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 modifying 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.

- 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.

```
| y  | 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|
```

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

```
| y  | 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| 118| 120| 125| 133|
|    | 4  | 111| 116| 110| 120| 130|
```

- The filtered image values.

```
| y  | 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| 118| 120| 125| 133|
|    | 4  | 111| 116| 110| 120| 130|
```

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 \(W_4\).

```
|   |   |   |   |   |
|---|---|---|---|---|
|   | o | o | o | o |
|   | o | o | o | o |
|   | o | o | o | o |
| wi| o | o | o | o |
|   | o | o | o | o |

|   |   |   |   |   |
|---|---|---|---|---|
|   |   |   |   |   |
|   |   |   |   |   |
|   | o | o | o | o |
|   | o | o | o | o |
|   | o | o | o | o |
| w1| o | o | o | o |
|   | o | o | o | o |

|   |   |   |   |   |
|---|---|---|---|---|
|   |   |   |   |   |
|   |   |   |   |   |
|   |   | o | o | o |
|   |   | o | o | o |
|   |   | o | o | o |
| w2|   |   |   |   |
|   | o | o | o | o |

|   |   |   |   |   |
|---|---|---|---|---|
|   |   |   |   |   |
|   |   |   |   |   |
|   |   |   | o | o |
|   |   | o | o | o |
|   |   | o | o | o |
| w3|   |   |   |   |
|   | o | o | o | o |

|   |   |   |   |   |
|---|---|---|---|---|
|   |   |   |   |   |
|   |   |   |   |   |
|   |   |   |   | o |
|   | o | o | o | o |
|   | o | o | o | o |
| w4|   |   |   |   |
|   | o | o | o | o |
```

Figure 1. Sub-windows used by Multilevel Filters [12].
The second step is to determine the median value of each set \( z_i \) 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 \([y_{\text{min}}, y_{\text{max}}, a]\) and replace the midpoint value of the original image into a filter image.

**Modified Multilevel Median Filtering**

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].

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.

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):

\[
MSE = \frac{1}{N} \sum_{x=0}^{N} (f(x,y) - o(x,y))^2
\]

(\( f \)-filtered image; \( o \)-original image; \( N \)-image size)

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

\[
PSNR = 10 \log_{10} \frac{255^2}{MSE}
\]

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

![Figure 5. SMLMF result with 50% noise](image)
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.
V. REFERENCES

[1] Gonzales, Rafael C. & Woods, Richard E. 2002. “Digital Image Processing 2nd Edition”, Prentice Hall, ISBN : 9780201180756.

[2] Halder, Amiya., Shekhar, Sandeep., Kant, Shashi., Mubarki, Musheer Ahmad & Pandey, Anand. “A New Efficient Adaptive Spatial Filter for Image Enhancement”, Proceedings of 2nd Int. Conf. on Computer Engineering and Applications, 2010, ISBN : 9780769539829, DOI: 10.1109/ICCEA.2010.55

[3] Chen, Hongyan. “A Kind of Effective Method of Removing Compound Noise in Image”, Proceedings of 9th Int. Congress on Image and Signal Processing, BioMedical Engineering and Informatics, 2016, ISBN : 9781509037100, DOI : 10.1109/CISP-BMEI.2016.7852700

[4] Lin, Zhu. “A Nonlocal Means Based Adaptive Denoising Framework For Mixed Image Noise Removal”, Proceedings of IEEE Int. Conf. on Imaging Processing, 2013, ISBN : 9781479923410, DOI : 10.1109/ICIP.2013.6738094

[5] Chen, QiQiang. & Wan, Yi. “A New Framework for Image Impulse Noise Removal With Postprocessing”, IEEE Visual Communications and Image Processing Conference, 2014, DOI : 10.1109/VCIP.2014.7051601

[6] S, Indu. & Ramesh, Chaveli. “A Noise Fading Technique for Images Highly Corrupted with Impulse Noise”, Proceedings of Int. Conf. on Computing: Theory and Applications, 2007, ISBN : 0769527701, DOI : 10.1109/ICCTA.2007.14

[7] Darus, Muhammad S., Sulaiman, Siti N., Isa, Iza S., Hussain Z., Tahir, Noorbitawati Md. & Isa, Nor A. M. “Modified Hybrid Median Filter for Removal of Low Density Random Valued Impulse Noise in Images”, Proceedings of 6th IEEE Int. Conf. on Control System, Computing and Engineering, 2016, ISBN : 9781509011780, DOI: 10.1109/ICCSCE.2016.7893633

[8] Nooshyar, Mahdi. & Momeny, Mohamad. “Removal of High Density Impulse Noise Using a Novel Decision Based Adaptive Weighted and Trimmed Median Filter”, 8th Iranian Conf. on Machine Vision and Image Processing, 2013, DOI: 10.1109/IranianMVIP.2013.6780016

[9] Kuang, Ping. & Sun, Lei. “An Improved Two-Dimensional Multi-Level Median Filtering Algorithm”, Int. Conf. on Apperceiving Computing and Intelligence Analysis, 2010, DOI: 10.1109/ICACIA.2010.5709919

[10] Khairul., Wijaya, R. F., Siahaan, Andysah P. U., et al. “Effect of Matrix Size in Affecting Noise Reduction Level of Filtering”, Int. Journal of Engineering & Technology, vol. 7 no. 3, pp. 1272-1275, 2018, DOI: 10.14419/ijet.v7i3.11333

[11] Hwang, Humor. & Haddad, Richard A. “Multilevel Nonlinear Filters for Edge Detection and Noise Suppression”, Journal of IEEE Transactions on Signal Processing, vol. 42 Issue 2, pp. 249-258, 1994, DOI: 10.1109/78.275599

[12] Arce, G. R. & Foster, R. E. “Multilevel Median Filters: Properties And Efficacy”, Int. Conf. on Acoustics, Speech, and Signal Processing, 1988, DOI: 10.1109/ICASSP.1988.196713

[13] Siahaan, Andysah. P. U. 2018. “How to Code: Advanced Encryption Standard in C#”, Fakultas Ekonomi Universitas Pembangunan Panca Budi.

[14] Ndajah, P., Kikuchi, H., Yukawa, M., Watanabe, H. & Muramatsu, S., 2011, “An investigation on the quality of denoised images” Int. Journal of Circuits, Systems and Signal Processing, vol. 5, no. 4, pp. 423-434.

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