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Smart Parking System With Dynamic Slot Detection

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Abstract- The Smart Parking System with Dynamic slot Detection is an intelligent solution designed to address the growing challenges of urban parking management. The rapid increase in urban vehicle usage has created significant parking challenges, including congestion, long search times, and inefficient utilization [1][3]. Traditional Parking Systems rely on manual monitoring or fixed sensors, which are costly and difficult to maintain to address these issues, this project proposes a Smart Parking System with Dynamic slot Detection using an ESP32-Cam. The ESP32-Cam captures real-time images of the parking area and process them using an machine learning model to detect slot occupancy [4]. The system dynamically updates the entry gate and exit gate occupied or free and send the information to a web dashboard. The solution eliminates the need for individual IR/ultrasonic sensors, reduces installation cost, and provides high accuracy. The proposed system enhances user convenience by guiding drivers to nearest available slot and improves overall parking management efficiency in smart cities.

KEYWORDS - Smart Parking, ESP32-CAM, Parking slot Detection, Computer Vision, Deep Learning, IOT-Based Parking System,Real-Time Monitoring, Smart City, Dynamic slot Allocation.

I. INTRODUCTION

Urban areas around the world face increasing traffic congestion and parking shortages due to rapid urbanization and growing vehicle ownership[1][3]. In cities, a significant portion of traffic congestion is caused by drivers searching available parking spaces [2]. The Smart Parking System with Dynamic slot Detection is designed to solve this problem by automatically detecting the availability of parking slots in real time. The system uses a ESP32-Cam for monitoring parking area and IR sensors installed in entry gate and exit gate to accurately detect the vehicle presence. In microcontroller such as Arduino UNO is used to process sensor data, and programming is carried out using the Arduino IDE. The system dynamically updates the status of entry gate and exit gate and displays the availability information to users.

The Smart Parking System aims to automatically detect the available parking slots in real-time and provide this information to drivers through a digital interface such as web dashboard. The system continuously monitors parking spaces using sensors or cameras and dynamically updates a lot availability, ensuring efficient space utilization and reduced search time.

The system uses:

- Detect vacant and occupied parking slots automatically.
- Provide real-time parking availability updates.
- Reduce traffic congestion caused by parking searches.
- Minimize fuel consumption and carbon emissions.
- Improve overall parking management efficiency.

II. PROBLEM STATEMENT

In rapidly growing urban areas, the increase in vehicle ownership has led to severe parking congestion and inefficient space utilization [1][3]. Drivers often spend a significant amount of time searching for available for parking spaces, leading to traffic congestion, full wastage, environmental pollution[2], and frustration. Traditional parking

systems lack real time monitoring and automated slot management, making it difficult for users to identify vacant spaces quietly and for administrators to manage parking efficiently. Most existing parking facilities rely on manual super vision or static information systems, which are inaccurate and unable to provide dynamic updates on slot availability. This results in overcrowded parking zones, and underutilized spaces in certain areas, and increased operational challenges.The problem addressed by this project is to design and implement an intelligent, automated parking management solution that dynamically monitors parking slots and delivers accurate, real time information to drivers and administrators, thereby enhancing convenience, efficiency, and sustainability in urban parking systems.

III. METHODOLOGY

The methodology of the Smart Parking System with Dynamic slot Detection explains the systematic approach used to design, develop, and implement the system[1]. The project follows to structured process from data collection to real time users notification. The methodology is divided into the following stages:

System Analysis:
In this stage, the requirements of the system are analyzed. The main objective is to detect vehicle presence in parking slots using both ESP32-Cam for AI based vehicle detection and IR sensors for slot level confirmation. The ESP32-Cam monitors the overall parking area, while IR sensors provide accurate detection at each individual slot. Functional requirements such as real time monitoring, automatic slot status update, and display of available slots are identified.

System Design:
After analysis, the system architecture is designed. The system consists of three main: The vision module(ESP32-Cam), the sensor module (IR Sensors), and the control module (Arduino). The ESP32-Cam is positioned at a suitable height to capture the entire parking area. IR sensors are installed in each parking slot to detect vehicle presence directly. The Arduino board acts as the central controller, receiving signals from IR sensors and updating slot status. The ESP32-Cam processes images using basic AI or computer vision techniques on a connected computer to detect vehicle entry and exit [4]. The data flow between these modules is clearly defined to ensure smooth operation.

Hardware Implementation
All components are assembled. The IR sensors are fixed in entry gate and exit gate and connected to the digital input pins of the Arduino UNO. The ESP32-Cam is mounted in a positioned where all slots are visible. An LCD or LED display is connected to the Arduino to show slot availability. Proper wiring, stable power supply, and grounding are ensured for reliable system performance.

Software Implementation:
The Arduino IDE to continuously read input from the IR sensors. If a sensor detects a vehicle, the corresponding slot is marked as occupied; otherwise, it is marked as vacant. Simultaneously, the ESP32-Cam captures live video, and computer vision techniques are applied on a connected computer to detect vehicles entering or leaving the parking area. The Arduino program is compiled and uploaded to the board for execution.

System Integration:
After the hardware and software development, all modules are integrated in to a single working system the ESP32-Cam detection system and Arduino based IR detection system are synchronized. The system is tested to ensure that when a vehicle enters a slot, both the esp32-Cam and IR sensor detect it correctly, and the slot status is updated immediately on the display.

Testing and Validation:
Each slot is tested individually to verify accurate detection. The response time and reliability of the system are evaluated. Any detection errors are corrected by adjusting sensor placement or modifying the program. The system is validated to ensure stable and efficient dynamic slot detection.

IV. BLOCK DIAGRAM:

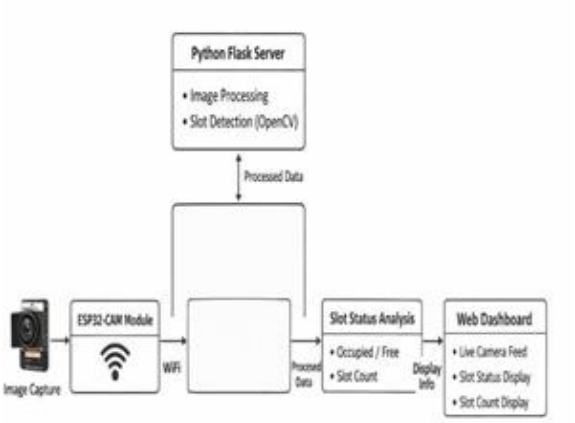


Figure. Block Diagram

V. COMPONENTS USED

ESP32-CAM

The ESP32-Cam is used in a Smart Parking System with Dynamic slot Detection to monitor and analyse parking spaces in a real-time it cuptures live images of the parking area and transmits them through its built-in wifi module to a server or processing unit [6], where vehicle detection algorithms are applied. By analysing entry gate and exit gate visually, the system determaines whether a slot is oocupied or vacant and updates the status dynamically. When a vehicle enters or leaves a space, the ESP 32-Cam continuosly refreshes the data and sense the updated information to an LCD display or web dashboard, showing the number of available and occupied slots. In some implementations it is combined with IR sensors for higher accuracy,where the camera performs overall monitoring and the sensors confirm slot-level detection.Due to its low cost,compact size,and wireless capability,the ESP32-CAM is an efficient and reliable component for implementing smart parking solutions

Figure: ESP32-CAM

SERVOMOTOR

Figure: Servo motor

Servo motor rotates to open the gate when a vehicle is detected at the entrance and available parking slots are confirmed. After the vehicle passess ,it returns to its original position to close the gate. The motor is controlled by the microcontroller,which sends precise angle signals to ensure smooth and accurate movement. Due to its ability to provide controlled rotation and quick response,the servo motor is ideal for automated gate control in smart parking systems.

ARDUINO UNO

The Arduino Uno plays a central role in a Smart Parking System with Dynamic Slot Detection by acting as the main controller [5]. It collects signals from IR sensors installed in parking slot to determine whether a space is occupied or vacant. The Arduino processes this information in real time and updates the system status accordingly. It also controls output components such as the LCD display to show available slots and the servomotor to manage the entry gate. With its easy programming and reliable performance, the Arduino Uno ensures smooth coordination of all components in the smart parking system.

Figure: Arduino Uno

IR SENSOR

Figure: IR Sensor

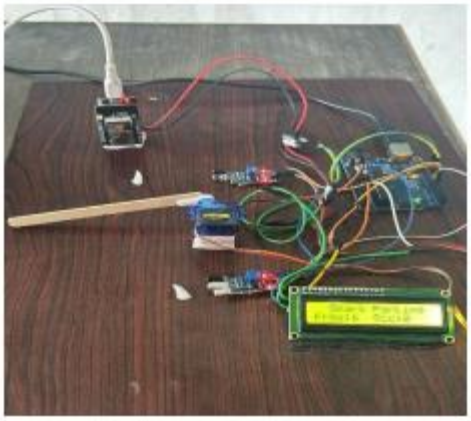
An IR sensor is used in a smart Parking System With Dynamic slot Detection to detect the presence or or absence of a vehicle in parking slots. The sensor works by emitting infrared light and measuring the reflected signal;when a vehicle is parked in front of it ,the reflected IR signal changes,indicating that the slot is occupied. This information is sent to the microcontroller,which updates the slot status in real time. IR sensors provide accurate,fast, and low-cost detection at the slot level and are often combined with a camera module to improve overall system reliability and dynamic slot monitoring.

LCD DISPLAY

An 16x2 LCD Display is used in a smart parking system with dynamic slot detection to show real time information about parking availability. It displays details such as the total number of slots, available spaces, and occupied slots, help ing drivers quickly identified parking status. The LCD receives updated data from the microcontroller whenever a vehicle enters or exits a slot, ensuring dynamic and accurate display of information. It simple interface, low power consumption, and clear visibility make it an effective output device for smart parking systems.

Figure: LCD Display

VI. RESULT



The Smart Parking System With Dynamic slot Detection was successfully desigened and tested, achieving accurate real-time monitoring of parking slots. The system effectively detected vehicle presence using IR sensors and a camera module such as ESP32-Cam, while the arduino uno proceesed the data and updated slot availability dynamically [1][4]. The LCD display showed the number of available and occupied slots instantly, and the servomotor automatically controlled the gate based on slot status. During testing, the system demonstrated fast response time, reliable operation, and high detection accuracy under normal conditions. Overall, the project is successfully reduced manual effort, minimized congestion, and provided an efficient, low cost solution for smart parking management.

VII. CONCLUSION

The combination of AI based vehicle detection through the ESP32-Cam and slot level confirmation using IR sensors improves the accuracy and reliability of the system [4][6]. The Arduino uno acts as the central controller, processing sensor data and controlling the display and gate mechanism. The LCD provides clear information about available parking spaces, while the servo motor automates the entry and exit barrier, reducing manual effort. Overall, the system reduces traffic congestion, saves time, minimizes fuel consumption, and IOT connectivity for enhanced performance and remote acccess.

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