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Parking Management System Using IoT and Tesseract OCR (ANPR)

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Abstract: *Urban traffic congestion and inefficient parking space utilization have become pressing challenges in smart city development. This research presents a low-cost, scalable, and intelligent Parking Management System that integrates IoT-based real-time slot detection with Optical Character Recognition (OCR) for automated vehicle verification. The system utilizes an ESP32 microcontroller interfaced with IR sensors and a multiplexer to monitor up to four parking slots, updating their status on a web dashboard via Wi-Fi. For access control, a laptop-mounted camera captures vehicle number plates, processed locally using Tesseract OCR in Python. Verified plates are transmitted serially to the ESP32, which authenticates them against a predefined list and controls a servo motor-driven gate mechanism accordingly. The system also incorporates an ultrasonic sensor for entrance monitoring, eliminating false triggers. This hybrid approach ensures secure entry, real-time monitoring, and centralized control, offering a promising solution for smart campus, commercial, and residential parking infrastructure.*

Keywords: ANPR, License Plate-Triggered Automation, OCR, ESP32 Microcontroller

I. INTRODUCTION

The increasing number of vehicles in urban areas has intensified the demand for efficient and automated parking solutions. This research presents a smart Parking Management System that integrates the Internet of Things (IoT) with Optical Character Recognition (OCR) for Automatic Number Plate Recognition (ANPR). Using the ESP32 microcontroller, the system monitors parking slot occupancy through IR sensors via a multiplexer and displays real-time slot availability on a web-based dashboard hosted by the ESP32 itself. A laptop camera captures vehicle number plates, which are processed using Tesseract OCR, and the extracted text is matched with an authorized list. If a match is found, a servo motor–controlled barrier gate opens automatically to allow vehicle entry, offering secure and contactless access. This integrated solution combines embedded systems, IoT, and computer vision to enhance parking efficiency, reduce human error, and contribute to the development of smart city infrastructure.

II. LITERATURE SURVEY

Smart parking systems have been a significant research focus due to the increasing challenges of urban vehicle management and the demand for efficient space utilization. Early works, such as Osmani (2016) [1], highlighted the potential of smart city parking systems to enhance urban infrastructure by integrating sensor networks and real-time monitoring. Cynthia (2018) [2] and Jiang & Zeng (2018) [3] further developed IoT-based smart parking management frameworks, demonstrating the role of wireless sensor technologies and cloud connectivity in facilitating dynamic parking solutions.

Subsequent studies by Patel & Shah (2019) [4] and Khan & Ullah (2020) [5] emphasized the effectiveness of IoT for real-time parking slot detection, introducing microcontroller-based platforms to provide scalable and cost-efficient implementations. Kumar & Singh (2020) [6] reviewed various IoT-enabled parking systems, pointing out challenges such as system integration, data accuracy, and user interface responsiveness. The design and implementation of smart parking using IoT frameworks were further explored by Ikhateeb & Hossain (2021) [7], focusing on system reliability and sensor fusion techniques.

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Recent advances integrate machine learning to optimize parking management. Agarwal et al. (2021) [8] employed deep learning networks to predict parking slot availability, enhancing system intelligence and user experience. Abdulsaheb et al. (2023) [9] and Asianuba & Aliyu (2023) [10] proposed improved IoT-based parking systems incorporating advanced sensor arrays and adaptive algorithms to improve accuracy and efficiency.

A series of influential papers by Wang, Li, and Liu between 2016 and 2025 [11-16] systematically investigated real-time information delivery and dynamic pricing in IoT-based parking systems, demonstrating how data-driven approaches can optimize space allocation and pricing strategies. Their research emphasized scalable architectures combining IoT sensors with cloud analytics and mobile interfaces to address urban parking challenges.

Kimetal. (2024) [14] introduced deep learning techniques into smart parking, integrating image processing and sensor data for automated vehicle detection and identification, thereby enhancing access control and security.

Overall, these studies establish a solid foundation for smart parking technologies, yet many systems lack affordable and seamless integration of vehicle identification mechanisms like Automatic Number Plate Recognition (ANPR). Our project addresses this gap by combining ESP32-based IoT parking slot detection with laptop-based OCR for license plate recognition, providing a cost-effective and practical solution for smart parking management.

III. PROPOSED SYSTEM ARCHITECTURE DESIGN

The proposed smart parking system integrates IoT-based sensor networks with Automatic Number Plate Recognition (ANPR) technology to create an efficient and intelligent parking management solution. The architecture consists of three major components: Parking Slot Detection Module, ANPR and Gate Control Module, and Web-Based Monitoring Dashboard.

Parking Slot Detection Module

This module uses an ESP32 microcontroller interfaced with multiple IR sensors connected via a multiplexer to monitor the occupancy status of parking slots. Each IR sensor continuously detects the presence or absence of a vehicle by measuring reflected infrared signals. The ESP32 reads these signals and updates the status of each parking slot in real-time. Corresponding LEDs indicate slot availability locally.

ANPR and Gate Control Module

A laptop or PC equipped with a camera captures images of vehicles entering the parking area. Using Tesseract OCR, license plate numbers are extracted from the images. The recognized plate number is transmitted serially to the ESP32 for validation against a predefined whitelist of authorized vehicles. Upon a valid match, the ESP32 activates a servo motor controlling the parking gate, allowing authorized access. The gate remains open for a preset duration (e.g., 10 seconds) before closing automatically.

Web-Based Monitoring Dashboard

The ESP32 also runs an embedded HTTP server accessible via Wi-Fi. It hosts a simple web dashboard that displays real-time parking slot status (occupied or available) with visual indicators. This dashboard enables parking managers and users to monitor slot availability remotely and make informed decisions.

Data Flow:

IR sensors → ESP32 → Slot occupancy status update → LED indicators & Web Dashboard
Camera → Laptop (OCR) → Recognized plate number → ESP32 → Gate servo control & Access logging

System Features:

- Real-time monitoring of parking slot occupancy using low-cost IR sensors
- Automated vehicle identification through OCR-based ANPR system
- Secure access control via servo motor-operated gate

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- User-friendly web interface for parking status visualization

This integrated architecture ensures optimized parking space utilization, improved vehicle access management, and enhanced user convenience, forming a comprehensive smart parking solution suitable for small to medium-sized parking facilities.

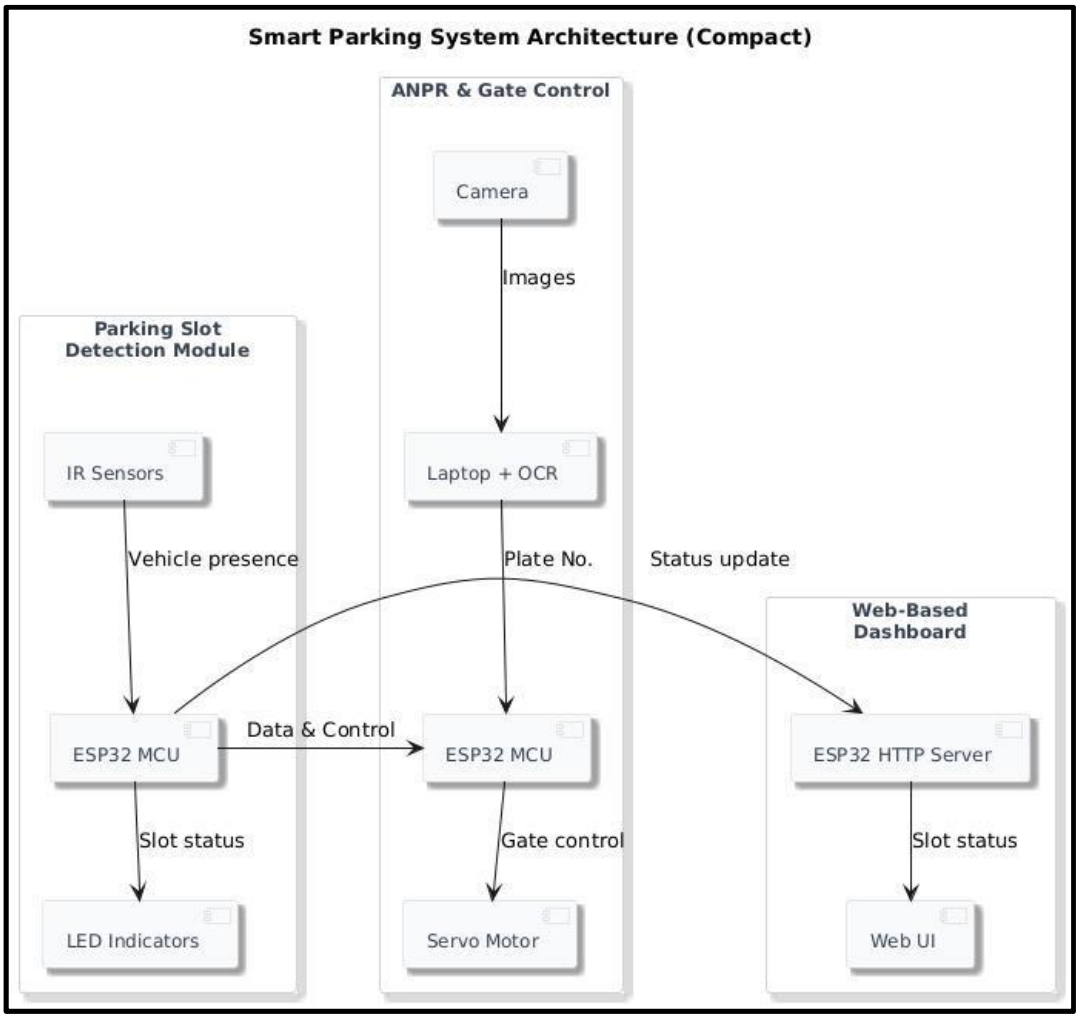

Fig No. 3.1 : System Architecture

IV. METHODOLOGY

The methodology adopted for this system is a hybrid approach combining Internet of Things (IoT) for real-time monitoring and Optical Character Recognition (OCR) for automated number plate recognition. The system architecture is divided into three key modules: **vehicle detection**, **plate verification**, and **gate access control**.

For vehicle detection, an array of four infrared (IR) sensors is connected to an ESP32 microcontroller via a multiplexer. The ESP32 sequentially reads each sensor through analog input and determines if a parking slot is occupied based on a predefined threshold. The status of each slot is visually indicated using corresponding LEDs and logged into a web-based dashboard hosted by the ESP32.

In parallel, an external laptop or PC equipped with a camera captures images of vehicle number plates as they approach the parking gate. These images are processed using OpenCV and Tesseract OCR to extract alphanumeric plate numbers. The extracted text is cleaned and filtered to isolate valid license plate formats.

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The final step involves secure communication between the OCR system and the ESP32 via Serial2. If the extracted plate number matches an entry in the ESP32's authorized plate list, the gate control module is triggered. This includes activating a servo motor to lift the barrier and grant access. If the plate is unauthorized or unreadable, access is denied, and the gate remains closed. The entire process is autonomous, eliminating the need for human intervention.

V. FLOWCHART

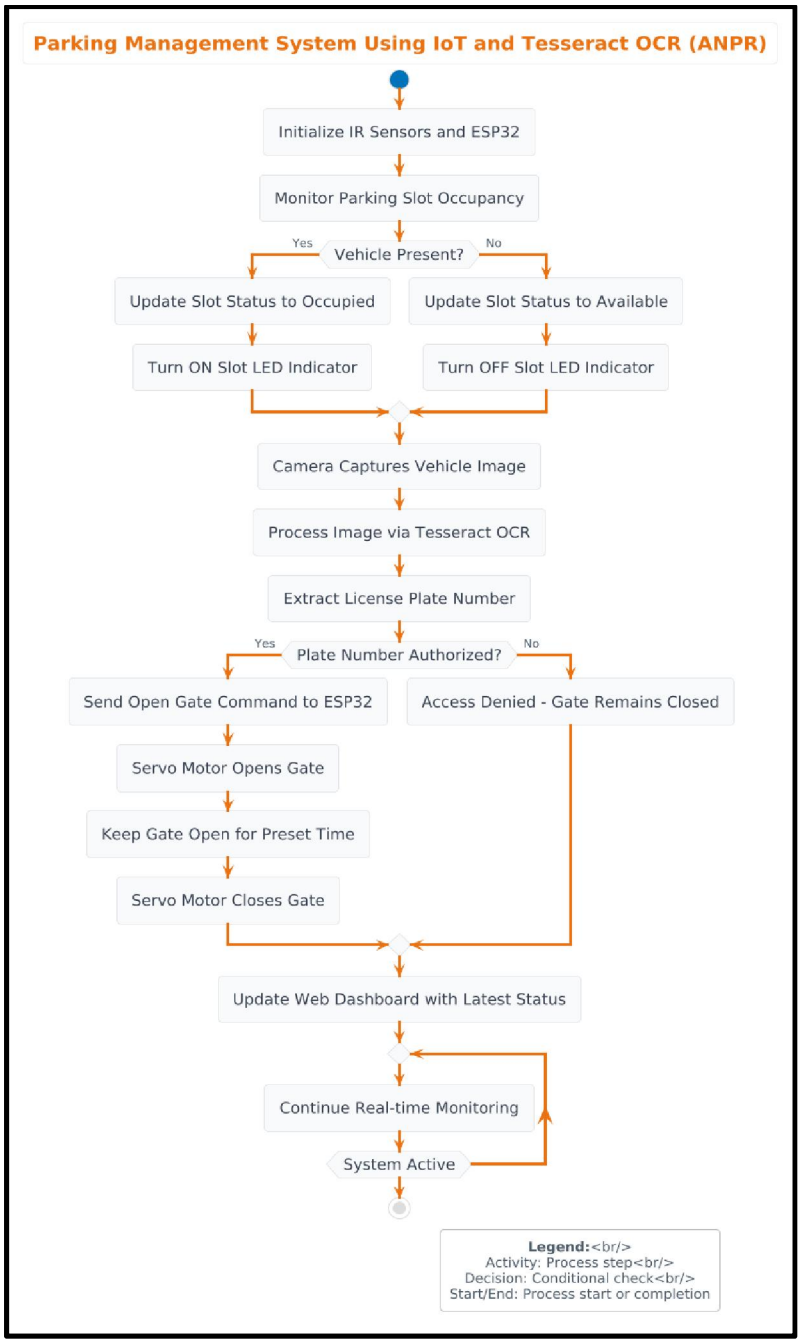

Fig No. 5.1: Flowchart

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VI. TECHNOLOGY STACK

The system integrates a combination of embedded hardware, software tools, and communication protocols to deliver a smart, real-time parking management and access control solution. Below is the breakdown of the technology stack used:

1. Hardware Components:

- ESP32 Dev Module – Central controller for IoT operations and web server.
- IR Proximity Sensors (x4) – Detects vehicle presence in parking slots.
- SG90 Servo Motor – Controls gate movement for entry/exit.
- PIR Motion Sensor – Triggers OCR processing upon detecting vehicle motion.
- 74HC4051 Multiplexer – Handles multiple IR sensor inputs via fewer ESP32 pins.
- LED Indicators – Represent status of parking slots (Occupied/Available).
- Laptop with Webcam – Captures real-time images for number plate recognition.

2. Software Tools:

- Arduino IDE – Used for writing and uploading firmware to the ESP32.
- Python 3.x – Primary language for OCR and serial communication.
- OpenCV – Handles image capture and preprocessing from the webcam.
- Tesseract OCR – Extracts alphanumeric text from captured number plate images.
- PySerial – Facilitates serial communication between Python and ESP32.
- ESP32Servo Library – Allows control of servo motors on ESP32.
- Blynk IoT Platform (optional) – Can be used for mobile-based slot monitoring (if extended).

3. Communication Protocols:

Serial Communication (USB/COM Port) – Transfers license plate data from Python to ESP32.
Wi-Fi (802.11 b/g/n) – Used by ESP32 to serve the parking status dashboard via local network.

4. Web Technologies:

HTML/CSS – Used by ESP32 to create a simple, auto-refreshing web interface showing parking slot availability.
HTTP Server (on ESP32) – Serves static content and handles client requests to display real-time data.

VII. ADVANTAGES

Automated Vehicle Entry: The system enables automatic recognition of authorized vehicle number plates using OCR, eliminating the need for manual gatekeeping and reducing human intervention.
Real-Time Slot Monitoring: With IR sensors and ESP32-based web hosting, users can view live availability of parking slots through a local Wi-Fi dashboard.
Efficient Space Utilization: Accurate detection of slot occupancy ensures optimal usage of parking space and prevents unauthorized or redundant parking.
Secure Access Control: Only vehicles with pre-approved number plates are granted entry, adding a layer of security and controlling access to private or reserved parking areas.
Low-Cost Implementation: The project uses affordable hardware components like ESP32, IR sensors, and a webcam, making it cost-effective and feasible for educational institutions, residential complexes, and small commercial areas.
Scalable and Modular Design: The system architecture allows easy scalability by adding more sensors or integrating cloud-based services for broader deployment.
User-Friendly Interface: The web dashboard is lightweight and easy to access through any browser-enabled device within the local network.

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Eco-Friendly and Paperless: No paper-based tickets or tokens are required, reducing environmental impact and simplifying operations.

VIII. LIMITATION

- Image Quality Dependent: OCR accuracy drops with poor lighting or unclear plates.
- Limited Plate Format: Only standard formats are reliably recognized.
- Fixed Camera Position: Plates must be directly in view; angled plates reduce accuracy.
- Wired Serial Communication: Limits flexibility and scalability.

IX. CONCLUSION

The proposed IoT and OCR-based Smart Parking Management System demonstrates a practical and intelligent approach to modern parking challenges. By integrating ESP32 microcontrollers, IR sensors, and a camera-based OCR module, the system effectively monitors parking slot availability and enables automatic gate control based on real-time vehicle number plate recognition. The use of serial communication between the laptop and ESP32 allows seamless data exchange, while the servo motor ensures efficient access control. The project enhances user convenience, reduces manual intervention, and showcases how embedded systems and computer vision can solve real-world problems. Though limitations exist in scalability and environmental dependencies, the system lays a strong foundation for future advancements in smart urban mobility solutions.

X. FUTURE SCOPE

- Integration of a mobile app for real-time parking slot booking
- Cloud-based data analytics for improved management and reporting
- Use of advanced AI and machine learning for higher accuracy in number plate recognition
- Support for multi-level and large-scale parking facilities

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