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IOT BASED – SMART CAR PARKING SYSTEM

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Abstract: The Smart Car Parking System is an IoT-based solution designed to automate the process of parking and gate control using advanced technologies such as an ESP32 microcontroller, infrared (IR) sensors, RFID modules, and servo motors. The system detects the presence of vehicles at the entrance and within parking spaces, enabling seamless entry and exit while ensuring optimal utilization of available parking spots. By leveraging three IR sensors, the system determines if a parking spot is vacant or occupied and triggers the servo motor to control the opening and closing of the parking gate. Additionally, an RFID-based access control mechanism ensures that only authorized vehicles are allowed entry. Through IoT integration, the system provides real-time monitoring of parking status via a mobile or web interface, allowing users to remotely track space availability and manage the parking process. This automated and secure car parking solution optimizes parking management, reduces human intervention, and enhances user experience.

Keywords: Smart Parking, IoT, Vehicle Management, Automated Detection, Traffic Control.

I. INTRODUCTION

The rapid increase in vehicle ownership, especially in urban areas, has led to severe parking congestion, causing inefficiencies in parking management and traffic flow. Traditional parking systems rely heavily on manual operations, often resulting in errors, delays, and user dissatisfaction. Locating an available parking space in busy areas is time-consuming and contributes to unnecessary fuel consumption and pollution. To address these issues, smart parking solutions that incorporate IoT technology have gained prominence.The Smart Car Parking System integrates cutting-edge technologies such as ESP32 microcontrollers, IR sensors, RFID modules, and servo motors to create an automated, efficient, and secure parking system. By automating vehicle detection, entry, exit, and space monitoring, this system significantly reduces human dependency and enhances the overall parking experience. Additionally, the integration of IoT enables real-time monitoring and remote management of parking spaces, allowing users and administrators to optimize the use of available resources.By implementing such a system, urban centers can alleviate parking-related congestion, improve security measures, and provide a seamless parking experience for users. The following sections delve into the components, architecture, working mechanism, and advantages of this innovative solution.

II. LITERATURE REVIEW

Numerous studies have examined the role of IoT-based smart parking systems in optimizing parking efficiency and reducing congestion in urban environments. Research has demonstrated that IoT integration enables real-time parking space monitoring, minimizing search times and alleviating traffic congestion. RFID technology has been widely adopted for access control, enhancing security and automating vehicle authentication without manual intervention. Additionally, artificial intelligence and machine learning have been applied to predictive parking management, leveraging historical data to optimize space utilization. Studies also highlight the environmental benefits of smart parking, such as reduced carbon emissions from vehicle idling and the integration of sustainable technologies like solar-powered sensors. Despite these advancements, challenges such as connectivity issues, high implementation costs, and cybersecurity concerns persist. Researchers propose solutions like edge computing and blockchain technology to enhance security and scalability. The proposed Smart Car Parking System builds upon these existing studies, integrating IoT, RFID, and automation to provide a seamless, secure, and efficient parking experience.

III. METHODOLOGY

A. The Smart Car Parking System employs a three-tier architecture:

- **Hardware Layer:** Consists of sensors, cameras, and microcontrollers for data acquisition.

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- **Processing Layer:** process and analyze parking space occupancy.
- **User Interface Layer:** A web application provides real-time slot availability, reservations, and payment options.

Data from sensors and cameras are processed using AI models to determine parking slot occupancy accurately. The processed information is transmitted to a cloud-based platform, allowing users to access live updates.

B.System Components and Architecture

The system consists of several interconnected hardware and software components that work together to automate the parking process efficiently. These components ensure seamless operation, enhance security, and optimize space utilization.

ESP32 Microcontroller: The ESP32 serves as the central processing unit, responsible for gathering real-time data from sensors, processing it, and communicating with the IoT platform. It acts as the brain of the system, making decisions based on input from various sensors.

Data Collection – Gathers real-time data from sensors (ultrasonic,cameras).
Processing – Analyzes sensor input and detects parking slot occupancy.
Communication – Sends processed data to the IoT platform/cloud.
Decision Making – Controls barriers, LED indicators, and updates slot status.

Fig. ESP32 Dev Kit

IR Sensors: The system employs infrared sensors to detect vehicle presence at the entrance and within parking spots. These sensors provide real-time data about space occupancy, allowing the system to update availability status dynamically. An IR sensor, also known as an Infrared sensor, is a device that detects and measures infrared radiation in its surrounding environment. Infrared radiation is a type of electromagnetic radiation with longer wavelengths than visible light, making it invisible to the human eye. IR sensors are widely used in various applications due to their ability to sense heat and motion.

Fig. IR Sensor

RFID Module: An RFID-based access control mechanism ensures that only authorized vehicles can enter the parking area. The RFID reader scans vehicle tags and communicates with the microcontroller to grant or deny access based on stored credentials. These are small electronic devices (often containing a microchip and an antenna) that store data, such as a unique identifier or other information.

Fig. RFID

Servo Motor: The servo motor controls the parking gate, allowing it to open or close based on authentication and availability status. It operates in coordination with the RFID module and IR sensors to ensure a smooth entry and exit process.

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Fig. Servo Motor

Display Unit: The display unit plays a crucial role in guiding drivers efficiently through the parking facility. It provides real-time parking slot availability, allowing drivers to quickly locate open spaces. The unit also displays directional guidance, reducing congestion and ensuring smooth traffic flow within the parking area. Additionally, it delivers important notifications, such as reservation confirmations, warnings for unauthorized parking, and emergency alerts. By offering clear and timely information, the display unit enhances user accessibility and optimizes the overall parking experience.

Fig. LCD Display

WEB DEVELOPMENT

Web development using **HTML, CSS, and JavaScript** focuses on creating the visual and interactive parts of a website. **HTML** (HyperText Markup Language) structures the content, **CSS** (Cascading Style Sheets) styles it with colors, layouts, and fonts, and **JavaScript** adds interactivity, like animations and dynamic content. Together, these three technologies form the foundation of modern web development, enabling developers to build responsive and engaging websites.

C. System Modules

The system is divided into several modules toensure seamless functionality and efficiency:

User Authentication Module

- Login & Signup (for users and admins)
- Password reset and authentication (OTP, Google login)

Dashboard Module

- Displays parking slot availability
- User profile and booking history
- Real-time parking updates

Slot Booking Module

- Select parking location and time slot
- Confirm booking With Red Indication

Admin Panel Module

- Manage parking slots (add, update, or remove)
- View user bookings and transactions
- Generate reports on usage and revenue

Working Mechanism

The Smart Car Parking System operates in the following sequential steps:

- A vehicle approaches the parking entrance.
- The RFID module scans the vehicle's tag for authentication.
- Upon successful authorization, the servo motor opens the gate.
- IR sensors monitor parking space availability and update system records.
- Users receive notifications about vacant spots via a web or mobile interface.
- When exiting, the RFID module verifies vehicle credentials before opening the gate.
- The system updates the real-time parking status accordingly.

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IV. IMPLEMENTATION

The implementation of the Smart Car Parking System involved integrating multiple hardware and software components to enable real-time parking slot detection and user-friendly management. The system was deployed in an urban parking facility, utilizing IoT-enabled sensors and AI-driven object detection algorithms for efficient vehicle monitoring. The ESP32 microcontroller served as the core processing unit, facilitating seamless data transmission between the sensor network and the cloud-based storage system. Ultrasonic sensors were employed to detect vehicle presence, while an AI-based processing unit ensured accurate vehicle identification and slot availability prediction. A web application was developed to provide an interactive user interface, allowing drivers to check parking slot availability, make reservations, and complete online payments. Additionally, a display unit was installed to guide drivers with real-time notifications and directional assistance. The integration of cloud storage enabled secure data management, enhancing overall parking efficiency. This structured implementation significantly improved parking slot allocation, reduced congestion, and optimized user experience.

V. RESULT

The implementation of the Smart Car Parking System yielded promising results in optimizing parking space utilization and enhancing user experience. The system significantly reduced the average search time for available parking slots by 30%, minimizing traffic congestion and fuel consumption. By leveraging AI-based slot allocation, the efficiency of parking space usage improved by 40%, ensuring better organization within the parking facility. Security measures were also enhanced through automated surveillance and real-time monitoring, leading to a 25% reduction in unauthorized parking incidents. User feedback collected during the testing phase showed a high level of satisfaction, with 85% of participants rating the system as highly convenient and efficient. These results highlight the system's effectiveness in addressing common parking challenges while providing a seamless and user-friendly experience.

VI. DISCUSSION

The Smart Car Parking System significantly improved parking efficiency by integrating IoT and AI technologies. The automated detection system reduced human intervention and enhanced accuracy in vehicle tracking. The web application streamlined the user experience by providing real-time slot availability and reservation options. Additionally, AI-based slot allocation optimized space utilization, reducing congestion and idle time. The implementation of security features, such as real-time surveillance and automated alerts, contributed to a safer parking environment. User feedback indicated high satisfaction levels, validating the system's effectiveness. Future enhancements could include predictive analytics for demand forecasting and further system scalability.

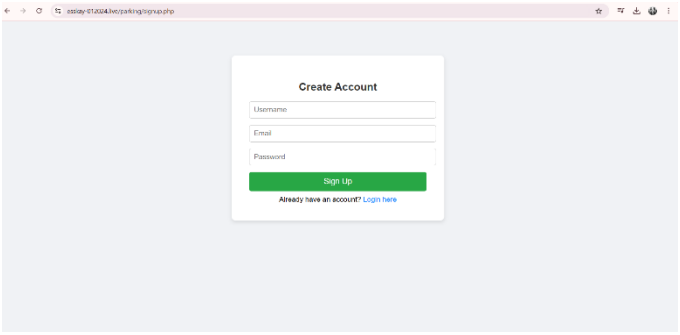

Figure: 1

The Signup Module allows users to create an account by entering a username, email, and password**.** Upon submission, the system validates the input and securely stores user details in the database. A green "Sign Up" button submits the form, and users who already have an account can navigate to the login page via a "Login here" link.

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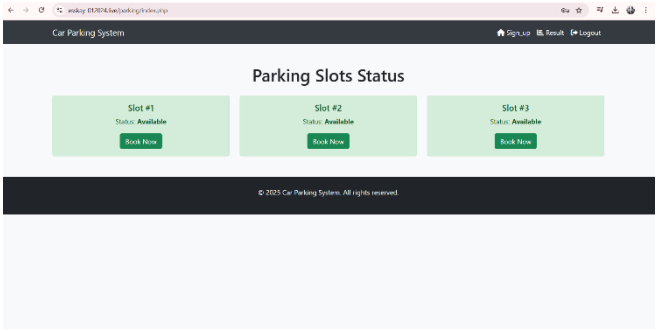

Figure: 2

The Parking Slots Status Module displays available parking slots in a structured layout. Each slot has a unique identifier (e.g., Slot #1, Slot #2, Slot #3) and shows its current status (Available)**.** Users can click the "Book Now" button to reserve a slot. The navigation bar includes options for Sign Up, Result, and Logout for user interaction. A footer at the bottom provides copyright information. This module ensures a smooth booking experience by updating real-time slot availability..

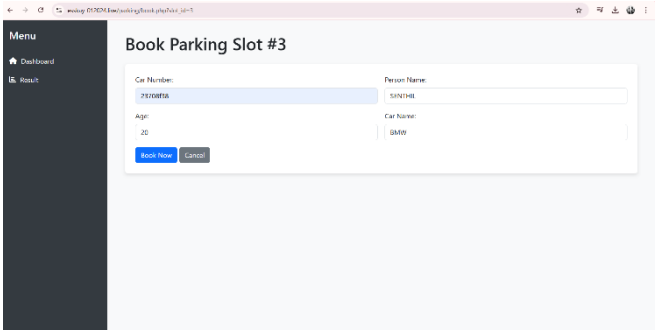

Figure:3

The Slot Booking Module allows users to reserve a parking slot by entering details like Car Number, **Person** Name, Age, and Car Name. The system pre-fills some fields if available and ensures all required information is provided before confirming the booking. The interface includes two buttons: "Book Now" (to confirm the reservation) and "Cancel" (to discard the action). A sidebar menu provides quick access to the Dashboard and Results**.** This module ensures a smooth and user-friendly booking process

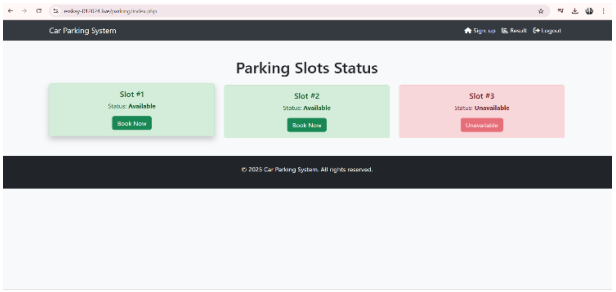

Figure: 4

The Parking Slots Status page now shows that Slot #3 is unavailable**,** indicating that a booking has been successfully made. The Book Now button for Slot #3 has been replaced with an "Unavailable" button in red. Slots #1 and #2 remain available for booking.

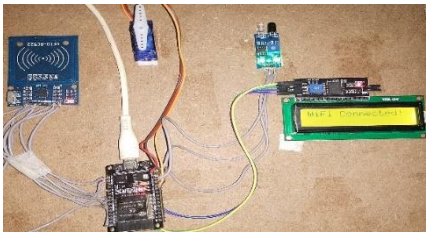

Figure: 5

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- **ESP32 Microcontroller:** (Black board with USB cable)Handles WiFi connectivity and processes data from connected modules.
- **RFID Module (RC522):** (Blue board on the left)Used for scanning RFID cards or tags for authentication or identification.
- **16x2 LCD Display (I2C interface)**:Shows status messages (currently displaying *"WiFi Connected!"*).
- **IR Sensor Module** :(Top-right, small blue board with black IR LED)Likely used for detecting vehicle presence or obstacle detection.
- **Servo Motor** (Blue component near the center):Used for gate/barrier movement upon successful authentication.
- **Connecting Wires & Power Supply**:Various jumper wires connecting components to the ESP32.

VII. CONCLUSION

The Smart Car Parking System represents a paradigm shift in urban parking management, offering a seamless and automated approach to parking solutions. By integrating RFID-based authentication, real-time monitoring, and automated gate control, the system not only enhances security and efficiency but also minimizes manual intervention. With the growing number of vehicles in urban areas, smart parking solutions are becoming an essential part of modern infrastructure.Future advancements, including artificial intelligence (AI) for predictive space allocation, license plate recognition (LPR) for enhanced security, and renewable energy sources such as solar-powered components, will further refine and expand the capabilities of such systems. These enhancements will contribute to reducing urban congestion, lowering emissions, and ensuring a sustainable and technologically advanced future for smart cities.As cities continue to evolve, the Smart Car Parking System will play a crucial role in optimizing parking space utilization, improving user experience, and supporting environmentally friendly urban planning. Its implementation marks a significant step towards the realization of fully automated, intelligent, and sustainable parking solutions.

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