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SmartPark: An IoT- Driven Urban Car Parking Solution Using NodeMCU and Android Integration

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***Abstract*—In today's world, more parking spaces are required as a result of growing car ownership and population congestion. Road congestion in emerging nations makes it challenging to achieve minimum parking requirements. The majority of parking lots are subterranean, which wastes electricity and damages equipment. Large parking spaces are also required due to the growing number of car owners. However, it can be difficult to locate vacant parking spots and deal with unauthorized parking. Due to the difficulty drivers face finding parking spaces and the increase in traffic, which results in fuel loss, smart parking facilities can help address this problem. An Internet of Things (IoT)-based smart parking system is presented in the study to solve urban parking problems like wasteful space use and traffic congestion. Through web-based applications, this system offers real-time updates on parking availability. Additionally, sensors, RFID (Radio Frequency Identification), and microcontrollers were utilized in the construction of this system. An efficient parking tracking system, smartphone apps for booking, online payments, and user verification are some of the main features. In addition, the system provides a working prototype for real-time data transfer and energy-efficient solutions. This innovative idea improves road safety while making the most of urban parking infrastructure.**

***Index Terms*—IoT, RFID (Radio Frequency Identification), Node MCU, Microcontrollers, Web-based applications.**

I. Introduction

Nowadays, parking management systems are complicated and challenging because of the fast growth of cities and an increasing number of vehicles worldwide. The conventional parking system is sometimes not efficient enough to handle the job. Looking for empty slots, traffic jams, and ineffective use of parking spaces are the major problems. The Smart Parking System using the Internet of Things (IoT) is proposed to make parking management systems efficient. It allows devices to have distinct profiles. It also facilitates the ability of devices to interact with each other [1]. It implements the collection, processing, and exchange of data and connects the physical and digital worlds by using sensors, applications, and internet connection [2]. These abilities make IoT suitable for parking management systems. It also enables real-time monitoring, automated access, and efficient space allocation for the systems [3]. The smart parking system has cloud computing and RFID in it. These enhance the efficiency of the system. The system saves and processes sensor data in the cloud. This cloud serves as a central hub that developers can access and adjust to improve system performance [3]. RFID automatically detects vehicles at the entry and exit points. It simplifies the parking process. It also prevents delays and manual interventions [4]. Furthermore, features such as real-time parking availability updates and mobile alerts make parking more convenient and user-friendly [5].

A. Literature Review

Smart contracts streamline contract execution, while blockchain technology guarantees safe and bunchangeable data sharing [1]. Real-time parking availability is provided using a web application, which makes it easy for users to reserve spots and make payments [2]. For registered customers, image processing ensures ease and security by using number plate recognition to verify vehicle access [3]. It uses ESP12-E (NodeMCU) and infrared sensors to implement an Internet of Things-based enclosed smart parking system programmed using the Arduino IDE [10].

II. Hardware and Circuit Implementation

An IoT-enabled smart car parking system's hardware and circuit implementation makes it easier for parts to integrate and enable automated parking management. This cutting-edge technology is especially made to maximize parking space

TABLE I
AN ANALYSIS OF RESEARCH BASED ON SMART CAR PARKING SYSTEM

Reference No.	Year of Publication	Node MCU8226	RFID	MIT App Inventor	IOT Technology	Smart & Intelligent
[6]	2022	✓	×	×	✓	✓
[7]	2024	×	✓	✓	×	✓
[8]	2022	✓	×	✓	✓	✓
[9]	2024	✓	×	✓	✓	✓
[10]	2018	✓	×	✓	✓	✓
Our work	–	✓	✓	✓	✓	✓

utilization, especially in metropolitan settings. These systems use Internet of Things technology to automate crucial processes including data synchronization, slot tracking, and access control. This greatly increases user satisfaction while lowering the requirement for manual mediation. Smart parking systems provide a smooth experience for users and system administrators by detecting open slots, guiding cars, and maintaining accurate parking records through the use of real-time data and sensor-based technology. An effective smart auto parking system addresses difficulties such as overpopulation, poor management, and the inefficiencies associated with finding parking spots. Its main features include:

- Automated entry with NFC or RFID-based authentication.
- Real-time slot availability updates are available on websites or through mobile applications.
- To guarantee stress-free parking, reserve a spot.
- Simplified procedures for entering and leaving, with real-time database updates.
- Integration of cloud platforms for reporting, analytics, and data storage.

This project focuses on creating a practical and reliable IoT-based smart car parking system tailored for urban environments. By integrating a NodeMCU microcontroller, RFID module, IR sensors, and a servo motor, the system ensures secure access, real-time slot monitoring, and dynamic updates to the cloud database. Users interact with the system through an intuitive mobile app or website, enabling them to view available slots and reserve spaces as needed. The project emphasizes automation, accuracy, and user convenience while addressing common parking challenges in congested cities. Below are the key hardware components and their respective roles in the system. The following Fig. 1 is an illustration of the project we completed for hardware and software implementation.

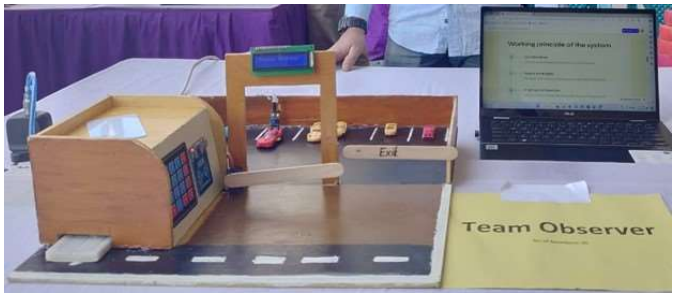

Fig. 1. Physical overview of car parking system

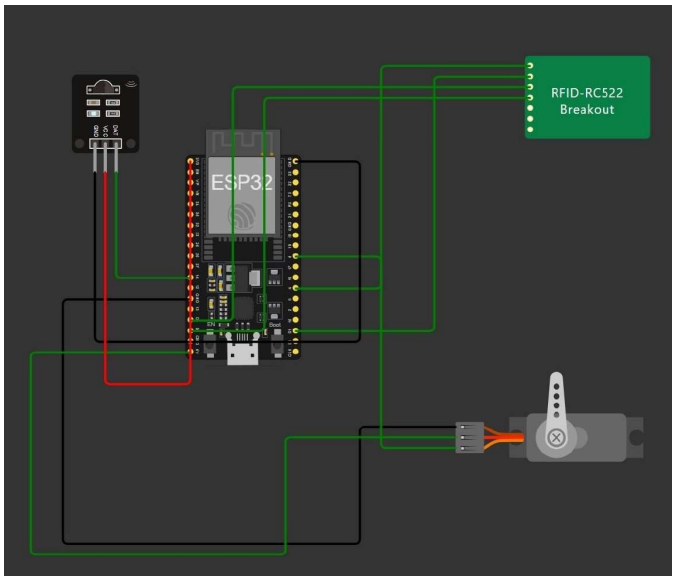

Fig. 2. Schematic diagram of Smart Car Parking system

A. NodeMCU (ESP8266/ESP32)

The NodeMCU acts as the core microcontroller and gateway, enabling communication between hardware components and the cloud server. It processes input signals from the RFID module and IR sensors, and sends commands to the servo motor. Additionally, it facilitates real-time data exchange with the cloud via Wi-Fi.

B. RFID Module (RC522)

The RFID module is used to authenticate users via RFID cards or NFC-enabled devices. When a card is tapped, the module reads its unique ID and sends it to the NodeMCU for validation.

C. IR Sensors

Infrared (IR) sensors are placed at each parking slot to detect the presence or absence of a vehicle. The sensor output is processed by the NodeMCU to update the cloud database regarding slot availability.

D. Servo Motor

The servo motor is used to control the gate, enabling or denying entry to vehicles based on authentication results. The motor is controlled by a PWM signal from the NodeMCU.

E. Power Supply

A regulated 5V power supply ensures stable operation of the entire system, including the NodeMCU, RFID module, servo motor, and IR sensors. The system uses a step-down converter or USB power for low-power components.

F. Cloud Integration

The NodeMCU communicates with a cloud platform (e.g., Firebase, AWS IoT) to update parking slot availability and authenticate user credentials. This enables real-time updates on the mobile app and website.

G. Circuit Diagram Description

And the Fig.2 is attached to visualize the interconnection described below:

- The RFID module connects to the NodeMCU via SPI communication for card scanning and validation.
- IR sensors are connected to digital GPIO pins to monitor parking slots.
- The servo motor is connected to a PWM pin to control gate movement.
- All components share a common ground and are powered by a regulated 5V source.
- NodeMCU's Wi-Fi module sends and receives data from the cloud to synchronize parking information.

III. Methodology

The system continuously monitors the parking area, ensuring that slot availability is updated dynamically. This real-time data is accessible to users through the application, enabling efficient parking management.

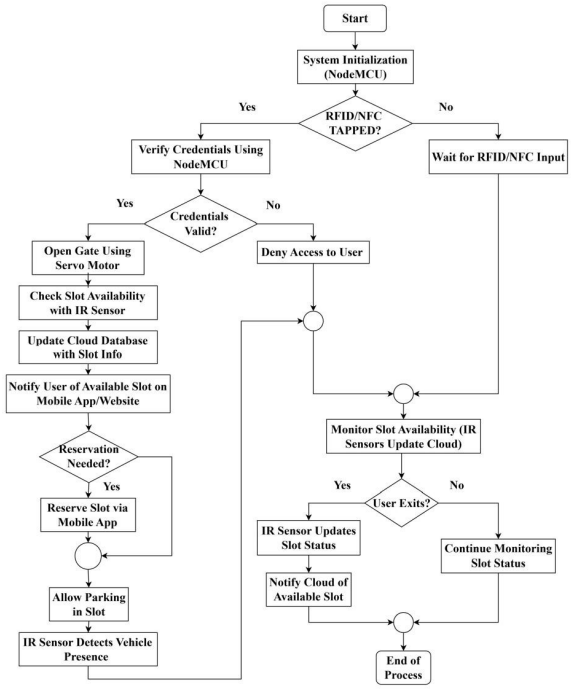

Fig. 3. Flow diagram of the Car Parking System or Workflow diagram.

A. System Initialization

The system begins with the initialization of the NodeMCU , which acts as the central processing unit. Upon startup, the NodeMCU establishes connections with the hardware components, including the RFID module, IR sensors, and servo motor, while synchronizing with the cloud server for real-time data management.

B. User Authentication

Users interact with the system by tapping their RFID card or NFC-enabled device on the RFID reader. The NodeMCU validates the credentials by comparing them with the stored database. If the credentials are valid, the system proceeds to grant access; otherwise, the user is denied access, and the process restarts, awaiting another input.

C. Gate Control

Upon successful authentication, the NodeMCU sends a control signal to the servo motor to open the gate, allowing vehicle entry. This ensures secure and automated access to the parking area.

D. Parking Slot Monitoring

Once the vehicle enters, IR sensors installed at each parking slot detect the availability of spaces. The sensor data is processed by the NodeMCU and sent to the cloud server, updating the parking slot availability in real time. Users are

notified of vacant slots via the mobile application or website interface.

E. Slot Reservation (Optional)

The system supports a reservation feature, allowing users to reserve a parking slot through the mobile application. When a reservation is made, the slot is marked as occupied in the database, preventing others from parking in that space until the reservation expires.

F. Vehicle Parking

The user parks the vehicle in the assigned or chosen vacant slot. The IR sensor at that slot detects the presence of the vehicle and updates the slot status in the cloud database.

G. Exit Process

When the user exits the parking lot, the IR sensor detects the absence of the vehicle and updates the slot status to make it available in the database. The system also sends notifications to users via the mobile app about the updated availability of parking slots.

H. Continuous Monitoring

The system continuously monitors the parking area, ensuring that slot availability is updated dynamically. This real-time data is accessible to users through the application, enabling efficient parking management.

I. System Flow

The methodology is visually represented in Fig.3, outlining the sequential processes of system initialization, user authentication, slot monitoring, and parking management. Each step ensures synchronization between hardware components and cloud services for accurate and real-time operations.

IV. Result

The results section provides a comparative analysis of existing studies on this topic. It has been observed that several papers do not incorporate the RFID ID module, resulting in unresolved security concerns. In contrast, our approach integrates the RFID module, addressing the security issue more effectively. Furthermore, many of the reviewed papers employ a larger number of sensors, which adds complexity and increases the resource requirements of the project. In our study, however, the selection of components has been optimized to ensure cost-effectiveness, making the project more economical. A detailed comparison of these studies is provided in the table I.

V. Conclusion

The development of IoT-based smart parking systems offers a transformative solution to urban parking challenges, including traffic congestion, fuel consumption, and environmental impact. By providing real-time updates on parking space availability through mobile applications, these systems significantly reduce the time spent searching for parking, thereby enhancing user convenience and reducing vehicle emissions.The proposed system demonstrates a cost-effective and scalable approach, integrating IoT technologies with real-time data processing to optimize parking space utilization. Key features such as online reservations, security enhancements, and energy efficiency underline the practical applicability of this technology in modern urban settings. Additionally, the research addresses hardware and software security concerns, laying the groundwork for future enhancements.Future work will focus on incorporating advanced machine learning techniques, such as license plate recognition using cameras, to improve security and further streamline the parking process. Efforts will also aim to reduce initial setup costs and improve system reliability, making the technology more accessible and sustainable.This research highlights IoT's transformative potential in urban infrastructure, paving the way for applications in traffic management, energy efficiency, and public safety while contributing to smarter, more sustainable cities.

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