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COMPARATIVE ANALYSIS OF CANNY, SOBEL, PREWITT AND ROBERTS EDGE DETECTION OPERATORS ON EYE IRIS IMAGES

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Abstract— *The iris is a part of the human anatomy that can be used as a biometric identifier. Data obtained from the iris can be converted into information through iris image processing, and in order to obtain accurate iris pixel results, an edge detection operator is required that can provide detailed and good image quality effects. In this research, a comparative analysis of the Canny, Sobel, Prewitt and Roberts edge detection operators was carried out on iris images. The purpose of performing a comparative analysis of edge detection methods is to compare the detection results of each edge detection operator on iris recognition detected by each operator. The results of the comparison of edge detection methods using precision tables can be analyzed to show that the Canny edge detection operator provides better, smoother and sharper edge results in actual edge point detection, namely 0.357867, while Sobel =, 0.210212, Prewitt = 0.212452 and Roberts = 0.279196. From these results it can be concluded that the edge detection results provided by Sobel and Prewitt are less sharp and sensitive to noise, and the comparison results can vary depending on the intensity of the image and the image object being compared.*

Keywords*: edge detection, image processing, iris.*

Intisari—*Iris mata merupakan bagian anatomi manusia yang dapat digunakan sebagai tanda pengenal biometric. Data yang diperoleh dari iris mata dapat ditransformasikan menjadi informasi melalui pengolahan citra iris mata, dan untuk mendapatkan hasil pixel iris mata yang akurat diperlukan suatu operator deteksi tepi untuk memberikan efek kualitas citra yang detail dan baik. Pada penelitian ini dilakukan analisis perbandingan operator deteksi tepi Canny, Sobel, Prewitt dan Roberts pada citra iris mata. Tujuan dilakukannya analisis perbandingan metode deteksi tepi ini adalah untuk membandingkan hasil deteksi masing-masing operator deteksi tepi dalam pengenalan iris mata yang dikenali oleh masing-masing operator. Hasil dari perbandingan metode deteksi tepi tersebut operator Canny mendeteksi objek dengan jumlah 9865 piksel, sedangkan Sobel sebanyak 2343 piksel, Prewitt 2329 piksel dan Roberts 1700 piksel. Akan tetapi untuk menentukan tingkat akurasi deteksi tepi tidak selalu dengan jumlah piksel yang menjadi parameter yang akurat, perlu dilakukan komparasi hasil perbandingan hasil deteksi tepi tersebut menggunakan metric precision untuk mendapatkan hasil deteksi tepi dengan tepi sebenarnya. Dari hasil perbandinngan dengan*

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menggunakan tabel precision dapat dianalisis bahwa operator deteksi tepi Canny memberikan hasil tepi yang lebih baik, halus dan tajam dalam deteksi titik tepi sebenarnya, yaitu 0.357867 sedangkan Sobel =, 0.210212 , Prewitt = 0.212452, dan Roberts = 0.279196. Dari hasil tersebut dapat disimpulkan bahwa hasil deteksi tepi Sobel dan Prewitt yang diberikan kurang tajam dan sensitive terhadap noise, dan hasil perbandingan dapat berubah sesuai dengan intensitas citra dan objek gambar yang dijadikan perbandingan.

Kata Kunci: *deteksi tepi, pengolahan citra, iris mata.*

INTRODUCTION

Image processing is a field of science which focuses on the manipulation and analysis of visual images to obtain information or improve the quality of the image. Image processing is used in various fields, including computer science, such as computer vision, remote sensing, medicine, robotics, and so on which are designed to change, analyse, and extract information from digital images [1]. In the image processing process, to detect an object you can use edge detection. Edge detection operators can be used in biometric images such as fingerprints, eye retina, iris, voice recognition, hand gestures, etc. The iris of the eye is a part of human anatomy that can be used as a biometric identifier[2]. Iris is an accurate and stable biometric identification that is often used [3]. Data obtained from the iris can be transformed into information through iris image processing [4], and to get accurate iris pixel results, an edge detection method is needed to provide detailed and good image quality effects, namely by conducting a comparative analysis of edge detection methods such as Canny, Sobel, Prewitt and Roberts.

Edge detection aims to improve unclear image details by increasing brightness, converting to grayscale, or applying filters in an effort to smooth object details [5]. The iris can be used as a reliable biometric identification method because the iris of the eye has a unique and stable texture [6].

Canny edge detection operator is an edge detection technique developed by John F. Canny in 1986. Canny detection is a technology used to extract useful information from various visual objects [7]. This operator has very good detection results in reducing noise and the resulting edge detection results are very sharp and clear [8].

Previous research also carried out comparisons of edge detection analyses such as Sobel, Prewitt, and Roberts. The Sobel operator is an operator used for edge detection in image processing. The Sobel operator is capable of identifying significant changes in image pixel intensity [9]. In the Sobel operator, the edge detection process is carried out through convolution of the image using two kernels (convolution matrices), specifically one kernel to detect changes in the horizontal direction and another kernel to detect changes in the vertical direction. The results of both convolutions are then used to calculate the gradient or rate of change of pixel intensity [10].

The Prewitt operator is an image processing operator that is used to detect edges by using a convolution matrix to produce changes in pixel intensity that indicate edges in the image[11]. The Prewitt operator and the Sobel operator are almost identical, using two kernels to detect edges in the horizontal and vertical directions, although both are almost identical. Prewitt and Sobel each have their respective advantages. Namely, the Prewitt operator's kernel weight is simpler (-1.0, 1), making operations on convolution simpler than Sobel. The Sobel operator, on the other hand, is more effective in detecting diagonal lines or edges that are not completely horizontal or vertical.

This research also compares the results of Roberts' detection, namely the edge detection operator which was first developed and uses a 2 X 2 kernel in the process of calculating the intensity difference between two adjacent pixels in the image[12]. The Roberts operator also has two directional versions, namely horizontal and vertical directions. Although the Roberts operator has similarities with the Prewitt and Sobel operators, it has limited advantages compared to the Prewitt and Sobel operators in modern image processing. The aim of conducting a comparative analysis of this edge detection method is to compare the detection results of each edge detection operator in iris recognition through the number of pixels recognised by each operator

MATERIALS AND METHODS

Edge detection is a process that produces image edge boundaries of highlighted objects so that they are clearly visible, which is used in image processing to recognize objects[13]. The edge detection operator used in this research is to analyse the comparison of Canny, Sobel, Prewitt and Roberts edge detection operators on iris images.

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A. Canny Operator

The canny operator in the edge detection process uses a Gaussian filter to reduce noise and false edge detection. [14].

The Canny kernel matrix is as :

1. Canny kernel matrix on convolution for horizontal edge detection (Gx) :

$$\begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix}$$

2. Canny kernel matrix on convolution for vertical edge detection (Gy) :

$$\begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix}$$

The Canny Edge Operator formula as :

1. Smoothing with a Gaussian filter :

$$G(x,y)=2\pi\sigma^2 1 e^{-(x^2+y^2)/(2\sigma^2)} \quad (1)$$

Formula description :
$G(x,y)$: Is a two-dimensional Gaussian function. This is the value of the Gaussian function at coordinates (x,y).
σ : It is a parameter referred to as the standard deviation or width of the Gaussian distribution. The value of σ controls how wide or narrow the Gaussian distribution is. The larger σ is, the wider the Gaussian distribution will be
π: This is the constant Pi, which has a value of approximately 3.14159. This constant often appears in the Gaussian function because the Gaussian distribution has a symmetrical circular shape, and Pi is involved in the calculation of the area of the circle.
e: This is the Euler number, which has a value of approximately 2.71828. The Euler number arises because the Gaussian function involves the exponential of the square of the distance from the centre of the distribution.
$e^{-(x^2+y^2)/(2\sigma^2)}$: Is the part of the Gaussian function that contains the exponential of the square of the distance (x,y) of the distribution centre

2. Gradient :

$$G_X=\frac{\partial I}{\partial x} \; G_Y=\frac{\partial I}{\partial y} \quad (2)$$

Formula description :
G : is the gradient vector

$G_x=\frac{\partial I}{\partial x}$: x is the independent variable and $\frac{\partial I}{\partial x}$ is the partial derivative of I to x
$G_x=\frac{\partial I}{\partial y}$: y is the independent variable and $\frac{\partial I}{\partial x}$ is the partial derivative of I against the X coordinate.

3. Gradient Magnitude :

$$G=\sqrt{G_X^2+G_Y^2} \quad (3)$$

Formula description :
G : Gradient
G_x : Components of the gradient in the horizontal axis at the point (x,y)
G_y : Components of the gradient in the vertical axis at the point (x,y)

B. Sobel Operator

The Sobel operator detects edge objects using horizontal edge and vertical edge detection. [15].

The Sobel Edge Operator formula as :

1. Gradient in horizontal direction :

$$G_x=\begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix} * I \quad (4)$$

$G_x=Ix1\cdot(-1)+Ix2\cdot(-2)+Ix3\cdot(-1)+Ix7\cdot 1+Ix8\cdot 2+Ix9\cdot 1$

Formula description :
G_x : Components of the gradient in the horizontal axis at the point (x,y).
I_x : Input image or image intensity at specific coordinates in the horizontal direction.
The coefficients -1, -2, -1, 1, 2, 1 are weights applied to the image intensity values to calculate the contribution of each pixel in the horizontal gradient calculation.

2. Gradient in vertical direction:

$$G_X \begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix} * I \quad (5)$$

$$G_y=Ix1\cdot(-1)+Ix3\cdot 1+Ix4\cdot(-2)+Ix6\cdot 2+Ix7\cdot(-1)+Ix9\cdot 1 \quad (6)$$

3. Gradient Magnitude:

$$G = \sqrt{G_X^2 + G_Y^2} \tag{7}$$

4. Gradient Direction :

$$\theta \arctan = \left(\frac{G_Y}{G_X} \right) \tag{8}$$

Formula description :
θ: Represents the direction or orientation of the gradient vector at a point in the image. Its value can range from 0 to 180 degrees.
arctan: This is the inverse tangent or arctangent function. This function produces an angle whose value corresponds to the ratio of $\frac{G_Y}{G_X}$

G_Y : Gradient component in the vertical direction
G_X : Gradient component in the horizontal direction

C. Prewitt Operator

The Prewitt operator detects edge objects using a convolution matrix[16].
The Prewitt Edge Operator formula as:

1. Gradient in horizontal direction as :

$$G_X = \begin{pmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{pmatrix} * I \tag{9}$$

Convolution formula :

$$G_x = Ix1 \cdot (-1) + Ix2 \cdot (-1) + Ix3 \cdot (-1) + Ix7 \cdot 1 + Ix8 \cdot 1 + Ix9 \cdot 1 \tag{10}$$

2. Gradient in vertuical direction as :

$$G_X = \begin{pmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{pmatrix} * I \tag{11}$$

Convolution formula:

$$G_y = Ix1 \cdot (-1) + Ix3 \cdot 1 + Ix4 \cdot (-1) + Ix6 \cdot 1 + Ix7 \cdot (-1) + Ix9 \cdot 1 \tag{12}$$

3. Gradient Magnitude :

$$G = \sqrt{G_X^2 + G_Y^2} \tag{13}$$

4. Gradient direction :

$$\theta = \arctan \left(\frac{G_Y}{G} \right) \tag{14}$$

D. Roberts Operator

The Roberts operator detects edge objects by using two versions of direction, namely horizontal and vertical directions, in the process of calculating the intensity difference between two adjacent pixels in the image..
The Roberts Edge Operator formula as:

1. Gradient in direction in first diagonal as :

$$G_{Roberts1} = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} * I \tag{15}$$

Convolution formula :

$$G_{Roberts1} = Ix1 \cdot 1 + Ix4 \cdot 0 - Ix5 \cdot 0 - Ix8 \cdot 1$$

2. Gradient in vertuical direction as :

$$G_X \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} * I \tag{16}$$

Convolution formula :

$$G_{Roberts2} = Ix2 \cdot 1 + Ix3 \cdot 0 - Ix6 \cdot 0 - Ix7 \cdot 1 \tag{17}$$

3. Gradient Magnitude :

$$G_{Roberts1} = \sqrt{G_{Roberts1}^2 + G_{Roberts2}^2} \tag{18}$$

Comparative analysis of edge detection operators Canny, Sobel, Prewitt and Robert by conducting tests based on the stages of converting images of iris objects in the eye into grayscale and binary. The results of the object conversion are then applied to the detection operator, and the results of determining the iris object in more detail are based on the parameter number of pixels that can be detected by each edge detection operator.

Convert the iris image to the original image in grayscale conversion.:

```
clear;
 RGB = imread('IRIS3.jpg');
 P = rgb2gray(RGB);
 subplot(1,2,1);
```


Accredited Rank 2 (Sinta 2) based on the Decree of the Dirjen Penguatan RisBang Kemenristekdikti No.225/E/KPT/2022, December 07, 2022. Published by LPPM Universitas Nusa Mandiri

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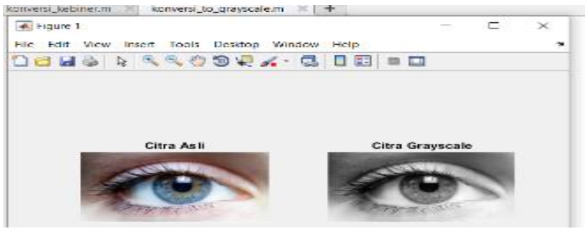
```
imshow (RGB);
title('Citra Asli');
subplot(1,2,2);
imshow (P);
title('Citra Grayscale');
```

The results of executing the coding above will result in converting the original image into a greyscale image. The conversion aims to appreciate the image representation and reduce color dimensions without losing important information. In a greyscale image, each pixel has only one color channel (gray intensity) with a value between 0 (black) and 255 (white). The results of the conversion of RGB iris image to grayscale can be seen in Figure 1 below:



Source: (Research Results, 2024)
Figure 1. Convert Original Image to Grayscale.

Convert the iris image to the original image in binary conversion :

```
j=imread('IRIS3.jpg');
 red=j(:,:,1);
 green=j(:,:,2);
 blue=j(:,:,3);
 gray=0.299*red+0.587*green+0.144*blue;
 bw=im2bw(gray,0.5);
 % bin=imbinarize(gray,'adaptive');

bin=imbinarize(gray,'adaptive','ForegroundPol
arity','dark','Sensitivity',0.6);
 figure, imshow(bin),title('Citra RGB to
biner');
```

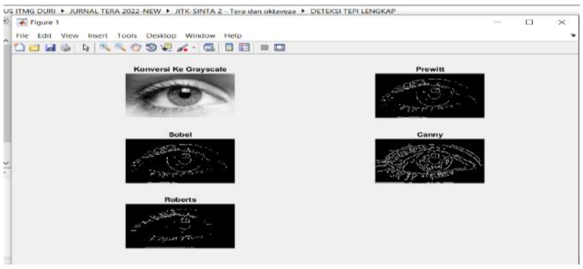
The result of the coding execution above will result in the conversion of the original image into a binary image. The conversion aims to simplify the image representation and focus on the intensity information or basic structure in the image. Binary images have only two pixel values, namely 0 (black) and 1 (white). The results of the conversion of RGB iris image to binary can be seen in Figure2 below :

Source: (Research Results, 2024)
Figure 2. RGB to Binary Image Conversion

Detect iris image edges in the original image using the Canny, Sobel, Prewitt and Roberts operators as :

```
i= imread('IRIS3.jpg');
imshow(i);
i=rgb2gray(i)
BW1 = edge (i,'prewitt');
BW2 = edge(i,'sobel');
BW3 = edge (i,'canny');
BW4 = edge(i,'roberts');
subplot(3,2,1);
imshow(i);
title('Citra Asli');
subplot(3,2,2);
imshow(BW1);
title('Prewitt');
subplot(3,2,3);
imshow(BW2);
title('Sobel');
subplot(3,2,4);
imshow(BW3);
title('Canny');
subplot(3,2,5);
imshow(BW4);
title('Roberts');
```

A comparison of edge detection using Canny, Sobel, Prewitt, and Roberts operators was carried out to evaluate the relative performance of each operator in finding edges in an image.
The results of the comparison can be seen in Figure 3 below.:



Source: (Research Results, 2024)
Figure 3. Edge Detection Operator Comparison Results

Further testing is carried out using the precision metric with the following formula:

$$\text{Precision} = \frac{\text{True Positives}}{\text{True Positives} + \text{false Positives}} \quad (19)$$

True Positives are the number of pixels that actually belong to an edge and are correctly identified by the edge detection operator, while False Positives are the number of pixels that are incorrectly identified as edges.
Pseudocode :

```
% Load citra asli dan ground truth
citraAsli = imread('iris1.jpg');
groundTruth = imread('iris1.jpg');  %
Gantilah dengan nama file ground truth yang
sesuai
```

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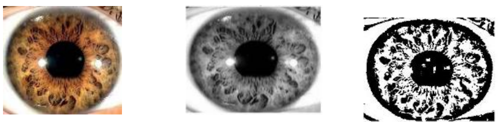
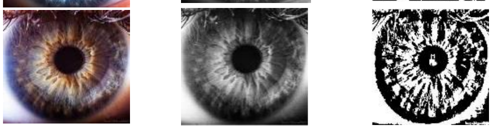
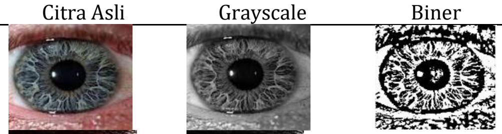
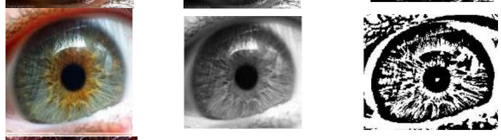
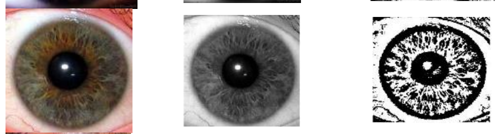
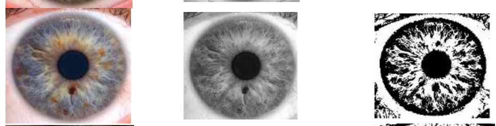
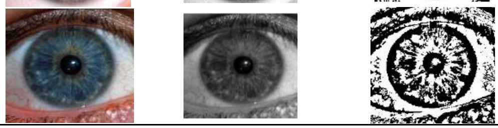
```
% Konversi citra asli menjadi citra grayscale
jika belum
if size(citraAsli, 3) == 3
    citraAsli = rgb2gray(citraAsli);
end

% Lakukan deteksi tepi dengan operator Canny,
Sobel, Prewitt, dan Roberts
edgesCanny = edge(citraAsli, 'Canny');
edgesSobel = edge(citraAsli, 'Sobel');
edgesPrewitt = edge(citraAsli, 'Prewitt');
edgesRoberts = edge(citraAsli, 'Roberts');

% Konversi citra ground truth RGB ke citra
biner
threshold_value = 128;  % Nilai ambang batas
groundTruthBiner = im2bw(groundTruth,
threshold_value/255);

% Hitung Precision untuk masing-masing
operator
precisionCanny = sum(sum(edgesCanny &
groundTruthBiner)) / sum(sum(edgesCanny));
precisionSobel = sum(sum(edgesSobel &
groundTruthBiner)) / sum(sum(edgesSobel));
precisionPrewitt = sum(sum(edgesPrewitt &
groundTruthBiner)) / sum(sum(edgesPrewitt));
precisionRoberts = sum(sum(edgesRoberts &
groundTruthBiner)) / sum(sum(edgesRoberts));

% Bandingkan hasil
fprintf('Precision Canny: %f\n',
precisionCanny);
fprintf('Precision Sobel: %f\n',
precisionSobel);
fprintf('Precision Prewitt: %f\n',
precisionPrewitt);
fprintf('Precision Roberts: %f\n',
precisionRoberts);
```

RESULTS AND DISCUSSION

In this research, tests were carried out on iris images by comparing the original, grayscale and binary images and then comparing each edge detection operator, Canny, Sobel, Prewitt and Roberts, which can be seen in Table 1. Comparison of edge detection operators below. :

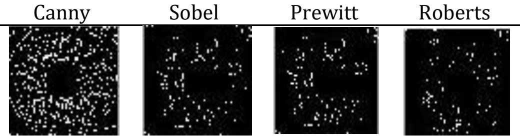
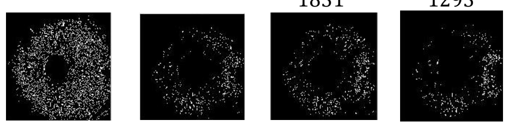
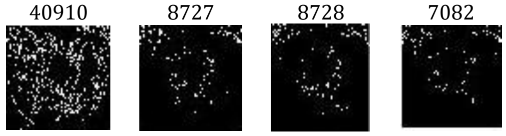
Table 1 RGB To Grayscale and Binary Conversion Table

No	Citra Asli	Grayscale	Biner
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Source: (Research Results, 2024)

The edge detection comparison results of the Canny, Sobel, Prewitt, and Roberts operators show that the best edge detection results can be determined through the number of pixels. The number of pixels is the number of edge detections that can be detected by each edge detection operator that is compared. The results of the number of pixels from each operator can be seen in table 2 below:

Table 2. Edge Detection Operators Comparison Table

No	Canny	Sobel	Prewitt	Roberts
1				
		Number of Pixels		
1a	6718	1841	1831	1293
2				
		Number of Pixels		
2a	40910	8727	8728	7082
3				

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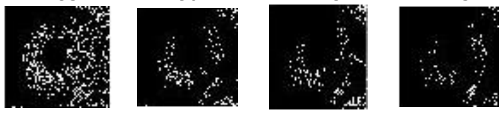
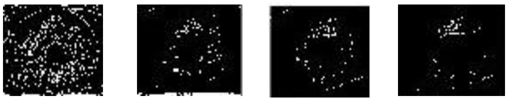
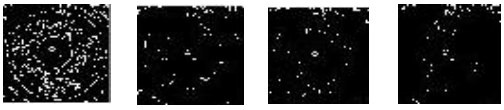
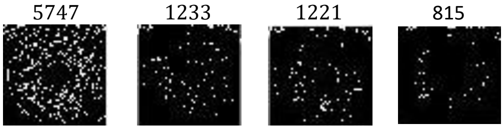
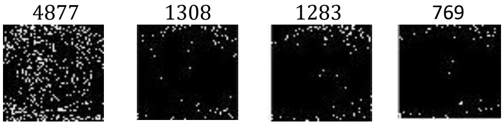
No	Canny	Sobel	Prewitt	Roberts
		Number of Pixels		
3a	6602	1606	1590	1161
4				
		Number of Pixels		
4a	7483	1801	1778	1245
5				
		Number of Pixels		
5a	6317	2267	2251	1498
6				
		Number of Pixels		
6a	6380	1586	1561	1090
7				
		Number of Pixels		
7a	6602	1606	1590	1161
8				
		Number of Pixels		
8a	5747	1233	1221	815
9				
		Number of Pixels		
9a	4877	1308	1283	769
10				
		Number of Pixels		
10 a	7012	1459	1465	888

Source: (Research Results, 2024)

The results of the comparison of edge detection operators, on 10 different samples of iris objects, show that the Canny operator has an edge detection level with the highest average number of pixels, namely 9865 pixels, the Sobel detection operator 2343 pixels, the Prewitt edge detection operator 2329 pixels and the Roberts edge detection 1700 pixels.

The detection test results are also proven on iris image samples using the precision metric, with the following results:

Table 3. Comparasion Table of Precision metrics

No	Edge Operator	Precision
1	Canny	0.357867
2	Sobel	0.210212
3	Prewitt	0.212452
4	Roberts	0.279196

Source: (Research Results, 2024)

From these results, in this study the canny detection operator still has the highest value of 0.357867 in the iris detection results.

CONCLUSION

From the results of the discussion of this research, it can be concluded that the edge detection of the Canny operator with precision table testing, namely 0.35786, has better, smoother and sharper edge results when detecting edge points on real pixels, and the results provided by the Sobel and Prewitt edge detection are less sharp and sensitive to noise. In addition, the Roberts detection operator is sensitive to noise and produces less sharp and coarse edge detection. For further research development, a combination with other metric testing methods such as recall or F1 score can be performed to obtain better results.

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