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Smart Parking Management System: Real-Time Space Count and Availability Detection through Video Monitoring

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ABSTRACT: The rapid increase in vehicle population has led to severe parking space shortages, particularly in urban areas. Traditional parking management systems, including manual monitoring and sensor-based solutions, are inefficient, costly, and lack real-time accuracy. This paper presents an automated smart parking system utilizing computer vision and real-time video analysis to detect available parking spaces dynamically.

The proposed system leverages Python, OpenCV, and Tkinter to process surveillance footage, detect parked vehicles, and highlight vacant spaces in real time. The system applies background subtraction, edge detection, and object recognition to improve accuracy. Experimental results demonstrate a high detection accuracy of up to 96% in well-lit environments, with significant reductions in parking search time and traffic congestion. The research contributes to smart city initiatives by offering a scalable, cost-effective, and real-time parking solution.

KEYWORDS: Smart Parking, Computer Vision, OpenCV, Image Processing, Real-Time Parking Detection, Urban Mobility

I. INTRODUCTION

With the rapid growth of urban populations and the increasing number of vehicles, finding parking has become a significant challenge. Traditional parking management systems rely on sensors or manual supervision, which can be inefficient and costly. Video-based parking space detection offers a scalable and cost-effective alternative by analyzing real-time camera feeds using artificial intelligence (AI).

Parking shortages contribute to traffic congestion, increased fuel consumption, and environmental pollution. According to urban studies, nearly **30% of urban traffic** is caused by drivers searching for parking spots. This inefficiency not only wastes time but also increases vehicle emissions, contributing to climate change. Automated parking space detection systems can significantly mitigate these issues by providing real-time vacancy updates, optimizing parking lot usage, and reducing unnecessary vehicle movement.

This paper explores the application of deep learning models for detecting available parking spaces from video footage. By utilizing object detection and image classification techniques, the system identifies vacant spots with high precision. The study also highlights challenges such as varying lighting conditions, occlusions, and camera angle distortions.

1.1 Background and Motivation

Conventional parking management approaches—whether based on manual oversight or sensor-driven systems—are often both expensive and inefficient. Manual monitoring is susceptible to human error and demands considerable labor, while sensor-based technologies, despite their technical sophistication, entail high initial investments and recurring maintenance expenses. These factors hinder their scalability, particularly in addressing the dynamic needs of large urban centers.

In contrast, recent advancements in computer vision, artificial intelligence, and real-time video analytics present a compelling alternative. By capitalizing on existing surveillance infrastructure, these technologies enable precise and

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cost-effective monitoring of parking spaces. Integrating these innovations into a unified system facilitates the real-time identification of both occupied and available spots, thereby reducing the time drivers spend searching for parking and contributing to a decrease in overall traffic congestion.

1.2 Problem Statement

Current parking management systems encounter several significant challenges. The lack of real-time parking data forces drivers to spend excessive time searching for available spaces, which in turn exacerbates traffic congestion. Manual monitoring is not only labor-intensive but also prone to human error, often resulting in outdated or inaccurate information. Sensor-based solutions, although more automated, require substantial infrastructure investments and ongoing maintenance, limiting their scalability. Moreover, these systems typically fail to integrate with modern smart city frameworks and lack predictive capabilities, leaving them ill- equipped to adapt to varying environmental conditions or fluctuating demand patterns.

1.3 Objectives

Automated Detection: Develop a video-based system using computer vision to accurately identify occupied and vacant parking spaces in real time.

Efficient Processing: Implement robust algorithms to ensure quick and reliable detection under varying conditions.

User-Friendly Interface: Create an interactive GUI to provide real-time parking status updates, enhancing both user experience and parking management efficiency.

Scalability and Integration: Design the system to seamlessly integrate with existing surveillance infrastructures, ensuring it can scale to accommodate different parking lot sizes and urban environments.

II. LITERATURE REVIEW

2.1 Existing Parking Management Techniques

Various parking management techniques have been explored, each with its own strengths and limitations. Manual monitoring remains the simplest approach, requiring no additional infrastructure, but it is prone to human error and inefficiency. Sensor-based systems, such as ultrasonic and RFID-based solutions, provide automated detection but involve high installation and maintenance costs.

Vision-based parking detection has gained attention due to its scalability and real-time monitoring capabilities. By leveraging computer vision and image processing, these systems can dynamically track parking occupancy without the need for physical sensors. However, challenges such as poor lighting conditions and environmental occlusions still affect their accuracy.

2.2 Research Gaps

Despite advancements in parking management, several challenges remain. Sensor-based solutions, though effective, are expensive and require regular maintenance, limiting their feasibility for large-scale deployment. Manual monitoring methods lack accuracy and are impractical for managing extensive parking areas. Vision-based systems, while promising, require further optimization to enhance real-time performance and adapt to low-light environments.

This study aims to address these gaps by developing a cost-effective, real-time vision-based smart parking system that improves detection accuracy and efficiency in diverse conditions.

III. METHODOLOGY

3.1 System Overview

The proposed Smart Parking Management System (SPMS) is a computer vision-based solution designed to detect occupied and vacant parking spaces in real-time video feeds. This eliminates the need for physical sensors and provides instant parking updates for drivers and parking lot operators. By leveraging advanced image processing techniques such as

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background subtraction, edge detection, and object recognition, the system ensures high detection accuracy while reducing operational costs.

3.2 System Architecture

3.2.1 **Video Acquisition** – Captures live video footage from surveillance cameras in the parking lot. These frames serve as input for vehicle detection and space analysis.

3.2.2 **Vehicle Detection** – Identifies parked vehicles using background subtraction, edge detection, and object recognition. It differentiates between moving and stationary vehicles to improve detection accuracy.

3.2.3 **Parking Space Analysis** – Maps Regions of Interest (ROI) to predefined parking slots and determines their occupancy status. If a vehicle is detected in a slot, it is marked as occupied; otherwise, it is available.

3.2.4 **Graphical User Interface (GUI)** – Displays real-time parking availability with a user-friendly interface. Vacant spaces are highlighted in green, and occupied spaces in red, allowing easy monitoring for users and operators.

IV. METHODOLOGY

4.1 System Overview

The proposed system uses computer vision and real-time video processing to detect parked vehicles and identify vacant spaces. By analyzing live surveillance footage, it eliminates the need for physical sensors and provides real-time parking updates.

4.2 Key Processing Techniques

4.2.1 **Background Subtraction:** Detects moving objects by analyzing frame differences.
4.2.2 **Edge Detection:** Identifies vehicle boundaries to improve recognition.
4.2.3 **Region of Interest (ROI) Mapping:** Defines and monitors specific parking slots.
4.2.4 **Status Updating:** Continuously updates parking availability based on video analysis.

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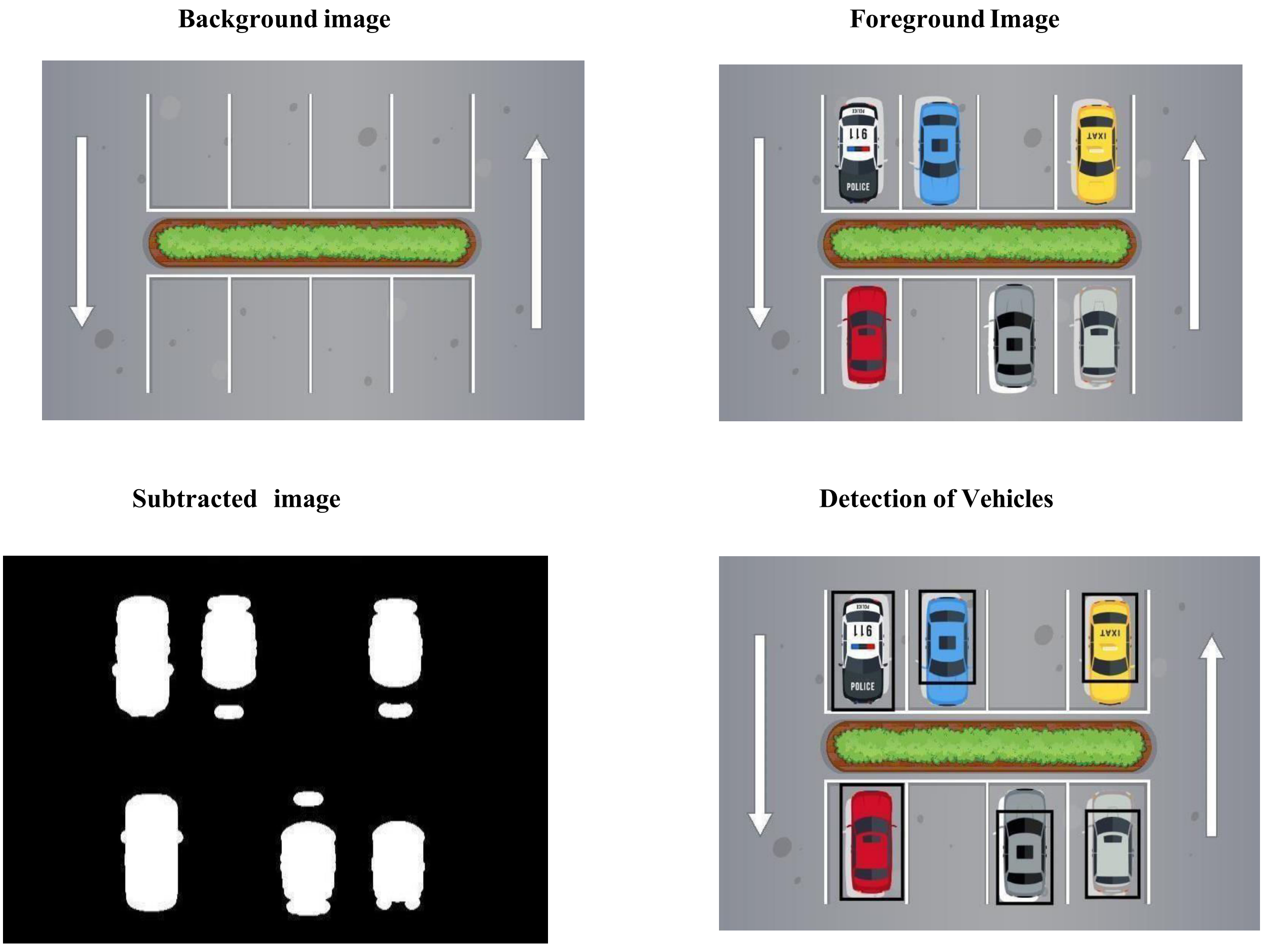

Figure 1:Experimental Results

4.3 System Workflow

The system follows a structured workflow to achieve efficient parking detection:

1. **Video Capture:** The system continuously receives live video input from surveillance cameras.
2. **Preprocessing:** The video frames are converted to grayscale, and Gaussian blur is applied to remove noise and enhance detection accuracy.
3. **Vehicle Detection:** The system uses edge detection and background subtraction to identify vehicles in designated parking slots.
4. **Parking Space Analysis:** Each parking slot is mapped as a region of interest (ROI), and its occupancy status is determined based on detected changes.
5. **Real-Time Update:** The analyzed data is processed, and parking availability is dynamically displayed for users.

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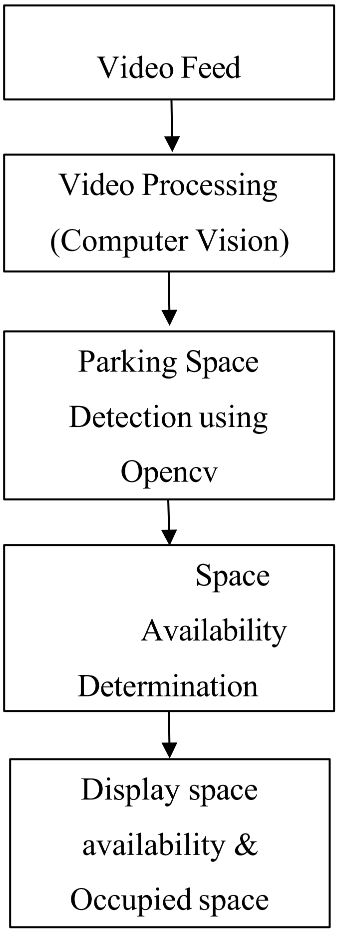

Figure 2:Workflow Diagram

4.4 Optimization Strategies

To enhance the system's performance, additional optimization techniques are employed:

- **Noise Reduction:** Applying Gaussian blur to minimize false detections.
- **Adaptive Thresholding:** Adjusting detection parameters based on lighting conditions.
- **Performance Optimization:** Ensuring efficient processing for larger parking lots.

4.5 Accuracy

The proposed system is tested in different real-world parking environments, including indoor and outdoor lots. Results indicate:

- **High accuracy (>95%)** in identifying available spaces under normal lighting conditions.
- **Real-time processing capability (15-30 FPS)** depending on the computational resources.
- **Challenges:** Accuracy drops under extreme weather conditions, shadows, and occlusions.

Traditional parking systems, such as **sensor-based solutions**, require physical installation and maintenance, leading to higher operational costs. In contrast, **video-based AI solutions** use existing surveillance infrastructure, making them more cost-effective and scalable.

Unlike manual monitoring, which is labor-intensive and prone to errors, AI-based solutions provide **continuous, automated** monitoring with minimal human intervention.

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V. CONCLUSION AND FUTURE WORK

This paper presents a video-based parking space detection system leveraging deep learning for real-time monitoring. The system offers a scalable, cost-effective solution to urban parking management challenges. Future work includes:

- **Enhancing robustness against weather conditions:** Using thermal imaging or LiDAR to improve detection in foggy or rainy conditions.
- **Developing predictive analytics:** Using AI to predict parking demand based on time, weather, and historical trends.
- **Integrating vehicle recognition:** Linking parking detection with **license plate recognition systems** for automated parking fee collection.
- **Testing in real-world smart city environments:** Deploying on a larger scale with **5Genabled cloud processing** for faster response times.

By implementing these advancements, the proposed system can contribute to **efficient urban mobility, reduced congestion, and enhanced user convenience** in parking management.

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