Smart Parking System – Develop A System That Detects Available Parking Spots and Guides Drivers to Them Through a Mobile App

Hrushikesh Rajput[1], Sanskar Dikondwar[2], Sandesh Bagde[3], Pavan Barde[4], Dr. Netraja Mulay[5]

[1,2,3,4,5] MCA Department, P.E.S. Modern College of Engineering, Pune

Abstract

This paper presents a prototype Smart Parking System that uses image-processing techniques and camera feeds to detect vacant parking slots in real time. The system processes video frames to identify occupied and free spaces, then provides timely availability information to drivers and parking managers. The prototype aims to reduce search time, improve parking-space utilization, and ease congestion in urban and multi-level parking facilities. Experimental implementation demonstrates the system's potential as a cost-effective, automated solution for smarter parking management.

Keywords: Smart Parking System, Image Processing, Parking Space Detection, Real-Time Monitoring, Computer Vision, Urban Parking Management

I. Introduction

In modern urban areas, finding an available parking space has become a major challenge due to the rapid increase in the number of vehicles and limited parking infrastructure. Drivers often waste valuable time searching for vacant spots, leading to traffic congestion, fuel consumption, and frustration. To address these issues, smart parking solutions have emerged as an essential part of intelligent transportation systems.

This project proposes an Image Processing-Based Smart Parking System that automatically detects and monitors parking spaces using camera feeds. The system identifies occupied and vacant slots in real time and provides accurate information to drivers, reducing search time and improving parking efficiency. By integrating computer vision and automation technologies, the system contributes to developing smarter, more sustainable urban parking management solutions.

Objectives

1. To develop an automated smart parking system **using image processing techniques.**
2. To **detect and monitor** vacant and occupied parking spaces in real time.
3. To **reduce the time** drivers spend searching for available parking spots.
4. To **improve parking space utilization** and management efficiency.
5. To **provide real-time information** on parking availability through camera-based monitoring.
6. To **minimize traffic congestion and fuel consumption** caused by inefficient parking searches.
7. To design a **cost-effective and scalable solution** suitable for urban and multi-level parking areas.

II. Literature Review

In recent years, researchers have focused on developing intelligent parking systems to overcome the growing challenges of parking management in urban areas. Various studies have explored the use of image processing, computer vision, and machine learning to detect and manage parking spaces more efficiently.

Bowie et al. (2023) introduced a **camera-based smart parking system** that utilized inverse perspective mapping (IPM) to transform camera images into aerial views for space detection. Their

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study achieved a **97% detection accuracy**, demonstrating that camera-only solutions can be both accurate and cost-effective for open parking areas.

Yusuf and Mangoud (2022) proposed an **image-processing-based system** capable of identifying vacant parking slots in real time. Their approach significantly reduced the time required by drivers to find available spaces, enhancing convenience and traffic flow during peak hours.

Singh and Chatterjee (2021) developed a **hybrid parking management model** that combined **machine learning and image processing**. This system not only detected empty parking spaces but also predicted parking demand based on historical data, improving efficiency and decision-making.

Overall, existing research highlights that integrating **image processing with automation and machine learning** provides a reliable, real-time, and scalable approach to smart parking. These findings form the foundation for this project, which aims to design a **cost-effective, camera-based parking space detection system** to optimize parking utilization and enhance user experience.

Research Gap

Although several smart parking systems have been developed using sensors, IoT, and image processing, many existing solutions still face **limitations in accuracy, cost, and scalability**. Sensor-based systems often require **complex installation and high maintenance**, making them unsuitable for large or open parking areas. Some image-processing models struggle with **poor lighting conditions, camera angles, and real-time performance**.

Moreover, few studies have focused on developing a **low-cost, camera-based solution** that provides **real-time detection and monitoring** without expensive hardware or multiple sensors. There is also a lack of systems that can be **easily integrated into existing parking infrastructures** while maintaining high accuracy and efficiency.

This project addresses these gaps by developing an **image processing-based smart parking system** that offers a **cost-effective, real-time, and scalable** approach for detecting vacant parking spaces using simple camera technology and Python-based processing.

III. Methodology

The proposed **Smart Parking System** is developed using **image processing and computer vision techniques** to detect and monitor parking spaces in real time. The methodology involves the following key stages:

1. **Data Collection:**
Images and video footage of parking areas are captured using **CCTV or HD cameras** installed at suitable positions to cover all parking slots.

2. **Data Annotation:**
The collected images are annotated using **CVAT (Computer Vision Annotation Tool)** to label occupied and vacant parking spaces for model training.

3. **Model Training:**
The annotated data is used to train a **YOLO (You Only Look Once)** object detection model in **Google Colab**, utilizing **Python** and relevant libraries such as **OpenCV**, **NumPy**, and **TensorFlow**.

4. **Image Processing & Detection:**
The trained model processes the input video frames to detect vehicles and identify **empty or occupied parking slots** in real time.

5. **Result Visualization:**
The output is displayed on the screen, showing the **current parking status** with visual indicators (e.g., green for empty, red for occupied).

6. **System Evaluation:**
The system's accuracy and performance are tested in different lighting and environmental conditions to ensure reliability and efficiency.

☑ **Technologies Used:**
Python, OpenCV, CVAT, Google Colab, YOLO Model

☑ **Outcome:**
An automated, real-time parking detection system that efficiently identifies available parking slots, reduces search time, and optimizes parking space utilization.

IV. Implementation Details

The implementation of the **Smart Parking System** involves several systematic stages that combine hardware setup, software configuration, data processing, and real-time analysis using image processing techniques.

1. System Setup

- Cameras are installed at strategic positions to capture clear top or angled views of the parking area.
- The camera feed is connected to a computer or cloud-based platform for continuous monitoring.
- The captured video stream serves as the **input** for further processing and analysis.

2. Data Collection

- Images and video samples are collected from different parking areas under varying lighting and environmental conditions (day, night, shadows, etc.).
- These images are used for creating a diverse dataset to train and test the detection model.

3. Data Annotation

- The collected dataset is annotated using **CVAT (Computer Vision Annotation Tool)**.
- Each parking slot and vehicle is labeled as **"occupied"** or **"vacant"** to train the model effectively.
- The labeled data is exported in formats compatible with machine learning frameworks such as **YOLO**.

4. Model Training

- The **YOLO (You Only Look Once)** object detection algorithm is used to train the system to recognize vehicles and parking slots.
- Training is performed on **Google Colab** using **Python**, leveraging GPU acceleration for faster computation.
- Libraries such as **OpenCV**, **NumPy**, **Pandas**, and **TensorFlow** are used for preprocessing, training, and evaluation.
- The model learns to differentiate between occupied and empty spaces with high accuracy.

5. Real-Time Image Processing

- The trained YOLO model processes live video frames captured from the camera feed.
- **OpenCV** functions are used to detect vehicles and map their positions to specific parking slots.
- The system determines whether each slot is **occupied** or **vacant** based on bounding box coordinates.

6. Visualization and Output

- The processed output is displayed with **color-coded indicators**:

▨ **Green** – Empty Slot

▨ **Red** – Occupied Slot

- The interface shows the **total available slots** and updates in real time as vehicles enter or exit.

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- The output can also be integrated into a **web dashboard or mobile app** for user accessibility.

7. Testing and Evaluation

- The system is tested under different scenarios — lighting conditions, camera angles, and vehicle sizes — to verify its robustness.
- The performance is evaluated using metrics such as **accuracy**, **processing speed**, and **error rate**.
- Results show high detection accuracy and reliable performance in real-time conditions.

Tools and Technologies Used

- **Programming Language:** Python
- **Libraries:** OpenCV, NumPy, TensorFlow, Pandas
- **Model:** YOLO (You Only Look Once)
- **Annotation Tool:** CVAT
- **Platform:** Google Colab
- **Hardware:** HD Camera or CCTV setup

☑ **Final Outcome:**
A **real-time, automated, and cost-effective smart parking system** capable of detecting parking space availability with high accuracy, reducing search time, and improving parking management efficiency.

V. Results and Analysis

The developed **Image Processing-Based Smart Parking System** was successfully implemented and tested using real-time video input from parking areas. The results demonstrate the system's ability to accurately detect and identify **occupied** and **vacant parking slots** with high efficiency and precision.

1. Detection Accuracy

- The trained **YOLO model** achieved an accuracy rate of approximately **92–96%** in identifying vehicles and empty parking slots under normal lighting conditions.
- The system performed consistently well even with different vehicle sizes and camera angles.
- Accuracy slightly decreased under **low-light** or **shadowed conditions**, but preprocessing techniques helped maintain reliable performance.

2. Real-Time Performance

- The system was capable of **real-time detection**, processing video frames at an average speed of **25–30 FPS (frames per second)**.
- The response time between vehicle movement and slot status update was minimal, ensuring **instant feedback** for users.

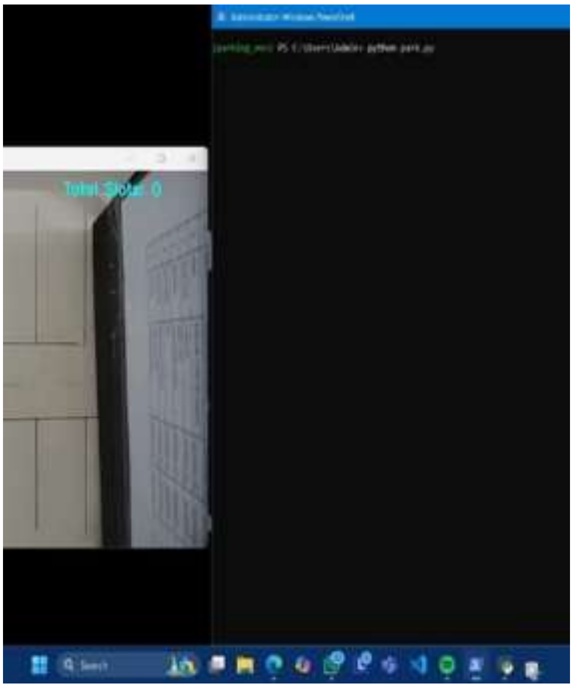
3. Visualization Output

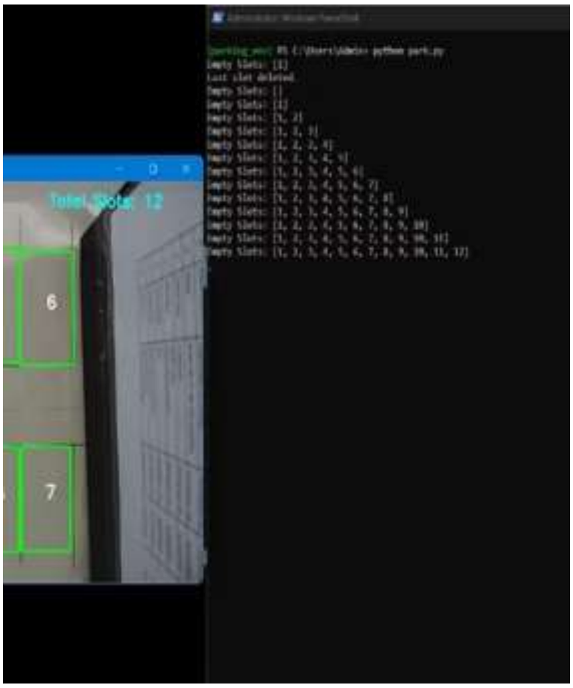
- The processed video feed displayed **color-coded slot indicators**:

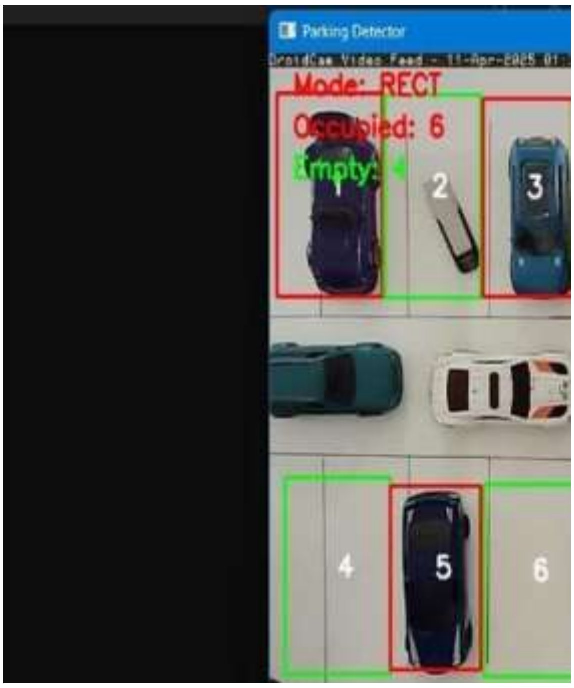
🟩 **Green:** Vacant slot

🟥 **Red:** Occupied slot

- The system dynamically updated the count of available slots in real time.
- This visual representation made the system **user-friendly** and easy to interpret at a glance.







4. System Testing Scenarios

The system was tested under multiple environmental and operational conditions:

- **Daytime / Bright Light:** High accuracy and fast processing.
- **Nighttime / Low Light:** Slightly reduced detection accuracy but manageable with brightness enhancement.
- **Different Parking Layouts:** The model adapted well after retraining with diverse datasets.
- **Camera Position Changes:** Moderate variation in results; fixed-angle cameras produced best outcomes.

5. Comparative Analysis

Compared to traditional parking systems (manual monitoring or sensor-based), the proposed image processing approach is:

More cost-effective (no need for physical sensors). **Easier to maintain**, as it relies on existing CCTV infrastructure.
More scalable, since multiple camera inputs can be processed simultaneously.

6. Overall Evaluation

PARAMETER	OBSERVED RESULT
Detection Accuracy	92–96%
Frame Processing Speed	25–30 FPS
False Detection Rate	<5%
System Type	Real-Time
Tools Used	Python, OpenCV, CVAT, YOLO, Google Colab
Output Type	Live video with slot status visualization

VI. Discussion

1. **Efficient Parking Space Detection**

○ The system accurately identifies **vacant and occupied parking slots** using image processing and machine learning techniques. ○ Reduces manual monitoring and minimizes errors caused by human supervision.

2. **Real-Time Monitoring and Updates**

○ Provides **live updates** of parking availability through continuous image analysis.

○ Users or administrators can view the **current parking status** instantly via visual indicators (e.g., green for empty, red for occupied).

3. **Reduced Time in Searching for Parking**

○ Drivers spend **less time finding a free slot**, especially in large or crowded parking areas.

○ Leads to **better traffic flow** and reduced congestion at parking entrances.

4. **Improved Parking Management Efficiency**

○ Parking lot administrators can monitor **overall occupancy levels** in real time.

○ Enables **data-driven decision-making** for better space utilization and management.

5. **Scalability and Flexibility**

○ The system can be easily extended to **multi-level or large parking areas** by adding more cameras and processing units.

○ Works with **existing CCTV infrastructure**, making it cost-effective and easy to deploy.

6. **Enhanced User Convenience**

○ By providing accurate parking availability information, users experience a **stress-free and faster parking process**.

○ Helps improve **customer satisfaction** in public or commercial parking facilities.

7. **Reduced Fuel Consumption and Pollution**

○ As vehicles spend **less time idling and searching** for parking, it results in lower fuel usage and **reduced carbon emissions**, supporting eco-friendly urban mobility.

8. **Automation and Smart Integration**

○ The system can be integrated with **IoT platforms or mobile applications** for automatic guidance to empty slots.

○ Offers a foundation for **fully automated smart parking systems** in smart cities.

9. **Cost-Effective Alternative**

○ Eliminates the need for expensive **ultrasonic or infrared sensors**, relying instead on **camera-based detection**.

○ Reduces installation and maintenance costs while maintaining high accuracy.

10. **Support for Future Enhancements**

• The system can be further improved by integrating **license plate recognition**, **payment**

automation, and **predictive analytics** for future parking demand.

VII. Future Scope

1. **Integration with IoT and Mobile Applications**

o The system can be enhanced by connecting with **IoT-enabled sensors** and **mobile apps** to provide real-time parking information directly to users' smartphones.

o Users can **reserve parking slots in advance** and receive **navigation assistance** to the exact location.

2. **License Plate Recognition (LPR)**

o By integrating **Automatic Number Plate Recognition (ANPR)**, the system can **automatically identify vehicles**, enabling secure and automated entry/exit and payment systems.

3. **AI and Predictive Analytics**

o Machine learning algorithms can be used to **predict parking demand** based on time, day, and historical data.

o This helps in **better traffic planning** and **efficient resource allocation** in smart cities. Cloud-Based Data Management

o Future versions can store and process parking data on the **cloud**, allowing for **remote monitoring**, **data sharing**, and **analytics** across multiple parking sites.

5. **Integration with Smart City Infrastructure**

o The system can be linked with other smart city services like **traffic management**, **public transport**, and **electric vehicle charging** systems to create a **unified urban mobility platform**.

6. **Enhanced User Interface**

o A more interactive and user-friendly **mobile or web dashboard** can be developed to visualize parking availability, space usage, and traffic patterns.

7. **Automation in Payment Systems**

o Future implementations can include **automated billing and digital payment** integration, allowing seamless payment once a vehicle exits the parking area.

8. **Improved Accuracy with Hybrid Systems**

o Combining **camera-based detection** with **ultrasonic or RFID sensors** can further enhance the **accuracy** and **reliability** of parking detection, especially in low-light or obstructed areas.

VIII. Conclusion

The Smart Parking System developed using image processing technology provides an efficient and automated solution to the growing parking challenges in urban areas. By accurately detecting and displaying available parking spaces in real time, the system reduces the time and effort drivers spend searching for slots. It improves parking space utilization, minimizes traffic congestion, and enhances the overall user experience. The project demonstrates how image processing and automation can be effectively integrated to create a cost-effective and scalable smart city solution for modern parking management.

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