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Enhanced BDND Algorithm for High Density Impulse Noise Removal

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Abstract : Switching median filters overcomes the performance of conventional median filters in the removal of impulse noise. The advantage is this filter separate the noisy pixels and leaves the remaining pixels unaltered. The Boundary Discriminative Noise Detection (BDND) works under different impulse noise models. Initially pixels are categorised into (*a*) low intensity pixels (*b*) high intensity pixels (*c*) uncorrupted pixels. Tracking down of the noise and filtering it are the further steps of process. The main drawback in BDND filtering algorithm is the pixel misclassification. So, a new and efficient filtering algorithm called Modified Boundary Discriminative Noise Detection (MBDND is being introduced that terminates noisy pixels without affecting the image quality. The modified algorithm restores the noisy pixels with mean value only when the 0's and 255's are present in the selected window and if not, it restores with mean of all the elements present in the selected window. The performance of the modified filter is evaluated by comparing various parameters of different filters like Centre weighted Median Filter (CWMF), Progressive Switched Median Filter (PSMF), Adaptive Threshold Median Filter (ATMF), Boundary Discriminative Noise Detection (BDND) and Modified Boundary Discriminative Noise Detection (MBDND).This work proves that MBDND carries out very well at extreme noise densities also (95%).

Keywords : BDND (Boundary Discriminative Noise Detection); CWMF (Centre weighted Median Filter); PSMF (Progressive Switched Median Filter); ATMF (Adaptive Threshold Median Filter); MBDND (Modified Boundary Discriminative Noise Detection); PSNR (Peak Signal to Noise Ratio); IEF (Image Enhancement Factor); FOM (Figure Of Merit); MSE (Mean Square Error).

1. INTRODUCTION

Image de-noising is one of the important steps in the field of image processing. This step not only involves in the process of eliminating noise but also it enhances the sharpness and other features of the image. Noise can be completely degraded with a good signal to noise ratio factor.

Noise may be caused by various sources for example, variations in detector sensitivity, environmental variations, and transmission or quantization errors. Noise can be of various types mainly categorised as external and internal noise into which many noises fall under. Pixels that are polluted with impulse noise are marked by the intensity values after comparing with neighbouring pixels. This can also fiercely affect images quality and it makes less suitable for human or machine vision applications [2].

Impulse noise may be broadly defined as the corruption which is random, sparse, and high or low amplitude relative to local pixel values. The goal of impulse noise elimination is to get rid of the noise but it keeps preserving the integrity of edge and detail information [18]. Median filters are mostly used because of their simplicity and they possess good preservation edge property. Besides this advantage, the switched median filter poses a great impact as it keenly preserves the edges in detail. [1], [10].

Boundary discriminative noise detection (BDND) is a highly used noise reduction method for strongly de-noising extremely corrupted images [9]. BDND works under different impulse noise models. It mostly uses switched

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median filter as it removes noise without any pixel misclassification [1].It classifies pixels of localized current window pixels into three distinct categories and this algorithm works on the affected pixels and replaces it for the noise free image. [1], [9].

The BDND algorithm is applied to each pixel of the noisy image in order to identify whether it is uncorrupted or corrupted. The uncorrupted pixels are left unchanged. It comprises of noise detection and filtering stages for impulse noise removal. The outline of the paper is organised as follows. Section II describes the proposed algorithm and comparative analysis of various filter performances. Section III gives the results of various filters with its measured performance parameters and the simulated output. Section IV provides the conclusion of the paper.

2. METHODOLOGY USED

A. Modified Boundary Discriminative Noise Detection

Two modifications are introduced to the filtering step in the BDND algorithm in order to improve its performance and this greatly depends on the filter window and blending the spatial as well as intensity information [1]. The first alteration is based on ignoring the action applied on expansion of the filtering window. The next step of alteration is to carry out the spatial details of those affected pixels in the processing window and the variation of their intensities from the median while calculating the approximated value of the affected (noisy) pixel [2]. Though MBDND is a highly accurate noise elimination method and also even if it provides easy detection of pixels it gives some complication in the computational point of view. Hence we propose some changes in the MBDND algorithm as given below.

B. Proposed Algorithm

Step 1 : Take an initial image and apply on it fixed valued impulse noise.

Step 2 : Check whether the pixels are between 0 to 255. Here two cases are generated.

1. If Pixels are between $0 < Y(i, j) < 255$ then, they are noise free and move to restoration image.
2. If the pixels are not lying between these ranges then proceed to step 3.

Step 3 : Now select window of size 3×3 of an image. Assume that the targeted noisy pixels are $W(i, j)$ which is processed in the next step.

Step 4 : If the preferred window contains not all elements as 0's and 255's, then remove all the 0's and 255's from the window and send to restoration image.

1. Now find the mean of the remaining pixels.
2. Replace $W(i, j)$ with the mean value.

Step 5 : Repeat steps one to three until all pixels in the whole image are processed. Hence a better de-noised image is obtained with improved filter parameters.

The proposed algorithm provides superior performance in terms of fine quality in the filtered image as well as improvement in PSNR values in order to get an enhanced image.

Comparative Analysis Of Filters

Various filters that are analysed are Centre weighted Median Filter (CWMF), Progressive Switched Median Filter (PSMF), Boundary Discriminative Noise Detection (BDND), Adaptive Threshold median filter (ATMF) and Modified Boundary Discriminative Noise Detection (MBDND).

Centre Weighted Median Filter

The centre weighted median (CWM) filter, which is a weighted median filter, gives more weight to the central value of each window. This filter can preserve image details while it suppresses additive white and/or impulsive-type noise. In CWM, [1] centre pixel of $(2k + 1)$ window is considered as test pixel. If centre pixel $(k + 1, k + 1)$ less than minimum value is present in rest of pixel and beyond the maximum value is present in the same window then centre pixel is treated as 'corrupted pixel'. Corrupted pixel is replaced by estimated median value [15].

Median is estimated by sorting all elements of window in ascending order by taking values till (N-L)th element where N represents the number of elements in an array.

Progressive Switched Median Filter

As it is a two phase algorithm, noise pixels are identified using a fixed size window. In second phase prior knowledge of noisy pixels are provided and noise pixels are further replaced by estimated median value from the pixels given in the window. Here median value is calculated same as in AMF without considering the corrupted pixel present in window. The corrupted pixel is obtained by finding whether the range lies between maximum or minimum value. If the estimated median is corrupted then the window size has to be increased and recalculate the median value till we find the exact median value for the set of pixels in the mask.

Adaptive Threshold Median Filter

The adaptive threshold median filter (ATMF) is a combination of the adaptive median filter (AMF) and two dynamic thresholds. Since the dynamic threshold being used, the ATMF is able to balance the reduction of highly affected impulse noise and the quality of image. The adaptive median filter (AMF) is non-linear conditional filter [2]. It uses variation in the window size to noise elimination. Size of the window increases till proper median value is calculated and then noise pixel is replaced with its calculated median value. Generally this filter is based on two conditions (1) to detect corrupted pixels and (2) to check correctness of median value.

Boundary Discriminative Noise Detection

The BDND algorithm [1] classifies the pixels of a localized window, centring on the current pixel as three important categories (1) lower intensity impulse noise (2) uncorrupted pixels (3) higher intensity impulse noise. The centre pixel will then be considered as uncorrupted whether if it belongs to the uncorrupted pixel group or corrupted one. For that, two boundaries that differentiate these three groups require to be accurately determined for giving very high noise detection accuracy. [2] The BDND algorithm is applied to each pixel of the noisy image in order to identify whether it is uncorrupted or corrupted.

Modified Boundary Discriminative Noise Detection

Modified BDND is proved to cut down the noise at high levels of noise densities. BDND initially detects the noise where it is modified to a particular extent that it works for extremely corrupted pixels [1]. The major flaw of BDND is huge number of pixels can be misclassified despite easy detection of pixels. To beat this difficulty and to enhance the quality of the obtained image, slight alterations were introduced and executed at the filtering process of BDND. Due to these alterations, impulse (salt and pepper) noise is being removed under effectual high noise densities (95%).

C. Filter Performance Parameters

In this paper, the filter performances are compared with respect to various performance parameters such as Peak signal to noise ratio (PSNR), Mean Square Error (MSE), Image Enhancement Factor (IEF), Figure of Merit (FOM).

The PSNR is defined as:

$$\mathrm{PSNR} = 10.\log_{10}\left(\frac{\mathrm{Max}_{\mathrm{I}}^{2}}{\mathrm{MSE}}\right)$$

Here, MAX_I is the maximum possible pixel value of the image.

MSE is defined as :

$$\mathrm{MSE} = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[\mathrm{I}(i, j) - \mathrm{K}(i, j)]^2$$

The MSE represents the cumulative squared error between the compressed and the original image, whereas PSNR represents a measure of the peak error. The lower the value of MSE, the lower is the error.

The MAE is defined as : $$\text{MAE} = \frac{1}{\text{MN}}\sum_{i,j}|r_{i,j} - x_{i,j}|$$

Where, $r_{i,j}$ is the pixel values of the restored image and $x_{i,j}$ is the pixel values of the original image.

The IEF is defined as : $$\text{IEF} = \sum_{i,j}\left\{\frac{(\eta(i,j) - \mathrm{Y}(i,j))^2}{(\eta(i,j)\,\mathrm{Y}(i,j) - \mathrm{Y}(i,j)^2}\right\}$$

Here, Y represents an original image, $Y^{\wedge}$ represents the denoised image and $Y^{\wedge}$ represents the noisy image.

FOM is defined as : $$\text{FOM} = \frac{1}{\text{Max}\{n_d, n_t\}}\sum_{K=1}^{n_d}\frac{1}{1 + \text{ad}_K^2}$$

Where, 'n_d' and 'n_t' are the number of edge pixels detected in the original and output images, respectively, t_k is the distance from the k^{th} edge pixel in the original image.

3. RESULTS AND DISCUSSION

The filter performance parameters such as PSNR, IEF and FOM for various filters are given below:

Table 1. Lena Image

Filterning Method Followed	*Noise Density = 90%*		
	PSNR	*IEF*	*FOM*
CWMF	24.876	13.65	0.67
PSMF	29.812	12.78	0.64
ATMF	27.561	11.89	0.70
BDND	22.653	13.62	0.61
MBDND	30.245	14.34	0.72

The result for colour image that is corrupted by 90% impulse noise is presented here as Lena image. The original and noise affected images as well as the filtering results for the MBDND and the proposed adjustments are shown in the above table. On analysing the filtering conclusion of the followed method admits the potency of the considered approach in bringing out super quality and sharper images.

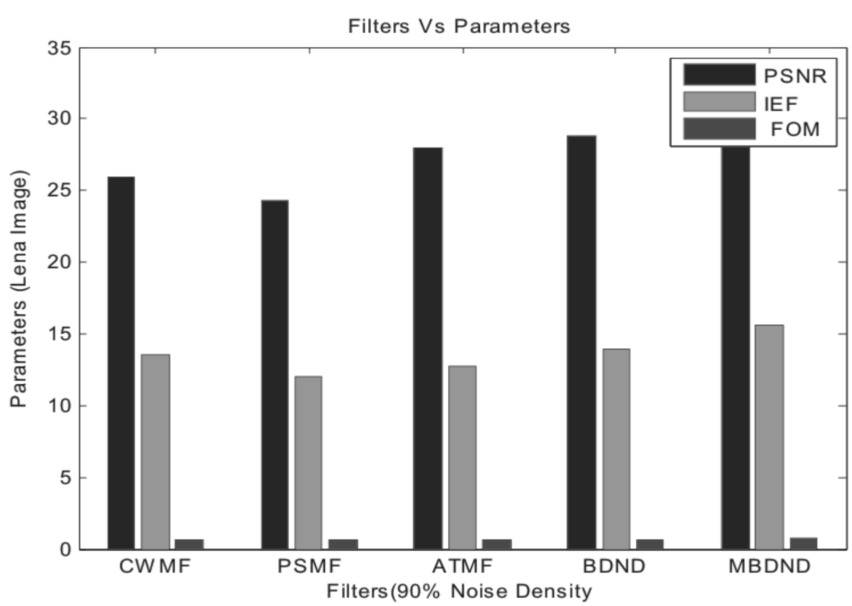

Fig. 1. Filters Vs Performance Parameters for Lena image

Analysing the filtering conclusions of the designed method affirms the capability of the proposed approach in producing fine quality and high resolution images.The original images are contaminated by noise densities ranging from 10% to 90%. The modified condition in this proposed algorithm is adaptive to very high noise densities also unlike the BDND algorithm [2]. FOM varies in less proportion while the PSNR reaches the maximum level in MBDND which is a must factor for any noise free image.

Table 2. Boat Image

Filterning Method Followed	*Noise Density = 90%*		
	PSNR	*IEF*	*FOM*
CWMF	24.121	13.97	0.70
PSMF	28.234	15.61	0.68
ATMF	25.43	14.36	0.73
BDND	24.98	17.41	0.64
MBDND	29.432	18.92	0.79

Though the PSNR value for both PSMF and MBDND filters are nearly close it is considered that MBDND filter proves to be the best in having good signal. The recovered images are shown in the above table Again, the attainment of the non-modified BDND filter is much backward to that of our proposed MBDND filter, while ours is a pretty well close enough to the switching filter.The simulation results affirm that our filter outplays the MBDND filter (specifically, with a large insignificant improvement at very high noise density) consistently by attaining much higher PSNR across a wide boundary of noise densities, from 10% to 95%.

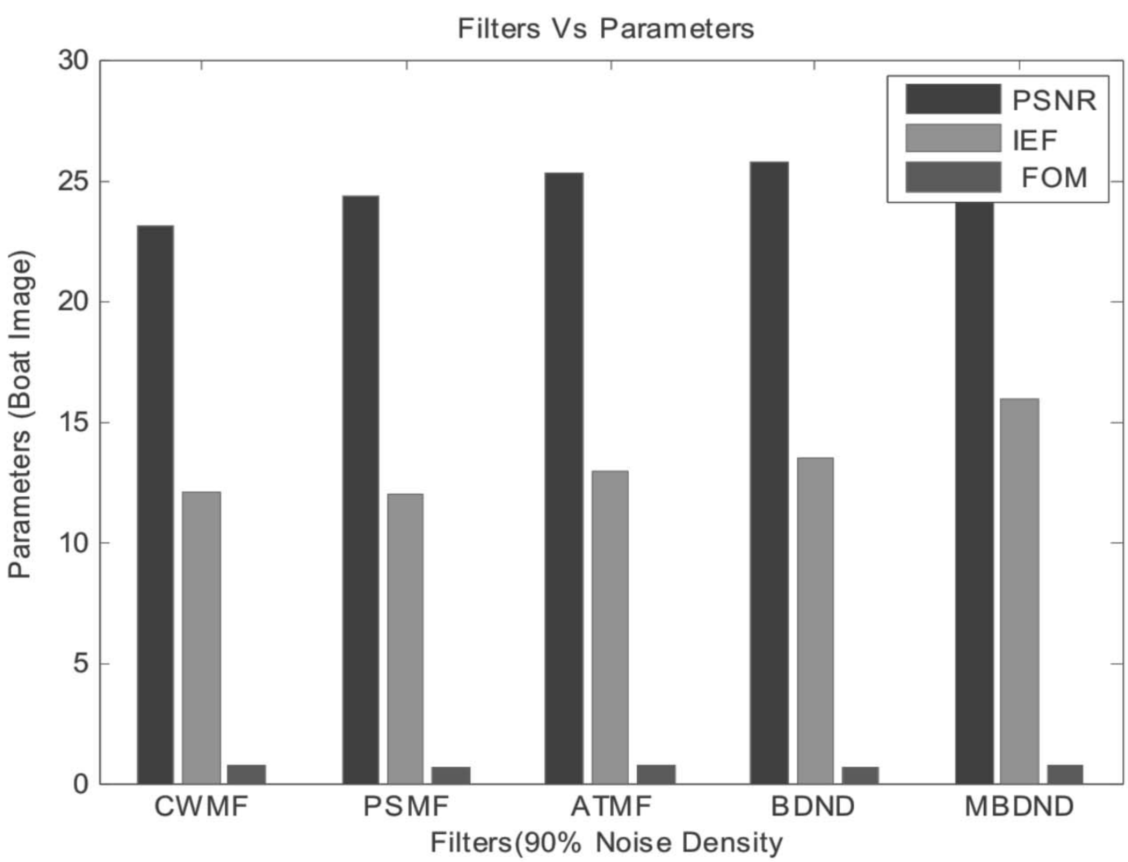

Fig. 2. Filters Vs Performance Parameters for Boat Image

The proposed filter outperforms the other median filters by balancing the trade-off between noise elimination and detailed preservation of edges [5]. When the noise density is above 50% then most of the filters fail to improve its signal to noise ratio level but MBDND filter preserves the complete details of the original image. It can remove the salt and pepper noise ranging from medium to high level of noise density. The graphical output shows that the proposed algorithm provides better PSNR and so good IEF is maintained throughout. This gives the better enhanced and recovered image.

Table 3. Cameraman Image

Filterning Method Followed	*Noise Density = 90%*		
	PSNR	*IEF*	*FOM*
CWMF	23.097	11.12	0.72
PSMF	25.012	10.08	0.70
ATMF	24.583	10.52	0.75
BDND	21.685	10.54	0.66
MBDND	26.122	11.56	0.81

The above table gives the quantitative performance comparison in terms of PSNR, IEF and FOM measurements.Obviously, our results outplay that the MBDND filter over a broad bounds of noise densities, and mostly synchronised with the various number of median filters present. Initially, the PSNR attainment of the filter starts to drop hysterically at noise density level 60% and on ahead. This is majorly because of the wrongly classified pixels obtained at these noise mixing levels. As for the modified MBDND approach, the PSNR is deliberately cut down as it is mainly conferred from more blurring when plenty number of pel elements are said to be mixed with noise. The output reveals that the original image can be recovered with finer image quality.

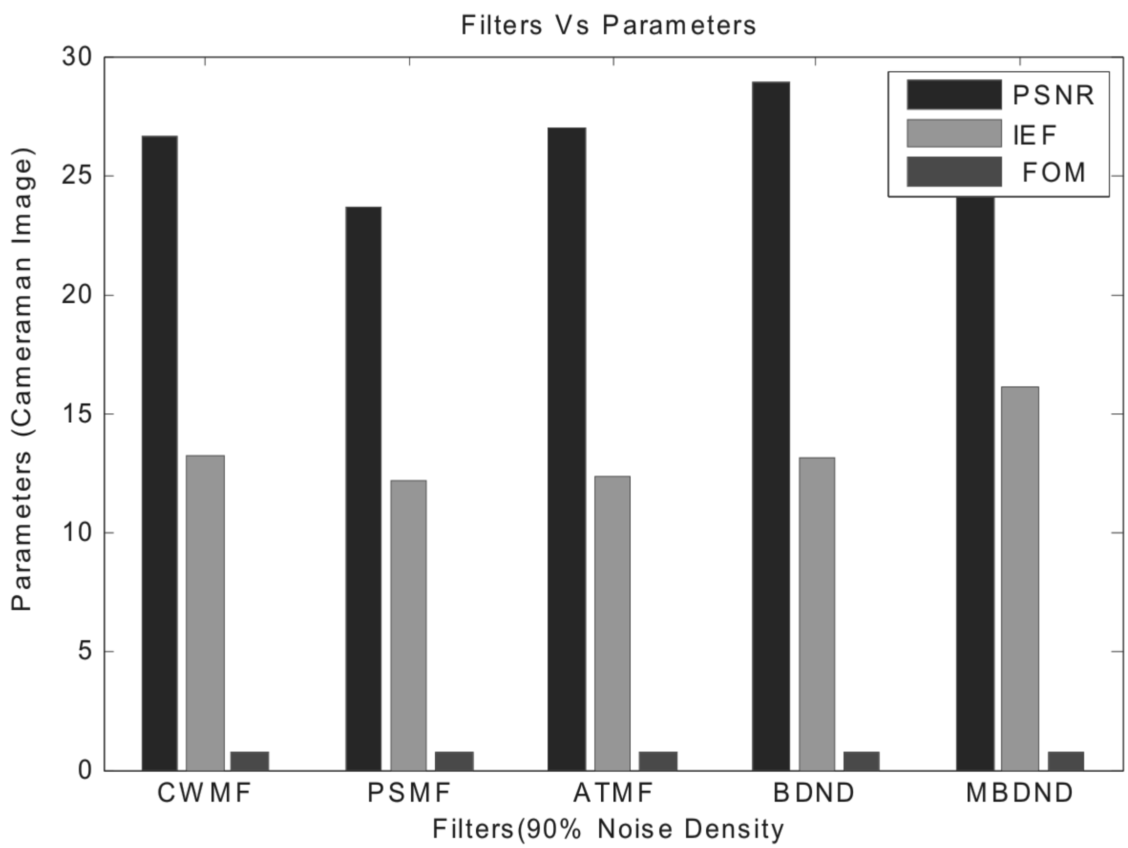

Fig. 3. Filters Vs Performance parameters for Cameraman image.

The above plot shows that the various filter responses can be compared and plotted.Thus for the cameraman image results of PSNR reaches to peak level and other parameters are also compared by taking noise density as 95%.The BDND algorithm can also yield better results but it will not be much suitable as it will be more time-consuming for real time applications.

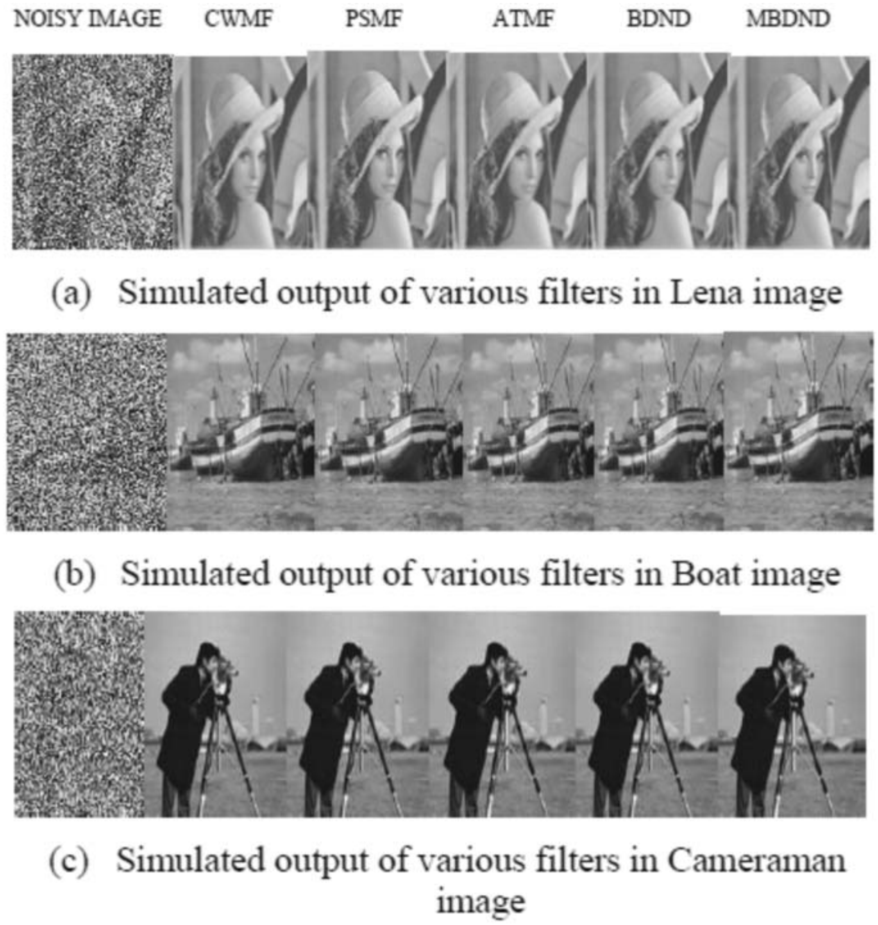

Fig. 4.

4. CONCLUSION

A new filtering approach named as, MBDND (Modified Boundary Discriminative Noise Detection Filter) is proposed for efficient impulse noise removal from corrupted images. This filter is designed in order to overcome problems like (*i*) blurring-loss of clarity in images due to expansion of filtering window (*ii*) increased computation time (*iii*) high complexity. It also helps to improve the quality of images for large window sizes and poor noise removal for smaller window sizes. Performance is evaluated by comparing various parameters like PSNR, MSE, IEF and FOM. It is analysed with consistent and stable performance across a wide range of noise densities, varying from 10% to 95%. Thus, we can conclude that by comparing different filtering methods like PSMF, CWMF, BDND and MBDND for corrupted images, MBDND (Modified Boundary Discriminative Noise Detection Filter) is best impulse noise removing filter.

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