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The Smart Car Parking System with IoT

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Abstract: *Urban parking congestion results in unnecessary delays, increased fuel consumption, and traffic buildup within confined areas. To address these challenges, this paper presents The Smart Car Parking System with IoT, an automated parking management solution developed using low-cost hardware com- ponents and cloud connectivity. The proposed system employs a NodeMCU ESP8266 microcontroller, infrared sensors for vehicle detection, servo motors for gate automation, and a cloud-based database for real-time monitoring. The NodeMCU is powered directly through a laptop USB interface, eliminating the need for an external power supply during prototyping. Parking slot occupancy information is transmitted to a Supabase cloud database and visualized using a web-based dashboard. When all slots are occupied, the system restricts vehicle entry by keeping the gate closed. The implementation demonstrates reliable operation and effective synchronization between physical infrastructure and cloud services, making it suitable for small-scale smart parking applications.*

Keywords: Internet of Things, Smart Parking System, NodeMCU ESP8266, Infrared Sensors, Cloud Monitoring, Au- tomation

I. INTRODUCTION

Rapid urban growth has significantly increased the de- mand for efficient parking management solutions. Traditional parking systems rely heavily on manual supervision or static signage, which fail to provide real-time information regarding slot availability. This limitation leads to unnecessary vehicle circulation, congestion, and user inconvenience.

The integration of Internet of Things (IoT) technologies enables the development of intelligent parking systems capable of automated detection, monitoring, and control. By combining sensors, microcontrollers, and cloud-based platforms, parking resources can be utilized more effectively. This paper presents an IoT-based smart car parking system that offers real-time slot monitoring and automated gate control using cost-effective and easily deployable components.

II. RELATED WORK

Existing research on smart parking systems includes solu- tions based on ultrasonic sensors, RFID-based access control, and camera-assisted detection mechanisms. While these ap- proaches provide accurate detection, they often involve higher implementation costs, increased computational requirements, or complex infrastructure.

Recent IoT-based systems emphasize cloud connectivity and real-time dashboards for monitoring parking status. However, many such systems require sophisticated middleware or pro- prietary platforms. In contrast, the proposed system adopts infrared sensors for simplicity and direct cloud communica- tion through a lightweight REST interface, thereby reducing complexity while maintaining functional reliability.

III. SYSTEM ARCHITECTURE

The overall architecture of the proposed smart parking sys- tem is illustrated in Fig. 1. The NodeMCU ESP8266 functions as the central controller, interfacing with infrared sensors deployed at individual parking slots and at the entry and exit points. Servo motors are used to automate gate operation based on sensor input and slot availability. Communication with the Supabase cloud database is established over Wi-Fi, enabling real-time data synchronization. During development and testing, the NodeMCU is powered through a laptop USB connection, which also facilitates firmware programming.

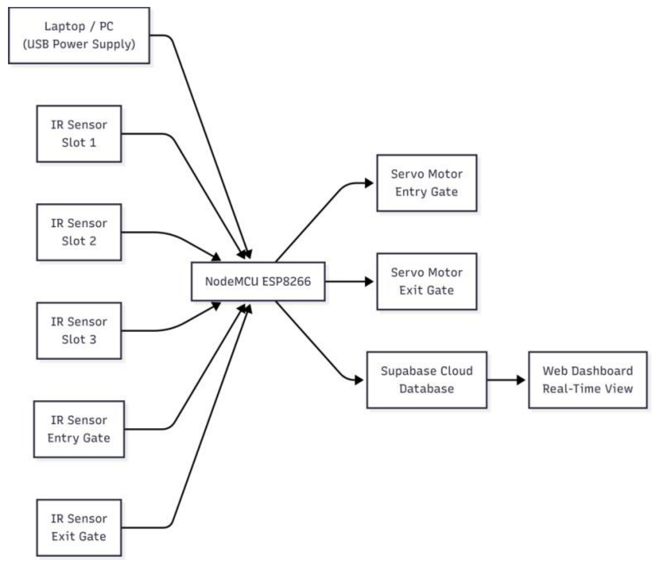

Fig. 1. System architecture of the smart car parking system

IV. METHODOLOGY

The system continuously monitors vehicle presence using infrared sensors. When a vehicle approaches the entry gate, the controller evaluates the availability of parking slots. If at least one slot is available, the entry gate is opened automatically. Upon occupying a slot, the respective sensor updates the slot status in the cloud database. The web dashboard reflects these changes in near real time. A similar process is followed at the exit gate to update the availability when a vehicle leaves.

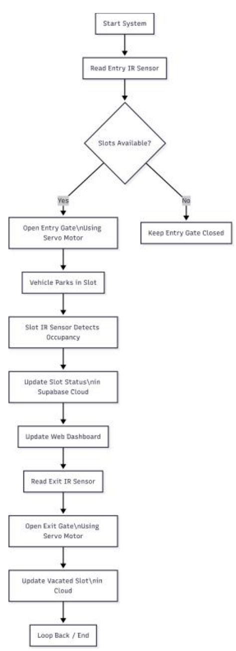

Fig. 2. Flowchart of smart parking system operation

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V. DESIGN RATIONALE AND TECHNOLOGY SELECTION

The design of the proposed system prioritizes affordability, ease of integration, and reliability. The NodeMCU ESP8266 was selected due to its built-in Wi-Fi capability, compact size, and compatibility with the Arduino development environment, which simplifies firmware development and debugging. Com- pared to traditional microcontrollers, it eliminates the need for additional networking hardware.

Infrared sensors were chosen for vehicle detection because they offer a straightforward and cost-effective method for identifying slot occupancy in controlled environments. Their low computational overhead makes them suitable for small- scale deployments. A cloud-based backend was incorporated to allow centralized data storage and real-time access. Su- pabase was selected for its RESTful interface and ease of integration with IoT devices and web applications.

VI. SCALABILITY AND EXTENSIBILITY ANALYSIS

The proposed architecture supports scalability by allowing additional parking slots to be incorporated through the integration of more sensors and corresponding database entries.

For larger installations, multiple NodeMCU units can be deployed across different parking zones, all reporting data to a centralized cloud backend.

The system is also extensible at the software level. The web dashboard can be enhanced to include historical usage analysis, user authentication, and mobile application support. Future extensions may involve integration with alternative sensing technologies or automated billing mechanisms, with- out requiring fundamental changes to the existing architecture.

VII. OPERATIONAL ASSUMPTIONS AND CONSTRAINTS

The system is designed under practical assumptions suitable for prototype-level and small-scale deployments. It assumes the availability of stable Wi-Fi connectivity to enable communication between the controller and the cloud database. In the event of temporary network interruptions, local gate control continues to operate independently, while cloud updates may be delayed.

The proposed design is intended for controlled parking environments where vehicle speed is low. Infrared sensors are sensitive to ambient lighting conditions and surface reflectivity, which may affect detection accuracy in certain outdoor scenarios. Additionally, the prototype is limited to a small number of parking slots; however, this constraint can be addressed through scalable deployment strategies.

VIII. USE-CASE SCENARIO AND SYSTEM BEHAVIOR

A typical operational scenario begins when a vehicle ap- proaches the entry gate of the parking facility. The entry sensor detects the vehicle and triggers the controller to verify current slot availability. If a slot is available, the gate opens automatically, allowing the vehicle to enter.

Once the vehicle occupies a parking slot, the corresponding infrared sensor updates the occupancy status in the cloud database. This change is reflected on the web dashboard, providing real-time visibility. When the vehicle exits, the exit sensor activates the gate and the system updates the vacated slot as available, ensuring continuous coordination between physical infrastructure and the digital monitoring interface.

IX. PROTOTYPE IMPLEMENTATION

The physical prototype of the system is shown in Fig. 3. It includes three parking slots equipped with infrared sensors, a NodeMCU ESP8266 controller, and servo-driven entry and exit barriers. The compact design makes the prototype suitable for demonstration and validation of the proposed approach.

The web-based dashboard used for monitoring parking oc- cupancy is illustrated in Fig. 4. The interface displays the real- time status of each parking slot using clear visual indicators, enabling quick assessment of availability.

X. RESULTS AND DISCUSSION

Testing of the our prototype confirmed consistent vehicle detection and reliable gate operation. Updates to parking slot status were reflected on the dashboard with limited delay under normal network conditions. The system effectively prevented vehicle entry when all slots were occupied, demonstrating its practical applicability for controlled parking environments.

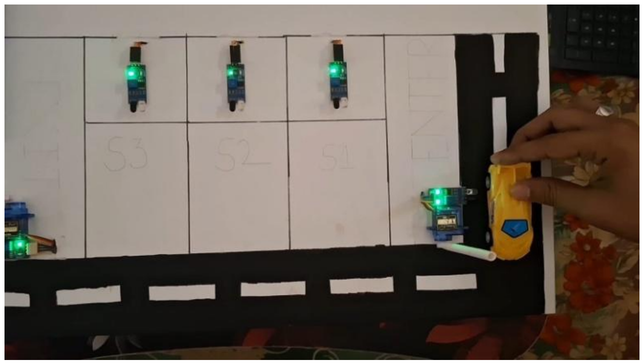

Fig. 3. Hardware prototype of the smart parking system

XI. CONCLUSION AND FUTURE WORK

This paper presented an IoT-based smart car parking system integrating sensor-based detection, automated gate control, and cloud-based monitoring. The solution is cost-effective, modular, and suitable for small-scale deployments. Future work may focus on expanding system capacity, enhancing user interaction through mobile applications, and integrating advanced sensing or analytical features to improve performance in larger installations.

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