSNR and IEF as defined in Eq. (1), (2) and (3) respectively. The proposed algorithm has been performed and evaluated on *Matlab R2015a*. The proposed noise removal method has been applied to five different grayscale images named as “Pepper”, “Aircraft”, “Candy”, “Clock”, and “F16” each of size 256×256 and corrupted with 90 % noise. Fig. 3-7 show the visual comparison of restored images using proposed method along with other methods.

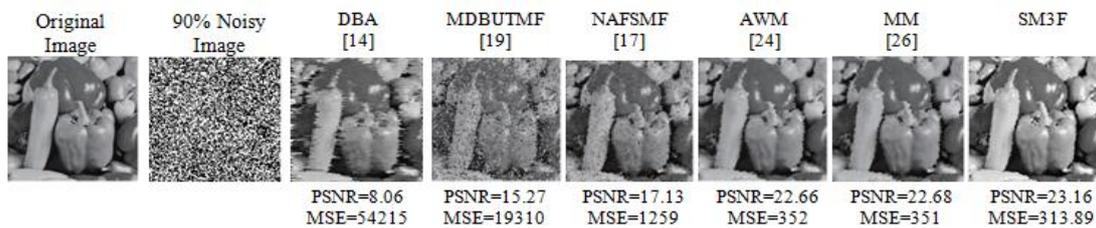


Fig. 3 - Denoising results for Peppers Image

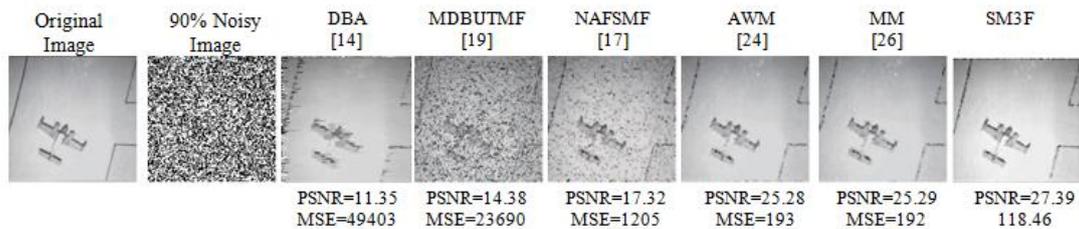


Fig. 4 - Denoising results for Aircraft Image

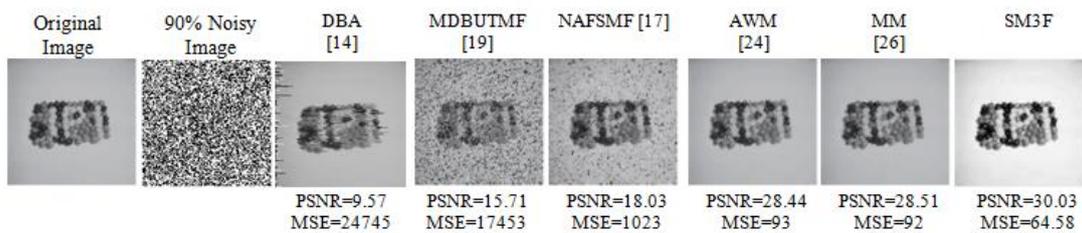


Fig. 5 - Denoising results for Candy Image

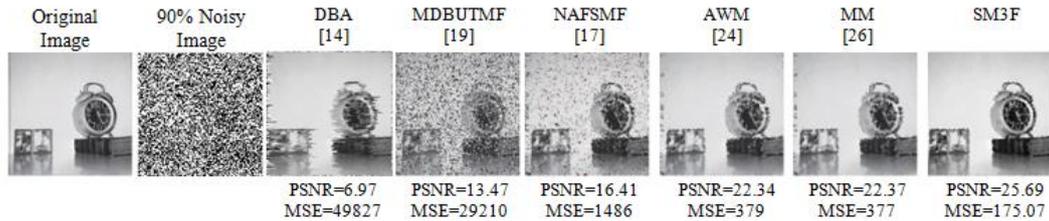


Fig. 6 - Denoising results for Clock Image

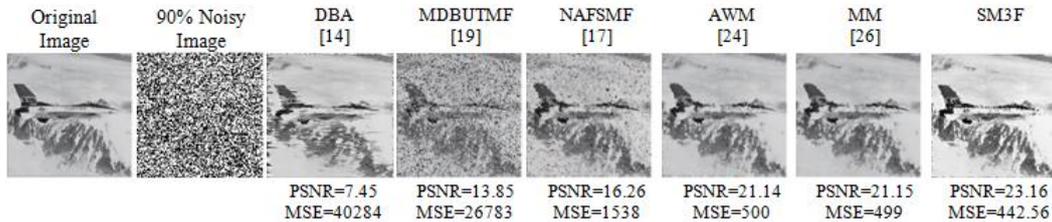


Fig. 7 - Denoising results for F16 Image

Fig. 3-7 show that the quality of image recovered from proposed method is much better than previous methods. It is observed that the original image can be restored without any loss in image details and quality of restored image is well improved. For the restored images using proposed algorithm lesser value of MSE and greater value of PSNR has been obtained, and thus provides better image quality.

4.3 Scheme Evaluation and Comparison

The proposed method has been tested with several grayscale as well as color standard test images of size 256×256, such as Pepper, Clock, Aircraft, Lena, Sailboat, Baboon etc. The proposed method is compared with several existing methodologies. The comparison in terms of PSNR and MSE is graphically represented in Fig. 8 and Fig. 9 respectively. The comparison in terms of IEF is given in Table 1. These comparisons indicate that the proposed method has well improvement in terms of PSNR, MSE and IEF values compared with existing impulse noise removal techniques.

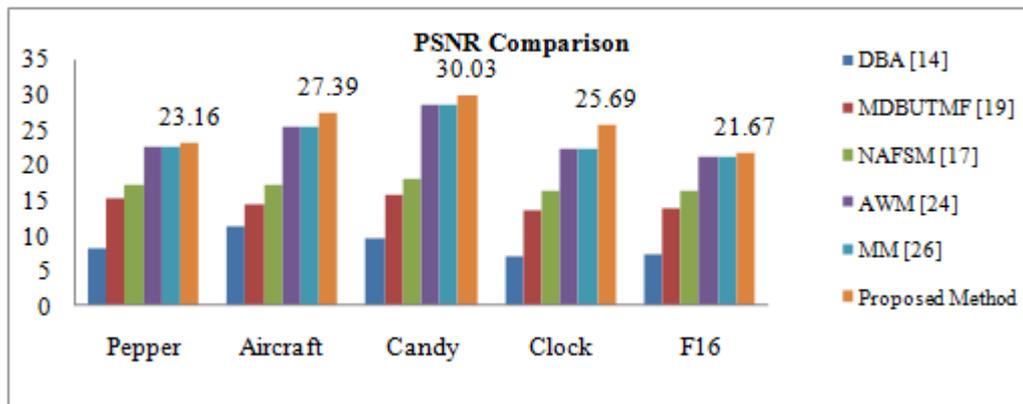


Fig. 8 - Graphical Representation of PSNR Comparison for Different Grayscale Images with Different Techniques at 90% Noise Density

Fig. 8 shows the PSNR values of different recovered images with proposed method and also with existing methods. This clearly shows that the proposed method has greater PSNR value as compared to previous methods, thus gives better image quality as increased value of PSNR gives better image quality.

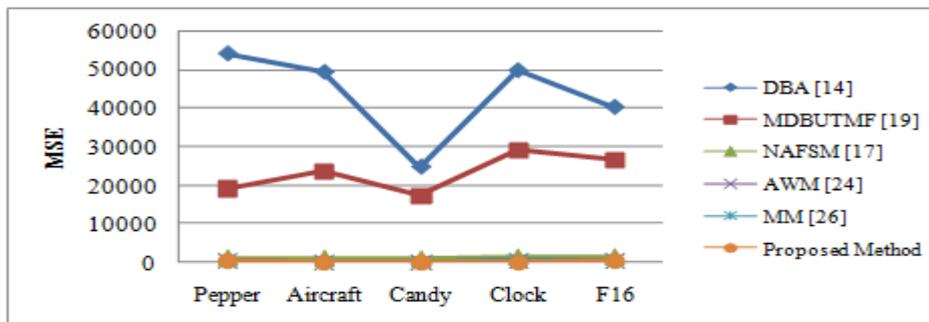


Fig. 9 - Comparison of MSE Values for Different Grayscale Images with Different Techniques at 90% Noise Density

Fig. 9 shows the MSE values of different recovered images with proposed method and also with existing methods. This clearly shows that the proposed method has lesser MSE values as compared to previous methods, thus gives better image quality as decreased value of MSE gives better approximation to original image.

Table 1 Comparison of IEF Values for Different Grayscale Images with Different Noise Removal Techniques at 90% Noise Density

Grayscale Images (256×256)	MF [2]	AMF [3]	DBA [14]	MDBUT MF [19]	Proposed Method
Pepper	1.27	1.38	8.08	5.44	55.07
Aircraft	1.28	1.40	23.21	4.91	156.37
Candy	1.26	1.41	23.86	5.88	264.75
Clock	1.27	1.38	18.56	4.35	112.88
F16	1.27	1.39	13.76	4.51	42.64

Table 1 shows the IEF value of different restored images with proposed method and also with some existing filtering techniques. This clearly shows that the proposed method has higher IEF values compared to other methods, thus gives better image quality as higher value of IEF gives better image quality.

4.4 Simulation Results for RGB Color Image

The proposed noise removal method has been applied to standard color test images named as “Pepper”, “Lena”, “Barbara”, “Baboon”, and “Sailboat” of size 256 ×256 each. The noise density is varied from 10% to 90%. The visual results of proposed method for these color images are shown in Fig. 10.

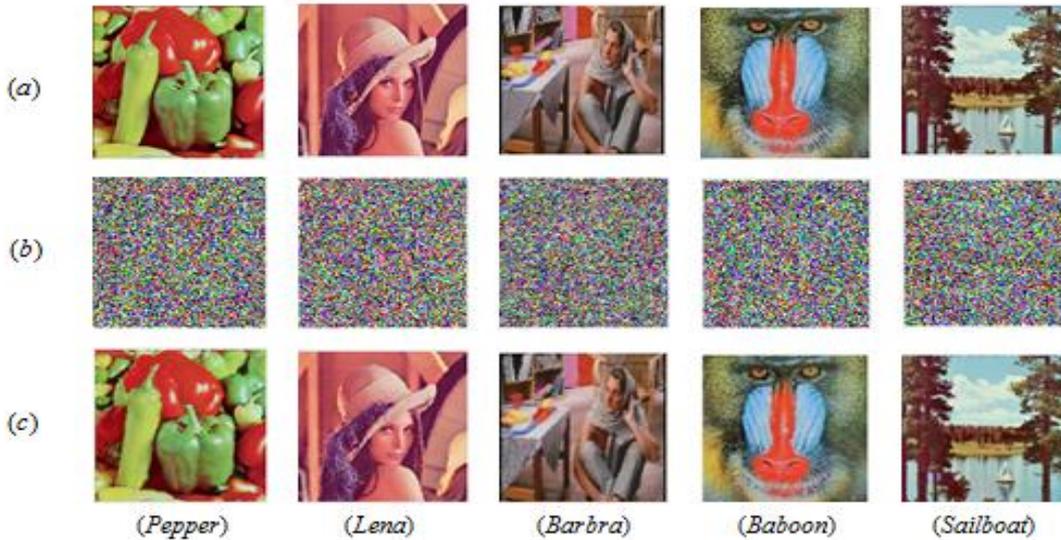


Fig. 10 - Application of Proposed Algorithm to different Color Images: (a) Original Images, (b) Images with 90% Impulse Noise, (c) Restored Images

From Fig. 10 it can be observed that the original color image can be restored without any loss in image details and quality of restored image is well improved. For the restored images using proposed algorithm lesser value of MSE and greater value of PSNR and IEF has been obtained, providing better image quality. Fig. 11 shows the graphical representation of PSNR, MSE and IEF values at 90% noise density.

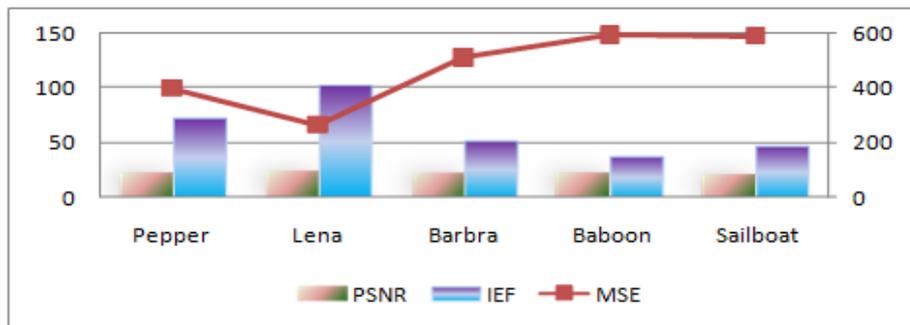


Fig. 11 - Graphical Representation of PSNR, MSE and IEF values for Different Color Images using Proposed Technique at 90% Noise Density

Fig. 11 provides the graphical representation of MSE, PSNR and IEF values for different RGB color images using Proposed Method. This result demonstrates the MSE, and PSNR values for five different Restored of size 256×256 each with 90% noise density. From this figure it can be observed that lesser MSE and higher PSNR values are obtained, providing better image quality.

5. Conclusion

In this paper an efficient impulse noise removal technique has been proposed. The proposed filtering scheme comprises two stages for its operation: noise detection and then noise removal by using a variant of the mean filter. At the first stage, for noise detection, the corrupted pixel has been identified based on local maximum & minimum intensity in the grayscale range. At second stage, SM3F algorithm has been applied. The proposed method is simple and less complex unlike some filtering algorithms having iterations and long-lasting processing time. It also does not involve the noisy pixels for its operation. The proposed method can remove impulse noise of high density from grayscale images as well as from color images and also preserve image information. The proposed method is tested for different images of size 256×256 and the results of restored images is compared with various existing methods in terms PSNR, MSE and IEF. The proposed method has better performance as compared to other filters. The performance of proposed method is tested for different noise densities varying from 10% to 90%. This method is specifically developed for impulse noise removal of high density.

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