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Parking Lot CCTV With Space Detection

Ms. Tule T. S	Ms. Shirke P. M	Ms. Ranpise S. K	Ms. Shinde M. P	Mr. Waghmode M. N
E&TC Dept. (JSPM's BSP)	E&TC Dept. (JSPM's BSP)	E&TC Dept. (JSPM's BSP)	E&TC Dept. (JSPM's BSP)	E&TC Dept. (JSPM's BSP)

Abstract: Urban areas waste a ridiculous amount of time and fuel on "parking Hunting" because most parking lots still run on manual checks or stale signboards. This project proposes an IoT- based Parking Lot CCTV with Space Detection System that provides real-time parking slot availability along with live video surveillance for verification and safety. An ESP32 acts as the main controller and connects four IR sensors, each mapped to a single parking slot, to detect vehicle presence instantly. Slot status is pushed continuously to Firebase Realtime Database, enabling live synchronization between the hardware and software layers.

For surveillance, an ESP32-CAM streams real-time parking footage through a lightweight HTML web interface, accessible via the device IP show in the Arduino IDE serial monitor. A Java/XML Android application reads the Firebase updates and display slot availability in a clean user interface, helping drivers decide before entering the lot. Supporting modules like a dot matrix display provide guidance/welcome messages, while a buzzer gives entry/exit alerts, improving user interaction. Built on a zero PCB, the design remains compact, low-cost, and scalable making it suitable for smart parking deployment in smart city environments.

Key words: IoT, Smart Parking, ESP32, ESP32-CAM, IR Sensor, Parking Space Detection, Firebase Real-time Database, Android (Java/XML), CCTV Live Streaming, Smart City Parking Management.

1.INTRODUCTION

Rapid urbanization and the nonstop rise in vehicle ownership have turned parking into a daily mess in most cities. Drivers often spend several minutes sometimes much longer circling parking areas to find an empty slot. This "search traffic" directly increases road congestion, wastes fuel, raises pollution, and creates unnecessary frustration for users. In many parking lots, availability information is either not displayed at all or is managed manually using guards, paper tokens, or basic signboards. These approaches are slow, error-prone, and cannot provide real-time visibility to users or administrators.

A smart parking system solves this core gap by continuously monitoring slot occupancy and sharing live status instantly. However, many existing "smart parking" setups focus only on detection and ignore security and verification. In real-life parking environments, slot data alone is sometimes not enough users and administrators also need visual confirmation to handle disputes, prevent unauthorized parking, and improve overall safety. That's where combining parking space detection with CCTV monitoring becomes a more complete and practical solution.

This project, Parking Lot CCTV with Space Detection using IoT, is designed to provide real-time parking slot detection along with live video streaming of the parking area. The system uses an ESP32 microcontroller as the main control unit due to its built-in Wi-Fi, low power consumption, and suitability for IoT-based monitoring applications. Each parking slot is monitored using an IR sensor, where one sensor is dedicated to one slot. In this implementation, four sensors are deployed to manage four independent parking spaces. The sensor output is processed by the ESP32 and uploaded in real time to the Firebase Realtime Database, enabling cloud-based synchronization and instant updates.

To strengthen security and remote monitoring, an ESP32-CAM module is integrated as a CCTV unit. It streams live parking footage through a lightweight HTML web page, accessible using the camera's IP address displayed in the Arduino IDE serial monitor. This allows a user or parking administrator to verify slot conditions visually without installing expensive CCTV systems. For better user guidance at the entry point, a dot matrix display shows welcome and parking-related messages, and a buzzer provides audible alerts during vehicle entry and exit events.

A dedicated Android application developed in Java/XML fetches the live slot availability from Firebase and displays it in a simple, user-friendly interface. This enables users to check slot status before entering the parking area, reducing unnecessary vehicle movement and improving traffic flow around parking zones. The entire hardware system is assembled on a zero PCB, keeping the implementation compact, organized, and cost-effective.

Overall, this project demonstrates an efficient and scalable smart parking solution by integrating sensor-based space detection, cloud connectivity, CCTV streaming, and mobile app support. It aligns well with smart city requirements by improving parking utilization, reducing congestion caused by parking search traffic, and enhancing safety through real-time monitoring.

2. Body of Paper

The proposed smart parking system is built on a layered IoT architecture consisting of sensing, control, cloud, and application layers. At the sensing layer, IR sensors are

deployed at individual parking slots to detect vehicle presence. Each sensor provides a digital signal indicating whether a slot is occupied or vacant. The control layer is handled by an ESP32 microcontroller, which reads sensor data, processes slot status, controls local peripherals, and communicates with cloud services through Wi-Fi.

The cloud layer uses Firebase Realtime Database to store and synchronize parking slot data in real time. Any change in slot occupancy is instantly reflected in the database, enabling seamless communication between hardware and user interfaces. For surveillance, an ESP32-CAM module operates independently as a CCTV unit, hosting a lightweight HTML-based streaming server accessible over the local network. Finally, the application layer includes an Android mobile application developed using Java/XML, which retrieves live data from Firebase and displays parking availability to users in an intuitive format.

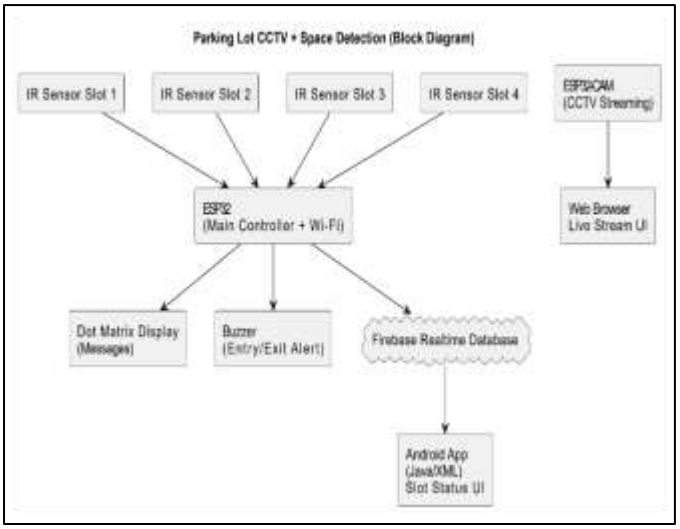


Fig: Block Diagram

2.1 Hardware Description

1.ESP32 Microcontroller

The ESP32 microcontroller acts as the central control unit of the system. It is responsible for reading inputs from IR sensors, processing parking slot status, controlling output devices, and communicating with the cloud backend. The ESP32 is chosen due to its built-in Wi-Fi, low power consumption, dual-core processor, and high GPIO availability, making it ideal for IoT-based applications.

In this project, the ESP32 continuously monitors four IR sensors corresponding to four parking slots. Based on sensor readings, it updates parking slot availability in the Firebase Realtime Database, triggers the buzzer, and updates the dot matrix display. Its Wi-Fi capability enables real-time cloud synchronization and seamless integration with the Android application.

2.ESP32-CAM Module

The ESP32-CAM module is used to implement the CCTV surveillance feature of the parking system. It includes an onboard camera and Wi-Fi connectivity, allowing live video streaming without the need for an external camera or processing unit. The module hosts a lightweight HTML-based web server, which streams live parking area footage.

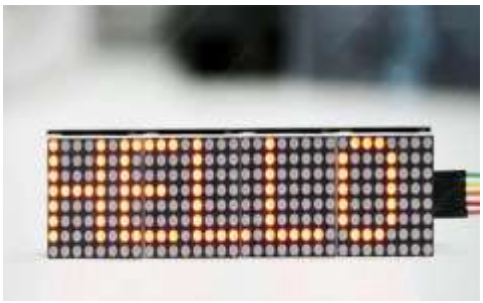
Once powered and connected to Wi-Fi, the ESP32-CAM displays an IP address on the Arduino IDE serial monitor. Accessing this IP address through a web browser allows users or administrators to view live video of the parking lot. This enhances system reliability by providing visual verification of parking slot occupancy and improves security.

3.IR Sensors

Infrared (IR) sensors are used for vehicle detection in each parking slot. In this project, four IR sensors are deployed, with each sensor dedicated to one parking space. These sensors detect the presence of a vehicle based on reflected infrared light and generate a digital output signal.

When a vehicle occupies a slot, the corresponding IR sensor output changes state, which is detected by the ESP32. This slot-wise sensor configuration ensures accurate detection and eliminates ambiguity in parking status. The use of IR sensors makes the system cost-effective, fast, and suitable for real-time detection.

4.Dot Matrix Display



The dot matrix display units are used to display welcome messages and parking slot information at the parking entrance. Four display modules are used to enhance visibility and readability. These displays show messages such as “WELCOME”, “PARKING AVAILABLE”, or real-time slot availability.

The displays are controlled by the ESP32 using appropriate communication protocols (such as SPI or I2C depending on the module). This visual feedback helps drivers quickly understand parking availability without requiring mobile access, improving user experience and reducing congestion at entry points.

5.Buzzer

A buzzer is included in the system to provide audible alerts during important events such as vehicle entry or exit. When a parking slot status changes, the ESP32 activates the buzzer to indicate successful detection.

The buzzer improves system interactivity and provides immediate feedback to users and administrators. It also helps in alerting parking attendants about vehicle movement, enhancing operational awareness.

6.Zero PCB

A zero PCB (general-purpose PCB) is used to mount and interconnect all electronic components securely. It ensures organized wiring, improves mechanical stability, and reduces loose connections compared to breadboard-based setups.

Using a zero PCB makes the system compact, reliable, and suitable for long-term deployment or demonstration. It also enhances the professional appearance of the project during evaluations and presentations.

2.2 Software Description

1. ESP32 Firmware

The ESP32 firmware is developed using the Arduino IDE. The code handles sensor input reading, decision-making logic, Firebase communication, and control of output devices. Wi-Fi credentials and Firebase authentication keys are configured within the firmware to ensure secure cloud connectivity.

2 Firebase Realtime Database

Firebase serves as the cloud backend for the system. It stores the real-time status of each parking slot and provides instant synchronization across connected devices. Any update from the ESP32 is immediately reflected in the Android application.

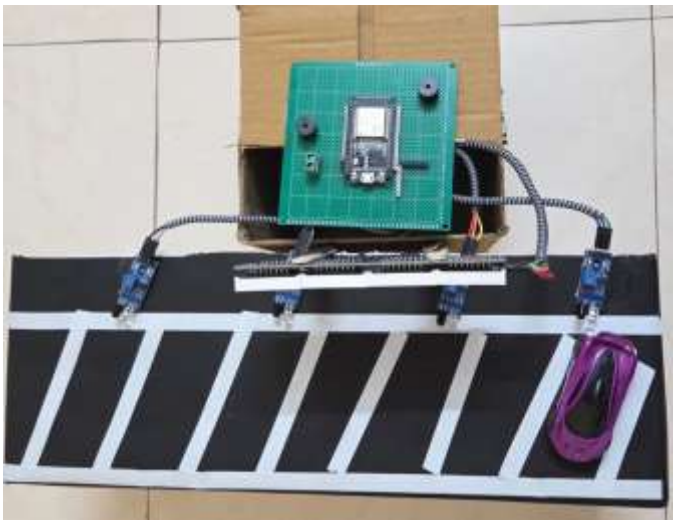
3 ESP32-CAM Web Interface

The ESP32-CAM hosts a lightweight HTML page that streams live video. This interface allows users or administrators to view the parking area in real time using a standard web browser without additional software installation.

4 Android Application (Java/XML)

The Android application retrieves slot availability data from Firebase and displays it in a clean, user-friendly interface. Each parking slot is clearly marked as available or occupied, helping drivers make informed decisions before entering the parking lot.

3. RESULT



4.CONCLUSIONS

The Parking Lot CCTV with Space Detection System demonstrates an effective IoT-based solution for modern parking challenges. By combining sensor-based detection, cloud connectivity, live video surveillance, and mobile application support, the system offers a complete and practical smart parking solution. Its low-cost, scalable, and modular design makes it suitable for real-world deployment in smart city environments.

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