Comparison of Image Smoothing Methods on Potholes Road Images

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Abstract. Before segmentation performed on potholes, road images is done first on the image smoothing. With the aim at the time of the next stage of the next process (segmentation) is expected to produce good accuracy. In this research, there will be a comparison of four smoothing methods consisting of lowpass filter, highpass filter, highboost filter and gaussian filter. The four smoothing methods applied to twenty pothole road image data that have been preprocessed using a combination of brightness and contrast methods. Comparative measurements of the four methods use the Means Square Error (MSE) value and Peak Signal to Noise Ratio (PSNR). Test results obtained from this research is the average value of MSE lowpass filter 68.12, MSE highpass filter is 569.99, MSE highboost filter is 838.54 and MSE Gaussian filter is 34.68. The average value of PSNR lowpass filter is 66.60 dB, PSNR highpass filter is 47.36 dB, PSNR highboost filter is 44.77 dB, and PSNR Gaussian filter is 75.94 dB. The measurement results obtained by the Gaussian filter method which is the best method for smoothing on potholes road images, because it produces the greatest PSNR value, and the smallest MSE value.

1. Introduction

In 2017, 20% of traffic accidents in Java were caused by damaged road conditions including potholes. Therefore, the DPU will immediately repair damaged roads including potholes that can result in traffic accidents [1]. In carrying out repairs to potholes, the DPU must know the exact depth and position of the potholes [2]. To find out the area of the pothole the smoothing process is done first [3]. The smoothing process has the aim to refine the image, reduce noise in the image and reduce deviation in the image caused by the process of taking pictures and the tools used are imperfect [4]. After the smoothing process is expected in the next process that is doing segmentation to find the surface area of the potholes resulting in high accuracy.

Smoothing or filterring methods on images a lot of filterring methods are used. The filtering method in the image is related to the frequency term. In the image, the term frequency is not related to time, but relates to space or spatial. Therefore, the image is said to have spatial frequency which states that spatial frequency is a characteristic of any structure that is periodic along the position in space.

Spatial frequency is a measure of how often structures occur repeatedly in a unit of distance. Spatial frequency in the image shows how often a gray level change occurs from one position to the next [5]. In the picture there is a low frequency (LPF) and there is a high frequency (HPF) . So that an image before being processed to the next stage must be filtered first, to normalize its frequency form [6].

The smoothing process in this study will compare four smoothing methods, namely lowpass filter, highpass filter, highboost filter and Gaussian filter. The four methods will be applied to the pothole road image that has been preprocessed by a combination of gravity and contrast methods. The four smoothing methods were analyzed by calculating the value of Mean Square Error (MSE), Root Mean Squared Error (RMSE) and Peak Signal to Noise Ratio (PNSR) [7]. From the results of the analysis of the smoothing method which has the best value of MSE, RMSE, PNSR which is used as a smoothing method on potholes road images.

2. Methodology

In this study used twenty potholes as the trial data and consisted of four processes. The system design in this study is shown in figure 1.

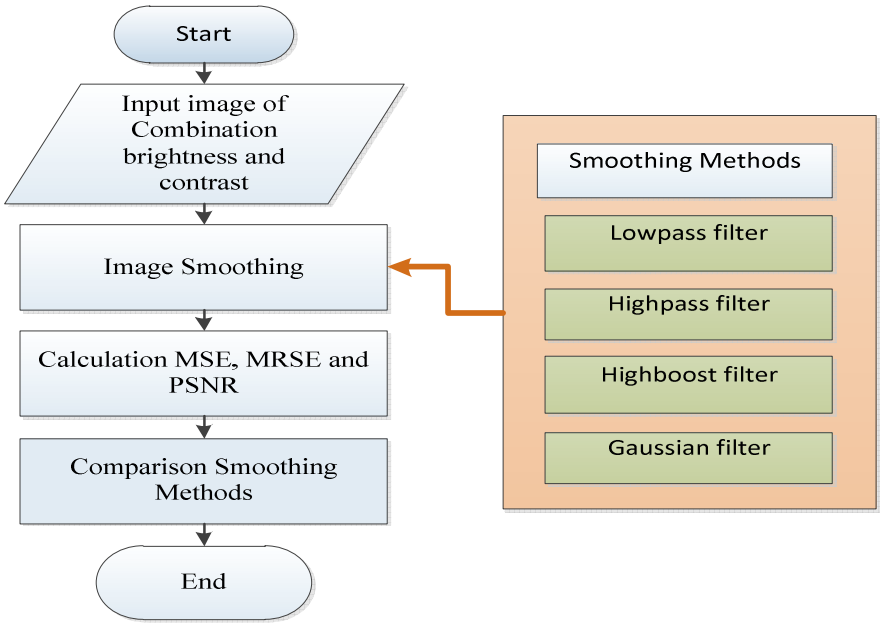

Figure1. System design

The first process is input the image of the hole with the results of brightness and contrast, the second process is smoothing the image of the hole with four methods, namely lowpass filter, highpass filter, highboost filter and gaussian filter. The third process of calculating the value of MSE, RMSE, and PSNR. The fourth process analyzes the results of the MSE, RMSE, and PSNR calculation values.

2.1. Lowpass filter

Low-pass filter is a filter that has the property of being able to pass the low frequencies and eliminate the high frequencies. This filter effect makes changes to the gray level softer. This filter is useful for smoothing noise and for the benefit of interpolating the edges of objects in an image [8]. Lowpass filter operation is carried out through convolution or without convolution. Convolution is often involved in pixel neighbor operations. Convolution in images is often referred to as two-dimensional convolution (2D convolution). 2D convolution is defined as the process of obtaining a pixel based on the value of the pixel itself and its neighbors, involving a matrix called a kernel that represents the weighting [9]. In this research, it involves convolution by using the kernel as shown in Figure 2 and equation 1.

1/16

1	2	1
2	4	2
1	2	1

Figure 2. Kernel lowpass filter

$$G(x,y)=1/16\ (F(x-1,y-1)+2*F(x-1,y)+F(x-1,y+1) + 2*F(x,y-1)+ 4*F(x,y) + 2*F(x,y+1)+F(x+1,y-1)+2*F(x+1,y) +F(x+1,y+1)) \quad (1)$$

2.2. Highpass filter

Highpass filters are filters intended to pass high frequencies and remove low frequencies. This is commonly used to get the edges of objects in the image or sharpen the image [10]. In this study the convolution uses the kernel as shown in Figure 3 and equation 2.

1	-2	1
-1	4	-1
0	-1	0

Figure 3. Kernel highpass filter

$$G(x,y)=F(x-1,y-1)-2*F(x-1,y)+F(x-1,y+1)-F(x,y-1)+ 4*F(x,y)-F(x,y+1)-F(x+1,y) \quad (2)$$

2.3. Highboost filter

Highboost filter is used to sharpen the image through convolution, the kernel that can be used is a highpass kernel filter with a value at the center filled with values greater than the values in the matrix [6]. In this study the highboost kernel is used as shown in Figure 4 and equation 3.

-1	-1	-1
-1	8.5	-1
-1	-1	-1

Figure 4. Kernel highboost filter

$$G(x,y)= -1*(F(x-1,y-1)+F(x-1,y)+F(x-1,y+1) + F(x,y-1)-8.5*F(x,y) + F(x,y+1)+F(x+1,y-1)+F(x+1,y) \quad +F(x+1,y+1)) \quad (3)$$

2.4. Gaussian filter

Gaussian filter functions to reduce noise in the image [11]. The way Gaussian works is to eliminate high-frequency components from the image, so the Gaussian technique is said to be a low-pass filter. Gaussian filters use the Gaussian distribution function[12]. The Gaussian filter is written in equation (4).

$$G(x,y) = e^{-\frac{x^2+y^2}{2\sigma^2}} \quad (4)$$

In this case, σ is the standard deviation and the pixels at the center (x, y) get the greatest weight in the form of 1 [13]. In this study the Gaussian kernel is used by entering the Gaussian function into the 5x5 matrix.

2.5. Mean Square Error (MSE) and Root Mean Square Error (RMSE)

MSE is the mean square error value of images that have been modified with the original image. The smaller the MSE value, the higher the image quality, whereas the greater the MSE value, the worse the image quality will be [14]. MSE calculations can be formulated in equation (5).

$$MSE = \frac{1}{KxL}\sum_{x=1}^{K}\sum_{y=1}^{L}(f(x,y) - G(x,y))^2 \quad (5)$$

Where $f(x,y)$ is input image, $G(x,y)$ is smoothing image, K is number of rows image, L is number of columns image. RMSE is the square root of MSE equation (5). The smaller the RMSE value, the greater the similarity between image input and dismoothing image. RMSE calculations can be formulated like equation (6).

$$RMSE = \sqrt{MSE} \quad (6)$$

2.6. Peak Signal to Noise Ratio (PSNR)

n this research, the quality of smoothing results on potholes will be assessed based on the size of the PSNR. The greater the PSNR value the better the quality of the image produced and vice versa the smaller the PSNR value the lower the quality of the image produced. The unit in PNSR is decible (dB) [15]. PSNR calculations can be formulated like equation (7).

$$PSNR = 10\ log_{10}\left(\frac{Max^2}{MSE}\right) \quad (7)$$

Where Max = the maximum value of pixels input.

3. Result and Discussion

The trial in this study used twenty pavement road image data in the form of graycale with a size of 256x256 pixels. The image smoothing method used in this study uses lowpass filter, highpass filter, highboost filter and Gaussian filter.

3.1. Results of comparison of smoothing methods

The trial uses four methods with twenty data potholes. The results of the comparison of the number of pixels in the removed image can be shown in Table 1.

Tabel 1. Testing the smoothing of image quality

Measurrement of 20 data images	Lowpass filter	Highpass filter	Highboost filter	Gaussian filter
Average of MSE	86.12	569.99	838.54	34.68
Average of RMSE	9.20	24.32	28.18	5.81
Average of PSNR	66.60	47.36	44.77	75.94

ased on the results of the average measurement of the four smoothing methods, the Gaussian method has the smallest MSE value and the largest PSNR value. A comparison chart of the four methods with MSE, RMSE and PSNR measurements is shown in Figure 5.

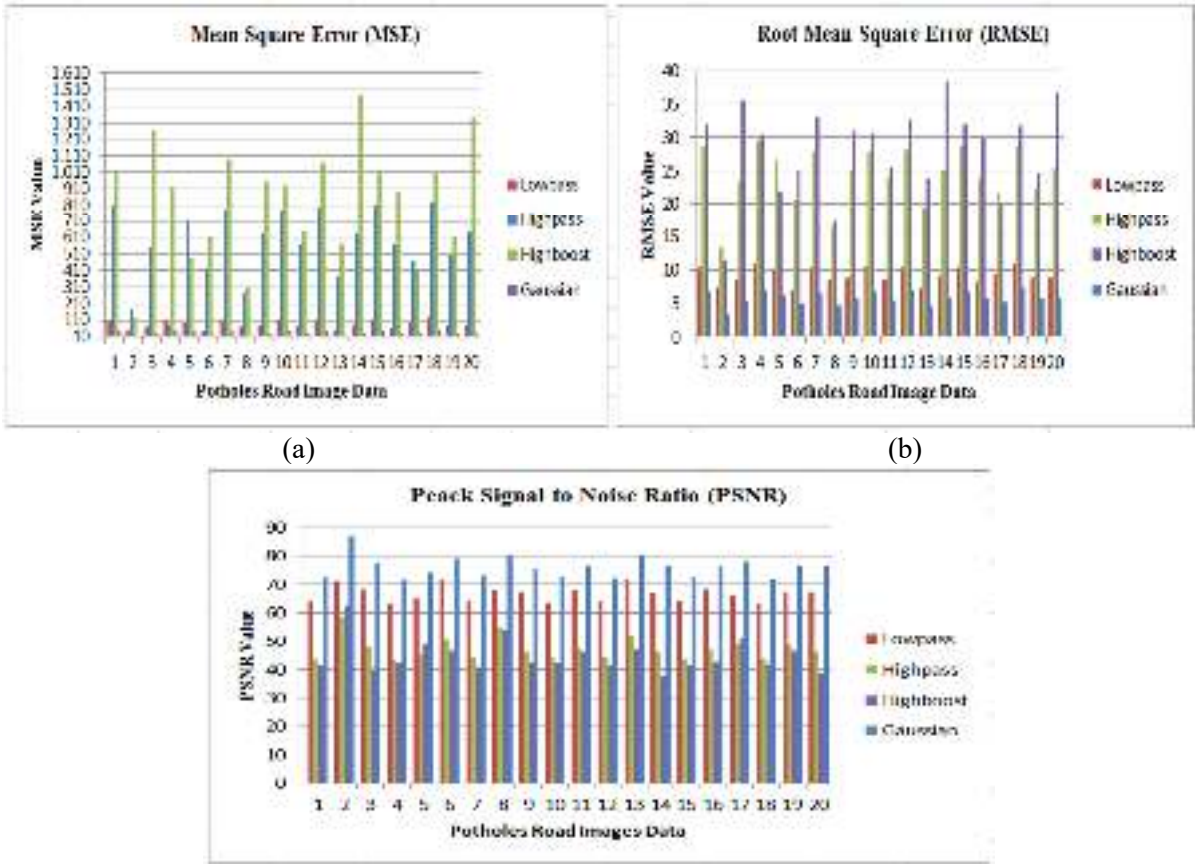

Figure 5.(a) Chart of the results of MSE calculations using four methods; (b) Chart of the results of RMSE calculations using four methods; (c) Chart of the results of the PSNR calculation using four methods.

Based on the chart results from Figure 5. A good method for smoothing potholes on the road is the Gaussian filter method. Because the Gaussian filter method produces the lowest average MSE value, 34.68, the lowest average RMSE value is 5.811 and the highest average PSNR value is 75.939 compared to other methods. The comparison of the input image with the image of the smoothing result can be shown in Figure 6.

Figure 6. Comparison between image input with four smoothing methods

The Gaussian filter method is an appropriate method to be applied to smoothing the input image because it is proven at the largest PSNR value ,the smallest MSE value, and the smallest RMSE value. The Gaussian filter method is also clearly shown in Figure 6, that the method produces the clearest picture.

4. Conclusion

In general, lowpass filter, highpass filter, highboost filter and Gaussian filter methods can be used as a method for image smoothing. But from the test results in this study the best Gaussian filter method is used for smoothing the image of potholes. The Gaussian filter method has an average value of MSE 34.68, RMSE 5.81 and PSNR 75.94 dB.

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References

[1] V. S. Felix Enigo, T. M. Vinoth Kumar, S. Vijay, and K. G. Prabu, "Crowd Sourcing Based Online Petitioning System for Pothole Detection Using Android Platform," *Procedia Comput. Sci.*, vol. 87, no. 2014, pp. 316–321, 2016.

[2] M. H. Yousaf, K. Azhar, F. Murtaza, and F. Hussain, "Visual analysis of asphalt pavement for detection and localization of potholes," *Adv. Eng. Informatics*, vol. 38, pp. 527–537, 2018.

[3] Y. O. Ouma and M. Hahn, "Pothole detection on asphalt pavements from 2D-colour pothole images using fuzzy c-means clustering and morphological reconstruction," *Autom. Constr.*, vol. 83, no. August, pp. 196–211, 2017.

[4] D. Diffusion, "Procedia Engineering Research on Burst Image Segmentation Based on Brightness Decrease Diffusion," 2011.

[5] S. C. F. Lin *et al.*, "Image enhancement using the averaging histogram equalization (AVHEQ) approach for contrast improvement and brightness preservation," *Comput. Electr. Eng.*, vol. 46, pp. 356–370, 2015.

[6] M. Yaseen, "Robust and direct design for highpass ladder wave digital filters exhibiting equiripple characteristics," *Digit. Signal Process. A Rev. J.*, vol. 23, no. 3, pp. 1059–1064, 2013.

[7] C. Y. Chen, C. H. Chen, C. H. Chen, and K. P. Lin, "An automatic filtering convergence method for iterative impulse noise filters based on PSNR checking and filtered pixels detection," *Expert Syst. Appl.*, vol. 63, pp. 198–207, 2016.

[8] L. L. Nguyen, R. Gautier, A. Fiche, G. Burel, and E. Radoi, "Digital compensation of lowpass filters imperfection in the Modulated Wideband Converter compressed sensing scheme for radio frequency monitoring," *Signal Processing*, vol. 152, pp. 292–310, 2018.

[9] I. J. Electron, C. Aeü, K. V. P. Kumar, and S. S. Karthikeyan, "Microstrip lowpass fi lter with fl exible roll-o ff rates," vol. 86, no. January, pp. 63–68, 2018.

[10] K. Baxevanaki, S. Kapoulea, C. Psychalinos, and A. S. Elwakil, "Electronically tunable fractional-order highpass filter for phantom electroencephalographic system model implementation," *AEU - Int. J. Electron. Commun.*, vol. 110, p. 152850, 2019.

[11] G. Wang, C. Lopez-Molina, and B. De Baets, "Automated blob detection using iterative Laplacian of Gaussian filtering and unilateral second-order Gaussian kernels," *Digit. Signal Process. A Rev. J.*, vol. 96, 2020.

[12] S. Yu and W. Yiquan, "An improved local Laplacian filter based on the relative total variation," *Digit. Signal Process. A Rev. J.*, vol. 78, no. 29, pp. 56–71, 2018.

[13] H. Wang and M. Hong, "Online ad effectiveness evaluation with a two-stage method using a Gaussian filter and decision tree approach," *Electron. Commer. Res. Appl.*, vol. 35, no. November 2018, 2019.

[14] K. S. Choi, "Bit plane modification for improving MSE-near optimal DPCM-based block truncation coding," *Digit. Signal Process. A Rev. J.*, vol. 23, no. 4, pp. 1171–1180, 2013.

[15] S. Forchhammer, H. Li, and J. Dahl Andersen, "No-reference analysis of decoded MPEG images for PSNR estimation and post-processing," *J. Vis. Commun. Image Represent.*, vol. 22, no. 4, pp. 313–324, 2011.