Parking Lot Management using YOLOv8 & Mask R-CNN

Abstract

In modern urban environments, the rapid increase in vehicle numbers has led to serious parking space management challenges. This project aims to develop an intelligent parking lot monitoring system using computer vision that detects and visualizes available parking slots in real-time. Utilizing static CCTV footage and a combination of object detection and segmentation algorithms, our system identifies empty and occupied slots based on predefined parking layouts. A user-friendly graphical interface displays the real-time status of parking spaces, enhancing both user convenience and parking space utilization. The system is initially developed using pre-recorded video streams but is designed for real-time deployment on live CCTV feeds.

---

1. Introduction

Efficient parking management is a critical component of smart city infrastructure. Traditional parking systems often lack automation, resulting in wasted time, congestion, and frustration. With the rise of computer vision and edge computing, it is now feasible to automate parking lot surveillance using cameras and AI. This project proposes a vision-based solution that monitors parking lots, detects empty slots, and presents the availability in a visual GUI. Unlike sensor-based systems that require physical installation, our approach is cost-effective, scalable, and adaptable to various lot configurations.

---

2. Objectives

- To develop a computer vision system that identifies and counts empty parking slots.
- To display real-time slot occupancy on a GUI using bounding boxes or overlays.
- To use pre-recorded video for development and test on live CCTV feeds.
- To ensure compatibility with fixed-slot layouts and static camera angles.
- To lay the foundation for future enhancements like license plate recognition and smart notifications.

---

3. Methodology

3.1 System Architecture

- **Input**: Pre-recorded or live CCTV footage of the parking lot.
- **Processing Pipeline**:
    - Frame extraction at regular intervals.
    - Preprocessing (resizing, contrast adjustment).
    - Object detection using YOLOv8 or Faster R-CNN to detect vehicles.
    - Slot-wise masking using segmentation models (e.g., Mask R-CNN).
    - Occupancy checking by mapping vehicle masks to predefined slots.
- **Output**: Visual indication of empty and occupied slots via GUI.

3.2 Tools & Technologies

- **Programming Language**: Python
- **Frameworks**: OpenCV, PyTorch, TensorFlow, Tkinter/PyQt for GUI
- **Models**:
    - YOLOv8 for fast vehicle detection
    - Mask R-CNN for pixel-level vehicle segmentation
- **Slot Management**:
    - Manually annotated parking slots stored as coordinates
    - Intersection-over-area calculations to determine occupancy

3.3 GUI Design

The GUI will feature:

- Live video panel with overlay rectangles for each parking slot.
- Colour codes: Green for empty, Red for occupied.
- Count of empty/occupied slots displayed on-screen.
- Option to reload/refresh feed or toggle views.

---

4. Expected Outcomes

- A working prototype capable of identifying and displaying empty parking slots on video.
- Modular code structure allowing easy deployment on different camera feeds.
- Smooth GUI that updates slot status in near real-time.

---

5. Future Work

- **License Plate Recognition (LPR)**: To associate vehicles with users and track durations.
- **Smart Notifications**: Alert users when slots become free or are about to be full.
- **Edge Deployment**: Porting to Raspberry Pi or NVIDIA Jetson for on-site low-latency processing.
- **Dynamic Slot Detection**: Automatically detect new slot layouts using clustering and unsupervised learning.
- **Night-time and Weather Robustness**: Use of infrared and thermal data to improve detection under adverse conditions.

---

6. Conclusion

This project presents an AI-based solution to the common problem of urban parking management using existing CCTV infrastructure. By leveraging object detection and segmentation, we can provide a scalable and efficient parking monitoring system without any physical sensors. The system's modular design allows for enhancements such as LPR and real-time notifications, making it a valuable component in the development of smart city ecosystems.

---

7. References

1. Scientific, Little Lion. "A HYBRID FRAMEWORK FOR OBJECT DETECTION AND SEGMENTATION IN AUTONOMOUS VEHICLES USING YOLO NAS AND MASK R-CNN." Journal of Theoretical and Applied Information Technology 103, no. 6 (2025).
2. Chughtai, B. Riaz, Haifa F. Alhasson, Md. Alnusayri, Mohammed Alatiyyah, Hanan Aljuaid, Ahmad Jalal, and Jeongmin Park. "R-CNN based Vehicle Object Detection via Segmentation capabilities in Road Scenes." IEEE Access (2024).
