An Improved Switching Median filter for Uniformly Distributed Impulse Noise Removal

Rajoo Pandey

Abstract—The performance of an image filtering system depends on its ability to detect the presence of noisy pixels in the image. Most of the impulse detection schemes assume the presence of salt and pepper noise in the images and do not work satisfactorily in case of uniformly distributed impulse noise. In this paper, a new algorithm is presented to improve the performance of switching median filter in detection of uniformly distributed impulse noise. The performance of the proposed scheme is demonstrated by the results obtained from computer simulations on various images.

Keywords—Switching median filter, Impulse noise, Image filtering, Impulse detection.

I. INTRODUCTION

FILTERING is an essential part of any signal processing system, which involves estimation of a signal degraded, in most cases, by additive random noise. Several filtering techniques have been reported over the years, for various applications. In image processing problems, nonlinear filtering techniques are preferred as they can cope with the nonlinearities of the image formation model and also take into account the nonlinear nature of the human visual system [1]. Thus, the filters having good edge and image detail preservation properties are highly desirable for image filtering. The median filter and its variants are among the most commonly used filters for impulse noise removal [2]. The median filters, when applied uniformly across the image, tend to modify both noisy as well as noise free pixels, resulting in blurred and distorted features. Recently, some modified forms of the median filter have been proposed to overcome these limitations. In these variants of the median filter, the pixel value is modified only when it is found corrupted with noise [3]. These variants of the median filter still retain the basic rank order structure of the filter. Among these filters, the center weighted median filters (CWMFs) give a large weight to the central pixel, while choosing between the current pixel and the median value [4]. In order to avoid the influence of the noisy pixels on the filtered output, it is necessary to perform the impulse detection before filtering. The progressive switching median filter (PSM) [5] achieves the detection and removal of impulse noise in two separate stages. In multi-state median (MSM) filter [6], the out-put of the filter is adaptively switched among those of a set of CWM filters having different center weights. The tri-state median filter [7] is a modified switching median filter that is obtained by including a center weighted median filter into a basic switching median filter

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structure. Another approach followed in [8] uses a difference-type noise detector and the noise detection-based adaptive medium filter. The boundary discriminative noise detection (BDND) filtering scheme proposed in [9] detects the impulse noise by employing two different size of filtering windows before the filtering operation.

Most of these filtering techniques assume the presence of salt and pepper type of impulse noise. The detection of salt and pepper type of noise is relatively easy as there are only two intensity levels in the noisy pixels. However, the study reveals that in case of uniformly distributed impulse noise, these techniques do not perform well. In this paper a new algorithm is presented which improves the performance of switching median filter as a result of efficient detection of impulse noise when the impulse amplitude is uniformly distributed.

The paper is organized as follows. Section II discusses the impulse noise removal technique using switching median filters. Section III presents the proposed noise detection algorithm for uniformly distributed impulses. The simulation results with different images are presented in section IV to demonstrate the efficacy of the proposed algorithm. Finally, conclusions are given in section V.

II. IMPULSE NOISE REMOVAL

The impulse detection is based on the assumption that a noise pixel takes a gray value which is substantially different than the neighboring pixels in the filtering window, whereas noise-free regions in the image have locally smoothly varying gray levels separated by edges. In the switching median filter, the difference of the median value of pixels in the filtering window and the current pixel value is compared with a threshold to decide about the presence of the impulse. We assume that the image is of size M×N having 8-bit gray scale pixel resolution that is, $I \in [0, 255]$. Now a 3×3 or a larger window $W_{i,j}^{x}$ is taken whose central pixel is $x(i,j)$. In the conventional switching median filter the output of the filter is given by:

$$y(i, j) = \begin{cases} m_{i,j}^{x}; & if \left| m_{i,j}^{x} - x(i, j) \right| > threshold \\ x(i, j); & otherwise \end{cases} \quad (1)$$

where $m_{i,j}^{x}$ represents the median value of the pixels inside the filtering window. When the above scheme is applied for impulse detection, a binary flag image $\{f(i, j)\}$ is constructed such that $f(i,j)=1$, when the pixel $x(i, j)$ is noisy and $f(i,j)=0$ for noise less pixel. Now during filtering operation, the noisy pixels are replaced by the median of the noise-free pixels

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present in the filtering window.

III. PROPOSED NOISE DETECTION ALGORITHM

In the proposed scheme, the image is assumed to be corrupted by noise with uniform distribution between 0 and 255. For the impulse detection, the median $m_{i,j}^x$ of the pixels in the filtering window $W_{i,j}^x$ is compared with a threshold and the following algorithm is used.

$$\text{If } (\left| m_{i,j}^x - x(i, j) \right| < threshold_1)$$
$$ind = \min\left\{ \{x_k(i, j)\}_{k=1}^8 - x(i, j) \right\};$$
$$\quad if \ (ind < threshold_2)$$
$$\quad f(i, j) = 0;$$
$$\quad else \ f(i, j) = 1;$$
$$\quad end$$
$$end$$

where $\{x_k(i, j)\}_{k=1}^8$ denote the neighbors of the central pixel $x(i,j)$ in the filtering window. For the filtering operation, the noise-free pixels in the filtering window are considered for computation of the median value as used in the conventional scheme.

IV. SIMULATION RESULTS

In order to test the proposed algorithm, experiments are performed at different noise levels on two different images viz. 'Lenna' and 'Peppers' of size 256×256. To evaluate the image restoration performance, mean square error (MSE) is used as the criterion. MSE is defined as

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(u(i, j) - y(i, j))^2 \qquad (2)$$

where the image is assumed to be of size M×N. The pixel values of original and restored image, at position (i, j) are denoted by u(i, j) and y(i, j). The test images are corrupted by noise with uniform distribution between 0 and 255. The noise density is varied from 5% to 35% in steps of 5%. The *threshold* parameter is kept at 35 for the switching median filter, whereas the two parameters $threshold_1$ and $threshold_2$ for the proposed algorithm are fixed at 35 and 20, respectively. In order to judge the performance of the proposed method, the test images are also filtered by some other conventional and recently proposed filtering methods including standard median filter, switching median filter and the BDND filter for comparison. The size of the filtering window for BDND is kept 11×11.

Fig. 1 shows the plot of the number of errors in the detection of impulse noise with 'Lenna' image. The detection error is more in case of the switching median filter in comparison with the proposed method when the impulse noise is uniformly distributed. The performance under the salt and pepper type noise is shown in Fig. 2 for these two schemes. It can be observed that the performance of the two algorithms is almost similar under this noise model.
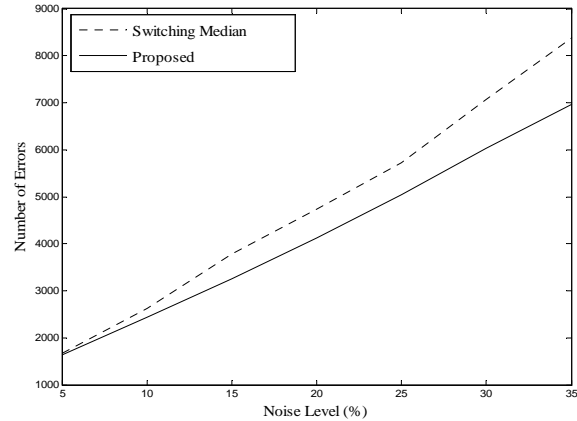

Fig. 1 Number of Detection Errors for the proposed and switching median filters with uniformly distributed noise
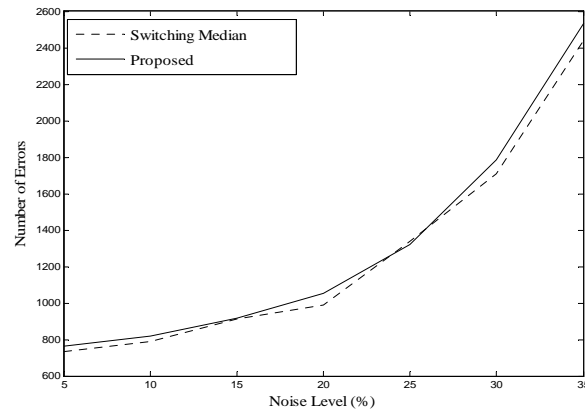

Fig. 2 Number of Detection Errors for the proposed and switching median filters with salt and pepper noise

TABLE I
MSE OF VARIOUS FILTER FOR 'PEPPERS' IMAGE

Noise %	MSE for various filters			
	Median	Switching Median	BDND	Proposed
5	40.1	27.8	369.1	22.3
10	54.5	43.3	465.3	37.8
15	70.2	65.6	612.7	55.4
20	92.6	92.5	745.2	77.8
25	122.4	131.4	905.3	117.4
30	165.3	185.9	1038	159.7
35	238.5	261.5	1248	224.2

The MSE resulting from various experiments is shown in Table I and Table II for 'Peppers' and 'Lenna' images, respectively. From these Tables it can be easily observed that the proposed method outperforms the other filtering schemes in case of uniformly distributed impulse noise.

Also, the MSE obtained with the BDND filter is much higher than the other schemes. Although, the BDND filter gives highly improved results when compared with other filtering methods in case of salt and pepper noise [9]. Fig3 (a-d) shows the original Peppers image, the image corrupted with 25% noise, and the filtered images with switching median and proposed methods, respectively.

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TABLE II
MSE OF VARIOUS FILTER FOR 'LENNA' IMAGE

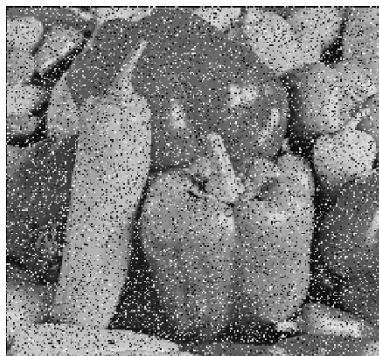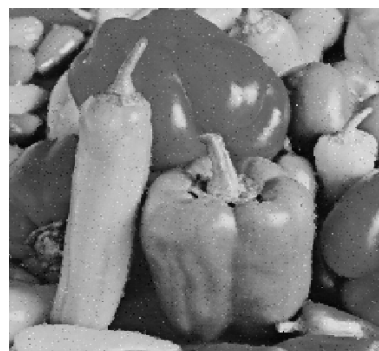| Noise %	MSE for various filters			
	Median	Switching Median	BDND	Proposed
5	75.3	42.8	245.1	39.1
10	82.7	58.4	344.3	51.4
15	96.4	83.7	458.2	72.4
20	117.9	104.5	582.4	92.3
25	141.7	138.6	761.9	126.2
30	185.6	186.3	917.3	165.8
35	236.5	252.3	1021	227.2

(a)

(b)

(c)

(d)

Fig. 3 (a) Original image (b) Image corrupted with 25% impulse noise (c) Image filtered with switching median filter (d) Image filtered with proposed method

V. CONCLUSION

The paper has presented an algorithm for efficient detection of uniformly distributed impulse noise for image filtering applications. It has been found that, in general, the MSE for various filtering schemes is much higher in this type of impulse noise in comparison with the salt and pepper noise. Computer simulations on various images have shown that a filtering system based on the impulse detection using proposed scheme yields lower MSE than the conventional switching median filters. The improvement in the noise detection ability is obtained without compromising the performance for salt and pepper noise.

REFERENCES

[1] R. C. Gonzales and R. E. Woods, *Digital Image Processing*, 2nd ed. Reading, MA: Addison –Wesley, 2002.

[2] G. R. Arce and M. P. McLoughlin, "Theoretical analysis of the MAX/Median filter," *IEEE Trans. Acoust. Speech,Signal Processing*, vol. ASSP-35, pp.60-69, 1987.

[3] S. Zhang, M.A. Karim, "A new impulse detector for switching median filters", *IEEE Signal Processing Letters*, vol. 9, No.11, pp. 360-363, 2002.

[4] S.-J.Ko and Y.-H Lee, "Center weighted median filters and their applications to image enhancement", *IEEE Trans. Circuits Syst.*, vol. 38, pp. 984-993, 1991.

[5] Z. Wang, D. Zhang, "Progressive switching median filter for the removal of impulse noise from highly corrupted images", *IEEE Trans. Circuits Syst.*, vol. 46, pp. 78-80, 1999.

[6] T.Chen and H.R.Wu, "Space Varient Median Filters for the Restoration of Impulse Noise Corrupted Images", *IEEE Trans. Circuits Syst.-II: Analog And Digital Signal Processing*, vol. 48, No. 8, pp.784-789, 2001.

[7] T. Chen, K.-K. Ma, and Li-Hui Chen "Tri-state median filter for image denoising", *IEEE Trans. Image Processing*, vol. 8, pp. 1834 – 1838, 1999.

[8] S.Q. Yuan and Y.H. Tan, "Difference type noise detector for adaptive median filter," *Electronics Letters*, vol.42, no.8, pp. 454-455, 2006.

[9] P.-E. Ng and K.-K. Ma, " A switching median filter with boundary discriminative noise detection for extremely corrupted images," *IEEE Trans. Image Processing*, vol. 15, no. 6, pp. 1506-1516, 2006.