IoT-Enabled Embedded System for Real-Time Parking Space Identification

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Abstract— **Parking congestion is the most common phenomenon in cities across the globe, which is caused by the increasing number of vehicles and the limited availability of parking spaces. In this project, a Smart Parking System is proposed using the Internet of Things concept. This helps in managing the parking space more efficiently using sensors and data communication techniques. The availability of parking space is sent to the cloud database through a Wi-Fi-enabled microcontroller.**

The parking space availability status is shown using the LCD screen and a web application. If the parking space is available, the parking gate is opened using a servo motor; otherwise, the display shows the status as "Parking Full." This project helps in reducing traffic jams, saves time, and efficiently manages the parking space using IoT concepts.

Index Terms— **Cloud Database, IoT (Internet of Things), Real-Time Monitoring, Smart Parking System, Wireless Sensor Network.**

I. INTRODUCTION

The increase in vehicles in the city has also led to many problems related to parking management. A significant amount of time is being wasted searching for parking space, which ultimately leads to traffic jams, fuel consumption, and pollution. Traditional parking systems mainly operate on manual control.

To avoid the problems associated with traditional parking systems, the concept of a Smart Parking System using IoT technology has attracted significant attention. IoT technology is used to enable communication between the devices/sensors connected through the internet. In smart parking systems, sensors detect the availability of vehicles in the parking slots.

The objective of this project is to develop an IoT-based smart parking system that can detect parking slots and displaying the status of parking slots in real time. The parking slots are visible on the LCD display as well as the web portal, making it easy to park the vehicles. This project can be developed by using the help of sensors as well as microcontrollers.

The proposed smart parking system can be implemented in shopping complexes, offices, universities, and smart cities.

II. LITERATURE REVIEW

With the increase in the number of vehicles, parking management has become one of the critical issues in urban areas. Several researchers have proposed efficient parking management using Internet of Things (IoT), sensor networks, and cloud computing technologies. An efficient smart parking system based on IoT was proposed in [1]. The authors have utilized the concept of sensors to sense the parking space availability and update the users through a web interface. The authors of the paper have demonstrated the efficiency of smart parking by showing the effectiveness of real-time parking space information in reducing traffic. An efficient parking management system based on IoT was proposed in [2].

The research in [3] introduced a smart parking framework using embedded systems and wireless communication to monitor parking slots and display their availability online. Another study in [4] proposed the use of IoT sensors and centralized monitoring systems to improve parking space management and reduce manual supervision. A comprehensive review of IoT-based parking technologies was presented in [5], highlighting how smart parking systems can minimize fuel consumption and traffic congestion. The study also emphasized the role of wireless communication and cloud platforms in improving parking system efficiency.

In [6], the authors developed a smart parking architecture that integrates sensors and cloud-based systems for real-time parking monitoring. The system allows users to access parking information through web or mobile applications. Similarly, the work in [7] proposed an IoT-based vehicle monitoring and parking system that automatically detects parking slot occupancy and updates the information to a central server. Another sensor-based smart parking solution was presented in [8], where parking slot detection was performed using sensor networks to provide accurate parking information. The research in [9] introduced an RFID-based parking management system that allows automated vehicle entry and improves parking security.

The recent advances in smart parking systems have also considered the concept of intelligent monitoring. In the study conducted in [10], the authors proposed a smart parking surveillance system that combines IoT technology with edge computing technology. From the above literature, the IoT-based smart parking systems have the potential to improve the management of the parking area. Thus, the proposed project aims to implement a sensor-based IoT smart parking system.

III. METHODOLOGY

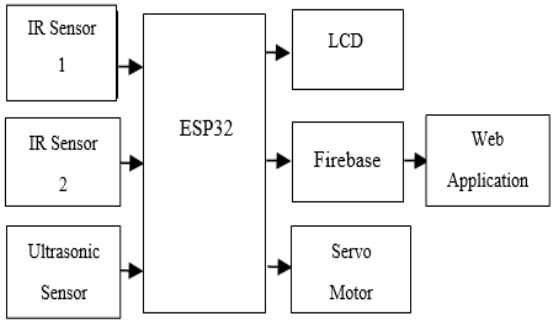
The concept of the proposed IoT-Based Smart Parking System is to sense the parking slot status and manage the parking of the vehicle by entering the parking slot through the detection of the sensor and communication.

In the proposed system, the IR sensors are required to be connected to the parking slot to sense the presence or absence of the vehicle. When the vehicle is parked, the IR sensor will be able to sense the changes and will be able to send the signal to the microcontroller to check whether the parking slot is occupied or not.

The ultrasonic sensor would be able to detect the arrival of the vehicle at the parking lot entrance. Once the vehicle arrives at the parking lot entrance gate, the ultrasonic sensor sends a signal to the controller. If the parking slot is available, the gate of the parking lot would be opened for the parking of the vehicle through the servo motor. If the parking slots are already occupied, the parking lot would deny the parking of the vehicle, and the message “Parking Full” would be displayed.

The information sent from the sensor would be sent through the controller to the Wi-Fi module. The information stored in the cloud would be retrieved through a web application.

In addition, an LCD is used to display the parking slots that are available at the parking entrance. This will help drivers to be aware of the availability before accessing the parking area. The system utilizes sensors, microcontroller processing, cloud connection, and the web to provide monitoring, gate control, and parking services, thus reducing traffic congestion.



IV. PROPOSED SYSTEM

The proposed system would be an IoT-based Smart Parking System. In the proposed system, there would be the use of IR sensor technology for detecting the presence of vehicles in the parking slots. In addition, there would be the use of ultrasonic sensor technology for detecting the presence of vehicles at the entry point. Once the vehicle is near the entry point of the parking area, the proposed system would check if there were a parking slot available.

If there is a parking slot available, the servo motor would be opened for the entry of the vehicle. If there is no parking slot available, the message “Parking Full” would be displayed so that the vehicle would not be allowed entry. This would be sent to the cloud database using a Wi-Fi microcontroller.

V. HARDWARE AND SOFTWARE COMPONENTS

- ESP32
- IR Sensors
- Ultrasonic Sensor
- Servo Motor
- LCD Display

- Arduino IDE
- Firebase
- HTML, CSS, JS
- Embedded C Programming

VI. SYSTEM IMPLEMENTATION

The complete IoT-Based Smart Parking System is implemented using embedded firmware developed in C++ for the ESP8266 NodeMCU using the Arduino IDE. The microcontroller continuously reads data from multiple sensors and processes the information to determine the availability of parking slots. The system operates in real time by transmitting sensor data to a Firebase Realtime Database through Wi-Fi connectivity. This allows the parking status to be updated instantly on a web application and displayed to users. The firmware ensures efficient communication between the sensors, gate control mechanism, and cloud database to provide accurate parking slot monitoring.

VII. HARDWARE SETUP

The Smart Parking System uses the ESP8266 NodeMCU as the central controller that manages all sensor inputs and system operations. IR sensors are installed in each parking slot to detect the presence or absence of vehicles. An ultrasonic sensor is positioned at the parking entrance to detect approaching vehicles and trigger the entry process. A servo motor is connected to the microcontroller to automatically control the parking gate mechanism. Additionally, a 16×2 LCD display is used to show the number of available parking slots at the entrance. All components are connected through a regulated power supply and arranged in a compact hardware setup for efficient operation.

VIII. SOFTWARE INTEGRATION:

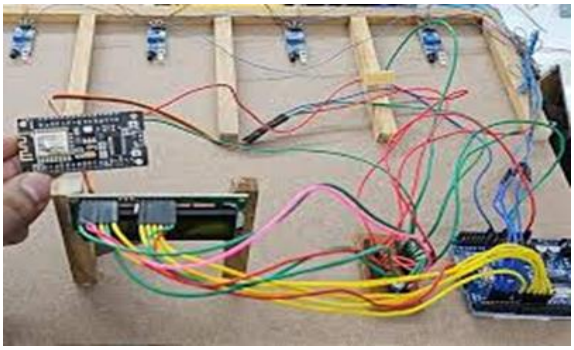
The firmware developed in the Arduino IDE processes the sensor data and determines the parking slot status. The system connects to a Wi-Fi network and sends the parking information to the Firebase Realtime Database. A web-based interface developed using HTML, CSS, and JavaScript retrieves the data from Firebase and displays the current parking availability to users in real time. This integration of hardware, firmware, and cloud services enables efficient monitoring and management of parking spaces.

VII. RESULT AND DISCUSSION

The implemented IoT-based Smart Parking System was tested to verify the accuracy of sensor detection, real-time data transmission, and automated gate control. The system successfully detected vehicle presence in parking slots and updated the parking status in the cloud database. The LCD display and web interface showed the availability of parking spaces in real time.

Test Case	Slot 1	Slot 2	Sensor Output
1	Empty	Empty	No Detection
2	Occupied	Empty	Slot 1 marked occupied
3	Empty	Occupied	Slot 2 marked occupied
4	Occupied	Occupied	Parking Full

Hardware Output



VII. CONCLUSION

The proposed IoT-Based Smart Parking System provides an efficient solution for managing parking spaces using sensor-based detection and real-time monitoring. The system accurately identifies the availability of parking slots and updates the information through a cloud database, which is displayed on both an LCD screen and a web application. The integration of sensors, microcontroller, and automated gate control ensures smooth and reliable operation.

The results demonstrate that the system reduces the time required to find parking spaces, minimizes traffic congestion, and improves overall parking

management. This project highlights the importance of IoT technology in developing smart and scalable solutions for modern urban infrastructure and can be effectively implemented in areas such as shopping malls, offices, and smart cities.

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