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Internet of things for monitoring parking system using optical character recognition

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Abstract — This study aims to build an IoT-based parking system that can help the transportation department. At present, there are several obstacles to parking fee collection in the field, such as the absence of real-time information on four and two-wheeled vehicles, and non-transparent parking fee procedures. In Bandar Lampung City, the implementation of motor vehicle tax levies, being a component of local revenue is still not optimal. Also, on-street parking service is provided using the curb to park motor vehicles, generally guarded by an attendant, at a space designated by the manager. At each on-street parking point, the attendants were facilitated with a tool, known as "Parking Monitor", having camera detection that captures the image of license plates and stores them in a database. The optical character recognition technique was used to annotate the plates and generate data. By using the binary-based Euclidean distance matrix image feature extraction method, it is hoped that it can detect or recognize characters accurately. This study produced a vehicle parking monitoring tool that can be operated from portable gadgets. Furthermore, the tool was simple to use and can help parking attendants as well as the transportation agency to easily monitor parking in the field.

Keywords – IoT, parking tools, segmentation, transportation

I. Introduction

Vehicle traffic congestion is caused by population growth in Lampung Province. According to Lampung Central Bureau of Statistics (BPS) data in 2014, there are 2,471,621 motorcycles and 54,218 cars. In 2020, this statistical report also showed an increase of 4,850 and 170,849 for buses and trucks, respectively. Based on this background, parking lots are needed to accommodate these vehicles [1]. As an effort to solve this problem, the government expanded the car parks but has been unable to monitor all parking lots and taxes.

It has been observed that parking lot providers tend to manipulate taxes and retributions as they are not fully deposited. This corrupt practice is often conducted from the moment parking fees have been paid. Also, the duration of parked vehicles still proves there is manipulation. This is the reason this study examines the transparency of parking lot providers when depositing taxes to the Regional Revenue Bureau (BAPENDA). Based on Law Number 28 of 2009 on Regional Taxes and Retribution, one of the regional retribution types is levied on the public roadside parking lots [2], [3]. According to the layout, parking lots are divided into two models, namely off-street and on-street parking. On-street parking services are generally guarded by an attendant at a location that is managed by Regional Tax and Retribution Management Bureau (BPPRD). This study aims to minimize fraud and corruption by building a parking monitoring system using digital image processing combined with the Internet of Things (IoT) [4].

Digital image processing [5], [6] is performed with mathematical operations using a signal-processing whose input is an image, such as photos or video frames. The output can also be an image or a set of features or parameters associated with the image [7]. In most image-processing techniques, the image is treated as a two-dimensional signal with the application of a standard signal-processing method [8]. This study focused on the parking area, in which the data on the license plate [1], [9], the vehicle type, as well as entry date and time are captured [10]. Furthermore, when the vehicle leaves, the system performs a detection to

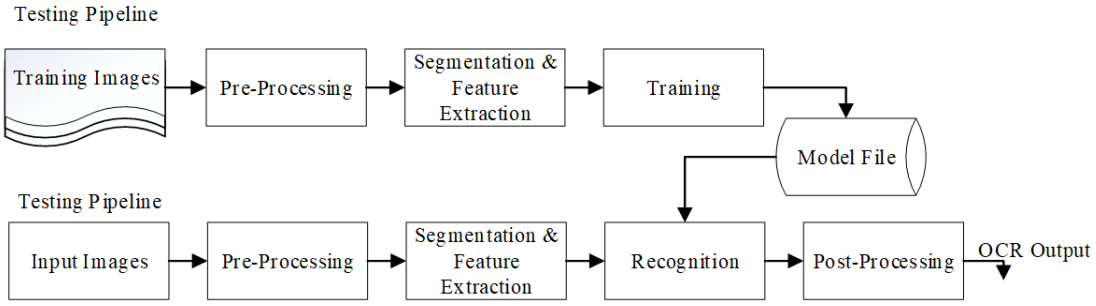

Fig. 1. OCR process flow.

match its plate and provides parking information [2]. Specifically, the system provides the parking [7], [8], [11] manager with a real-time summary of the parking report [10]. So far, vehicle plate detection rarely uses segmentation and feature extraction and is more likely to be typed manually by an operator. In this research, researchers are trying to do recognition through segmentation of vehicle plate images. This can be done with the help of the Internet-based technology and other things through the network.

II. Study Method

Optical character recognition (OCR) [7], [12] is a process of converting text images into a machine-readable format (the flow process is shown in Fig. 1). For example, when a form or receipt is scanned, the computer saves it as an image file, but a text editor cannot be used to edit, search, or count the words [1]. However, OCR can be used to convert the image into a text document with its contents stored as text data. Therefore, OCR can be defined as a process of detecting and reading text from images through computer vision [10]. This enables natural language processing algorithms to decipher the text and make clear what the document conveys. Additionally, the text can be easily translated into multiple languages, making it easy to be interpreted by various individuals. It is important to note that the OCR [13] is not only limited to text recognition from document images, it can also use computer vision [14] and NLP to detect text from supermarket product names, traffic signs, and even from billboards, thereby making it an effective translator and interpreter [15].

This indicates that by training several fonts, more possible character types can be recognized on modified motor vehicle plates.

A. Feature Extraction

There are two main methods for extracting features in OCR:

1) In the first method, the algorithm for feature detection defines a character by evaluating its lines and strokes.
2) In the second method, pattern recognition works by identifying the entire character.

We can recognize a line of text by searching for white pixel rows that have black pixels in between. Similarly, we can recognize where a character starts and finishes. Next, we convert the image of the character into a binary matrix where white pixels are 0s and black pixels are 1s as shown in Fig. 2.

Then, by using the distance formula in (1), we can find the distance from the center of the matrix to the farthest.

$$d = \sqrt{(y_2 - y_1)^2 + (x_2 - x_1)^2} \quad (1)$$

B. Flow Process

This study identified vehicle license plate numbers at the entrance and exit of the parking area under five phases, namely (i) Shooting, (ii) Pre-processing, (iii) Processing, (iv) Segmentation Results, (v) The database recorded is displayed on the Internet. Process details are described in Fig. 3.

Fig. 2. Binary matrix image.

C. Pre-processing

The flowchart of pre-processing was designed to obtain uniformity of images in order to facilitate the next process, which was conducted after the system executed the image capture process. This aims to obtain the plate's shape, which begins with capturing the original image and then converting the RGB image into gray. Furthermore, it helps to facilitate the next process, which is image edge recognition. In this phase, the image that has been converted into gray was subjected to edge detection containing objects. The edge detection [16] type used in this system was Canny Edge, and the value of the image was binary, which is 0 or 1.

A morphological process was further performed to remove noise lines or objects, hence the output is

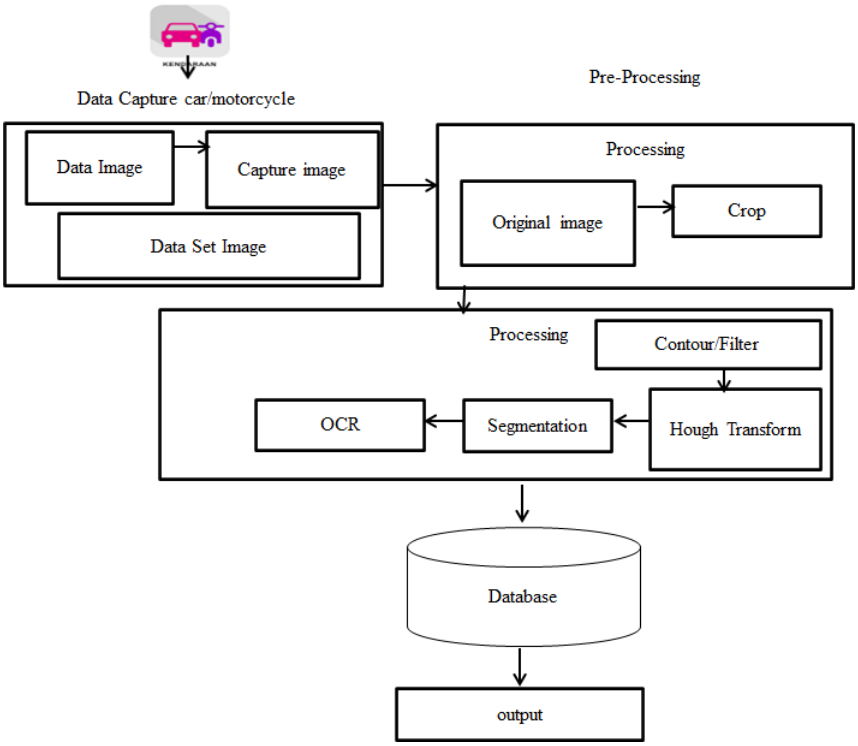

Fig. 3. Segmentation and feature extraction.

only in the form of a vehicle plate. It is important to mention that there are four steps in this process, namely, bwareaopen, melting, charging, and erosion. In the next stage, the segmentation process was conducted with Hough Transform, which is the technique or method for obtaining the image features. This method can be used to improve the object's quality from the previous one by using the majority sound to determine the corresponding parameter value. Several different formulas were applied in Hough's transformation, depending on the type of object being searched. For example, it can be used to search for a line object that looks straight and easy for the next angle detection process, as well as to remove the object attached to the plate.

Additionally, the angles on the license plates were detected using the Harris Corner method, which indicates the plates were a perfect rectangle. This method produced consistent image values even when they have undergone rotation, scaling, lighting variations, or contained noise. To carry out this process, the following steps are taken:

(i) Convert binary image to grayscale. In this context, the Hough Transform's [17] output was binary images, therefore they need to be converted into grayscale.
(ii) Calculate the gradient of the images.
(iii) Calculate the horizontal and vertical gradient values of the images with convoluted grayscale using the Prewitt [18], [19] kernel.
(iv) Compute the sub-values, in this aspect, after obtaining the gradients, the next step is to calculate each derived pixel.
(v) Convolution with Gaussian filters, performed between the derived matrix and the gaussian filter matrix to determine the sum of derived product values for each pixel using the Gaussian equation and filter.

D. Segmentation Process

The object's segmentation process was performed after obtaining a license plate image that has been cut in the pre-processing stage [6], [14]. The process helps to detect the colors in the image, hence the system can recognize the vehicle type based on the color obtained. In this scenario, the RGB to YCbCr was previously obtained in the form of a plate in the pre-processing stage, then the system uses the YCbCr color space to detect colors on the plates because it is easier to limit or threshold its values in the plate shape image [20]. The YCbCr color space consists of two elements, namely Y as the lighting component, used to represent RGB colors while Cb and Cr as chromance, were used to represent hue and saturation. This means the YCbCr colors can be obtained by using RGB colors. When Cb and Cr were averaged, the color of the changed image was also averaged from the values of the Cb and Cr components.

In this process, the mean was performed two times, the first was for each column in the matrix, while the second was for all columns. Consequently, the obtained values of Cb and Cr were real numbers, indicating that they are in the range of black Cb and Cr values. This simply implies the plates can be recognized by the system as private vehicles. It is important to note that

this process was performed in the range of Cb and Cr values created according to the system calculations.

III. Result

This section discusses the system workflow and the hardware design.

A. System Workflow

The on-street parking service [3], in which motorized vehicles are parked on sidewalks, is generally manned by attendants whose parking spaces are designated by the manager [10], [21], [22]. At each on-street parking lot, the attendants were equipped with a "Parking Shaft" tool with camera technology capable of capturing images of motor vehicle license plates and storing them using the OCR techniques [23]. The study aims to design a system and produce a vehicle parking monitoring device in the form of a portable gadget called the "Parking Shaft" that can be easily used by parking attendants and the Transportation Agency to monitor parking [24] in the field. When a vehicle enters, the system immediately captures [15] its information recorded on the license plate as well as the entry date and time. After the vehicle leaves, the system performs cheating to match its plates and then provides parking information. Additionally, the system provides a real-time recap of parking reports and data to parking [11] managers and the Department of Transportation.

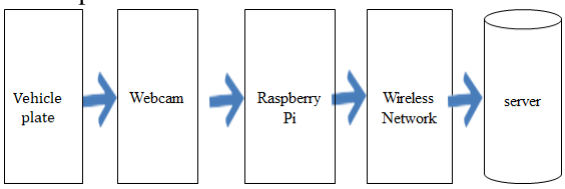

Fig. 4. Hardware design.

B. Hardware Design

The description of the hardware design used was shown in Fig. 4. Two communication media were used, namely a USB cable for connecting the webcam to the Raspberry Pi [25] and a Wi-Fi network for connecting the Raspberry Pi to a laptop/server that functions as an image processor using software. The communication quality on the Wi-Fi network [25] was measured during the license plate detection process [26], [27].

The function of each block is as follows:

(i) charge coupled device (CCD) camera module: This is a digital camera module with a CCD sensor type used to detect vehicles entering the parking lots [2]. The sensor on the camera converts each cell's light, which is an image into electrons. Furthermore, the value was sent to a chip via an analog-to-digital converter that converts each pixel value into a digital value [15].
(ii) Single board processor (Raspberry Pi) [25] is a single-board circuit (SBC) that functions as a processing unit [2] or data processor sent from the CCD camera module in the form of digital value data of an image.
(iii) GSM/GPRS modem: This module sends information or data packets processed from SBC through the GSM/GPRS network to the data storage system.
(iv) TFT LCD: This monitor display unit that shows the graphical representation on the screen.

It is important to note that this mobile web-based parking monitoring application can be accessed with smartphones via a web browser [28]. The system was equipped with a camera to monitor and capture image data. Furthermore, it can keep daily records for easy calculation of parking income through embedded algorithms and queries. The several modules in the system include:

(i) Dashboard module.
(ii) Entrance parking module, which records entry vehicle plate data.
(iii) Exit parking module that records outgoing vehicle plate data.
(iv) The administrator module manipulates the data by editing or deleting, processes the data, and calculates parking costs.

C. Web-based Parking Monitoring Application

The web-based parking monitoring application was operated online by logging in as an administrator on the parking shaft using the address on display. This user login page has several levels, such as administrators and operators.

1) User Login Page

This is where clients log in to the application as real users.

2) Entrance Parking Module

On this Entrance Parking Module page, users are able to obtain vehicle data through unique numbers on the vehicle plate. This is because the system automatically records dates and times in hours, minutes, and seconds, and then records image data on the database by clicking the "Save" button. Also, the system provides information as to whether it can store data. This page is shown in Fig. 5.

3) Exit Parking Door Module

On this Exit Parking Module page, users are able to check detected vehicles by inputting the license plate number. After the data is found, the system checks the time to determine how long the parking time is, then it automatically calculates the parking fee.

4) Administrator Module

In this module, administrators and operators are able to manage existing parking vehicle plate data. For example, the admin can delete data and reset the total revenue from the previous day. Also, operators can identify the amount of daily income from parking lots. It is important to note that the system was equipped

Fig. 5. Capture plate image.

Fig. 6. Fee calculation.

with a Data Backup menu and Data Delivery Facilities in order to send financial reports to the central server. The process of this module is shown in Fig. 6.

IV. Discussion

From the data analysis results, it can be concluded. Firstly, OCR was used to detect plate numbers based on a pattern recognition process through binary vectors to achieve better segmentation results. Furthermore, the pattern recognition process has several stages, such as i) the input stage, where the images are captured into the program, ii) The pre-processing stage, where the images are converted to grayscale and cleansed from noise, and iii) The feature extraction phase entails the following, a) the using of OCR to convert the data into a binary image. b) Line and character segmentation, a method based on the proximity of the training data to the test data. c) Post-processing, which involves success evaluation by calculating the accuracy value. Secondly, the plate number recognition accuracy level using OCR was 87 %. Also, from the 100 test data, the number and letter detection accuracies were 92.75 % and 93.92 %, respectively.

V. Conclusion

The results of a vehicle number plate identification system designed using Raspberry Pi have been tested with light parameters,test time based on angle, distance, and camera height in a parking retribution area. The vehicle plate recognition model uses the Euclidean distance algorithm to detect characters and letters on the plate with an accuracy of up to 87 %. According to the system architecture, the camera was able to detect license plates with the help of the OCR algorithm used as a component to calculate parking fees and report them to the regional revenue department.

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