



Application of YOLOv5 for Automatic Parking Lot Detection and Monitoring System

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Abstract

The rapid growth of vehicles in urban areas has led to parking space limitations and longer search times for available spots. This study aims to design and implement an automated parking availability detection and monitoring system using the YOLOv5 algorithm and image input from drone cameras. The methodology includes image data acquisition through drone recordings from two different viewpoints (top-down and side view), data labeling, object detection model training, and classification of parking slot status (vacant or occupied). System evaluation was conducted by measuring precision, recall, accuracy, and mAP@0.5. The testing results show that camera angle affects detection accuracy: from the side view, the system achieved 100% precision, 75.86% recall, and 75.86% mAP@0.5, while from the top-down view, recall and mAP@0.5 dropped to 35.29% and 35.00%, respectively. These findings are supported by the Confusion Matrix and Precision-Recall Curve visualizations. The developed system successfully detects and monitors parking slot availability in real-time, displaying the results via a digital dashboard. The use of drone cameras enables broader and more flexible area coverage compared to static cameras. Therefore, this system has the potential to be a practical solution in the development of deep learning-based smart parking in public areas.



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INTRODUCTION

Parking systems are a crucial element in modern transportation infrastructure that play a role in regulating, monitoring, and providing temporary storage facilities for motorized vehicles in certain areas, both in public and private areas. (A. Elsonbaty & Shams, 2020).

Along with the rapid growth of the number of motorized vehicles in urban areas, the availability of parking spaces is becoming increasingly limited. This imbalance has an impact on increasing the time spent searching for parking spaces, traffic congestion around the parking area, and the emergence of illegal parking practices that disrupt environmental order (Sani & Ayyasy, 2022). This condition causes drivers to have difficulty finding available parking spaces and have to go around the parking lot, which ultimately results in wasted time and fuel as well as increased

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exhaust emissions (Putra & Susilawati, 2021). Therefore, a system is needed that is able to provide information on the availability of parking slots in real time to minimize congestion, increase time efficiency, and support better traffic management in urban areas (Ektrada et al., 2023).

The smart parking system is one of the solutions offered to find out the availability of parking slots (Dhutanggara et al., n.d.). As technology advances, computer vision and deep learning-based approaches offer more efficient and adaptive solutions in automatically detecting vehicles (Fergina et al., 2024).

Computer vision is a field that presents an interesting challenge to make computers able to capture information contained in an image or video (Sardjono et al., 2023). One of the popular methods is YOLO (You Only Look Once), which allows the process of detecting and classifying objects to be done in just one image scan. This method is known to be fast and accurate for the needs of systems that operate in real-time (Alauddin & Rosadi, 2023).

Several previous studies have shown the success of using the YOLO method in detecting vehicles in parking areas. This method has been used to count vehicles entering and leaving the campus area (Alauddin & Rosadi, 2023), and detect empty slots using Mask R-CNN even though it requires high computing power (Ayudhawara et al., 2023). In addition, the YOLO method has also been applied in the automatic marking system for parking areas to detect the availability of vehicle parking spaces directly through video recordings from CCTV cameras (Tanuwijaya & Fatichah, 2020).

This study aims to design and implement an automatic parking space availability detection and monitoring system using the YOLOv5 method, with input in the form of images from drone cameras. This system works by detecting the presence of vehicles in certain parking slots and displaying the slot status (empty or occupied) through a digital interface in real-time. The use of YOLO technology is very appropriate because of its ability to detect objects quickly and accurately in various environmental conditions, and can even perform object recognition in real time at a speed of 45 frames per second (Rizkatama et al., 2021).

The integration of drones as an image source offers wider and more flexible monitoring area coverage compared to conventional static cameras, as shown in previous research that utilized top-down imagery for efficient parking availability analysis (Sardjono et al., 2023). This approach provides a more cost-effective alternative to physical sensor-based systems, which generally require high installation and maintenance costs and are not flexible at scale.

Unlike previous studies that used static CCTV, this study uses drone cameras to cover a wide and dynamic area, and utilizes YOLOv5 in a real-time park monitoring scenario with comprehensive evaluation. The main contribution of this study lies in the integration of drone cameras as a dynamic image source and the use of YOLOv5 in a real-time parking slot detection system, which has not been widely applied in similar systems in previous studies.

Thus, the system developed in this research is expected to be a practical solution to overcome the problem of limited parking space in public areas, as well as contribute to the development of a deep learning-based intelligent parking system that can be combined with other supporting technologies such as the Internet of Things (IoT) or automatic navigation systems in the future (Tinoe Mauludy et al., 2020).

METHOD

This study uses a descriptive qualitative approach with the aim of designing an automatic parking lot detection and monitoring system based on the YOLO algorithm. The following are the stages of the research method used:

Data Collection Method

Data collection is carried out through three main methods, namely:

1. Field Observation
Used to identify the actual conditions of the parking area, including vehicle movement patterns, and determining the optimal viewing angle for taking pictures.
2. Video Documentation
Data is obtained by recording the parking area using a drone from a top-down perspective, so that it covers the entire area as a whole and supports the object detection process with high accuracy.
3. Literature Study
A review of scientific journals, technical articles, and documentation of object detection methods are used as a theoretical basis for selecting the YOLO algorithm, system development, and comparing research results.

System Flowchart

A flowchart is used to describe the sequence of processes starting from image capture using a drone camera, data pre-processing, vehicle detection using the YOLOv5 deep learning model, parking slot status classification (empty or occupied), to presenting detection results into a dashboard interface in real-time (Reeja Susan Reji et al., 2023). The flow diagram image can be seen in figure 1.

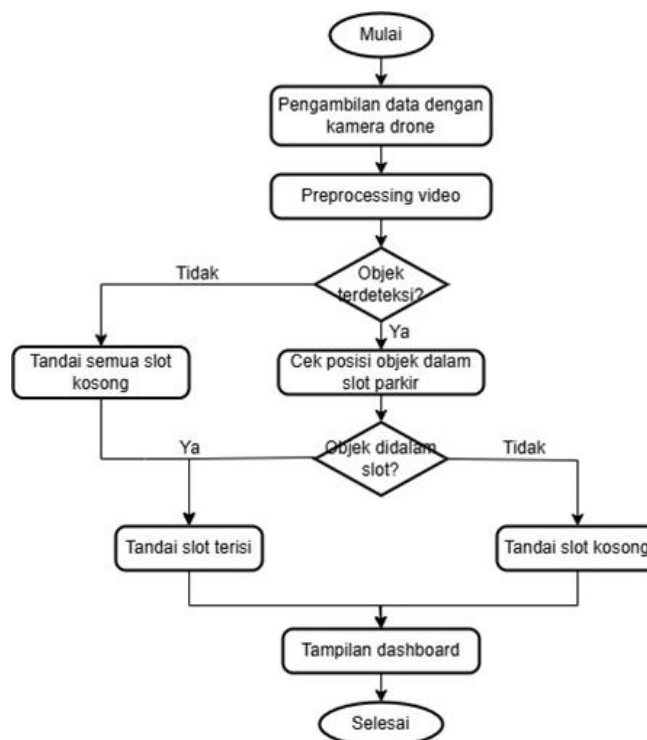


Figure 1. System Flow Diagram

System Development Method

System development is carried out through five main stages as follows:

1. System Architecture Design

This stage includes planning the overall system flow, which includes image input from the drone camera, image processing using the YOLOv5 object detection model, mapping vehicle positions to parking slots, and presenting results in the form of slot status visualization (empty or occupied).

2. Data Acquisition and Labeling

Image data is collected from drone footage that records the parking area from a top viewpoint. Furthermore, each image is labeled using Labelling software to mark vehicle objects in a format that suits the YOLOv5 training needs.

3. Object Detection Model Training

The YOLOv5 model is trained using the PyTorch framework with certain configurations, such as the number of epochs, learning rate, and batch size. The training process is also accompanied by data augmentation (rotation, flipping, light changes) to improve the model's generalization ability to real conditions.

4. Parking Slot Detection and Classification

After the model is trained, the system detects vehicles on each video frame. The bounding box results from the detection are then mapped to the predetermined parking slot area. The slot status is determined as:

- a. Empty, if there are no vehicles in the slot area.
- b. Occupied, if a vehicle is detected within the slot boundary.

5. Visualization of Detection Results

The system presents the status of each parking slot through a visual interface using a green indicator for occupied slots. This visualization makes it easier for users to monitor parking availability in real-time.

RESULT AND DISCUSSION

Implementation

The developed system utilizes the YOLOv5 algorithm to detect four-wheeled vehicles in the parking area recorded by the drone camera. The drone camera records video from a certain height so that the entire parking area can be monitored thoroughly.

Each frame of the video is analyzed by the detection model to identify vehicles and determine the status of each parking slot. The detection results are visualized in the form of a bounding box on each vehicle, and mapped into a previously defined parking slot.

Information on the status of the parking lot (empty or occupied) is then displayed via the admin dashboard, which can be accessed in real-time.

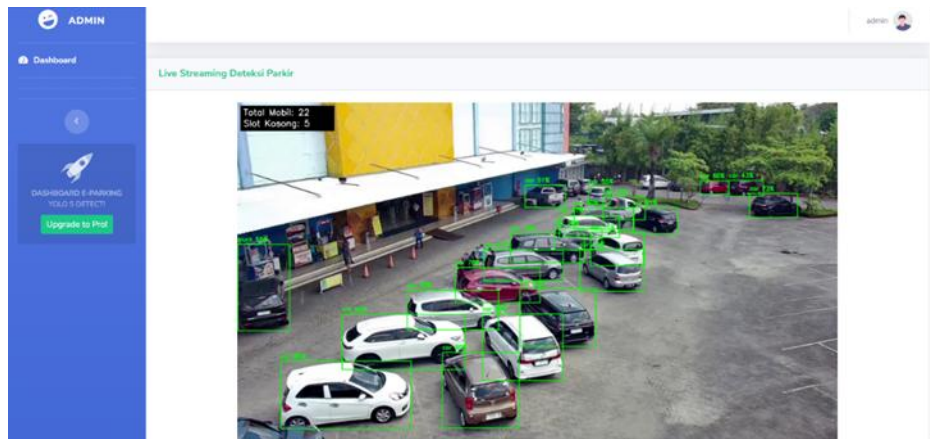


Figure 2. Parking Detection System Admin Dashboard Display

The dashboard shows real-time information on the number of vehicles and parking slot status, as well as a visual display of vehicle detection based on video input from the drone camera.

Parking Slot Calculation

After the detection process is successful, the system calculates the number of empty parking slots based on the number of detected vehicles. The calculation uses the following formula:

$$\text{Empty Slots} = \text{Total Parking Slots} - \text{Filled Slots}$$

This formula is used by the system to estimate parking space availability in real-time, which is then displayed via the admin dashboard. This dashboard displays the number of detected vehicles (filled slots), the number of empty slots, and a live video display of the detection.

Comparison of Image Capture Angles

In the process of implementing the vehicle detection system, testing was carried out with two types of video capture angles, namely:

1. Side View
2. Top-Down View

Both methods were tested to determine the effect of the image capture angle on the accuracy of vehicle detection and parking slot mapping.



Figure 3. Parking Area Detection View from Side View

This image shows the recording from the drone camera with a side view. Although there is a little occlusion between vehicles, the YOLO model is still able to detect cars quite well because the silhouette of the vehicle is still visible.



Figure 4. Parking Area Detection View from a Top Perspective

This image shows footage from a drone camera from a top perspective. Although the entire parking area is fully visible without any visual obstructions, the model has difficulty detecting some vehicles, possibly due to the similarity of the car's color to the parking surface or the lack of visual features that distinguish the object from the background.

Detection Accuracy Evaluation

The evaluation was conducted using image data taken using a drone camera. The system was tested based on precision, recall, and mean average precision (mAP).

1. Detection Evaluation Results from Side View

The video was taken from a horizontal direction parallel to the vehicle (side-view). Although there was a little occlusion, the system was able to detect most of the vehicles well because the side contours were still clearly visible to the model.

Table 1. Evaluation Results from a Side Perspective

Evaluation Metrics	Mark (%)
Precision	100%
Recall	75,86%
mAP@0,5	75,86%
Accuracy	75,86%

The graphic images of the Precision-Recall Curve and Confusion Matrix can be seen in Figure 5 and Figure 6.

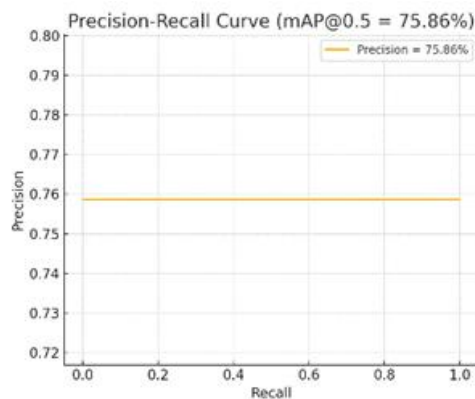


Figure 5. Precision-Recall Curve Graph (Side Angle)

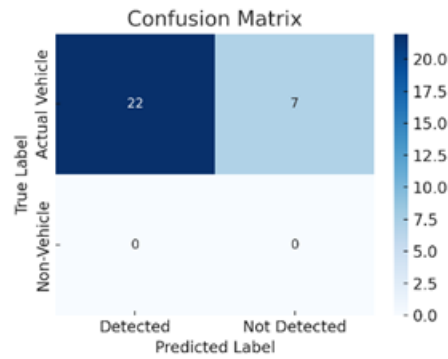


Figure 6. Confusion Matrix (Side Angle)

2. Evaluation Results of Detection from a Top View

For comparison, a test was conducted by taking video from above using a drone camera. Although the area looks intact without visual obstructions, the system has difficulty detecting vehicles due to the lack of shape features from the top view and the low contrast between the car and the parking surface.

Table 2. Evaluation Results from a Top Viewpoint

Evaluation Metrics	Mark (%)
Precision	100%
Recall	35,29%
mAP@0,5	35,00%
Accuracy	35,29%

The graphic images of the Precision-Recall Curve and Confusion Matrix can be seen in Figure 7. and Figure 8.

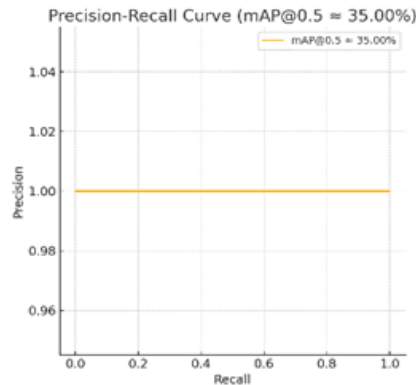


Figure 7. Precision-Recall Curve Graph (Top Corner)

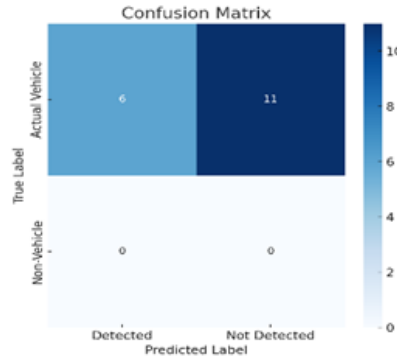


Figure 8. Cunfosition Matrix (Top Corner)

Test Result Analysis

The test results show that the shooting angle affects the vehicle detection performance. At the side view angle, the model achieves recall, accuracy, and mAP@0.5 of 75.86%, while at the top angle it is only 35.29% and 35.00%. Precision remains high (100%) at both angles, indicating that all detections are correct, but many vehicles are not detected especially from the top angle.

The visualization of the Precision-Recall and Confusion Matrix graphs strengthens this finding. The side view provides clearer object contours, while the top view lacks visual features and contrast, making it more difficult for the model to recognize. Thus, the side view angle is more recommended for YOLO-based vehicle detection systems in the context of open parking areas.

CONCLUSION

This study produces an automatic parking lot detection and monitoring system using YOLOv5 based on drone imagery. The system is able to detect vehicles and determine the parking slot status in real-time.

The test results show that the side view provides higher accuracy (mAP@0.5: 75.86%) compared to the top view (mAP@0.5: 35.00%). This is due to the clearer contour of the object from the side, while the top view has limited visual features. Thus, this approach is effective for smart parking systems, and the side view is more recommended for more accurate implementation.

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