DUAL FILTER OF DIGITAL IMAGE PROCESSING

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ABSTRACT

Keywords: Dual, Filter, Chaurenet, Smoothing, Sharpening

This paper adopts Chaurenet's criterion, combining with the different spatial distributional natures of noise and edge, to establish a new approach (named as Dual Filter) of the discrimination for both the noise and edge, for the purpose of the noise smoothing with edge reservation and edge enhancement with noise depression for digital images in one algorithm.

I. INTRODUCTION

Noise removal and edge enhancement play important roles in digital image processing. However, the edge blurring caused by smoothing and the noise enhancement caused by sharpening reduce the efficiency of these operations.

Nowadays, there are some edge preserving filters, like the famous Median filter. But edge protection, especially the subtle edge protection, is unlikely to be good enough. Moreover, some filters are limited their ability to only remove selective noise type. For example, Sigma filter cannot remove the spike noise although it is efficient at Gausian noise removal with edge preservation. Therefore, it is desirable to develop a filter with absolute edge preservation for the smoothing and the noise removal for the sharpening.

II. MEAN AND CHAURENET'S CRITERION

An approach to compute mean from a data set {x}, was suggested by W. Chaurenet (1868) [1] as follows:

1) Compute first mean value M_1 and variance V_1.
2) Check each datum x_i in data set {x} whether it deviates from M_1 within a range R. If all the data in {x} passed this check, the mean value can be regarded as reliable.
3) If there are some data beyond the range R, these extraordinary data which have significant errors must be rejected.
4) Compute the second mean M_2 and variance V_2 using the remaining data. Then continue the above process until all of the data can pass the range R, and last mean M_k can be taken as reliable mean of {x}.

The range of R is determined by the following equation:

$$R_k = C_k\ V_k \qquad (1)$$

Where:
R_k is the range value of k_{th} check.
V_k is the variance of k_{th} check.
C_k is the Chaurenet's Coefficient which changes with the number of data {x} and shown in Table 1.

Table 1 CHAURENET'S COEFFICIENT

N	C_k	N	C_k	N	C_k	N	C_k
5	1.65	13	2.07	21	2.26	29	2.38
6	1.73	14	2.10	22	2.28	30	2.39
7	1.79	15	2.13	23	2.30	35	2.45
8	1.86	16	2.16	24	2.32	40	2.50
9	1.92	17	2.18	25	2.33	50	2.58
10	1.96	18	2.20	26	2.34	60	2.64
11	2.00	19	2.22	27	2.35	80	2.74
12	2.04	20	2.24	28	2.37	100	2.81

(From Zhang Shi-Ji, 1979)

III. ESSENTIAL ALGORITHM

The distribution of noise has been proved as Gaussian by some scholars, like Lee [3]. Dual filter also supposes that the appearance of noise in the kernel is random. In order to smooth and sharpen images in one operation, the kernel is chosen as 3 x 3.

Consider a given pixel v(i,j) in a 3 x 3 kernel, if it can pass Chaurenet's check it can be regarded as a noise-free pixel located where has no edge on the image. If it cannot pass the first Chaurenet's check, then the second check (without v(i,j)) can be applied.

1) If all of the remaining pixels can pass the second check, v(i,j) must be an isolated noise and will be replaced by M_2.
2) If v(i,j) is one part of an edge, there must be at least 3 or more pixels which cannot pass the second check.

In this way, the noise and edge can be discriminated and the corresponding process-ing can be applied. For smoothing, the noise will be removed and the edge will be left as its original status. For sharpening, it will remove the noise and enforce the edge.

Owing to the non-selective property of this algorithm, the edge enhancement is also non-selective.

The above algorithm is completely based on Chaurenet's criterion, it works well on Gaussian noise. However, it cannot remove the spike noise. Hence, it needs an improvement.

IV. IMPROVEMENTS

The original purpose of Chaurenet's Coefficient is to depress the subtle errors of mean value by rejecting the error data from the data set which have similar magnitudes. The spike noise, showing great difference from the signal data, naturally have another attributes. Therefore, it will be beyond the range of discrimination after even making a maximum relaxation for Chaurenet's criterion.

The relaxation must be controlled by kernel size. For a 3 x 3 kernel, the maximum variance of edges is by no means over 4 times of variance whereas spike can be over 10 times. therefore the relaxation is taken as 4 variance.

After the 4 variance rejection, the spike will be removed. The remaining Gaussian noise will be removed by Chaurenet's checks.

Chaurenet's coefficient is strict at individual noise detection, but not sensitive enough at edge detection. This algorithm recommends a coefficient 0.97 to improve the sensitivity. Then the equation (1) changes as

$$R_k = 0.97\ C_k\ V_k \quad ....(2)$$

The final algorithm is as follows:

```
IF v(i,j) > 4 V1    THEN    ( spike )
   v(i,j)= M1
ELSE
IF v(i,j) < R1 THEN    ( noise free )
     v(i,j)  unchanged
ELSE
IF ALL v(i,j) < R2 THEN  (isolated noise)

     v(i,j) = M2
ELSE
     v(i,j) unchanged for smoothing if
     3 or more pixels not passed
     v(i,j) enforced for sharpening if
     3 or more pixels not passed
ENDIF(s)
```

A simple description for the algorithm is:

1) Reject spike by a relaxation of Chaurenet's criterion.
2) Make a stricture of Chaurenet's criterion to reject Gaussian noise and to detect edge.

V. APPLICATIONS

In order to prove the results of processing of the algorithm, a simulated image is designed and shown in Table 2.

Table 2 SIMULATED IMAGE (10 X 10)

12.	155	160	160	160	4.0	4.0	4.0	~~255~~	5.5
12.	155	160	160	160	162	32	32	32	32
12.	155	12	12.3	160	160	160	4.0	4.0	4.0
~~14.~~	155	12	12.0	12	160	161	4.0	~~14~~	~~160~~
12.	155	11.5	~~0.00~~	12.5	160	160	4.2	4.2	4.3
12.	155	12.0	~~16.0~~	12.0	160	161	4.5	~~0.0~~	4.0
~~50.~~	155	12.2	~~12.7~~	12.1	160	160	4.0	4.0	~~14~~
12.	155	12.0	12.1	12.0	162	162	232	232	232
12.	155	160	160	160	160	4.0	4.0	4.0	4.1
~~255~~	155	161	~~1.0~~	159	160	4.0	4.2	~~14~~	4.2

NOTE:
The data which are strikethrough are supposed spike and noise.

In the Table 2, there are edges oriented in different directions dotted by spikes and Gaussian noises. The processed image is shown in Table 3 after the algorithm is applied once.

Table 3 SMOOTHED IMAGE (iteration 1)

12	155	160	160	160	4.0	4.0	4.0	9.8	5.5
12	155	160	160	160	162	32	32	32	32
12	155	12	12.3	160	160	160	4.0	4.0	4.0
~~14~~	155	12.0	12.0	12	160	161	4.0	~~14~~	4.2
12	155	11.5	12.0	12.5	160	160	4.2	4.2	4.3
12	155	12.0	9.0	12.0	160	161	4.5	4.1	4.0
~~50~~	155	12.2	~~12.7~~	12.1	160	160	4.0	4.0	~~14~~
12	155	12.0	12.1	12.0	162	162	232	232	232
12	155	160	160	160	160	4.0	4.0	4.0	4.1
38	155	161	160	159	160	4.0	4.2	4.3	4.2

NOTE:
The noise removed are underlined.

The spikes have been removed no matter where they are located. The big noise have been removed except those located exactly at the edges. If the algorithm is applied more, more noise will be removed, shown in Table 4:

Table 4 SMOOTHED IMAGE (iteration 3)

12	155	160	160	160	4.0	4.0	4.0	9.8	5.5
12	155	160	160	160	162	32	32	32	32
12	155	12.0	12.3	160	160	160	4.0	4.0	4.0
~~14~~	155	12.0	12.0	12.0	160	161	4.0	4.1	4.2
12	155	11.5	12.0	12.5	160	160	4.2	4.2	4.3
12	155	12.0	12.0	12.0	160	161	4.5	4.1	4.0
~~50~~	155	12.2	12.0	12.1	160	160	4.0	4.0	~~14~~
12	155	12.0	12.1	12.0	162	162	232	232	232
12	155	160	160	160	160	4.0	4.0	4.0	4.1
38	155	161	160	159	160	4.0	4.2	4.3	4.2

NOTE:
The noise removed are underlined.

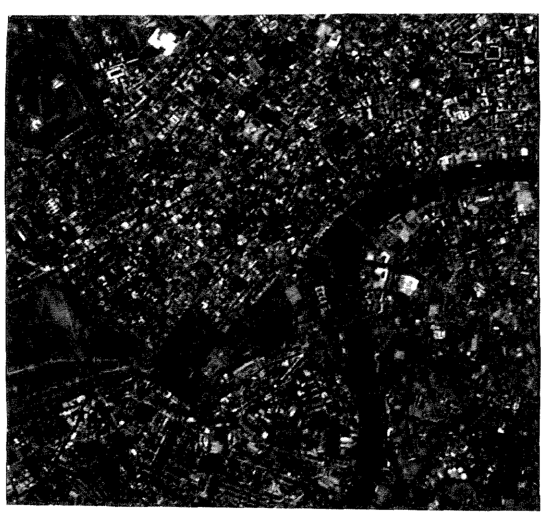
By making comparisons with the original image and the smoothed images, it is obviously that the algorithm can clean the spike and noise without causing any blurring on edges, no matter the edges are subtle or great, at any directions. The edge sharpening result of the algorithm can be checked by Table 5:

Table 5 SHARPENED IMAGE

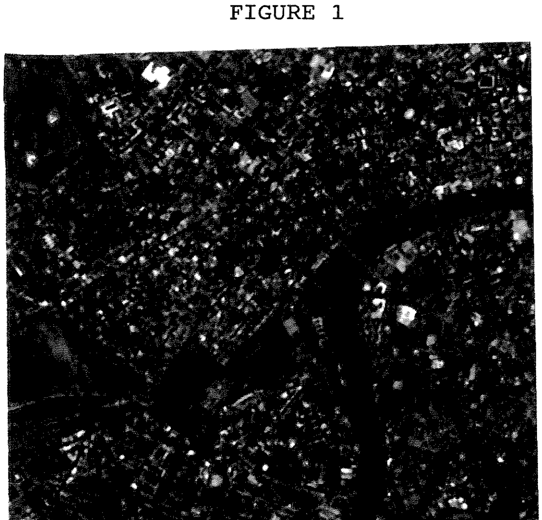
1.3	155	160	160	255	0.4	4.0	0.4	9.8	0.6
1.2	255	160	160	160	255	32	32	60.8	60.8
1.2	255	1.2	1.2	255	160	255	0.4	0.4	0.4
14	255	1.2	12.0	1.2	160	255	0.4	4.1	4.2
1.2	255	1.2	12.0	1.3	255	255	0.4	4.2	8.2
1.2	255	1.2	12.0	1.2	255	255	0.5	4.1	4.0
50	255	1.2	12.0	1.2	160	160	0.4	0.4	14
1.2	255	1.2	1.2	1.2	255	162	255	255	255
1.2	255	160	255	160	255	0.4	0.4	0.4	0.4
38	155	255	160	159	255	4.0	4.2	4.3	4.2

' Table 5 shows that the algorithm is able to enhance the edges at any directions without causing significant noise enhancement and unwanted feature creation. The real images processing (LANDSAT TM and SPOT images) have been processed and the results are shown in following figures (Figure 1 -- figure 5).

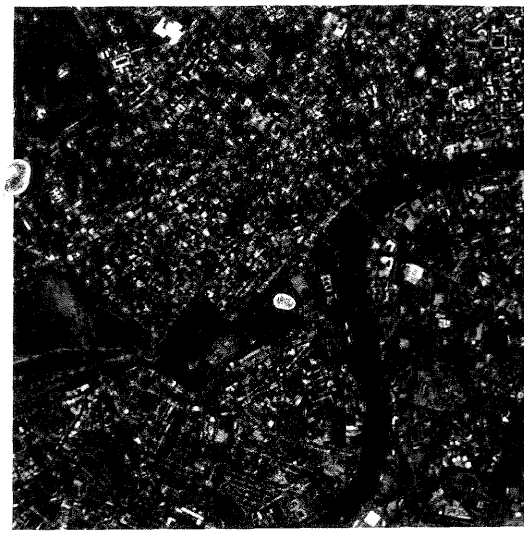
It will take a length if the comparisons with all of other filters are taken, therefore only 2 filters have been selected. For the smoothing, the Median filter is chosen because it is well known at spike depression and reliability. For sharpening, the Laplacian filter is chosen for its non-selective enhancement ability.



RAW SPOT IMAGE
FIGURE 1

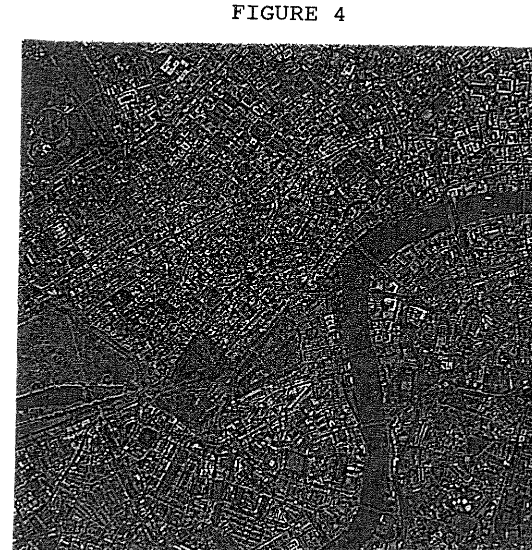


SMOOTHED BY MEDIAN FILTER
FIGURE 2



SMOOTHED BY DUAL FILTER
FIGURE 3

SHARPENED BY DUAL FILTER
FIGURE 4



SHARPENED BY LAPACIAN FILTER
FIGURE 5

Based on the figures, Dual filter shows that it can be applied to real images and output good results with absolute edge preservation as expected. Therefore, one unique advantage of Dual filter is that it can smooth the sharpened image without causing blurring. Figure 6 is a smoothed image which was sharpened before hand.

SHARPENED FIRST, THEN SMOOTHED BY DUAL FILTER FIGURE 6

VI. CONCLUSIONS

1) Dual filter can smooth and sharpen digital image in one algorithm.
2) Dual filter can absolutely protect edges without causing blurring and unwanted feature creation.
3) The iterations are encouraged to take more without worrying blurring.
4) Dual filter can remove both noises in spike and Gaussian types.
5) Dual filter can be used to process real raw satellite imagery.

Dual filter, which is reliable on image processing for its simplicity of the algorithm, is hopeful to become a practical filter for real image processing.

VII. PROBLEMS

Dual filter can not remove the Gaussian noise which is located at exactly on the edge.

VIII. ACKNOWLEDGMENTS

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