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DEVELOPMENT OF AN ARDUINO-BASED SMART PARKING SYSTEM PROTOTYPE FOR OPTIMIZING PARKING LAND USE

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Abstract

The increase in the number of vehicles is not matched by an adequate expansion of parking spaces, while conventional parking systems still rely on manual methods, making it difficult for users to find empty slots. This research aims to develop a prototype of a smart parking system based on the Arduino Mega 2560 that is capable of detecting parking slot availability in real-time. The system was designed by integrating 5 HC-SR04 ultrasonic sensors, 5 FC-51 infrared sensors, a 16×2 LCD, and LED indicators. The research method included hardware design, programming using the Arduino IDE, as well as accuracy and response time testing. The test results showed a detection accuracy of 98% out of 100 trials, with an average response time of 1.87 seconds for the LCD and 1.84 seconds for the LEDs. The combination of the two sensors using OR logic improved system reliability. This system allows drivers to know empty slots without having to circle around, thus optimizing the use of parking space.

Keywords: Smart parking system, Arduino Mega 2560, HC-SR04 ultrasonic sensor, FC-51 infrared sensor, parking space optimization

1. INTRODUCTION

The development of information technology and automation systems has brought significant changes to various aspects of human life. One area experiencing rapid development is intelligent transportation systems (ITS). Modern transportation systems focus not only on vehicles and road infrastructure but also encompass the management of supporting facilities such as parking areas. As the number of motorized vehicles increases annually, the need for an efficient parking management system becomes increasingly crucial. The continued growth in vehicle numbers has led to an increase in the need for parking. Based on conditions in various large cities and public areas such as shopping centers, offices, universities, hospitals, and other public facilities, parking issues are often a cause of traffic congestion and user inconvenience. Limited parking space often results in drivers spending more time searching for a vacant parking space.

Conventional parking systems, still widely used today, generally rely on manual monitoring by parking attendants. Vehicle users must navigate the parking area searching for available spaces. This process not only wastes time but also increases fuel consumption, increases traffic congestion in the parking area, and reduces user comfort. Furthermore, parking managers often struggle to accurately monitor parking occupancy levels due to the lack of a monitoring system capable of providing real-time information. Another common problem with conventional parking systems is the low efficiency of parking space utilization. In many cases, there are still empty parking slots that drivers don't know about due to a lack of available information. As a result, some parking areas become congested, while others remain empty and underutilized. This situation demonstrates the need for a system capable of providing fast and accurate information on parking slot availability.

The development of microcontroller and sensor technology opens up opportunities for developing more modern and efficient parking systems. One technology widely used in automated system development is the Arduino microcontroller. Arduino is an easy-to-use, open-source electronics platform capable of integrating various types of sensors and output devices. Its ease of programming and relatively low implementation costs make it an ideal solution for developing intelligent parking system prototypes. A smart parking system is a parking management concept that utilizes sensor technology, microcontrollers, and communication devices to automatically detect and communicate information about parking conditions. This system detects the presence of vehicles in each parking slot in real time, thereby displaying parking space availability information to users. This study used a combination of an HC-SR04 ultrasonic sensor and an infrared (IR) sensor as a vehicle detection device. The ultrasonic sensor works by utilizing high-frequency sound waves to measure the distance between the sensor and an object, while the infrared sensor works by detecting the reflection of infrared light from objects near the sensor. The use of these two types of sensors is expected to increase the level of vehicle detection accuracy compared to using only one type of sensor. Ultrasonic sensors have the advantage of accurately measuring distance, allowing them to detect vehicle presence based on the vehicle's position relative to the sensor. However, these sensors can be affected by certain environmental conditions, such as the angle of reflection of objects and the presence of obstacles in the detection area. On the other hand, infrared sensors respond quickly to object presence but have limited detection range. Therefore, a combination of these two sensors can complement each other, resulting in a more reliable detection system.

The Arduino Mega 2560 is used as the system's central controller. The Arduino Mega was chosen because it has more input-output pins than the Arduino Uno, allowing it to handle multiple sensors simultaneously. This is crucial because the parking system being designed consists of multiple parking slots, each requiring its own detection sensor and indicator. Information regarding the condition of each parking slot is displayed via LED indicators and a 16x2 LCD screen. The LEDs serve as visual indicators to show the status of each parking slot. Green indicates that a parking slot is available, while red indicates that a parking slot is in use. Furthermore, the LCD displays the total number of available parking slots, allowing users to check the parking area's condition before entering.

The implementation of a smart parking system offers various benefits for both users and parking managers. For users, the system can help reduce the time spent searching for a parking space, thereby increasing travel comfort and efficiency. For parking managers, the system can provide real-time information on parking lot utilization levels, facilitating monitoring and decision-making regarding parking area management. Many researchers have previously conducted research on smart parking systems. Various methods and technologies have been implemented to improve parking management efficiency, including ultrasonic sensors, infrared sensors, RFID, license plate recognition cameras, and integration with the Internet of Things (IoT). However, most of the systems developed are complex and expensive to implement, making them less suitable for small- and medium-sized parking areas.

Therefore, a simpler, more economical solution is needed, while still delivering good performance. Developing a prototype of an Arduino-based smart parking system with a combination of ultrasonic and infrared sensors is one possible solution to address this issue. The developed system is expected to provide a high level of detection accuracy, fast response times, and ease of implementation and operation. Beyond the technical aspects, this research is also highly relevant to the needs of modern transportation systems, which demand efficiency, speed, and accuracy of information. In today's digital age, people increasingly require services that provide instant and accurate information. Smart parking systems are one example of technology implementation that can support the creation of a more organized and efficient transportation environment.

Through this research, it is hoped that a prototype of a p system can be obtained.

2. RESEARCH METHODS

2.1 HARDWARE DESIGN

The hardware used in this research consists of:

- Arduino Mega 2560
- 5 HC-SR04 Ultrasonic Sensors
- 5 FC-51 Infrared Sensors
- 16×2 LCD with I2C module
- 5 red LEDs
- 5 green LEDs
- Breadboard
- Jumper cables
- 5 Volt power supply

Each parking space is equipped with ultrasonic and infrared sensors at the top of the parking area to detect vehicle presence. An Arduino Mega 2560 serves as a data processing center, receiving input from all sensors and controlling the output, which consists of an LCD and LED indicator.

2.2 SOFTWARE DESIGN

The software was developed using the Arduino IDE with the C/C++ programming language. The program is designed to repeatedly read sensors using the loop() function so that the condition of each parking slot can be monitored in real time.

The software process stages include:

1. Initialize input and output pins.
2. Ultrasonic and infrared sensor data reading.
3. Data processing using OR logic.
4. Determination of parking slot status.
5. LED and LCD display updates.
6. Continuous repetition of the monitoring process.

2.3 RESEARCH FLOWCHART

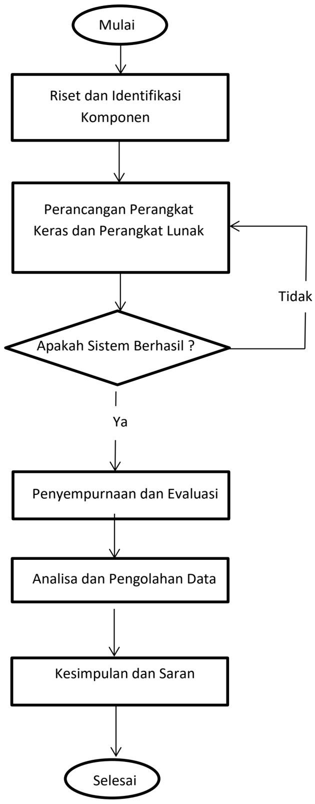

Figure 2.1 Research Flowchart

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2.4 SYSTEM FLOW DIAGRAM

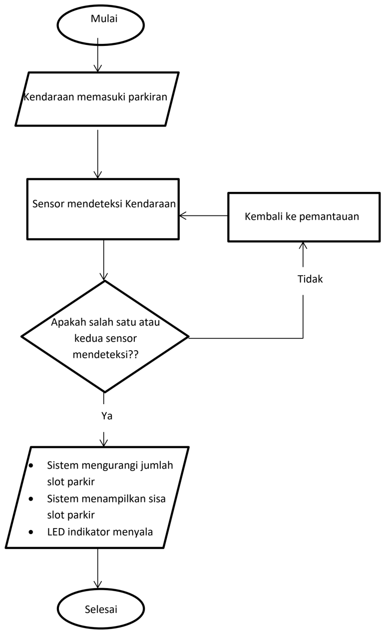

Figure 2.2 System Flow Diagram

The system workflow is shown in Figure 2.2.

1. The system is initialized.
2. Ultrasonic and infrared sensors read the condition of the parking slot.
3. Arduino checks the sensor readings.
4. If one of the sensors detects a vehicle, the slot is declared occupied.
5. The red LED lights up and the number of empty slots decreases.
6. If no vehicles are detected, the slot is declared empty.
7. The green LED lights up and the number of empty slots is displayed on the LCD.
8. The system is monitoring again.

3. RESULTS AND DISCUSSION

3.1 16x2 LCD Test Results

LCD testing was conducted to ensure that information could be displayed properly. Test results showed that the LCD was able to display characters and system information clearly without any display interference.

Table 1.1 Results of testing the 16x2 LCD indicator

Testing	Appearance	Results
1	SMART PARKING	Succeed
2	READY	Succeed
3	T:1 K:4	Succeed
4	01000	Succeed

Figure 3.1 16x2 LCD Display First Experiment

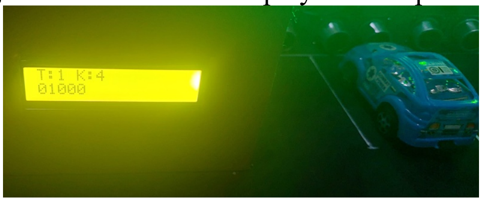

Figure 3.2 16x2 LCD Display Second Experiment

Test results showed that all characters were displayed correctly, with no dead pixels or blurry displays. The LCD is capable of updating the number of available parking spaces in real time, making it easier for users to monitor parking conditions.

3.2 16x2 LCD Test Results

Ultrasonic sensor testing was carried out to determine the sensor's ability to detect the presence of vehicles at various distances.

```
7.02 cm    KOSONG    Objek terlalu jauh
6.90 cm    TERISI    Objek terdeteksi
7.00 cm    KOSONG    Objek terlalu jauh
7.02 cm    KOSONG    Objek terlalu jauh
7.02 cm    KOSONG    Objek terlalu jauh
6.90 cm    TERISI    Objek terdeteksi
7.00 cm    KOSONG    Objek terlalu jauh
7.02 cm    KOSONG    Objek terlalu jauh
6.90 cm    TERISI    Objek terdeteksi
6.90 cm    TERISI    Objek terdeteksi
7.00 cm    KOSONG    Objek terlalu jauh
7.02 cm    KOSONG    Objek terlalu jauh
```

Figure 3.3 HC-SR04 measurement on serial monitor

Table 1.2 HC-SR04 Sensor Test Results

Actual Distance (cm)	Measured Distance (cm)	Status
10	10.20	Not detected
9	9.50	Not detected
8	8.80	Not detected
7	7.02	Threshold
6	6.90	Detected
5	5.02	Detected
4	4.01	Detected
3	3.01	Detected
2	2.02	Detected
1	1.01	Detected

Test results show that the HC-SR04 sensor is capable of detecting objects well at distances of less than 7 cm. At a distance of 7 cm, there was a variation in readings of 6.90 cm to 7.02 cm, which is still within the sensor's tolerance limits. This difference is due to the characteristics of ultrasonic sensors, which have a specific measurement resolution and are influenced by environmental conditions and sound wave reflection.

3.3 Infrared Sensor Test Results

Infrared sensor testing is carried out to determine the sensor's ability to detect the presence of objects after the calibration process.

Table 1.3 Infrared Sensor Test Results

Object Distance (cm)	Status
10	Not detected
9	Not detected
8	Not detected
7	Not detected
6	Not detected
5	Not detected
4	Detected
3	Detected
2	Detected
1	Detected

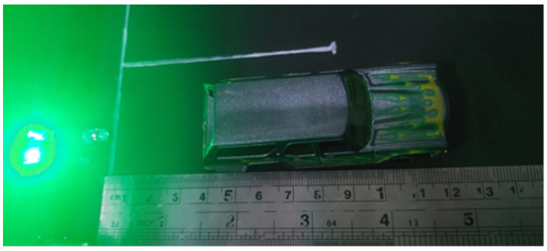

Figure 3.4 Results of infrared sensor distance measurements

Test results show that the FC-51 infrared sensor can stably detect objects at a maximum distance of 4 cm after sensitivity calibration using a potentiometer. The sensor generates a low signal when an object is detected and a high signal when no object is present in front of the sensor. With this configuration, the sensor can be used as a support for ultrasonic sensors to improve the reliability of vehicle detection.

3.4 System Accuracy Test Results

Accuracy testing was conducted on five parking slots, both empty and occupied. Each condition was tested 10 times, resulting in a total of 100 trials.

Table 1.4 System Accuracy Test Results

Slot	Total Testing	Match Detection	Mismatch Detection
1	20	19	1
2	20	20	0
3	20	20	0
4	20	20	0
5	20	19	1
Total	100	98	2

These results demonstrate that the system is capable of detecting parking slot conditions with excellent accuracy. Detection errors were caused by ultrasonic wave reflections from objects around the parking area and the sensor's position being less than perpendicular to the object during testing. The combination of ultrasonic and infrared sensors has been shown to improve system reliability compared to using a single sensor alone.

3.5 System Response Time Test Results

Response time test results were carried out to measure the time required by the system from when the vehicle enters the parking slot until the LCD and LED update the status.

Table 1.5 System Test Results Against Time

Slot	The First Experiment	LCD response (seconds)	Green LED Response (seconds)	Red LED Response (seconds)
1	1	2.42	1.92	1.68
1	2	2.46	2.23	1.92
1	3	1.93	2.03	1.93
2	1	1.81	2.00	1.72
2	2	3.00	2.22	3.03
2	3	2.60	1.94	1.64
3	1	1.21	1.56	1.45
3	2	2.14	2.22	1.67
3	3	1.67	1.67	1.81
4	1	1.21	1.89	1.49
4	2	2.47	2.34	1.79
4	3	1.60	1.56	2.33
5	1	1.08	1.52	1.62
5	2	1.01	1.28	1.56
5	3	1.39	1.32	1.48
Average		1.87	1.84	1.81

The response time test results were conducted by measuring the time interval from when the vehicle occupied the parking slot until the LCD and LED indicators updated their status. Based on 15 trials on 5 parking slots, the average LCD response time was 1.87 seconds, while the Green LED was 1.84 seconds, and the Red LED was 1.81 seconds. All three showed almost the same value with a difference of only 0.03 seconds. This response time of under 2 seconds is still considered very good for a prototype-scale parking system and meets the criteria of a real-time system.

3.6 System Response Graph Against Time

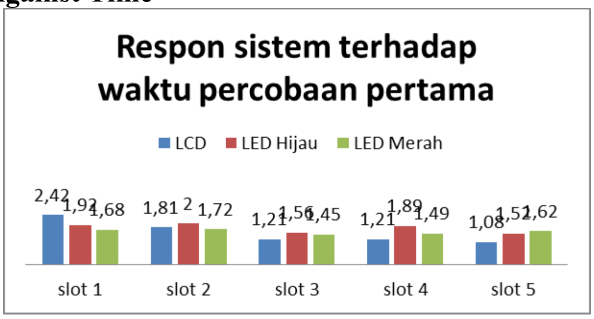

Figure 3.5 First trial response time

In the first experiment, the response times were in the range of 1.08–2.42 seconds. The fastest LCD response occurred in slot 5 at 1.08 seconds, while the slowest LCD response occurred in slot 1 at 2.42 seconds. For the green LED, the fastest response was obtained in slot 5 at 1.52 seconds and the slowest in slot 2 at 2.00 seconds. Meanwhile, the red LED showed the fastest response in slot 3 at 1.45 seconds and the slowest in slot 2 at 1.72 seconds. These results indicate that the system is able to update parking status quickly in all tested slots.

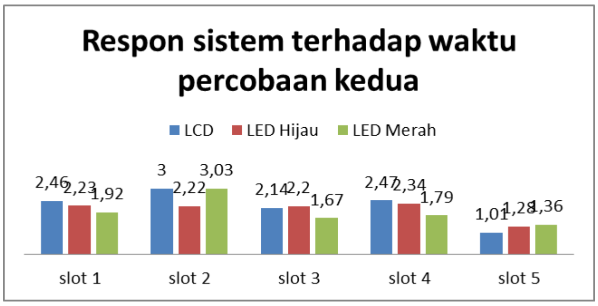

Figure 3.7 Third Experiment response time

The second experiment experienced greater variation compared to the first experiment. The fastest LCD response occurred in slot 5 with a time of 1.01 seconds, while the slowest response time occurred in slot 2 at 3.00 seconds. For the green LED, the fastest response was obtained in slot 5 at 1.28 seconds and the slowest in slot 4 at 2.34 seconds. The red LED showed the fastest response in slot 5 at 1.56 seconds and the slowest in slot 2 at 3.03 seconds. Despite some higher response values, the system was still able to update the parking status in less than 4 seconds.

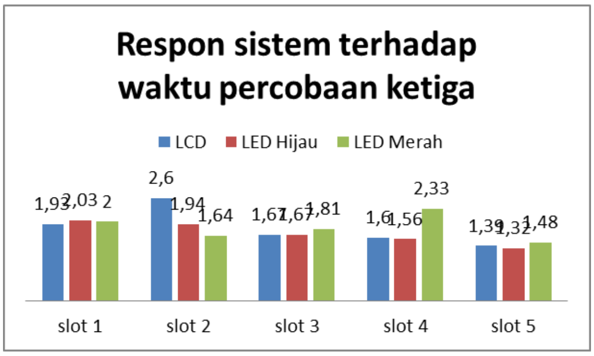

Figure 3.6 Second time response experiment

It can be seen that the system response time in the third experiment was relatively stable. The fastest LCD response occurred in Slot 5 at 1.39 seconds and the slowest in Slot 2 at 2.60 seconds. For the green LED, the fastest response was obtained in Slot 5 at 1.32 seconds and the slowest in Slot 1 at 2.03 seconds. Meanwhile, the red LED showed the fastest response in Slot 5 at 1.48 seconds and the slowest in Slot 4 at 2.33 seconds. These results indicate that the system is able to maintain good response performance despite small variations in each experiment.

3.7 Discussion of Research Results

Test results of the HC-SR04 ultrasonic sensor show that the sensor is able to consistently detect objects at distances of less than 7 cm. At distances of 1–6 cm, objects are successfully detected, while at distances above 7 cm, objects are not detected. The variation in readings that occurs is still within the sensor's tolerance limits and therefore does not affect the overall system performance. These results indicate that the ultrasonic sensor can be used as the primary detector for vehicle presence in parking slots. Testing of the FC-51 infrared sensor showed that it can detect objects at a maximum distance of 4 cm after sensitivity calibration. The sensor generates a low signal when an object is detected and a high signal when no object is present. Using an infrared sensor as a supporting sensor can improve the system's reliability in detecting vehicles, especially when there is interference with the ultrasonic sensor readings. The system's accuracy was tested on five parking slots, with a total of 100 trials. The test results showed that the system successfully made 98 correct detections, achieving an accuracy rate of 98%. Only two detection errors occurred, caused by ultrasonic wave reflections from objects around the parking area. This high accuracy rate demonstrates that the combination of ultrasonic and infrared sensors improves detection performance compared to using a single sensor alone. In addition to accuracy, the system's response time also demonstrated good results. Based on 15 tests, the average LCD response time was 1.87 seconds, the green LED 1.84 seconds, and the red LED 1.81 seconds. The difference in response time between components was only 0.03 seconds, so the information displayed was synchronous. A response time of less than 2 seconds indicates that the system is capable of providing parking availability information quickly and meeting the needs of real-time parking monitoring. Overall, The Research Results Show That The Arduino Mega 2560-Based Intelligent Parking System Prototype Is Capable Of Performing According To The Research Objectives. The System Successfully Detected Vehicle Presence With A High Level Of

Accuracy And Fast Response Time. Thus, The Developed System Has The Potential To Be Implemented As A Solution For Monitoring parking space availability in small to medium-scale parking areas .

4. CONCLUSION

Based on the results of the design, implementation, and testing that have been carried out, it can be concluded that the prototype of the smart parking system based on Arduino Mega 2560 has been successfully developed and is able to detect the availability of parking slots in real-time. The combination of the HC-SR04 ultrasonic sensor and the FC-51 infrared sensor can work well in detecting the presence of vehicles in each parking slot. The test results show that the system has a detection accuracy rate of **98%** from a total of 100 trials. In addition, the system has an average response time of **1.87 seconds** on the LCD, **1.84 seconds** on the green LED, and **1.81 seconds** on the red LED. These results indicate that the system is able to provide parking availability information quickly and accurately so that it can help improve the efficiency of parking space use. Thus, the developed system has the potential to be applied and further developed in larger-scale parking areas through the integration of internet of things (IoT) technology.

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