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Car Parking Monitoring System Based on Location Plate Detection Using Web Camera

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Abstract

This research aims to design a car parking monitoring system based on license plate detection using a webcam to improve efficiency and accuracy in parking area management. The scope of the research includes hardware design using an ESP32 microcontroller, ultrasonic sensors, proximity sensors, a 16x2 LCD, servo motors, and a thermal printer. The research methodology involves literature review, as well as laboratory testing and data validation. The system is evaluated based on its ability to accurately detect vehicle license plates, monitor parking space availability in real-time, and automatically record vehicle entry and exit data. Experimental results show that the system correctly detects, matches it with a database, and controls access to the parking area. All components operate within the specified voltage range, with measurement errors remaining below 5%. The system successfully records vehicle entry and exit times, and the website interface updates parking space availability in real-time based on sensor readings. In conclusion, the proposed system is effective in helping operators monitor slot availability, minimize vehicle placement errors, and simplify the parking process with automation.

Keywords: *Parking Monitoring System, License Plate Detection,* ESP32, *Web Camera*

Abstrak

Penelitian ini bertujuan untuk merancang sistem pemantauan parkir mobil berbasis deteksi plat nomor menggunakan kamera web untuk meningkatkan efisiensi dan akurasi dalam pengelolaan area parkir. Lingkup penelitian meliputi desain perangkat keras menggunakan mikrokontroler ESP32, sensor ultrasonik, sensor jarak, LCD 16x2, motor servo, dan printer termal. Metodologi penelitian melibatkan studi literatur, serta pengujian laboratorium dan validasi data. Sistem dievaluasi berdasarkan kemampuannya untuk secara akurat mendeteksi plat nomor kendaraan, memantau ketersediaan tempat parkir secara real-time, dan merekam data masuk dan keluar kendaraan secara otomatis. Hasil eksperimen menunjukkan bahwa sistem mendeteksi dengan tepat, mencocokkannya dengan basis data, dan mengontrol akses ke area parkir. Semua komponen bekerja dalam rentang tegangan yang ditentukan, dengan kesalahan pengukuran tetap di bawah 5%. Sistem berhasil merekam waktu masuk dan keluar kendaraan, serta antarmuka situs web memperbarui ketersediaan tempat parkir secara real-time berdasarkan pembacaan sensor. Kesimpulannya, sistem yang diusulkan efektif dalam membantu operator memantau ketersediaan slot, meminimalkan kesalahan penempatan kendaraan, dan menyederhanakan proses parkir dengan otomatisasi.

Kata kunci: Sistem Monitoring Parkir, Deteksi Plat Nomor, ESP32, Web Camera

Introduction

For owners of private vehicles, particularly those with four wheels, parking is a necessary amenity. Many companies with a large number of employees often face challenges in parking management due to the manual system, resulting in vehicles being parked haphazardly and untidily, leading to long queues when entering and exiting the parking area. Furthermore, employees often struggle to find empty parking spaces, ultimately wasting a lot of time searching for a suitable parking spot. Various studies have been conducted to find solutions to this parking problem. An ESP32 microcontroller-based parking monitoring system capable of detecting incoming and outgoing vehicles and providing users with information on empty parking slots [1]. In term parking a car easier and more efficient, a parking guide is needed to show the distance to surrounding objects [2]. This system has been proven to improve parking management efficiency by utilizing simple, easy-to-implement technology.

Meanwhile, another study developed a system for recording car license plates on parking barriers using cameras and microcontrollers with OCR technology [3]. This technique is more accurate than manual registration since it enables automatic vehicle registration through cameras. The concept of smart parking was also developed by Agung, et al., who designed an Internet of Things (IoT)-based system [4][5]. This method makes it easier for vehicles to locate open parking spaces by connecting parking sensors to the internet, allowing real-time access to information about available spots.

Additionally, simulated parking sensors conducted by using an Arduino Uno with ultrasonic sensors [6]. Although still in the simulation stage, this study demonstrated that ultrasonic sensors can be used effectively to detect the presence of vehicles in parking slots. The development a parking slot monitoring system running by using a JSN-SR04T ultrasonic sensor combined with ESP32-CAM-based vehicle license plate recognition technology [7][8]. The results of the study showed that the combination of sensors and license plate recognition was able to provide more accurate information to users.

Furthermore, a relevant research designed a parking lot monitoring system equipped with automatic gate control based on license plate detection [9]. This system not only helps drivers find empty parking slots but also improves parking area security because only registered vehicles can enter. Furthermore, an applied OCR technology to vehicle license plate recognition is appropriate in an automated parking system [10]. This research demonstrated that OCR can work well to recognize license plate data, which is then used for vehicle identification in modern parking systems. Furthermore, it could demonstrated that the concept of Internet of Things-based monitoring can also be applied in other sectors, such as clinics [11]. The IoT monitoring system they developed demonstrated that data can be monitored in real time and accurately [12]. The same principle can be adapted to parking systems to monitor parking slot availability and vehicle activity.

Another research proved that YOLO-based license plate detection and real-time online monitoring can be integrated into smart parking systems to improve hardware performance [13][14]. Basically, a parking lot monitoring system with automatic gate control highlights the significance of hardware integration in the form of cameras and

sensors which the system operates in accordance with user needs [9]. In the meanwhile, another research demonstrates how intelligent parking management apps can help hardware design with a better organized interface, allowing software and hardware to work together as best they can [15][16].

Based on these various studies, it can be concluded that the development of IoT technology, ultrasonic sensors, and OCR provides a great opportunity to create an efficient parking monitoring system. Therefore, this study proposes the development of a car parking monitoring system based on license plate detection using a web camera and OCR, which is connected to a database to store vehicle information and an ESP32 microcontroller as the main controller. This system is expected to be a practical solution in improving the efficiency, orderliness, and security of parking management in areas with high vehicle activity.

Method

The research method used in this study consists of several mutually supporting stages. These stages include literature review, experiment laboratory testing and data collection. The methods used are as follows literature review, experiment in laboratory. The literature method is carried out by collecting data and information from various references relevant to the research title, such as books, journals, scientific articles, and other reliable sources [13]. Similar research proved that emphasized the importance of literature studies in designing IoT-based system prototypes to provide a strong foundation for the design [17][18]. The laboratory method is carried out by taking and measuring data directly in the campus laboratory to obtain accurate results and support research. This method is complemented by conducting controlled experiments, system validation tests, and several trials to evaluate the performance, accuracy, and reliability the system, for ensuring that the developed system operates as intended and meets the research objectives.

It is hoped that the system's design and construction would satisfy expectations. All circuit-related phases, including hardware and software planning, component installation, and tool testing, are included in this tool production planning process. Hardware planning starts with the production of a block diagram to show the overall design of the device utilizing a simulator. Choosing the components to be used, designing a schematic circuit or component layout, and installing the components are all steps in this process. The hardware utilized in this design consists of parts like sensors, an ESP32, and a webcam.

An ESP32 microcontroller controls and processes all components, include:

1. A webcam that reads or records vehicle license plates.
2. A servo motor that drives the barrier.
3. A thermal printer that prints parking paper.
4. An LCD to display information about the vehicle license plate recording process.
5. An ultrasonic sensor that detects vehicle movement and the barrier cover.
6. A proximity sensor that detects the presence of vehicles in the parking slot.

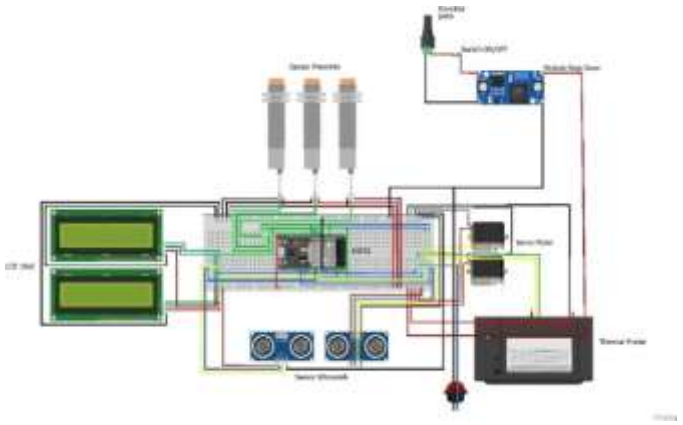

Figure 1. Circuit Schematic

This research stage includes the installation stage of the Car Parking Monitoring System components based on License Plate Detection Using a Web Camera, the details of which are as follows.

1. The power supply is a source of input voltage that converts AC current to DC current, which then flows the electrical current to the device circuit.
2. The webcam is used to capture images or record license plates entering and exiting the vehicle. It functions to open and close the parking barrier.
3. The ultrasonic sensor detects the entry and exits of vehicles into the parking area.
4. The servo motor provides thrust or movement to the parking barrier, allowing it to open or close.
5. The LCD (Liquid Crystal Display) is a component that displays data, such as system status information or sensor readings.
6. The proximity sensor detects the presence or absence of vehicles in the parking slot.
7. The thermal printer is used to dispense the parking slips required by drivers.
8. This stage is the installation of the most important and crucial component: the Esp32 microcontroller, which controls or processes data for the entire circuit.

Next, measurements were taken of all system components to gauge the success of the device, which was tested at several measurement points. This measurement process facilitated the author's analysis and discussion.

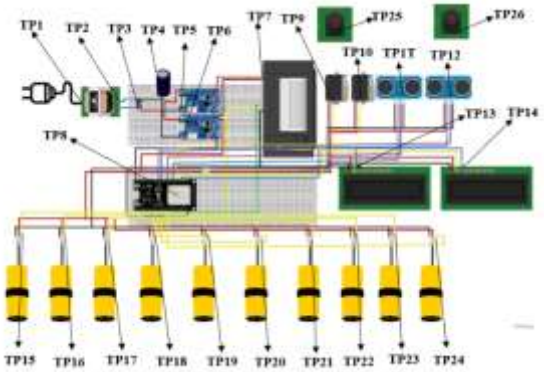

Figure 3. Measurement Points

Component testing was performed five times to obtain accurate results. The used the principle of repeated testing is essential to obtain a valid average value in designing an Arduino-based thermal relay tester to ensure the accuracy of the measurement results [18].

$$x = \frac{x_1+x_2+x_3+x_4+x_5}{n} = \frac{S_{xi}}{n} \quad \text{..... 1)}$$

Description:

$\frac{S_{xi}}{n}$ = Total Sample
x_1 = Measurement
n = Number of Measurement
x = Average value

The percentage formula uses the equation in testing the OCR-based automatic parking system, to ensure the reliability of the experimental data [10].

$$\%\ errors = \frac{measurement-calculation}{measurement}\ x\ 100\% \quad \text{..... 2)}$$

Result and Discussion

This table presents the results of AC and DC voltage measurements at each test point on the aspect power supply system, thermal printer, and ESP32, which were carried out five times trials to obtain an average value as an evaluation of system performance and stability. The measurement results can be seen in the following table.

Table 1. Measurement Data

No	Position	Point	Unit	Measurement Data					X	Information
				1	2	3	4	5		
1.	Power Supply TP1-TP8	Input PLN (TP1)	ACV	223	224	223,1	223,5	223,3	223,5	Input PLN
		Trafo (TP2)	ACV	11,80	11,81	11,82	11,80	11,86	11,82	Output Trafo
		DB (TP3)	DCV	13,7	13,7	13,7	13,7	13,73	13,71	Input Dioda
		Capacitor (TP4)	DCV	13,7	13,6	13,72	13,7	13,74	13,69	Input Capacitor
		SD 1 (IN) TP5	DCV	13,69	13,61	13,58	13,50	13,46	13,56	Input SD 1
		SD (OUT) TP6	DCV	9,81	9,82	9,81	9,82	9,81	9,81	Output SD 1
		SD 2 (IN) TP7	DCV	13,39	13,40	13,39	13,49	13,42	13,41	Input SD 2
		SD 2 (OUT) TP8	DCV	5,69	5,69	5,70	5,71	5,70	5,69	Output SD 2
2.	Thermal Printer	TP9	DCV	9,76	9,82	9,80	9,78	9,82	9,79	Input Thermal
3.	Esp32	TP10	DCV	5,26	5,20	5,23	5,22	5,24	5,23	Input Esp32
4.	Motor Servo	TP11	DCV RFM	5,55 0,23	5,67 0,25	5,59 0,15	5,59 0,23	5,60 0,20	5,60 0,21	Output Motor Servo
5.	LCD (Input) LCD (Output)	TP12	DVC	5,22 5,51	5,22 5,22	5,21 5,52	5,22 5,53	5,22 5,53	5,22 5,22	Output LCD
6.	US Intake US Out	TP13 TP14	DVC	5,47 5,40	5,48 5,43	5,48 5,44	5,48 5,41	5,48 5,47	5,48 5,43	US Output
7.	PS PS	With Object No Object	DCV DCV	5,51 5,42	5,52 5,39	5,52 5,33	5,53 5,45	5,53 5,46	5,53 5,41	PS Output
8.	Web Camera	Time In	DVC	4,02	4,01	4,60	4,07	4,60	4,26	LP Reading

*SD : Step Down
DB : Dioda Bridge
US : Ultrasonic Sensor

PS : Proximity Sensor
LP : License Plate

The following is a table showing the results of calculating the percentage error from each measurement point.

Table 2. Percentage Error in Measurement

No	Measurement Point	Measurement Location	Data Sheet	Measurement value	Unit	Error (%)
1.	Power Supply	TP 1	220	223,52	VAC	1,57%
		TP 2	12	11,82	VAC	1,52%
		TP 3	10,19	13,71	VDC	25,67%
		TP 4	13,5	13,69	VDC	1,39 %
		TP 5	9	9,81	VDC	8,26 %
		TP 6	5	5,69	VDC	12,11 %
2.	Thermal Printer	TP7	9,0-12	9,81	VDC	-
3.	ESP32	TP8	5	5,23	VDC	4,40 %
4.	Motor Servo	TP9	4,8-6	5,6	VDC	-
5.	Ultrasonic	TP10	5	5,48	VDC	8,76 %
6.	LCD	TP11	5	5,55	VDC	9,91 %

Table 2 shows that most measurement points exhibit a relatively small percentage error, indicating that the designed system is performing according to the expected specifications. However, there are quite high errors at several points, such as TP3 in the power supply section with an error of 25.67%, indicating a voltage drop or fluctuation. Overall, these test results indicate that the parking monitoring system is safe and suitable for use, although further evaluation is needed at points with high errors to improve the stability and accuracy of system performance.

Table 3. Test Results of the Ultrasonic Sensor for the Entry Cross Distance

No	Actual Object Distance (cm)	Distance Read by Sensor (cm)	% Error	Information	Conclusion
1	5	5.2	4%	Very close object	appropriate
2	15	14.8	1,3%	Objects at medium distance	appropriate
3	30	30.1	0,3%	Objects at ideal distance	appropriate
4	50	49.7	0,6%	Objects are quite far away	appropriate
5	>100 (No Object)	999.9		No objects	appropriate

Based on Table 3, the ultrasonic sensor is capable of detecting object distance with good accuracy. The error that appears is relatively small and still within the tolerance limit. At the ideal distance, the sensor performs optimally. The test results indicate that the sensor is suitable for use in an automatic barrier-based parking monitoring system. This finding aligns with the research [12], which demonstrated the effectiveness of ultrasonic sensors in simulating parking sensors based on the Arduino Uno microcontroller. Similar support demonstrated that a parking slot monitoring system using the JSN-SR04T ultrasonic sensor and license plate recognition conducted using ESP32-CAM, which resulted in high accuracy in distance detection [7]. Furthermore, an IoT-based parking location monitoring system also confirmed that the use of ultrasonic

sensors can minimize detection errors, making it suitable for an automated parking system [19][20].

Table 4. Results of Ultrasonic Sensor Testing for Cross Exit Distance

No	Actual Object Distance (cm)	Distance Read by Sensor (cm)	% Error	Information	Conclusion
1	5	5.1	2%	Very close object	Appropriate
2	15	15.3	2%	Objects at medium distance	Appropriate
3	30	29.9	-0,3%	Objects at ideal working distance	Appropriate
4	50	50.4	0,8%	Objects are quite far away	Appropriate
5	>100 (No Object)	999.9	-	No objects	Appropriate

The results of ultrasonic sensor testing on the exit barrier showed accurate performance with an average error of 1.3%. The sensor is capable of detecting objects at close to long distances with a low error rate. At the ideal distance, the error is only 0.3%, making the sensor suitable for use in automated parking monitoring systems. However, ultrasonic sensors have the ability to detect distances with a high level of accuracy and are suitable for application in parking system simulations [6]. This is reinforced that the use of the JSN-SR04T ultrasonic sensor can minimize distance detection errors, making it suitable for use in automation-based parking systems [7]. The following is how the equipment works in a parking monitoring system.

Figure 4. Registered License Plate Data

The image above displays the vehicle plate data registered on the website, where only the plate data has access to enter the parking area.

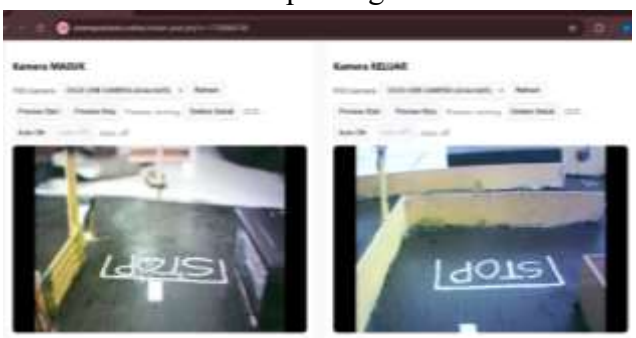

Figure 5. Plate Record View

The image is a view of the camera entering and exiting the parking area, which is used to monitor or view the vehicles being recorded.

Figure 6. Empty Parking Log View

The image shows the parking log display on the website. When a vehicle has entered the parking area, the parking log will record the entry time, the name of the vehicle owner, the slot occupied by the vehicle, and when the vehicle has left, the log will record the time the vehicle left.

Figure 7. Parking Slot Layout View

Figure 8. Empty Parking Slot

The image shows the condition of an empty parking slot on a tool or prototype, where when it is filled it will change the appearance of the slot layout on the website based on the proximity sensor.

Figure 9. Vehicles Stop at the Stop Sign

When a driver enters the parking area, the driver will stop at the sign that says "stop" in front of the parking area entrance barrier, then the camera will record the license plate of the vehicle that stops in the stop area.

Figure 10. Incoming Plate Recording Process

Figure 10 showed the process of recording the vehicle plate on the entry camera, then the recorded data will be matched with the data on the registered plate to provide vehicle access to the parking area.

Figure 11. Open Door Latch

Figure 11 indicate the process when the system checks the availability of parking slots and if a parking slot is available, the parking paper will be printed, the barrier will open, and the LCD will display a notification.

Figure 12. Parking Paper in Print

This is a more detailed form of the contents of the parking paper when the parking paper has been printed, which contains vehicle data, parking slot information, and entry time.

Figure 13. Display on the Entrance LCD

Figure 13 exhibit the display on the LCD screen at the entrance when vehicle access has been granted. When the vehicle has passed the entrance barrier, the vehicle will automatically be detected by an ultrasonic sensor which functions to close the entrance barrier which was previously still open (Figure 14).

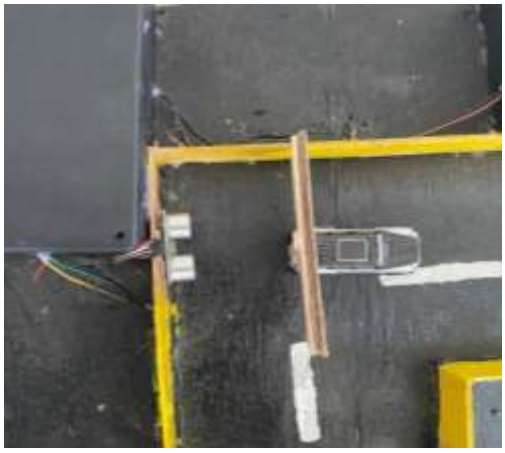

Figure 14. Vehicle Detected by Ultrasonic Sensor

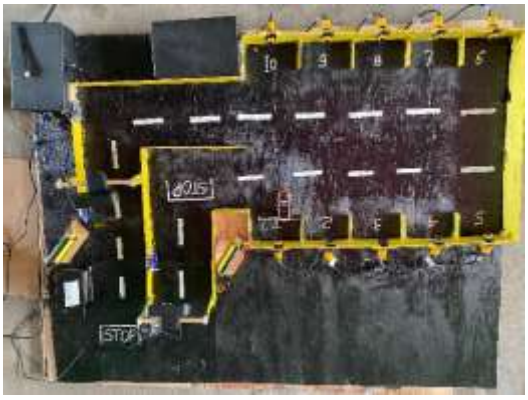

Figure 15. Vehicles Are in the Parking Slots

The image above shows that when the vehicle has been placed in the parking slot according to the information on the parking paper, the proximity sensor will detect the presence of the vehicle which will then change the appearance on the website.

Figure 16. Display on the Website

The image illustrates that when the slot map display on the website receives a signal from the proximity sensor, the occupied parking slots will turn green. The image below shows the slot map display on the website. When all 10 parking slots are empty, the website will display 10 gray boxes, indicating that 10 parking slots are available and ready to be used.

Figure 17. Parking Log View

The image shows the parking log display on the website. When a vehicle enters the parking area, the data will automatically be recorded in the parking log, displaying the vehicle owner's data, slot information, and entry time, but without the exit time. The image explains the exit process, when the camera at the exit gate records the license plate of the vehicle that is leaving the parking area, the system will check the data in the parking log which does not have an exit time yet

Figure 18. Plate Recording at the Exit Door

Figure 19. Exit Barrier Open

Figure 20. Vehicle Passing Ultrasonic Sensor

In the image above, when the vehicle has been given exit access, the exit barrier will open. After the vehicle passes the exit barrier, the vehicle will automatically be detected by an ultrasonic sensor which functions to close the exit barrier (Fig. 21). When the vehicle has left, the parking slot map display on the website will return to blank because the proximity sensor no longer detects the presence of the vehicle (Fig. 22). The image shows the parking log display on the website when the vehicle has left, where the parking log will record the time the vehicle left.

Figure 21. Empty Parking Slot Plan

Figure 22. Parking Log Records Exit Time

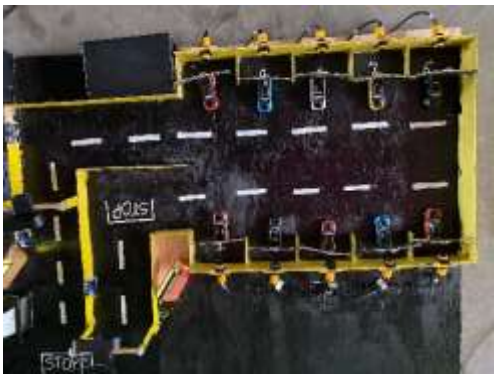

Figure 21. Full Parking Slot Condition

This image shows the condition when the parking slots are full or all of them have been filled by vehicles. When it is full, it will change the appearance of the slot layout on the website.

Figure 22. Display on the Website

This image is a view of the slot layout on the website when all parking slots have been filled, where all the boxes will be green, indicating that the sensor has detected the presence of a vehicle (Fig. 23). The image indicates a display of the parking log when the parking slot is fully occupied, and there is no exit time data (Fig. 24). Finally, the image displays on the parking log when all vehicles have left, then the parking log will display the exit time data.

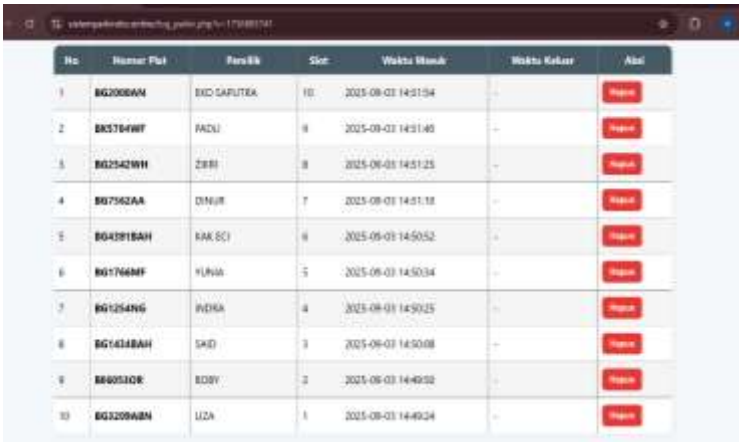

Figure 23. Display on Parking Log Entry Time

Figure 24. Parking Log Display When the Vehicle Has Exited

Conclusion

Based on the results of the design, testing, and analysis that have been carried out, it can be concluded that the car parking monitoring system based on license plate detection using a web camera is able to function according to the initial objectives and design. All components used, both hardware and software, can work well within the specified tolerance limits. This system is proven to be able to detect license plates automatically without manual intervention, record vehicle entry and exit times accurately, and update the number of available parking slots in real-time. In addition, this system also makes a significant contribution to increasing the efficiency and accuracy of parking area management, reducing the potential for recording errors, and speeding up the administrative process. Thus, the implementation of this technology-based monitoring system not only supports more modern and integrated parking management, but also provides added value in the form of comfort and convenience for parking service users and facility managers.

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