Comparison of image edge detection methods on potholes road images

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Abstract. Dinas Pekerjaan Umum (DPU) in Surabaya in carrying out road repairs, especially on potholes, must know the position, area and depth. So it is important to do research to find out the surface area of potholes. To find out the surface area of the hole, the edge detection process is done first. Edge detection functions to get the edge of an object. Edge detection is obtained by utilizing a drastic change in the intensity value at the boundary of two areas. In this study, to determine the edge of an object (potholes road) by comparing three edge detection methods consisting of the Frei-Chen, Laplacian and Laplacian of Gaussian (LoG) methods. From the results of testing the Laplacian of Gaussian method has an average value of accuracy of 67%, sensitivity of 81.97% and specificity of 65.16%. The measurement results obtained by the Laplacian of Gaussian method which is the best method for edge detection in potholes road images, because it produces the highest accuracy, sensitivity and specificity.

1. Introduction
Dinas Pekerjaan Umum (DPU) in Surabaya in carrying out road repairs, especially on potholes, must know the position, area and depth of the pothole. So it is important to do research to find out the surface area of potholes. To find out the surface area of the pothole, the edge detection process is performed first [1]. In the edge detection process has the purpose of marking the details of the image and improve the details of the blurred image, which occurs because of the effect of the process of image data retrieval edge detection is obtained by utilizing changes in the value of drastic intensity at the boundary of two areas [2]. After the edge detection process is expected in the next process to find the surface area on potholes resulting in high accuracy [3].

Edge detection in images can be obtained through the use of masks or kernels [4]. In general, edge detection uses two types of detectors, namely line detectors (Gx) and column detectors (Gy) [5]. Some examples belonging to this type are operators Sobel, Prewitt, Roberts and Frei-Chen. Edge detection can be divided into two forms [6]. The first form is called first order edge detection, which works by using first order differential. Included in this group are operators Sobel, Prewitt, Roberts and Frei-Chen. The second form is called second order edge detection, which uses second order derivatives [7]. Examples that fall into this group are Laplacian and Laplacian of Gaussian (LoG). Derivatives in the first and second orders in both continuous and discrete forms are very useful for edge detection [8].

The edge detection process in this study will compare three detection methods namely Frei-Chen, Laplacian and Laplacian of Gaussian. The three methods will be applied to twenty potholes that have
been smoothed using the Gaussian Filter method [9]. The three detection methods are analyzed by calculating the value of accuracy, sensitivity and specificity. From the results of the analysis of the edge detection method which has the best accuracy, sensitivity and specificity values used as an edge detection method on potholes road images [10].

2. Methodology
In this study using twenty potholes road image data as a trial and there are four processes. The system design in this study is shown in Figure 1.

![Figure 1: System design](image)

The first process of input potholes road images is the result of smoothing using the Gaussian method, the second process is edge detection on image input with three methods, namely the Frei-Chen operator, the Laplacian operator and the Laplacian of Gaussian operator. The third process of calculating the value of accuracy, sensitivity and specificity. The fourth process analyzes the results of the calculation of the accuracy, sensitivity and specificity values.

2.1. Frei-Chen operator
The Frei-Chen operator is the basic concept of calculating edge detection using the first derivative that utilizes the difference in value of a pixel with its neighboring pixel [11]. The Frei-Chen Mask is a unique mask, which contains all the base vectors [12]. This operator is similar to the Sobel operator, with each number 2 changing to $\sqrt{2}$, using a matrix called a kernel that represents weighting [4]. In this study Frei-Chen operator using a convolution with the kernel as shown in Figure 2 and Equation (1).
Sensitivity is a measure of accuracy, which is how likely the edge detection method is to detect specific features in images. Measurement of the results of edge detection is done by calculating the accuracy, sensitivity and specificity [10]. Accuracy is a measurement of how close the system results are to their true values. Specificity is a measure of how well the edge detection method identifies which is not a potholes road. Sensitivity is a measure of accuracy, which is how likely the edge detection method is to detect.

2.2. Laplacian operator

The Laplacian operator is an operator based on the second derivative [13]. This operator is omnidirectional which thickens the edges in all directions [7]. However, Laplacian operators have the disadvantage of being sensitive to noise, giving double thickness, and not being able to detect edge direction [14]. This is commonly used to get the edges of objects in the image or sharpen the image. In this study using the kernel as show in Figure 3 and Equation (2).

2.3 Laplacian of Gaussian operator

The Laplacian of Gaussian (LoG) operator works by finding the zero value in the second derivative of the image, because when the first derivative has a maximum value, the second derivative will produce a zero value [16]. The second derivative of the x direction and the y direction is combined into one operator value [17]. This value is represented in the form of the sum of the two convolution matrices from the x and y directions [18]. The function of the Laplacian of Gaussian operator is used to find the kernel value as a weighting with convolution, using the equation shown in Equation (3) [19].

\[
\text{Log}(x,y) = \frac{1}{\pi \sigma^2} \left[ 1 - \frac{x^2 + y^2}{2\sigma^2} \right] e^{-\frac{(x^2+y^2)}{2\sigma^2}}
\]
Pothole areas [20]. Calculation of accuracy, sensitivity and specificity are found in Equations (4) to (6).

\[
\text{Accuracy} = \frac{(TP + TN)}{(TP + TN + FP + FN)} \times 100\% \quad (4)
\]

\[
\text{Sensitivity} = \frac{TP}{(TP + FN)} \times 100\% \quad (5)
\]

\[
\text{Specificity} = \frac{TN}{(FP + TN)} \times 100\% \quad (6)
\]

where,

- TP : True positive, is potholes detected as potholes.
- FN : False negative, is potholes detected not potholes.
- FP : False positive, is not potholes detected as potholes.
- TN : True Negative, is not potholes detected not potholes.

3. Result and Discussion

The trial in this study used twenty pothole road image data with the Gaussian method in the form of grayscale with a size of 256x256 pixels. The edge detection method in potholes used in this study uses the Frei-Chen operator, Laplacian operator and Laplacian of Gaussian (LoG) operator.

3.1. The results of the comparison of edge detection methods

The trial uses three methods with twenty data road image potholes. The results of comparison of the number of pixels in the image that has been detected can be shown in Table 1.

| Measurement of 20 data images | Frei-Chen | Laplacian | Laplacian of Gaussian |
|-------------------------------|-----------|-----------|-----------------------|
| Average of Accuracy           | 65.11 %   | 66.18 %   | 6.00 %                |
| Average of Sensitivity        | 70.51 %   | 78.05 %   | 8.91 %                |
| Average of Specificity        | 62.39     | 64.14 %   | 65.16 %               |

Based on the average measurement results of the three edge detection methods, the Laplacian of Gaussian method has an average accuracy value greater than the average accuracy value of the Laplacian and Frei-chen methods. The measurement results of the sensitivity of the Laplacian of Gaussian method have an average value greater than the Frei-Chen and Laplacian methods. Likewise, the average value of Specificity. A comparison chart of the three methods with measurements of accuracy, sensitivity and specificity is shown in Figure 4-6.
Figure 4. Chart of the results of accuracy calculations using three methods

![Sensitivity Chart](chart-sensitivity.png)

Figure 5. Chart of the results of Sensitivity calculations using three methods

![Specificity Chart](chart-specificity.png)

Figure 6. Chart of the results of specificity calculations using three methods

Based on the chart results from Figure 4-6. A good method for edge detection in potholes is the Laplacian of Gaussian (LoG) method. Because the Laplacian of Gaussian method produces the highest average nilar sensitivity compared to the Frei-Chen and Laplacian methods, which has an average sensitivity value of 81.91%. Comparison of the input image with the image of the edge detection method can be shown in Figure 7.
The Laplacian of Gaussian method in this study is a better edge detection method, because it is proven at an accuracy value of 67%, sensitivity 81.91% and the highest specificity of 65.16% compared to the Frei-Chen and Laplacian methods. The Laplacian of Gaussian method is also clearly shown in Figure 7, that the method produces better edge detection images than the Frei-Chen and Laplacian methods.

4. Conclusion
The test results that have been carried out in this study, obtained several points that need to be considered as follows: the first In general, Frei-Chen, Laplacian, Laplacian of Gaussian methods used as a method for image detection. The second from the test results in this study, the Laplacian of Gaussian produces sensitivity better than other methods. The third method is Laplacian of Gaussian (LoG) has an average value of accuracy of 67%, sensitivity of 81.97% and specificity of 65.16%.

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