BAREKENG: Journal of Mathematics and Its Applications
September 2023 Volume 17 Issue 3 Page 1815–1824
P-ISSN: 1978-7227 E-ISSN: 2615-3017
https://doi.org/10.30598/barekengvol17iss3pp1815-1824

# COMPARISON OF EDGE DETECTION METHODS USING ROBERTS AND LAPLACIAN OPERATORS ON MANGO LEAF OBJECTS

**Dedi Darwis[1], Yusra Fernando[2], Fika Trisnawati[3], Dwiki Hafizh Marzuki[4], Setiawansyah[5*]**

*[1]Accounting Information System Department, Faculty of Engineering and Computer Science, Teknokrat Indonesia University*
*[2,4,5*]Informatic Department, Faculty of Engineering and Computer Science, Teknokrat Indonesia University*
*[3]Computer Engineering Department, Faculty of Engineering and Computer Science, Teknokrat Indonesia University*

*ZA. Pagar Alam Street No.9 -11 Labuhan Ratu-Kedaton, Bandar Lampung, 35132, Indonesia*

*Corresponding author's e-mail: * **setiawansyah@teknokrat.ac.id***

***Article History:***

*Received: 02nd June 2023*
*Revised: 23rd August 2023*
*Accepted: 29th August 2023*

***Keywords:***

*Edge detection;*
*Laplacian;*
*Roberts*

*ABSTRACT*

*Edge detection is a technique to find the outlines of an object in an image by detecting significant changes in brightness or discontinuities. This study discusses the comparison of edge detection using Roberts operators and Laplacian operators. The object used in edge detection is four types of mango leaves (Golek, Arum Manis, Madu, and Kuweni) with the *.jpeg format that has been pre-processed with 1000 x 278 pixels. The test used in this study was comparing the results of White Pixel values, MSE, and PSNR with test data as many as 24 data samples from four types of mango leaves. The results of the comparison of edge detection methods using the Laplacian operator get the lowest MSE value of 7.8577, the highest PSNR value of 39.2119, and the white pixel value of 164951, while the Roberts operator gets the lowest MSE value of 8.9723, the highest PSNR value of 38.6358, and the white pixel value of 155889.*



***How to cite this article:***

D. Darwis, Y. Fernando, F. Trisnawati, D. H. Marzuki and Setiawansyah., "COMPARISON OF EDGE DETECTION METHODS USING ROBERTS AND LAPLACIAN OPERATORS ON MANGO LEAF OBJECTS," *BAREKENG: J. Math. & App.*, vol. 17, iss. 3, pp. 1815-1824, September, 2023.


Journal homepage: *https://ojs3.unpatti.ac.id/index.php/barekeng/*
Journal e-mail: *barekeng.math@yahoo.com; barekeng.journal@mail.unpatti.ac.id*

**Research Article · Open Access**

## 1. INTRODUCTION

Mango plant (Mangifera indica Linn) is an annual fruit plant originating from India[1], the plant then spread to Southeast Asia, including Malaysia and Indonesia[2]. In Indonesia, mango is one of the fruits that are very liked by the people of Indonesia. Mango fruit is favored by the people of Indonesia because it can be consumed fresh or in processed form and contains vitamin C, vitamin A, high fiber and pectin to lower cholesterol in the blood [3],[4].

The development of technology in image processing is also growing quite rapidly. For various purposes and needs, various technologies have been developed to facilitate human work, including image processors, image analysts, and image users[5],[6]. Often the image used is not in good condition to be researched because of many disturbances such as shadows, unclear images, the appearance of unclear objects that will cause problems and affect the analysis and planning to be carried out, so various image processing techniques are needed to get the ideal image. Edge detection can be used as a feature to represent objects in an image. It allows the computer to understand the structure of objects, such as contours, shapes, and textures. In object recognition in an image, edges can be used as a first step to identify and separate objects from the background.[7]–[9].

One of the image processing techniques used is edge detection. The edge detection method is the process of generating the edges of objects on an image[10]. Edges are used to mark the detail parts of the image and correct image details that are blurred by mistake[11]. The objects used in this study are 4 (four) types of mango leaves, namely sweet arum mango, honey mango, golek mango, and kuweni mango. Arumanis mango has a fairly large leaf characteristic with a leaf length of ± 45 cm, and in an oval shape and tapered tip. Golek mango has characteristic oval-shaped leaves, with a tapered base and spearhead-shaped tip, ± 24 cm long, with a width of 6 cm. Honey mango has relatively few leaves and branching, the leaves are oval and folding, with a pointed ± 22.5 cm. Mango kuweni has wavy leaves, tapering at the base and end, has a length of ± 25 cm[12].

One of the problems with digital image processing is detecting an object so that the object can be recognized automatically based on the data entered. To overcome this problem, one way that can be used is to detect the edges of objects so that the pattern of an image can be recognized for further processing. The roberts operator method is a gradient-based operator that uses two 2x2 pixel kernels. Roberts operators are one of the simplest edge detection techniques and have fast calculations. Roberts operators tend to detect sharp edges well. This means that when there is a sudden change in pixel intensity, Roberts operators can best identify these edges, because using a 2x2 matrix kernel, Roberts requires only a small amount of data to be processed. This reduces the consumption of computing resources. While the Laplacian Operator measures the change of gradient in all directions, so it can detect vertical, horizontal, and diagonal edges. This makes it a good choice for detecting different types of edges in images. Laplacian is not only useful for edge detection but also useful in finding changes in brightness levels. It can help in identifying angles, curves, and other features in the image. Laplacian operators are sensitive to small changes in intensity, so they can reveal fine details in the image. In some applications, Laplacian can be used to enhance images by emphasizing certain features.[13]. The roberts operator takes the diagonal direction for direction determination in the calculation of gradient values[14],[15]. The laplacian operator method, also called the second derived operator, is a method that is more sensitive to noise, can produce double edges, and detect edges more accurately, especially at steep edges[16], [17].

The test method used to compare edge detection is to compare the quality produced in edge detection, calculating MSE (Mean Square Error) and PSNR (Peak Signal to Noise Ratio) values. The number of white pixels is the pixels obtained from the edge detection results, the more white pixels, the more edge detection is produced[18].

The purpose of this study was to compare the Roberts and Laplacian methods to compare which method displays the best results for edge detection on manga leaf objects, and find out the best results based on the calculation of MSE and PSNR values.

## 2. RESEARCH METHODS

The stages of research include research steps from beginning to end. The steps will be described in detail and will be depicted in chart form in **Figure 1**.

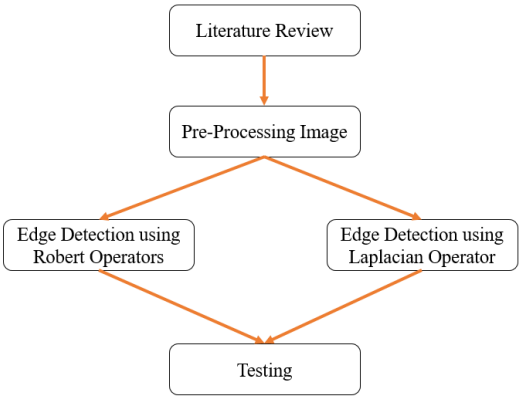



**Figure 1. Stages of research**

The steps taken in the research stage will be explained in the following stages.

1. Literature Review

At this stage, the main focus carried out is to review the results of previous research related to the proposed research. In previous studies, detecting objects using Roberts and Laplacian operators was still not optimal, because it produced pixels with fewer white colors. Thus, it still needs to be developed or improved on the edge detection system to make it more optimal[16],[17].

2. Pre-Processing Image

After the image is collected, the image preprocessing stage is then carried out to equalize the pixel size of each image object. The application used for preprocessing is Adobe Photoshop 2020. The pixels in each image are made into (1000x278). From the images that have been collected, Resize, and Rotation are carried out in accordance with the data needed when testing image detection into edge detection applications so that the resulting data is appropriate.

3. Edge Detection using Roberts Operators

Robert's operator is another name for the differential technique in the horizontal direction and the differential in the vertical direction, with the addition of the binary conversion process after the differential[19], [20]. Binary conversion is used to even out the black and white color distribution. The Roberts operator uses two $2x2$ kernels ($G_x$ and $G_y$) with gradient magnitudes (G) based on **Equation (1)** and **Equation (2)**.

$$G_x = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} G_y = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} \quad (1)$$

$$G = \sqrt{I * {G_x}^2 + I * {G_y}^2} \quad (2)$$

The * operator declares a $2-$dimensional convolution operation and declares an image.

4. Edge Detection using Laplacian Operators

The Laplacian operator (Pierre-Simon Laplace) used transformation techniques in probability theory. This technique was invented by Leonhard Euler, a Swiss prolific mathematician in the 18th century. The second derivative operator is also called the Laplace operator. Laplace operators detect edge locations more accurately, especially on steep edges[21], [22]. The Laplacian operator uses a 3 x 3 kernel. In this operator there are various forms of kernels that are used as needed. Here is the kernel used in this study in **Equation (3)**.

$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix} \quad (3)$$

5. Testing

In the testing stage, a comparison will be made between the Robert and Laplacian methods by comparing the quality produced in edge detection, and a comparison will be made using the MSE and PSNR

functions. MSE is a metric used to measure the extent of the difference between two images or between the original image and the processed image. If the smaller the MSE value, the better the image repair procedure used. By this point that the image quality after undergoing noise correction is almost similar to the original image quality. While PSNR is the opposite, if the PSNR value is greater, the quality of the original image will be more similar to the quality of the resulting image. **Equation (4)**, is the formula used to calculate the MSE value.

$$MSE = \frac{1}{MN}\sum_{x=1}^{M}\sum_{y=i}^{N}(S_{xy} - C_{xy})^2 \quad (4)$$

Information:

$MSE$ = Mean square error value of the image.

$M$ = Stego image length (in pixels).

$N$ = Stego image width (in pixels).

$S_{xy}$ = Pixel value of the cover image.

$C_{xy}$ = Pixel values of stego image.

After obtaining the MSE value, the PSNR value can be calculated from the square of the maximum value divided by MSE. Mathematically, the PSNR value can be calculated using **Equation (5)**.

$$PSNR = 10_{log10}\left(\frac{255^2}{MSE}\right) \quad (5)$$

Information:

$PNSR$ = The PSNR value of the digital image.

$MSE$ = The Mean Square Error value of the image.

Test results from edge detection using Roberts and Laplacian operators are presented in the form of tables and graphs to assess the best method of detecting edge image of mango leaves and compare with the results of previous studies.

## 3. RESULTS AND DISCUSSION

The discussion that will be carried out begins with carrying out the image pre-processing process, then carrying out edge detection using the Robert and Laplacian methods. The results obtained after detecting the edge can be used as information among the public or of course the author himself in comparing edge detection of mango leaf images using the Robert and Laplacian Methods.

### 3.1 Pre-Processing Image

The image preprocessing process is carried out on all test image data, the following are the results of image preprocessing from the original camera image into test image data for use in Matlab.

**Table 1. Pre-Processing Image**

| Original Image | Image Preprocessing Results |
|---|---|
|  |  |
| Mango Golek | |
|  |  |

| Mango Harum Masin | |
|---|---|
|  |  |
| Mango Honey | |
|  |  |
| Mango Kuweni | |

### 3.2 Convert Image to Grayscale using Matlab

This stage the image used is entered into the program then converted to Grayscale mode. The images entered into the application have JPG format with RGB mode (Red, Green, Blue) then converted to grayscale mode to facilitate the image processing process at a later stage. The image conversion process using the Roberts method using the matlab application is shown in **Figure 2** below.

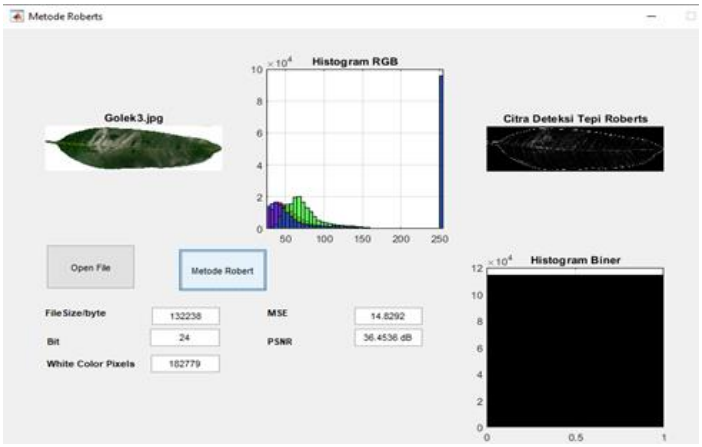
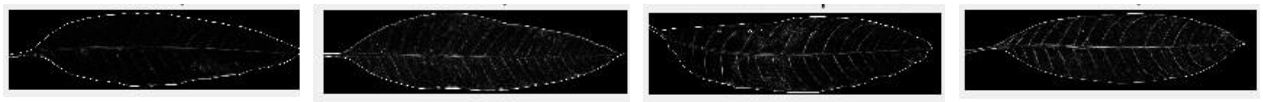



**Figure 2. Matlab view for image conversion using Roberts method**

Edge detection in grayscale images with the Roberts method. The process in the Roberts method in detecting edges in image data by convolution using the Roberts kernel with a 2x2 matrix. The result of convolution using the Roberts kernel **Figure 3**.



(a) (b) (c) (d)

**Figure 3. Results of conversion using Roberts kernel (a) mango golek, (b) mango harum manis, (c) mango honey, (d) mango kuweni**

The image conversion process using the Laplacian method using the matlab application is shown in **Figure 4** below.

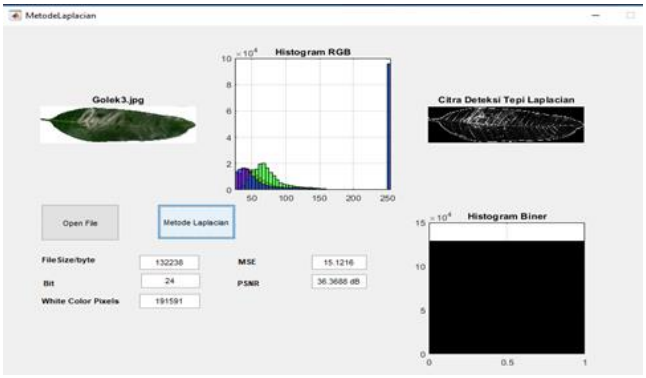
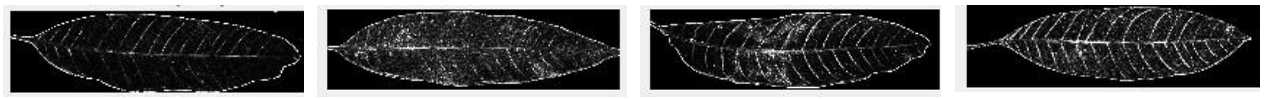



**Figure 4. Matlab view for image conversion using Laplacian method**

The Roberts operator processes to detect edges in image data by convolution it using a Laplacian kernel with a 3x3 matrix. The result of convolution using the Roberts kernel can be seen in **Figure 5**.



(a) (b) (c) (d)

**Figure 5. Results of conversion using Laplacian kernel (a) mango golek, (b) mango harum manis, (c) mango honey, (d) mango kuweni**

### 3.3 Comparison of MSE Values on Roberts and Laplacian Operator Edge Detection

The results of edge detection using Roberts and Laplacian operators using four types of mango leaf objects, namely golek mango leaves, sweet arum mango, honey mango and kuweni mango have been tested and succeeded well. The test used 6 samples from each type of mango leaf used for edge detection. **Table 2** is the result of edge detection using the roberts and laplacian operators in finding MSE values.

**Table 2. MSE Value Test Results**

| Image | Method Roberts | Method Laplacian |
|---|---|---|
| | MSE | MSE |
| Golek1 | 10.6612 | 11.2253 |
| Golek2 | 10.2502 | 10.2444 |
| Golek12 | 10.2580 | 10.1154 |
| Golek22 | 10.2885 | 9.5667 |
| Golek30 | 8.9723 | 7.8577 |
| Golek31 | 10.1948 | 8.8748 |
| ArumManis15 | 12.3889 | 12.4002 |
| ArumManis19 | 13.2682 | 13.5829 |
| ArumManis23 | 13.2060 | 13.3644 |
| ArumManis28 | 13.2982 | 13.6547 |
| ArumManis35 | 12.3646 | 12.8109 |
| ArumManis45 | 12.0374 | 12.4431 |
| Madu3 | 11.3666 | 10.9183 |
| Madu12 | 11.6453 | 11.5063 |
| Madu13 | 11.4135 | 10.7503 |
| Madu15 | 11.8839 | 12.3494 |
| Madu17 | 11.0797 | 10.5845 |
| Madu18 | 11.2947 | 11.3396 |
| Kuweni3 | 10.8634 | 9.7127 |
| Kuweni11 | 10.0903 | 8.8504 |
| Kuweni13 | 10.9394 | 9.7345 |
| Kuweni17 | 10.9957 | 9.4819 |
| Kuweni38 | 10.5795 | 8.1016 |
| Kuweni44 | 11.1390 | 10.9260 |

**Table 2** provides information that the parameter of the MSE value is that the smaller the MSE value (close to 0) indicates that the image quality is getting better. Table II shows the smallest MSE value from 24 data samples for four types of mango leaves. The lowest MSE value is in the Laplacian operator on the mango golek leaf image object with a value of 7.8577. While the Robert operator with the same object, namely the image of mango leaves, golek obtained the lowest MSE value with a value of 8.9723. This shows that the image quality of edge detection using the Laplacian operator produces better result quality than the Robert operator.

### 3.4 Comparison of PNSR Values on Roberts and Laplacian Operator Edge Detection

The results of edge detection using Roberts and Laplacian operators are by finding PSNR values on four types of mango leaf objects, namely golek mango leaves, sweet arum mangoes, honey mangoes and kuweni mangoes have been tested and succeeded well. The test used 6 samples from each type of mango leaf used for edge detection. **Table 3** is the result of edge detection using the Roberts and Laplacian operators in finding the PSNR value.

**Table 3. PNSR Value Test Results**

| Image | Method Roberts | Method Laplacian |
|---|---|---|
| | PNSR | PNSR |
| Golek1 | 37.8868 | 37.6628 |
| Golek2 | 38.0575 | 38.0599 |
| Golek12 | 38.0542 | 38.1150 |
| Golek22 | 38.0413 | 38.3572 |
| Golek30 | 38.6358 | 39.2119 |
| Golek31 | 38.0810 | 38.6832 |
| ArumManis15 | 37.2345 | 37.2305 |
| ArumManis19 | 36.9367 | 36.8349 |
| ArumManis23 | 36.9571 | 36.9053 |
| ArumManis28 | 36.9269 | 36.8120 |
| ArumManis35 | 37.2430 | 37.0890 |
| ArumManis45 | 37.3595 | 37.2155 |
| Madu3 | 37.6085 | 37.7832 |
| Madu12 | 37.5033 | 37.5554 |
| Madu13 | 37.5906 | 37.8506 |
| Madu15 | 37.4152 | 37.2483 |
| Madu17 | 37.7195 | 37.9181 |
| Madu18 | 37.6361 | 37.6188 |
| Kuweni3 | 37.8051 | 38.2914 |
| Kuweni11 | 38.1257 | 38.6952 |
| Kuweni13 | 37.7748 | 38.2817 |
| Kuweni17 | 37.7526 | 38.3959 |
| Kuweni38 | 37.9202 | 39.0791 |
| Kuweni44 | 37.6964 | 37.7802 |

**Table 3** provides information that the parameter PSNR value is that the greater the PSNR value, indicating that the image quality is better or more powerful than the original image. Conversely, the smaller the PSNR value, the worse the image quality. Table III shows the highest PSNR value is in the Laplacian operator on the mango golek leaf image object with a value of 39.2119 dB. While in the Robert method with the same object, namely the image of mango leaves, golek obtained the highest PSNR value with a value of 38.6358 dB. This shows that the image quality of edge detection using the Laplacian operator results in better quality than the Robert operator.

### 3.5 Comparison of Edge Detection on White Pixels for Roberts Operator and Laplacian Operator

The results of edge detection using Roberts and Laplacian operators to find white pixel values in four types of mango leaf objects, namely golek mango leaves, sweet arum mangoes, honey mangoes and kuweni mangoes were successfully tested well using 6 samples from each type of mango leaf used for edge detection. **Table 4** results from edge detection using the Roberts and Laplacian operators to find white pixel values.

This shows that edge detection image quality using the Laplacian operator results in detection capabilities with better results compared to Robert's method.

**Table 4. White Pixel Test Results**

| Image | Method Roberts | Method Laplacian |
|---|---|---|
| | White Color Pixel | White Color Pixel |
| Golek1 | 168668 | 182668 |
| Golek2 | 161334 | 174749 |
| Golek12 | 177844 | 191164 |
| Golek22 | 182779 | 191591 |
| Golek30 | 179661 | 192645 |
| Golek31 | 139544 | 150313 |
| ArumManis15 | 184163 | 189441 |
| ArumManis19 | 155148 | 160196 |
| ArumManis23 | 179014 | 184650 |
| ArumManis28 | 169540 | 175190 |
| ArumManis35 | 176237 | 181611 |
| ArumManis45 | 177411 | 182768 |
| Madu3 | 173408 | 185037 |
| Madu12 | 176852 | 185633 |
| Madu13 | 161481 | 172578 |
| Madu15 | 180157 | 190467 |
| Madu17 | 159983 | 169431 |
| Madu18 | 168148 | 178383 |
| Kuweni3 | 150203 | 156742 |
| Kuweni11 | 140917 | 146747 |
| Kuweni13 | 150039 | 157191 |
| Kuweni17 | 142599 | 149886 |
| Kuweni38 | 133256 | 140298 |
| Kuweni44 | 172275 | 179643 |

Comparison graph of PSNR values in Roberts and Laplacian methods with four types of mango leaves in **Figure 6**.

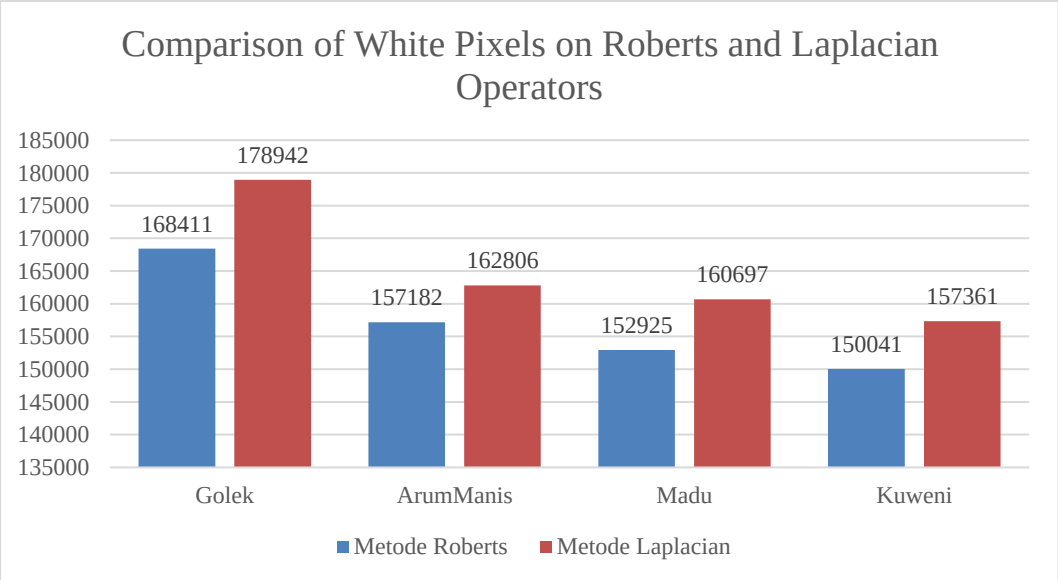



**Figure 6. PSNR Value Comparison Graph**

Based on the data presented in **Table 4** and **Figure 6** is a comparison of white pixel values using the Roberts and Laplacian operators. In an edge detection comparison using the Roberts and Laplacian operators on mango leaf-type objects to find pixel values, the Laplacian operator produces more white pixels with an average value of 164951.5 compared to the roberts operator produces fewer white pixels with a value of 155889.75. This shows that edge detection image quality using the Laplacian operator results in detection capabilities with better results compared to Robert's method.

This shows that edge detection image quality using the Laplacian operator results in detection capabilities with better results compared to Robert's method.

## 4. CONCLUSIONS

Comparison of edge detection on mango leaf objects with four types, namely golek mango leaves, sweet arum mango, honey mango, kuweni mango using Roberts and Laplacian operators in finding accurate information goes as expected. Based on the results of trials on the mango leaf objects used, a variety of MSE, PSNR and white pixel values were obtained due to differences in the shape and texture of the leaf objects. The Roberts operator produces the smallest MSE value of 8.9723, while the Laplacian operator produces the smallest MSE value of 7.8577. The Roberts operator produces the largest PSNR value of 38.6358 dB, while the Laplacian operator produces a PSNR value of 39.2119 dB. The Roberts operator results in an average white pixel value of 155889.9 while the Laplacian operator results in an average white pixel value of 164951. It can be concluded that Laplacian operators have better capabilities than Roberts operators in detecting edges on mango leaf objects.

## REFERENCES


[1] B. Mirza *et al.*, "Mango (Mangifera indica L.): A magnificent plant with cancer preventive and anticancer therapeutic potential," *Crit. Rev. Food Sci. Nutr.*, pp. 1–27, 2020.

[2] S. Arivazhagan and S. V. Ligi, "Mango leaf diseases identification using convolutional neural network," *Int. J. Pure Appl. Math.*, vol. 120, no. 6, pp. 11067–11079, 2018.

[3] E. Mansyah and A. Sutanto, "Tropical fruit research and development programs of Indonesian Tropical Fruits Research Institute (ITFRI)," in *IOP Conference Series: Earth and Environmental Science*, 2020, vol. 583, no. 1, p. 12013.

[4] N. Pujirahayu, T. Suzuki, and T. Katayama, "Cycloartane-type triterpenes and botanical origin of propolis of stingless Indonesian bee Tetragonula sapiens," *Plants*, vol. 8, no. 3, p. 57, 2019.

[5] A. Mulyanto, R. I. Borman, P. Prasetyawan, and A. Sumarudin, "Implementation 2D Lidar and Camera for detection object and distance based on RoS," *JOIV Int. J. Informatics Vis.*, vol. 4, no. 4, pp. 231–236, 2020.

[6] M. Xu, C. Li, S. Zhang, and P. Le Callet, "State-of-the-art in 360 video/image processing: Perception, assessment and compression," *IEEE J. Sel. Top. Signal Process.*, vol. 14, no. 1, pp. 5–26, 2020.

[7] J. Gu, Y. Shen, and B. Zhou, "Image processing using multi-code gan prior," in *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*, 2020, pp. 3012–3021.

[8] Q. Li *et al.*, "3D map-guided single indoor image localization refinement," *ISPRS J. Photogramm. Remote Sens.*, vol. 161, pp. 13–26, 2020.

[9] D. Darwis, A. Junaidi, and D. A. Shofiana, "A New Digital Image Steganography Based on Center Embedded Pixel Positioning," vol. 21, no. 2, pp. 89–104, 2021, doi: 10.2478/cait-2021-0021.

[10] M. Mittal *et al.*, "An efficient edge detection approach to provide better edge connectivity for image analysis," *IEEE Access*, vol. 7, no. c, pp. 33240–33255, 2019, doi: 10.1109/ACCESS.2019.2902579.

[11] Z. Yu, C. Feng, M. Y. Liu, and S. Ramalingam, "CASENet: Deep category-aware semantic edge detection," *Proc. - 30th IEEE Conf. Comput. Vis. Pattern Recognition, CVPR 2017*, vol. 2017-Janua, pp. 1761–1770, 2017, doi: 10.1109/CVPR.2017.191.

[12] N. I. Z. Rahman, "Relasi sematik pada penamaan jenis-jenis mangga di Indonesia," *Kredo J. Ilm. Bhs. dan Sastra*, vol. 3, no. 2, pp. 322–337, 2020.

[13] X. Xie, S. Ge, M. Xie, F. Hu, and N. Jiang, "An improved industrial sub-pixel edge detection algorithm based on coarse and precise location," *J. Ambient Intell. Humaniz. Comput.*, vol. 11, no. 5, pp. 2061–2070, 2020.

[14] A. Kushwah, K. Gupta, A. Agrawal, G. Jain, and G. Agrawal, "A Review: Comparative Study of Edge Detection Techniques.," *Int. J. Adv. Res. Comput. Sci.*, vol. 8, no. 5, 2017.

[15] P. Fan, R.-G. Zhou, W. W. Hu, and N. Jing, "Quantum image edge extraction based on Laplacian operator and zero-cross method," *Quantum Inf. Process.*, vol. 18, no. 1, pp. 1–23, 2019.

[16] E. Budianita and F. Yanto, "Implementasi Algoritma Canny Dan Backpropagation Untuk Mengklasifikasi Jenis Tanaman Mangga," in *Seminar Nasional Teknologi Informasi Komunikasi dan Industri*, 2019, pp. 13–21.

[17] F. Liantoni and L. A. Hermanto, "Pengembangan Metode Ant Colony Optimization Pada Klasifikasi Tanaman Mangga Menggunakan K-Nearest Neighbor," 2017.

[18] H. Pangaribuan, "Optimalisasi Deteksi Tepi Dengan Metode Segmentasi Citra," *J. Inf. Syst. Dev.*, vol. 4, no. 1, 2019.

[19] O. F. B. Barus, "Penerapan metode robert pada deteksi tepi citra split underwater," *J. MEDIA Inform. BUDIDARMA*, vol. 2, no. 1, 2018.

[20] A. Sharma, R. Dronawat, and A. Jhapate, "Automatic diabetic retinopathy detection using Roberts cross edge detection in

DIP," in *2021 10th IEEE International Conference on Communication Systems and Network Technologies (CSNT)*, 2021, pp. 363–368.
[21] I. Lorencin, N. Anđelić, J. Španjol, and Z. Car, "Using multi-layer perceptron with Laplacian edge detector for bladder cancer diagnosis," *Artif. Intell. Med.*, vol. 102, p. 101746, 2020.
[22] D. Deepa and A. Sivasangari, "An effective detection and classification of road damages using hybrid deep learning framework," *Multimed. Tools Appl.*, vol. 82, no. 12, pp. 18151–18184, 2023.