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Switching Median Filter for Image Enhancement

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Abstract— In this paper, a new nonlinear filtering technique is introduced for enhancement of images that are highly contaminated by impulse noise. The proposed filtering technique is more effective in eliminating impulse noise and preserving the image features. The filter replaces a corrupted pixel by the median value or by its processed neighboring pixel value. The uncorrupted pixels are left undisturbed. Simulation studies show that the proposed filter can eliminate impulse noise of densities up to 70% while preserving the edges and fine details satisfactorily. The performance of the filter is evaluated by applying it on different test images and the results obtained are presented.

Index Terms—Impulse Noise, Median Filtering, Nonlinear Filter, Order Statistics Filter, Image Enhancement.

1 INTRODUCTION

FILTERING is a vital part of any signal processing system, which entails estimation of signal degradation and restoring the signalsatisfactorily with its features preserved intact. Several filtering techniques have been reported in the literature over the years, suitable for various applications. Nonlinear filtering techniques are preferred for denoising images which are degraded by impulse noise. These nonlinear filtering techniques take into account for nonlinear nature of the human visual system. Thus, the filters having good edge and image detail preservation properties are highly desirable for visual perception. The median filter and its variants are among the most commonly used filters for impulse noise removal. The median filters, when applied uniformly across the image, modify both noisy as well as noise free pixels, resulting in blurred and distorted features [1-2]. Recently, some modified forms of the median filter have been proposed to overcome these limitations. In these variants, namely, the switching median filters, a pixel value is altered only if it is detected to have been corrupted by impulse noise [3-5]. These variants of the median filter still retain the basic rank order structure of the filter. Salt-and-pepper noise is relatively considered for two intensity levels in the noisy pixels, that is, 255 and 0. The impulse noise is detected using decision mechanism with a pre-set threshold value [6] and the corrupted pixels alone are subjected to filtering. The window size is increased to achieve better noise removal; however, the increased window size results in less correlation between the corrupted pixel values and replaced median pixel values.

A Switching Median Filter with Boundary Discriminative Noise Detection for Extremely Corrupted Images has been proposed [7]. This technique is proficient in eliminating high densities of impulse noise as well as preserving the edges and fine details. However, the computational complexity involved in restoring the images is quite high. An Improved Decision – Based Algorithm for Impulse Noise Removal has been investigated [8]. In this method, a corrupted pixel is replaced by the average value of already processed neighbouring pixels inside the filter window. Although this filter suppresses impulse noise satisfactorily, it is found to exhibit inadequate perfor

-mance in terms of preserving edges and fine details due to the averaging process involved in filtering. A New Adaptive Decision Based Robust Statistics Estimation Filter for High Density Impulse Noise in Images and Videos has been recently proposed [9]. In this filter, the corrupted pixel is replaced by the median of the pixels inside the filter window. If the median value is also an impulse, size of the window is increased for eliminating it. Although this filter eliminates impulse noise satisfactorily, it entails more computation time to perform filtering. A Highly Effective Impulse Noise Detection Algorithm for Switching Median Filters has been experimented [10].This algorithm has been shown to remove high density impulse noise. However, the computational complexity is quite high.

A new Switching Median Filtering Technique (SMFT) for removing impulse noise from the images is proposed. This filtering technique detects whether a pixel is noisy or noise-free. If the pixel is noise-free, the filtering window is moved forward to process the next pixel. On the other hand, if the pixel is a noisy one, then it is replaced by the median pixel value if it is not an impulse; otherwise, the pixel is replaced by the already processed immediate top neighbouring pixel in the filtering window. The proposed filter will be shown to exhibit good response at signal edges besides filtering out noise sufficiently. The paper is organized as follows. Section II discusses the scheme proposed for impulse noise detection and elimination. The simulation results obtained by applying the filter on different images are presented in section III to illustrate its efficacy. The conclusions are summarized in section IV.

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2 PROPOSED FILTERING ALGORITHM

2.1 Impulse Noise Detection

The impulse noise detection is based on the assumption that a corrupted pixel takes a gray value which is significantly different from its neighboring pixels in the filtering window, whereas noise-free regions in the image have locally smoothly varying gray levels separated by edges. In widely used Standard Median Filter (SMF) and Adaptive Median Filter (AMF), only median values are used for the

replacement of the corrupted pixels.
In switching median filter, the difference between the median value of pixels in the filtering window and the current pixel value is compared with a threshold to determine the presence of impulse. If the current pixel is detected to have been corrupted by impulse noise then the pixel is subjected to filtering; otherwise, the pixel is left undisturbed and described in Fig.1.

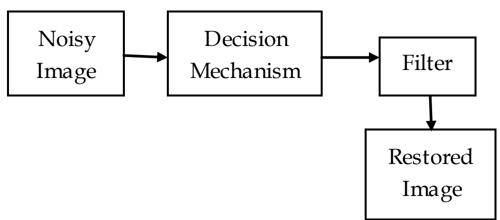

Fig. 1 Impulse Detection

2.2 Filtering Algorithm

The filtering technique proposed in this paper detects the impulse noise in the image using a decision mechanism. The corrupted and uncorrupted pixels in the image are detected by comparing the pixel value with the maximum and minimum values in the selected window. If the pixel intensity lies between these minimum and maximum values, then it is an uncorrupted pixel and it is left undisturbed. If the value does not lie within the range, then it is a corrupted pixel and is replaced by the median pixel value or already processed immediate neighboring pixel in the current filtering window.

Consider an image of size M×N having 8-bit gray scale pixel resolution. The steps involved in detecting the presence of an impulse or not are described as follows:
Step 1) A two dimensional square filtering window of size 3 x 3 is slid over a highly contaminated image as shown in below.

161	**162**	**159**	**163**	63
167	**255**	**0**	**255**	255
164	**255**	**255**	**255**	255
165	0	255	255	255
166	255	159	255	167

Step2) The pixels inside the window are sorted out in ascending order.

0 159 162 163 **255** 255 255 255 255

Step 3) Minimum, maximum and median of the pixel values in the processing window are determined. In this case, the minimum, maximum and median pixel values, respectively, are 0, 255 and 255.
Step 4) If the central pixel lies between minimum and maximum values, then it is detected as an uncorrupted pixel and the pixel is left undisturbed. Otherwise, it is considered a corrupted pixel value. In the present case, the central pixel value 255 does not lie between minimum and maximum values. Therefore, the pixel is detected to be a corrupted pixel.
Step 5) The corrupted central pixel is replaced by the median of the filtering window, if the median value is not an impulse. If the median value itself is an impulse then the central pixel is replaced by the already processed immediate
top neighbouring pixel $A_{i-1,j}$ in the filtering window. In the present case, the median value is also an impulse and therefore, the pixel is replaced by its already processed top neighbour pixel value 214.

161	**162**	**159**	**163**	63
167	**255**	**159**	**255**	255
164	**255**	**255**	**255**	255
165	0	255	255	255
166	255	159	255	167

Then the window is moved to form a new set of values, with the next pixel to be processed at the centre of the window. This process is repeated until the last image pixel is processed. This Impulse noise detection and filtering is based on the following condition:

if $A_{min} < A_{i,j} < A_{max}$
{$A_{i,j}$ *is a noiseless pixel;*
no filtering is performed on $A_{i,j}$ *}*
else
{$A_{i,j}$ *is a noisy pixel;*
determine the median value}
if median $\neq 0$ *and median* $\neq 255$
{Median filter is performed on $A_{i,j}$ *}*
$A_{i,j} = A_{med}$
else
{Median itself is noisy}
$A_{i,j} = A_{i-1,j}$
end;
end;

where, $A_{i,j}$ is the intensity of central pixel inside the filtering window, A_{min}, A_{max} and A_{med} are the minimum, maximum and median pixel value in filtering window of noisy image. $A_{i-1,j}$ is the intensity of the already processed immediate top neighboring pixel.

In order to process the border pixels, the first and last columns, respectively are replicated at the front and rear ends of the image matrix; similarly, the first and last rows, respectively, are replicated at top and bottom of the image. The first row pixels of the image are processed using the same algorithm described above except that in step 5, if the median value is also detected to be an impulse it is replaced by one of the uncorrupted nearest neighbourhood pixel values in the processing window.

The proposed SMFT algorithm is simpler than Boundary Discriminative Noise Filtering technique [6] and Improved Decision Based Algorithm (IDBA) [8] in terms of computational requirements. Further, the Boundary Discriminative Noise Filtering technique is considerably more complex in terms of computation; therefore, it has not been taken into account for performance comparison with the proposed filter algorithm. The proposed filter exhibits superior performance than the IDBA in terms of eliminating impulse noise up to 70 % and preserving edges and fine details.

3 Result and Discussion

The performance of proposed filter is compared with that of IDBA by applying them on Lena image of size 256 x 256, corrupted with various densities of impulse noise. SMFT has also been evaluated by applying it on several test images including Lotus and Boat of size 256 x 256. The objective measures used for quantitatively evaluating the performance of the filters are Mean Square Error (MSE) and Peak Signal to Noise ratio (PSNR) and these metrics are defined as follows:

(1)

$$PSNR = 10 \log_{10}\left[\frac{255 * 255}{MSE}\right] \quad (2)$$

where, x(i,j) and f(i,j) denote, respectively, the intensity of (i,j)th pixel of the original and filtered images. In order to prove the better performance of proposed filter, existing filtering techniques are experimented and compared with the proposed filter for visual perception and subjective evaluation on Lena image including the standard Median Filter (MF), the Weighted Median Filter (WMF), the Center Weighted Median Filter (CWMF), the Tri State Median Filter (TSMF), a New Impulse Detector (NID), Multiple Decision Based Median Filter (MDBMF), DBSM filter, IBA and proposed filter in Fig.2. The values of objective measures obtained by applying the filters on Lena test image contaminated with the impulse noise of various noise densities are summarized in Tables 1 and are illustrated graphically in Fig.3.

Fig.2 Performance of Test image: Lena (a) Noise free images, (b) image corrupted by 50% impulse noise, (c) images restored by MF, (d) images restored by WMF,(e)images restored byCWMF, (f)images restored by TSMF,(g) images restored by MDBSMF, (h) images restored by NID, (i) images restored by DBSMF, (j)images restored by IDBA, (k) images

Fig.3 illustrates the performance of proposed filter and compares with other filtering algorithms in terms of PSNR when applied on Lena image contaminated with noise densities up to 90%. This switching median filter outperforms the existing filtering algorithms for the noise densities up to 50%.

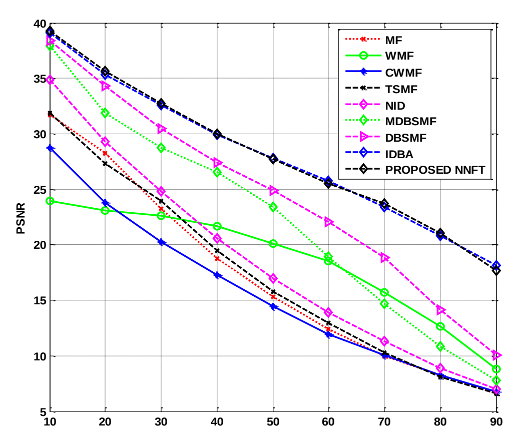

Fig.3 PSNR obtained using proposed filter on Lena image corrupted with different densities of impulse noise compared with other existing filtering techniques

TABLE 1
PERFORMANCE OF PSNR FOR DIFFERENT FILTERING TECHNIQUES ON LENA IMAGE

Filtering Techniques	Noise percentage 10	20	30	40	50	70	90
MF	31.74	28.23	23.20	18.80	15.28	9.98	6.58
WMF	23.97	23.06	22.58	21.65	20.11	15.73	8.83
CWMF	28.72	23.80	20.28	17.28	14.45	10.04	6.75
TSMF	31.89	27.35	23.96	19.46	15.82	10.33	6.58
MDBSMFS	34.83	30.03	24.79	20.59	16.99	11.28	6.97
NID	37.90	31.85	28.75	26.52	23.42	14.65	7.77
DBSMF	38.42	34.28	30.47	27.38	24.92	18.84	10.03
IDBA	36.5	33.39	29.72	28.64	26	23.5	19.3
NFT	39.30	35.66	32.70	30.01	27.73	23.73	17.69
Proposed Filter	51.29	43.46	39.89	35.86	33.07	26.31	18.72

The filtered images are presented in Fig.4 for visual perception and subjective evaluation. The proposed new nonlinear filter can be seen to have eliminated the impulse noise completely. The filter is seen to exhibit superior noise cleaning properties on Pepper image in comparison with the other test images in the presence of impulse noise. This is due to the fact that the Pepper image is replete with the homogeneous regions and fine details. At the same time, the filter is seen to exhibit poor noise cleaning properties on Baboon image in com[illegible] impulse nois[illegible] lete with the [illegible] are non-stat[illegible] ges are char[illegible] this filter is b[illegible] roved deci[illegible]

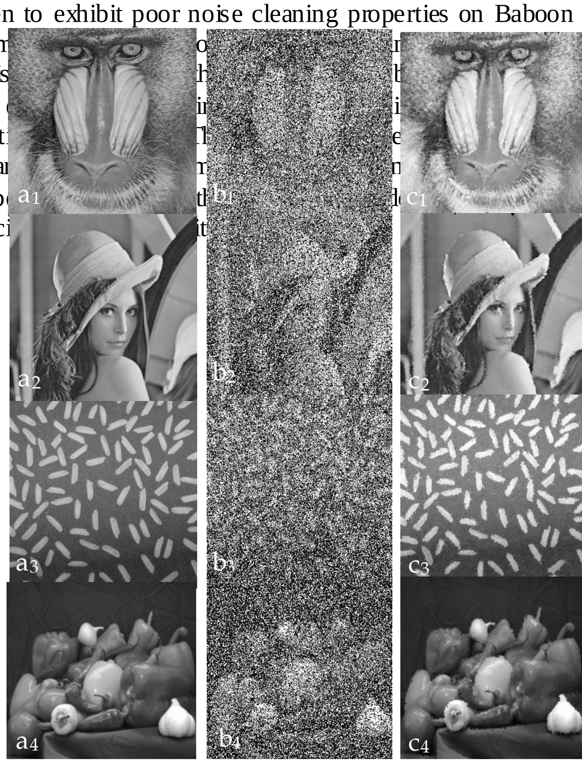

Fig.4 Subjective performance illustration of proposed filtering algorithm for Baboon, Lena, Rice and Pepper images:($a_{1,2\ \&\ 3}$)noise free image ($b_{1,2,\&\ 3}$) Lena image corrupted with 50% impulse noise, ($c_{1,2\ \&\ 3}$) proposed filtered images.

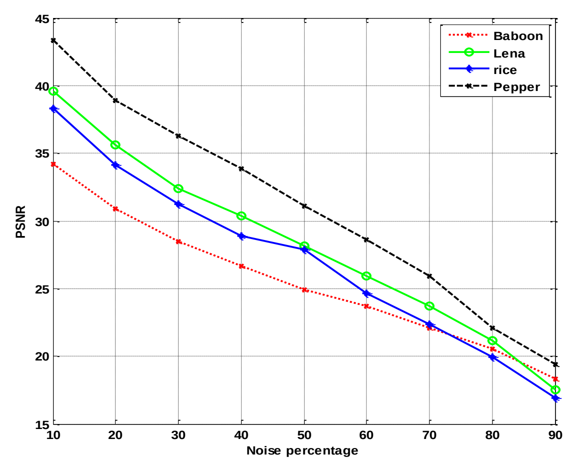

Fig.5 PSNR obtained by applying proposed filter for different images corrupted with various densities of impulse noise

The values of objective measures obtained by applying the filters on different test images contaminated with the impulse noise of various noise densities are summarized in Table 2 and are illustrated graphically in Figure.5

4 CONCLUSION

A switching median filtering technique has been developed in this paper. The filter has been shown to be quite effective in eliminating the impulse noise. The filtering operation is performed only on corrupted pixels, uncorrupted pixels are undisturbed; as a result, misclassification of pixels is avoided. So that the proposed filter output images are found to be pleasant for visual perception and also the essential features of the images, namely, edges and fine details are preserved satisfactorily. The proposed filter has been shown to outperform other existing filters in terms of noise elimination and feature preservation properties.

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TABLE 2
PSNR VALUES OBTAINED USING PROPSED FILTER ON DIFFERENT TEST IMAGES CONTAMINATED WITH VARIOUS DENSITIES OF IMPULSE NOISE

Noise percentage	Baboon	Lena	Rice	Pepper
10	34.22	39.57	38.27	43.35
20	30.91	35.63	34.17	38.92
30	28.51	32.41	31.27	36.28
40	26.67	30.37	28.95	33.88
50	24.91	28.13	27.89	31.08
60	23.69	25.91	24.68	28.61
70	22.10	23.68	22.36	25.95
80	20.52	21.16	19.95	22.12
90	18.34	17.52	16.90	19.39