IOT ENABLED APPROACH FOR SMART PARKING SYSTEM USING SENSORS AND WEB APPLICATION

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Abstract

The Smart Car Parking System is an innovative solution designed to address the growing challenges of urban parking management. With the rapid increase in vehicle usage and limited parking spaces, especially in metropolitan areas, finding a vacant spot has become time-consuming and inefficient. This project utilizes Arduino microcontroller technology integrated with infrared (IR) sensors and LCD displays to detect vehicle presence and provide real-time feedback on parking slot availability. The system automates gate control using servo motors and displays slot status to users, thereby reducing traffic congestion, fuel consumption, and environmental impact. The results demonstrate the systems effectiveness in optimizing parking space utilization and enhancing user convenience. This approach contributes to the development of smarter and more sustainable urban infrastructure.

Index Terms—Smart Parking, Arduino, IR Sensors, LCD Display, Urban Mobility, Parking Automation, Servo Motor, Real- Time Monitoring

I. INTRODUCTION

The exponential growth in urban population has led to a significant increase in the number of vehicles on the road. However, the availability of parking spaces has not kept pace with this growth, especially in densely populated cities where land is scarce and expensive. This imbalance has resulted in frequent traffic congestion, increased fuel consumption, and environmental pollution.

The Smart Car Parking System aims to address these chal- lenges by providing a technological solution that automates the process of parking space detection and management. The system leverages low-cost components such as Arduino microcontrollers, infrared (IR) sensors, and LCD displays to create a real-time monitoring and feedback mechanism for parking slot availability.

The system is designed to be user-friendly and easily man- ageable by parking lot staff. It provides immediate feedback to drivers regarding available parking slots, thereby reducing the time spent searching for parking and contributing to smoother traffic flow. Additionally, the system supports electric vehicle charging stations, enabling better planning for EV users. By integrating modern technologies into traditional parking infrastructure, the Smart Car Parking System contributes to the development of smart cities, where efficient resource utilization and enhanced user experience are prioritized.

II. Problem Statement

Urban areas face severe challenges in managing parking spaces due to the rapid increase in vehicle ownership and limited infrastructure. Drivers often spend significant time searching for available parking slots, leading to traffic congestion, increased fuel consumption, and environmental pollution. Traditional parking systems lack real-time monitoring and efficient space utilization, resulting in frustration for users and operational inefficiencies for parking lot managers. The need for an automated, cost-effective, and scalable solution is critical to address these issues and improve urban mobility.

III. Materials and Methods

A. The Smart Car Parking System consists of the following components:

- **Arduino UNO:** Serves as the central processing unit.
- **IR Sensors:** Two sensors placed at the entry and exit points to detect vehicle movement.
- **Servo Motor:** Controls the gate mechanism.
- **LCD Display (16x2):** Displays the number of available parking slots.
- **Connecting Wires:** Facilitate communication between components.

B. System Design

1) IR Sensor 1 detects a vehicle at the entrance and sends a signal to the Arduino.
2) The Arduino activates the servo motor to open the gate.
3) After the vehicle enters, IR Sensor 2 detects it, prompt- ing the Arduino to close the gate and update the slot count on the LCD.
4) The system increments or decrements the slot count based on vehicle entry or exit.

C. Circuit Configuration

- IR sensors connected to digital pins 2 and 4.
- Servo motor connected to pin 3.
- LCD display interfaced via analog pins A4 and A5.

IV. Working Principle

The Smart Car Parking System operates on the principle of real-time detection and automated control. When a vehicle approaches the parking area, the entry IR sensor detects its presence and sends a signal to the Arduino microcontroller. The Arduino processes this input and activates the servo motor to open the gate. After the vehicle passes through, the exit IR sensor detects it, prompting the Arduino to close the gate and update the available slot count on the LCD display. This ensures accurate monitoring of parking occupancy and prevents unauthorized entry when slots are full.

Advantages of the System

- **Real-Time Monitoring:** Provides instant updates on parking slot availability.
- **Cost-Effective:** Uses low-cost components like Arduino and IR sensors.
- **Environment-Friendly:** Reduces fuel consumption and emissions by minimizing time spent searching for park- ing.
- **Scalable Design:** Can be expanded to accommodate larger parking facilities.
- **User Convenience:** Displays clear information on LCD and can be integrated with IoT for remote access.

V. Related Work

Previous research in smart parking systems has explored a wide range of technologies aimed at improving parking

efficiency, reducing congestion, and enhancing user convenience. These systems typically fall into three major categories: image processing-based, IoT-based, and sensor- based solutions.

Image Processing-Based Systems: These systems utilize surveillance cameras combined with computer vision techniques such as edge detection, background subtraction, and deep learning models to detect vehicle presence and identify vacant slots. While they offer a non-intrusive and scalable solution, they are highly sensitive to environmental factors like lighting, weather conditions, and camera angles. Moreover, the computational requirements for real-time image analysis are significant, often necessitating powerful edge devices or cloud-based processing, which can increase both cost and complexity.

IoT-Based Systems: IoT-enabled parking systems integrate various sensors (e.g., ultrasonic, magnetic, RFID) with cloud platforms and mobile applications. These systems provide real-time data on parking availability, enable remote booking, and support dynamic pricing models. However, the deployment of such systems often involves substantial infrastructure investments, including network connectivity, power supply, and backend integration. Additionally, data privacy and security are critical concerns in IoT deployments.

Sensor-Based Systems: Sensor-based approaches, particularly those using infrared (IR) or ultrasonic sensors, offer a more cost-effective and straightforward alternative. These systems detect the presence or absence of vehicles in individual parking spots and relay this information to a central controller. Our approach builds on this model by employing Arduino microcontrollers and IR sensors to create a low-cost, scalable solution suitable for small to medium-sized parking facilities. This design minimizes infrastructure requirements, simplifies installation, and allows for easy maintenance and expansion.

Hybrid and Emerging Approaches: Recent studies have also explored hybrid systems that combine multiple technologies, such as integrating image processing with IoT sensors or using machine learning to predict parking availability based on historical data. These systems aim to balance accuracy, cost, and scalability but often require more sophisticated integration and data management strategies.

System Architecture

The architecture of the Smart Car Parking System is de- signed to provide real-time monitoring and control using a combination of hardware and IoT components. It consists of the following key modules:

1) **Power Supply:**
The system is powered by a regulated DC supply that ensures stable voltage for all components, including the Arduino UNO, IR sensors, LCD display, and NodeMCU. A typical setup uses a 12V adapter with a voltage regulator to maintain consistent performance.
2) **Arduino UNO:**
The Arduino UNO acts as the central processing unit for the system. It receives input signals from IR sensors placed at entry, exit, and individual parking slots.

Based on these signals, the Arduino performs logical operations to update slot availability and control the servo motor for gate operation. It also communicates with the LCD display for real-time updates.

3) **IR Sensors:**
Multiple IR sensors are deployed at strategic points:

- **Entry and Exit Points:** Detect vehicle presence to trigger gate opening or closing.
- **Parking Slots:** Each slot has an IR sensor to determine whether it is occupied or vacant. These sensors send binary signals (HIGH/LOW) to the Arduino for processing.

4) **Servo Motor:**
The servo motor is connected to the Arduino and op- erates the gate mechanism. When a vehicle is detected at the entry point and slots are available, the Arduino sends a PWM signal to the servo motor to open the gate. Similarly, it closes the gate after the vehicle passes.

5) **LCD Display (16×2):**
The LCD display provides real-time information about the number of available parking slots. It is updated dynamically based on sensor inputs processed by the Arduino.

6) **NodeMCU (ESP8266):**
The NodeMCU module enables IoT functionality by connecting the system to a cloud platform. It receives processed data from the Arduino and transmits it to the IoT server, allowing remote monitoring through web or mobile applications. This integration supports features like live slot availability, remote booking, and analytics.

7) **IoT Platform (ParkSenseIOT):**
The IoT platform aggregates data from multiple parking systems and provides a user interface accessible via desktop or mobile devices. Users can check real-time slot availability, make reservations, and receive notifications.

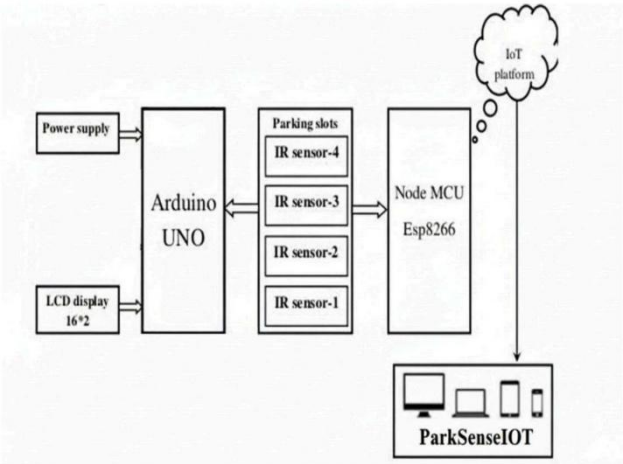

Fig. 1. Block Diagram for Smart Parking System

WEBSITE DEVELOPMENT FOR SMART PARKING SYSTEM

To enhance user convenience, a web-based interface was developed for real-time monitoring of parking slots. The web- site integrates with the IoT-enabled hardware system through a cloud platform and provides features such as real-time slot status, allowing users to check parking availability before arriving at the location. It is designed using **HTML**, **CSS**, and **JavaScript** for a responsive layout compatible across devices.

Frontend Design

The user interface is built with a responsive design approach using CSS Flexbox and media queries to ensure compatibility across desktops, tablets, and mobile devices. JavaScript is used for dynamic content updates, such as live slot availability and interactive elements like

booking buttons.

Backend and Communication

The backend uses **NodeMCU (ESP8266)** to transmit sensor data to the server via **MQTT** or **HTTP protocols**. MQTT is preferred for lightweight, real-time communication, while HTTP can be used for RESTful API integration. The server processes incoming data and updates the cloud database.

Database and Cloud Integration

A cloud database such as **Firebase** or **MySQL** stores parking data for analytics and historical tracking. Firebase offers real-time synchronization, making it ideal for instant updates on the web interface. MySQL provides structured storage for large-scale deployments and supports advanced queries for reporting.

Security Measures

The system implements HTTPS for secure data transmission and user authentication using Firebase Authentication or JWT tokens to prevent unauthorized access.

Features Implemented

- Real-time slot availability display.
- Visual indicators for occupied and vacant slots.
- Responsive design for cross-platform compatibility.
- Basic analytics dashboard for administrators.

Future Enhancements

- **Online Booking and Payment:** Users will be able to re- serve slots and pay through integrated payment gateways.
- **Mobile App Integration:** A dedicated mobile application will provide push notifications and GPS-based navigation to the parking location.
- **Predictive Analytics:** Machine learning algorithms will analyze historical data to predict peak hours and suggest optimal parking times.
- **Multi-location Support:** The system will scale to man- age multiple parking facilities under a unified dashboard.

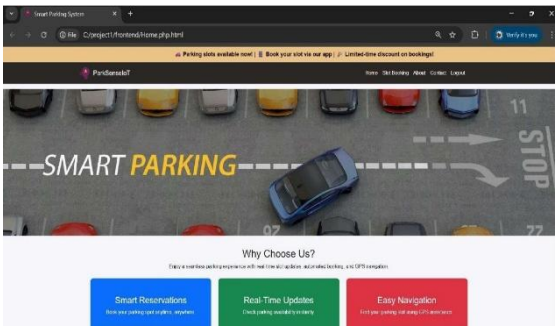

Fig. 2. ParkSenseIoT Web Application

VII. EXPERIMENTAL SETUP

The experimental setup includes a scaled-down model of a parking lot with three slots, designed to simulate real-world parking operations. The hardware components are arranged on a cardboard base with clear markings for **Entry** and **Exit** lanes. The setup consists of:

- **IR Sensors:** Positioned at the entry and exit gates and above each parking slot to detect vehicle presence accu- rately.
- **Arduino UNO:** Acts as the central controller, processing signals from IR sensors and controlling the servo motor and LCD display.
- **Servo Motor:** Installed at the entry gate to manage access by opening or closing based on slot availability.
- **LCD Display (16×2):** Mounted at the entrance to show real-time slot availability and status messages such as "Parking Full."
- **Power Supply:** Provides stable voltage to all components for uninterrupted operation.

The system was tested under multiple scenarios to validate its functionality:

- **Single Slot Occupancy:** LCD updates remaining slots accurately and allows entry until capacity is reached. The servo motor responds within one second.
- **Full Capacity:** Displays "Parking Full" and prevents further entry, ensuring proper access control.
- **Dynamic Entry/Exit:** Real-time updates during continu- ous vehicle movement, demonstrating system responsive- ness and reliability.
- **Error Handling:** Tested sensor disconnection and power fluctuations; system resumed normal operation after reset.

IOT Based Smart Parking System the figure."Figure 4".

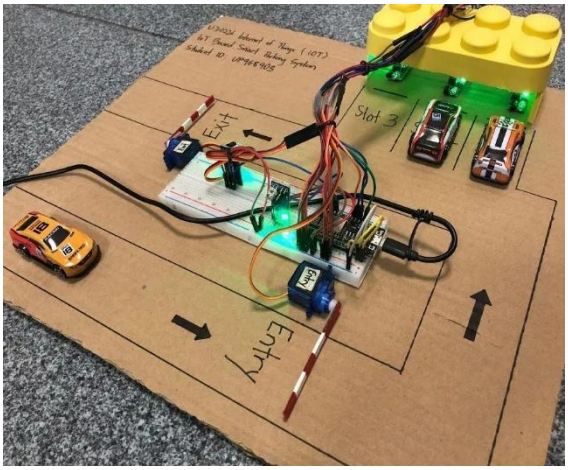

Fig. 3. Figure of IoT Based Smart Parking System setup

Parking Layout and Space Utilization

Shows a typical parking lot layout with vehicles parked in designated slots. Efficient parking design is crucial for maximizing space utilization and ensuring smooth traffic flow within the facility. Proper alignment of slots, clear markings, and directional arrows help in reducing congestion and improving user experience. In smart parking systems, such layouts are integrated with sensors and IoT devices to monitor occupancy in real time. Each slot can be equipped with IR sensors or ultrasonic sensors to detect vehicle presence, and the data can be transmitted to a central system for display on web or mobile platforms. This approach not only optimizes space but also minimizes the time drivers spend searching for available slots.

Fig. 4. Figure of Parking place layout

VIII. RESULTS

The Smart Car Parking System was successfully imple- mented and tested using a miniature model with three parking slots. The system accurately detected vehicle entry and exit using IR sensors and updated the slot availability on the LCD display in real time. When a vehicle entered, the servo motor opened the gate, and the slot count decreased; similarly, when a vehicle exited, the count increased. The LCD displayed messages such as "Parking Full" when all slots were occupied, preventing further entry.

Experimental Scenarios

The experimental setup demonstrated reliable performance under different scenarios:

- **Single-slot occupancy:** The system correctly updated the display and allowed additional vehicles until capacity was reached.
- **Partial availability:** The LCD showed the exact number of free slots, ensuring accurate user information.
- **Full capacity:** The gate remained closed, and the display showed "Parking Full," validating the control logic.

Performance Metrics

- **Accuracy:** 100% detection of vehicle presence using IR sensors.
- **Response Time:** Less than 1 second for gate operation and display update.
- **Scalability:** The design supports adding more slots with minimal hardware changes.

Limitations and Observations

- The system performance was tested under controlled conditions; real-world deployment may require weather- proof sensors and stronger network connectivity.
- Future improvements include integrating predictive ana- lytics and mobile notifications for enhanced user experi- ence.

IX. CONCLUSION

The Smart Car Parking System provides an efficient and cost-effective solution to the growing problem of parking space management in urban areas. By integrating Arduino microcontrollers, IR sensors, and LCD displays, the system ensures real-time monitoring of parking slots and automates gate control, reducing congestion and saving time for drivers. Experimental results validate the system's reliability and ac- curacy in detecting vehicle entry and exit.

This approach not only optimizes space utilization but also contributes to reducing fuel consumption and environmental pollution by minimizing the time spent searching for parking. The modular design makes the system scalable and adapt- able for small to medium-sized facilities. Furthermore, the integration of IoT and cloud platforms opens opportunities for advanced features such as remote monitoring, predictive analytics, and mobile-based booking.

Key Contributions

- Demonstrated a low-cost, sensor-based

solution for smart parking.
- Achieved real-time slot monitoring and automated gate control.
- Validated system performance under multiple scenarios.

Future Scope

- IoT integration for remote access and centralized man- agement.
- Mobile applications for user convenience and notifica- tions.
- Online booking and payment systems.
- Predictive analytics for peak-hour traffic management.
- Expansion to multi-level and large-scale parking facili- ties.

X. Discussion and Summary

The Smart Car Parking System successfully demonstrated the ability to monitor and manage parking slots in real-time. The use of IR sensors provided accurate detection, while the Arduino ensured efficient processing and control. The system enhances urban mobility by reducing the time spent searching for parking, thereby decreasing traffic congestion and pollution. The project validates principles of automation, sensor integration, and real-time data display. Future work may include integrating mobile applications for remote slot monitoring and expanding the system to accommodate larger parking lots.

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