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Park Ease: Streamlined Parking Reservation and Management

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Abstract
City street parking is generally a hassle and time-wasting experience. It can test your patience, congest the roads, and waste fuel. The smart parking system is designed to reduce such hassle by bringing more convenience and order to parking. This project introduces a working prototype equipped with sensors to detect vehicles, an automated gate system for entry and exit, and a live display that shows real-time slot availability. With a simple web interface, clients can pre-book a parking bay, pay, and receive a unique QR code in their email. When they arrive, by presenting the QR code at the gate, it verifies the booking and opens the gate. Slot bookings are automatically updated in the system, which also handles early exits and prevents unauthorized people from entering the parking area. Overall, the project is an efficient and economical means of eliminating parking stress within the city. By eliminating and preventing the need for manual checks, it saves fuel, reduces time, and streamlines the whole parking experience.

Keywords: *IoT-Based Parking, Real Time Slot Monitoring, QR Code Verification, Automated Entry and Exit, Web-Based Interface, Unauthorized Access Control, Urban Traffic Reduction, Parking Efficiency.*

1. Introduction
As the population increases and more vehicles take to the streets, cities are experiencing parking spaces. Traditional parking systems generate inefficiencies such as traffic congestion, wasted time searching for parking space, and inefficient use of parking facilities. Never has there been a greater demand for an efficient, automated parking solution. Smart Parking System is designed to solve these issues by providing a real-time, self-service parking management solution. The system leverages Internet of Things (IoT) sensors, real-time processing, and web-based interface to maximize the parking experience of users. It enables users to reserve parking spaces, obtain QR codes for access, and offers convenient entry and exit from the parking premises. The system aims at optimizing the utilization of parking areas, avoiding traffic jams, and reducing waiting time to park. Through the use of technologies like IoT sensors, Flask web development, and generating QR codes for verification, the Smart Parking System offers a real-time efficient solution for parking lot operators and users alike. This paper discusses the design, development, and implementation of the Smart Parking System, its core aspects, features, and the methodology used in developing it. By using such a revolutionary method, the system delivers a sustainable as well as handy solution to parking issues in the city.

2. Problem Statement
Urban centers are experiencing immense parking losses caused by the growing numbers of vehicles and restricted parking areas. Conventional parking schemes normally bring about inefficiencies such as traffic jams, lost time finding spaces, and being underused. Such schemes are usually manual-based and have no real-time information, causing aggravation to motorists. The Smart Parking System seeks to resolve these challenges by providing an automated, real-time solution using IoT sensors for

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slot monitoring, web interface for reservation, and QR code verification for entry, thus maximizing parking space usage, minimizing congestion, and improving the overall parking experience.

3. Literature Survey

The smart parking system based on IoT has been identified as a promising solution to parking problems in urban areas, using IoT, AI, and real-time data processing to improve efficiency, user satisfaction, and sustainability. Different strategies have been developed to maximize parking slot detection, energy efficiency, scalability, and communication reliability. [1] suggested an IoT-based model with Arduino UNO and First-Come-First-Serve (FCFS) scheduling, which is suitable for small parking lots but not scalable for large environments. [2] incorporated RFID technology for accurate slot identification, enhancing scalability in larger parking lots. [3] implemented an IoT-enabled smart parking system based on ultrasonic sensors and cloud integration for updating slot availability in real time, although it relies on reliable network connections, which may prove difficult in crowded areas. [4] applied LoRaWAN for management of large-scale parking systems, but the requirement for high-end infrastructure restricts its large-scale implementation.AI-based systems have also improved smart parking, e.g., [15] predicting parking availability with 90% accuracy using deep LSTM networks to enable users to plan ahead. [9] utilized Grey Wolf Optimization (GWO) for sensor placement for optimal energy consumption, minimizing energy consumption while improving localization, although GWO's complexity demands expertise. Energy efficiency has also been an area of interest, with [23] proposing energy-autonomous IoT devices that are powered by renewable energy, lowering maintenance costs considerably. Conversely, systems such as [1] that use external power supplies are not as scalable. [29] employed Zigbee as an energy-efficient means of communication, albeit with a more limited range than that of LoRaWAN. User engagement is central to this, with research such as [14] placing emphasis on mobile and web app usage for reservation, real-time updates, and safe payment. [8] included the integration of edge AI for real-time processing of data in order to minimize latency, although this increases complexity. [7] implemented dynamic pricing models to maximize revenue in accordance with demand without sacrificing user satisfaction. Overall, the literature identifies key features of smart parking systems as slot detection, real-time processing, energy efficiency, and scalability. Although each proposal has its advantages, issues persist regarding infrastructure reliance, high upfront expenses, and complexity of implementation. Future development should aim at incorporating these innovations in scalable and sustainable solutions for urban parking management.

4. Architecture of Smart Parking System

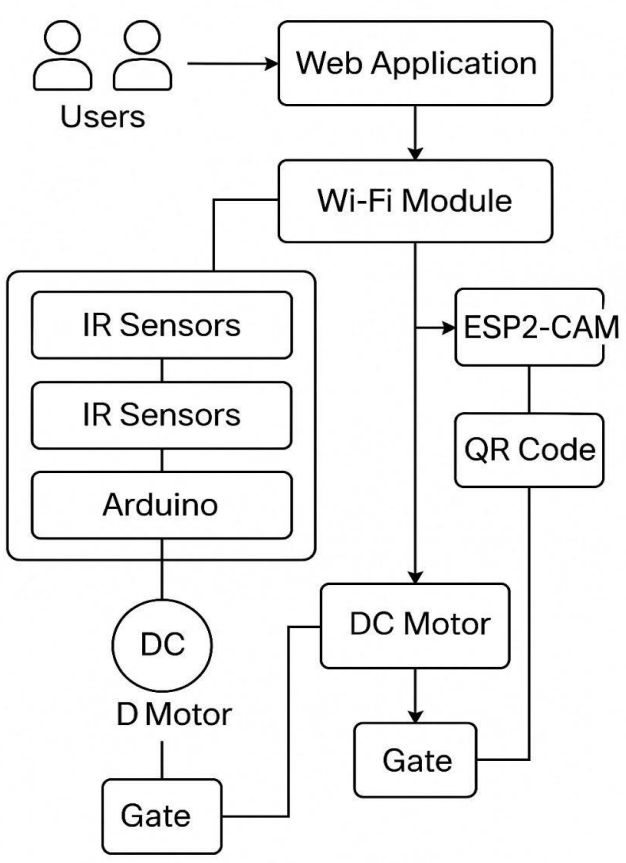

Figure 1 Architecture of Smart Parking System

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Figure 1 organized into several distinct modules, each responsible for handling a specific layer of functionality. These modules work together to offer seamless parking experience through real-time slot detection, QR-based authentication, and automated gate control.

4.1.User Interface Module

The User Interface Module is the system's front-end through which users can interact with the smart parking platform using a web application that is both desktop and mobile device accessible. Users can see available and reserved parking spots, choose a preferred spot, enter the intended duration of parking, and make secure payment. On successful payment and booking, the system creates a personalized QR code and forwards it to the user's email. The module is usability centric and user experience centric to make the booking simple and seamless.

4.2.Communication & Networking Module

This module controls all the data transfer between the hardware devices and the web application. The ESP8266 Wi-Fi module serves as the interface between the Arduino-based sensor system and the cloud-connected web interface. It sends real-time sensor data from the IR modules to the web application and forwards control signals back to the hardware devices. This module also takes care of QR code delivery via an integrated email service, allowing for smooth communication from backend to user.

4.3.Hardware Sensor Module

Hardware Sensor Module includes three IR sensors and an Arduino board. Every sensor detects whether there is a vehicle in a parking slot or not. Arduino continuously senses sensor information and finds the occupancy of each slot. Arduino sends the data to the Communication Module using serial communication, and the Communication Module displays real-time slot availability on the web application. This module is essential to making certain the system shows correct up-to-date parking status.

4.4.QR Verification Module

The QR Verification Module verifies the validity of a user's booking of a parking slot. At the gate physical entry, an ESP32-CAM module reads the QR code produced by the user. The read QR is then checked against the system. If the code is valid and corresponds to an active existing booking, the module triggers an authorization signal to the gate control system. This ensures that only authentic users are provided access to the parking building.

4.5.Gate Control Module

The Gate Control Module controls the physical barrier for controlling the entry and exit of vehicles. It is a DC motor attached to a gate mechanism, activated by signals from the QR Verification Module. When the valid entry signal is received, the motor turns to open the gate for the vehicle entry. The gate closes automatically after a short delay when it senses the movement of the ve-hicle. This module streamlines the physical access process and ensures greater security by deterring unauthorized access.

5. Results

The Smart Parking System was tested on its effectiveness in handling parking slots, providing real-time updates, correct detection of available slots, and smooth user interaction. The accuracy of the detection of occupied slots by IoT sensors, booking response time for slots, and QR code verification upon entry were comprehensively tested. The system exhibited good efficiency in the handling of parking slots with negligible latency, presenting the users with real-time feedback on available spaces as well as a seamless booking process. Experiments also indicated that the system can scale, supporting numerous users at once without much delay, and that the system operated steadily in dynamic settings. The user interface met with welcome feedback, with simple access to slot availability and the booking function. Overall, the system achieved the goal of decreasing parking congestion, enhancing user convenience, and delivering an efficient solution for urban parking management. Yet, future enhancement can be done on scalability to bigger parking lots and incorporating more advanced features like dynamic pricing. (Figure 2) Fig 2 shows the user registration page developed for the ParkEase Smart Parking System. The page enables new users to register their

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accounts to gain access to the services of the platform's parking. The registration page features the input fields for the key user details like username, password, phone number, and email address in a central position. After completing the required information, users proceed to the last stage of registration by clicking the "Register" button. Also, at the bottom of the form, an option is given for returning users to link directly to the registration page. The design is set out in a manner that is conducive to providing user-friendly experience, promoting smooth registration and still having a functional & aesthetically pleasing look of a contemporary parking management system. (Figure 2)

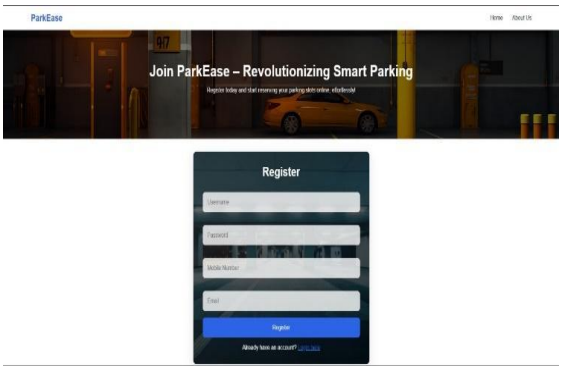

Figure 2 Registration Page

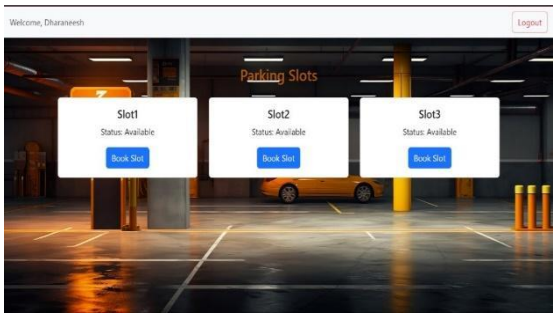

Figure 2 Parking Slot Booking Interface of ParkEase System

Figure 2 shows the parking slot selection page accessible to users upon login. Each card is a parking slot (Slot1, Slot2, Slot3) with a live status indicator and a "Book Slot" button. Users can readily see available slots and go ahead with booking. At the top of the page, there is a personalized greeting and a "Logout" button for session management. The page layout is user-friendly, facilitating smooth booking and mirroring live sensor data for slot availability. Figure 3 displays the interface for confirming a parking slot and selecting a time duration. After selecting a slot, the user is prompted to enter their mobile number and choose a preferred time slot for booking. The form auto-fills the username from the current session. Once the details are provided, the user proceeds by clicking the “Proceed to Checkout” button. This step ensures the system captures user-specific booking details before payment and QR generation.

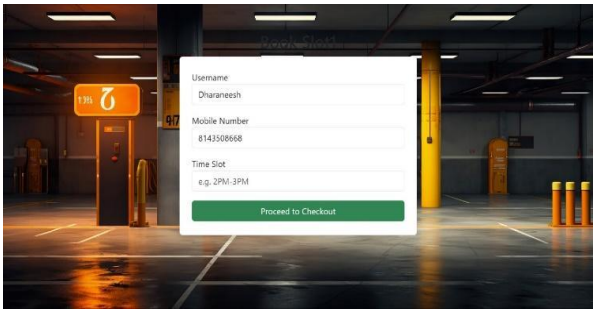

Figure 3 Slot Confirmation and Time Selection Interface

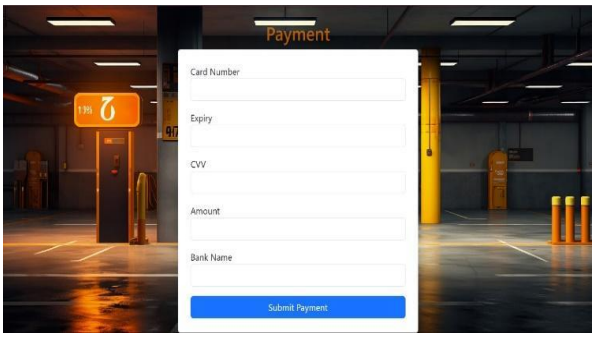

Figure 4 Payment Interface of ParkEase System

Figure 4 represents the payment interface where users securely complete their parking slot booking. The form requires essential payment details such as card number, expiry date, CVV, amount, and bank name. After filling in the required fields, users can confirm the transaction by clicking the “Submit Payment”

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button. This interface ensures a smooth transition from slot selection to booking confirmation while maintaining user data privacy and transaction integrity.

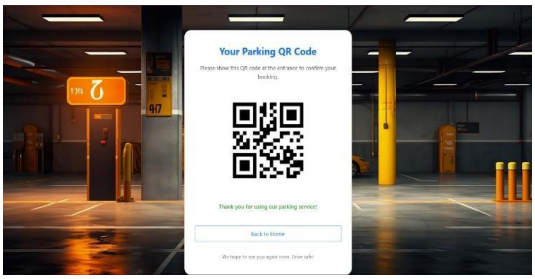

Figure 5 ParkEase System QR Code Confirmation Interface

Figure 5 presents the QR code confirmation page, displayed to the user upon successful payment and booking. The page dynamically creates a unique QR code linked to the details of the booking, which the user is asked to show at the entry point for verification. A confirmation message and a "thank you" note affirm completion of the process. A "Back to Home" button is also available. This screen is the last step in the user process, allowing secure and contactless access to gates through QR code scanning.

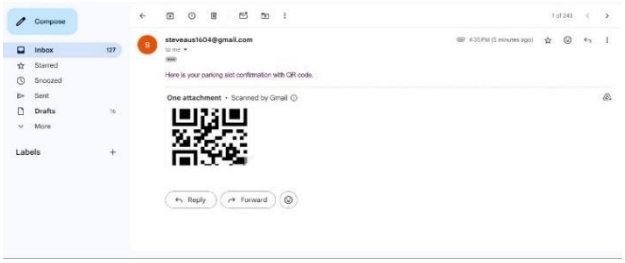

Figure 6 QR Code Confirmation Email Notification

Figure 6 presents the email confirmation that is sent to the user upon successful parking slot booking. The email, which is sent from the system's backend, presents a small confirmation message and an attached QR code. The QR code is vital for confirming the booking at the entrance of the parking facility. Users can use this QR code straight from their email account, thus achieving easy and contactless entry into the parking facility. The addition of automated email delivery improves user experience and booking traceability.

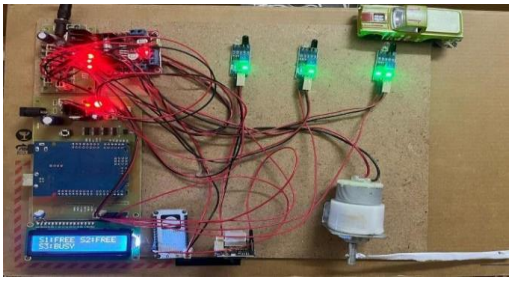

Figure 7 Hardware Prototype of Smart Parking System

Figure 7 illustrates the physical hardware prototype of the Smart Parking System. The arrangement consists of an Arduino microcontroller interfaced with three IR sensors, a DC motor, a motor driver module, and an ESP8266 Wi-Fi module. Each IR sensor is positioned to sense the presence of cars in individual parking spaces. The sensors are wired using a set of red and black jumper wires, and their live status is indicated visually using onboard LEDs. The LCD display at the bottom left displays the slot statuses—S1: FREE, S2: FREE, S3: BUSY—displaying the live monitoring feature. The ESP8266 module facilitates communication with the web application, and the DC motor provides gate control simulation, rotating to enable vehicle entry depending on booking verification. Above the sensors, a toy car is positioned to emulate an occupied slot for testing purposes. This integrated configuration confirms the efficacy of real-time parking status detection and automated gate access automation.

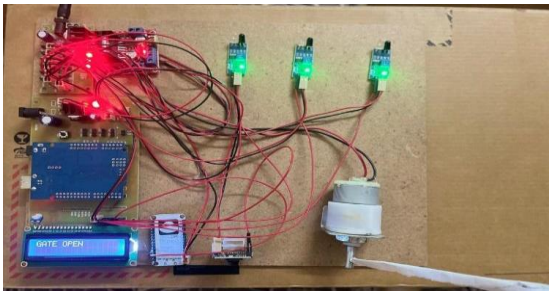

Figure 8 Gate Open State after QR Verification

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Figure 8 indicates the status of the Smart Parking System following successfull code authentication. The LCD display on the hardware module can clearly show the message "GATE OPEN", thus confirming that vehicle entry was authorized by the system. The DC motor, which can be seen to the right, has been energized to mimic the gate opening mechanism, which is usually activated upon valid booking confirmation via QR scan. The IR sensors continue to function to monitor slot availability. The real-time hardware output proves the implementation of authentication, automation, and physical actuation within the smart parking process.

Conclusion

The Smart Parking System effectively tackles typical urban parking issues through the combination of IoT sensors, real-time processing, and an intuitive web interface. The system effectively controls parking space usage, alleviates congestion, and improves user convenience through features such as real-time slot availability, simple booking, and QR code-based entry. Test results have indicated that the system works well in both small and medium-scale settings, with rapid and accurate responses even when multiple users are interacting at the same time. In spite of its efficiency, there are areas of improvement, especially in scalability for large parking lots and the incorporation of advanced functionalities like dynamic pricing. Future work may also aim to enhance communication reliability and include mobile app support for wider reach. Overall, the Smart Parking System shows tremendous potential in transforming urban parking management through a sustainable, efficient, and convenient solution for users and parking operators alike.

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