

Recursive Switching Median Filter for High Density Impulse Noise Using Double Threshold

Sonam Ramteke, Savan Oad

Abstract – In this paper, we proposed a recursive median filtering approach for removing the random valued impulse noise while preserving the image fine details gray scale images. It reduces the noise very effectively in two stages. First stage is noise detection and second stage is noise removal. The noisy pixels are first detected using dual threshold technique and then subsequently replaced by the enhanced median value. Simulations is carried out on Matlab for different natural images. Experimental results represents the efficiency of proposed method with better PSNR even at high noise ratios.

Keywords – Recursive, PSNR, MSE, Median.

I. INTRODUCTION

Preservation of image fine details and removal of image noise are the two important concepts of image processing. Because during the transmission and acquisition of images, different type of noise present in medium effects the image details. These noise can be impulse noise, Gaussian noise, shot noise, speckle noise etc [6]. The most general and important type of noise which affects the image is impulse noise. Impulse noise is of two types ; one is Fixed value impulse noise or Salt and Pepper Noise and second is Random valued impulse noise. Salt and pepper noise in 8- bit digital image can have value either 0 or 255., where 0 represent complete black and 255 represent complete white colour on gray scale image but random valued impulse noise can have any value between 0 and 255, that is why, removal of random noise is very difficult.

The linear filters are very simple and easy for impulse noise removal but during the noise removal, linear filter causes of blurring into the image. Therefore non-linear filters are better option than mean filter. A simple median filter (SMF)[5] is very common used non-linear filter. It produces better results and quality than mean filter and other linear filters but also effects all the pixels. Many improvements have been made in median filter to produce better results and visual quality like first detection of noisy pixels and then removal of those noisy pixels while left other pixels unaltered. Weighted median filter (WMF)[4], centre weighted median filter (CWM)[11][12], Adaptive median filter (AMF), Decision based adaptive (DBA) median filter, Adaptive centre weighted median filter (ACWM)[4], Switching median filter (SMF)[3], progressive switching median filter (PSMF)[9] are some improvements in median filtering approach.

This paper presents a switching based nonlinear filtering technique with recursive operation to remove the random valued impulse noise from highly corrupted images. This paper also include the overall comparison of quality and complexity of the proposed algorithm. Experiments are carried out in natural images, particularly at high noise

ratio, and compared with other existing techniques. Rest of the paper is organized as follows. Section II contains impulse noise model and proposed algorithm is explained in Section III. The simulation and experimental results for different images represented in Section IV. Finally, conclusion explained in Section V.

II. NOISE MODEL

Impulse noise is very common type noise in digital images. [5] Impulse noise is completely independent and not correlated to the pixels and is randomly distributed over the entire image. Hence unlike Gaussian noise, for an corrupted image effected by impulse noise, all the image pixels are not noisy, only a number of image pixels are effected by impulse noise and the rest of pixels will be noise free. There are two types of impulse noise called as salt and pepper noise or fixed valued impulse noise and random valued impulse noise. In fixed type noise, the noisy pixels takes either salt value (gray level-225) or pepper value (gray level -0) and it distributed in form of black and white dots on the images. If p represents the noise density then salt and pepper noise both will have a noise density of $p/2$. This can be mathematically represented in eq. (1).

$$f_n(y) = \begin{cases} f(y) & \text{for } \dots 1 - P \\ 0 & \text{for } \dots P/2 \\ 1 & \text{for } \dots P/2 \end{cases} \dots\dots(1)$$

P = Noise density

$f_n(y)$ = Corrupted Image

$f(y)$ = Original Image

In random value impulse noise, the pixel will be affected by any gray value between 0 to 255 and noise will be randomly distributed over the image. It can be represented as

$$f_n(y) = \begin{cases} f(y) & \text{for } \dots 1 - P \\ 0 \text{ or } 255 & \text{for } \dots P \dots\dots\dots(2) \end{cases}$$

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III. PROPOSED METHOD

We have developed the simple algorithm in which we perform the noise detection & noise removal process simultaneously. We use the smallest window size which preserves the fine details of image. The window of size 3x3 chooses for noise detection and noise removal. The window contains total 9 elements which are as follows:

$Z_1, Z_2, Z_3, Z_4, Z_5, Z_6, Z_7, Z_8, Z_9$.

The hardware structure of complete process is shown in figure 1. Different blocks are shown for different steps. First block selects the maximum, minimum and median values of columns. Second block stores these values and third block selects minimum threshold, maximum threshold and final median value. Comparator use threshold values for noise detection and multiplexer uses final median value for noise removal. We can divide the complete process into no. of steps as follows:

Table I. Filtering window of size 3x3

	Column 1	Column 2	Column 3
Row 1	Z_1	Z_2	Z_3
Row 2	Z_4	Z_5	Z_6
Row 3	Z_7	Z_8	Z_9

Step-1:

First we select all columns of filtering window one by one and then we find three values i.e. Maximum, Minimum and Median in each column. The mathematical expression can be shown as follow:

The minimum values of three columns are represented as

$$\begin{aligned} \text{Min (cln1)} &= \min \{ Z_1, Z_4, Z_7 \} \\ \text{Min (cln2)} &= \min \{ Z_2, Z_5, Z_8 \} \\ \text{Min (cln3)} &= \min \{ Z_3, Z_6, Z_9 \} \end{aligned}$$

The maximum value of these three column are represented as

$$\begin{aligned} \text{Max (cln1)} &= \max \{ Z_1, Z_4, Z_7 \} \\ \text{Max (cln2)} &= \max \{ Z_2, Z_5, Z_8 \} \\ \text{Max (cln3)} &= \max \{ Z_3, Z_6, Z_9 \} \end{aligned}$$

The median value of the these three column are represented as

$$\begin{aligned} \text{Med (cln1)} &= \text{med} \{ Z_1, Z_4, Z_7 \} \\ \text{Med (cln2)} &= \text{med} \{ Z_2, Z_5, Z_8 \} \\ \text{Med (cln3)} &= \text{med} \{ Z_3, Z_6, Z_9 \} \end{aligned}$$

Step-2:

Now we have total nine values (three maximum, three minimum and three median). We will use these values to calculate threshold values (maximum threshold and minimum threshold) and median value. For these calculations, we make three different groups of these nine elements.

$$\begin{aligned} \text{Max_group} &= \{ \text{Max (cln1)}, \text{Max (cln2)}, \text{Max (cln3)} \} \\ \text{Min_group} &= \{ \text{Min (cln1)}, \text{Min (cln2)}, \text{Min (cln3)} \} \\ \text{Med_group} &= \{ \text{Med (cln1)}, \text{Med (cln2)}, \text{Med (cln3)} \} \end{aligned}$$

First we will calculate maximum threshold by choosing maximum value in min_group. Then we choose minimum threshold by choosing minimum value in max_group.

$$\begin{aligned} \text{Thmax} &= \text{Max} \{ \text{Min (cln1)}, \text{Min (cln2)}, \text{Min (cln3)} \} \\ \text{Thmin} &= \text{Min} \{ \text{Max (cln1)}, \text{Max (cln2)}, \text{Max (cln3)} \} \end{aligned}$$

These two threshold values will be used for noise detection. Now we will calculate the median value for noise removal.

$$\text{Med_new} = \text{Med} \{ \text{Med (cln1)}, \text{Med (cln2)}, \text{Med (cln3)} \}$$

Step-3:

Now we will perform noise detection and noise removal operation using these three values i.e. Thmax, Thmin, and Med_new. We compare the central pixel with threshold values. If the central pixel is in between the Thmin and Thmax, then the pixel will be considered as noise free, then pixel will remain unchanged and window will move or slide to the next pixel. Otherwise pixel will consider as noisy and it will be replaced by median value.

If
 $\text{Thmin} \leq Z_5 \leq \text{Thmax}$
 Then
 X_5 is unchanged.
 Else
 $X_5 = \text{Med_new}$,

Here we are parallely calculating the threshold values and median value. So there is no need to perform noise detection and noise removal separately.

IV. RESULTS AND SIMULATION

Proposed de-noising technique is simulated using MATLAB 7.9 on Intel-core i-5 processor with 4 GB RAM. De-noising is performed on Lena image of size 256X256. We have analyzed the performance of existing and proposed methods by using performance parameters like PSNR (Peak Signal to Noise Ratio) and MSE (Mean Square Error). The simulation result shows that PSNR (Peak Signal to Noise Ratio) of de-noised image by this filter is better than other filters.

The PSNR (Peak Signal to Noise Ratio) is expressed as:

$$PSNR = 10 \log_{10} \frac{(255)^2}{MSE}$$

Where MSE (Mean Square Error) is

$$MSE = \frac{\sum_{i=1}^m \sum_{j=1}^n \{Z(i, j) - A(i, j)\}^2}{m \times n}$$

The results in the Table II clearly show that the PSNR of proposed method is better at high density random valued impulse noise.

The results are compared with several standard median based filters like Median filter (SMF)[5], Centre weighted median filter (CWM)[14], Progressive switching median filter (PSM)[9], Signal dependent rank order median filter (SDROM)[8], Adaptive centre weighted median filter (ACWM)[14]. The fig 2(b), 2(d), 2(f), 2(h), 2(j) shows Lena image corrupted by 50%, 60%, 70 %, 80% and 90% respectively and figure 2(c), 2(e), 2(g), 2(i), 2(k) show images De-noised by proposed method.

Table 2. Comparison of PSNR Values of Different Filters for Lena Image

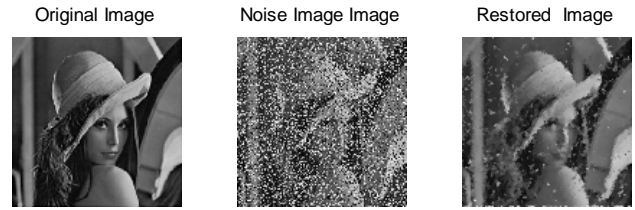
De-noising Methods	Noise density				
	50%	60%	70%	80%	90%
MF	15.0	12.2	9.8	8.1	6.5
PSM	20.0	15.2	11.1	8.3	6.4
SDROM	14.4	11.7	9.4	7.8	6.4
ACWM	14.8	12.1	9.7	8.1	6.5
ACWMR	20.8	18.1	15.0	11.8	8.1
TSM	12.7	10.4	8.4	7.1	6.0
LEAM	23.1	21.5	19.6	17.8	14.9
Proposed Method	23.2	21.6	20.3	19.1	17.9

Table 3. Comparison of Mse Values of Different Filters for Lena Image.

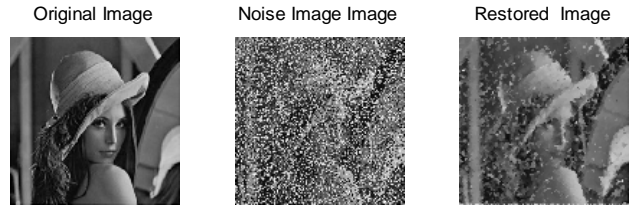
De-noising Methods	Noise density				
	50%	60%	70%	80%	90%
MF	2057.7	3919.5	6808.9	10071.1	14557.2
PSM	650.25	1963.9	5048.5	9619.0	14913.9
SDROM	2360.9	4396.2	7465.8	10791.4	14896.3
ACWM	2153.1	4009.4	6967.5	10071.1	14557.2
ACWMR	540.8	1007.1	2056.2	4296.1	10071.1
TSM	3492.0	5930.3	9398.9	12678.8	16333.5
LEAM	318.47	460.34	712.98	1079.14	2104.16
Proposed Method	316.31	455.44	616.53	813.03	1103.9



(a). For 50% Noise density



(b). For 70% Noise density



(c). For 70% Noise density

Fig. 1. Experimental Results of Proposed Method for Lena Image

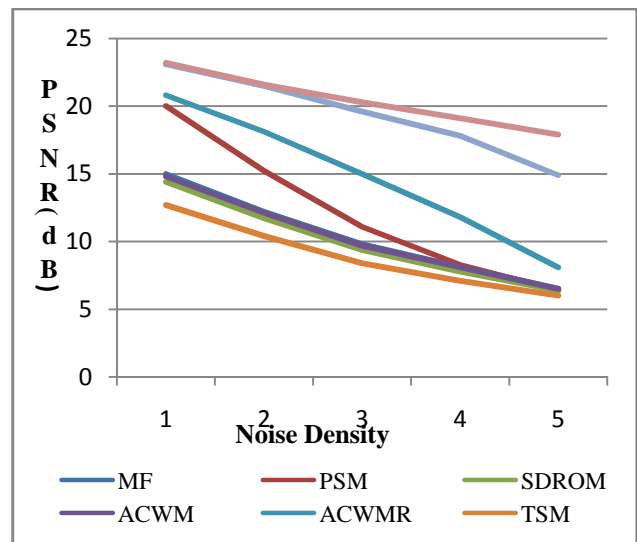


Fig. 2. PSNR Comparison of different filters

V. CONCLUSION

This paper proposed a simple, accurate and very efficient impulse-noise removal method based on Median operation, which has been further improved with recursive operation. Extensive simulation results showing that this proposed filter consistently produce better results than existing filters and produce higher PSNR for wide range of impulse noise densities specially when noise density is very high. The key success of is recursive operation and better noise detection algorithm having high noise detection ratio. Here visual and quantitative analysis results are demonstrated and concluded that proposed algorithm is much superior than existing methods.

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AUTHOR'S PROFILE

Sonam Ramteke did B. E. in Electronics and Telecommunication from Chhattisgarh Swami Vivekanand Technical University (C.G.) India. She is Pursuing M.Tech in Digital Communication from Rajiv Gandhi Proudhogiki Vishwavidyalaya Bhopal (M.P.) India. One review paper on "Different Image De-noising Methods: A Review" selected in an national conference NCETEE-2013.



Savan Kumar Oad, currently working as an Asst. Professor in the Department of Electronics and Communication and pursuing Ph. D. from KL University, Vijaywada. Graduated in the year 2005 from SATI, Vidisha in Electronics and Instrumentation. Post Graduated from Barkatullah University in Digital Communication. So far published One research papers in IJCA. Associate Life member of IETE.