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Research Article

Parking Slot Scanning for Maximum Efficiency Using Python

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Abstract: Efficient parking management has become an increasingly important concern in urban environments due to the growing number of vehicles and limited parking space availability. Conventional parking monitoring methods often rely on manual observation or sensor-based systems, which can be costly, less scalable, and operationally inefficient. Therefore, this study aims to develop and evaluate a smart parking slot detection system capable of improving parking space utilization through an image processing approach. The proposed system is implemented using Python programming and the OpenCV library, utilizing computer vision techniques to detect parking slot occupancy in real time. The methodology involves several image preprocessing stages, including grayscale conversion, Gaussian blur filtering, and adaptive thresholding, followed by pixel-intensity analysis within predefined parking slot coordinates. Parking slots with white pixel values below the threshold of 900 pixels are classified as vacant, while values above the threshold indicate occupied status. Experimental testing was conducted on 69 parking slots across multiple scenarios. The results show that in the first test, the system successfully detected 57 occupied slots and 12 vacant slots, while in the second test, it identified 54 occupied slots and 15 vacant slots. These findings indicate that the system achieves a satisfactory detection performance while offering advantages in cost efficiency, ease of implementation, and deployment flexibility compared to sensor-based solutions. However, performance degradation was observed under extreme lighting conditions and monochrome video inputs, highlighting sensitivity to environmental factors. In conclusion, the proposed OpenCV-based smart parking system provides a practical and efficient alternative for real-time parking monitoring and has strong potential to support smarter parking management in densely populated urban areas.

Keywords: Smart Parking System; Python; OpenCV; Image Processing; Parking Slot Detection.

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1. Introduction

The increasing number of vehicles in urban areas has created significant challenges in parking management systems (Mahardita et al., 2024). Motorists frequently encounter difficulties in locating available parking slots within a short time, leading not only to time inefficiency but also to increased traffic congestion and environmental pollution. Prolonged parking searches may also reduce operational efficiency and user satisfaction in parking facility management (Haposan Yoga Pradika Napitupulu & I Gde Dharma Nugraha, 2024). Consequently, there is a growing demand for intelligent parking solutions that are efficient, practical, and economically feasible to implement (Nadeak et al., 2024).

Various smart parking technologies have been developed (Ahmed & Rahman, 2021), including systems based on ultrasonic sensors, infrared sensors, and RFID. These technologies are capable of detecting parking slot availability; however, they present several limitations, particularly related to high installation costs and complex infrastructure requirements (Kumar et al., 2022). Such constraints make them less suitable for deployment in environments with limited financial and technical resources (Ardina et al., 2024). In addition, long-term maintenance and hardware dependency may impose further operational burdens on parking managers (Yonil et al., 2024).

To address these limitations, computer vision–based approaches have emerged as promising alternatives. This research proposes a smart parking system developed using Python and the OpenCV library to detect parking slot occupancy in real time (Dasari et al., 2023). The system utilizes camera devices as primary sensors and processes captured images through several stages, including grayscale conversion, Gaussian blur filtering, and adaptive thresholding (Wulandari et al., 2022). These image processing techniques enable the system to classify parking slots as occupied or vacant with satisfactory accuracy (Adnan & Rohmah, 2020). Furthermore, parking slot coordinate data are stored in CSV format to ensure flexible and efficient data management (Haposan Yoga Pradika Napitupulu & I Gde Dharma Nugraha, 2024).

System testing using recorded parking videos demonstrates that the proposed approach performs effectively under various parking scenarios (Siregar et al., 2024). In addition to being cost-efficient, this system is relatively easy to implement compared to sensor-based alternatives, making it suitable for scalable deployment in different parking environments (Ardina et al., 2024). Therefore, this study aims to develop and evaluate a practical computer vision–based parking detection system capable of optimizing parking space utilization, reducing vehicle search time, and minimizing negative externalities such as congestion and carbon emissions (Siregar et al., 2024; Putra, 2020).

2. Literature Review

Several previous studies have explored the development of smart parking systems using different technological approaches to improve parking efficiency and monitoring accuracy (Badii et al., 2021). Sensor-based parking detection systems are among the most widely implemented solutions. Technologies such as ultrasonic sensors, infrared sensors, and RFID have been utilized to identify parking slot occupancy automatically. These systems are capable of providing real-time availability information; however, they require dedicated hardware installation for each parking slot, resulting in high implementation and maintenance costs (Ardina et al., 2024). In addition, hardware dependency may reduce system scalability, particularly in large parking environments (Yonil et al., 2024).

To overcome these limitations, researchers have begun exploring computer vision–based parking detection methods. By utilizing camera devices and digital image processing, parking slot monitoring can be conducted without installing physical sensors in each slot. Dasari et al. (2023) developed a parking detection system using Python and OpenCV to identify vehicle presence through visual pattern recognition. Their study demonstrated that image-based detection can achieve reliable performance while reducing infrastructure complexity. Further advancements in image processing techniques have improved detection accuracy. Wulandari et al. (2022) implemented preprocessing methods such as grayscale conversion and Gaussian blur filtering to enhance object segmentation quality. Similarly, Adnan and Rohmah (2020) applied adaptive thresholding techniques to distinguish occupied and vacant parking slots more effectively under varying lighting conditions. These preprocessing stages play a crucial role in minimizing noise and improving classification reliability.

In addition to detection algorithms, data management mechanisms also contribute to system efficiency. Parking slot coordinate mapping stored in structured formats, such as CSV, enables flexible system configuration and easier scalability (Haposan Yoga Pradika Napitupulu & I Gde Dharma Nugraha, 2024). System validation through real parking video testing further confirms the feasibility of computer vision approaches in operational environments (Siregar et al., 2024). Although prior studies have demonstrated the effectiveness of both sensor-based and image-based parking detection systems, challenges remain in balancing detection accuracy, cost efficiency, and implementation practicality. Therefore, this research focuses on developing a Python-based parking slot scanning system that integrates efficient image processing techniques to maximize parking space utilization while maintaining affordability and deployment flexibility.

3. Method

This study employs a computer vision-based approach to scan and monitor parking slots in real-time using Python libraries such as OpenCV and NumPy. The development and implementation of this method involve the following steps:

a) **Parking Area Identification**

Each parking slot is identified manually by specifying coordinates through user interaction via mouse clicks. These coordinates are stored in a CSV file to ensure flexibility and ease of modification.

b) Image Preprocessing

Images captured from the camera are processed using techniques such as grayscale conversion, Gaussian Blur for smoothing, and adaptive thresholding for segmentation. This step is designed to enhance contrast between empty and occupied parking slots.

c) Slot Scanning and Validation

Identified areas are scanned using a non-black pixel detection method to determine the status of each slot (empty or occupied). Empty slots are highlighted in green, while occupied slots are displayed in red.

d) Data Reporting and Visualization

Information on available slots is organized by rows and columns and displayed in a visual interface. An additional information panel is designed to provide a summary of the total, occupied, and available slots.

e) Testing and Validation

The system was tested with various parking slot configurations to ensure detection accuracy and data processing efficiency.

This approach was chosen for its ability to efficiently detect parking slot statuses without requiring additional hardware. The method can also be replicated by adjusting parameters for different scenarios

4. Results and Discussion

The testing results demonstrate the system's capability to detect parking slot occupancy with a satisfactory level of accuracy. As illustrated in Figures 1 and 2, the system evaluated a total of 69 parking slots across two testing scenarios. In the first test, the system successfully identified 57 occupied slots and 12 vacant slots, whereas in the second test, 54 slots were detected as occupied and 15 as vacant. The detection analysis was conducted by calculating the number of white pixels within each predefined parking slot coordinate extracted from the processed image frames (Chandra & Putra, 2023). Parking slots registering white pixel values below the established threshold of 900 pixels were classified as vacant, while those exceeding the threshold were categorized as occupied. Furthermore, the system interface provides a real-time information panel displaying comprehensive parking data, including the total number of occupied and vacant slots as well as their distribution across each parking row. This visualization assists users in understanding overall parking availability conditions more efficiently and supports faster parking decision-making.

Figure 1. First Test Normal Light

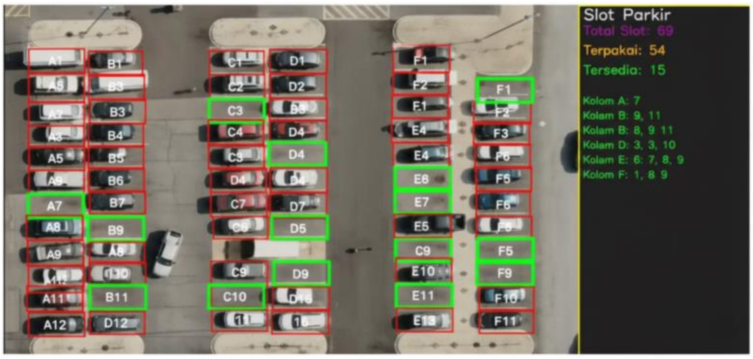

Figure 2. Second Test Normal Light

Additional testing was conducted to evaluate system performance under extreme environmental lighting conditions, namely low-light and overexposure scenarios. As presented in Figure 3, testing under low-light conditions revealed that the system experienced difficulties in accurately detecting parking slot occupancy due to limited image visibility and reduced object contrast. The insufficient illumination affected pixel segmentation quality, resulting in several parking slots being inaccurately classified (Prasetyo & Nugroho, 2022). Conversely, as shown in Figure 4, testing under overexposed lighting conditions also produced detection challenges. Excessive brightness caused white vehicles to visually blend with the background surface, reducing the system's ability to distinguish vehicle objects from empty parking areas. This led to misclassification, where occupied slots were incorrectly identified as vacant. These findings indicate that the proposed parking detection system is highly sensitive to lighting variability and relies on balanced illumination to maintain optimal detection accuracy (Rangkuti et al., 2023). Therefore, environmental lighting conditions remain a critical factor influencing the reliability and robustness of computer vision–based parking slot detection systems.

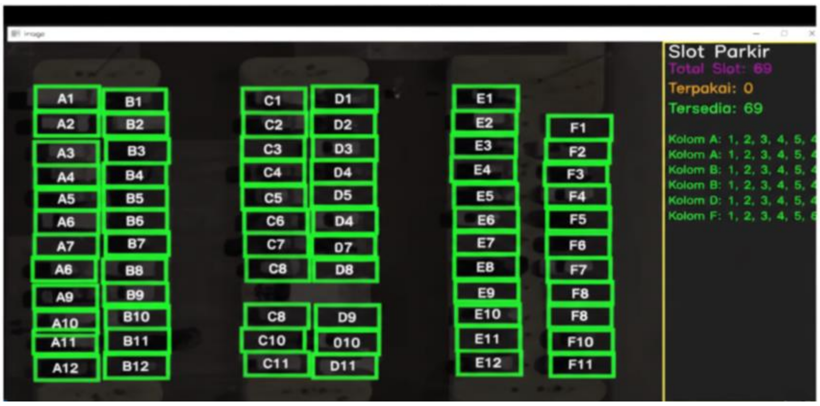

Figure 3. Low-Light Test

Figure 4. Overexposure Test

Furthermore, additional limitations were identified during system evaluation using black-and-white video formats. As illustrated in Figure 5, the absence of color information significantly affected detection performance and increased classification errors. Under these conditions, the system frequently misidentified non-vehicle objects such as pedestrians or unrelated items as vehicles occupying parking slots (Li et al., 2022). This issue occurred because the detection mechanism relied primarily on calculating white pixel intensity within predefined parking coordinates without incorporating higher-level object features such as shape, contour, or dimensional characteristics (Taylor et al., 2021). As a result, any object producing pixel patterns similar to vehicle silhouettes was incorrectly classified as an occupied slot. These findings highlight a methodological limitation of pixel-threshold–based detection approaches, particularly when applied to monochrome visual data. Consequently, reliance solely on pixel density analysis reduces system robustness and underscores the need for more advanced object recognition techniques to improve classification accuracy in diverse visual conditions.

Figure 5. Black and White Test

This research aims to develop an intelligent parking system capable of automatically detecting parking slot statuses using video analysis. While the system performed well in identifying vacant and occupied slots with good accuracy, several limitations need to be addressed to improve its performance. The system's sensitivity to lighting conditions was evident during the tests. Under lowlight conditions, poor visibility made it difficult to accurately detect parking slots, while overexposure caused white vehicles to blend into the background, resulting in misclassification. These findings suggest that while the system is functional, its reliance on lighting balance limits its performance under extreme environmental conditions. Future iterations could incorporate advanced image processing techniques or adaptive lighting correction algorithms to improve accuracy across diverse lighting scenarios.

Another key issue identified was the false detection of objects in black-and-white video formats. The system was unable to differentiate between vehicles and non-vehicle objects, leading to frequent misclassification. This limitation arises because the detection process is based solely on white pixel analysis without considering object characteristics. Addressing this issue may require the integration of machine learning models or advanced object detection frameworks capable of distinguishing between vehicle and non-vehicle objects.

Moreover, testing so far has been limited to recorded videos, and real-time performance using live camera feeds has yet to be evaluated. Similarly, the system depends on manual input to define parking slot coordinates, which could be challenging in dynamic or large-scale parking areas. Implementing an automated slot detection feature could enhance the system's usability and scalability in such scenarios. In conclusion, while the system demonstrates strong potential as an efficient smart parking solution, there are several areas for improvement. Future development should focus on mitigating the impacts of environmental lighting conditions, integrating advanced object recognition capabilities, and conducting real-time tests to ensure reliability in real-world applications.

6. Conclusion

Based on the testing results of the Python and OpenCV-based smart parking system, it can be concluded that the proposed system is capable of detecting parking slot occupancy status in real time with a fairly good level of accuracy. By applying image processing techniques such as grayscale conversion, Gaussian blur filtering, and adaptive thresholding, the system successfully classifies parking slots as either vacant or occupied. Compared to smart parking technologies that rely on physical sensors, the developed system demonstrates greater cost efficiency, simpler implementation, and higher deployment flexibility. In addition, the system shows adaptability across various parking environments, including different lighting and weather conditions within certain operational limits. Therefore, this smart parking solution offers practical benefits for parking management by helping motorists locate available spaces more quickly, reducing internal parking congestion, and potentially minimizing vehicle emissions caused by prolonged parking searches. Overall, the findings indicate that an OpenCV-based computer vision approach can serve as an effective alternative for optimizing parking space utilization, particularly in densely populated urban areas.

Despite these promising results, several limitations were identified. The system remains sensitive to non-ideal lighting conditions, where low illumination or overexposure can reduce detection accuracy and affect slot classification outcomes. Furthermore, the pixel-intensity–based detection approach has limited capability in distinguishing vehicles from non-vehicle objects, such as pedestrians or goods, potentially leading to false occupancy detection. The experimental evaluation was also restricted to recorded video datasets and has not yet been validated using live camera feeds, which may introduce additional challenges for real-time operational deployment. Moreover, the use of manually defined parking slot coordinates reduces system scalability and requires recalibration when applied to new parking layouts. These limitations indicate opportunities for future enhancement, particularly through the integration of adaptive imaging techniques, automated slot mapping, and more advanced object recognition methods.

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