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Switching Directional Median Filter Specially Designed for Impulse Noise and Its Comparison with other Median Filters

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Abstract: Now a days, median filters are used to de-noise corrupted digital images. A variety of noises occur in the channel but the major occurrence is of impulse noise. The hardship in de-noising is that the image gets corrupted with a high density of impulse noise. Median filters are modified to provide better results on corrupted images. A new median filter based on detection and de-noising technique is proposed to reduce the frequent occurrence of salt & pepper impulse noise. The proposed method is very effective in de-noising the images corrupted with high density salt & pepper noise.

Keywords: SMF (standard median filter), SWMF (switching weighted median filter), DWM (directional weighted median filter), DWMSP (directional weighted median filter for salt & pepper).

I. INTRODUCTION

Digital images are corrupted due to bit errors in transmission or introduced during the signal acquisition stage. There are two types of impulse noise, they are salt and pepper noise and random valued noise. Salt and pepper noise has the property that it corrupts the images where the corrupted pixel takes either maximum or minimum of gray scale level [1]. Several nonlinear filters have been proposed for restoration of images contaminated by salt and pepper noise. Among these standard median filter has been established as reliable method to remove the salt and pepper noise without damaging the edge details. The basic technique of median filter is replacing the gray-level value of every pixel by the median of its neighbors. However, both noise and noise-free pixels are modified since filters are usually implemented identically across the images, due to which some desirable and important details are also removed [2].

The most representative paradigm in this family is known as "Switching Weighted Median Filtering" (SWMF), which partitions the whole filtering process into two sequential steps—noise detection and filtering. By utilizing the *a priori* knowledge obtained from the noise detection step, the filtering step could be more targeted and does not need to touch those uncorrupted pixels. Obviously the accuracy of the noise detection is critical to the final result [3]-[5].

Here we are proposing directional weighted median filter for salt-and-pepper noise (DWMSP) for removing salt & pepper noise. The proposed filter combines the directional difference based noise detector with the weighted mean filter to restore the corrupted images. Compared with the standard median filters, the proposed filter can identify salt-and-pepper noise more effectively and provide better image restoration performance and higher signal to noise ratio with higher density of noise.

II. DWM 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 figure 1.

Four directions in the 3×3 sliding window is,

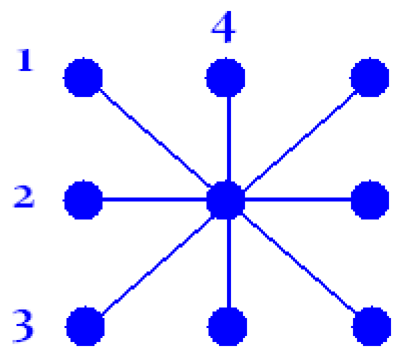

Figure 1: Four directions for impulse noise detection

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

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

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

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

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

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

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 [4]-[5][8].

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

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

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

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

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

III. PROPOSED DWMSP FILTER

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 figure 1 .

Impulse detection algorithm for proposed method is given by:

$$x(i,j)\ is\ a\ \begin{cases} noisy\ pixel, & if\ x(i,j) = 0\ or\ (Z-1) \\ noise-free\ pixel, & else \end{cases}$$
(9)

Where Z is the number of gray scale level (e.g. Z=256, 0 represent black ans 255 represent white).

Left is same as the DWM filter. 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.

$$l_{i,j} = \underset{k}{argmin}\ \{\sigma_{i,j}^k \ : k = 1\ to\ 4\}$$
(10)

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[4]-[5][8].

$$m(i,j) = median\,\{ \widetilde{w}_{s,t} * x(i+s,j+t) \ : (s,t) \in \Omega^3\}$$
(11)

Where $$\widetilde{w}_{s,t} = \begin{cases} 2, & (s,t) \in s_{l_{i,j}}^{(0)} \\ 1, & otherwise \end{cases}$$
(12)

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

$$y(i,j) = \alpha(i,j)x(i,j) + (1-\alpha(i,j))m(i,j)$$
(13)

Where $$\alpha(i,j) = \begin{cases} 0, & noisy\ pixel \\ 1, & non-noisy\ pixel \end{cases}$$
(14)

IV. DISCUSSIONS & RESULTS

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,

$$PSNR = 10\log_{10}\frac{(255)^2}{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(o(i,j)-x(i,j))^2}$$
(15)

PSNR is calculated for different density of noise and the result is shown in table 1 below, Figure 2 shows PSNR plot for different value of salt & pepper noise.

Table 1 : PSNR values of recovered image using different filter techniques in the variation of noise (salt & paper) density 1 to 20 %

Percentage of noise	SMF	SWMF	DWM	DWMSP
1	26.77	27.21	33.08	34.41
2	26.70	27.15	32.01	34.00
3	26.61	26.96	31.50	33.58
4	26.52	26.73	30.62	33.14
5	26.36	26.81	30.01	32.84
6	26.26	26.63	29.13	32.23
7	26.22	26.39	28.68	32.02
8	26.06	26.20	27.78	31.59
9	25.74	26.09	27.10	31.39
10	25.71	25.90	26.14	31.21
15	24.54	25.33	25.35	28.35
20	23.77	24.54	22.90	26.35

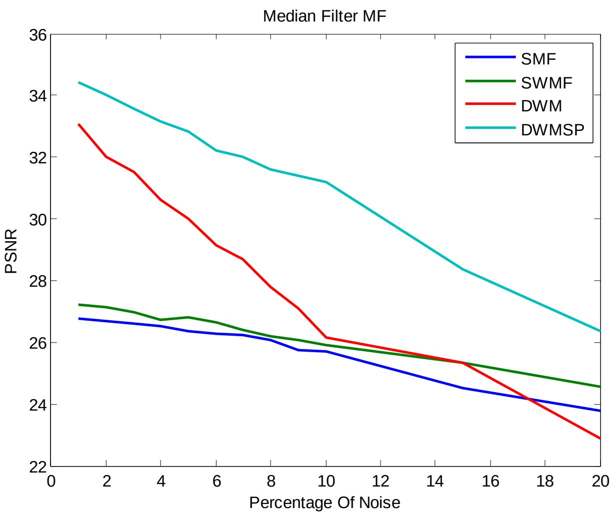

Figure 2: PSNR for different filter technique with the variation of noise (salt & paper) density 1 to 20%.

Figure 3: Original Image of Cameraman

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

(f) **(g)** **(h)** **(i)** **(j)**

(k) **(l)** **(m)** **(n)** **(o)**

Figure 4: image de-noising using SMF, SWMF, SWMFSP, DWM, DWMSP (a)Corrupted image with 1% salt & pepper noise, Recovered image by (b) SMF, (c)SWMF, (d)DWM, (e)DWMSP, (f)Corrupted image with 10% salt & pepper noise, Recovered image by (g) SMF, (h)SWMF, (i)DWM, (j)DWMSP, (k)Corrupted image with 20% salt & pepper noise, Recovered image by (l) SMF, (m)SWMF, (n)DWM, (o)DWMSP.

figure 3 above shows the original cameraman image and figure 4 displays the images with 1%, 10% and 20% impulse noise as well as the filtered images using standard median filter, switching weighted median filter, directional weighted median filter and proposed directional weighted median filter for salt and pepper noise.

V. CONCLUSION

Above graph clearly indicate that the proposed algorithm is very effective and accurate for impulse detection. Simulation result shows that DWMSP is much better in detecting salt & pepper noise than any other median filters. It works better at both low density and high density noise. In the future, this algorithm can be implemented by combining with other switching methods and multiple iterations to improve its performance.

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