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Smart Parking Design Using Arduino Mega 2560 and Infrared Sensor for Automatic Parking Efficiency

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Abstract- Efficient parking management is a challenge in urban areas with high vehicle density. This study aims to design and implement a smart parking system based on Arduino Mega 2560 by utilizing infrared (IR) sensors to detect vehicles, automatic signs, and display the number of empty parking slots using an OLED screen. This system works automatically, where the IR sensor detects vehicles entering and exiting, triggering the parking sign to open or close automatically. In addition, the OLED screen displays the number of available parking slots in real-time to facilitate users.

The test results show that the system has accurate performance in detecting vehicles and operating the automatic sign. The display of the number of empty parking slots on the OLED works well, providing information accurately and responsively. Thus, this system is able to improve efficiency and convenience in parking management, while reducing the time to find a parking space.

Keywords: *Smart Parking, Arduino Mega 2560, IR Sensor, Automatic Bar, OLED*

1 Introduction

The increase in the number of vehicles in urban areas continues to show a significant trend every year (Hidayati, 2021). Based on data from the Central Statistics Agency (BPS), the number of vehicles in Indonesia increases by an average of 6-7% per year. This growth creates various challenges, one of which is the limited availability of adequate parking facilities (BPS, 2023). According to a report from the Ministry of Transportation, the lack of efficient parking infrastructure often causes congestion in urban areas, contributing to more than 30% of drivers' travel time spent looking for a parking space (Farhan et al., 2023).

This problem not only affects the comfort of vehicle users, but also the environment. Research shows that vehicles circling looking for a parking space increase fuel consumption by up to 15% and contribute to significant carbon emissions (Pradana et al., 2018). In big cities such as Jakarta, Bandung, and Surabaya, this problem is becoming increasingly complex due to the dense number of vehicles that is not balanced with the availability of parking areas (Murdiansjah & Rahayu, 2019).

Smart parking technology has emerged as an innovative solution to overcome this problem. This system integrates sensors and microcontrollers to automatically detect parking space availability, provide real-time information to users, and guide them to available parking locations (Shebillawy et al., 2021). In the context of physics, smart parking technology involves the application of basic principles such as electromagnetic radiation, the law of light reflection, and electrical signal processing (Suryani et al., 2024). One of the main components in the development of a smart parking system is an infrared sensor. This sensor works based on the principle of electromagnetic wave radiation in the infrared spectrum to detect the presence of objects (Supriyatna & Roza, 2021). When the infrared signal emitted by the sensor hits the vehicle, some of the energy is reflected back to the sensor, and the intensity of the received signal is used to determine the presence of the object (Aldhanhani et al., 2021). This principle is based on the law of light

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reflection and wave propagation, which is the basis for the design of a distance and presence detection system (Yunardi et al., 2017).

Arduino Mega is used in this system because it has a large memory capacity, supports data processing from multiple sensors simultaneously, and provides multiple input/output ports. Arduino Mega allows efficient processing of digital signals from infrared sensors and converts them into data that can be used to provide real-time information to users (Afria & Winarno, 2017). By utilizing Ohm's and Kirchhoff's laws, this system is designed to ensure optimal power management in its electronic circuits.

Several previous studies have proven the effectiveness of using this technology. For example, research by Kumar et al. (2022) shows that a smart parking system based on infrared sensors has succeeded in reducing parking space search time by up to 40% in shopping center parking areas. A study by Rodic et al. (2020) which used a combination of infrared sensors and Arduino microcontrollers showed a vehicle detection accuracy of 95% in complex parking environments. Local research in Indonesia by Afrizal & Prastowo (2022) proved that the implementation of a smart parking system on campus was able to reduce vehicle fuel consumption by up to 12% by directing drivers to available parking spaces directly.

This research aims to build a prototype of a smart parking system that can be implemented on a small to medium scale by utilizing the principles of physics. It is expected that this system will not only improve the efficiency of automatic parking, but also have a positive impact on reducing wasted time and fuel, as well as reducing carbon emissions in urban environments. With successful implementation, this system can be a model for further development in modern parking management in the future..

2 Basic Theory

2.1 Microcontroller

A microcontroller is a chip that functions as an electronic circuit controller and can generally store programs, generally consisting of a CPU (Central Processing Unit), memory, certain I/O and supporting units such as the Analog-to-Digital Converter (ADC) which are already integrated into it (Sitorus & Tahyudin, 2018).

2.2 Arduino Mega 2560

Arduino Mega 2560 is a microcontroller board based on ATMega 2560. This module has 54 digital inputs/outputs where 14 are used for PWM output and 16 are used as analog inputs, 4 for UART, 16 MHz crystal oscillator, USB connection, power jack, ICSP Header, and reset button (Hadisusila, 2023). This module has everything needed to program the microcontroller such as a USB cable and power source via adapter or battery (Louis, 2016). Arduino Mega 2560 has a number of facilities to communicate with a computer, another Arduino, or other microcontroller. This ATmega2560 provides four hardware UARTs for serial communication. The Light Emitting Diode (LED) will blink when data is being sent via the ATmega8U2/ATmega16U2 chip connection and USB to the computer (Pujithsai et al., 2020).

Figure 1. Arduino Mega 2560

2.3 Infrared Sensor

Infrared (infrared) is a spectrum of electromagnetic light waves with a wavelength longer than visible light, namely between 700 nm and 1 mm. The infrared sensor consists of a transmitter (infrared) and an infrared light receiver (phototransistor). This component can convert infrared light energy into electrical signal pulses (Simatupang et al., 2020). The transmitter in this system consists of an infrared Light Emitting Diode (LED) equipped with a circuit that can generate data to be sent via infrared light, while the receiver usually has a phototransistor, fato diode, or infrared module that functions to receive infrared light sent by the transmitter (Yunardi, 2017).

Figure 2. Infrared Sensor

2.4 Servo Motor

Servo motors are electrical devices used in industrial machines that function to push or rotate objects that require high-precision control in terms of angular position, acceleration, and speed. These control capabilities are not possessed by AC motors. This is because servo motors use a closed-loop system in the form of an encoder for position feedback to control the target position of the motor, torque output, rotational speed (Autsou et al., 2024).

Figure 3. Servo Motor

2.5 Oled

OLED (Organic Light Emitting Diode) is an advanced display technology that uses organic materials to produce light without the need for a backlight, because each pixel can emit its own light. This allows OLED to produce perfect blacks with very high contrast, as well as bright and accurate colors. This technology also supports thin, light, and flexible screen designs, making it ideal for modern devices such as smartphones and televisions. In addition, OLED's viewing angle is wider than LCD, so images remain clearly visible from various angles. However, OLED has several disadvantages, such as the potential for burn-in, shorter lifespan in certain colors, and higher production costs. Even so, its visual advantages and flexibility make OLED the main choice for premium devices (Setyawan, 2017).

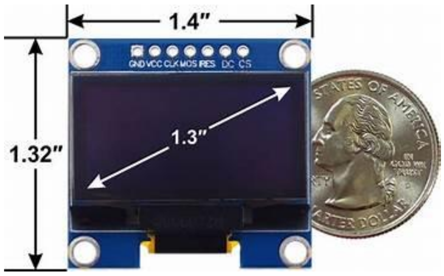

Figure 4. Oled Display

3 Research Methods

The research method begins with identifying problems to determine the system development method, followed by data collection accompanied by the collection of system development literature, until a smart parking system is produced. The design steps in this research are as follows.

3.1 Design Steps

The following flowchart illustrates the steps in developing a system or tool. The process begins with the preparation of the necessary tools and materials, followed by the design of the system and tools, and the assembly of the components that have been designed. After that, the next stage is coding or programming the system to run the tool. After the code is complete, a trial is carried out to ensure that the system and tool work properly. If not, the previous steps, such as design or programming, need to be fixed and retested. If the tool trial is successful, analysis and discussion are carried out to evaluate the results and document the findings. This process ends when all stages are successfully completed.

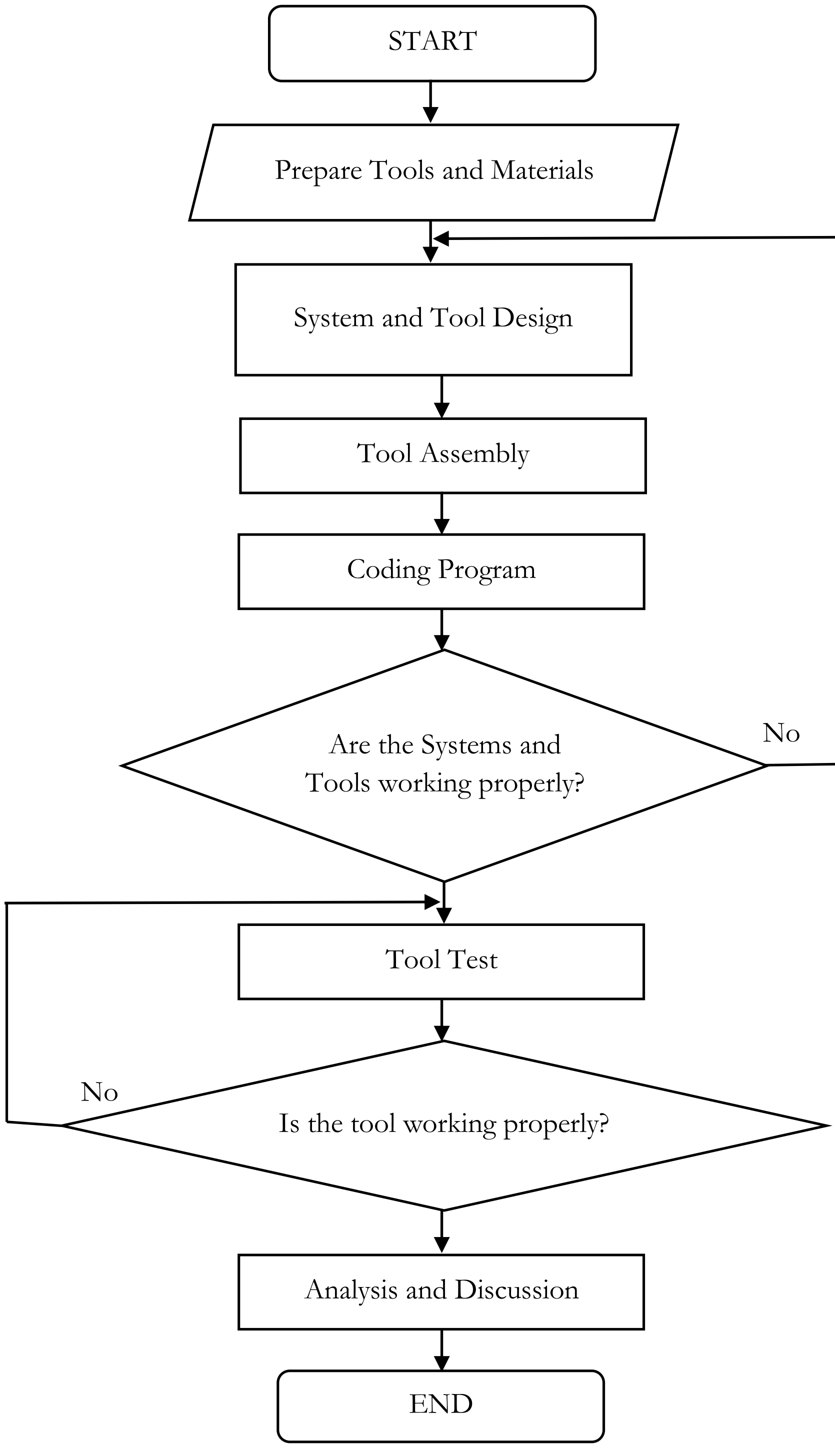

Figure 5. Research Steps

3.2 System Design

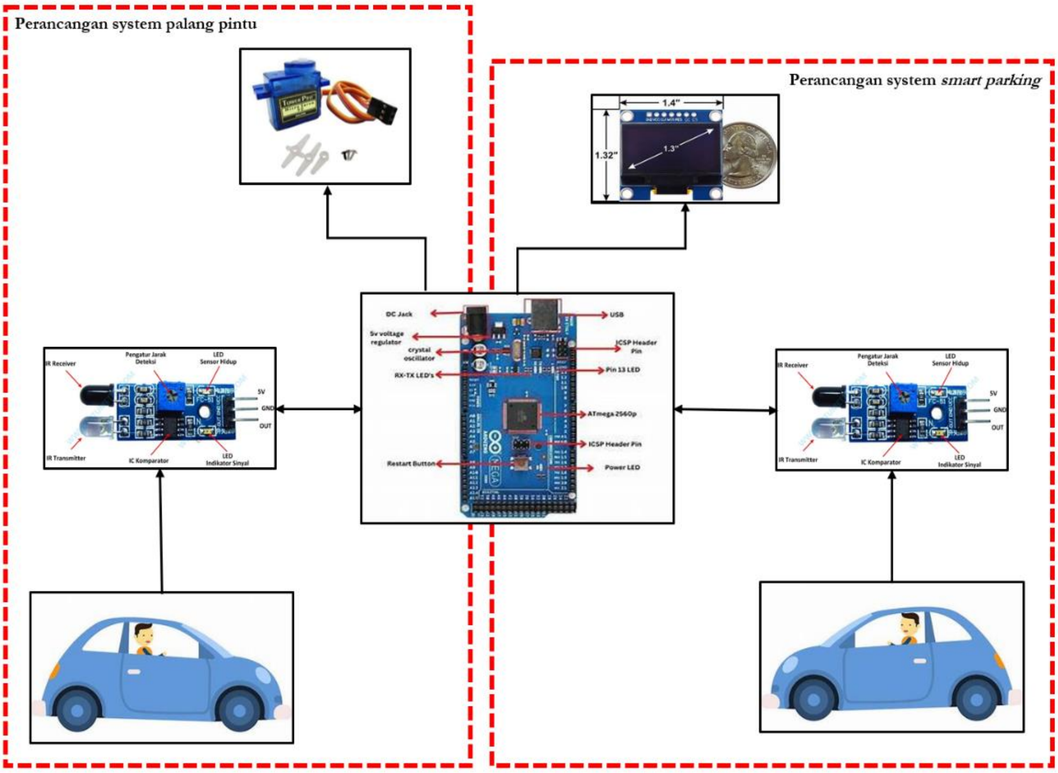

Figure 6. System Design

Figure 6 shows the design of a smart parking system which is divided into two main parts: the barrier system and the smart parking system. The following is an explanation of each part of the smart parking system.:

1. Infrared (IR) Sensor for Vehicle Detection

   In this section, the IR sensor is used to detect the presence of a vehicle. This sensor has a transmitter and receiver that will identify the presence of an object (vehicle) based on the reflection of the infrared signal. When a vehicle is detected, the signal will be sent to the microcontroller for further processing.

2. Mikrokontroler (Arduino Mega 2560)

   The microcontroller acts as a data processing center. Data from the IR sensor is received and processed by the Arduino to run certain commands, such as displaying parking information or controlling other devices. This microcontroller has many input/output pins that allow integration with several other sensors and components.

3. OLED Screen for Information Display

   The OLED screen is used to display information related to the parking system. For example, the number of available parking slots, parking status (full or empty), or other notifications. This screen is directly connected to the microcontroller to receive data that will be displayed in real-time.

4. Data Communication

   All components work in an integrated manner, where data from the sensors is sent to the microcontroller, processed, and the results are displayed on the OLED screen. This system ensures that parking monitoring runs automatically, efficiently, and provides clear information to users.

5. Smart Parking System Flow, namely::
   1) The vehicle approaches the parking area.
   2) The IR sensor detects the presence of the vehicle.
   3) The microcontroller processes data from the sensors and sends output in the form of an information display on the OLED screen.
   4) If there is an empty parking slot, this information will be displayed on the screen to guide the driver to the available parking location.

3.3 Smart Parking Design and Construction

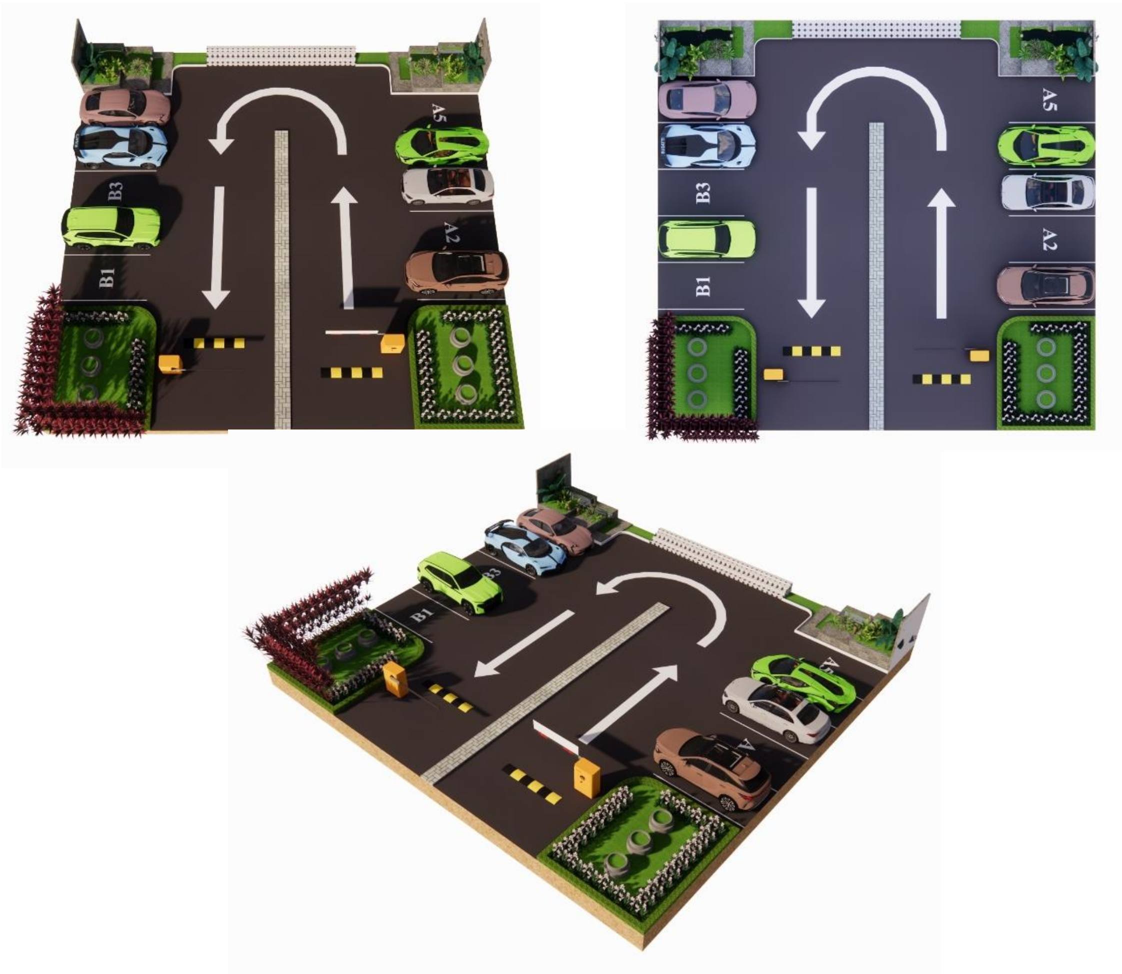

Figure 7. Smart Parking Design and Construction

The figure shows the smart parking design that integrates automation systems with an orderly parking layout. The system includes automatic barriers, vehicle detection sensors to monitor parking slot availability, and information screens to guide drivers to empty slots. Road markings and entry-exit lanes are also added to ensure smooth traffic flow and environmental comfort. This design is designed to improve efficiency and convenience in parking management..

4 Results and Discussion

4.1 Prototype *Smart Parking*

The following is an image of the smart parking prototype design that has been designed as seen in Figure 8.

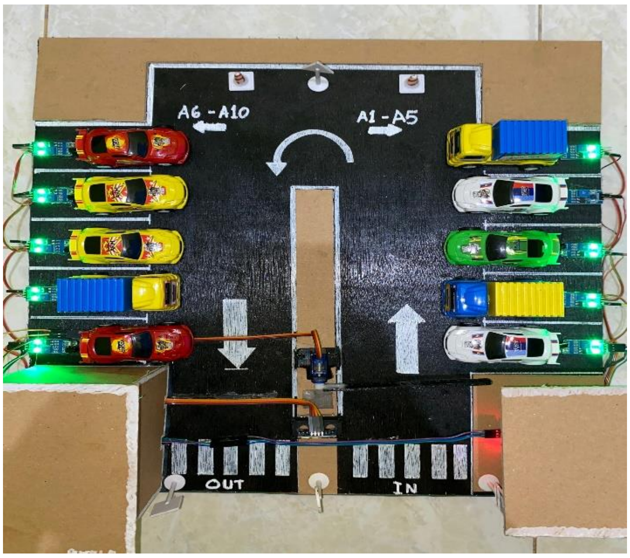

Figure 8. Prototype *Smart Parking*

Figure 8 explains that when a car is about to enter a parking area, it must first pass through a sign that uses an automatic sign and look at the OLED to find out which parking slots are empty. If the vehicle is in front of the IR sensor, the sign will go up. If the vehicle has passed the sign, the sign will automatically close again and the car will park in an empty area. Likewise, when another vehicle wants to park its vehicle, the user must first look at the OLED screen to see which parking slots are still empty.

4.2 Tool Testing

The first test is done by checking the function of each sensor and the display used. Then continued with testing the wiring circuit. In this process, errors often occur that make the tool not work so that a troubleshooting process must be carried out to find where the error or error occurs.

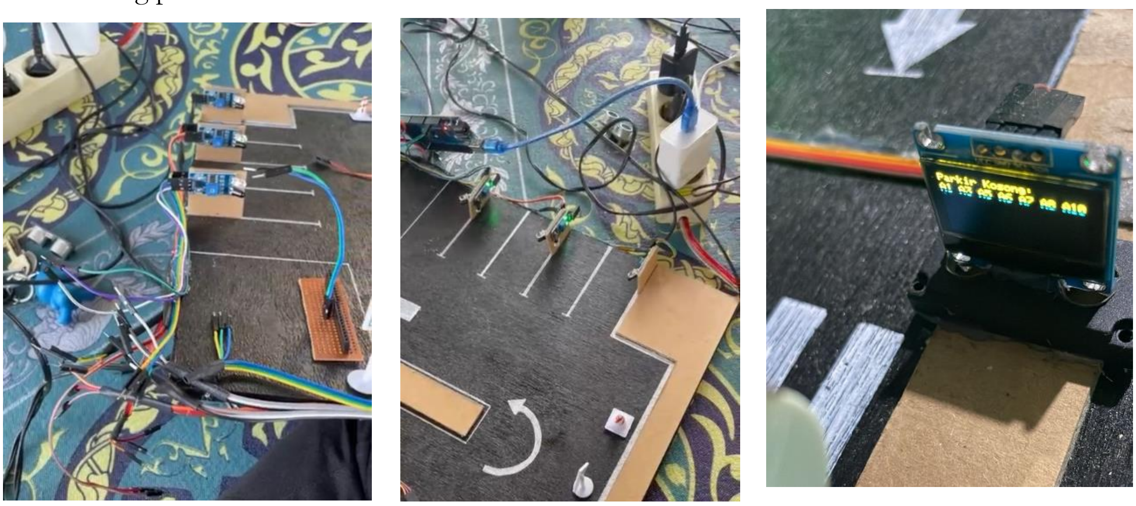

Figure 9. Tool and Sensor Testing

After the circuit and sensors are running well, then continue by placing everything into a plywood miniature as a base that has been provided. The miniature is then glued with hot glue for each equipment and sensor. Then after the position is complete, continue with the placement of the equipment according to their respective positions. After that, the testing process is carried out again with the aim that the equipment can still function after being placed in the miniature.

4.3 Smart Parking Monitor Test

After testing the equipment so that the tool functions as expected. Then the equipment is installed on the smart parking prototype board. Furthermore, the monitoring process via oled by viewing empty slots for parking. In addition, in this study a servo motor is used for the crossbar section which functions to open the crossbar when the car is right in front of the sensor. When the car is in the front position of the sensor, the sign will rise and when the car is running, the crossbar will close again. When the car enters the parking slot, the display on the oled can be seen in the following image.

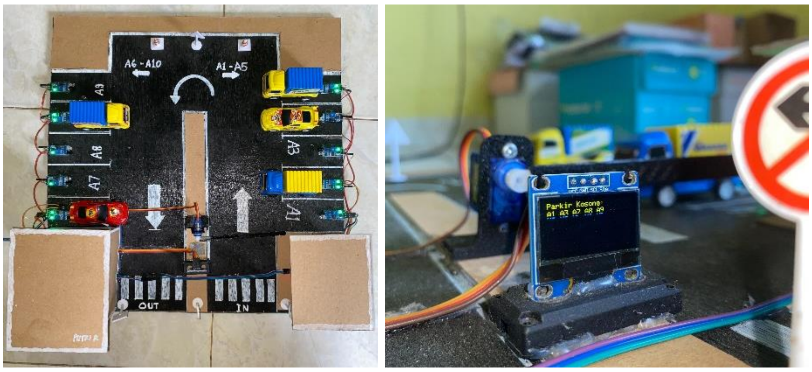

Figure 10. Smart Parking monitoring when 5 slots are filled

Figure 11. Smart Parking monitoring when all slots are filled

Figure 12. Monitoring the door latch when there is a car and when there is no car

4.4 Test Distance and Time of Data Transmission to OLED on Smart Parking

The infrared sensor used in the smart parking system has a characteristic delay time for sending data which is influenced by the distance of the vehicle from the sensor. The following table shows the data on the distance and time of sending data to the OLED.

Table 1. Distance and Time of Data Transmission to OLED

No	Distance (cm)	Sensor Response	Vehicle Status	Parking Status	Delay Time (s)
1	10	Not detected	No Vehicles	Empty	0,100
2	9	Detected	There are Vehicles	Containing	0,090
3	8	Detected	There are Vehicles	Containing	0,080
4	7	Detected	There are Vehicles	Containing	0,070
5	6	Detected	There are Vehicles	Containing	0,065
6	5	Detected	There are Vehicles	Containing	0,060
7	4	Detected	There are Vehicles	Containing	0,055
8	3	Detected	There are Vehicles	Containing	0,050
9	2	Detected	There are Vehicles	Containing	0,045
10	1	Detected	There are Vehicles	Containing	0,040
11	0	Detected	There are Vehicles	Containing	0,035

Based on table 1, at a further distance, such as 10 cm, the delay time is longer, reaching 0.10 seconds. This is due to the weak intensity of the infrared reflection signal at a long distance, so it takes longer to be processed by the Arduino Mega 2560 microcontroller before the data is sent to the OLED screen. Conversely, at a closer distance, such as 0 cm, the delay time becomes shorter, which is 0.035 seconds. This condition occurs because the infrared reflection signal is stronger at close range, so the detection and data transmission process takes place faster. With a pattern of delay time that decreases as the distance of the vehicle from the sensor decreases, this system shows good responsiveness in processing and displaying data in real-time. The Arduino Mega 2560 microcontroller is able to manage data from the sensor efficiently and send information to the OLED in a very short time, ensuring that the system remains relevant for smart parking implementation.

The infrared sensor with the Arduino Mega 2560 microcontroller connected to the OLED can function well in detecting vehicles and managing data transmission time according to the distance of the vehicle from the sensor. This system is effective, responsive, and supports smart parking management accurately and in real-time.

4.5 Test Distance and Time of Data Transmission to Servo on Automatic Cross

The automatic barrier system uses infrared sensors to detect the presence of vehicles based on distance. When the sensor detects a vehicle at a certain distance, the data is immediately processed by the Arduino Mega 2560 microcontroller to control the servo motor that is responsible for opening or closing the barrier..

Table 2. Distance and Time of Data Transmission to Servo on Automatic Cross

No	Distance (cm)	Sensor Response	Vehicle Status	Cross Stature	Opening Delay Time (s)	Closing Delay Time (s)
1	10	Detected	There are Vehicles	Opened	0,093	5
2	9	Detected	There are Vehicles	Opened	0,089	5

3	8	Detected	There are Vehicles	Opened	0,082	5
4	7	Detected	There are Vehicles	Opened	0,073	5
5	6	Detected	There are Vehicles	Opened	0,065	5
6	5	Detected	There are Vehicles	Opened	0,060	5
7	4	Detected	There are Vehicles	Opened	0,057	5
8	3	Detected	There are Vehicles	Opened	0,051	5
9	2	Detected	There are Vehicles	Opened	0,045	5
10	1	Detected	There are Vehicles	Opened	0,040	5
11	0	Detected	There are Vehicles	Opened	0,038	5

Based on table 2, When a vehicle is detected within a distance of 10–0 cm, the barrier automatically opens. The delay time for opening the barrier depends on the distance of the vehicle from the sensor. The closer the vehicle is to the sensor, the shorter the opening delay time. In addition, after the vehicle leaves the sensor area, the system has a closing delay of 5 seconds before the barrier closes again. This time provides tolerance to ensure that the vehicle has completely left the barrier area. The automatic barrier system based on infrared sensors and servo motors shows efficient performance in detecting vehicles, opening the barrier with minimal delay, and closing it automatically after the vehicle leaves. With a waiting time of 5 seconds before closing, this system ensures the safety and comfort of vehicles passing through the barrier. This system is very suitable for application in automatic parking entrances to improve the efficiency of vehicle access management..

5 Conclusion

In this study, a smart parking system based on Arduino Mega 2560 has been successfully developed by utilizing IR sensors to detect vehicles, as well as automatic signs that are operated based on vehicle detection using IR sensors. This system is also equipped with an empty parking slot display displayed on an OLED screen to make it easier for users to find out the availability of parking spaces in real time.

The implementation results show that the IR sensor is able to detect vehicles with good accuracy, and the automatic sign can function responsively according to the conditions of vehicles entering or exiting. The OLED display provides clear and real-time information regarding the number of empty parking slots, increasing user efficiency and convenience in finding a parking space.

With this system, parking area management becomes more structured and automatic, reducing manual intervention, minimizing parking space search time, and providing a more modern parking experience. This system can be further developed by adding features such as IoT connectivity for remote monitoring or electronic payment integration to create a more comprehensive parking solution.

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