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Analysis of Non Linear Filters with Various Density of Impulse Noise for Different Window Size

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Abstract
Corrupted digital images are recovered by using median filters. The most frequently occur noise is salt and pepper type impulse noise. As the noise increases it becomes hard to recover the noisy digital image. Different median filters have been suggested to recover it. Size of the window taken in the filter is also the important factor at different level of noises. The performance of standard median filter (SMF), centered weighted median (CWM) filter and directional weighted median (DWM) filter is tested on gray scale images corrupted with variable percentage of salt & pepper noise impulse noise. It is also tested for different window sizes of filters. Some filter performs better at low noise while some performs better at high noise. At higher level of noise, large window size in the filters works better than small window size. These comparisons are very helpful in deciding the best filter at different level of noise.
Keywords: SMF, CWM, DWM.

I. INTRODUCTION

The images corrupted by impulse noise are often occurred in practice. This type of noise may appear in digital images because of channel decoder damages, dying down of signal in communication links, communication subscriber's moving, video sensor's noises and other. The amplitude of the corruption is relatively very high compared to the strength of original signal. So, when the signal is quantized into L intensity levels, the corrupted pixels are generally digitized into either of the two extreme values (i.e. 0 or L-1). The impulse noise generally appears as white and black spots in the image [1].

Since signals are nonlinear in nature, it is evident that nonlinear filters are generally superior to linear filters in terms of impulse noise removal [4]. It's important to eliminate noise before subsequent image processing tasks such as edge detection or segmentation is carried out [5].

II. THEORY

[1] STANDARD MEDIAN FILTER

Median filter is very important non linear filter; implementation of this filter is very easy. Large window size median filter destroy the fine image details due to its rank ordering process. This filter behaves like low pass filter which blocks all high frequency component of the images like noise and edges, thus blurs the image. In median filter, each pixel is replaced by the median of its surrounding pixels as shown by the equation below,

$$y(i,j) = median\{x(i-s, j-t), (s,t) \neq (0,0)\} \quad (1)$$

For the filtering of high density corrupted image need large window size so that the sufficient number of noise free pixels will present in the window. So the size of the sliding window in the median filter is varying according to the noise density. A center pixel either it is corrupted by impulse noise or not is replaced by the median value. Due to this reason this filter blurs the image. The window size 3×3, 5×5, 7×7, and 9×9 median filter are mainly applicable.

[2] CENTER WEIGHTED MEDIAN FILTER

Center weighted median is a special case of weighted median filters. This filter gives more weight only to the center pixel in the window and easy to implementable. CWM filter preserves more edges, details is compared with simple median filter at the expense of less noise suppression.

Suppose {X} is the noisy image and (2N+1) × (2N+1) is the sliding window size, centered at (i,j). The adjustment of the center pixel according to weight is given by following equation.

$$y(i,j) = median\{x(i-s, j-t), w_c \lozenge x(i,j) / (s,t) \in W, (s,t) \neq (0,0)\} \quad (2)$$

Where $w_c$the weight of the center pixel, W is is the window size and $y(i,j)$ is the output pixel. If w_c=1, then CWM filter become the simple median filter.

[3] DIRECTIONAL WEIGHTED MEDIAN FILTER

Directional weighted median filter gives the better result as compared with other median based filters, especially when image corrupted by high density random impulse noise.The basic assumption in this method is that the noise free image consists of locally smoothly varing areas separated by edges.

Let S_k represent a set of pixels aligned with the k-th direction which is centered at (0,0) is given

S_1 = {(-2,-2) ,(-1,-1) ,(0,0) ,(1,1) ,(2,2)}
S_2 = {(0,-2) ,(0,-1) ,(0,0) ,(0,1) ,(0,2)}
S_3 = {(2,-2) ,(1,-1) ,(0,0) ,(-1,1) ,(-2,2)}
S_4 = {(-2,0) ,(-1,0) ,(0,0) ,(1,0) ,(2,0)}

Four directions in the 5×5 sliding window is,

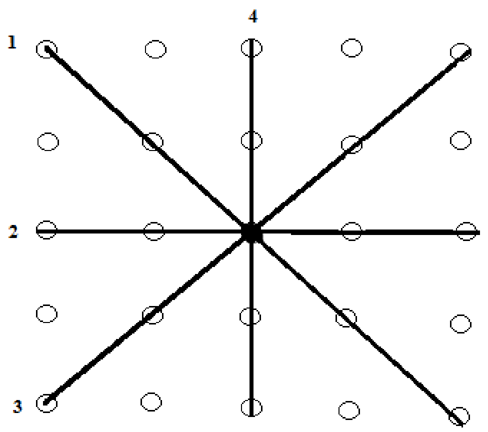


Figure 1: Four directions for impulse noise detection

Now calculate the direction index $d_{i,j}^{(k)}$ using the following formula.

$$d_{i,j}^{(k)} = \sum_{(s,t)\in S_k^0} w_{s,t} \left| y_{i+s,j+t} - y_{i,j} \right| \ ,1 \le k \le 4 \quad (3)$$

$$w_{s,t} = \begin{cases} 2, & (s,t) \in \Omega^3 \\ 1, & otherwise \end{cases} \ , \quad \Omega^3 = \{(s,t): -1 \le (s,t) \le 1\} \quad (4)$$

Each direction index is sensitive to the edge aligned with a given direction. Minimum value of these four direction indexes is basically used for impulse detection. Minimum value of the direction index is given by following equation.

$$r_{i,j} = \min\{ d_{i,j}^{(k)} \ : 1 \le k \le 4\} \quad (5)$$

Now there are three case possible

1) When the current pixel is a noise-free flat-region pixel then $r_{i,j}$ is small, because of the four small direction indexes.
2) When the current pixel is an edge pixel then $r_{i,j}$ is also small, because at least one of the direction indexes is small.
3) When the current pixel is an impulse then $r_{i,j}$ is large, because of the four large direction indexes.

Now impulse detection in this method is given by following formula:

$$x(i,j)\ is\ a \begin{cases} noisy\ pixel, & if\ r_{i,j} > T \\ noise-free\ pixel, & if\ r_{i,j} \le T \end{cases} \quad (6)$$

If the mimimum value of direction index is greater than the threshold T, then the center pixel is noisy otherwise pixel is not noisy.After the impulse noise detection, most of the median based filters replace the noisy pixels by the median value in the sliding window.

Now calculate the standard deviation $\sigma_{i,j}^k$ of the gray scale value in each direction and find out the mimimum standard deviation direction by using following formula.

$$l_{i,j} = \underset{k}{argmin} \ \{\sigma_{i,j}^k \ : k = 1\ to\ 4\} \quad (7)$$

Where the operator arg min is used to find the minimizer of the function.Standard deviation gives the knowledge about how tightly all pixel value are clustered around the mean in the set of pixels and $l_{i,j}$ shows that the four pixels aligned with this direction are the closest to each other. So the center pixel should also be close to them in order to keep the edges unchanged. Median calculate by using the following formula.

$$m(i,j) = median\{ \tilde{w}_{s,t} \diamond x(i+s,j+t) \ : (s,t) \in \Omega^3\} \quad (8)$$

$$\text{Where } \tilde{w}_{s,t} = \begin{cases} \tilde{w}_m, & (s,t) \in s_{l_{i,j}}^{(0)} \\ 1, & otherwise \end{cases} , \quad (9)$$

operator $\diamond$ denotes repetition operation and normally $\tilde{w}_m = 2$.

The output of the DWM filter is given by following formula.

$$y(i,j) = \alpha(i,j)x(i,j) + (1-\alpha(i,j))m(i,j) \quad (10)$$

$$\text{Where } \alpha(i,j) = \begin{cases} 0, & r_{i,j} > T \\ 1, & r_{i,j} \le T \end{cases} \quad (11)$$

III. EXPERIMENTAL PROCEDURE

Data set used for testing the performance of SMF, CWM, DWM filter is a standard test gray scale image of cameraman

in MATLAB. These filters are implemented in MATLAB [10]. The steps of experimental procedure are as follows

1) Read standard test image.
2) Add salt and pepper noise of varying density.
3) Apply filter on corrupted image.
4) Calculate PSNR from original and restored image for the filter.
5) Repeat steps 1 to 4 for other two filters.

Noise density is varied from 1 to 60 percent. Then apply above steps by changing the widow size in the filters. Window size of 3x3 and 5x5 is used in implementing filters.

IV. EXPERIMENTAL REULTS

PSNR CALCULATION: If $o(i,j)$ is the original image, $x(i,j)$ is the corrupted image then PSNR of the corrupted image is given by following formula,

$$PSNR = 10\log_{10}\frac{(255)^2}{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(o(i,j)-x(i,j))^2} \qquad (12)$$

PSNR is calculated for different density of noise and the result is shown in table below,

Table 1
PSNR values of image by 3 x 3 window of different window filter techniques in the variation of noise (salt & paper) density 1 to 60

Percentage of Noise density	Window Filter Technique		
	SMF	CWM	DWM
1	26.79	25.77	33.02
5	26.43	25.56	29.60
10	25.47	25.10	26.77
15	24.56	24.71	23.31
20	23.72	23.95	21.18
25	23.22	23.71	19.28
30	20.64	22.82	17.32
35	18.97	22.00	16.09
40	17.28	20.89	14.70
45	15.73	19.47	13.53
50	14.30	17.40	12.25
55	12.64	16.07	11.18
60	11.56	14.30	10.40

Table 2
PSNR values of image by 5 x 5 window of different window filter techniques in the variation of noise (salt & paper) density 1 to 60

Percentage of Noise density	Window Filter Technique		
	SMF	CWM	DWM
1	23.43	24.38	25.54
5	23.32	24.20	24.81
10	22.96	24.12	24.06
15	22.65	23.67	23.26
20	22.12	23.37	22.45
25	21.77	23.22	22.01
30	21.25	22.58	21.41
35	20.66	22.06	20.82
40	20.04	21.63	20.15
45	19.61	20.78	19.50
50	18.50	19.89	18.24
55	17.36	18.70	17.13
60	16.06	17.21	15.47

For the comparison point of view, the PSNR values of different window size with the help of three different window filter techniques in the variation of noise density from 1 to 60 is plotted and it is shown in the figure 2.

Also, the original image on which all the values of PSNR is calculated is shown in the figure 3. The noisy images and their respective filtered images are also shown in the figure 4 with the different density of noise.

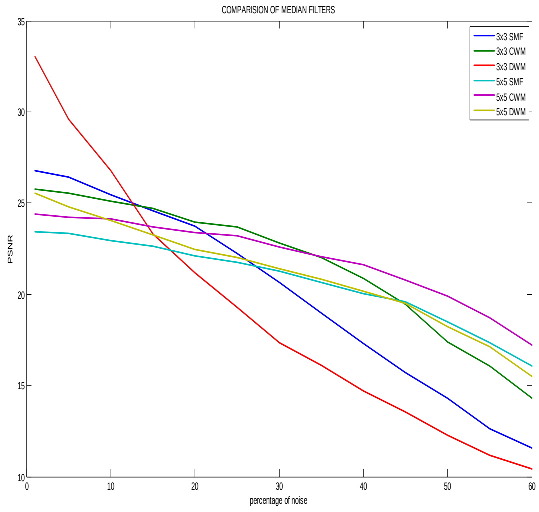
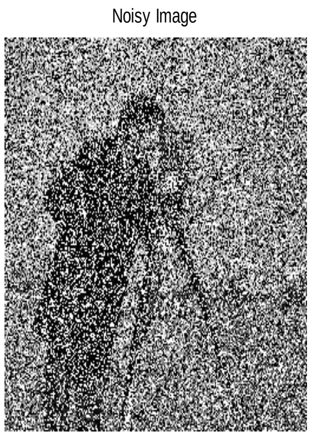


Figure 2: PSNR of different window size with different window filter technique in the variation of noise (salt & paper) density 1 to 60.

Figure 3: Original Image of Cameraman

V. CONCLUSION

In the above comparison graph, It is been seen that up to 12 percent noise DWM filter with 3x3 window is having best performance while in between 12 to 33 percent noise CWM filter with 3x3 window has best performance. but for the high density noise CWM filter with 5x5 window provides maximum filtering. It is been concluded that At higher level of noise, large window size in the filters works better than small window size while at lower level of noise small window size performs better.

5% (salt & paper) noise			**DWM filter With 3x3 Window size**
25% (salt & paper) noise			**CWM filter With 3x3 Window size**
60% (salt & paper) noise			**CWM filter With 5x5 Window size**

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