

IoT-Based Smart Parking System with Real-Time Violation Detection and Alarm

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Abstract

This paper presents an IoT-based Smart Parking System designed to modernize urban parking management using NodeMCU ESP32 and the Blynk platform. The system employs infrared sensors to control entry and exit barriers based on slot availability, as well as ultrasonic sensors for real-time tracking of occupied and available spaces. Each parking slot is linked to a specific car plate number through a QR code scanning process, ensuring authorized use. Unauthorized parking triggers a yellow LED and a buzzer alarm. The system features a user-friendly interface via the Blynk app, enabling remote monitoring and control. Users receive real-time notifications and can view slot status and control components remotely. Visual indicators include red LEDs for occupied slots and yellow LEDs with buzzers for parking violations. This smart parking solution enhances security, efficiency, and convenience in managing urban parking spaces.

1.0 Introduction

Parking spaces are crucial for drivers, particularly in urban settings where locating an available spot can be difficult. Many existing parking systems face significant inefficiencies, notably their failure to provide real-time updates on available parking spaces. This often results in wasted time, exacerbated traffic congestion, and increased frustration among drivers. Furthermore, high-occupancy buildings frequently have limited parking availability, compounded by inadequate measures to deter unauthorized parking. Building owners need to modernize their parking facilities to tackle these challenges by integrating advanced technologies that can deliver real-time information and enhance security measures [1].

Research highlights the pressing need for more effective parking solutions. For instance, studies indicate that urban drivers spend an average of 20 minutes searching for parking, contributing to higher fuel consumption and carbon emissions [2]. Additionally, findings suggest that the demand for parking in high-occupancy buildings often surpasses available spaces, leading to further inconvenience [3]. These shortcomings underscore the necessity for smart solutions to manage parking resources efficiently.

Recent advancements in Internet of Things (IoT) technology present promising solutions. IoT-enabled smart parking systems leverage real-time data to assist drivers in quickly finding available parking spots, thereby alleviating congestion [4]. Furthermore, cloud-based IoT systems optimize parking management by processing

large datasets, improving overall system efficiency. Research has also demonstrated that integrating IoT with machine learning techniques can enhance the ability to predict future parking availability, making these systems even more effective [5]. The problem of unauthorized parking persists as a significant challenge. Studies have shown that unauthorized vehicles can occupy as much as 15% of available spaces during peak times, limiting access for legitimate users [6].

This research proposed that smart parking systems utilize RFID and automated access controls to mitigate unauthorized parking and enhance security, as shown in Fig. 1. The functionality of IoT-based smart parking systems hinges on several essential components. Sensors, including ultrasonic and infrared devices, are employed to detect the presence of vehicles in parking spots. Microcontrollers, such as Arduino, process the data collected from these sensors. Communication modules using Bluetooth and Blynk facilitate the transfer of information to cloud platforms, where it is analyzed and stored in real-time. Together, these elements form a streamlined and user-friendly system that improves parking management and enhances customer satisfaction.

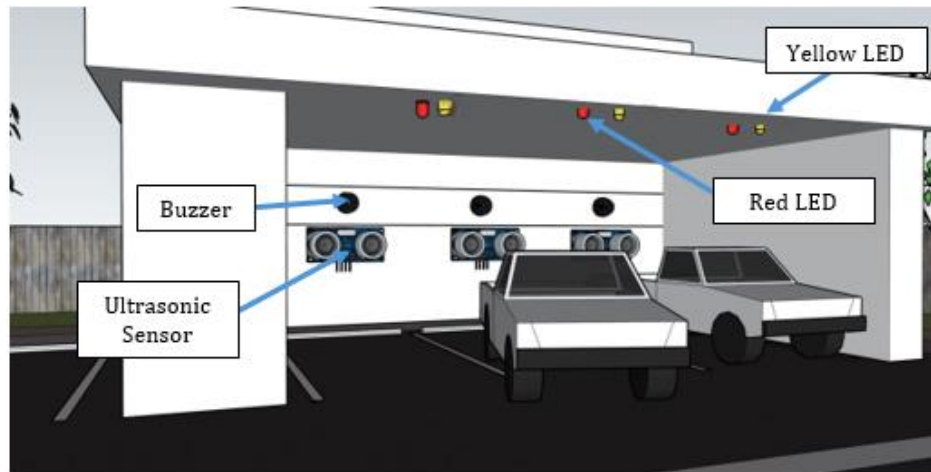


Fig. 1 Overview of the Project

2.0 Material and Methodology

2.1 Material

The materials and equipment used for IoT-Based Smart Parking System with Real-Time Violation Detection and Alarm are described below:

- NodeMCU ESP32 as microcontroller is used for processing data, controlling sensors and communicating with the Blynk Platform.
- IR Sensors (2 units) are used to detect car entry and exit at the parking barrier.
- Ultrasonic Sensors (3 units) are used to detect the presence of car in each parking slot.
- Servo motor controls the barrier at parking entrance, allowing or denying car entry based on parking slot availability.
- Red LEDs (3 units) indicate the occupancy status of each parking slot.
- Yellow LEDs (3 units) and Buzzer (3 units) are used to alert drivers of parking violations.
- Each parking slot has a unique QR Code for validation purposes.
- Blynk IoT Platform provides the interface for monitoring and controlling the parking system.

These components are necessary to build the system. Through the integration of these elements and the utilization of the Blynk platform, the project seeks to provide a parking management system that is more effective, safe, and intuitive.

2.2 Methodology

2.2.1 System Overview

The IoT-Based Smart Parking System with Real-Time Violation Detection and Alarm helps with parking. This revolutionary device automates indoor parking lots. This section explains the system structure. NodeMCU microcontroller has IR sensors, an ultrasonic sensor, a servo motor, red LEDs, yellow LEDs, and a buzzer. Ultrasonic sensors detect vehicles. IR sensors send data to NodeMCU ESP32. NodeMCU ESP32 receives and stores

data in Blynk IoT. At the entry/exit point, an infrared sensor and a servo motor detect vehicles entering and exiting. Gate opener servo motor. If a slot is available, the servo motor rises and lowers the barrier in five seconds. If all slots are filled, the servo motor won't raise the barrier. The prototype has three spaces. Each parking spot has an ultrasonic sensor and a unique QR Code for the registered owner of the parking lot. Each parking place has a red LED that lights up when a car is parked there. There are also yellow LEDs, and a buzzer will activate if the scanned car plate number does not match the registered owner of the parking slot. Besides a prototype, the Blynk first displays the current car park status, followed by the parking violation button (yellow LEDs and buzzer). The Blynk allows the parking management to monitor the parking status and the parking violation status. The user needs to click on the "button" option to activate the yellow LEDs and buzzer if the car is against the parking violation.

2.2.2 Prototype of the System

When the system starts, infrared sensors at the entrance or exit begin sensing the car. If all or a few slots are unoccupied, the servo motor will rotate 90 degrees, signaling that the gate is open and allowing a car to access the parking area when the IR sensor detects a vehicle. After 5 seconds, the servo motor resets. Once the ultrasonic sensor detects a car at parking lot, the Red LEDs will light up to indicate occupied parking slot. Then, drivers need to scan QR Code to fill the car plate number. The yellow LED and buzzer will activate if the scanned car plate number does not match the registered owner of the parking lot. The functionality of the system is shown in Fig. 2.

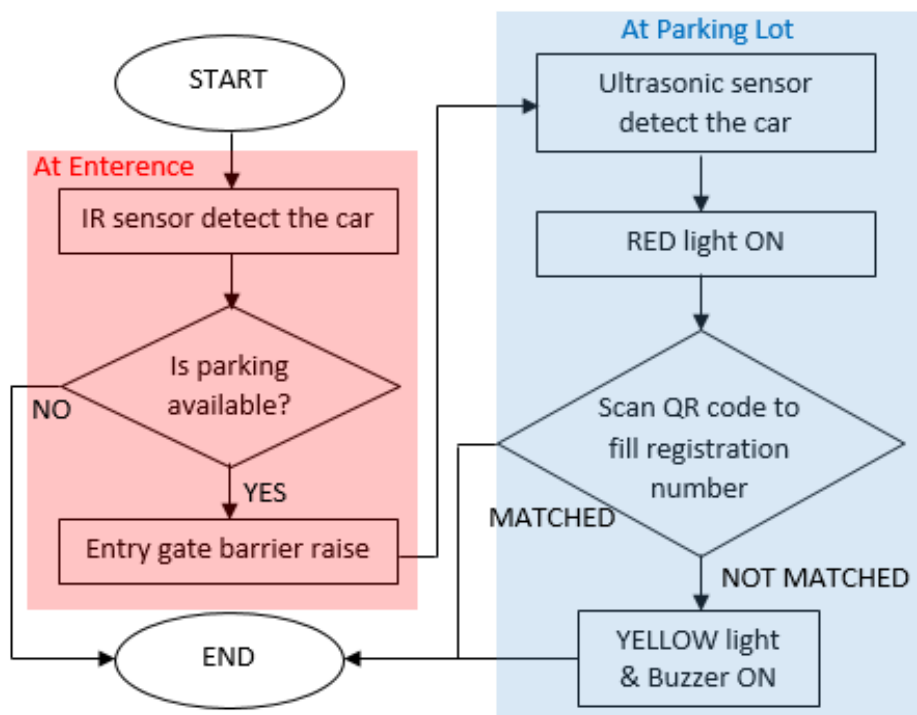


Fig. 2 The Flowchart of the Prototype

2.2.3 The Blynk IoT Platform

Through the Blynk platform, users can remotely monitor the real-time status of parking slots, indicated by red LEDs for occupied slots and different indicators for available ones. The system also sends immediate notifications for parking violations such as double parking, parking over the line, and unauthorized parking, allowing for timely intervention. Remote control capabilities include the activation and deactivation of yellow LEDs and the buzzer to alert drivers of parking violations, as well as the control of entry barriers to manage vehicle access based on slot availability. The platform supports QR code scanning to validate parking authorization, ensuring that only authorized vehicles park in designated slots. The mobile app dashboard provides a comprehensive overview of the parking lot, showing available and occupied slots and any ongoing violations.

2.2.4 Block Diagram

Fig. 3 represents the block diagram of the IoT-Based Smart Parking System with Real-Time Violation Detection and Alarm. This prototype is developed with three parking slots, P1, P2, and P3. The ultrasonic sensors 1, 2, and 3 installed at the parking slots and the infrared sensors installed at the entry/exit gate are all connected to the NodeMCU ESP32, which acts as the controller. The servo motor, yellow LEDs, buzzer, and red LEDs are the output devices, where the servo motor operates the common single entry and exit gate. The yellow LED and buzzer will activate if the scanned car plate number does not match the registered owner of the parking slot. Finally, the red LED lights up when the slot is occupied. The NodeMCU receives input from infrared sensors to navigate the user to an available parking space and finally displays it on the Blynk apps.

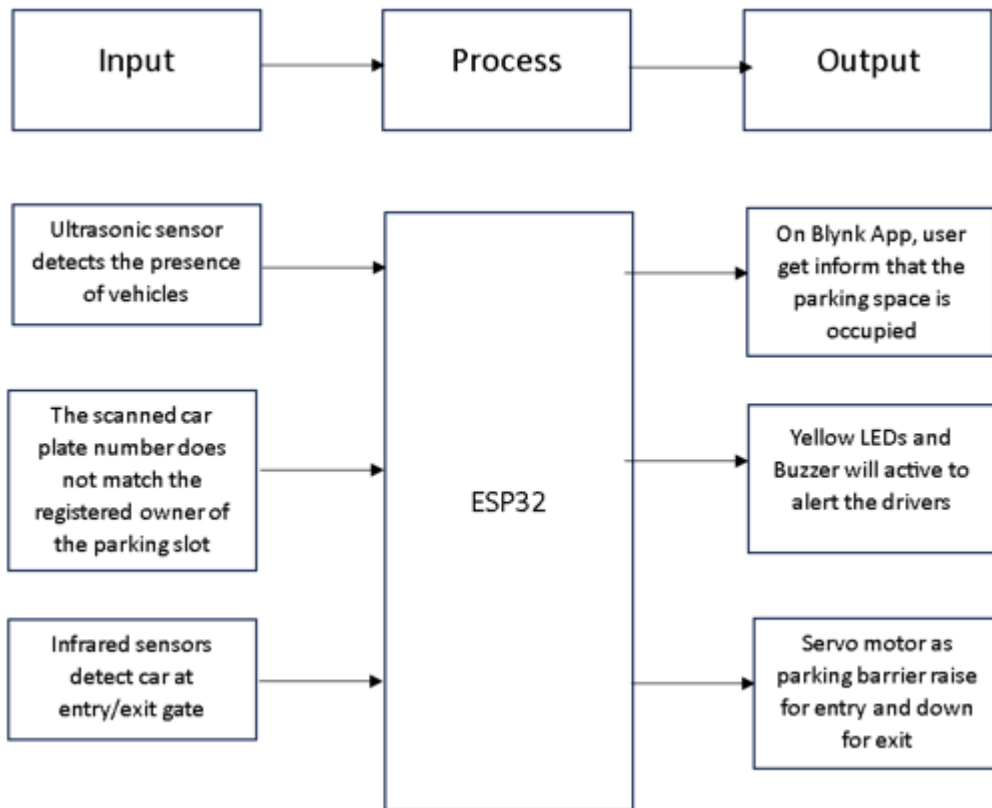


Fig. 3 The Block Diagram of the System

2.2.5 Hardware Implementation and Setup

The prototype comprises a NodeMCU ESP32, the main controller. In addition, two IR sensors are installed at the entry/exit gate to identify vehicles entering and exiting the parking lot. Each slot is occupied with an ultrasonic sensor to detect the parking slot's availability. The servo motor is installed at the entry/exit gate to open and close the gate.

3.0 Results and Discussion

3.1 Results of the Red LEDs, Yellow LEDs and Buzzer

In this section, the working of the red LEDs, yellow LEDs and buzzer will be discussed in detail. The car park has three slots in total. When the car parking slot is occupied detects by ultrasonic sensor, red LED will light up immediately. Each parking slot is associated with a specific QR Code car plate number. If the scanned car plate number does not match the registered owner of the parking slot, a yellow LED and a buzzer are activated to signal a parking violation. The results from the red LEDs, yellow LEDs and buzzer are presented in Fig. 4(a) and Fig. 4(b).



(a) Red LED light up when parking slot is occupied

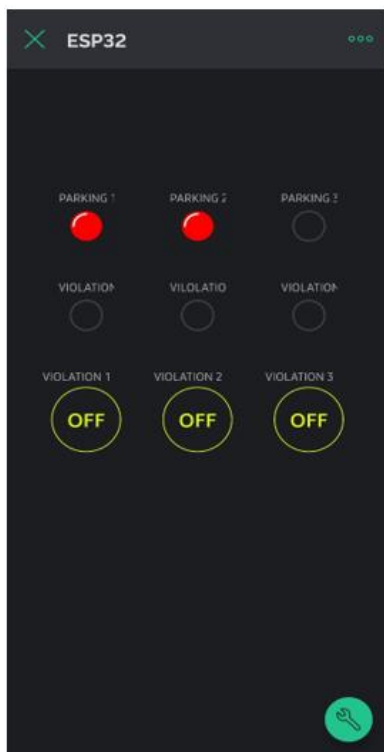


(b) Yellow LED and Buzzer activated

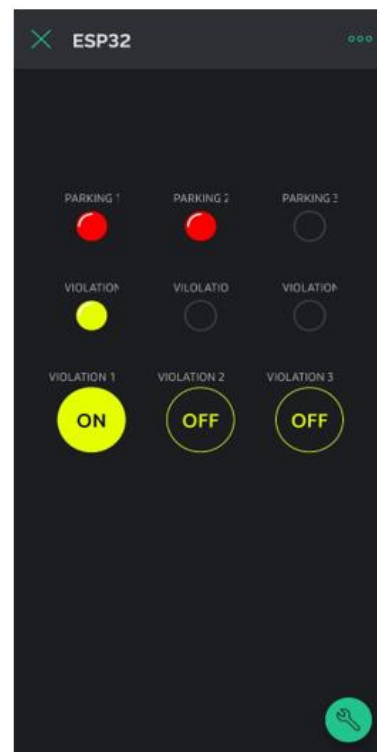
Fig. 4 Actual results of the system output

3.3 Results of the Blynk IoT Platform

When a parking slot is occupied, the red LED will light up on the Blynk interface. If the scanned car plate number does not match the registered owner of the parking slot, a yellow LED and a buzzer can be activated by clicking on the button on the Blynk interface to signal a parking violation. Fig. 5 shows the Blynk interface outcomes after each operation.



(a) Red LED light when it is occupied



(b) Yellow LED and Buzzer activated when there is a parking violation

Fig. 5 The Parking Status Display on Blynk System

3.4 Results of the IR Sensors and Servo Motor

There are two IR sensors and servo motor are used at the entry and exit gate to detect the cars entering /exiting and automatically will open and close the gate. Fig. 6 show the Functionality of IR sensors and servo motor and Table 1 show the data of servo motor movement based on parking slot available.

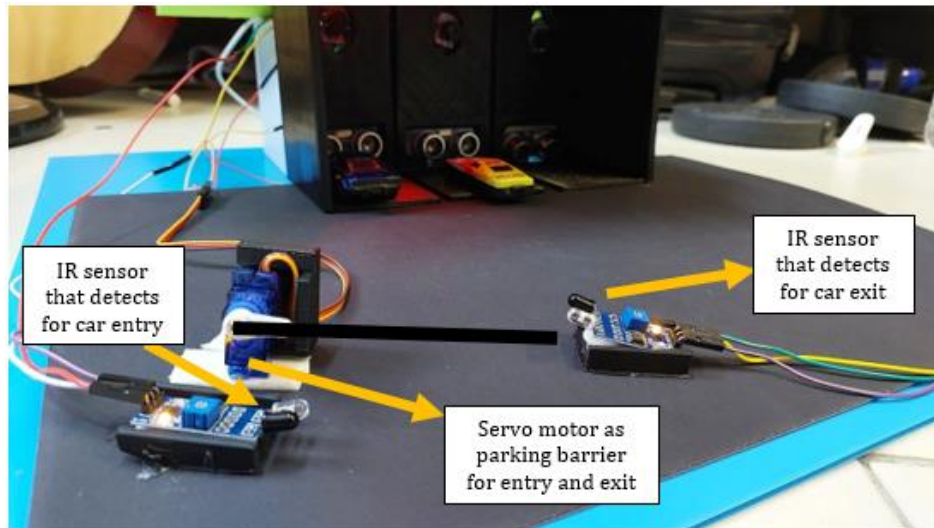


Fig. 6 The Functionality of IR Sensors and Servo Motor

Table 1 Data of Servo Motor Movement (Parking Barrier)

CAR COUNT	ENTRY BARRIER	EXIT BARRIER
0	OPEN	CLOSED
1	OPEN	OPEN
2	OPEN	OPEN
3	CLOSED	OPEN

4.0 Conclusion

The IoT-Based Smart Parking System with Real-Time Violation Detection and Alarm have achieved its primary objectives, demonstrating significant potential for real-world application. The system optimized parking space utilization through the use of IR and ultrasonic sensors, which provided accurate and timely detection of car entry, exit, and slot occupancy. This ensures the efficient use of available parking spaces. A fully functional prototype was developed, featuring automated barriers, LED indicators, and buzzers, all controlled by a NodeMCU ESP32 and integrated with the Blynk IoT platform for remote management. This integration allowed users to receive real-time updates on parking slot status and violations via their smartphones, enhancing convenience and operational efficiency. The system's ability to detect car entry and exit, monitor parking slot status, and signal parking violations was thoroughly tested and verified. The QR code validation ensured that only authorized vehicles occupied designated slots, while the alarm system, comprising yellow LEDs and buzzers, promptly alerted drivers of violations such as double parking, parking over the line, and unauthorized parking. By achieving these objectives, the project demonstrated the feasibility and benefits of a smart parking system that promotes disciplined parking behavior, optimizes space utilization, and enhances the overall user experience. The successful implementation of this system indicates its potential to effectively address urban parking challenges, contributing to more organized and efficient parking facilities.

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Conflict of Interest

Author declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: Study conception and design: Amirul Syakir Kamarudin; data collection: Amirul Syakir Kamarudin; analysis and interpretation of results: Amirul Syakir Kamarudin, Zainab

Zainal, Md Nor Ramdon Baharom and Ziana Che Ros; draft manuscript preparation: Amirul Syakir Kamarudin. All authors reviewed the results and approved the final version of the manuscript.

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