Analysis and Comparison of Hough Transform Algorithms and Feature Detection to Find Available Parking Spaces

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Abstract Parking space is one of the most critical needs of people's lives, especially in Indonesia. According to the Central Statistics Agency, vehicle growth in Indonesia in the last ten years is 9% per year. Meanwhile, parking needs are being eroded by settlements, shops, and public service buildings. Limited parking lots make it hard for drivers to find available parking spaces. When looking for a parking space, it was causing impacts such as traffic jams, air pollution, causing noise and panic. The intelligent parking system is the solution to this problem. This system can provide information on available parking slots. In this study, parking locations are marked with a circle. If a circle is visible, then a parking lot is available, and if not, then the parking location has been filled by the vehicle. Circle objects in images taken using the camera can be identified by the Hough transformation method or feature extraction. These two methods are compared to measure the accuracy and speed of the process. Experiments and observations on the performance of both methods show that both methods can recognize the location of the available parking slot. The feature extraction method has a better detection speed with an average processing time of 1.1 seconds. The Hough transformation algorithm has an average processing time of 4.1 seconds. Then it can be concluded that the feature extraction method is better applied to the smart parking system.

1. Introduction

Environmental problems that often occur in cities due to urbanization are land availability, clean water quality, air pollution, noise, and waste disposal [1]. One of the factors causing this problem is motorized vehicles. Indonesia, as a developing country with a relatively large population, causes the need for vehicles also to increase. Based on vehicle growth data from the Central Bureau of Statistics Republic of Indonesia in the last ten years in an average of 9%, with a total of 138.6 million vehicles in 2017. With the growth in the number of vehicles such as this causes air pollution, noise, lack of parking space, traffic congestion, and fuel use has increased. Vehicle exhaust gas is the primary source of anthropogenic carbon dioxide (CO₂) in metropolitan cities [2], which is hazardous to public health. Also, emissions and use of vehicle fuel have increased [3].

The lacks of parking lots have a negative impact on the urban area. According to some recent research, it was found that 30% of the causes of traffic congestion were due to motorists going around looking for a parking space [4]. Based on the problem, the need for a system that can provide information on the availability of parking spaces is crucial. Research on the detection of parking space availability has been widely carried out, for example, by detecting vehicles that are in parking slots [5] or detecting markers in slots [6]. This research focuses on detecting the availability of parking slots by
recognizing the circle sign. There are two methods used to detect the circle sign, namely the extraction of shape features and the Hough transformation algorithm.

Hough transformation (HT) was introduced by Paul Hough in 1962 [7]. In the implementation, HT mapped the points on the image into parameter space based on the shape function to be detected. Initially, HT was used to detect lines in an image. However, by Duda and Hart, HT was developed to detect curves such as circles and ellipses. HT is better than Radon Transformation in terms of speed and accuracy. The HT method will be compared with the feature extraction method for detecting circular shapes. The shape is one of the features that can be extracted from an object. This feature can be used to differentiate between objects. One of the parameters that can be used to determine the shape of a circle is eccentricity. Eccentricity has a range of values between 0 and 1. In the detection of a straight line, eccentricity has a value close to 1, while to detect a circle, the value of eccentricity has a value close to 0 [8]. The results of the comparison will get the best solution to detect the circle in the parking lot. A comparison is made by measuring the level of accuracy and speed in recognizing the shape of a circle.

2. Research methodology
The research framework for comparing methods in finding available parking locations is to analyze needs, design miniature parking lots. Miniature equipped with a circle marker in the parking slot. Circle object recognized by HT and feature extraction. Then compare the two methods to find the accuracy and speed of the process. The research framework can be illustrated in Figure 1 below:

![Figure 1. Research Phase.](image)

2.1. Miniature parking design
Miniature parking is made by duplicating the real parking area. At this stage, the parking area is sketched before being designed using wood. This miniature functions as a mock object from the parking area for testing. Figure 2 shows a miniature parking design, and Figure 3 is miniature parking that was built based on the previous sketch. Miniature parking uses ten parking space slots, where each slot is given a red circle. The circle object is used to recognize the availability of parking slots.

![Figure 2. Miniature parking sketch](image)
2.2. **Shape feature extraction**

The human can recognize an object from its shape, color, and smell. The shape is essential to recognize the object. The orientation, size, and position of an object are called features. This feature is very important in recognizing objects. One way to distinguish objects is to measure the value of eccentricity. Eccentricity has a range of values between 0 and 1. Eccentricity is the ratio of the distance between the elliptical focus and the major axis \[9\]. Objects formed from lines have eccentricity values close to 1, while circular objects have eccentricity values is 0 \[8,10\]. The eccentricity formula is shown in equation (1).

\[
e = \frac{b^2}{a^2}
\]

(1)

with \(e\), \(a\) and \(b\) are eccentricity, major axis and minor axis, respectively.

Another parameter that can distinguish between one object with another object is the matric. Matric is the value of the ratio between the area and the circumference of the object. Matric also has a range of values between 0 and 1 like eccentricity. To recognize the matric object has a negation value of eccentricity, which is 1 for circle and 0 for circular. To get the matric value, first, look for the values of parameters \(C\) and \(A\) on the circle. Here, \(C\) is the perimeter of a circle, and \(A\) is the area of a circle. Perimeter calculations are shown in equation (2)

\[
C = \text{radius} \times 2n.
\]

(2)

The area can be calculated by equation (3)

\[
A = r^2 \times n.
\]

(3)

Matric can be calculated with Equation (4)

\[
M = \frac{4n + \alpha}{C}^2
\]

(4)

\(C\) is the circumference of an object in the image with pixel size. \(A\) is the area of the object in the image in pixels. To distinguish the size of one object with another object, it can use the parameters of area and perimeter. The area is the number of pixels that make up an object, while the circumference called the perimeter is the number of pixels surrounding an object.

2.3. **Circle Hough transform**

Hough transform can be expanded by replacing the curve equation in the recognition process. The curve equation can be given in the form of parameters or explicit. In an explicit form, the Hough transformation can be defined by equation (5) \[11,12\].

\[
(x - x_0)^2 + (y - y_0)^2 = r^2.
\]

(5)
3. Results and discussion
This section discusses how to use the application that was built. Then do some experiments to observe and analyze the results of the comparison of the feature extraction method using Hough transformation.

3.1. Feature extraction form
In Figure 4, we display the final results. When the play/pause button is pressed, we can see the recorded parking area. Users can find out which slots are empty and full. There are two columns in the main view, the position column and the status column. The first column displays the parking position in the x and y coordinates in the image. The second column displays full or empty parking status information. The take button is used for snapshots of real-time videos. The image test button is used to test the speed of the parking slot detection process. For testing will be carried out with an empty parking state until the parking lot is filled with cars with different parking locations positions. Figure 4 shows that the condition of a parking slot is full, and nine parking slots are available.

![Figure 4. Feature Extraction Testing Form.](image1)

3.2. Hough transform form
Figure 5 shows how the Hough transformation works to recognize the circle object. The take button functions to take pictures and recognize circle objects to save the coordinates of the object as initial initialization data while the real-time button is used to test in real-time. Coordinate detection results in the "real-time" process are compared with coordinates at initial initialization to find available or filled parking slots. Display Hough transformation work can be seen in Figure 5.

![Figure 5. Hough transformation testing.](image2)
3.3. **Comparison of feature extraction and Hough transformation**

A comparison of shape feature extraction and Hough transformation is assessed from the accuracy and speed of the system process. The following table is the result of a comparison of the two methods.

**Table 1. Comparison of Shape Extraction and Hough Transformation.**

| Number | picture of parking space | Shape Feature Extraction | Hough Transformation |
|--------|--------------------------|--------------------------|----------------------|
|        |                          | Accuracy | Processing speed | Accuracy | Processing speed |
| 1      |                          | accurate | 1.039082          | accurate | 3.955387        |
| 2      |                          | accurate | 1.137883          | accurate | 4.013153        |
| 3      |                          | accurate | 1.164591          | accurate | 4.158512        |
| 4      |                          | accurate | 1.096729          | accurate | 4.203212        |
| 5      |                          | accurate | 1.175512          | accurate | 4.236015        |
| Average|                          |         | **1.1227594**     |         | **4.1132558**   |

Some experiments have been carried out. It can be concluded that the feature extraction method has a speed of 1.1227594 seconds, where the results are better than hough transformation, which has a speed of 4.1132558 seconds.

4. **Conclusion**

Based on the results of the research conducted, it can be concluded that the shape feature extraction method and Hough transformation method can detect circular objects that are used to detect empty parking spaces. Both methods have a good degree of accuracy when detecting circle objects. Feature extraction has a better processing speed in detecting circle objects with an average speed of 1.1227594 seconds per image capture. For further research, it is expected that the system can detect more than ten parking slots, and can make a parking space map from the combined image capture of several different cameras. Further research can be developed in real parking spaces that have more enormous obstacles.
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