Removal of Salt and Pepper Noise in Images using Modified Directional Filter

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Abstract

In this paper, an algorithm based on directional filtering for suppressing salt and pepper noise is proposed. This algorithm is similar to the modified directional weighted median filter proposed by Ching-Ta-Lu et al but has been modified to achieve better subjective quality images with better edge preservation capability ,higher peak signal to noise ratio(PSNR) and lower execution time. The algorithm of Ching et al uses directional weighted median filter whereas the proposed algorithm uses directional nearest neighbour pixel identification method for filtering. The results obtained using the proposed algorithm are compared with those obtained by Ching et al in terms of subjective quality, PSNR and execution time for 80% noise density. It is found that the proposed algorithm yields better results and also preserves the edge details to a greater extent.

Keywords
Salt and pepper noise, directional weighted median filter, PSNR, execution time.

1. INTRODUCTION

Impulse noise is generally encountered in images during image acquisition or transmission. It is caused by damaged pixels in camera sensors, erroneous memory locations in hardware, or transmissions in a noisy channel. Two common types of impulse noise are the salt and pepper noise and the random valued noise. Salt and pepper noise is a form of noise where the image contains distributed black and white dots according to a particular distribution or random. A black or white dot occurs when a pixel takes the minimum or maximum value respectively in the dynamic range of the intensity levels.

Linear filters are not suitable for removing this type of noise as these do not have the required logic to identify noisy pixels alone. Hence their application to images results in producing blurring effect in images. On the other hand, non-linear filters, especially the median based filters have been found to be very efficient for filtering impulse noise while preserving the image details. The standard median filter (SMF) is the most popular nonlinear filter. It uses the rank order information of the pixel intensities in a filtering window and replaces the central pixel with the median value. Besides SMF, there are other filters such as the weighted median filter (WMF) and the center weighted median filter (CWMF).

The conventional median filters replace every pixel by the median value of the surrounding pixels without distinguishing between noisy and non-noisy pixels. Therefore, this causes blurring of the image details. Hence, it is necessary to apply a noise detection scheme before using median filtering. Sun and Neuvo proposed a switching median filter (SWMF) in 1994 by combining noise detection scheme with median filter [1]. The accuracy of Noise detection algorithm is the key point whether a switching median filter could achieve good performance.

The adaptive median filter of Hwang and Hadded uses the median filter based on homogeneity information [2]. These are called "decision-based" or "switching" filters. The main problem in this approach is that the noisy pixels are replaced by some median value in their vicinity without taking into account local features such as the possible presence of edges. Hence the detailed information of edges are not retained satisfactorily, especially when the noise level is high. The performance of adaptive median is good at low noise densities. The window size is increased to achieve better noise level; however the increased size results in less correlation between the corrupted pixel values and replaced pixel values.

The modified switching median filters by Zhang and Karim, and Bovik uses a pre defined threshold value [3]. The impulse noise pixel is identified and removed based on this threshold value. The major drawback of this filter is that defining a threshold value is very tedious. Another drawback of these filters is that the edge details cannot be recovered satisfactorily when the noise density is high.

The directional weighted median filter is a method for extremely corrupted images was proposed by Dong and Xu [4]. This method analyzed the neighbour information of the center pixel in four directions to assign weights to the pixels in a local window. A noise corrupted pixel could be detected and hence removed by the weighted median filter by considering the pixels in the optimum direction. Although the DWM filter can efficiently denoise a noisy image under slight noise corruption, this filter fails to enhance a heavy noise corrupted image (noise density above 70%).

In the algorithm proposed by Ching- Ta Lu,[5], twelve directions were used to find the edge details and weights are used for the pixel in a local window by analysing the neighbour information of the center pixel. This technique is eliminates high densities of impulse noise while preserving the edge details. However, the execution time involved in restoring the images is quite high. In this paper, a modified directional filter algorithm for removing salt and pepper noise from the images is proposed. In this algorithm, the neighbouring non-noisy pixel is identified and substituted for the center pixel after noise detection technique is performed. The experimental results have shown that the proposed method can significantly improve the performance of the directional filter in the presence of noise even when it is as much as 80%, while the details of the original images are well preserved.

This paper is organized as follows. Section 2 discusses the proposed modified directional algorithm. The simulation results obtained by applying the filter on different images are presented in section 3. The conclusions are summarized in section 4

2.PROPOSED 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 neighbouring pixels in the filtering window, whereas noise-free regions in the image have locally smoothly varying gray levels separated by the edges. For images corrupted by salt and pepper noise the image pixels are randomly corrupted by two fixed extremal values of the dynamic intensity range (for 8 bit gray scale image are 0 and 255) with equal probability. In this algorithm, a 7x7 sliding window is considered for analysing a noisy image. If the value of the center pixel in a local window is not an extreme value (0 or 255), the center pixel is classified to noise free and kept unchanged to maintain the image quality. Conversely, the center pixel is classified to be noisy if the pixel is an extreme value (0 or 255) and it should be filtered by the modified directional filter. The local window slides from left side to right side, and slides from upper left- corner to the bottom- right one in an image until all pixels have been processed. If the pixel has an extreme value (0 or 255) then it should be excluded before filtering operation to remove salt and pepper noise thoroughly. The filtering operation is performed iteratively until attaining a preset iteration. The filtered images are obtained for various PSNR values. The block diagram is shown in figure (1).

In this algorithm, twelve directions are used to detect the edge direction of an image, enabling the detection accuracy to be improved. A 7x7 window centered at (i,j) for each direction is considered. The absolute differences of gray level values $d_{i,j}(k)$ between the center pixel $x_{i,j}$ and its neighbours $x_{i+\Delta i,j+\Delta j}$ is computed for noise detection. The difference is given as

$$d_{i,j}(k) = \sum_{\Delta i} \sum_{\Delta j} w_{\Delta i,\Delta j} \left| x_{i+\Delta i,j+\Delta j} - x_{i,j} \right| \quad \text{---- (1)}$$

where k represents the direction index, $1 \le k \le 12$, and $w_{\Delta i,\Delta j}$ represents the weight of the neighbour pixel where Δi is the offset on horizontal direction and Δj is the offset on vertical direction from the centre pixel.

The weights in equation (1) can be defined by

$$w_{\Delta i,\Delta j} = \begin{cases} 2, & -1 \le \Delta i,\Delta j \le 1 \\ 1, & \text{elsewhere} \end{cases} \quad \text{---- (2)}$$

In equation (2), the weight of the absolute difference between the closest pixels has higher value than that of the pixels which are not adjacent to the center pixel. The spatial distance defined by expression (1) should be small.

The edge of an object in a 7x7 window can be detected by selecting the direction with minimum absolute difference out of twelve directions which is considered as the optimum direction. The twelve directions for edge detection is shown in figure 2. where the center pixel is represented by black dot circle. The optimum direction can be obtained by

$$k^* = \arg\min \{ d_{i,j}(k) , 1 \le k \le 12 \} \quad \text{---- (3)}$$

where k^* represents the index of optimum direction in a local window.

The direction with minimum difference among twelve direction is found as $d_{i,j}(k^*)$ as an optimum direction. The center pixel can be classified as noise-free or noisy based on the value of $d_{i,j}(k^*)$ which can be compared with the threshold value. If the value of the $d_{i,j}(k^*)$ is less than the threshold value, then the center pixel is classified as noise free pixel and it should be kept unchanged. If the value of the $d_{i,j}(k^*)$ is greater than the threshold value, then the center pixel is classified as noisy pixel and it should be modified according to the filtering operation performed. The noise pixel can be detected by

$$x_{i,j} \in \begin{cases} \text{noise-free pixel,} & \text{if } d_{i,j}(k^*) \le T \\ \text{noisy pixel,} & \text{otherwise} \end{cases} \quad \text{--- (4)}$$

where T is a threshold value defined to classify noise-free or noisy pixel.

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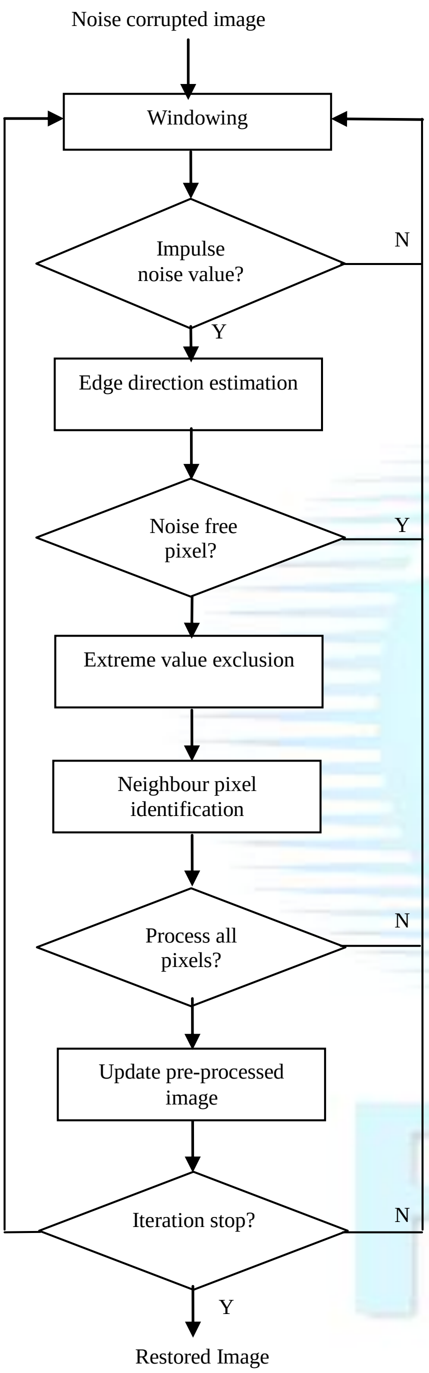

Fig.1. Block Diagram of proposed Algorithm

1.2. Modified Directional Filtering

The performance of the filtering operation can be improved by excluding the extreme value pixels 0 and 255 on the optimum direction before taking filtering and it is given as

$$x_{i,j}^{k*} = \{ x_{i,j}^{k*} , x_{i,j}^{k*} \neq 0 \text{ and } x_{i,j}^{k*} \neq 255\} \qquad \text{---(5)}$$

If the center pixel is classified as noisy then directional filtering is performed by identifying the nearest pixel which is not either 0 or 255 and it is substituted for the noisy pixel. It is given as

$$X_{i,j} = \text{nearest pixel } \{ x_{i,j}^{k*} \} \qquad \text{---- (6)}$$

The pixel can be computed after filtering is given as

$$S_{i,j}^{*} = \alpha_{i,j} x_{i,j} + (1- \alpha_{i,j})\, x_{i,j} \qquad \text{--- (7)}$$

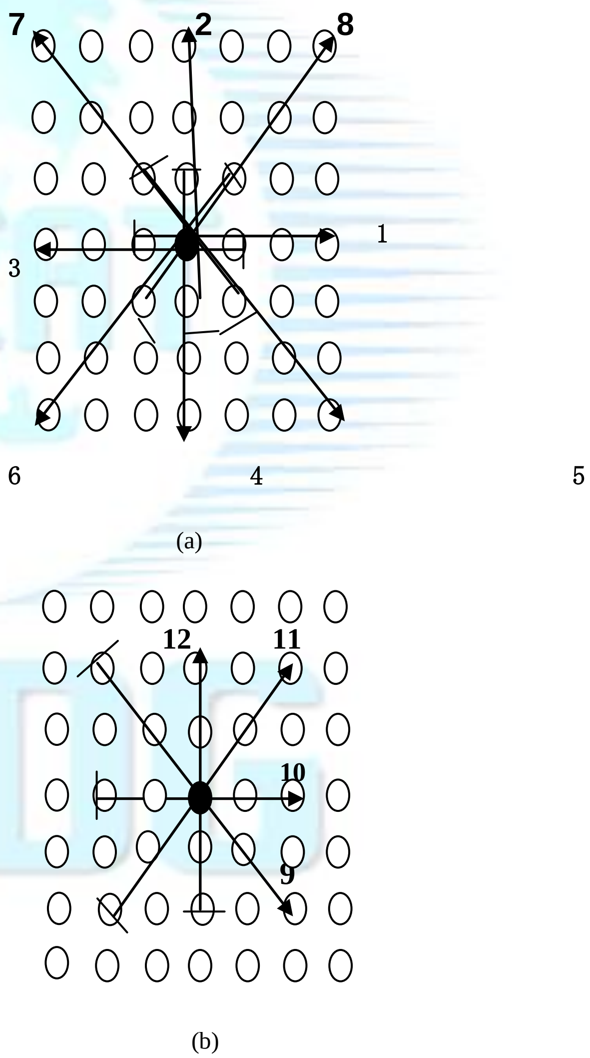

Fig.2 Pixels in 7x7 window for twelve directions (a) 1-8 (b) 9-12

where $S_{i,j}$ and $x_{i,j}$ represents the denoised pixel and filtered one respectively.

$\alpha_{i,j}$ is a noise free flag which can be decided according to the optimum absolute difference $d_{i,j}^{(k*)}$,given as

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$$\alpha_{i,j} = \begin{cases} 1, & d_{i,j}^{(k*)} \le T \\ 0, & \text{otherwise} \end{cases} \quad \text{---- (8)}$$

If the value of $\alpha_{i,j}$ is equal to one , then the centre pixel is noise - free. If the value of $\alpha_{i,j}$ is equal to zero, then the centre pixel is noisy. The filtered value computed by (6) will not appear either 0 or 255, since the extreme values are excluded before filtering. Hence the noise can be thoroughly removed from the original image. This algorithm uses iterative filtering. The threshold value used in the algorithm is modified in every iteration according to the following expression

$$T_{n+1} = T_n * 0.8 \quad \text{----- (9)}$$

where n represents the number of iterations. The initial value of threshold T_0 is chosen as 510. The number of iteration varies from 5 to 10.

2. Experimental Results

Four different test images including the standard lena image were used to analyze the performance of the denoising algorithm. These images include lena, fish,flower1,flower2 each with different sizes 512x512,448x336,900x600,600x347 respectively. Noise density that is considered in this paper is 80%. The peak signal to noise ratio (PSNR) can be expressed by

$$\text{PSNR (dB)} = 10 \log_{10} (255*255/MSE) \text{ --- (10)}$$

The MSE represents mean square error between the original and the restored image. It is defined as in equation (11).

$$MSE = 1/(MN) \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} |S_{i,j} - S_{i,j}*|^2$$

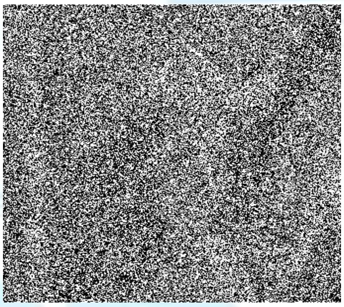
where $S_{i,j}$ and $S_{i,j}*$ represent the original and restored pixels. M and N are the sizes of an image for the width and the height, both of them are 512.

Figures 3a and 3b show the original 'Lena' and noisy images. Figures 3c and 3d show the filtered images with the algorithm of [5] and the proposed algorithm. Table 1 shows the PSNR values and the execution times obtained with these two algorithms for the four images mentioned above. The images are presented only for 'Lena' here.

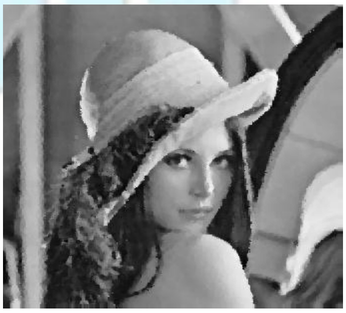
Table 1

Sl No	Images	PSNR(dB)		Execution Time(secs)	
		DWM filter	Proposed algorithm	DWM filter	Proposed algorithm
1	Leena	38.0932	39.762	0:41:18	0:35:42
2	Fish	43.776	44.8738	0:24:00	0:20:31
3	Flower 1	48.7032	50.0628	1:19:00	0.047963
4	Flower 2	31.2593	32.3482	0:32:56	0.0195023

(a)



(b)



(c)

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(d)

Fig. 3 (a) original 'Lena' image (b)Noisy image with 80% Noise density (c)Restored image using DWM of that of [5] (d) Restored image using proposed algorithm.

From the figures 3c and 3d, it can be seen that the filtered image obtained using the proposed algorithm has better subjective quality with better edge retention than that obtained using the approach of Ching et al[5]. Also, from table1, it can be seen that the proposed approach yields better PSNR values. Further, the proposed approach requires lesser execution time than that of [5].

Similar results have been obtained for the other three images.

4. Conclusions

In this paper, a modified directional filter that does filtering by considering the nearest neighbour non-noisy pixel is presented. This approach not only yields better subjective quality images by preserving the edges to a great extent than the directional median filter of Ching et al but also has lower execution time.

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