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Experimental Study of Modified Multilevel Median Filter for Noise Reduction

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ABSTRACT

Digital image enhancement is efforts to improve the quality of a declining image and one of the causes of the decline in the quality of digital images is the emergence of spots called noise. Median filter is one method that is widely used and developed to digital images noise reduction. In this paper, we conducted an experiment study to reduce noise using a standard multilevel median filter and a modified multilevel median filter. Further, we measured the images filtered quality using MSE and PNSR to find out the advantages of both methods.
Keywords : Image Processing, Median Filter, Multilevel Median Filter

I. INTRODUCTION

Digital image enhancement is efforts to improve the quality of a declining image. The principal objective of enhancement is to process an image so that the result is more suitable than the original image for a specific application. Image enhancement is one of the most interesting and visually appealing areas of digital image processing. Image enhancement approaches fall into two broad categories : spatial domain methods and frequency domain methods. The term spatial domain refers to the image plane itself, and approaches in this category are based on direct manipulation of pixels in an image. Frequency domain processing techniques are based on modifiying the fourier transform of an image[1][2].

One of the causes of the decline in the quality of digital images is the emergence of spots called noise during image acquisition and transmission process so that the image becomes difficult to represent. In digital image processing, there are several types of noise commonly used, namely Gaussian Noise and Impulse Noise[3]. Gaussian noise typically occurred in image acquisition process and is modeled by adding each pixel a value from a zero-mean Gaussian distribution, thus all pixels of the image are affected. Because of its zero-mean nature, Gaussian noise can normally be removed by averaging similar pixels in a pixel's local neighborhood[4]. Impulse noise is caused by defective pixels in the camera sensors, faulty memory locations in the hardware, or due to transmission of image in a noisy communication channel[5]. Impulse noise can be classified as fixed-valued (salt and pepper noise) and random-valued[6]. In this paper, we use salt and pepper noise.

The method used to impulse noise reduction commonly is a spatial filter method that works with statistical principles such as mean / average filter, median filter, minimum filter, maximum filter, and mode filter [2-6]. In recent years, many studies have developed the median filter method such as hybrid median filters, adaptive median filters, multi-level median filter, etc [7-9]. In this study, we use modified multi-level median filter.

II. METHODS AND MATERIAL

Median Filter

The median filter is a simple nonlinear operator whose output value is equal to the median of input value samples inside a sub-window. Sub-window are square with odd sizes such as 3x3, 5x5, 7x7 and so on. Besides being able to suppress noise, the median filter can also smooth the image according to the spatial window size used[10-11]. The sub-window works from first coordinate (0,0) of original image until last pixel coordinate. It collects pixel values, then sorted and determines the median value. The obtained value will be pixel value of filtered image which located in the middle coordinate of sub- window.

	0	1	2	3	4	x
0	123	125	122	130	140	
1	122	124	118	127	135	
2	118	120	150	125	134	
3	119	115	119	123	133	
4	111	116	110	120	130	
y						

- 3x3 sub-window (yellow square) works at 0.0 coordinates (x, y) in the 5x5 original image.
- The sub-window collects the pixel values of original image into a set of values and then sorted (118, 118, 120, 122, 122, 123, 124, 125, 150).
- Find the middle position of the set of values with (n+1)/2 to get the median value (i.e 122); n is the length of the set of values. The obtained value will be pixel value of filtered image which located in the middle coordinate of sub- window.

	0	1	2	3	4	x
0	123	125	122	130	140	
1	122	122	118	127	135	
2	118	120	150	125	134	
3	119	115	119	123	133	
4	111	116	110	120	130	
y						

- The sub window moves to next coordinate (1,0) until last coordinate (2,2).

	0	1	2	3	4	x
0	123	125	122	130	140	
1	122	124	118	127	135	
2	118	120	150	125	134	
3	119	115	119	123	133	
4	111	116	110	120	130	
y						

- The filtered image values.

	0	1	2	3	4	x
0	123	125	122	130	140	
1	122	122	125	130	135	
2	118	119	124	127	134	
3	119	118	120	125	133	
4	111	116	110	120	130	
y						

Multilevel Median Filter

Standard multilevel filtering uses a spatial window as a sub-window like a median filter but the sub-window does not collect all values. The sub-window collects the original image pixel value in orthogonal directions. There are 4 step processes in standard multilevel median filtering [9][11][12].

- The first step is to determine the set of values (W) from the sub window horizontally (W_1), right diagonally (W_2), vertically (W_3), and left diagonally (W_4).

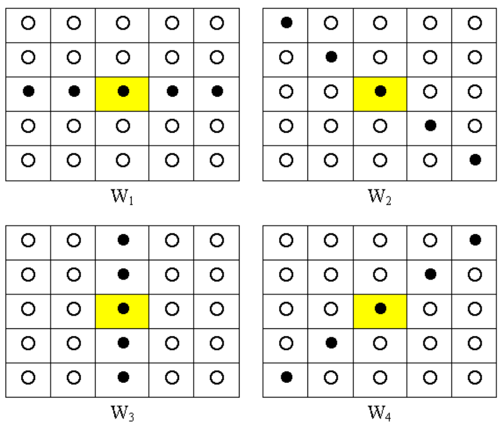

Figure 1. Sub-windows used by Multilevel Filters [12].

- The second step is to determine the median value of each set (z_1 for the median value from W_1 and so on) so that it becomes $y = [z_1, z_2, z_3, z_4]$ and the midpoint value for a (yellow box).
- The third step is to determine the median value of $[y_{min}, y_{max}, a]$ and replace the midpoint value of the original image into a filter image.

Modified Multilevel Median Fitering

Kuang & Sun changed standard multilevel filter process. They divided the spatial window into 4 sub-windows and added 2 sub-windows vertically and horizontally so that there were a total of 6 sub-windows [9].

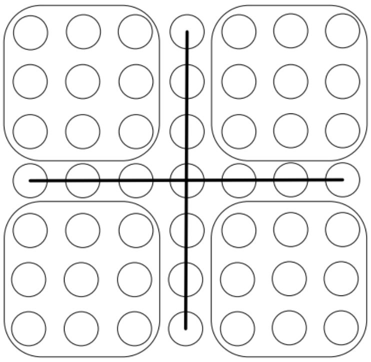

Figure 2. The basic sub-windows of Kuang & Sun [9].

In principle, we conducted a study using a standard multilevel filter standard. However, values are collected in 4 blocks which are divided vertically and horizontally as in figure 3.

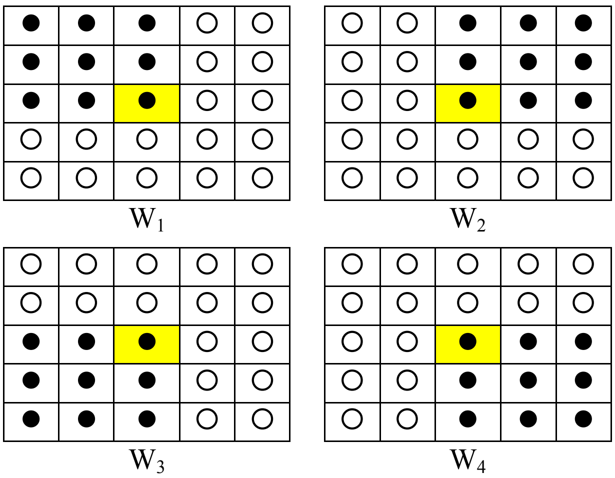

Figure 3. The proposed sub-windows

The 3x3 and 7x7 sub-windows have even members in a block so there are 2 values that are in the middle, and we use the largest value of them.

III. RESULTS AND DISCUSSION

We conducted an experimental study using 4 different reference images (2 color image and 2 grayscale image). We use C # programming language [13] for digital image processing and measuring image quality using mean squared error (MSE) :

$$MSE = \frac{1}{N}\sum_{x=0,y=0}^{N}\left(f_{(x,y)} - o_{(x,y)}\right)^2$$

(f=filtered image; o=original image; N=image size)

and peak signal to noise ratio (PSNR)[14]

$$PSNR = 10\, log_{10}\frac{255^2}{MSE}$$

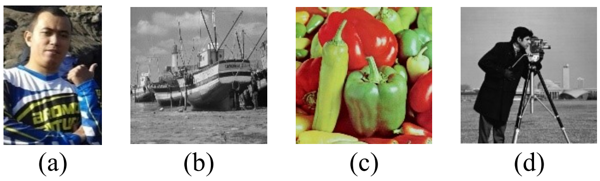

Figure 4. Reference images; (a) author; (b) boat; (c) peppers; (d) cameraman.

Each reference image is added salt & peppers noise with different percentage values (30%, 50%, and 70%). After that the noisy image is enhanced using Standard Multilevel Median Filter (SMLMF) and Modified Multilevel Median Filter (MMLMF) with 4 different sub-window sizes. Following are the results of the experiment.

Figure 5. SMLMF result with 50% noise

3x3 5x5 7x7 9x9

Figure 6. MMLMF result with 50% noise

Table 1. Image quality measurement result of 3x3 sub-window

Salt & Peppers Noise	Reference Images	Image Quality Index			
		MSE		PNSR	
		SMLMF	MMLMF	SMLMF	MMLMF
30%	author	1558,8	368,99	16,2	22,46
	boat	954,87	242,67	18,33	24,28
	peppers	1263,13	496,57	17,11	21,17
	cameraman	1173,55	573,08	17,43	20,54
50%	author	2505,68	504,91	14,14	21,09
	boat	1526,72	326,81	16,29	22,98
	peppers	2071,4	1698,3	14,96	15,83
	cameraman	1910,12	679,07	15,32	19,81
70%	author	3465,15	703,81	12,73	19,65
	boat	2060,2	1352,28	14,99	16,82
	peppers	2848,38	2078,12	13,58	14,95
	cameraman	2550,96	1038	14,06	17,96

Table 2. Image quality measurement result of 5x5 sub-window

Salt & Peppers Noise	Reference Images	Image Quality Index			
		MSE		PNSR	
		SMLMF	MMLMF	SMLMF	MMLMF
30%	author	1014,47	969,83	18,06	18,26
	boat	618,13	496,42	20,21	21,17
	peppers	762	732,38	19,31	19,48
	cameraman	739,32	706,24	19,44	19,64
50%	author	1943,04	1032,09	15,24	17,99
	boat	1181,45	541,1	17,4	20,79
	peppers	1583,42	1017,62	16,13	18,05
	cameraman	1477,66	790,92	16,43	19,14
70%	author	2984,16	1077,5	13,38	17,8
	boat	1742,47	922,38	15,71	18,48
	peppers	2386,1	806,89	14,35	19,06
	cameraman	2132,96	877,74	14,84	18,69

Table 3. Image quality measurement result of 7x7 sub-window

Salt & Peppers Noise	Reference Images	Image Quality Index			
		MSE		PNSR	
		SMLMF	MMLMF	SMLMF	MMLMF
30%	author	577,96	1728,09	20,51	15,75
	boat	343,85	693,02	22,76	19,72
	peppers	365,16	965,52	22,5	18,28
	cameraman	357,26	898,69	22,6	18,59
50%	author	1173,69	1946,31	17,43	15,23
	boat	678,46	897,18	19,81	18,6
	peppers	847,29	1111,33	18,85	17,67
	cameraman	829,97	850,08	18,94	18,83
70%	author	1957,4	1979,32	15,21	15,16
	boat	1099,12	819,33	17,72	18,99
	peppers	1479,78	1124,99	16,42	17,61
	cameraman	1330,85	915,28	16,88	18,51

Table 4. Image quality measurement result of 9x9 sub-window

Salt & Peppers Noise	Reference Images	Image Quality Index			
		MSE		PNSR	
		SMLMF	MMLMF	SMLMF	MMLMF
30%	author	535,31	2047,39	20,84	15,01
	boat	306,28	816,28	23,26	19,01
	peppers	310,25	1024,98	23,21	18,02
	cameraman	310,54	1027,71	23,2	18,01
50%	author	947,31	2286,16	18,36	14,53
	boat	516,6	924,55	20,99	18,47
	peppers	604,45	1137,17	20,31	17,57
	cameraman	580,76	1121,19	20,49	17,63
70%	author	1501,98	2303,91	16,36	14,5
	boat	796,54	1012,67	19,11	18,07
	peppers	999,5	1196,28	18,13	17,35
	cameraman	917,97	1264,32	18,5	17,11

IV. CONCLUSION

In the standard multilevel median filter, the larger of the sub-window size that is used, can reduce noise significantly and image sharpness is maintained properly. Whereas in the modified multilevel median filter, the larger of the sub-window size that is used, making the filtered image more blurred. This is corroborated by the image quality measurement results that shows the value of MSE and PNSR in 3x3 and 5x5 sub-windows better for MMLMF while 7x7 and 9x9 sub-windows show better MSE and PNSR values for SMLMF.

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