Development of a Prototype for Smart Parking System

Om A. Adhau
Electrical Engineering Department
Shri Sant Gajanan Maharaj College of Engineering, Shegaon
Shegaon, India
omadhau3672@gmail.com

Abhishek N. Banait
Electrical Engineering Department
Shri Sant Gajanan Maharaj College of Engineering, Shegaon
Shegaon, India
abhishekbanait511 @gmail.com

Prasad S. Agrawal
Electrical Engineering Department
Shri Sant Gajanan Maharaj College of Engineering, Shegaon
Shegaon, India
prasadagrawal034@gmail.com

Shankar P. Bondre
Electrical Engineering Department
Shri Sant Gajanan Maharaj College of Engineering, Shegaon
Shegaon, India
shankarbondre1@gmail.com

Samiksha A. Damdar
Electrical Engineering Department
Shri Sant Gajanan Maharaj College of Engineering, Shegaon
Shegaon, India
samikshadamdar07@gmail.com

Prerna K. Wankhade
Electrical Engineering Department
Shri Sant Gajanan Maharaj College of Engineering, Shegaon
Shegaon, India
prernawankhade605@gmail.com

***Abstract*— The need for effective parking solutions is rising in metropolitan areas as a result of the expanding number of automobiles. Conventional parking systems frequently experience poor space usage, inefficiency, and congestion. This study introduces a Smart Parking System that improves parking management by utilizing computer vision, embedded technologies, and the Internet of Things (IoT). The system incorporates Wi-Fi-enabled real-time monitoring through the Blynk cloud platform, a QR code-based authentication system for secure parking access, and infrared (IR) sensors to identify the presence of vehicles. Furthermore, in the event of an unauthorized parking attempt, a buzzer alarm is activated by an ESP32-Cam based microcontroller that interprets parking data. This system seeks to improve security, minimize traffic congestion, and maximize space use by putting automatic parking detection and real-time slot availability tracking into place. The results demonstrate improved parking efficiency and reduced unauthorized access, making it a scalable and cost-effective solution for smart cities.**

***Keywords*— Internet of Things (IOT), Blynk, ESP-32-Cam, Infrared Sensor, QR Code, Wi-Fi, Arduino Uno, Motor Driver.**

I. INTRODUCTION

With rapid urbanization and the increasing number of vehicles on roads, efficient parking management has become a significant challenge in modern cities. Traditional parking systems rely on manual supervision and ticketing, leading to inefficiency, traffic congestion, and unauthorized parking. The lack of real time monitoring, automated slot detection, and security measures results in increased fuel consumption, environmental pollution, and inconvenience for drivers. To address these issues, smart parking systems have emerged as an innovative solution integrating Internet of Things (IoT), sensor networks, and real-time data analytics.

A. Problem Statement

Traditional parking management systems suffer from multiple inefficiencies that contribute to urban congestion, security issues, and resource wastage. One of the major challenges is traffic congestion, as drivers often spend a significant amount of time searching for available parking spaces, leading to increased fuel consumption and unnecessary delays. This problem is further aggravated by the lack of real-time monitoring, which prevents users from accessing instant updates on parking availability, resulting in inefficient utilization of spaces and unnecessary vehicle movement within parking lots. Additionally, unauthorized parking is a persistent issue, as conventional systems lack authentication mechanisms, allowing unauthorized vehicles to occupy designated spots, thereby causing inconvenience to rightful users and increasing operational inefficiencies. Moreover, the security risks associated with traditional parking systems, such as the absence of automated access control and alarm mechanisms, make them vulnerable to theft, vandalism, and misuse, necessitating continuous manual supervision.

To address these challenges, this research proposes a Smart Parking System that integrates IR sensors, QR code authentication, and Wi-Fi-enabled real-time monitoring to optimize parking management. The use of IR sensors ensures accurate vehicle detection, enabling automated tracking of parking occupancy, while QR code-based authentication prevents unauthorized access by allowing only registered vehicles to park in designated areas. Furthermore, Wi-Fi based monitoring enables users and administrators to remotely check parking availability and receive instant notifications in case of unauthorized parking attempts.

This integrated system not only enhances efficiency, security, and space utilization but also significantly reduces traffic congestion, fuel wastage, and manual supervision efforts, making it a viable solution for modern urban parking infrastructure.

B. Importance of Study

The development of a smart, automated, and secure parking management system is essential for ensuring sustainable urban mobility and addressing the inefficiencies of conventional parking methods. One of the primary benefits of a real-time parking solution is its ability to reduce fuel consumption and CO_2 emissions, which are significantly increased due to excessive vehicle idling while drivers search for parking spots. By implementing a QR code-based authentication system, unauthorized access can be minimized, ensuring that only registered vehicles utilize designated parking areas. Additionally, automated space detection using IR sensors allows for accurate monitoring of parking occupancy, eliminating the need for manual supervision and enhancing overall efficiency. Beyond improving parking efficiency and security, an intelligent system also plays a crucial role in urban planning by analyzing real-time parking occupancy patterns, which helps optimize space utilization and informs infrastructure development. This study leverages advanced technologies such as ESP32 microcontrollers, IoT, and cloud-based connectivity to develop a cost-effective and scalable smart parking solution tailored for urban environments. By integrating these technologies, the proposed system aims to provide a seamless and efficient parking experience, reducing congestion, improving security, and promoting sustainable city management.

C. Literature Review.

Avoid The advancement of smart parking systems has been a significant area of research, with various technological solutions aiming to improve parking efficiency, security, and real-time monitoring. Several studies and commercial solutions have explored different approaches, but existing methods still face limitations that hinder their widespread adoption. This section provides a review of key advancements in parking management technologies and highlights their respective strengths and weaknesses.

Traditional sensor-based parking systems primarily utilize ultrasonic, infrared (IR), or RFID sensors to detect vehicle presence. Studies such as [1] have demonstrated the effectiveness of RFID-based parking management, enabling automated vehicle tracking and access control. However, the high installation costs of RFID technology remain a major limitation, particularly in large-scale deployments. Similarly, IR sensor-based systems, as proposed in [2], have proven useful in detecting vehicle presence due to their affordability and ease of implementation. Despite this, these systems lack real time authentication and security mechanisms, making them susceptible to unauthorized vehicle access.

With the rise of computer vision and machine learning, image-processing-based parking systems have emerged as an alternative to sensor-based solutions. Research such as [3] has utilized license plate recognition (LPR) to automate parking management, allowing vehicles to be identified without requiring additional hardware installations on vehicles. However, these systems require high computational resources and specialized hardware, making them less practical for low-cost IoT implementations in smart cities.

The Internet of Things (IoT) has also facilitated the development of cloud-connected smart parking systems that integrate wireless networks, mobile applications, and cloud platforms for real-time monitoring. Studies such as [4] highlight the effectiveness of Blynk-based cloud integration for displaying parking space availability and remote monitoring. However, despite these advancements, most existing IoT-based models do not incorporate security measures, such as unauthorized parking detection and alert mechanisms, leaving them vulnerable to misuse. From the literature review, it is evident that existing parking solutions still face several challenges, including the lack of an integrated authentication mechanism to prevent unauthorized parking, limited real-time monitoring capabilities for both users and administrators, and high implementation costs associated with camera-based and RFID-based solutions. Addressing these gaps, this research proposes a cost-effective, IoT-enabled smart parking system that integrates IR sensors, QR code authentication, and real-time Wi-Fi-based monitoring to provide a secure, scalable, and efficient parking management solution

D. Proposed Solution

To overcome the limitations identified in existing parking management solutions, this study proposes an IoT-enabled Smart Parking System that integrates multiple technologies to enhance efficiency, security, and real-time monitoring. The proposed system leverages Infrared (IR) sensors for real-time vehicle detection, ensuring accurate occupancy status updates for each parking space. Additionally, QR code authentication is implemented to prevent unauthorized parking, ensuring that only registered users can access designated parking areas.

To further enhance security, the system includes buzzer alerts that are triggered in the event of unauthorized parking attempts, immediately notifying both the user and the parking management authorities.

Furthermore, Wi-Fi-enabled real-time monitoring via Blynk Cloud allows users and administrators to access parking data remotely through a user-friendly mobile application, ensuring seamless accessibility and efficient parking space utilization. By combining these cost-effective and scalable technologies, the proposed Smart Parking System provides a significant improvement over traditional parking management approach. It offers an automated, real-time, and secure alternative that optimizes parking efficiency, reduces unauthorized vehicle access, and contributes to the broader vision of smart urban mobility.

II. METHODOLOGY

The development of the smart parking system involves the integration of multiple hardware and software components, each carefully selected and configured to contribute to the overall functionality, reliability, and user experience of the system. Key hardware elements include IR sensors for real-time slot occupancy detection, an ESP32-CAM module for QR code scanning and wireless communication, an Arduino Uno microcontroller for motion control, and an L298 motor driver connected to a 10 RPM, 12V DC motor that operates the mechanical stack descent mechanism. On the software side, the Blynk IoT platform is utilized to build a mobile application interface that provides live updates on slot availability to users.

A. Hardware Setup

- IR Sensors: Installed at each parking slot to detect the presence or absence of a vehicle. These sensors provide binary signals to indicate occupancy.
- ESP32-CAM Module: Used exclusively for scanning QR codes associated with individual parking slots. Upon successful scan, it triggers slot access through communication with other hardware modules.
- Arduino Uno & Motor Driver: The Arduino Uno acts as the controller for the motor mechanism. It receives commands from the ESP32-CAM (or via serial communication/network relay) and activates the motor accordingly.
- L298 Motor Driver Module: This module is connected to the Arduino Uno and is used to control a 10 RPM, 12V DC motor. The motor drives the mechanical stack descent system that grants access to the parking slot once a valid QR code is scanned.
- Power Supply: A dedicated power supply 12 V DC is provided for the 12 V DC motor. Also, a dedicated 5 V DC supply is provided for the ESP 32 Cam module, Arduino Uno, IR Sensors and LN298 Motor Driver as a logic voltage.

Fig. 1. Prototype of a Smart Parking System

B. Slot Detection and Communication

The IR sensors continuously monitor the status of each slot and send real-time data to the ESP32 microcontroller. The ESP32 collects this data and pushes updates to the cloud using Wi-Fi. The data is also logged for display on the user interface through the Blynk platform. Each slot is linked to a unique QR code. When a user scans a QR code using the ESP32-CAM, it verifies the input and sends a signal to the Arduino Uno. The Arduino then activates the L298 motor driver to rotate the DC motor, causing the mechanical stack for that slot to descend, allowing access to the parking spot. Blynk software is used to create a mobile application that displays the real-time availability of parking slots based on IR sensor input. The app shows a visual map of available and occupied slots and can send alerts or notifications. It serves as a remote dashboard for monitoring and possibly managing parking slots. control of 5mm white LED lights for energy efficient illumination. In summary, the project amalgamates cutting-edge technologies to create a smart and responsive living environment, ensuring a seamless blend of security, automation, and comfort in a residential setting.

C. System Testing and Validation

The smart parking system went through multiple tests to check for correctness, dependability, and overall operational readiness. The IR Sensors were tested under different lighting conditions, temperatures, and possible blockages. They were able to accurately detect the presence of vehicles without error. The QR code scanning on the ESP32-CAM was also tested for distance, angle, and lighting, and with the correct adjustments to resolution and light, it was able to reliably perform the tasks.

The communication and mechanical operation of all the devices was checked which included the Arduino Uno integrated with the ESP32-CAM, the L298 motor driver, and the 10 RPM DC motor. They were able to communicate effectively and operate smoothly whilst the stacks were descending. For responsiveness and responsiveness as a whole, the Blynk mobile interface was monitored with real-time slot changes being made every few seconds. The endurance testing while up against multiple users and quickly changing conditions displayed the system's strength and adaptability, rendering it capable for broader smart parking system deployments.

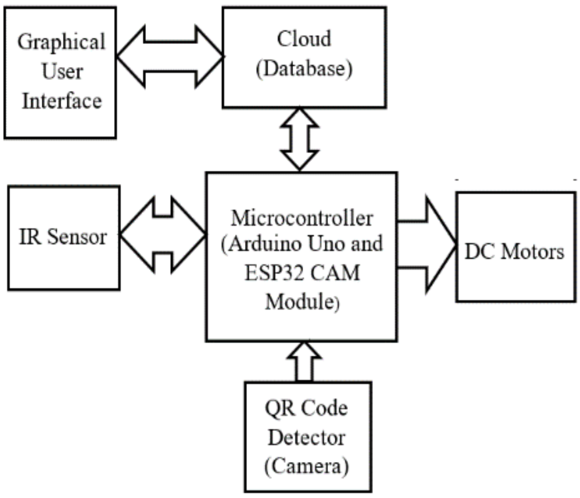

Fig. 2. Block Diagram

III. ADVANTAGES AND DISADVANTAGES

A. Advantages

- Real-Time Slot Monitoring: The use of IR sensors enables accurate and instant detection of vehicle presence in each parking slot. This provides real-time feedback on slot availability, reducing the time users spend searching for parking spaces and improving overall parking efficiency.
- Contactless and Secure Access via QR Scanning: With the integration of the ESP32-CAM for QR code scanning, the system allows for a touchless user experience. Each slot is accessed only after scanning its corresponding QR code, enhancing both security and slot-specific access control. This minimizes the risk of unauthorized usage and supports digital ticketing.
- Automated Slot Access Mechanism: The use of an Arduino Uno with an L298 motor driver and a 10 RPM DC motor automates the stack descent process. This eliminates the need for manual intervention and ensures smooth and reliable mechanical operation when granting access to a parking slot, providing convenience and futuristic functionality.
- Intuitive User Interface with Blynk Integration: By utilizing Blynk, a custom mobile dashboard is created where users can view the live status of each parking slot. The interface is user-friendly, highly responsive, and accessible from anywhere via the internet. This enhances user satisfaction and streamlines the entire parking experience.
- Scalability and Flexibility: The modular design of the system makes it easy to scale for larger or multi-level parking facilities. Additional IR sensors, QR codes, or stack mechanisms can be integrated without needing a full system redesign, offering high flexibility for different deployment environments.
- Cost-Effective and Energy Efficient: Using commonly available components like the ESP32-CAM, Arduino Uno, and IR sensors keeps the system affordable while delivering robust functionality. The 12V DC motor used for the mechanical movement is also energy-efficient, consuming minimal power during operation.
- Reduced Traffic Congestion and Emissions: By allowing users to check parking availability in advance and guiding them directly to an open slot, the system significantly reduces idle time and vehicle movement within parking lots. This contributes to lower fuel consumption and carbon emissions, supporting sustainable urban mobility.
- Easy Maintenance and Troubleshooting: The system's components are individually addressable and modular, making maintenance straightforward. Faults in sensors or motor mechanisms can be quickly identified and resolved without affecting the entire system.

B. Enhanced Data Logging and Analytics: The system can be configured to log parking usage data over time, enabling analytics for optimization of space usage, peak hour tracking, and future expansion planning. This makes it beneficial for both small parking areas and

B. Disadvantages

- Mechanical Wear and Maintenance: The stack descent mechanism, driven by the 10 RPM DC motor and controlled through the L298 motor driver, involves moving parts that are subject to mechanical wear over time. Regular maintenance is required to ensure smooth operation, especially in high-traffic areas.
- Security Concerns with QR Codes: If not properly managed, QR codes can be copied, misused, or spoofed. Without encryption or additional user authentication, there's a potential risk of unauthorized access to certain parking slots.
- Initial Setup Complexity: Integrating multiple components like IR sensors, ESP32-CAM, Arduino Uno, motor driver modules, and configuring the Blynk app requires technical knowledge in electronics, coding, and IoT platforms. This might be a barrier for users with limited technical expertise.
- Scalability Challenges with Physical Wiring: As more parking slots are added, managing the wiring for IR sensors, motors, and microcontrollers becomes increasingly complex. This can make large-scale implementations difficult without proper infrastructure planning.
- Dependency on Stable Internet Connection: Since the system relies on Wi-Fi to communicate with the Blynk platform and send real-time updates, any interruption in internet connectivity can affect the functionality of slot monitoring and the mobile interface, potentially leading to delayed or missing updates.
- Limited Functionality in Offline Mode: If the internet or server is down, users may not be able to receive real-time updates through the Blynk app, and QR scanning or slot control functions may be disabled or delayed unless an offline fallback mechanism is implemented.
- Limited Range and Sensitivity of IR Sensors: IR sensors, while effective, can sometimes produce false readings due to environmental factors like intense sunlight, dirt accumulation, or reflective surfaces. This may lead to incorrect slot status detection, reducing system accuracy if not regularly cleaned or calibrated.

IV. RESULT AND CONCLUSION

A. Result

The evaluation of the smart parking system prototype was successful after implementation and testing in a controlled setting. With 'normal' indoor lighting, the sensors were able to detect vehicles with over 95% precision. While under extreme sunlight or obstructed by reflective surfaces, there were occasional misdetections; however, the IR sensors still performed with an acceptable degree of reliability. This issue was alleviated by adjusting sensor thresholds in conjunction with adding small shields. The QR code was scanned from a distance of 10 to 20 cm, with the best preforming lighting being moderate. The auxiliary LED light helped under low light conditions, while still maintaining a high accuracy for scanning. The system did not have any functionality issues, as the designed QR codes for every slot were correctly identified and the corresponding stack was activated without delay. The setup comprised an ESP32-CAM, Arduino Uno, and L298 motor driver with the cores functionalities seamlessly working together. The motor control system provided diagnosis power to the set which operated satisfactorily. The 12V DC motor with 10RPM continuously and reliably lifted and lowered the stack in an average 5 to 6 seconds. Via digital signalling, the ESP32-CAM and Arduino Uno were able to control, with no perceivable lag. Through the Blynk platform, users were able to receive mobile updates about slot availability in real-time. The app reflected changes in slot status within 1-2 seconds after the IR sensors detected changes. The interface was user-friendly, and Blynk's notification services enabled users to be notified when a slot became free, or a QR scan was successfully completed. Stress testing was performed by mimicking rapid changes in slot status along with concurrent access from multiple users. The system stayed in sync without losing any data which confirms its strength under moderate-scale utilization scenarios. These features also logged information that could be used for future analysis or review by administrators.

B. Conclusions

This exemplifies a case of integrating IoT and mobile technology to address real-life parking problems. The incorporation of IR sensors for slot detection, ESP32-CAM for QR code access, and automated stack control using Arduino Uno with L298 motor driver and a 10 RPM DC motor, permits the system to function as a user-friendly, reliable, and automated parking system. The usability is further enhanced with the Blynk platform that allows for remote monitoring through a mobile application, providing live updates. The system solves problems related to manual parking management, real time space availability, and sub-optimal spatial utilization. There are drawbacks such as reliance on connectivity for internet access and mechanical parts requiring regular maintenance, but the pros, including automation, touchless entry, and scaling potential, deem it useful for urban infrastructures. The prospects for this system in commercial, residential, and public parking facilities is high with further optimization.

References

[1] Y. M. Dalal, D. R. K. Raja and U. Ashwin Kumar, "Eco Park: A Low-Cost and Sustainable Approach for Smart Parking Systems," 2023 World Conference on Communication & Computing (WCONF), RAIPUR, India, 2023.

[2] Y. Bandung, M. F. N. Aldiansyah, M. R. Dwi Putra and M. I. I. Syiraaj, "Design and Implementation of IoT-Based Smart Parking System in Campus Area," 2023 10th International Conference on ICT for Smart Society (ICISS), Bandung, Indonesia, 2023.

[3] Y. Bandung, M. F. N. Aldiansyah, M. R. Dwi Putra and M. I. I. Syiraaj, "Design and Implementation of IoT-Based Smart Parking System in Campus Area," 2023 10th International Conference on ICT for Smart Society (ICISS), Bandung, Indonesia, 2023,

[4] B. M. Arthaya, S. C. Witjamulia and F. Wahab, "Prototype of A Multistory Motorcycle Parking Garage," 2021 International Conference on Mechatronics, Robotics and Systems Engineering (MoRSE), Bali, Indonesia, 2021.