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Circle Object Detection Of A Moveable Vision Robot Using Hough Circle Method

Herlambang Sigit Pramono[1*]; Soenarto[2]; Putu Sudira[3]

[1]Department of Electrical Engineering Education, Yogyakarta State University, Indonesia
[2, 3]Departmen of Technical and Vocational Education, Yogyakarta State University, Indonesia
[1]Corresponding Email: herlambang@uny.ac.id

ABSTRACT

The object detection system is very important in an automatic mobile robot system. The functions of this system for a navigation robot are to find objects and also at the same time to avoid obstacle. Detecting objects here including the shape, size, and color of object. Various implementations of robot detection have been made in various fields, especially in industrial field. In this study, a circular object detection application system was developed using the Hough Circle Transformation method. Circle object detection system developed in the following stages: Image processing (capturing video from the camera, BRG color conversion to Gray scale, and Gaussian Blur); the application of Hough Circle Transformation; and calculation of diameter and distance of circle objects. The test results show that the system works well to detect circle objects in various variations of the object given. The system can also detect the distance of circle objects with an average error of 8.17%. By contrast, upon measuring circle object diameter, the system can measure with an average error of 5.55%.

Keywords: Robot navigation, Hough circle transformation, object detection, robot vision

Correspondence:
Herlambang Sigit Pramono
Department of Electrical Engineering Education, Yogyakarta State University, Indonesia*Corresponding author: herlambang@uny.ac.id

INTRODUCTION

In a robot that moves automatically, object detection and tracking are very important. With this object detection and tracking, robots can interact as humanly as possible, move automatically, search for objects, and avoid the obstacle[1][2].The input signals from the robot sensor which imitate living creature sense, will provide information to the robot controller, so correct decisions can be made[3]. Cameras are one type of sensors that are closest to the senses of living things widely applied in robot vision navigation system[4]. Robot vision navigation systems are widely used in robots that cannot be operated by humans up close because it can endanger the operator or because it is not possible to allow direct contact between the sensor and the object[5].

Robot vision employs image processing and computer vision technology in its tasks, both for object recognition and for robot motion control. In its implementation, robot vision requires an input/output device such as a Central Processing Unit (CPU) that can process objects in the form of digital images into an output in the form of robotic motion control. As such, the use of robot is still dependent on the CPU device, so that the robot is not mobile and the robot ability is limited. Therefore, replacing CPU device with a minicomputer is an alternative solution to improve the robot's performance. The solution to this problem is to use a single board computer. Object Detection robot performed on Web Streaming System with Transmission Control Protocol/Internet Protocol (TCP/IP), Protocol as a System Mini PC-based Mobile Robot Navigation [6][7]. With the template matching method, robotic camera can read the information shown by the arrow direction image.So, from the reading, the robot can perform motion control based on image information according to the basic conditions of the robot movement, which is moving forward, stopping, turning right, and turning left. Similarly, in previous research, robot's navigation system is driven based on image processing techniques, that is by detecting eyeball movements using the Hough Circle Transformation Method [8].

In image processing, object detection process can be done by separating the foreground (object detected) from the background. Object detection is a process in image processing that create a moving image (video image) [9]. The video image is basically a combination of several images that change each other at a certain time. These interchangeable images are often referred to as frames. The process of changing frames on video images takes place so fast that we do not even notice it. In a video image, the second frame is not always the same (identical) with the first frame, and so are the subsequent frames. This is the rationale for object detection techniques in image processing by analyzing the difference between the first frame, which can also be called the background with subsequent frames.

Hough Transformation method is one of the main methods of image transformation that researchers use to isolate an object in an image by detecting boundaries. In 1962, initially it only aimed to detect a straight line in an image. The main purpose of the transformation was to get a more specific feature.Therefore, classical Hough transformationis known as the most commonly used technique for detecting curve-shaped objects, like lines, circles, ellipses, and parabola. The main advantage with this Hough transformation is that it can detect an edge with a gap at the feature boundary and it is relatively unaffected by the noise around it [10].

Hough Transformation method has been applied in several previous studies. A research conducted by Sa'diyah, R.Rizal Isnanto, and Achmad Hidayatno has been proven that a straight line can be detected using the Line Hough Transform method [11]. The process of transforming from cartesian coordinates into polar coordinates is performed on each pixel of the edge boundary image that has a white gray level[12] [17]. Then the process of straight line detection and reconstruction begins with the calculation and determination of the image midpoint resulting from edge detection as a reference point. This study has success rate of 90%. In addition, other research conducted by Riwinoto has also proven that it is capable of detecting

circles using the Circular Hough Transformation method through video media, where in its implementation, Riwinoto maps the points in the image into the spacebar parameters based on a function that defines the shape that we want to detect. In addition to being successful in detecting circles, experiments conducted by Riwinoto can also display the exact coordinate points [13]. Hough Transformation is a method used to place a shape in an image. In particular, it has been used to extract lines, circles, and ellipses (or other cone-shaped parts) [14]. Another similar opinion is that Hough's transformation is classified as a method for making efficient binary convolution of a model with edge images [15].

Thisstudy only discusses the detection of circular objects. The shape, size, and distance of circle objects have been examinedby using Hough Transformation method. Therefore, a vision robot can find a particular object in the form of a circle and can also detect the size and the distance of the circle object. With the ability to detect size and distance, it can be implemented for automatic robotic navigation systems that highly needed in industrial robots. With the application of navigation system using this method, the robot will detect objects correctly in terms of bothshape and size. In addition, the robot can also predict the distance of objects to the robot, so it can run faster. The accuracy and speed of robot performance is a demand in the robot industry.

RESEARCH METHOD

This section explains the methods and procedures for developing circular object detection software. A step of the detection path of the circle object is:

Analyze the development needs to detect circleobjects, both software, hardware and testing purposes.

Design and create a Graphical User Interface (GUI).

Implement the GUI and test the performance of the results of detecting circle objects.

Evaluating and perfecting the system for detecting circle objects.

2.1 Development of Graphical User Interface (GUI)

Program development and display of GUI learning media applications is supported by Visual Studio 2012 software with C # programming language and EmguCV library. Programs are made for processing digital images in their applications. Circle data information displayed in the form of area, diameter, and circle distance to the webcam. To detect circles accurately, the display of GUI application is equipped with sliders that configure each parameter in the Hough Circle method. The results of the program implementation are presented in Figure 1.

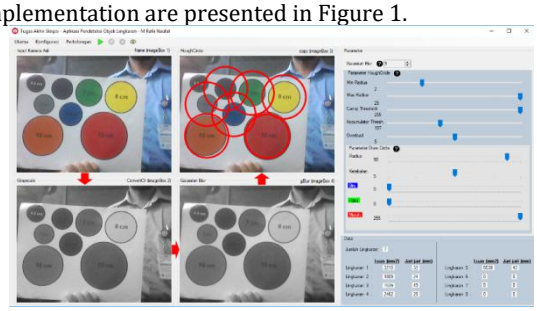

Fig 1. Main Interface of GUI Circle Object Detection Program

2.2 Image Processing

Image processing is one image processing in camera. This process comprises of several stages which include capturing video from camera, BRG color conversion to Gray scale, and Gaussian Blur.

Image processing and object detection process can be done by separating the foreground (object detected) from the background. Object detection is a process in image processing which is a moving image (video). The video image is basically a combination of several images that change each other at a certain time duration. These interchangeable image images are often referred to as frames. The process of changing frames on video images takes place so fast that we donot even realize it. A video image consists of a second frame that is not always the same (identical) with the first frame, and so are the subsequent frames. This is the rationale for object detection methods in image processing by analyzing the difference between the first frame which can also be called the background with the subsequent frames.

An image can be divided into several formats. The color formats provided by EmguCV library include (a) Red, Green, Blue (RGB), with the main colors including red, green, and blue; (b)Cyan, Magenta, Yellow, Key (CMYK), with the main colors being light blue, pink, yellow, and black; (c) Hue, Saturation, Value (HSV), with Hue indicating the type of color, Saturation indicating the purity or strength of the color, and Value, which is also called intensity, indicating color brightness. (d) Gray scale, only has one channel value for each pixel. The color is only gray, but it varies in black at its weakest intensity and white at its strongest intensity; and (e) Binary (Binary Image), commonly called monochrome imagery, only has two colors, namely black and white.

2.3 Detection of Circles and Calculation of CircleDistance and Diameter

Detecting circle objects is done using the Hough transformation method. The Hough transformation method is generally used to detect curve objects such as curved lines, ellipses, parabola, and circles. To distinguish one curved object from other curved objects detected by the Hough Transform method, the Hough Circle Transformation method is used.

Hough Transformation is a technique used to place a shape in an image. In particular, it has been used to extract lines, circles, and ellipses (or other cone-shaped parts). The Hough transform is classified as a method for conducting efficient binary convolution of a model shape with edge drawings. The main objective of a transformation namely to get a more specific feature. Classical Hough transform is created as the most commonly used technique for detecting curve-shaped objects, like lines, circles, ellipses, and satellite. The main advantage with Hough transformation is that it can detect an edge with a gap at the feature boundary and relatively unaffected by noise. Hough transforms follow the path as shown in Figure 2 [14].

OpenCV already provides a function to complete the Hough Circle transformation, namely cv2.HoughCircles (). The circle is represented mathematically as follow (Formula 1):

$$(x - x_{center})^2 + (y - y_{center})^2 = r^2$$

Where (x_{center}, y_{center}) is the center of the circle, and is the radius of the circle.From the equation, we can see that we have 3 parameters, so we need a 3D accumulator for Hough transformation, which will be very ineffective. As such, OpenCV uses a more complicated method, the Gradient Hough Method that uses edge gradient information.

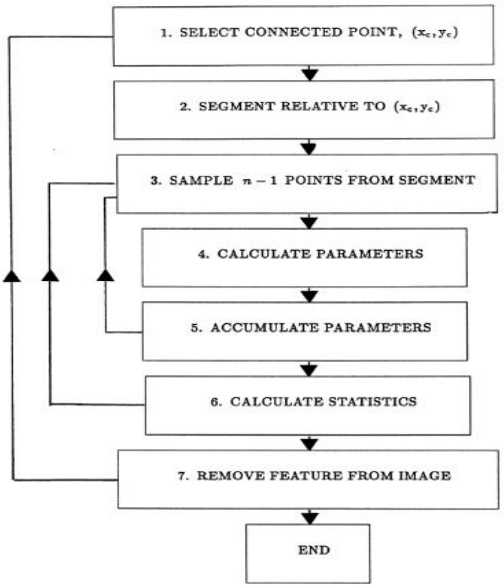

Fig 2. Steps in HoughTransformationMethod

The Hough Circle transformation involves a process that consists of three basic parts, namely [15]:

Edge detection, which aims to reduce the number of points in the search for space for objects. When the edge point is found by edge detection, Hough's transformation algorithm works only at the detected point. Edge detection usually uses Canny edge, Roberts Cross, or Sobel edge detectors, which aim to maximize the signal to noise ratio and localization and can minimize errors in edge detection.

Depiction of a circle, along the edge that has been found with a radius of r. After drawing the circle along the edge line, then we need to look for the area that has the most line crossed, then the area is assumed to be the midpoint of the sought image.

Accumulator is a series of arrays that are used so to support Hough's transformation. This accumulator array has different dimensions, depending on the number of parameters of the object sought. For example, Hough Lines transformation requires two parameters, namely r and θ, and then a two-dimensional accumulator array is formed. The search is then performed on a pixel area by looking for possible relationships or lines. Each possible line is calculated by its r and θ values towards the center. Afterward, the values of r and θ are stored from each possible relationship in the accumulator array. Later, the values in theaccumulator will be mapped into a graph called the accumulator graph with θ as the abscissa and r as the ordinate. The following is an example of the input image and graphic form of the accumulator as shown in Figure 3[16][16].

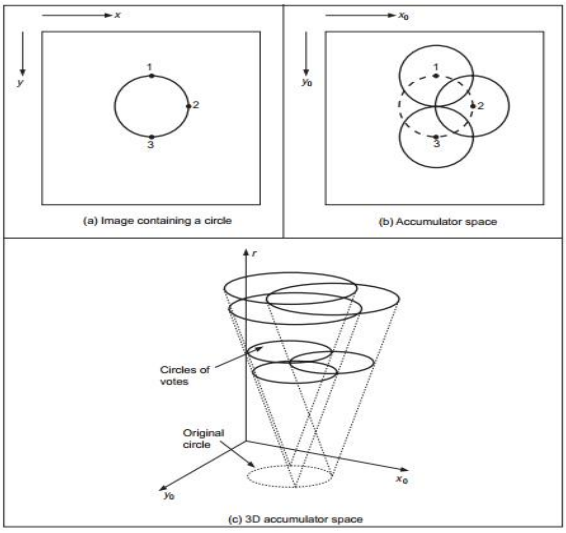

Fig3.Hough Circle Transformation

FINDING AND DISCUSSION

The software implementation is designed to obtain measurement results data, which is calibrated with a real measuring device, to investigate the error detection results. In accordance with the implementation, several investigations were carried out on the results of object detection, object distance detection results, and the results of the detection of circle object sizes.

Testing is carried out in a room with a standard level of workplace lighting conditions which is 300 Lux. Object detection testing is done with various forms of objects such as triangle, square, rectangle, hexagon, and also circles. The testing of circle object detection distance is done by giving variable distances ranging from 100mm to 700mm and errors are calculated by percentage of the difference in distance from the measurement results with the actual distance measured by a standard-length measuring instrument. Testing the detection results of circle size / diameter is done by testing various sizes of circles ranging from 55mm to 120mm. Errors are calculated by the percentage difference in measurement of the circle diameter compared to the actual circle diameter measured by a standard-length measuring instrument.

3.1. Object Shape Detection

Performance test of object shape detection is done by giving various forms of objects such as triangles, square, pentagons, hexagon, and circles. As a distractor, the variation of object color and object size is applied. The test results are shown in Table 1. The table 1 shows that the application can detect circle and the other objects perfectly.

Table 1.Object Shape Detection

Shape	Detection Result
Circle	Detected
Triangle	Undetected
Square	Undetected
Pentagon	Undetected
Hexagon	Undetected

3.2. Distance Detection Test of Circle Object

Testing of the accuracy of distance measurements of circle objects is done by giving some variations distance of objects to the camera, which in this case ranges from a distance of 100mm to 700mm. The results of distance measurements of circle objects as in Table 2 show that

the percentage of errors is directly proportional to the distance of the circle object. The correlation between the error of the distance of the circle object is shown in Figure 4.

Table 2. The Measurement of Circle Object Distance

Detection result	Actual Object Distance (mm)	Detected Distance in Application (mm)	Error percentage (%)
Detected	100	102	2
Detected	150	158	5.33
Detected	200	185	7.5
Detected	250	226	9.6
Detected	300	271	9.67
Detected	350	315	10
Detected	400	352	12
Detected	500	428	14.4
Detected	700	576	17.71

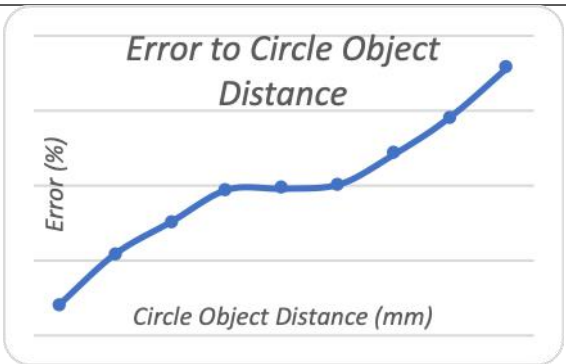

Fig 4. Graph of Correlation of Errors Against Distance of Circle Objects.

From the Graph in Figure 4, the linear regression method is obtained by the equation (1):

$Y=-0.084+0.042X-0.000023X^2$

In which: Y= Error

X= Circle Object Distance

3.3. Detection Test on The Size of Circle Objects

The accuracy of circle object diameter is examined with circle objects of various sizes, in this case ranging from circles 55 mm to 120mm in diameter. Test results according to Table 3 show that the greater the circle objects, the more errors are come up.The correlation between the error of the diameter of the circle object is shown in Figure 5.

Table3.Detection Test on the Size of Circle Objects

Actual circle diameter (mm)	Detected diameter in the application (mm)	Error Percentage (%)
55	54	3.3
68	65	4.4
70	74	5.7
100	106	6
120	130	8.33

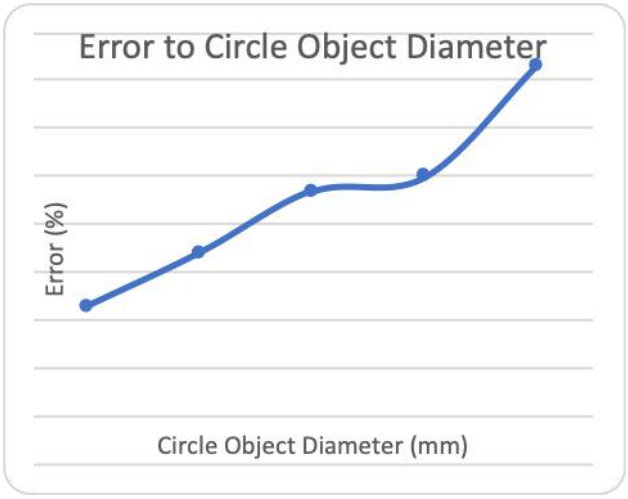

Fig 5. Graphs of Correlation of Errors Against the Diameter of Circle Objects.

From the Graph Figure 5, linear regression is obtained by means of the equation (2):

$Y=-34.41+1.351X-0.0153X^2+ 0.00006X^3$

In which: Y= Error

X= Circle Object Diameter

3.4. Distance and Size Detection Test in Other Objects

Comparing with other detection tests done by the navigation robot, the robot can also detect the distances and sizes of many kinds of objects beside the circle, such as triangle, square, pentagon, and hexagon object. Although, in this study, the detection test in other objects is not possible to detect the shape of other objects. The results of distance test of the others object beside the circle with the other system (not Hough circle method) show that the navigation robot can detect some other objects clearly (most of them more than 90 %).In size detection test,the navigation robot can detect all the size of the objects.

CONCLUSION

The circle object detection system of Hough Transformation Method (Circle method) works well to detect the shape, size and distance of circle objects.However, whenthe results of this object detection system compared with the other detection test results, the result show to us that this method still need more improvement.

The test results are carried out with variable circle object distances from 100mm to 1200mm, the errors obtained are from 2% to 17.71% and can be written with the Error equation (2) for Distance is $Y=-0.084+0.042X-0.000023X^2$. While the results of testing for circle variables from diameters 55mm to 120mm obtained an error of 3.3% to 8.33% and found the error equation (3) for the diameter of the circle object is $Y=-34.41+1.351X-0.0153X^2 + 0.00006X^3$.

In measuring distance and the size of the circle object, the larger the size and the farther the distance to the object is, the more error is come up. So, to make this system perfect in detecting larger size and farther distances, this system needs more improvement and more adjustment by the experts in this field. With the rapid development of sciencenowadays, especially in Robotic field, we need the new good way how to take advantage ofthis method in great way.

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