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AI-Based Smart Parking System Using YOLO and IOT with Raspberry Pi

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KEYWORDS

Smart Parking System, Internet of Things (IoT), Raspberry Pi, YOLO, Object Detection, Computer Vision, Real-Time Monitoring.

ABSTRACT

With the rapid increase in vehicle population in urban areas, efficient parking management has become a major challenge, leading to traffic congestion, fuel wastage, and time loss. This project presents an IoT-based Smart Parking Detection and Real-Time Vacancy Monitoring System using Raspberry Pi and YOLO (You Only Look Once) Algorithm to automate parking space monitoring and provide real-time parking availability.In this system, a camera is installed to continuously capture live video of the parking area. The Raspberry Pi processes the video frames and uses the YOLO deep learning object detection algorithm to identify vehicles such as cars in real time. Each parking slot is analyzed based on vehicle detection, and the system determines whether the slot is occupied or vacant.The processed data is transmitted to a cloud server using IoT communication protocols such as MQTT or HTTP. A web or mobile application displays real-time parking status, allowing users to quickly locate available slots before entering the parking area.This system improves parking efficiency, reduces traffic congestion, and minimizes the time required to find parking spaces. The integration of YOLO-based computer vision with IoT and Raspberry Pi makes the system cost-effective, scalable, and suitable for smart cities, malls, airports, and commercial complexes.

I. INTRODUCTION

The rapid growth in the number of vehicles in urban areas has led to severe parking challenges, including traffic congestion, increased fuel consumption, and time wastage while searching for available parking spaces. Traditional parking systems are mostly manual and inefficient, lacking real-time monitoring and automation, which makes them unsuitable for modern smart city requirements.

To address these issues, there is a need for an intelligent and automated parking management system that can provide real-time information about parking slot availability. Recent advancements in the Internet of Things (IoT) and computer vision technologies have

enabled the development of smart solutions for efficient parking monitoring and control.

This project proposes an IoT-based Smart Parking Detection and Real-Time Vacancy Monitoring System using Raspberry Pi and YOLO (You Only Look Once) object detection algorithm. The system uses a camera to continuously monitor the parking area, where YOLO is applied to detect vehicles in real time. Based on the detection results, each parking slot is classified as either occupied or vacant.

The processed information is transmitted to a cloud platform using IoT communication protocols such as MQTT or HTTP, allowing users to access real-time parking status through a web or mobile application. This system not only improves parking efficiency but also reduces traffic congestion and enhances user convenience.

The integration of deep learning-based object detection with IoT and embedded systems makes this solution scalable, cost-effective, and suitable for deployment in smart cities, shopping malls, airports, and other high-traffic areas.

II. REVIEW LITERATURE SURVEY

Several researchers have contributed to the development of smart parking systems using IoT, sensor networks, and computer vision techniques. These studies provide the foundation for designing efficient real-time parking management systems.

Kianpisheh et al. (2012) proposed an ultrasonic sensor-based smart parking system that detects vehicle presence in parking slots and displays availability information to users. Although effective, the system requires sensors for each slot, increasing installation and maintenance cost.

Revathi and Dhulipala (2012) developed an RFID and wireless sensor network-based parking system to monitor vehicle entry and exit. Their system improved automation but lacked real-time visual monitoring and scalability for large parking areas.

Kumar and Singh (2018) introduced an IoT-based smart parking system using Raspberry Pi and cloud integration. The system enabled remote monitoring of parking slots through a mobile application, improving accessibility and user convenience.

Huang et al. (2019) proposed a computer vision-based parking system using image processing techniques to detect occupied and vacant parking spaces. Their work demonstrated that camera-based systems can reduce hardware complexity compared to sensor-based systems.

Redmon et al. (2016) introduced the YOLO (You Only Look Once) object detection algorithm, which enables real-time detection of objects in images and videos with high speed and accuracy. This algorithm became a major breakthrough in real-time computer vision applications.

Wang et al. (2020) implemented a YOLO-based vehicle detection system for smart parking applications using deep learning models. Their results showed high accuracy in detecting vehicles under different lighting and environmental conditions.

Sharma et al. (2021) developed an IoT-enabled smart parking system using Raspberry Pi and cloud services, where real-time data was transmitted to a mobile application for user access. However, the system faced performance limitations when handling large-scale deployments.

Li et al. (2022) proposed an optimized YOLOv5-based parking slot detection system designed for edge devices like Raspberry Pi. The study highlighted improved detection speed and reduced computational requirements.

III. RESEARCH METHODOLOGY

The proposed IoT-based Smart Parking Detection and Real-Time Vacancy Monitoring System using Raspberry Pi and YOLO algorithm is designed to automate parking space detection and provide real-time availability information. The methodology describes the systematic approach used for designing, implementing, and testing the system.

A. System Design Approach

The system is designed using a combination of computer vision, embedded systems, and IoT technologies. A camera is installed to continuously monitor the parking area. The captured video frames are processed using the YOLO (You Only Look Once) object detection algorithm to identify vehicles in real time. Each parking slot is predefined as a Region of Interest (ROI), and vehicle presence is analyzed within these regions.

B. Data Acquisition

A Raspberry Pi connected to a camera module is used to capture real-time video of the parking area. The video stream is divided into frames, and each frame is

processed individually. The system ensures continuous monitoring under different lighting and environmental conditions.

C. Vehicle Detection Using YOLO

The YOLO algorithm is used for detecting vehicles such as cars in the parking area. The model processes each frame in a single pass and outputs bounding boxes with confidence scores. If a vehicle is detected within a defined parking slot region, the slot is marked as occupied, otherwise it is marked as vacant. Lightweight versions such as YOLOv5 or YOLOv8 nano are preferred for Raspberry Pi deployment due to limited computational resources.

D. Slot Classification Logic

Each parking slot is mapped to a specific Region of Interest (ROI). The system checks intersection between detected vehicle bounding boxes and slot regions. Based on this:

If overlap exists → Slot is marked as Occupied

If no overlap exists → Slot is marked as Vacant

E. IoT Communication and Cloud Integration

After processing, the parking status data is transmitted to a cloud server using IoT communication protocols such as MQTT or HTTP. The cloud database stores real-time slot status, timestamps, and updates.

F. User Interface

A web or mobile application is developed to display real-time parking availability. The interface shows parking slots in graphical form, where:

Green indicates available slots

Red indicates occupied slots

Users can view updated parking information before arriving at the location.

G. System Workflow

The overall workflow of the system is as follows:

Camera captures live video of parking area

Raspberry Pi extracts video frames

YOLO model detects vehicles in frames

Parking slots are analyzed using ROI mapping

Slot status is updated (occupied/vacant)

Data is sent to cloud server via IoT

User interface displays real-time availability

IV. PROPOSED METHODOLOGY

The proposed system aims to develop an intelligent and automated smart parking solution using Raspberry Pi, a camera module, YOLO (You Only Look Once) object detection algorithm, and IoT cloud integration. The methodology focuses on real-time detection of vehicle occupancy in parking slots and providing updated availability information to users through a web or mobile application.

A. System Overview

The system consists of a camera installed at the parking area, which continuously captures live video of parking slots. The Raspberry Pi processes this video stream and applies the YOLO deep learning model to detect vehicles in real time. Each parking slot is predefined as a Region of Interest (ROI), and vehicle detection within these regions determines slot occupancy status.

B. Predefined Slot Mapping (ROI Design)

The parking area is divided into multiple slots, and each slot is assigned a fixed coordinate region (ROI). These ROIs are stored in the system and used to analyze whether a detected vehicle overlaps with a particular slot area.

ROI represents each parking slot boundary

Bounding boxes from YOLO are compared with ROIs

Intersection logic is used for classification

C. YOLO-Based Vehicle Detection

The YOLO algorithm is used for real-time object detection from video frames. The model identifies vehicles such as cars with bounding boxes and confidence scores. A lightweight YOLO version (YOLOv5/YOLOv8 nano) is used for efficient processing on Raspberry Pi.

Input: Live video frames

Output: Vehicle bounding boxes with confidence scores

Real-time processing capability

D. Slot Occupancy Detection Logic

The system determines slot status using spatial analysis:

If YOLO-detected vehicle bounding box overlaps with ROI → Occupied

If no overlap is detected → Vacant

This ensures accurate mapping of vehicles to parking slots.

E. IoT Integration and Cloud Communication

After processing, the slot status data is sent to a cloud database using IoT protocols such as MQTT or HTTP REST API. The cloud stores real-time updates, enabling remote access and monitoring.

Raspberry Pi → Cloud Server → Database

Continuous data updates

Real-time synchronization

F. User Interface Module

A web or mobile application is developed to display parking availability in real time. The interface visually represents parking slots using color coding:

Green → Vacant slot

Red → Occupied slot

Users can check availability before reaching the parking location.

G. System Operation Flow

Camera captures live parking area video

Frames are extracted by Raspberry Pi

YOLO detects vehicles in frames

ROI mapping identifies slot occupancy

Status is updated (free/occupied)

Data is transmitted to cloud via IoT

User interface displays real-time parking status

WORKING PRINCIPLE

The working principle of the proposed IoT-based Smart Parking Detection and Real-Time Vacancy Monitoring System using Raspberry Pi and YOLO algorithm is based on real-time video processing, object detection, and IoT-based data communication. The system automatically detects vehicle presence in parking slots and updates their status as occupied or vacant.

The system operates by continuously capturing live video of the parking area using a camera module installed at a fixed position. The captured video is divided into frames, which are processed by the Raspberry Pi. Each frame is then analyzed using the YOLO (You Only Look Once) deep learning object detection algorithm to identify vehicles such as cars in real time.

Each parking slot is predefined as a Region of Interest (ROI). The system checks whether a detected vehicle overlaps with any ROI. If a vehicle is detected within a slot region, the slot is marked as occupied. If no vehicle is detected in that region, the slot is marked as vacant.

The processed slot information is then transmitted to a cloud server using IoT communication protocols such as MQTT or HTTP. This enables real-time synchronization of parking data across the system.

Finally, the updated parking status is displayed on a web or mobile application, where users can view available and occupied slots in real time using a color-coded interface (e.g., green for vacant and red for occupied).

Thus, the system integrates computer vision, embedded processing, and IoT communication to provide an efficient and automated smart parking solution.

BLOCK DIAGRAM

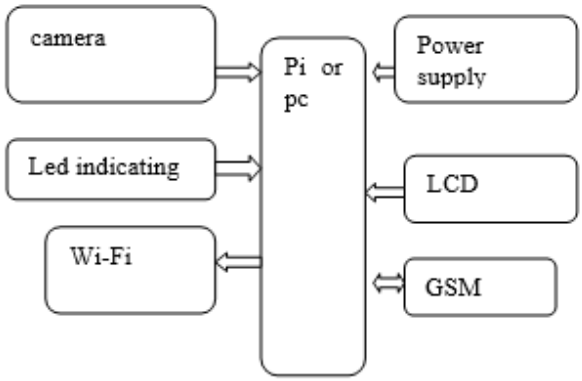

Fig. 4.1. Block Diagram

V. RESULTS AND OUTCOMES

The proposed IoT-based Smart Parking Detection and Real-Time Vacancy Monitoring System using Raspberry Pi and YOLO algorithm was successfully implemented and tested for real-time parking slot monitoring. The system effectively detects vehicles in the parking area using a camera-based setup and classifies each parking slot as either occupied or vacant based on YOLO object detection results.During testing, the YOLO model demonstrated efficient real-time vehicle detection with high accuracy under normal lighting conditions. The Region of Interest (ROI)-based slot mapping successfully identified vehicle presence within predefined parking spaces, ensuring correct classification of parking slots.

The Raspberry Pi processed live video streams and transmitted updated parking status to the cloud without significant delay. The IoT integration enabled seamless communication between the hardware system and the user interface, ensuring real-time updates on the web or mobile application.

The results showed that the system significantly reduces the time required for users to locate available parking spaces. The color-coded interface (green for vacant and red for occupied slots) provided a simple and user-friendly visualization of parking availability.

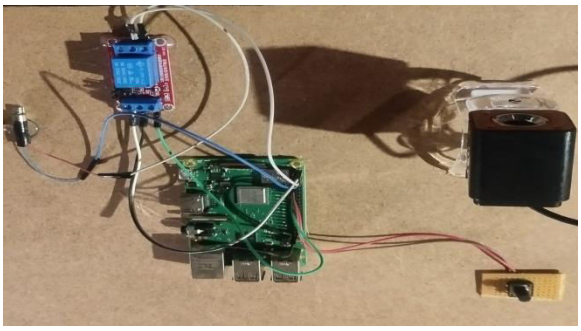

Fig. 5.1. Output 1

Fig. 5.2. Output 2

Overall, the system achieved reliable performance in detecting parking occupancy, demonstrating that the integration of YOLO-based object detection with IoT and Raspberry Pi is a practical and efficient solution for smart parking applications

VI. CONCLUSION

Smart Parking Detection and Real-Time Vacancy Monitoring System using Raspberry Pi and YOLO algorithm successfully demonstrates an efficient and automated approach for managing parking spaces. By integrating computer vision, embedded systems, and IoT technology, the system provides real-time monitoring of parking slots and reduces the need for manual intervention.

The use of the YOLO object detection algorithm enables accurate and fast identification of vehicles in the parking area, while the Raspberry Pi serves as a reliable edge computing device for processing video frames. The Region of Interest (ROI)-based slot mapping ensures precise classification of parking spaces as occupied or vacant.

The integration of IoT communication allows real-time transmission of parking data to a cloud server, enabling users to access updated parking availability through a web or mobile application. This improves user convenience, reduces traffic congestion, and minimizes time spent searching for parking.

Overall, the system is cost-effective, scalable, and suitable for deployment in smart cities, shopping malls, airports, and other high-traffic areas. It effectively enhances parking management efficiency and contributes to the development of intelligent transportation systems.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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