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Real-Time Space Availability Detection in Smart Parking Systems using Infrared Sensor and Microcontroller ATmega 328p

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***Abstract*—In the growing digital era, vehicles have become a staple for daily mobility. This poses a significant parking problem, especially in urban areas with limited parking spaces. The search for parking spaces often leads to congestion, air pollution, fuel waste, and frustration for drivers. This research aims to develop an smart parking system using infrared sensors and an ATmega328p microcontroller to detect the availability of parking slots in real time. This system provides information to the driver through a Liquid Crystal Display (LCD) screen installed at the entrance of the parking area. The methods used in this research are direct testing and tool prototyping. The test results show that the parking system model successfully displays the availability status of each parking area in real-time on the display screen, with data obtained from infrared sensors and processed by the ATmega328p microcontroller.**

***Index Terms*—Automatic Parking Slot; Internet of Things (IoT); Infrared sensor; Traffic Congestion**

I. Introduction

In the current development of the digital era, vehicles have become a basic need for mobility in daily life [1-5]. This leads to crucial parking problems, affecting people's quality of life. With a limited number of parking spaces in almost every city, finding a parking space is often time-consuming and causes traffic congestion, air pollution, fuel waste, and frustration for drivers [5-11]. In addition, urban expansion leads to traffic congestion, where the search for parking spaces accounts for up to 30%-50% of congestion within cities [4][7][12-14]. Therefore, the availability of parking spaces is a major issue in urban areas, and awareness of its importance is increasing. So smart parking management systems that collect real-time information about parking locations that are accessible to the public are becoming a major focus [4][5][15-20].

According to Statista [21], it is estimated that the number of autonomous vehicles worldwide will increase to more than 54 million by 2024, with a global market value of nearly 62 billion US dollars by 2026. This indicates a growing need for efficient and innovative parking solutions. Smart parking systems can help overcome various problems arising from conventional parking by utilizing technologies such as the Internet of Things (IoT), sensors, and mobile applications [1-7][12][14-17][22][23].

Some research on automotive parking systems has been carried out, such as research conducted by S. Saravanan et al. [17] designed an IoT-based smart parking system. This system uses infrared sensors to detect available parking spaces and display the information on a mobile application, where users can reserve parking spaces and reduce traffic congestion. The system also includes an experimental setup with Infrared sensors, Arduino Uno, and Wireless Fidelity (Wi-Fi) modules.

Research by Md. Thoufiq Zumma et al. [24] designed an Arduino Uno-based smart car parking system. The system uses MobileNet Classifier to recognize available parking slots based on images taken from cameras that continuously monitor parking lot conditions. In addition, the system also involves components such as servo motors, IR sensors, fire alarms, and Liquid Crystal Display (LCD) that are all connected to Arduino.

Research by Soni et al. [25] also designed a smart parking system that uses ATmega 328p microcontroller technology. The parking system uses infrared sensors to detect the availability of parking slots and then display them on the LCD screen. Buzzers and Light Emitting Diode (LED) are also used as warnings if there are vehicles in and out.

From various literature conducted, the application of technology in parking management systems can be an effective solution to overcome this problem. One approach that can be taken is to develop a smart parking system that can detect the availability of parking spaces in real time and provide that information to the driver [4][5][8][15-20][22][24][25]. This system not only helps drivers find parking spaces quickly but also reduces traffic congestion caused by prolonged searches for parking spaces [5][6][12][20].

In this study [15] introduced a smart parking system that uses Arduino and infrared sensors to detect the presence of vehicles and display parking availability in real-time. Aimed at reducing traffic congestion and fuel consumption, the system uses LEDs to indicate slot status.

In [17], an Arduino Uno-based smart parking system was developed using IR sensors and a Telnet-based mobile app to monitor parking availability. However, the system lacks user-friendly features, object differentiation, and real-world validation. This highlights the need for a more scalable and intelligent parking system with improved accuracy and usability.

In [18], an ultrasonic-based parking assistance system uses Arduino Uno to improve safety and convenience by providing real-time visual and auditory feedback. While the system is low-cost and easy to implement, it has limitations such as inaccurate distance measurement and difficulty in detecting certain objects.

This research will be carried out with a direct test method and prototyping tools by utilizing infrared sensors to detect the availability of parking slots. Real-time information regarding the availability of parking slots will be displayed on the information screen installed at the entrance of the parking area. This allows drivers to know the status of parking availability before entering the parking area, so they can avoid full areas and find alternatives more efficiently.

The implementation of this automated parking system is expected to increase convenience and efficiency in parking management in urban areas, reduce the negative impact of searching for parking spaces, and support the creation of a more environmentally friendly and organized urban environment.

II. Methodology

The method used in this research is hands-on testing and prototyping which involves several stages, including overall system design through block diagrams, system flowcharts, and hardware and software system design. The initial stage involved designing a block diagram to provide an overview of the main components and their relationships, followed by designing a system flowchart that describes the operational steps. Next, the hardware and software design were carried out to ensure that the physical components and applications that support the operation of the system are designed as required.

A. System Block Diagram

The initial stage in this research is a system design that identifies the system components using a block diagram. The system is designed using electronic components shown in Figure 1 as a block diagram. These electronic components include an infrared sensor, Atmega328 microcontroller, servo motor, LCD and Power Supply.

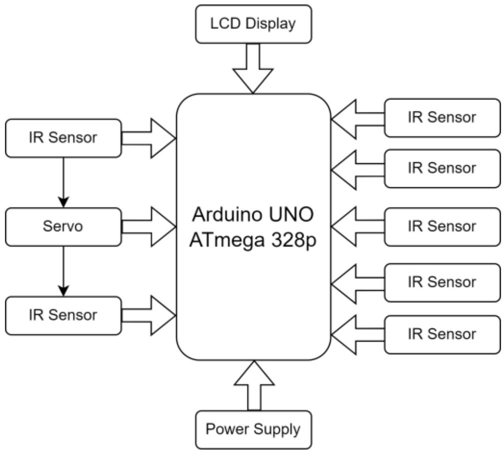

Fig. 1. System Block Diagram

The system uses infrared sensors to detect vehicles. The sensors are installed in each parking slot, entrance gate, and exit gate to monitor vehicle occupancy and vehicle entry and exit. Where the gate is controlled using a servo motor.

The main component of this parking system is the Arduino ATmega 328p microcontroller, which interprets input data from Infrared sensors based on instructions programmed and stored in its memory.

Here are the functions of the components in the block diagram [26]:

1. Power Supply: This circuit begins with a 5-volt, 2-ampere power source from an Arduino Uno. The 5-volt power supply has various components in the system.
2. Arduino UNO: The Arduino UNO board serves as the main controller for the system. It processes sensor data, controls servo motors, and displays information on the LCD.
3. Module I2C: This module interfaces with the 20×4 LCD (Liquid Crystal Display), simplifying the connection between the LCD and the Arduino.
4. 20×4 LCD: This LCD displays information about parking slots, including messages about slot availability and other system statuses.
5. Infrared Sensor: The system utilizes two infrared sensor, one positioned at the entrance and the other at the exit gate.
6. Mini Servo Motor: Mini servo motors control the opening and closing of gates, allowing or preventing vehicle entry based on data from the IR sensors.
7. Six Parking Slots: The system features six parking spaces, each equipped with an Infrared sensor to detect the presence of a car. These sensors are crucial for monitoring which spaces are occupied and which are available.

Overall, the Arduino microcontroller processes sensor data, controls gate access, and displays parking slot information, making the parking system automated and efficient.

B. Software Design

This research utilizes the Arduino IDE software to write program code for the automatic parking system and slot availability management that has been designed to provide instructions to the system. For the Arduino Uno device to function properly, this program code must be entered into the Arduino Uno. To run the program in the Arduino Uno microcontroller, a USB drive, Arduino IDE software, and an ATmega328p Microcontroller are required. The following program code in C language serves to connect the various modules according to the condition of the components when used.

C. System Flow Chart Design

An illustration of the overall system flow chart is shown in Figure 2 below.

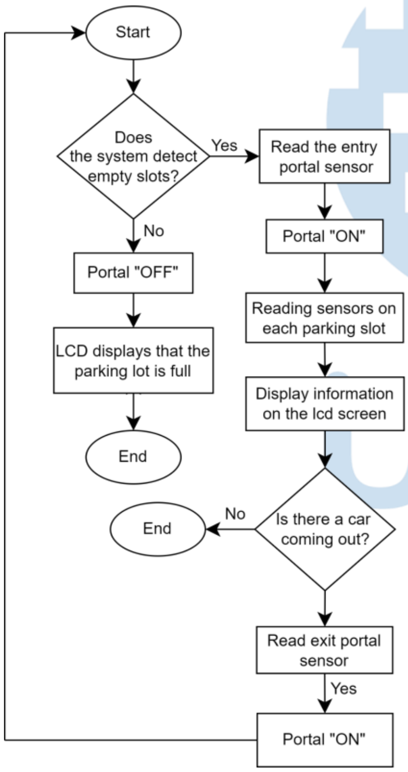

Fig. 2. System Flow Chart

In the flowchart system above, the Arduino will receive input from the infrared sensor at the entrance, and then the Arduino will process the input to drive the servo motor so that the door portal opens. However, if the parking slot is detected to be full, the servo motor will not work, so the entrance portal will not open. The Arduino will also receive input from the infrared sensors installed in each parking slot, and then the Arduino will process the input to move the servo motor so that the entrance portal opens. The system will continue to run if the Arduino is connected to the power supply.

D. Hardware System Design

The circuit scheme of the system is shown in Figure 3.

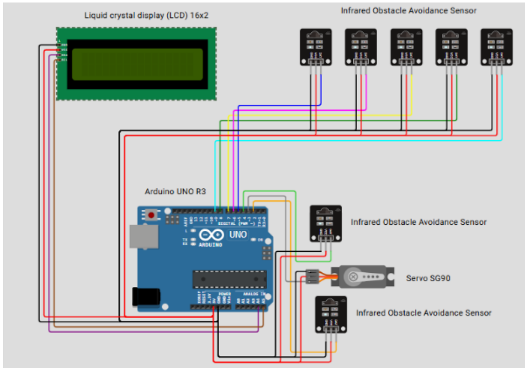

Fig. 3. Circuit Diagram

In Figure 3, the circuit configuration of the automatic parking system and parking slot availability is illustrated. This system utilizes an ATmega 328p microcontroller as the central controller. Arduino handles sensor data processing, servo motor control, and information display on the LCD. The microcontroller is connected to infrared sensors at the entrance and exit of the parking lot as well as at the five parking slots through digital pins 2-9 Arduino to detect the presence of cars. Besides being connected to the infrared sensor, the microcontroller is also connected to the I2C module and servo. The Arduino pin is connected to the I2C module on pins A4 and A5, then this I2C module is connected to the LCD to display parking slot availability information. The servo is connected to digital pin 3 of the Arduino to regulate the opening and closing of the parking bar. Based on the data collected from the Infrared sensor, the servo motor will be activated.

This innovative automated parking system is designed to improve efficiency and convenience for users. The system utilizes various reliable components in Table 1 below.

TABLE I. COMPONENTS OF PROTOTYPING

No.	Components	Amount
1	Arduino UNO	1
2	IR Sensor	7
3	Servo Motor	1
4	Jumper Cables	± 30
5	LCD	1

III. Results and Analysis

Based on a series of methods, the results of the tool design are shown in Figure 4.

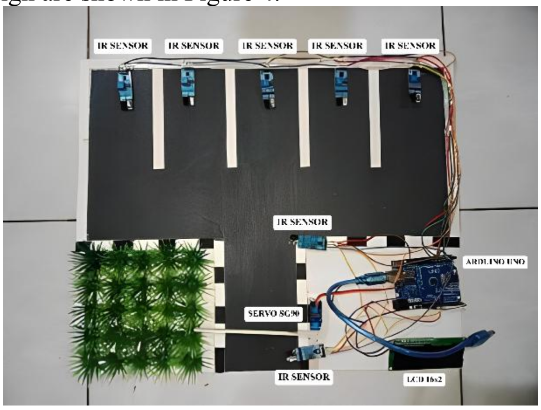

Fig. 4. Prototype Design

The design results of the parking system and the automatic parking slot availability using Arduino are presented through prototypes and simulations, as shown in Figure 4. The initial step of the simulation of the prototype of this tool starts when a car approaches the parking entrance, then two infrared sensors installed on both sides of the gate will detect it. The task of this infrared sensor is to detect objects at a predetermined distance.

This research utilizes the Arduino IDE software to write program code for the automatic parking system and slot availability management that has been designed to provide instructions to the system. In order for the Arduino Uno device to function properly, this program code must be entered into the Arduino Uno. To run the program in the Arduino Uno microcontroller, a USB drive, Arduino IDE software, and an ATmega328p Microcontroller are required. The following program code in C language serves to connect the various modules according to the condition of the components when used.

In the test, once the car is detected at the parking entrance, the servo will open. Then the Infrared sensors installed in each slot will detect the empty parking slots and display them on the LCD screen at the entrance. Thus, the driver can know the available spaces within the parking area with perfect location accuracy from the entrance. Moreover, once the vehicle occupies one of the slots, the LCD screen will reduce the number of empty spaces by one unit, providing information about the number of available spaces at the entrance.

Fig. 5. Initial Display on LCD

In Figure 5 above, the initial display on the LCD when the system starts running is shown. Once the automated parking system and automated parking slot availability have been designed, the next step is to conduct a thorough test of the device. This test involves various conditions to ensure that the device is functioning properly. The results of this test will be displayed on a 16x2 LCD screen that provides information about available parking slots. The test results will be displayed in Table 2 below.

TABLE II. IR SENSOR TESTING OF ENTRANCE AND EXIT DOORS

Test Conditions	IR Sensor	Servo	Gate	LCD Display
Car approaching entrance gate	Detected	Active	Open	"Availabl e Slots: 5"
Car approaching entrance gate (all slots full)	Detected	Inactive	Closed	“Parking Full”
Car moving away from the entrance gate	Not Detected	Inactive	Closed	"Availabl e Slots: 5"
Car approaching the exit gate	Detected	Active	Open	"Availabl e Slots: 5"
Car moving away from the exit gate	Not Detected	Inactive	Closed	"Availabl e Slots: 5"

Table 2 above shows the system response to vehicles approaching the entry and exit gates. When a car approaches the entrance gate and there is an available slot, the IR sensor detects the vehicle, activates the servo motor to open the bar, and the LCD screen displays "Slot Available: 5." If the parking lot is full, the system correctly identifies this and keeps the bar closed, with the LCD display showing "Parking Full." This ensures that vehicles are not allowed to enter when there are no slots available, to prevent overcapacity. The 'Parking Full' condition is shown in Figure 6 below.

Fig. 6. Full Slot Indication

As the vehicle approaches the exit gate, the IR sensor again detects the vehicle, and the servo motor activates to open the bar. The LCD display updates to the original slot availability and shows that the slot has become available after the vehicle exits. This real-time condition of available slots helps in managing parking efficiently, as the system dynamically adjusts the displayed information to reflect the current condition of the parking area.

Infrared sensor testing was also carried out on each parking slot which will be shown in table 3.

TABLE III. IR SENSOR TESTING OF EACH PARKING SLOT

No	Parking Slot	IR Sensor	Slot Condition	LCD Display
1	Slot 1	Detected	Occupied	Slot 1: Occupied
2	Slot 2	Detected	Occupied	Slot 1: Occupied
3	Slot 3	Detected	Occupied	Slot 1: Occupied
4	Slot 4	Detected	Occupied	Slot 1: Occupied
5	Slot 5	Detected	Occupied	Slot 1: Occupied

Table 3 evaluates the performance of the IR sensor in detecting the occupancy status of each parking slot. Each slot is tested for empty and occupied conditions. When the slot is empty, the IR sensor does not detect any vehicles, and the LCD screen displays the slot as empty. Conversely, when the slot is occupied, the IR sensor detects the presence of a vehicle, and the LCD screen updates to show the slot as occupied. This detailed and accurate detection of the status of each slot is essential to provide the driver with precise and up-to-date information about available parking spaces. Here is when the whole system is running and the parking slot detects the presence of a car:

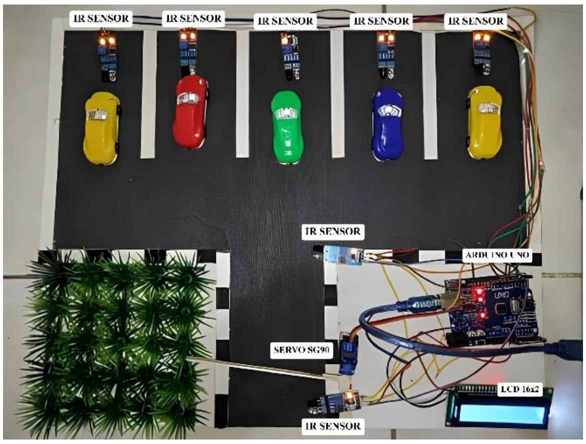

Fig. 7. Prototype When Running

Overall, the system functioned as expected, accurately detecting the presence of vehicles, controlling the servo motors to set the entry and exit bars, and providing real-time updates on the LCD screen regarding the availability of parking slots. This automated approach improves the efficiency of parking management, reduces the time drivers spend searching for available spaces, and helps reduce traffic congestion within the parking area.

Below is when the IR sensors one by one detect the presence of a car, the serial monitor display on the Arduino IDE software and also the LCD will change according to which part of the slot is empty and also filled.

```
Slot status: S1=1, S2=1, S3=0, S4=1, S5=1
Slot status: S1=1, S2=1, S3=0, S4=1, S5=1
Slot status: S1=1, S2=1, S3=0, S4=1, S5=1
Slot status: S1=1, S2=1, S3=0, S4=1, S5=1
Slot status: S1=1, S2=1, S3=0, S4=1, S5=1
Slot status: S1=1, S2=1, S3=0, S4=1, S5=1
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Slot status: S1=1, S2=1, S3=0, S4=1, S5=1
Slot status: S1=1, S2=1, S3=0, S4=1, S5=1
Slot status: S1=1, S2=1, S3=0, S4=1, S5=1
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Fig. 8. Serial Monitor When the Slot Detects a Car

IV. Conclusion

This research successfully designed and implemented a smart parking system using IoT technology and infrared sensors. The system is able to detect the availability of parking slots in real time and display the information on the LCD screen at the entrance of the parking area. Tests show that the system can detect vehicles passing through the infrared sensors, control servo motors to open and close the parking portals and provide accurate information about the availability of parking slots on the LCD. The system not only helps drivers find parking spaces quickly but also reduces traffic congestion caused by searching for parking spaces. Thus, the implementation of this automated parking system is expected to increase convenience and efficiency in parking management in urban areas and support the creation of a more environmentally friendly and organized urban environment. In the future, the development of mobile applications, the integration of payment systems, the use of other sensors, and further research can improve the accuracy, efficiency, and functionality of the system, as well as provide greater benefits to users and contribute to the creation of a smart, integrated, and sustainable urban environment.

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