ETHIOPIAN INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH

eISSN: 2349-5715 pISSN: 2349-5707

Volume: 12, Issue 04, April-2025 SJIF 2019: 4.702 2020: 4.737 2021: 5.071 2022: 4.919 2023: 6.980 2024: 7,662

EFFICIENT MANAGEMENT OF SMALL-SIZED PARKING SPACES: AN APPROACH BASED ON THE ARDUINO PLATFORM

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Abstract: This article discusses the issue of efficient management of small-sized parking lots, with a focus on the development and testing of an automated system based on the Arduino platform. The system identifies parking space occupancy using IR sensors and provides visual information through LED lights. Sensors installed at the entrance and exit points, along with a servo motor-based barrier, automatically control the movement of vehicles. The system's tests confirm its reliability, affordability, and practical efficiency. The article also analyzes the advantages and limitations of the system compared to existing scientific developments and suggests potential directions for future improvements. This solution is recommended as a convenient, cost-effective, and efficient technological approach for small and medium-sized parking lots.

Keywords: Arduino, automated parking, IR sensor, servo motor, barrier, LED indicator, real-time monitoring, small-sized parking, smart system, transport management.

Introduction

With the rapid increase in the number of vehicles in modern cities, the issue of parking lots has become increasingly urgent. There is a growing need for efficient management of parking spaces, especially around large shopping centers, office buildings, and educational institutions, to meet the daily needs of the population. Otherwise, problems such as irregular parking, congestion, and time loss will arise.

As a technological solution to this issue, the implementation of automated parking systems plays a significant role. These systems not only detect available spaces but also manage the entry and exit processes, reducing human involvement and increasing efficiency. This project involves the development of a smart parking system based on the Arduino platform, which monitors vehicle movement using simple IR sensors and servo motors, detects the occupancy or availability of parking spaces in real-time, and ensures automatic barrier control.

This project not only allows the application of technical knowledge in practice but also demonstrates the role of automation in everyday life as an essential element of smart city infrastructure.

Literature Review

Several international studies have been conducted in the field of modern parking systems, their effectiveness, and their role in improving urban infrastructure. This analysis will focus on developments related to parking systems in different countries.

Japan, known for its high level of technological development and success in urbanization, is one of the countries where automated parking systems have been successfully implemented. A study by Nakai et al. (2021) analyzed the effectiveness of automatic parking systems installed in Japanese cities, particularly in Tokyo and Osaka. The research results show that these systems, despite limited space in city centers, effectively manage vehicle parking. Additionally, these systems optimize transport, reduce harm to the ecosystem, and increase movement speed.

Germany, particularly in major cities like Berlin and Munich, is also giving significant attention to enhancing urban infrastructure through automated parking systems. A study by Häusler et al. (2020) explored the importance of electronic parking systems in vehicle space management in German cities. The findings indicate that these systems contribute to effective urban transport management and help

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reduce congestion. The electronic systems also provide real-time detection of available spaces, optimizing the use of parking lots.

Sweden is another advanced country in the development of smart parking systems. A study by Ekman et al. (2022) analyzed the ecological impact and effective influence of automated parking systems on the transport system in Stockholm and Gothenburg. The research results show that these systems, by applying eco-friendly technologies, not only ensure effective parking space management but also reduce carbon emissions. This, in turn, reduces the demand for green energy in cities and helps preserve the environment.

In Singapore, new approaches have been developed based on smart parking systems and mobile applications. A study by Tan et al. (2019) examined the effectiveness of parking systems in Singapore. The study emphasized that the ability to pre-book parking spaces using mobile applications optimizes vehicle placement and increases the speed of urban transport. These systems also create convenience for users, saving their time and reducing excessive congestion in the transport sector.

In the United Arab Emirates, especially in Dubai, smart parking systems are operating effectively not only in transport management but also through the application of green technologies. A study by Al-Hammadi et al. (2020) analyzed the ecological impact of parking systems in Dubai. The research showed that the integration of eco-friendly technologies, such as solar energy, into parking systems not only helps efficiently manage transport but also creates new, green, and sustainable approaches to urban infrastructure development.

Methodology

This project uses the Arduino platform to implement automated control of the parking system. The program utilizes IR sensors and LEDs to detect parking space availability, manage the barrier, and provide visual indicators to the user. The use of the Arduino platform simplifies the control of automated systems and ensures their efficient operation. The sensors and actuators used in this project have been discussed in our previous articles. Below are the devices required for this specific project:

IR Sensors

IR sensors are used to detect available parking spaces. They operate through the infrastructure that aligns with illuminated areas and detect the presence of vehicles. These sensors are directly connected to the Arduino board and set as INPUT.

Four IR sensors are allocated for parking spaces. Each sensor works with its corresponding LED, indicating whether the space is occupied or free.

One entrance sensor detects the entry of a vehicle and allows the barrier to open if parking spaces are available.

One exit sensor detects the exit of a vehicle and opens the barrier.

LEDs

LEDs are used to indicate the status of parking spaces. If the space is free, the LED lights up; if the space is occupied, the LED turns off.

Entrance and exit LEDs indicate whether the barrier is opening or closing.

Servo Motor (Barrier)

The servo motor controls the barrier. The barrier opens or closes depending on the status of the entrance sensor. The servo motor can be connected to the 13th pin of the Arduino board. The control code moves the servo motor from 0 degrees to 90 degrees, raising or lowering the barrier.

Arduino Board

An Arduino Uno board is used. All sensors and actuators are connected to the Arduino Uno board. A program is written to control them, processing the data from the sensors and making decisions based on the results, such as turning LEDs on or off and opening or closing the barrier.

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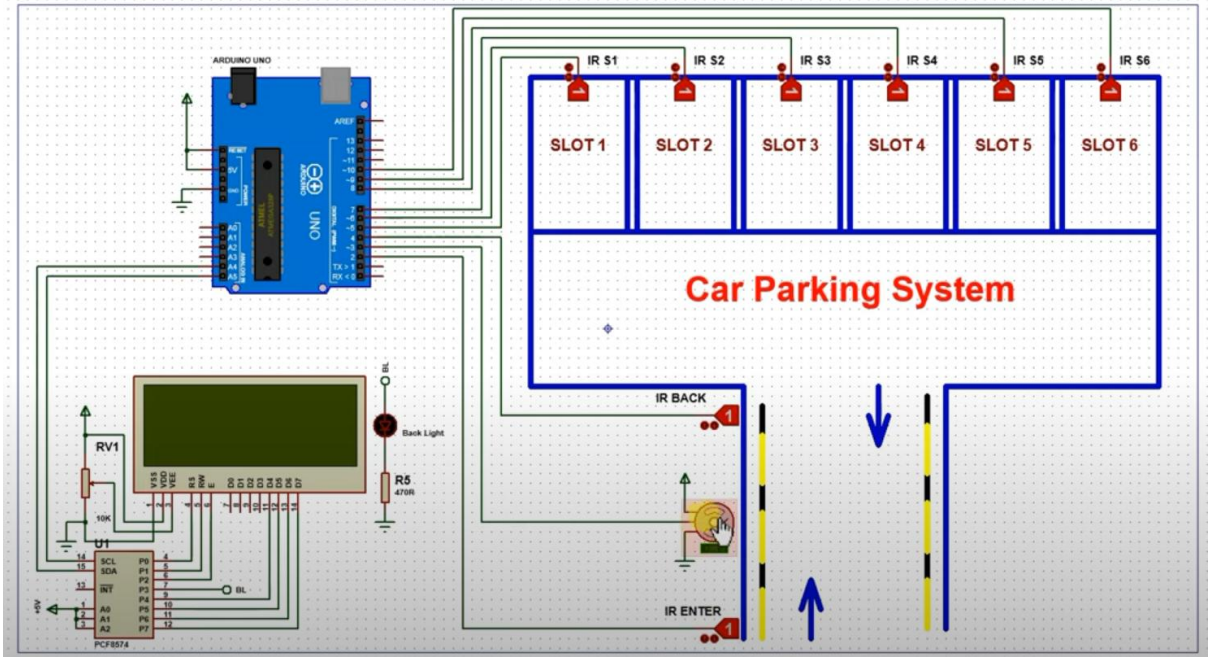

Figure 1. Schematic of connecting sensors and actuators to the Arduino UNO board

Device	Arduino Pins	Function / Description
IR Sensor – Entrance	D2	ir_enter – Detects vehicle entry
IR Sensor – Exit	D4	ir_back – Detects vehicle exit
IR Sensor 1	D5	ir_car1 – Detects the status of parking spot 1
IR Sensor 2	D6	ir_car2 – Detects the status of parking spot 2
IR Sensor 3	D7	ir_car3 – Detects the status of parking spot 3
IR Sensor 4	D8	ir_car4 – Detects the status of parking spot 4
IR Sensor 5	D9	ir_car5 – Detects the status of parking spot 5
IR Sensor 6	D10	ir_car6 – Detects the status of parking spot 6
Servo Motor	D3	Controls the barrier (open/close)
LCD 20x4 (I2C)	SDA → A4	Displays information on the screen
SCL → A5	Connected via I2C interface	
Power for Sensors and LCD	5V, GND	Common power supply for all devices

Results

The automated parking system developed in this project ensured effective management through the Arduino platform using IR sensors, LED lights, and a servo motor. The system monitors four parking spaces, and each space's availability is detected via IR sensors, with corresponding information provided through LED lights.

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Additionally, the movement of vehicles was determined using IR sensors installed at the entry and exit points. If parking spaces were available, the entry barrier opened automatically, and a special LED light signaled the driver. If the parking lot was full, entry was blocked, and the barrier did not open. Upon exit, the barrier always opened automatically, and a signal was given via the exit LED light.

Tests showed that the system accurately determined the parking space availability and effectively controlled the barrier. This allows for the regulation of traffic flow in real-life conditions and reduces human intervention. The project provides an affordable and reliable solution for small-sized parking lots.

Discussion

In recent years, the issue of effectively managing parking spaces has become one of the most pressing matters due to the increasing number of vehicles. International research indicates that the implementation of smart parking systems plays a crucial role in optimizing traffic flow in urban environments (Chen et al., 2020; Kumar & Raj, 2019). This project is based on the same principles, aiming to create a simple yet effective system using IR sensors and servo motors.

Previous studies, such as the automated parking system developed by Singh and Patel (2018), focused on improving accuracy using ultrasonic sensors, while this project offers a simpler solution in terms of cost and convenience by relying on IR technology. Additionally, although Baral et al. (2021) developed smart systems connected to mobile applications, our solution emphasizes physical-level control for small-sized parking lots.

The advantage of this project lies in the real-time monitoring of available spaces, automated entry-exit control, and the visible signaling system for the user. Despite its simple architecture, it provides high functionality. However, the system also has limitations — for example, it may not be sufficient for large-sized parking lots, and the reliability of IR sensors can be affected by environmental conditions (lighting, dust, etc.).

Future work may focus on analyzing traffic flow with advanced algorithms, offering recommendations based on user statistics, or integrating artificial intelligence tools to make the system even more efficient.

Conclusion

Based on the results of this study and practical project, it can be concluded that the automated parking system developed on the Arduino platform provides effective management for small-sized parking lots. The IR sensors used in the system demonstrated high accuracy in detecting whether each parking space was occupied or free, and the LED indicators provided convenient visual information for drivers. The automatic barrier system, controlled by a servo motor, regulated traffic at the entry and exit points, enabling efficient use of available spaces. The non-opening of the barrier when spaces were unavailable and the information provided to users demonstrated the system's intellectual approach.

The research showed that such systems are of significant importance in traffic management, saving time, enhancing safety, and reducing reliance on human involvement. Since the solution is implemented with simple components, it is economically viable and can be widely adopted.

Future work could further enhance this system, for example, by enabling monitoring via a mobile application or integrating artificial intelligence algorithms to make the system more functional.

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