Optimum value Analysis of threshold level in Directional weighted Median filter for various density of impulse noise

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Abstract: Switching median filters are applied to recovered corrupted digital images and get maximum PSNR (Peak signal to noise ratio) value. Switching weighted median filter successfully detects impulse noise but unable to preserve minor details in the image. Therefore a new direction based filter is proposed in which noise is detected by the method based on comparison of directional differences. The proposed filter is directional weighted median filter. Directional weighted median filter is the most suitable switching filter to recover corrupted images. This filter detects noise and then replaced the noisy pixel from the directional median value unlike switching weighted median filter where noisy pixel is replaced by median of its neighboring pixels. In noise detection method, Threshold level is selected for comparison to detect the impulse. After experimentation, it is seen that this threshold level must be changed with change in noise density to get better filtering and high PSNR. Optimum value analysis is performed to deduce the optimum value of threshold at different noise density level to get the best possible filtering result using directional weighted median filter. It is seen that in optimum value analysis, images with higher level of impulse noise density are filtered at lower optimized threshold value while at lower level of impulse noise density images are filtered at higher optimized threshold value.

Keywords: DWM (directional weighted median), DBSF (direction based switching filters), SBF (switching based filters), SMF (standard Median Filter), PSNR (Peak signal to noise ratio).

1. INTRODUCTION

Signal acquisition, faulty memory locations in hardware, camera sensors, transmission of the image in a noisy channel, are some of the common causes for impulse noise. Even low noise percentage of impulse noise can change the appearance of the image significantly, because the impulse noise normally has a very high contrast in comparison with its neighbor. Here the corrupted pixel takes either maximum or minimum gray level. SMF (Standard median filter) [1] is very reliable method to remove the impulse salt and pepper noise but the major drawback of SMF is that the filter is effective only at low noise densities. It is due to the fact that SMF processes all pixels in the image equally, including the "*noise free pixels*" [3]. It eliminates fine details such as thin lines and corner and also adds blurring or distortion in the images. Thus, many variations and improvements of median filter have been introduced.

Variety of the median filters have been proposed and the best are "*decision-based*" or "*switching*" [5] filters which first identify possible noisy pixels and then apply median filter on detected pixels while leaving all other pixels unchanged. Thus, SBF (Switching based filters) are good at *detecting* noise even at higher noise densities. Although SBF are much better than SMF but they commit one problem 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, details and edges are possibly not fully recovered specially at higher noise density [6-8].

This problem is solved with the help of DBSF (Direction based switching filters) where edges are well preserved even at higher noise densities. Noise detection technique in DBSF detects the noise by comparing it with pre-defined threshold value. This pre-defined value gives better results but after experimentation, it is seen that if this pre-defined threshold value is changed with change in noise density then results can be much improved. Therefore we perform optimum value analysis to find the optimum threshold value corresponds to every noise density.

2. DWM (DIRECTIONAL WEIGHTED MEDIAN) FILTER

In DWM filter, we used two techinques; first we detect the noisy pixel and second we replace that noisy pixel by the median of the nearest direction. Let S_k represent a set of pixels aligned with the k-th direction which is centered at (0,0) is given

S_1 = {(-1,-1),(0,0),(1,1)}, S_2 = {(0,-1),(0,0),(0,1)}, S_3 = {(1,-1),(0,0),(-1,1)}, S_4 = {(-1,0),(0,0),(1,0)} as shown by fig. 1.

Four directions in the 3×3 sliding window [2],[4] is,

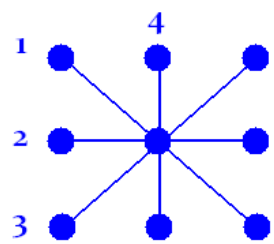

Fig. 1 Four directions in 3x3 window

Now calculate the direction index $d_{i,j}^{(k)}$ using the following formula [4].

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

Minimum of these four direction indices is basically used for impulse detection. Minimum value of the direction index is given by following equation.

$$r_{i,j} = \min\{ d_{i,j}^{(k)} \ : 1 \le k \le 4\} \qquad (2)$$

Now after experimentation and data analysis, it is found that:

1) Current pixel is a noise-free then $r_{i,j}$ is small.
2) Current pixel is an edge pixel then $r_{i,j}$ is also small.
3) Current pixel is an impulse then $r_{i,j}$ is large.

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

$$x(i,j) \text{ is a } \begin{cases} noisy\ pixel, & if\ r_{i,j} > T \\ noise-free\ pixel, & if\ r_{i,j} \le T \end{cases} \qquad (3)$$

If the mimimum value of direction index is greater than the threshold T, then the center pixel is noisy otherwise pixel is not noisy.

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.

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

Standard deviation gives the knowledge about how closely all pixel values are clustered around the mean in the set of pixels and $l_{i,j}$ shows that the two 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 [3],[4].

$$m(i,j) = median\{\, \tilde{w}_{s,t} * x(i+s, j+t) \;:\; (s,t) \in \Omega^3 \} \quad (5)$$

Where $$\tilde{w}_{s,t} = \begin{cases} 2, & (s,t) \in s_{l_{i,j}}^{(0)} \\ 1, & otherwise \end{cases}, \quad (6)$$

The output of the DWM filter is given by following formula[3],[4].

$$y(i,j) = \alpha(i,j)x(i,j) + (1-\alpha(i,j))m(i,j) \quad (7)$$

Where $$\alpha(i,j) = \begin{cases} 0, & r_{i,j} > T \\ 1, & r_{i,j} \le T \end{cases} \quad (8)$$

3. EXPERIMENTAL PARAMETERS

PSNR CALCULATION: If $O(i,j)$ is the original image, $R(i,j)$ is the corrupted image then PSNR of the corrupted image is given by following formula [1],[5],

$$PSNR = 10\log_{10}\frac{(Imax)^2}{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(O(i,j)-R(i,j))^2} \quad (9)$$

Here M and N denotes the resolution of the image. Resolution of Cameraman image is 256x256 therefore M=N=256 and I_{max} is the maximum gray scale level that is 255 which represents white color.

4. OPTIMUM VALUE ANALYSIS

In noise detection technique of DWM filter, threshold value T as given in equation (8) has to be decided to get the best noise detection. Standard gray scale image Cameraman and Castle image has been used for this analysis as shown in fig. 2 and fig. 3 respectively. Image is filtered by using different possible threshold value from 30 to 120 for impulse noise density from 1% to 30% as shown in Table 1 and Table 2 for cameraman and castle image respectively. This tabulated data has been plotted for comparison purpose as shown in fig. 4 and fig. 5 which shows that with change in noise density threshold value also changes to get maximum noise filtering.

Fig. 2 Original Image of Cameraman

Fig. 3 Original Image of Castle

Table 1
PSNR values of recovered CAMERAMAN image for multiple values of noise density and threshold value using DWM filter

THRESHOLD LEVEL	NOISE						
	1%	5%	10%	15%	20%	25%	30%
30	28.91	28.41	26.18	24.74	22.36	20.39	19.04
40	29.98	29.11	26.91	25.22	22.58	20.45	18.62
50	30.59	29.78	27.29	24.81	22.79	20.44	18.75
60	31.59	30.17	27.53	25.40	22.47	20.41	18.59
70	31.96	30.23	28.06	25.00	22.49	20.37	18.49
80	32.06	30.24	27.64	24.73	22.17	20.32	18.50
90	32.91	30.26	26.95	24.10	21.81	19.79	18.09
100	33.14	29.7	26.21	23.12	21.16	19.29	17.56
110	33.22	29.89	25.83	22.98	20.49	18.54	17.00
120	33.53	29.19	25.35	22.52	20.06	18.17	16.77

Table 2
PSNR values of recovered CASTLE image for multiple values of noise density and threshold value using DWM filter

THRESHOLD LEVEL	NOISE						
	1%	5%	10%	15%	20%	25%	30%
30	25.31	24.96	24.03	22.88	21.53	19.69	18.33
40	26.1	25.71	24.5	23.21	21.64	20.13	18.24
50	26.68	26.09	25.06	23.36	21.71	19.93	18.25
60	27.46	26.44	25.3	23.67	21.65	19.93	18.29
70	28.35	27.21	25.42	23.39	21.62	20	18.05
80	28.92	27.64	25.3	23.08	21.15	19.23	17.77
90	29.7	27.61	24.8	22.73	20.98	19.09	17.52
100	30.19	27.42	24.53	22.21	20.16	18.55	17.3
110	30.53	27.48	24.47	21.85	19.96	18.06	16.87
120	30.9	27.71	23.74	21.4	19.46	17.83	16.3

Table 3
Optimum values of threshold for noise density vary from 1% to 30% for both cameraman and castle image

Noise percentage	1	5	10	15	20	25	30
Optimum value	120	90	70	60	50	40	30

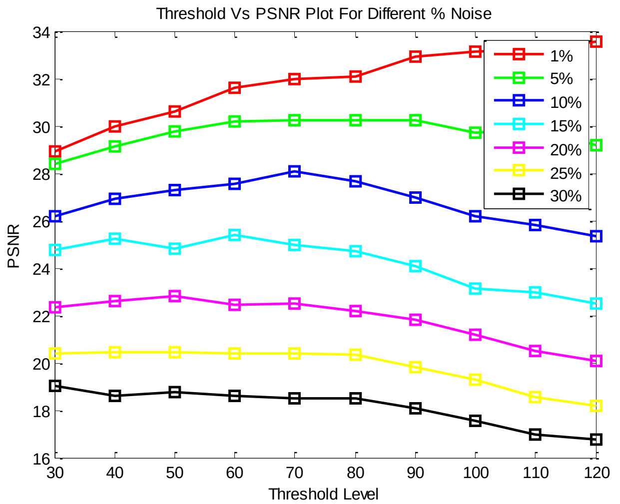

Fig. 4 Threshold Vs PSNR plot with varying noise density for cameraman image

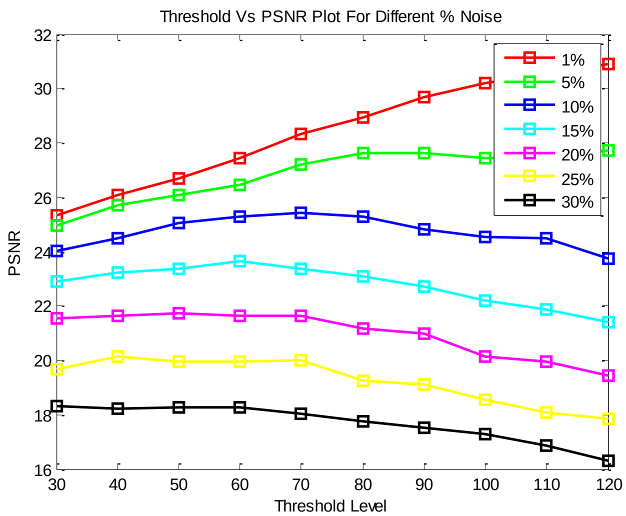

Fig. 5 Threshold Vs PSNR plot with varying noise density for castle image

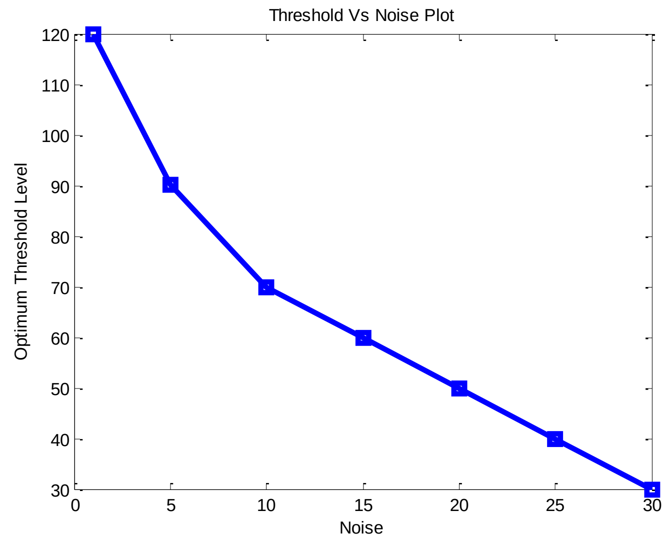

Fig. 6 Optimum threshold value for different noise density for both cameraman & castle image

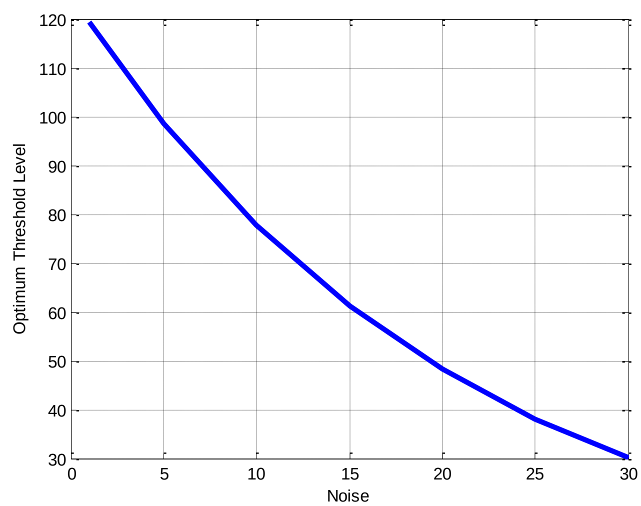

Fig. 7 Plot from equation of optimum threshold value for different noise density

(a) **(b)** **(c)**

(d) **(e)** **(f)**

Fig. 8 Cameraman image with noise density of (a) 25% , recovered image with threshold value of (b) 40 (c) 120, cameraman image with noise density of (d) 30% , recovered image with threshold value of (e) 30 (f) 120

(a) **(b)** **(c)**

(d) **(e)** **(f)**

Fig. 9 Castle image with noise density of (a) 25% , recovered image with threshold value of (b) 40 (c) 120, castle image with noise density of (d) 30% , recovered image with threshold value of (e) 30 (f) 120

Table 1 is the outcome of optimum value analysis and Fig. 6 is its graphical representation for noise density from 1% to 30%. Fig. 6 can be approximated as exponential graph between optimum value of threshold and noise density which can used to approximate the equation of threshold for different value of noise density. The equation for optimum value of threshold can be approximated as

$$T(N) = 125 * exp\left(-\frac{N}{21}\right) \quad (10)$$

Where T(N) is the optimum value of threshold and N is the density of noise in percentage for DWM filter.

Fig. 6 and fig. 7 can be seen almost identical which ensured that the equation of optimum value of threshold is approximated the experimental data finely.

Fig. 8 and fig. 9 show the results on image. In fig. 8, cameraman image with 25% and 30% impulse noise is shown with filtered images at 40, 30 (40 and 30 are the optimum value at 25% and 30% noise respectively) and 120(maximum threshold value taken) threshold value. Similarly fig. 9 show the results on castle image. The results with optimum threshold value for both the images follow the same plot of fig. 6 and equation (10).

5. CONCLUSION

Threshold value contributes a major role in impulse noise detection. Experimental results show that with change in noise density threshold values are changed to improve quality of filtered image. Optimum value analysis come up with an equation shown in equation 10 which provides optimum value of threshold to get best filtering using DWM filter. This exponential equation concludes that higher noise density requires less threshold value and lower noise density requires high threshold value. This analysis is performed on two different standard gray scale digital images (cameraman and castle image) to ensure the optimum value analysis and results clearly indicates that proposed equation successfully works on any digital image. In future, with the help of this optimum value analysis and its equation, better adaptive DWM filter can be created.

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