DESIGN AND DEVELOPMMENT OF AUTOMATIC DOORSTOP AT TELKOM INSTITUTE OF TECHNOLOGY SURABAYA SYSTEM BASED ON IOT AND IMAGE PROCESSING

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***Abstract*— Telkom Institute of Technology Surabaya, which currently relies on a conventional system with the main issues being lack of security and efficiency in managing incoming and outgoing vehicles. The proposed solution involves the development of an automatic gate barrier system that integrates RFID technology, digital image processing, and Optical Character Recognition (OCR). In this effort, an Internet of Things (IoT) device connected to a website was developed to assist parking attendants in scanning Student ID Cards and vehicle license plates. The results of this research show that the IoT system and sensors function well, allowing the gate barrier to operate accurately as vehicles approach. To measure the system's performance in various situations, a total of 40 experiments were conducted at the entrance gate and 40 experiments at the exit gate. Variations in time (daytime and evening), location (indoors and outdoors), and lighting conditions (dim, bright, and dark) were tested at each gate. Image processing using OCR methods was able to detect vehicle license plates with a reasonable level of accuracy, reaching around 90% at the entrance gate and 80% at the exit gate. The connected website facilitates data monitoring and provides features for parking access verification, such as editing, deleting, and registering Student ID Cards. The implementation results of this automatic gate barrier system have successfully enhanced parking efficiency and security at Telkom Institute of Technology Surabaya. (*Abstract*)**

Keywords— Automated Parking, Gate Barrier System, IoT Technology, Optical Character Recognition (OCR)

I. INTRODUCTION

The gate barrier is an object intended to provide access for vehicles to enter and exit a parking area [1]. In some places, manually operated or conventional gate barriers are often found [2] [3]. This leads to vehicle queues at the parking area entrance. The gate barrier system at the Telkom Institute of Technology Surabaya still employs a conventional gate barrier system for its parking services, resulting in a lack of security and efficiency for vehicles entering or exiting the Telkom Institute of Technology Surabaya premises. The parking system at the Telkom Institute of Technology Surabaya can be considered poorly managed, both in terms of convenience, comfort, and efficiency, especially for the academic community of the Telkom Institute of Technology Surabaya. Without proper management and development of a better system, new problems related to vehicle security can arise.

There are several factors causing these issues, such as the lack of driver identity and vehicle registration information, as well as the continued use of human operators to check vehicle documents and driver identities, leading to inefficiencies. If not addressed promptly, the consequences for the Telkom Institute of Technology Surabaya premises include a lack of security for parked vehicles. To assist security personnel, an automated parking access and exit management system is needed, which can reduce the reliance on security personnel for gate barriers. By implementing methods such as Optical Character Recognition (OCR) for license plate recognition and Internet of Things (IoT) technology, specifically Radio Frequency Identification (RFID) for scanning Student ID Cards (KTM) on the automated gate barrier system, an effective solution can be achieved to address the aforementioned problems.

II. METHODS

A. Flowchart

In the flowchart, this system will demonstrate how the automatic barrier gate system works at the entrance, starting from KTM scanning to the opening of the entrance barrier gate. In the flowchart of this entrance barrier gate system, it begins with the condition of no vehicles present. When a vehicle arrives and is heading towards the campus, the driver scans the KTM using the RFID Reader. If the KTM is registered in the database, the webcam captures an image of the vehicle's license plate, which is then sent to the database. Following this, the barrier gate will open, and the Ultrasonic sensor (HC-SR04) will detect whether the vehicle has passed through the gate or not. If it's detected that the vehicle has passed the gate, the servo motor will automatically close the gate.

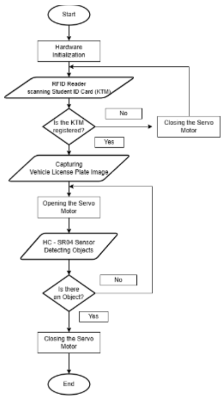

Figure I. Entrance Gate Flow Diagram

In this system flowchart, it will illustrate how the automatic barrier gate system works at the exit door, starting from KTM scanning to the opening of the exit barrier gate. In the flowchart of this exit barrier gate system, it begins with the condition of no vehicles present. When a vehicle arrives and is exiting the campus, the driver scans the KTM using the RFID Reader. If the KTM is registered in the database, the webcam captures an image of the vehicle's license plate. Following this, the system validates the license plate number against the records from the time of entry. If they match, the barrier gate will open, and the Ultrasonic sensor (HC-SR04) will detect whether the vehicle has passed through the gate or not. If it's detected that the vehicle has passed the gate, the servo motor will automatically close the gate.

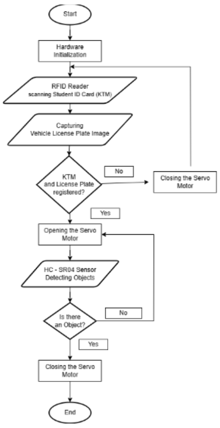

Figure II. Exit Gate Flow Diagram

B. Diagram Block

A block diagram is a graphical representation used to depict a system or process by breaking it down into several interconnected sections. Each block represents a function or task performed within the system and is connected by lines or arrows that indicate the flow or interaction between blocks. The purpose of a block diagram is to facilitate the visualization of the structure and functions of a system, aiding in system design, analysis, and improvement. Block diagrams can be used in various fields, including engineering, electronics, manufacturing, and systems engineering.

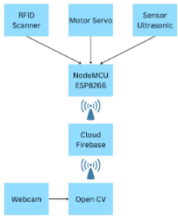

Figure III. System Block Diagram

In the system block diagram, it explains how the system design works to interconnect and communicate with each other, resulting in a process that can be implemented. The ESP8266 functions as a microcontroller capable of receiving input signals, processing them, and providing output signals according to the programmed instructions [4] [5]. The ESP8266 supplies power to the RFID sensor (RC522), which is used for automatic identification. This sensor reads data, retrieves data, and transmits data without physical contact or touch, typically from barcodes or magnetic cards. The HC-SR04 is utilized to detect vehicles passing through the gate, and a servo motor is employed to open and close the gate. If a vehicle passes the ultrasonic sensor (HC-SR04), the gate will close again. A USB webcam is employed to capture real-time images of the vehicle license plates, which will later be processed using OpenCV.

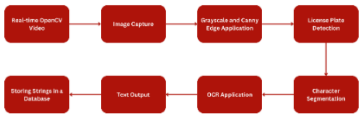

Figure IV. Image Processing Block Diagram

block diagram for License Plate Detection using OCR typically involves several key components that explain the workflow of the system. Here's an explanation of the components that may exist in the OCR License Plate Detection block diagram:

- Real-time OpenCV Video: Captures, processes, and displays video streams in real-time from various sources such as cameras, video files, or network streams. It's beneficial for applications requiring direct image analysis or manipulation from continuous video sources.

- Image Capture: Using a video input device, like a camera, sequentially captures images. Each image frame becomes input for subsequent image processing steps.

- Grayscale and Canny Edge Application: Captured video frames are converted to grayscale, reducing each pixel to a single gray level representing light intensity. Grayscale conversion simplifies subsequent steps. The Canny Edge Detection algorithm is then applied to the grayscale image, detecting sharp changes in pixel intensity, often indicating object contours. The result is an image with well-identified edges for license plate detection.

- License Plate Detection: This component locates the position of vehicle license plates within the image. Common methods involve object detection techniques such as edge detection, region separation, or image processing algorithms to identify potential areas containing license plates.

- Character Segmentation: Once the license plate is detected, the next step is to separate individual characters within the plate. This component divides the license plate into recognizable individual characters.

- OCR Application: The core of the OCR system, this component uses character recognition techniques to convert license plate characters into computer-readable text. Common OCR methods include pattern recognition, neural networks, or rule-based approaches.

- Text Output: The final result of the OCR license plate detection process is the text representing the readable vehicle plate number from the input image. This text can be used for identification or further processing.

- Storing Strings in a Database: The end result of the OCR license plate detection process is the text representing the readable vehicle plate number from the input image. This text can be used for identification or further processing.

The OCR License Plate Detection block diagram provides a visual overview of the system's workflow and the key components involved in the process of detecting and recognizing characters from a vehicle license plate. This diagram helps in understanding how the input image transforms into recognizable text from the license plate number through structured steps in the OCR License Plate Detection system.

C. Design System

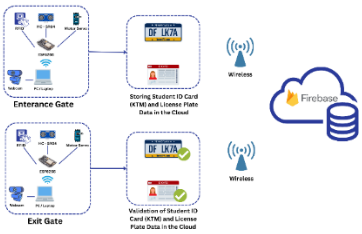

Figure V. Automatic Gate System Design

The system design aims to detect vehicle license plates and perform validation to identify the owner of the vehicle wishing to exit the parking area of the Telkom Institute of Technology Surabaya. The HC-SR04 sensor is intended to detect objects passing through it; if an object or vehicle passes the sensor, the automatic barrier gate will close. The servo motor functions as an actuator to control the gate's movement. The RFID RC522 is used for automatic identification, which involves reading data, retrieving data, and transmitting data without physical contact or touch, using barcodes or magnetic cards, in this case, KTM cards. These three components need to be connected to the NodeMCU ESP8266 to be used and implemented in this research. The NodeMCU ESP8266 serves as a microcontroller board acting as an intermediary to connect these three components and link them to the Arduino IDE for programming on a PC/laptop.

The main focus of this research is the barrier gate. The studied barrier gate is located in the parking area of the ITTelkom Surabaya campus. Data transmission is a stage that occurs after the components are successfully installed within the barrier gate. RFID and USB Webcam are tasked with capturing KTM data and vehicle license plate numbers that are entering the ITTelkom Surabaya parking area. This data is then sent to the exit barrier gate. At the exit barrier gate, validation takes place using the input KTM of the exiting vehicle. This validation includes comparing whether the entered KTM matches the exiting one and whether the vehicle's license plate number matches the one recorded during entry. If both the KTM and the license plate number match the entry records, the barrier gate will automatically open.

III. Result and Discussion

A. Hardware Design

The Hardware Description will explain the modules connected to the ESP8266, which are the RFID (RC522) module, servo motor (SG90), and ultrasonic sensor (HC-SR04). Each sensor module serves a specific function in this research:

- ESP8266 acts as a microcontroller that serves as the central control unit for managing the sensor modules connected to it. It also functions as a wireless communication module, connecting the system to the internet and personal computers (PCs) over the internet network.

- RFID RC522 is a module that detects KTM (Student Identification Card) for access to the parking area of the Information Technology Institute.

- HC-SR04 Ultrasonic Sensor functions to detect vehicles that have passed through the gate. When a vehicle passes the sensor, it sends an input signal to the servo motor to close the gate.

- SG90 Servo Motor is used to automatically move the gate.

Each sensor module has specific pins that will be connected to the ESP8266. Here are the pin functions of some sensor modules that will be connected to the ESP8266.

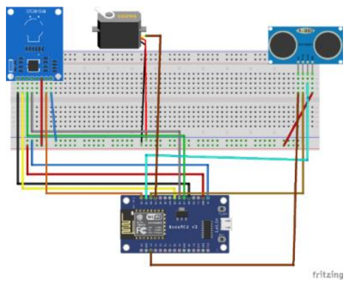

Figure VI. Hardware Implementation

Table I. Table RFID to ESP8266

ESP8266	HC SR04
D2	Trigpin
D1	Echopin
G	GND
VU	Vin

Table II. Table HC-SR04 to ESP8266

ESP8266	RFID RC522

D8	SDA (SS)
D4	SCK
D7	MOSI
D6	MISO
-	IRQ
G	GND
D0	RST
3V	3.3 V

B. IoT Device Testing

Testing of IoT devices includes several sensors: RFID RC522, HC-SR04 ultrasonic sensor, and SG90 servo motor. Can the RFID sensor read the KTM (Student Identification Card) which serves for access entry, exit, and registration to gain entry to the campus area? Subsequently, the ultrasonic sensor is useful for detecting whether a vehicle has passed through the gate or not. If the ultrasonic sensor detects a passing vehicle, it will send a response to the servo motor to close the gate.

Figure VII. Gate Barrier Closed

In the image, it depicts the testing of the IoT device with the gate barrier in a closed state, where the user has not yet placed the KTM on the RFID sensor, and the camera has not detected the vehicle's license plate.

Figure VIII. Gate Barrier Open

In the image, it shows the testing of the IoT device with the gate barrier in an open state because the user has attached the KTM to the RFID sensor, and the camera has detected the vehicle's license plate.

Figure IX. Gate Barrier Closed After Tap

In the image, it demonstrates the testing of the IoT device with the gate barrier closed because the user has attached the KTM to the RFID sensor, and the camera has detected the vehicle's license plate. The vehicle that has passed through the gate is detected by the ultrasonic sensor. Subsequently, the ultrasonic sensor sends data to the system indicating that the vehicle has passed the gate, causing the gate barrier to close.

C. Image Processing Steps

Figure X. GrayScale Processing

In the image, the application of grayscale in the license plate detection system can be performed as a preprocessing step before executing OCR algorithms or other character detection techniques. Here are several steps for applying grayscale in the license plate detection system:

1. Conversion to Grayscale: The first step is to convert a color image into a grayscale image. In a grayscale image, each pixel only has a single gray level representing the light intensity at that pixel location. Conversion can be achieved by taking the weighted average of the red, green, and blue color components at each pixel in the color image.

2. Removing Unnecessary Color Information: In license plate detection, irrelevant color information such as background or other objects can interfere with the character recognition process. Therefore, additional processing on the grayscale image can be done to remove or reduce unnecessary color information. Techniques like thresholding or color-based segmentation can be used to separate the license plate from the background.

3. Contrast Enhancement: After conversion to grayscale, contrast enhancement can be applied to clarify the image content. This can help improve the clarity of license plate characters and facilitate the character recognition process.

4. Further Processing: After the grayscale image is ready, the subsequent steps in the license plate detection system, such as license plate segmentation, character cropping, and OCR method application, can be performed on this preprocessed grayscale image.

The advantages of using grayscale images in license plate detection lie in focusing on gray-level information and eliminating the complexity introduced by color. This can simplify the character recognition process in images, especially when color variations on the license plate are not significant or contribute to unnecessary noise [6]. However, it's important to consider the characteristics of the license plate and ensure that the conversion to grayscale doesn't remove crucial information necessary for accurate character recognition.

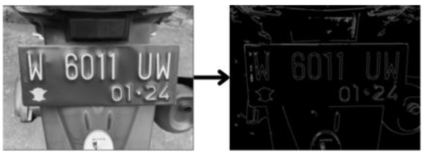

Figure XI. Canny Edge Detection Implementation

In Figure 4.6, the application of Canny edge detection in the license plate detection system can assist in obtaining clear character contours or edges to facilitate further character recognition. Here are the steps for applying Canny edge detection in the license plate detection system:

1. Conversion to Grayscale: The first step is to convert the color image into a grayscale image, as explained earlier. Conversion to grayscale enables a focus on pixel intensity information.

2. Applying Canny Edge Detection: The Canny edge detection algorithm involves several processing stages to identify edges in the image. These stages include:

    a. Noise Reduction: Before applying Canny Edge Detection, image noise can be reduced using techniques like Gaussian Blur. Gaussian Blur involves convolving the image with a Gaussian kernel to smooth the image and reduce unwanted noise.

    b. Gradient Computation: Gradient signifies the profound intensity change between neighboring pixels. Gradients are used to determine where edges might be located in the image. This is achieved by applying convolution operations with Sobel kernels to calculate the horizontal and vertical gradients of the image.

    c. Non-maximum Suppression: This step aims to enhance significant edges while suppressing irrelevant ones. After calculating the gradient, the image is pixel-wise analyzed to ensure only edges with the highest values are retained, while others are suppressed or removed.

    d. Hysteresis Thresholding: In this stage, threshold values are chosen to differentiate strong edges from weak edges. Hysteresis Thresholding involves using two threshold levels: a high threshold and a low threshold. Edges with values above the high threshold are considered strong, while edges with values between the low and high thresholds are deemed weak. Weak edges are only accepted if connected to strong edges.

3. Further Processing: After obtaining edges using Canny Edge Detection, subsequent steps in the license plate detection system, such as license plate segmentation, character cropping, and OCR method application, can be performed on the resulting edge-detected image.

The application of Canny Edge Detection helps identify sharp and significant edges on the license plate, facilitating the character recognition process. However, each processing step should be tailored to the specific characteristics and requirements of the license plate to ensure accurate and reliable results [7]. After performing the grayscale and Canny edge detection processes, which aim to reduce noise and display detected edges in the input image, the implementation of Optical Character Recognition (OCR) in the license plate detection system can involve a series of following steps:

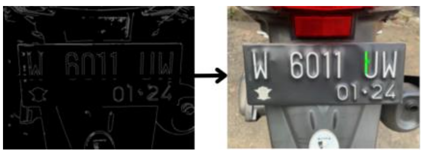

Figure XII. Optical Character Recognition

4. Image Processing: The license plate image is captured using a camera or sensor installed in the system. Initial processing is carried out to enhance image quality, such as noise reduction, contrast enhancement, and brightness adjustment.

5. License Plate Segmentation: At this stage, the license plate image is separated from the background. Segmentation methods used can include thresholding, color-based segmentation, or other segmentation techniques. The goal of this stage is to obtain a region that contains the license plate separately.

6. Character Cropping and Normalization: After successfully isolating the license plate, individual characters on the plate are cropped and normalized. This involves adjusting size, rotation, and other transformations to ensure characters are in a uniform and easily readable format.

7. OCR Application: In this stage, the selected OCR method, such as Tesseract OCR or neural networks, is applied to recognize characters on the license plate. The OCR algorithm compares the normalized characters with a language model or pre-trained character template. The result is text or character data identified from the license plate.

8. Verification and Correction: The results of character recognition may contain errors or incorrectly recognized characters. Hence, a verification and correction stage is conducted to ensure accuracy and consistency. Verification methods might involve specific rules about the license plate format. If any character doesn't comply with the rules, correction is performed based on contextual correlation or further processing.

9. Integration with the System: The successfully identified character data can then be used in the automatic barrier gate system. For instance, the license plate data can be utilized to verify membership, check access permissions, or record vehicle entry and exit times.

The implementation of OCR in the license plate detection system enables rapid and accurate character recognition [8]. However, OCR performance can be influenced by factors such as image quality, character variations, lighting, and environmental conditions. Therefore, comprehensive testing and performance evaluation of the system are crucial to ensure optimal success rates.

D. License Plate Detection Accuracy

Table III. License Plate Detection Accuracy

No	**Original**	**Hasil Deteksi**		**Presentase Keberhasilan**	
		Masuk	**Keluar**	**Masuk**	**Keluar**
1	S 4887 LZ	SL877	SL877	40 %	40 %
2	L 5053 CAB	L 5053	5053 CAB	60 %	90 %
3	L 2318 ABA	2318 ABA	2318 ABA	90 %	90 %
4	L 5407 HC	5407 HC	5407 HC	90 %	90 %
5	L 3085 JZ	3085 JZ	3085 JZ	90 %	90 %
6	W 4575 DN	W 4575 DN	W 4575 DN	100 %	100 %
7	L 5253 GI	5253 GI	5253 GI	90 %	90 %
8	N 3616 CX	N 3616 CX	3616 CX	100 %	90 %

9	W 2759 CN	2759 CN	2759 CN	90 %	90 %
..	.....	...	....	....	....
40	B 6706 KTA	B 6706 KTA	6706 KTA	100 %	90 %
	Average			90 %	80 %

. In Table , the results of license plate detection testing using OCR method are presented. In this test, 40 vehicle license plates with different characters were used to be detected under two conditions: when entering the gate barrier and when exiting the gate barrier. The success percentage is calculated differently between entry and exit, using the formula:

$$Akurasi = \frac{Jumlah\ Karakter\ Benar}{Jumlah\ Karakter\ Plat\ Nomor} \times 100\ \%$$

(1)

Table IV. Entrance Testing Scenarios

No	Original	Hasil Deteksi	Waktu	Lokasi	Pencahayaan	Presentase Keberhasilan
1	S 4887 LZ	SL8 77	Evening	indoor	Low Light	40 %
2	L 5053 CAB	L 5053	Day	indoor	Low Light	60 %
3	L 2318 ABA	2318 AB A	Day	indoor	Sunny	90 %
4	L 5407 HC	5407 HC	Day	indoor	Sunny	90 %
5	L 3085 JZ	3085 JZ	Day	indoor	Sunny	90 %
6	W 4575 DN	W 4575 DN	Day	indoor	Sunny	100 %
7	L 5253 GI	5253 GI	Day	indoor	Sunny	90 %
8	N 3616 CX	N 3616 CX	Day	indoor	Sunny	100 %
...	....	.....	.....	.....	.....	.....
40	B 6706 KTA	B 6706 KTA	Day	indoor	Sunny	100 %

Table V. Exit Testing Scenarios

No	Original	Hasil Deteksi	Waktu	Lokasi	Pencahayaan	Presentase Keberhasilan
1	S 4887 LZ	SL8 77	Evening	indoor	Dark	40 %
2	L 5053 CAB	5053 CA B	Evening	indoor	Sunny	90 %
3	L 2318 ABA	2318 AB A	Evening	indoor	Sunny	90 %
4	L 5407 HC	5407 HC	Evening	indoor	Sunny	90 %
5	L 3085 JZ	3085 JZ	Evening	indoor	Sunny	90 %
6	W 4575 DN	W 4575 DN	Day	indoor	Sunny	100 %
7	L 5253 GI	5253 GI	Evening	indoor	Sunny	90 %
8	N 3616 CX	3616 CX	Evening	indoor	Sunny	90 %
9	W 2759 CN	2759 CN	Evening	Outdoor	Sunny	90 %
...	.....	.....	.....	.....	.....	....
40	B 6706 KTA	6706 KT A	Evening	indoor	Sunny	90 %

The accuracy calculation results for license plate detection are displayed in Table, Tables and list various testing scenarios for detection at entry and exit gates, encompassing variations in time, location, and lighting. The tables explain the accuracy calculation results, showing an average success rate of 90% for entry gate and an average success rate of 80% for exit gate.

E. Testing Web Admin

In Figure 4.8, there is a user data page that functions to monitor the entry and exit of students. Within the user data page, there are several details provided, including name, Student ID Number (NIM), program of study, vehicle license plate, remarks, and actions that allow for data deletion and modification when necessary.

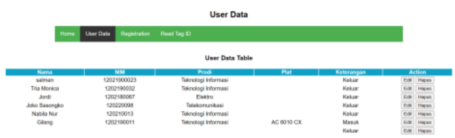

Figure XIII. User Data Page

In Figure 4.8, the "Edit" button is intended for modifying data as needed. However, the "Remarks" column cannot be altered, as the remarks serve to validate whether the license plate variable is absent. If the license plate column is empty, the remarks indicate "Exit." Conversely, if the license plate column contains a license plate number, the remarks indicate "Entry."

Figure XIV. Edit Page

In Figure 4.10, the registration page is designed to register the Student ID Card (Kartu Tanda Mahasiswa or KTM) to grant access for entering the parking area. This page requires several pieces of information to be filled out: the ID, which is the KTM number tapped on the RFID sensor, appearing in real-time on the web page; along with the student's name, NIM, and program of study, the last three of which can be found on the KTM.

Figure XV. Registration Page

Figure 4.11 showcases the "Read Tag ID" page, which functions to verify whether the KTM has been registered in the Firebase database. If the KTM is registered, the information will appear as shown in Figure 4.12, displaying the owner's data. If the KTM is not registered, a message indicating "User not found" will be displayed.

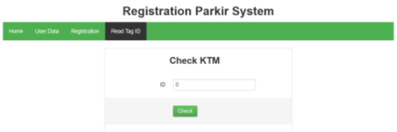

Figure XVI. Read Tag ID Page

Figure XVII. Registered Tag ID Reading Page

IV. Conclussions and Recommendations

A. Conclusions

This research has produced an integrated IoT device with a website and digital image processing. The data used in this study consists of 40 different vehicle license plates. The performance results for each aspect related to the research are as follows:

1. In the IoT aspect of the system, the RFID successfully detected the Student ID Card (KTM), and the ultrasonic sensor detected vehicles passing through the gate barrier. The ultrasonic sensor sent data to the motor servo to close the gate barrier after the vehicle passed. The integration of RFID and ultrasonic sensors ensured that only vehicles with valid access could enter and exit the parking area. The system operated smoothly, enhancing the performance of the automated gate barrier.

2. In the digital image processing aspect, the system successfully detected vehicle license plates using Optical Character Recognition (OCR) method. This method enabled the system to recognize characters on the license plates from camera images. The image processing results showed an accuracy of around 90% for license plate recognition at the entry gate and 80% at the exit gate. Although the accuracy level at the exit gate was slightly lower, it was still satisfactory. Attention to factors such as lighting, image quality, and license plate conditions is needed to improve accuracy. The system underwent testing under various scenarios, totaling 40 trials at both entry and exit gates. Testing included variations in time (day and evening), location (indoors and outdoors), and lighting conditions (dark, dim, and bright). The test results demonstrated the system's consistent and adaptive performance in different conditions. In conclusion, the Optical Character Recognition (OCR) method has been successfully implemented in the automated gate barrier system. The obtained accuracy level indicates a promising potential for license plate recognition. Continuous development of image processing techniques and OCR methods will help enhance the system's accuracy. The extensive testing results also provide confidence in the system's reliability in real-world situations. It is anticipated that this step will support the enhancement of functions and security in automated gate barrier systems in the future.

3. The website created in this research functions effectively. The website includes a user data page for monitoring students who enter and exit the parking area. The features on this page include editing and deleting data. The registration page is used to register the Student ID Card (KTM) to grant access to the parking area. The "Read Tag ID" page verifies whether the KTM is registered. The functionality of these pages ensures the proper functioning of student data management and parking area access. With this website, personnel can easily monitor and manage student data, ensuring controlled parking access is only granted to legitimate and registered students.

As for limitations in the research, detected Indonesian license plates displayed the entire area, including the cover, bolts, and the active vehicle registration period. This should not be detected, potentially impacting image processing results..

B. Recommendations

Limitations identified in this study, the author proposes the following recommendations:

1. Explore alternative methods to determine a more effective approach.

2. Standardize the installation of vehicle license plates for improved image detection results

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