

Hybrid Smart Parking System Using Espcam and Sensors

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Abstract—Parking space management has become increasingly difficult due to the rapid growth in the number of vehicles and inefficient utilization of available areas. This paper presents a smart parking solution that combines image-based monitoring with basic sensor-driven automation. The system utilizes an ESP32-CAM module to capture real-time visuals of the parking area, while OpenCV is employed to analyze these images and determine the status of each parking slot. An infrared sensor is positioned at the entrance to detect incoming vehicles, and a servo motor is used to regulate the gate based on slot availability. A display module indicates the total number of occupied and vacant slots, and a laptop interface provides detailed slot-level information. Compared to conventional systems that depend on multiple sensors, this approach reduces hardware complexity and improves system flexibility.

Index Terms—Computer Vision, ESP32-CAM, Infrared Sensor, Servo Control, Slot Monitoring, Smart Parking

I. INTRODUCTION

In modern urban environments, parking has become a major concern due to the increasing number of vehicles and limited space. Locating a free parking slot often leads to time wastage and traffic congestion. Conventional parking systems either rely on manual supervision or use individual sensors for each slot, which increases system complexity and maintenance requirements.

With advancements in image processing, it is now possible to monitor multiple parking spaces using a single camera system. This significantly reduces hardware dependency and simplifies system design.

The proposed system adopts a hybrid approach, where image processing is used for detecting parking slot availability, and sensor-based control is implemented for managing the entry gate.

II. LITERATURE REVIEW

Various smart parking systems have been developed using different techniques. Some systems use ultrasonic or infrared sensors for each parking slot to detect vehicle presence. Although these methods provide accurate results, they require extensive wiring and increase maintenance efforts.

On the other hand, camera-based systems utilize image processing techniques to identify parking availability. These systems reduce hardware usage but may face challenges under varying lighting conditions.

The proposed model combines both approaches by using a camera for slot detection and a single IR sensor for entry monitoring, providing a balanced and efficient solution.

III. PROPOSED SYSTEM

The developed system integrates computer vision with minimal sensor usage to achieve efficient parking management.

Main Components: -

- ESP32-CAM: Captures high-resolution images of vehicles at the entry point.
- IR Sensor: Triggers the system by detecting the physical presence of a vehicle.
- OpenCV (via Laptop): Analyses image data to identify license plates or vehicle types.
- Servo Motor: Physically operates the parking gate for entry and exit.
- LCD Display: Provides real-time visual updates on available parking slots.
- Central Processing Unit (Laptop): Manages data traffic, runs logic, and monitors the overall system.

IV. SYSTEM ARCHITECTURE

The architecture of the proposed hybrid smart parking system combines image-based monitoring with sensor-driven control to manage parking spaces effectively. The system is built using an ESP32-CAM module, an IR sensor, a servo motor, a processing unit, and a display module.

The ESP32-CAM continuously captures live images of the parking area and transfers them to the processing unit. These images are analyzed using OpenCV techniques to identify which parking slots are occupied and which are free. An IR sensor is placed at the entry point to sense the arrival of a vehicle. Based on the availability of parking spaces, the system sends a signal to the servo motor to either open or keep the gate closed.

At the same time, the display module shows updated information such as the total number of slots, the number of occupied spaces, and the number of vacant slots, allowing users to quickly understand the parking status.

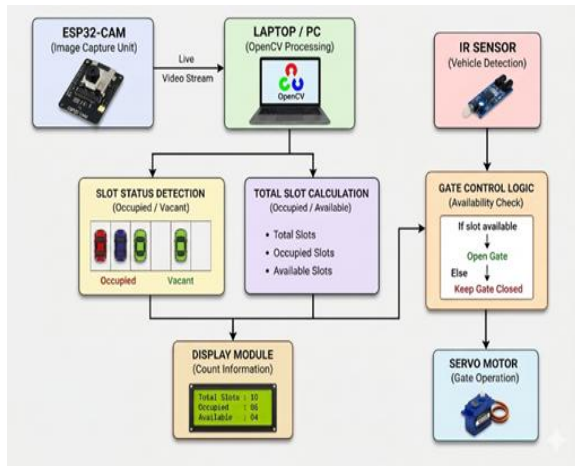


Figure 1. Block Diagram of Hybrid Smart Parking System

V. WORKING PRINCIPAL

The proposed system operates by combining image processing and sensor-based automation to efficiently manage parking spaces.

The camera continuously monitors the parking area and captures live images. These images are processed using OpenCV algorithms to detect whether individual

parking slots are occupied or vacant. The system then updates the count of total available spaces.

When a vehicle approaches the entry point, the IR sensor detects its presence. The system immediately checks the availability of parking slots based on processed image data. If a vacant slot is available, the servo motor is activated to open the gate automatically. If the parking area is full, the gate remains closed, preventing unnecessary entry.

This integrated approach ensures efficient parking management, reduces manual intervention, and minimizes traffic congestion inside the parking area.

VI. METHODOLOGY

Step 1: Image Acquisition

The ESP32-CAM captures real-time images of the parking layout.

Step 2: Image Processing

Conversion of image into grayscale

Application of thresholding techniques

Detection of parking regions using contour analysis

Step 3: Slot Identification

Pixel intensity values are analyzed to classify slots as occupied or empty.

Step 4: Slot Count Calculation

The system computes total slots, occupied slots, and available slots.

Step 5: Gate Control Mechanism

The IR sensor detects vehicle entry → system verifies slot availability → servo motor operates accordingly.

VII. RESULTS AND DISCUSSION

The proposed smart parking system was successfully tested on a prototype setup. The camera-based detection accurately identified occupied and vacant slots, displaying results in real time using OpenCV. The system correctly marked slots as occupied and free, along with overall slot count and gate status.

The LCD module displayed updated information such as occupied and available slots, ensuring clear and quick understanding for users. The IR sensor and servo motor worked as expected, allowing gate operation only when parking space was available

Table 1: Parking System Output Analysis

Test Case	Total Slots	Occupied	Vacant	Gate Status
Case 1	8	4	4	Open
Case 2	8	2	6	Open
Case 3	8	8	0	Closed

The system was tested under various conditions, as presented in Table 1. The observations show that it reliably identifies occupied and available slots and appropriately controls the gate based on space availability.



Figure 2. Real Time Parking Slot Detection

Real-Time Parking Slot Detection Output

This output shows the OpenCV-based detection of parking slots. Occupied slots are marked in red and available slots in green, along with total count and gate status. It confirms accurate real-time slot identification.

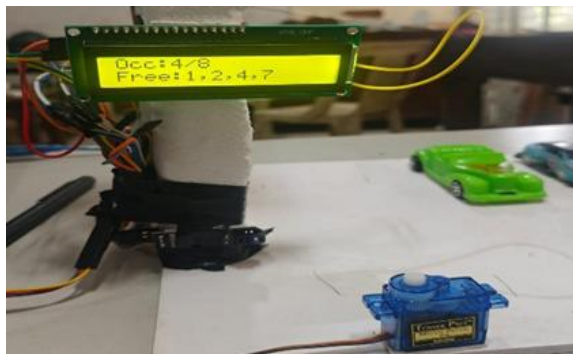


Figure 1.LCD Display Output

The LCD displays live parking information, including occupied and available slots. The values update dynamically based on system detection, reflecting correct hardware output.



Figure 4: Hardware Setup of the System

This image shows the integrated setup with ESP32-CAM, IR sensor, servo motor, and LCD module. It represents the complete working model of the proposed system.

VIII. CONCLUSION

The proposed smart parking system provides an effective solution by combining image processing and minimal sensor-based automation. It reduces hardware complexity while maintaining accurate monitoring of parking spaces. The system improves scalability and offers both overall slot count and detailed slot-level information, making it practical for real-world applications.

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