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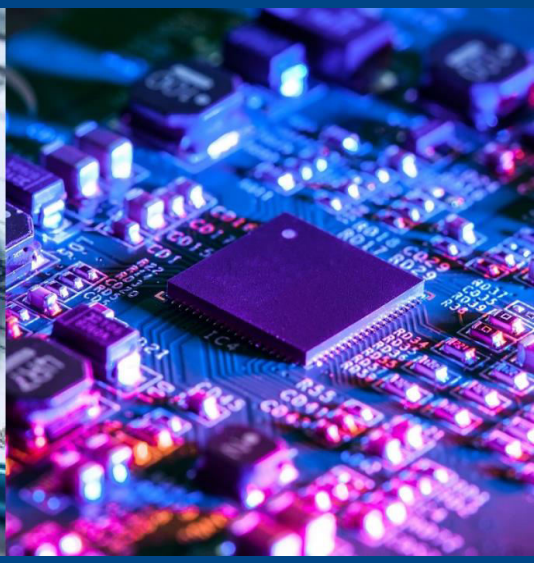

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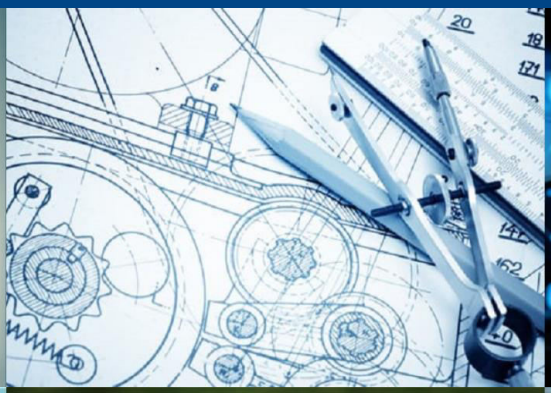

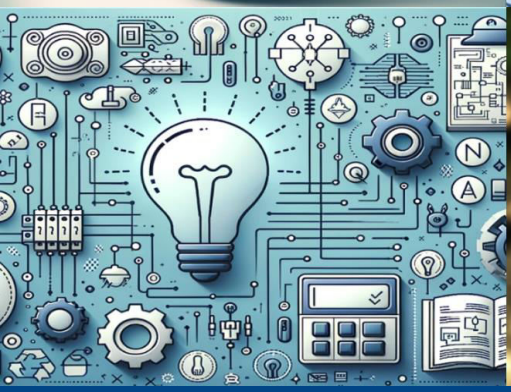

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Design and Implementation of an IoT-Based Smart Parking System – Swayam Park

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ABSTRACT: The rapid increase in vehicle population has intensified parking-related challenges in urban environments, leading to congestion, inefficient space utilization, and time loss. In order to address these issues, this paper presents an IoT-enabled intelligent parking system named as "Swayam Park" which is designed for real-time monitoring and automated parking management. The proposed system utilizes a Raspberry Pi 3+ as the central processing unit which is integrated with a 5MP camera module for reliable vehicle detection. Sensor data is first processed locally and transmitted to a Firebase Realtime Database that ensures continuous synchronization with a mobile application developed. The application provides users with live parking availability, slot reservation, and navigation support via Google Maps integration. In addition, an SG90 servo motor is employed to automate the entry gate mechanism based on slot availability that enables controlled access to the parking area. A hybrid detection approach combining camera-based vision and IR sensing improves system reliability under varying environmental conditions. Experimental evaluation on a prototype with 4–5 parking slots demonstrates efficient real-time performance with low latency and high detection consistency. The system helps to significantly reduce parking search time which enhances space utilization efficiency. Overall, Swayam Park is a scalable, cost-effective, and smart-city-ready solution for automated parking system management that make use of IoT, embedded systems, and cloud technologies.

I. INTRODUCTION

Due to the continuous increase in vehicle ownership has made efficient parking management a big challenge in modern cities. The situation has become critical in densely populated regions and during public events such as the Kumbh Mela in which vehicle inflow is highly dynamic and unpredictable. In scenarios like these, the absence of real-time parking might leads to congestion, increased fuel consumption, and considerable time loss for drivers who will be searching for available parking spaces. Traditional parking systems rely on manual supervision which are usually not capable of adapting to real-time changes in slot availability. These systems lack of automation, scalability, and efficient communication mechanisms which results in poor utilization of parking infrastructure leading to unsatisfactory user experience. To address these challenges, this paper presents Swayam Park, an Internet of Things (IoT)-based automated smart parking system designed to enable real-time monitoring and intelligent parking space management. The proposed system is built using a Raspberry Pi 3+ as the central processing unit, integrated with IR sensors and a camera module for vehicle detection. A hybrid detection approach is adopted, where sensor-based inputs are complemented by camera-assisted verification to improve reliability. The system then continuously monitors parking slot occupancy and keeps updating the status to a cloud-based backend with help of Firebase Realtime Database. This then enables seamless synchronization between the hardware setup and a mobile application which is developed using Android technologies. The application then provides users with real-time slot availability, booking functionality, and navigation support through integrated mapping services. In addition, the system also incorporates an automated entry mechanism using an SG90 servo motor, which regulates vehicle access based on parking availability and this reduces manual intervention which ensures controlled entry into the parking area.

The primary objective of this work is to develop a lightweight, cost-effective, and scalable smart parking solution that can operate efficiently on embedded hardware platforms. The system is particularly suitable for deployment in small to medium-scale parking environments and event-based scenarios. The key contributions of this work are summarized as follows:

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- Design and implementation of a real-time IoT-based smart parking prototype
- Integration of sensor fusion (IR and camera-assisted detection) for improved accuracy
- Development of an Android application for live monitoring, booking, and navigation
- Implementation of automated gate control using a servo motor
- Cloud synchronization in real-time using Firebase

The process in textual format looks like: Camera → YOLO → Slot Detection → Firebase → Mobile App → Gate Control

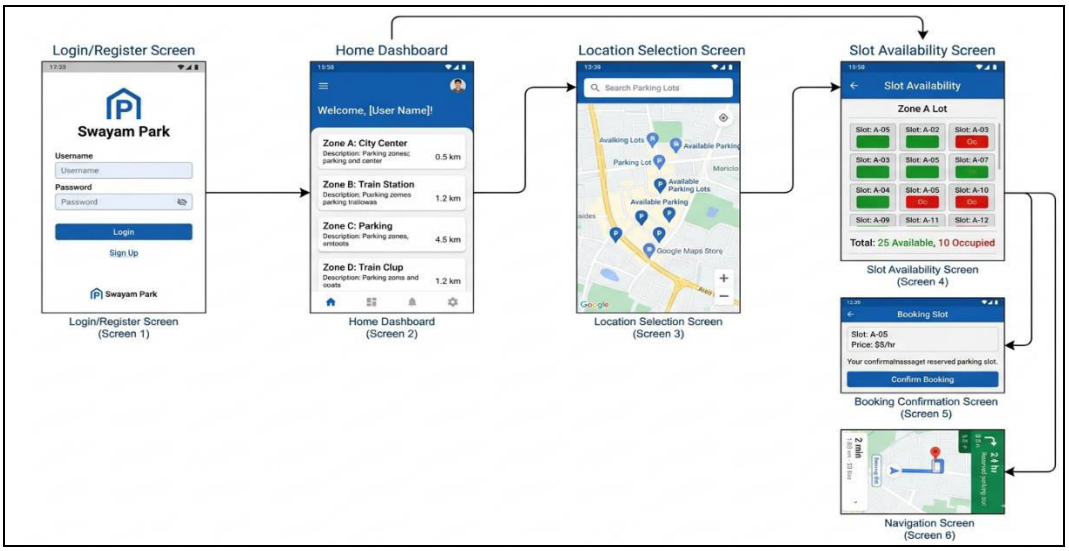

Fig1.Overall Flow of Project

In conclusion, the proposed system demonstrates a practical approach toward parking management by combining various technologies like IoT, embedded systems, and cloud technologies, and thereby contributing to improved efficient utilization of parking resources.

II. LITERATURE REVIEW

With the growth of urbanization and vehicle population, efficient parking management has currently become a big challenge in smart cities. The traditional parking systems were manual, time consuming, and also lacked real-time monitoring capabilities which led to congestion, fuel wastage, and user inconvenience. So in order to overcome the limitations, researchers did explore various technologies namely IoT, machine learning, computer vision, wireless sensor networks, and algorithms. Also, the recent advancements in Artificial Intelligence (AI) and Internet of Things (IoT) have transformed smart parking systems in significant ways. Techniques like object detection (YOLO), predictive machine learning models, and sensor-based networks are widely used to automate the parking detection which then improves efficiency. Each approach will offer a unique advantages in terms of accuracy, scalability, and cost, but also presents certain limitations such as computational complexity, infrastructure dependency, or scalability issues. This literature survey definitely reviews major existing approaches and highlights their key contributions, helping to identify research gaps and motivating the proposed system.

Bandla Siva Ranjani et al. [1]

Proposed a smart parking system using YOLO and Raspberry Pi for real-time vehicle detection. Parking slots are defined using ROI and classified as occupied or vacant, with data sent to the cloud via IoT protocols. The system improves efficiency but is sensitive to lighting conditions and hardware limitations.

Relevance to current Research

This paper forms the base of the proposed system using YOLO + IoT + Raspberry Pi for real-time monitoring.

Wang et al. [2]
Proposed a YOLO-based vehicle detection system for real-time parking applications. It offers high accuracy and faster detection compared to traditional methods but faces computational challenges on edge devices.

Relevance to current Research
This work is relevant as it supports the use of YOLO for real-time detection; motivates lightweight model optimization

Sharma et al. [3]
Presented an IoT-based parking system using Raspberry Pi and cloud integration for real-time monitoring. While user-friendly, it suffers from scalability and latency issues in large deployments.

Relevance to current Research
This study is relevant as it highlights importance of cloud integration, improved in proposed system using vision-based detection.

Li et al. [4]
Proposed an optimized YOLOv5 model for edge devices, reducing computational load while maintaining accuracy. Suitable for real-time embedded applications.

Relevance to current Research
This paper is directly relevant as it supports use of lightweight YOLO models for efficient Raspberry Pi deployment.

Kianpisheh et al. [5]
proposed a sensor-based parking system using ultrasonic sensors for slot detection. Provides accurate results but requires high installation and maintenance cost.

Relevance to current Research
This work is relevant as it justifies shift toward camera-based systems to reduce hardware dependency and improve scalability.

Sr. No.	Method / Algorithm	Key Idea	Advantages	Disadvantages	Author / Source
1.	YOLO + IoT + Raspberry Pi (Base Paper)	Uses YOLO for vehicle detection + Raspberry Pi for processing + IoT cloud integration	Real-time detection, low cost, scalable, no per-slot sensors	Performance depends on lighting and hardware limitations	Bandla Siva Ranjani et al. (2026)
2.	YOLO-based Smart Parking System	Real-time vehicle detection using YOLO deep learning model	High accuracy and fast detection	Computational load on edge devices	Wang et al. (2020)
3.	IoT Smart Parking using Raspberry Pi	Cloud-connected parking system using IoT and Raspberry Pi	Remote access, user-friendly	Scalability and latency issues	Sharma et al. [3]
4.	YOLOv5 Edge Optimization	Lightweight YOLO model for embedded systems	Faster inference, edge compatibility	Slight accuracy trade-off	Li et al. (2022)
5.	Sensor-based Parking System	Ultrasonic sensors detect parking occupancy	Accurate detection	High cost per slot	Kianpisheh et al. (2012)
6.	MILP for Dynamic Resource Allocation	Mathematical optimization for slot allocation	Optimal allocation, reduces congestion	Computationally expensive, requires infrastructure	Yanfeng Geng & Cassandras [6]

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7.	ACO + Decision Tree + GPS	Optimization using ACO and GPS navigation	No extra hardware, reduces congestion	Dependent on GPS and cloud reliability	Ankita Yadav, Mohammad Arif [7]
8.	Fuzzy Logic Prediction Model	Predicts parking availability using fuzzy inference	Handles uncertainty, useful for prediction	Depends on dataset quality	Fahim et al. [8]
9.	Predictive ML (LightGBM) + IoT Deployment	Time-series prediction using ML models	High accuracy, real-time prediction	Requires training data and maintenance	MDPI Sensors 2025 [9]
10.	FCFS Slot Allocation on Arduino	First-come-first-serve parking allocation	Very simple and fair arrival order	No optimization, inefficient in congestion	Arduino-based model [10]
11.	Arduino + Ultrasonic + LCD/Buzzer (Standalone)	Sensor-based standalone parking system	Low cost, easy implementation	Not scalable, no remote access	Soumyadep Mondal, (Apr 2025) [11]
12.	GSM/SMS-Based Secure Reservation	Parking reservation via SMS	Works without smartphone	Slow communication, limited features	Rahayu & Mustapa [12]
13.	AI-based LPR + Dynamic Allocation	License plate recognition with dynamic allocation	High security, real-time tracking	Expensive, complex implementation	Elfaki et al., 2023 [8]
14.	Multi-Agent System (MAS) with Negotiation	Agent-based parking negotiation and allocation	Flexible, adaptive allocation	Complex design, requires coordination	Cited in Fahim et al., 2021 [14]
15.	IoT-based Crowd Density Mapping	Tracks crowd density using IoT sensors	Useful for event management	High installation cost and Privacy Issues	Jalaja & Deeksha [15]
16.	AI Predictive Analytics	ML models predict congestion and demand	Improves planning, reduces congestion	Requires large datasets and Complex calibration	Jalaja & Deeksha [16]
17.	Wireless Sensor Network (WSN) + Shortest Path	Wireless sensors with navigation guidance	Reliable wireless data transmission and Guides users to the shortest path	Potential for wireless interference	Idris et al. [17]
18.	AI-powered Systems & Deep Reinforcement Learning (DRL)	Reinforcement learning for smart allocation	Adaptive, intelligent decision-making	Depends on the accuracy of AI models	Sarathambekai et al. [18]
19.	WSN-based Parking System	General wireless sensor network parking system	High reliability in data gathering and Reduces installation	Battery life of sensor nodes can be a limitation	Sai Sneha Channamallu et al. [19]

The literature survey shows the perfect evolution of smart parking systems from traditional approach which was sensor-based to modern AI and IoT-based solutions. The early systems focused on hardware-based detection, meanwhile recent approaches makes use of deep learning and edge computing for real-time performance. However, existing systems yet faces challenges such as scalability, computational cost, and environmental dependency. So, the proposed system solves these limitations by integrating YOLO-based real-time vehicle detection with Raspberry Pi and IoT cloud communication. This combination provides an efficient, low-cost, and scalable solution for smart parking systems which makes it suitable for deployment in smart cities, malls, airports, and commercial complexes.

III. METHODOLOGY OF PROPOSED SURVEY

The proposed smart parking system is designed as an intelligent, automated solution for real-time detection and monitoring of parking slots using a combination of computer vision, edge computing, and IoT-based communication.

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The system aims to eliminate manual parking supervision and provide accurate, real-time parking availability information to users.

The overall methodology is divided into multiple functional modules: data acquisition, vehicle detection, edge processing, slot classification, cloud communication, and user interface display.

System Architecture Overview:

The system architecture consists of four major layers:

- **Input Layer (Camera Module)**
- **Processing Layer (Raspberry Pi + YOLO Model)**
- **Decision Layer (Slot Classification Engine)**
- **Communication Layer (IoT Cloud Server + User Interface)**

The camera continuously captures live video of the parking area. These frames are processed by Raspberry Pi, where YOLO performs object detection. Detected vehicles are mapped to predefined parking slots (ROIs). The system then determines whether each slot is **Occupied or Vacant**. Finally, the processed data is transmitted to a cloud server, which updates a mobile/web dashboard in real time.

Data Flow Process :

The data flow in the system follows a sequential pipeline:

1. Camera captures real-time parking lot video.
2. Frames are extracted and sent to Raspberry Pi.
3. YOLO model processes frames for vehicle detection.
4. Bounding boxes are generated around detected vehicles.
5. ROI mapping assigns detection to specific parking slots.
6. Slot status is updated (Occupied / Empty).
7. Data is transmitted to cloud using IoT protocols (MQTT/HTTP).
8. User interface displays real-time availability.

This ensures **low latency processing and continuous monitoring**.

YOLO-Based Vehicle Detection:

The core of the system is the **YOLO (You Only Look Once)** object detection algorithm.

YOLO is a deep learning model that performs **real-time object detection in a single forward pass**, making it highly suitable for edge devices like Raspberry Pi.

Working Steps:

- Input image/frame is divided into grid cells
- Each grid predicts bounding boxes and confidence scores
- Vehicle classes (car, bike, truck) are detected
- Non-Max Suppression removes duplicate detections
- Final output provides accurate vehicle localization

The lightweight version (YOLOv5 nano / YOLOv8 nano) is used to optimize performance on Raspberry Pi.

Raspberry Pi Edge Processing Unit:

Raspberry Pi acts as the **edge computing device** responsible for:

- Capturing live video feed
- Running YOLO inference model
- Performing ROI-based slot mapping
- Reducing cloud dependency
- Ensuring real-time processing

Advantages of using Raspberry Pi:

- Low cost
- Portable deployment

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System Workflow:

The complete workflow of the system is summarized below:

1. Start system initialization
2. Capture live video stream
3. Apply YOLO detection on frames
4. Identify vehicles in parking area
5. Map detections to parking slots
6. Update slot status
7. Send data to cloud server
8. Display results on user interface
9. Repeat continuously in real time

IV. CONCLUSION AND FUTURE WORK

The proposed smart parking system presents a comprehensive and efficient solution for real-time parking slot detection and monitoring by integrating YOLO-based deep learning, Raspberry Pi edge computing, and IoT cloud communication. The system effectively eliminates the limitations of traditional manual and sensor-based parking methods by enabling automatic detection of vehicles and instant classification of parking slots as occupied or vacant. Through continuous video capture and real-time processing on edge devices, the system ensures low-latency performance while reducing dependency on high-end cloud computing resources. The use of lightweight YOLO models enhances detection speed without significantly compromising accuracy, making it suitable for embedded hardware implementation. Furthermore, IoT integration allows seamless transmission of parking status to a cloud server, enabling users to access real-time availability information through web or mobile applications, thereby improving user convenience and reducing unnecessary traffic congestion in parking areas. The proposed approach is cost-effective, scalable, and adaptable to various environments such as malls, airports, universities, and smart city infrastructures. Overall, the system demonstrates high potential for improving urban parking management by optimizing space utilization, reducing search time, and enhancing overall operational efficiency.

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