Iterative Selective & Progressive Switching Median Filter for removal of salt and pepper noise in images

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***Abstract*— In this paper, we propose a new median-based switching filter, called Iterative Selective & Progressive Switching Median (ISPSM) filter, where both the noise density and Threshold value are calculated dynamically from noisy input image by the impulse detector also impulse detection window size is iteratively detected by impulse detector. Simulation result shows that our method is significantly better than a number of existing techniques including PSM in terms of image restoration and noise detection.**

Keywords- PSM, ISPSM, Impulse noise detector , PSNR.

I. INTRODUCTION

Images are often corrupted by impulse noise due to transmission errors, malfunctioning pixel elements in the camera sensors, faulty memory locations & timing errors in analog-to-digital conversion [1]. Median one of the most popular filtering method has been established as a reliable method to remove impulse noise without damaging edge details [2-4] with high computational efficiency. Several median filtering methods have been proposed for removal of impulse noise densities [5-8]. The weighted median filter & Center weighted Median filter give more importance to current pixel, preserving good image details, but offered less noise suppression when the center weighted pixel itself is corrupted [9-12]. Recently, switching schema has been studied for removal impulse noise in images [13-14]. This schema detect whether the current pixel is corrupted by impulse noise at each pixel. Then, filtering is active for pixels that are detected as noisy pixels, while good pixels are kept. As a switching scheme, progressive switching median (PSM) filter [13] was proposed for removal impulse noise. With the PSM filter, both the impulse noise detector and noise filter are applied progressively. The noise detector detects an impulse noise and outputs a binary flag image. The binary flag image denotes whether pixels are corrupted or not. According to a binary flag image, the noisy filter processes to only noise pixels using neighborhood good pixels. Since the noise filter process according to the binary flag image, the PSM filter performs satisfactory in removing impulse noise. In this paper, we present a new median-based switching filter, called Iterative Selective & Progressive Switching Median (ISPSM) filter, where both the noise density (R), Threshold value(T_D) are calculated dynamically from noisy input image by the impulse detector also impulse detection window size (W_D) is iteratively detected by impulse detector. Whereas existing PSM method manually select the value of R and T_D. In switching section of fig 1 if no noises are available in the image then output is the uncorrupted image. For noises the iterative noise filter is selected. For further removal of noises the output of the iterative noise filter portion are fed to the selective median filter. For minimum noise filter window size, W_f x W_f, there may remains minimum number of noise. For that we add a selective median filter which select the noisy pixel (whose values are not 0) and replace this value by the neighborhood value of the previous output of iterative noise filter.

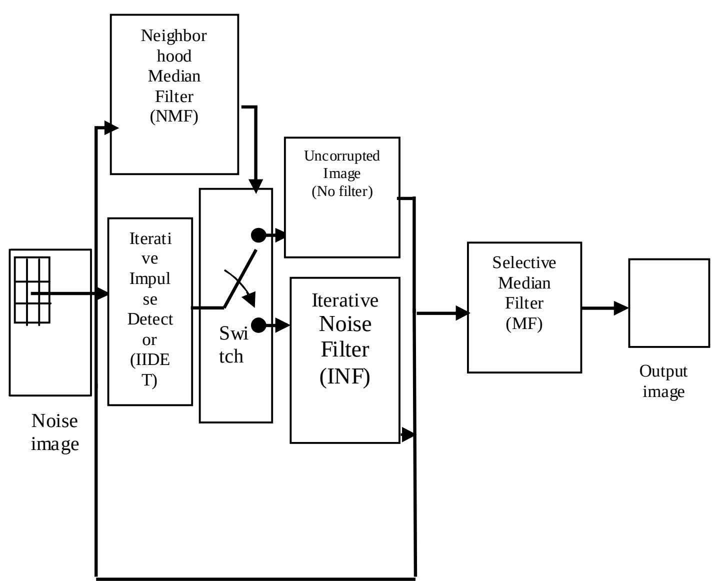


Figure 1. Schematic diagram of Iterative Selective & Progressive Switching median (ISPSM) filter.

II. ISPSM FILTER

The principle of identifying noisy pixels & processing only noisy pixels has been effective in image degradation. The limitation of the PSM filter is that defining a robust decision measure is difficult because the decision is usually based on a predefined threshold value [13]

Iterative Impulse Detection

A noise free image should be locally smoothly varying, and is separated by edges [4]. In the n^{th} iteration (n = 1, 2, ……), for each pixel $x_i^{(n-1)}$ we first find the median value of the samples in a $W_D \times W_D$ (W_D is an impulse detection window size. Also an odd integer not smaller than 3) window centered about it. The noise density (R) respect to input image (X) given by,

$$R = \frac{\text{sum of the pixel of X}}{(\text{size}(X,1) * \text{size}(X,2))} \tag{1}$$

The value of noise density (R) is calculated iteratively. Where,

If $R \leq 0.25$ then set the impulse detection window size

$W_D = 3$ *Else* $W_D = 5$, Here, $W_D = 3$ is more suitable for low noise ratio & $W_D = 5$ is better for high noise ratio[5], Figure 2 with a cross point at about R = 20%.The threshold value (T_D) according to noise density(R) are given by,

$$T_D = a + (b \times R) \tag{2}$$

The Effects of T_D with respect to MSE are shown in Figure 3. According to experiment results, we choose a & b as 65, & -50, respectively. Where it appears that the best T_D is decreasing with the increase of R.[13]. Two image sequences are generated during the impulse detection procedure. The first is a sequence of gray scale images, $\{\{x_{ij}^{(0)}\}, \{x_{ij}^{(1)}\}, \ldots\ldots\{x_{ij}^{(n)}\}, \ldots\ldots\}$, where the initial image $\{x_{ij}^{(0)}\}$ is the noisy image to be detected. The second is a binary flag image sequence, $\{\{f_{ij}^{(0)}\}, \{f_{ij}^{(1)}\}, \ldots\ldots\{f_{ij}^{(n)}\}, \ldots\ldots\}$, where the binary value $f_{ij}^{(n)}$ is used to indicate whether the pixel ij has been detected as an impulse, i.e., $f_{ij}^{(n)} = 0$ means the pixel ij is good & $f_{ij}^{(n)} = 1$ means it has been found to be an impulse. Before the first iteration, we assume that all the image pixels are good, i.e., $f_{ij}^{(0)} \equiv 0$. First median value of neighborhood pixels $m_{ij}^{(n-1)}$ is obtained using,

$$\Omega_i^W = \{(j_1, j_2) | i_1 - (W-1)/2 \leq j_1 \leq i_1 + (W-1)/2,\; i_2 - (W-1)/2 \leq j_2 \leq i_2 + (W-1)/2\} \tag{3}$$

Then we get,

$$m_i^{(n-1)} = \text{Med}\left\{x_j^{(n-1)} \middle| (j_1 j_2)\right\} \in \Omega_i^{W_D} \tag{4}$$

Where $\Omega_i^{W_D}$ represent the set of the pixels within a $W_D \times W_D$ Window centered about ij. And then the difference between $m_{ij}^{(n-1)}$ & $x_{ij}^{(n-1)}$ provide binary flag image $f_{ij}^{(n)}$, which is detected as an impulses given by,

$$f_{ij}^{(n)} = \begin{cases} f_{ij}^{(n-1)}, & \text{if } |x_{ij}^{(n-1)} - m_{ij}^{(n-1)}| < T_D \\ 1, & \text{else} \end{cases} \tag{5}$$

Where T_D is calculated threshold value. Once a pixel ij is detected as an impulse, the value of $x_{ij}^{(n)}$ is subsequently modified

$$x_{ij}^{(n)} = \begin{cases} m_{ij}^{(n-1)}, & \text{if } f_{ij}^{(n)} \neq f_{ij}^{(n-1)} \\ x_{ij}^{(n-1)}, & \text{else } f_{ij}^{(n)} = f_{ij}^{(n-1)} \end{cases} \tag{6}$$

When the impulse detection procedure is stopped after the impulse detection iteration number, N_D^{th} iteration, two output images $\{x_{ij}^{(N_D)}\}$ and $\{f_{ij}^{(N_D)}\}$ are obtained, but only $\{f_{ij}^{(N_D)}\}$ is useful for our noise filtering algorithm

Iterative Noise Filtring

In this procedure generates a gray scale image sequence, $\{\{y_{ij}^{(0)}\}, \{y_{ij}^{(1)}\}, \ldots\ldots\{y_{ij}^{(n)}\}, \ldots\ldots\}$, is the noise image to be filtered & a binary flag image sequence, $\{\{g_{ij}^{(0)}\}, \{g_{ij}^{(1)}\}, \ldots\ldots\{g_{ij}^{(n)}\}, \ldots\ldots\}$. Where the value $g_{ij}^{(n)} = 0$ means the pixel ij is good & $g_{ij}^{(n)} = 1$ means it is an impulse that should be filtered. The difference between the Iterative Impulse Detection (IIDET) & Iterative Noise Filtering (INF) procedure is that the initial flag image $\{g_{ij}^{(0)}\}$ of the Iterative Noise Filter (INF) procedure is not a blank image. In this method at the n^{th} iteration (n = 1, 2, ……), for each pixel $y_{ij}^{(n-1)}$, Firstly we find its median value $m_{ij}^{(n-1)}$ of a $W_F \times W_F$ (W_F is an filtering window size. Also an odd integer not smaller than 3) window centered about it. Then switch the noise filter. Let M denote the number of all the pixels with $g_{ij}^{(n-1)} = 0$ in the $W_F \times W_F$ window.

If M is odd, then

$$m_{ij}^{(n-1)} = Med\left\{ y_{ij}^{(n-1)} \middle| g_{ij}^{(n-1)} = 0, ij \in \Omega_{ij}^{W_F} \right\}. \quad (7)$$

Where $\Omega_i^{W_F}$ represent the set of the pixels within a $W_D \times W_D$ window centered about *ij*. Where

If M is even but not 0, then

$$m_{ij}^{(n-1)} = \left(Med_L\left\{ y_{ij}^{(n-1)} \middle| g_{ij}^{(n-1)} = 0, ij \in \Omega_{ij}^{W_F} \right\} + Med_R\left\{ y_{ij}^{(n-1)} \middle| g_{ij}^{(n-1)} = 0, ij \in \Omega_{ij}^{W_F} \right\} \right) \div 2 \quad (8)$$

Where Med_L & Med_R denote the left $((M/2)^{th}$ largest) & right $((M/2+1)^{th}$ largest) median values, respectively that means neighborhood pixel.

If M is greater than 0 (impulse noisy pixel), then value $y_{ij}^{(n)}$ is modified

$$y_{ij}^{(n)} = \begin{cases} m_{ij}^{(n-1)}, & if\ g_{ij}^{(n-1)} = 1; M > 0. \\ y_{ij}^{(n-1)}, & else. \end{cases} \quad (9)$$

Once an impulse pixel is modified, it is considered as a good pixel in the subsequent iterations

$$g_{ij}^{(n)} = \begin{cases} g_{ij}^{(n-1)}, & if\ y_{ij}^{(n)} = y_{ij}^{(n-1)} \\ 0, & if\ y_{ij}^{(n)} = m_{ij}^{(n-1)} \end{cases} \quad (10)$$

The procedure stops after the N_F^{th} iteration when all the impulse pixels have been modified, i.e,

$$\sum_{ij} g_{ij}^{N_F} = 0 \quad (11)$$

But there have least impulse (Picture. 1), then apply selective median filter, reduce lest impulse noise & get Restored output image $\{g_{ij}\}$ of size $N \times M$.

III. PRPOSER (ISPSM FILTER) ALGORITHM

Step 1: Takes pixels of the input image (*Xij*).

Step 2: Define the noise density(*R*) respect to input image (*Xij*) given by,

$$\mathrm{R} = \frac{\text{sum of the pixel of X}}{(\text{size}(\mathrm{X},1) * \text{size}(\mathrm{X},2))} \quad (12)$$

Step 3: If $R \leq 0.25$ then set the impulse detection window size (W_D) = 3 Else W_D = 5

Step 4: Define the threshold value (T_D) according to *R*.

Step 5: Detect the noise respect to impulse detection window size (W_D) & detection iteration number N_D (not smaller then 3 for best restoration). Also define binary flag image, f_{ij}, Where f_{ij} is define 0(zero) before first iteration.

Step 6: In iterative noise filtering (INF), respect to nth iteration (n = 1, 2, ……), for each pixel $y_i(n-1)$. Where, $y_i(n-1)$ is the gray scale image sequence. Define a binary flag image $\{g_i(n)\}$, the value $g_i(n) = 0$ means the pixel (i,j) is good & $g_i(n) = 0$ means it is an impulse that should be filtered. Where, $g_i(0)$ of the noise-filtering procedure is not a blank image, but the impulse detection result $\{ f_i(N_D) \}$, i.e., $g_i(0) \equiv f_i(N_D)$.

Step 7: Perform Selective Median filtering (SMF) that select the noisy pixel, $g_i^{(n)}$ (whose values are not 0) and replace this value by the neighborhood value of the previous output, $y_i^{(n-1)}$ of iterative noise filter.

IV. SIMULATION RESULTS

The performance of the proposed method has been evaluated by the simulations. T_D and R are calculated dynamically from the noisy input image.

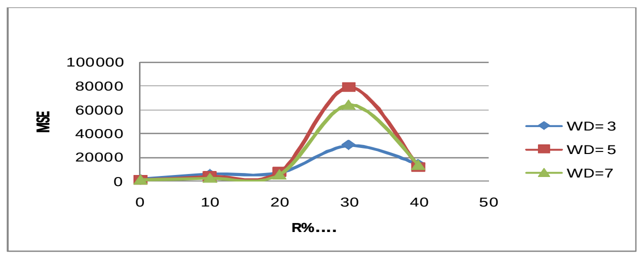


Figure 2 Effects of W_D respect to MSE.

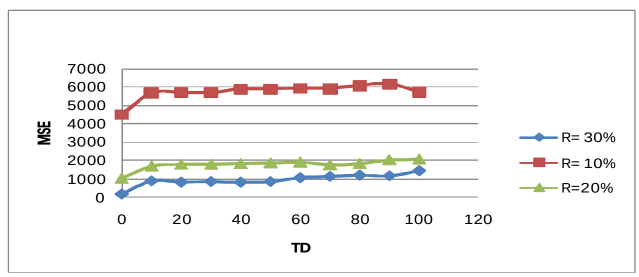


Figure 3 Effects of T_D with respect to MSE for various *R*

The performance of noise detection of restoration is quantitatively measured by Mean Square Error (MSE)

$$MSE = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} (r_{ij} - x_{ij})^2 \quad (13)$$

And the Peak Signal to Noise Ratio (PSNR).

$$PSNR = 10log10(255^2/MSE) \tag{14}$$

Where r_{ij} is the original image & x_{ij} is the restored image. The performance of the proposed method is compared with MED, CWM, PSM filters. Figure. 4. & Table. 1 Shows that our proposed filter reduce more noise. That is the proposed method PSNR is better than the others mentioned methods. Our proposed method is applied on lena and pepper. Figure 5 also visually shows that its performance is better than other mentioned methods. Figure 6 shows after applying PSM method more noises are available and than our proposed method also remove them.

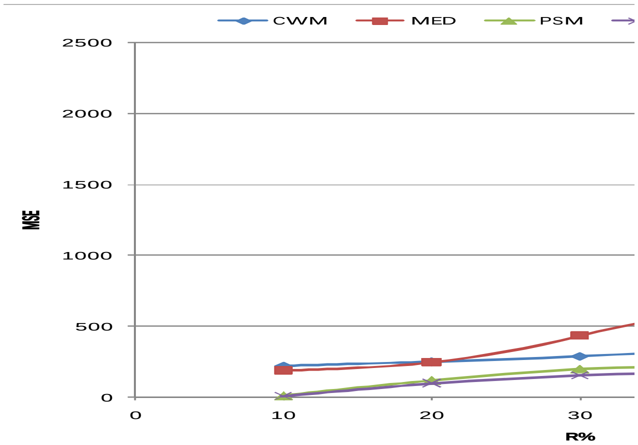


Figure 4 A comparison of different median-based filters for the restoration of corrupted image "bridge" under a large number of noise ratio.

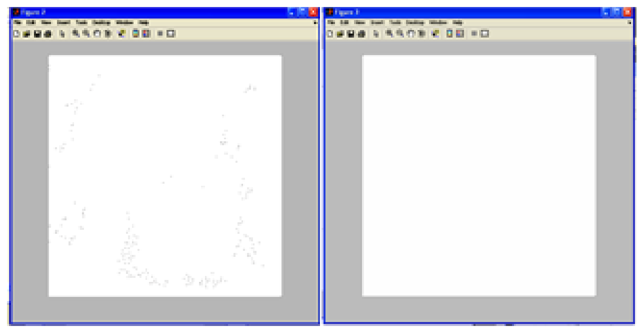
TABLE 1. Comparative results of impulse noise filters in PSNR (dB) with Salt & pepper noise = 0.31

Image Name	Filter Name			
	MED	CWM	PSM	ISPSM (proposed)
Pepper	24.134	27.881	29.384	30.631
Lena	23.310	26.991	28.092	30.039

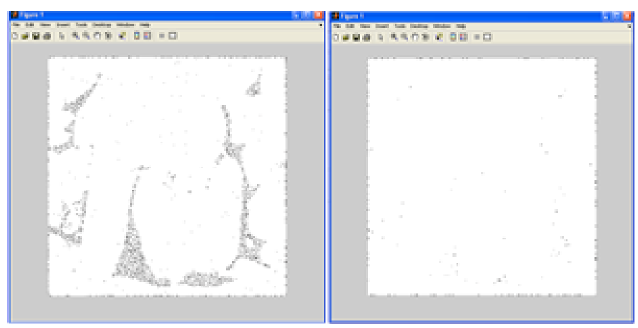
(a) (b) (c) (d)

(e) (f)

Figure 5 Visual representations of the test image with Salt & pepper noise = 0.31: (a) original image, (b) noisy image, (c) MED, (d) CWM, (e) PSM, (f) ISPSM(proposed).



(a) Salt & Pepper noise = 0.02 (b) Salt & Pepper noise = 0.02



(c) Salt & Pepper noise = 0.31 (d) Salt & Pepper noise = 0.31

Fig. 6 (a) & (c) Performance of PSM filter. (b) & (d) Performance of ISPSM filter (proposed).

V. CONCLUSION

We have proposed a new median base filter that can identify more noisy pixels, also outperforms a number of existing methods (MED, CWM, PSM, ISPSM) both visually and quantitatively.

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