Absolute Difference Based Progressive Switching Median Filter for Efficient Impulse Noise Removal

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Abstract— *Digital images are often corrupted by different noises. These noises can be removed by designing an efficient filter. Based upon the specified operation the pixels are classified. Absolute Difference Based Progressive Switching Median Filter (ADBPSMF) outperforms all other filter for the removal of impulse noise from corrupted images. This filter performs two basic operations for efficient noise removal. The first stage is noise detection and the second is noise filtering. For noise detection, Modified Boundary Discriminative Noise Detection (MBDND) algorithm is used. For noise filtering, Absolute Difference Based Progressive Switching Median Filter (ADBPSMF) is used. The Modified Boundary Discriminative Noise Detection (MBDND) incorporate two modifications after classifying the pixels as follows: (1) Expansion of filtering window. (2) Incorporating spatial and intensity information. By introducing these modifications into the algorithm, it is found that there is increase in the performance and the quality of image has improved. Results are compared with other median filters like Boundary Discriminative Noise Detection Filter (BDND), Tri State Median Filter (TMF), Center Weighted Median Filter (CWMF), Progressive Switching Median Filter (PSMF), Adaptive Threshold Median Filter (ATMF) and it is found that ADBPSMF performs well even at high noise density (95%).*

Keywords— *Absolute Difference Based Progressive Switching Median Filter (ADBPSMF); Adaptive Threshold Median Filter (ATMF) ;Boundary Discriminative Noise Detection Filter (BDND); Center Weighted Median Filter (CWMF; Modified Boundary Discriminative Noise Detection (MBDND); Progressive Switching Median Filter (PSMF); Tri State Median Filter (TMF);*

I. INTRODUCTION

During the transmissions of images over channels, images are often corrupted by impulse noise due to faulty communication or noisy channels, faulty camera or the like. In a black and white digitized image, pixels corrupted by positive impulses appear as white dots and those corrupted by negative impulses appear as black dots. The objective is to remove impulses so that the noise-free image fully recovered with a minimum signal distortion. To reduce the effect of noise, restoration techniques are available. Filtering is one among those techniques. Filters are of two types: linear filters and non-linear filters.

Linear filters have been the primary tool for signal processing. They are easy to design and offer excellent performance. They also provide distortionless transmission. This is particularly true for spectral separation where the desired signal spectrum is significantly different from the interference. The drawbacks of linear filters are poor performance in the presence of non-additive noise, non-Gaussian noise. In image processing applications, linear filters tend to blur the edges, but do not remove the impulse noise effectively and do not perform well in the presence of signal dependent noise. The transmission of the digital image requires communication channels which are often modeled by theory of non-linearity. So, noise in image due to communication channels must be filtered using non-linear filters.

II. MEDIAN FILTER

A Median filter is a non-linear digital filter which is able to preserve sharp signal changes and is very effective in removing impulse noise. While linear filters have no ability to remove this type of noise without affecting the distinguishing characteristics of the signal, median filters have remarkable advantages over linear filters for this particular type of noise. Therefore median filter is very widely used in digital signal and image processing applications. The SM filter can suppress noise while retaining sharp sustained changes (edges) in signal values. Median filter is the best filter for removing impulse noise.

The main objective is to remove the impulse noise present in digital images using suitable noise detection and filtering steps. An efficient filter with BDND detector is designed to alleviate the effects encounted in other commonly used median filters. An Absolute Difference Based Progressive Switching Median Filter (ADBPSMF) is designed, which eliminates noisy pixels without causing any loss of information in an image.

III. EXISTING METHOD

The switching median filter is Boundary Discriminative Noise Detection (BDND) filter. The BDND filter is proven to operate efficiently when compared to other filters, even under high noise densities upto 90%. Being a switching – based median filter, the BDND algorithm filters the noisy image in two steps. The first step is essentially a noise detection step which is based on clustering the pixels in the image in a localized window into three groups, namely;

- Low intensity impulse noise
- High intensity impulse noise
- Uncorrupted pixels

The BDND filter is proven to operate effectively under different impulse noise models. However, two main observations can be made about its filtering steps.

Expanding the window until the number of uncorrupted pixels is at least half the number of pixels in the window may impose additional blurring in the output image. The impact of this is clearly noticeable under high noise densities.

The filtering step relies on computing the median value of the uncorrupted pixels found in the window without any regard to the spatial relationship of these pixels to the noisy pixels, and the deviation of the pixels' intensities from the median value. This also affect the quality and the sharpness of the edges in the filtered image.

IV. PROPOSED MODIFICATIONS

After introducing modifications in the filtering steps of BDND, it is named as MBDND. The performance of MBDND is high when compared with other standard median filters. The main drawback of MBDND is blurring due to expansion of filtering window. In order to overcome this drawback, we designed a new filter with improved performance.

ADBPSMF (Absolute Difference Based Progressive Switching Median Filter) is the proposed new filter. Instead of expansion of filtering window, the absolute difference calculation and sliding window mechanism is followed with BDND noise detection. In BDND noise detection, the pixel misclassification occurs. This drawback can be overcome by ADBPSMF, in which different cases are considered in the obtained window. Let us consider an example which elaborates the filtering operation of the ADBPSMF.

Consider the original image with following pixel values in a 9x9 window. Initially, the 3x3 window is considered for illustrating different conditions. Centre pixel is taken as Processing Pixel (PP) and then each neighboring pixel is compared with PP to find the Absolute Difference (AD) value.

155	160	158	152	157	165	162	163	164
160	155	155	157	152	155	162	161	160
156	152	150	151	154	165	162	163	157
155	152	154	158	157	159	156	152	158
154	156	153	158	152	150	157	159	160
154	156	157	158	159	153	152	150	156
159	160	162	163	164	156	152	157	158
154	156	153	152	154	157	158	159	159
162	154	158	157	159	153	152	150	157

Fig .1: Original image with 9x9 mask

155	160	158	152	157	165	162	163	164
160	145	155	157	152	155	162	10	160
156	152	150	151	154	165	162	163	157
155	152	154	158	157	159	156	152	158
154	156	153	158	130	150	157	159	160
154	156	157	158	159	153	152	150	156
20	160	30	163	164	156	152	157	158
154	155	153	152	154	157	158	85	159
162	25	55	157	159	153	152	150	157

Fig 2: Corrupted image

Different cases are considered for illustrating the operation of the filter.

A. Case 1

If the Absolute Difference is very low value, then the Processing Pixel is considered as "noise free" and it is unaltered.

B. Case 2

If all the values in the absolute difference are high, then the processing pixel is considered as noisy and it must be eliminated by computing the median value. The median value is computed by sorting the pixels in the window without considering the PP value. After sorting the left and right extreme pixel values are eliminated one by one and then remaining two values [(162+162)/2] are summed up and average is calculated. The computed median value for the AD value is 162. So, the PP = 10 in the window is replaced by 162.

C. Case 3

Here we need to define two new variables, N1 and N2. Count of the lowest difference is N1 and Count of the highest difference is N2. Here N1>N2, so the PP is considered as noise free and unaltered.

These are the three different cases considered for illustrating the filtering operation. This operation is performed iteratively until noise free pixels are obtained in a noisy image. This helps to improve the performance of the filter and hence ADBPSMF is proved to be best when compared with other filter.

V. ALGORITHM I [NOISE DETECTION]

Step 1 : Get an input image of size 512x512.

Step 2 : Add impulse noise to the original image.

Step 3 : Then detect the type of noise introduced on the input image by performing BDND noise detection step.

Step 4 : Classify pixels into three types as follows:

i) High intensity impulse noise pixels

ii) Medium intensity impulse noise pixels

iii) Uncorrupted pixels

Step 5 : Identified noisy pixels are applied for filtering and other noise free pixels are left unchanged.

VI. ALGORITHM II [NOISE FILTERING]

Step 1 : Construct a 3x3 window centered on the Processing Pixel (PP).

Step 2 : Identify whether the processing pixel is noisy or noise free with the help of BDND noise detection.

Step 3 : If the processing pixel is identified as "noisy", then calculate the Absolute Difference(AD) with the neighborhood pixels in the selected window.

Step 4 :Three different cases are considered and each

cases are explained one after other.

(i) If all the obtained values in the absolute difference are less, then processing pixel is considered as noise free.

(ii) If all the obtained values are large, then PP is considered as noisy and then median is found and replaced.

(iii) When majority of the values obtained in absolute difference are high- PP is noisy, else PP is noise free and unaltered.The above steps are repeated until the processing is completed for the entire image.

VII. PERFORMANCE EVALUATION

Filtering performance can be evaluated by computing parameters like, Peak Signal to Noise Ratio (PSNR), MAE (Mean Absolute Error), MSE (Mean Square Error), IEF(Image Enhancement Factor) and FOM (Figure Of Merit). The obtained values are compared for different filters. MAE is used to focus on the detail preserving characteristics of the filter. Smaller MAE values signify better detail preservation of restored image and high PSNR value indicates better image restoration.

MSE is defined as:

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

The PSNR is defined as:

$$PSNR = 10 \cdot \log_{10}\left(\frac{MAX_I^2}{MSE}\right)$$

Here, MAX_I is the maximum possible pixel value of the image. When the pixels are represented using 8 bits per sample, this is 255.

The MAE is defined as:

$$MAE = \frac{1}{MN}\sum_{i,j}\left|r_{i,j} - x_{i,j}\right|$$

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:

$$IEF = \sum_{i,j}\left\{\frac{\left(\eta(i,j) - Y(i,j)\right)^2}{\left(\eta(i,j)\hat{Y}(i,j) - Y(i,j)\right)^2}\right\}$$

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

The FOM is defined as:

$$FOM = \frac{1}{Max\{n_d, n_t\}}\sum_{K=1}^{n_d}\frac{1}{1 + ad_K^2}$$

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

Based on the two modifications in the filtering step of BDND algorithm are:

- Expansion of filtering window
- Incorporating spatial and intensity information.

The above process is carried out for evaluating the performance of the filter used. Comparisons of various filters are analyzed by using simulation software.

NOISY IMAGE SALT & PEPPER NOISE | **TRI-STATE MEDIAN FILTER** | **MABDND METHOD** | **CBAFSMF METHOD** | **CBASMF METHOD** | **ADBPSMF METHOD**

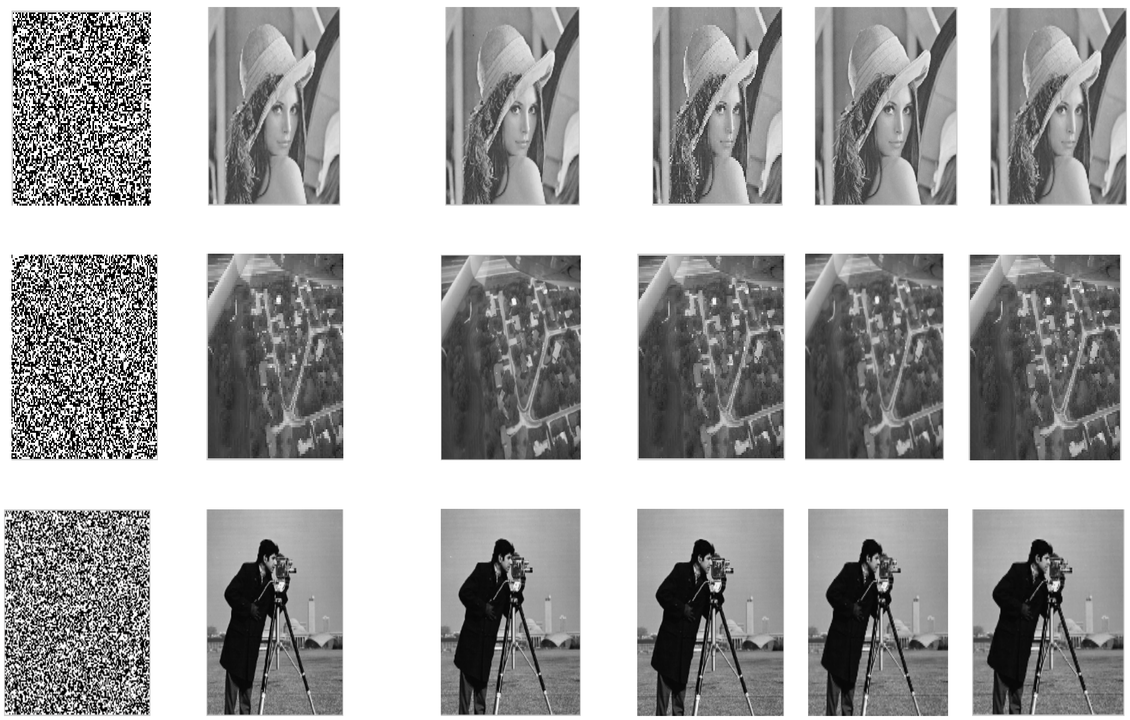

Figure. 3: Simulation output for 95% noise density

VIII. SIMULATION RESULTS

TABLE I
COMPARISON TABLE FOR VARIOUS PARAMETERS AND FILTERING METHODS FOR LENA IMAGE

FILTERING METHOD FOLLOWED	NOISE DENSITY=95%		
	PSNR	IEF	MAE
ADBPSMF	27	13.02	19.7
CBAFSMF	25	12.00	27.2
CBASMF	24	11.75	28.0
MABDND	23	11.52	29.4
TMF	20	11.04	30.0

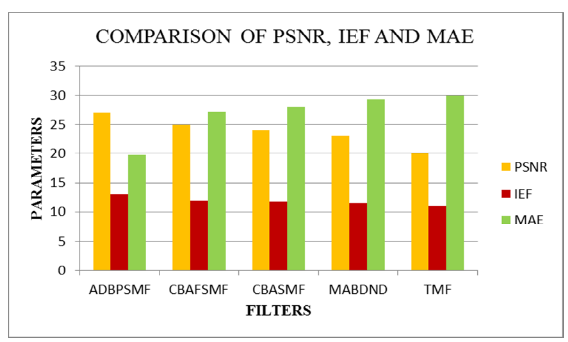

Fig 4: Plot Obtained for Table 1

TABLE II.

COMPARISON TABLE FOR VARIOUS PARAMETERS AND FILTERING METHODS FOR CAMERAMAN IMAGE

FILTERING METHOD FOLLOWED	NOISE DENSITY=95%		
	PSNR	**IEF**	**MAE**
ADBPSMF	27.5	13.33	19.9
CBAFSMF	25.5	11.52	27.3
CBASMF	24.5	11.28	27.8
MABDND	23.5	10.56	30.3
TMF	20.4	10.08	29.8

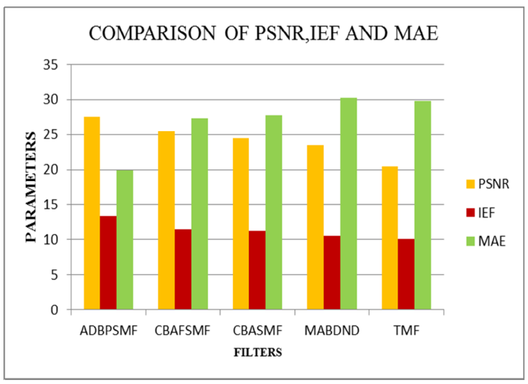

fig .5: Plot Obtained for Table II

TABLE. III.

COMPARISON TABLE FOR VARIOUS FILTERING METHODS

PARAMETERS	FILTERING METHOD USED				
	ADBPSMF	**CBAFSMF**	**CBSMF**	**MABDND**	**TMF**
MSE	1112.3	1203.6	1213.8	1221.9	1275
FOM	0.88	0.87	0.86	0.85	0.84

TABLE IV.

COMPARISON TABLE FOR VARIOUS FILTERING METHODS

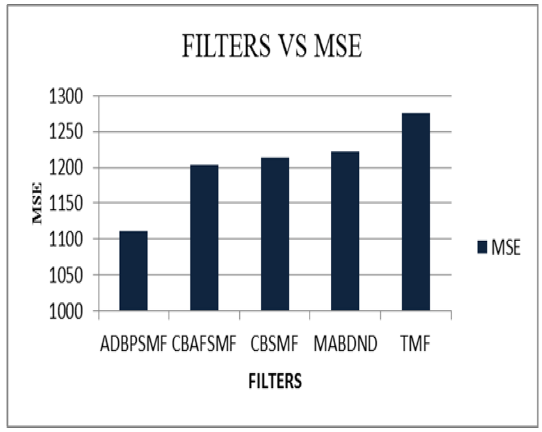

Fig 6: Plot Obtained for Table III

IX. CONCLUSION

A new filtering approach named as, ADBPSMF (Absolute Difference Based Progressive Switching Median 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, FOM and MAE. It is analyzed 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 CBAFSMF, CBASMF, MABDND and TMF for corrupted images, ADBPSMF (Absolute Difference Based Progressive Switching Median Filter) is best impulse noise removing filter.

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