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A New Switching Median Filter for Impulse Noise Removal from Corrupted Images

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ABSTRACT
In the process of image acquisition or transmission, digital images often get affected by noise. Noise can seriously affect the quality of images. This Paper introduces a new algorithm for removing impulse noise. The most popular approach for impulse noise removal is Standard Median Filter (SMF) and the performance of SMF is improved by adding Switching mechanism called Switching Median Filter (SWM), this paper introduces a new-algorithm that is "A New Switching Median Filter (NSWM) for Impulse Noise removal from corrupted images". In this method SWM is modified with one or more process by using the concept of rank order to improve the noise removal capability. The simulation results show that the proposed method has the better noise removal capability than the SWM method for both gray scale and colour images.
Keywords- Impulse noise, NSWM, Rank order, SMF, SWM

I. Introduction

Images are frequently corrupted by impulse noise due to the errors generated in noisy sensors and communication channels [6]. The impulse noise is Fat-tail distributed or "impulsive" noise is sometimes called salt-and-pepper noise [1-5] or spike noise. An image containing salt-and-pepper noise will have dark pixels in bright regions and bright pixels in dark regions. This type of noise can be caused by analog-to-digital converter errors, bit errors in transmission, etc. It can be mostly eliminated by using dark frame subtraction and interpolating around dark/bright pixels.

An image is a picture, photograph or any other form of 2D representation of any scene. Most algorithms for converting image sensor data to an image, whether in-camera or on a computer, involve some form of noise reduction. There are many procedures for this, but all attempt to determine whether the actual differences in pixel values constitute noise or real photographic detail, and average out the former while attempting to preserve the latter. However, no algorithm can make this judgment perfectly, so there is often a tradeoff made between noise removal and preservation of fine, low-contrast detail that may have characteristics similar to noise. Many cameras have settings to control the aggressiveness of the in-camera noise reduction

The subsequent image processing procedures such as edge detection, image segmentation and object tracking etc. might get worse performances if the noise exists in the input image with high noise density. Therefore, detecting noise and replacing the noise pixel with an appropriate value is an important work for image processing.

The median (**MED**) filter [1] is a well-known nonlinear filter to eliminate the noise in the smooth regions in image. But in the detail regions such as edge and texture, MED might smear the detail. The MED based impulse noise filters have been proposed in [1–5, 9-10] already to solve this problem.

The switching MED filters determine the difference between the current pixel and the MED in the corresponding sliding window and then use a threshold to determine whether the current pixel is noise. The noise is detected only when the current pixel and neighbors are much different. By using the concept of rank order to improve the noise removal capability.The simulations results show that the proposed modified SWM (NSWM) has the better noise removal capability than the SWM for both gray scale image and colour image.

This paper is arranged as follows section 2 introduces the working principle of switching median filter, section 3 explains about the description and flow of new switching median filter, section 4 gives the definitions of image fidelity measures used to quantify the results obtained by the proposed algorithm, section 5 explains the simulation results and performance analysis, Finally section 6 gives conclusion.

II. Switching Median Filter (SWM)

Let $\{x_{i-L,j-L},\ldots,x_{i,j},\ldots,x_{i+L,j+L}\}$ represent the input sample in the (2L+1)×(2L+1) sliding window where $x_{i,j}$ is the current pixel locating at position (i,j) in the image. The output of SWM is defined as

$$y_{i,j} = \begin{cases} x_{med}, & \Delta x \geq T_i \\ x_{i,j} & \Delta x < T_i \end{cases} \tag{1}$$

Where $\Delta x = \left| x_{i,j} - x_{med} \right|$

$$x_{med} = MED\{x_{i-L,j-L} ,..., x_{i,j} ..., x_{i+L,j+L}\}$$

T_i is a threshold and $y_{i,j}$ is the filtered pixel locating at position (i,j) . $\Delta x \geq T_i$ means that the current pixel is much more different from its neighbors and can be treated as a noise. $\Delta x < T_i$ denotes the current pixel to be regarded as a noise-free pixel. In fact, the impulse noise value is uniformly distributed, once its value is rather close to its neighbors such that $\Delta x < T_i$ happens, the noise pixel cannot be detected by SWM. Hence, this noise pixel cannot be filtered unless the threshold is lowered down. The lower threshold is used, the more noise pixels are detected, but less detail pixels are preserved. In other words, there is a trade-off between noise detection and detail preservation on tuning the threshold.

III. New switching median filter

Proposed NSWM modifies SWM by adding one more process when $\Delta x < T_i$ happens. Arrange the input samples in ascending order such as $x^1 \leq x^2 \leq x^3 \leq$ - - - - - - - - - - - - - $\leq x^{(2L+1)*(2L+1)}$ the superscript of the sorted x represents its rank order denoted by R(x). Then, the one more noise detection process under the case $\Delta x < T_i$ is shown as

$$y_{i,j} = \begin{cases} x_{med} & \Delta R \geq T_r \\ x_{i,j} & \Delta R < T_r \end{cases} \qquad (2)$$

Where $\Delta R = |R(x_{i,j}) - R(x_{med})|$ and T_r is another threshold. The case $\Delta R \geq T_r$ means that the rank order of the current pixel $x_{i,j}$ is larger than the corresponding MED with T_r order. It denotes that $x_{i,j}$ is a noise pixel and must be filtered since the pixel close to the MED has the less probability to be corrupted by impulse noise and the pixel close to one of two ends of the sorted samples is very possible an impulse noise . The proposed NSWM is summarized in the flowchart of Fig. 1.

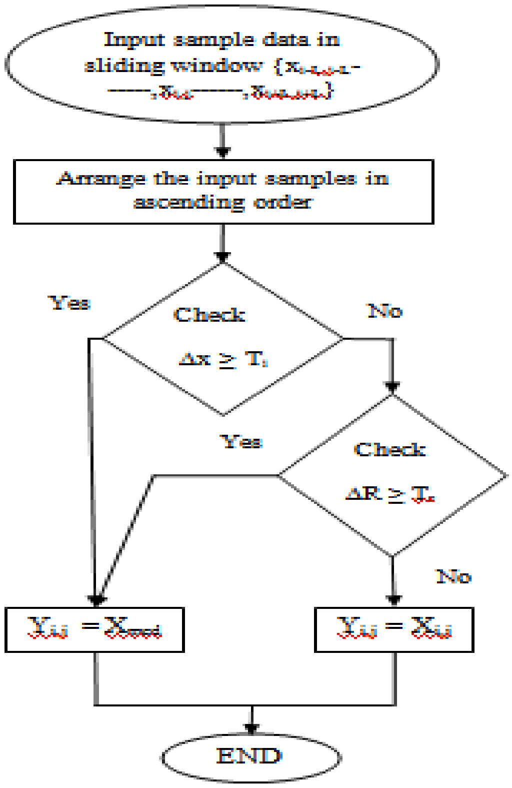

Fig.1: Flow chart of NSWM.

So that there is an additional process for identifying the noise pixel .The above figure shows the flow of new switching median filter in which the pixels are arranged in rank order. In practical applications, the selections of T_i and T_r and size of sliding window [1] depend on the noise density (p) of the specific image

Noise density	Window Size
$0\% < p \leq 20\%$	3x3
$20\% < p \leq 40\%$	5x5
$40\% < p \leq 100\%$	7x7

Table 1: Window size corresponding to noise density

IV. Image fidelity measures

The performance evaluation of noise removal using the proposed method was quantified by peak signal- to-noise ratio (PSNR). The PSNR of gray scale image [1] and colour image is calculated using the standard formula given as follows

$$PSNR = 10 \log_{10}\left(\frac{L^2}{mse}\right) \qquad (3)$$

Where L is the dynamic range of allowable intensities, *mse* is the mean squared error, and

$$mse = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} \left(y_{i,j} - x_{i,j}\right)^2 \qquad (4)$$

Where M, N are the image dimensions (in pixels) $y_{i,j}$ is the intensity of pixel at location (i,j) in the original image and $x_{i,j}$ is the intensity of pixel at location (i,j) in the filtered image. Mean square error (mse) of the colour image [6, 11] is mean of the individual mse's of three colours (Red, Green& Blue).

$$mse\,(colour\ \ image) = \frac{mseR + mseG + mseB}{3}$$

V. Simulation Results

To check the noise removal capability of the proposed new median filtering algorithm, choose the "Cameraman" as input image and choose parameters *Ti* = 40 and *T*r = 3for the noise density level is upto 20% and T_r = 5 when the noise density level in between 20% to 50%. Now, corrupt the input image with salt& pepper noise having the noise density of 10%, 20%, 30%, 40% and 50%. This degraded image is filtered through SWM and NSWM. Performance of NSWM and SWM algorithms are compared by taking PSNR as performance criteria.

Fig 2: Input image of Cameraman

Noise density (%)	Noisy Image	SWM Image	NSWM Image
10			
20			
30			
40			
50			

Fig 3: from left to right
Column 1: Noise density, column 2: Noisy Images, Column 3: Filtered Image using SWM, column 4: Filtered Image using NSWM

Noise Density (%)	PSNR of Lena Image		PSNR of Cameraman Image	
	SWM	NSWM	SWM	NSWM
10	25.28	28.07	24.13	30.69
20	23.78	25.22	23.19	26.96
30	21.05	22.96	20.82	23.85
40	17.56	21.91	17.62	22.67
50	14.54	19.85	14.28	20.88

Table 2: Performance comparison of gray scale images "Lena and Cameraman"

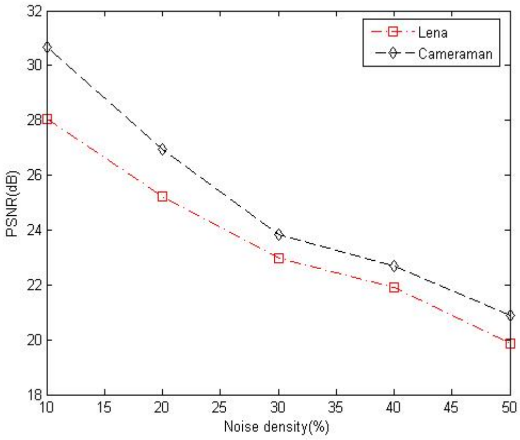

Fig 4: Changes of the denoised image in function of noise density in the corrupted image and PSNR of grayscale images through NSWM

Noise removal process mostly performed on gray scale images. So, the new proposed NSWM algorithm is applied on colour images for reduction of salt& pepper noise. Now, to check the noise removal capability of the proposed new median filtering algorithm, choose the "Peppers" as input image and choose parameters *Ti* = 40 and *T*r = 3 for the noise density level is upto 20% and T_r = 5 when the noise density level in between 20% to 50%. Now, corrupt the input image with salt& pepper noise having the noise density of 10%, 20%, 30%, 40% and 50%. This degraded image is filtered through SWM and NSWM. Performance of NSWM and SWM algorithms are compared by taking PSNR as performance criteria.

Fig 5: Input colour image of Peppers

Noise Density (%)	Noisy Image	SWM Image	NSWM Image
10			
20			
30			
40			
50			

Fig 6: from left to right
Column 1: Noise density, column 2: Noisy Images, Column 3: Filtered Image using SWM, column 4: Filtered Image using NSWM

Noise density (%)	PSNR of Lena colour Image		PSNR of Peppers colour Image	
	SWM	NSWM	SWM	NSWM
10	28.68	31.21	35.57	38.31
20	27.27	28.84	32.49	33.15
30	24.87	26.77	27.56	32.22
40	21.72	25.72	23.12	30.51
50	18.78	24.10	19.36	27.49

Table 3: Performance comparison of colour images "Lena and Peppers"

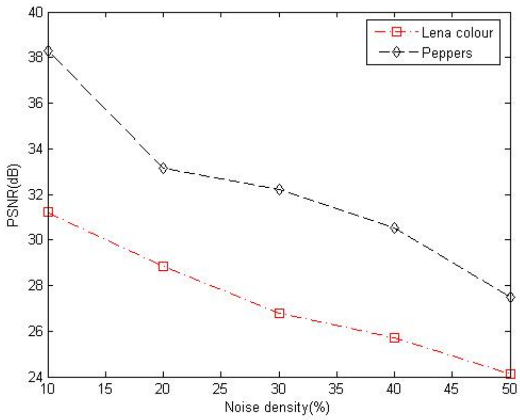

Fig 7: Changes of the denoised image in function of noise density in the corrupted image and PSNR of colour images through NSWM

Comparison graphs shown in the figure 8 and figure 9, is in between NSWM and SWM of the gray scale image cameraman and colour image peppers respectively.

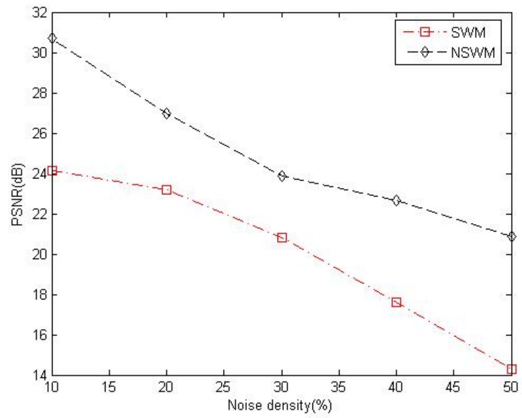

Fig 8: Changes of the denoised gray scale image (cameraman) in function of noise density in the corrupted image and PSNR

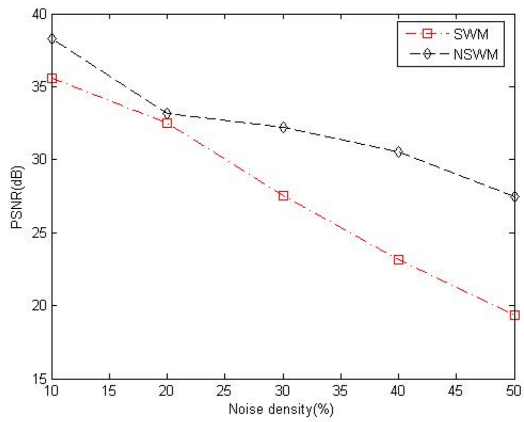

Fig 9: Changes of the denoised colour image (peppers) in function of noise density in the corrupted image and PSNR

The proposed algorithm NSWM has a capability to reduce the noise in the both gray scale and colour images. The NSWM filter effectively removing the noise in colour images. This is proved by observing the PSNR values of the denoised gray scale image and colour image of Lena. From the figures 8 and 9, simulation graphs shows that the NSWM algorithm gives the better performance compared to SWM.

VI. Conclusion

This paper has proposed a new switching median filter (NSWM) based on the rank order arrangement to implement impulse noise removal NSWM modifies SWM with one more process in which the MED of the sliding window and the rank order of the current pixel are used to determine whether the current pixel is noise. The more noise pixels with values close to its neighbors are detected in NSWM. From the simulation results, we have seen that the proposed NSWM has a better performance than other existing filter SWM.

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