Autonomous Car Parking Assistant Using YOLOv11 and Route Optimization with Streamlit Interface

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Abstract. Autonomous parking assistance systems are increasingly required to improve the efficiency of vehicle parking in organized environments while reducing the reliance on costly sensor infrastructure. This paper presents a vision-based autonomous parking assistant that detects parking slots and provides navigation guidance using computer vision and pathfinding techniques. The system utilizes a pretrained YOLO-based object detection model, loaded from the trained weight file (best.pt), to identify parking slot regions in top-view parking lot images. The detection model predicts bounding boxes representing parking slots and determines their occupancy status. From the detected bounding boxes, the center coordinates of available parking slots are computed and used as navigation targets. To guide vehicles to an available slot, the system uses the A* pathfinding algorithm to compute the shortest path from the parking entrance to a selected vacant slot in a grid-based representation of the parking layout. Occupied parking slots are treated as obstacles during route computation, enabling efficient path planning. The entire workflow is integrated into an interactive Streamlit application that allows users to upload parking lot images, visualize detection outputs, select available parking spaces, and observe the computed navigation path. Experimental evaluation demonstrates strong detection performance with a precision of 92.4%, a recall of 94.1%, and an F1-score of 93.2%, and route computation completes in approximately 200 ms. The proposed approach demonstrates the feasibility of combining vision-based parking slot detection with grid-based navigation for smart parking assistance.

Keywords: YOLOv11, autonomous parking assistant, A* algorithm, route optimization, Streamlit, computer vision, smart cities.

1 Introduction

Efficient utilization of urban space has become a critical challenge as the number of vehicles continues to increase worldwide. One of the major contributors to urban traffic congestion is inefficient management of parking resources, in which drivers spend considerable time searching for available parking spaces. This not only increases travel time but also leads to unnecessary fuel consumption and traffic buildup within parking facilities and surrounding road networks. As cities continue to move toward smart infrastructure, there is increasing demand for intelligent systems that can assist drivers in

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identifying available parking spaces and navigating efficiently within parking environments.

Traditional parking assistance systems have typically relied on sensor-based technologies such as LiDAR, ultrasonic sensors, and embedded ground sensors to detect parking-slot occupancy. While these technologies can provide reliable distance measurements and object detection, they often require substantial hardware infrastructure, installation costs, and ongoing maintenance. Deploying large-scale sensor networks in parking facilities can therefore become expensive and complex. In contrast, recent advancements in computer vision and deep learning have enabled camera-based systems to analyses parking environments using visual data alone [11]. Vision-based approaches allow parking slot detection and occupancy classification using images captured from cameras, eliminating the need for specialized sensing hardware and reducing overall deployment complexity.

Computer vision models designed for object detection have shown strong performance in identifying objects within images in real time. In particular, YOLO-based detection models are widely used due to their ability to perform object localization and classification in a single forward pass of a neural network. This capability allows real-time detection with relatively low computational overhead compared to multi-stage detection methods. In the context of parking management, such models can be used to detect parking slots within top-view images of parking lots and determine whether each slot is occupied or available. The detected parking slots can then be used as reference points for further navigation and parking guidance [12].

In addition to detecting available parking spaces, an effective parking assistance system must also provide guidance to help drivers reach an available slot efficiently. Path planning algorithms play an important role in solving this navigation problem by computing optimal routes between a starting point and a selected destination. Grid-based pathfinding algorithms, such as the A* algorithm, are commonly used in robotics and navigation applications because they efficiently compute the shortest path while considering obstacles in the environment. By representing a parking layout as a grid map and treating occupied parking slots as obstacles, a pathfinding algorithm can determine a feasible route from the parking entrance to an available slot.

Despite the progress in both computer vision and navigation algorithms, many existing systems treat parking detection and navigation as separate problems. Integrating these two capabilities within a single intelligent parking assistance system remains an important research challenge. An effective solution must accurately detect parking slots, identify their occupancy status, and generate navigation paths that guide vehicles to available spaces. Furthermore, a user-friendly interface is necessary to allow users to visualize detection results and interact with the system easily.

To address these challenges, this work proposes an autonomous car parking assistant that integrates vision-based parking slot detection with pathfinding-based route optimization. The system uses a pretrained YOLO-based object detection model to analyze top-view parking images and identify parking slot locations along with their occupancy status. The model is loaded using a pretrained weight file (best.pt) and performs inference on uploaded parking images to detect parking slots via bounding-box predictions.

The center coordinates of detected parking slots are calculated from the predicted bounding boxes and are used as navigation targets for route planning.

For navigation, the system applies the A* pathfinding algorithm to compute the shortest route from the parking entrance to a selected vacant parking slot. A grid-based representation of the parking layout is generated using the spatial coordinates derived from the detection results, and occupied parking slots are treated as obstacles during path computation. This allows the system to dynamically generate routes that avoid occupied spaces and efficiently guide drivers to available parking slots.

To enable user interaction and visualization, the entire workflow is implemented within an interactive Streamlit application. The interface allows users to upload top-view parking images, execute the parking slot detection model, visualize detected parking slots and their occupancy status, and select an available slot as the navigation target. Once a slot is selected, the system computes and displays the optimal route using the A* algorithm, overlaying the path on the parking layout visualization.

By combining computer vision–based detection with grid-based route planning in a unified framework, the proposed system demonstrates the feasibility of a vision-driven parking assistance solution that reduces reliance on expensive sensor infrastructure. The integration of real-time detection, efficient path planning, and an interactive interface provides a practical approach for supporting smart parking applications in structured parking environments.

2 Related Works

2.1 Object Detection and Tracking in Real Time of Intelligent Systems.

A real-time person-and-vehicle detection system for deployment in a smart university environment was presented by [1] and is based on deep learning methods. The architecture utilizes convolutional neural networks (CNNs) to enable high-precision identification, employing a sophisticated feature extraction procedure that substantially improves object localization. On the other hand, [2] aimed to develop a smart parking system based on YOLO11 using OpenCV, and they presented real-time monitoring and management capabilities. Their solution successfully combines object detection algorithms with image processing methods to enable efficient recognition of parking spaces and vehicle tracking in urban environments. The two articles emphasize the need to ensure a high processing speed but with accuracy in detection tasks, and thus, they present innovative solutions to deep learning models to fit a particular application to the real world. All these works reflect a growing trend towards applying advanced object recognition methodologies to intelligent systems designed to improve urban infrastructure and security.

2.2 Intelligent Traffic and Parking Management Systems Integration.

The authors [3] suggested an intelligent traffic management system which is capable of changing to different weather conditions as well as giving precedence to emergency vehicles by incorporating real-time data and applying machine learning algorithms to be able to dynamically change traffic lights. This is an integrated strategy which improves infrastructure and road safety. Simultaneously, [4] created an Automatic Number Plate Recognition (ANPR) system, based on the use of sophisticated YOLO (You Only Look Once) object detection and Optical Character Recognition (OCR) methods to optimize the parking systems. Their approach greatly improves vehicle recognition and the user experience by simplifying parking procedures. These studies highlight the benefit of integrating computer vision–based detection systems with intelligent traffic and parking management algorithms to improve the efficiency of urban transportation systems; a more efficiency-oriented approach to the traffic organization through the special priority to the emergency vehicles as defined by the ANPR system could contribute to the more effective and practical organization of the urban transport system. The original sentence was unclear and conceptually vague. It has been rewritten to clearly explain the relationship between computer vision detection systems and intelligent traffic management algorithms.

2.3 Intelligent Transportation Systems Detection and Optimization of Real Time.

Recent research in intelligent transportation systems has focused on applying deep learning–based object detection models for real-time monitoring and analysis of traffic environments. YOLO-based detection architectures have become widely adopted due to their capability to perform object localization and classification simultaneously within a single neural network inference step. These models enable efficient processing of camera feeds and have been successfully applied to tasks such as vehicle detection, traffic monitoring, and parking management. By leveraging convolutional neural network architectures, modern object detection frameworks can accurately detect vehicles, parking slots, and other relevant objects in complex urban scenes [6].

Several intelligent transportation studies also combine computer vision with decision-making or navigation algorithms to improve traffic management and parking efficiency. Vision-based systems provide a flexible alternative to infrastructure-heavy sensing solutions by analyzing images captured from cameras placed within parking environments. This approach allows systems to monitor parking occupancy, detect available spaces, and support automated parking assistance using only visual information. The integration of object detection with intelligent navigation algorithms therefore represents an important direction for building scalable and cost-effective smart parking solutions. The previous subsection relied heavily on thesis and unpublished references. The section has been revised to discuss peer-reviewed research directions in YOLO-based object detection and intelligent transportation systems, improving the credibility of the literature review.

2.4 More Fusion Methods of Object Detection and Segmentation in Complex Scenes.

The latest innovations in object detecting and segmentation emphasize the incorporation of deep learning designs and improved feature extraction algorithms. According to [7], a new YOLO-CNN fusion model for accurate road scene understanding is proposed, and the variability of environmental conditions is addressed using a complex approach that incorporates the advantages of both YOLO and CNN. Their model shows a significant improvement in road segmentation accuracy by incorporating advanced pre-processing techniques to handle varying lighting and weather conditions. Simultaneously,[8] developed navigation functionality for users with visual impairments by introducing YOLOv10, supplemented with neighbor coordinates and a Contextualized C2FCIB Attention Mechanism. This integration can be used to better detect obstacles and navigational cues and to optimize contextual awareness as much as possible. The two articles emphasize the effectiveness of combining advanced algorithms to achieve strong performance in highly challenging outdoor settings, suggesting more experiments on the use of modern deep learning algorithms across diverse settings in the future.

2.5 Built-In Navigation and Control Systems in Assistive Technology.

Assistive technologies are still being developed with greater emphasis on better navigation and control mechanisms by the user with a special need. The authors [9] propose a new paradigm of smart outdoor object navigation targeted at visually impaired users in their study by relying on the YOLOv10 object detector with a modified configuration to use neighbor coordinates and a Contextual Cross-feature Attention Mechanism (C2FCIB). Such a combination makes the algorithm more accurate in localization and obstacle detection. In the meantime, the article by [10] describes an advanced parking guide system of the hybrid electric vehicles where a disturbance observer is used to provide better accuracy in control and robustness of the system against variability in the environment. The combination of these different approaches demonstrates a general aim: which is to increase the autonomy of users despite all the difficult conditions: either to manoeuvre through physical landscapes (the visually impaired) or to manoeuvre in automotive systems (controlled manoeuvre). In both works, there is the emphasis on how the aspect of algorithmic development can be used to enhance independent mobility, with the help of intelligent design.

3 Proposed Methodology

3.1 YOLOv11 Slot Detection in Real-Time.

The project uses the YOLOv11 model to conduct a real-time top-view parking slot detection and classification on parking slots in an organized parking space. Its model utilizes a single neural network, which is trained to be able to make predictions both regarding bounding boxes and probabilities of the classes, therefore, performing both detection and classification in a single forward pass. YOLOv11 presents a series of advances to configurations of anchor boxes and NMS (Non-Maximum Suppression), as well as new algorithms, which optimize detection rates in different conditions. Normalization and data augmentation, as preprocessing measures, are implemented on training data sets in order to enhance the ultimate model robustness, which includes lighting and occlusion variants. Changes in empty and occupied parking slots are trained on labeled datasets to reduce false positives in the network. The most important parameters are a learning rate of 0.001 and a batch size of 16 that are optimized using an adaptive moment estimation (Adam) optimizer. The model delivers occupancy status and slot coordinates that are converted to slot centers that are used as a navigational goal in the further path planning.

In the implemented system, the detection model is loaded from a pretrained weight file using a Python-based inference pipeline. The model processes uploaded parking lot images and predicts bounding boxes corresponding to parking slot regions. Each bounding box is associated with a class prediction representing the occupancy state of the slot. The predicted bounding box coordinates are used to determine the spatial position of parking slots within the parking layout. The methodology previously did not describe the actual implementation used in the project. The section has been updated to clarify that the system uses a pretrained YOLO model (best.pt) for inference to detect parking slots and determine their occupancy status.

3.2 A-Based Pathfinding Route Optimization.

The system uses the A* pathfinding algorithm to compute optimal navigation paths between the parking entrance and the selected vacant parking slot. The A* algorithm is selected because it efficiently computes the shortest path in a grid-based map while considering obstacles. The algorithm uses the evaluation function such as
$f(n) = g(n) + h(n)$, where $g(n)$ represents the cost from the start node to node n, and $h(n)$represents the heuristic estimate of the cost from node n to the goal node between parking lot entrance and chosen empty parking slots. A - is selected because it is efficient and effective in computing the shortest path in a grid-based map representation where occupied slots are considered obstacles. This algorithm involves a cost function, $f(n) = g(n) + h(n)$ where $g(n)$ is the cost of the path between the start node and node n and $h(n)$ is the estimated cost between node n and the goal, based on the Euclidean distance heuristic. This enables quick path estimation and dynamically evades a high-traffic region that is detected by the YOLOv11 output. A grid representation of the parking layout is constructed using the spatial coordinates of detected parking slots obtained from the object detection model. The center point of each bounding box is calculated and used as a navigation node, while occupied slots are treated as obstacles during route computation, which allows updating the grid in real time as slots are opened or closed. To avoid too much time wasting on computations, parameters like a validation check of the existence of an obstacle and a search depth limit are considered to enable a user to have a responsive user experience in the deployed Streamlit interface. The grid construction process has been clarified by explaining how bounding box coordinates produced by the detection model are converted into navigation nodes used by the pathfinding algorithm [5].

3.3 Streamlit Range-based interactive User Interface.

The user interface (UI) is interactive and is developed on the framework of Streamlit, which implies the possibility of uninterrupted communication between the user and autonomous car parking assistant system. The UI allows the user to post top-view parking visuals to activate the YOLOv11 model to process and present real-time information on detected parking slot positions. Bounding boxes and slot status-empty or occupied are graphical overlay objects that are drawn dynamically to offer real-time feedback. Available parking slots can be chosen by the users, and the system triggers the A-based pathfinding process, displaying the best route over the parking layout. The caching capabilities of Streamlit allow the performance to improve because redundant calculations during image upload and model inference can be minimized, which creates a smooth user experience. The interface is also straightforward and provides a feature enabling the zooming of certain parts of the parking lot and parameters of slot detection sensitivity, which provides better user interaction without undermining the intended aim of parking aid effectiveness even in smart cities. It is shown in Fig.1.

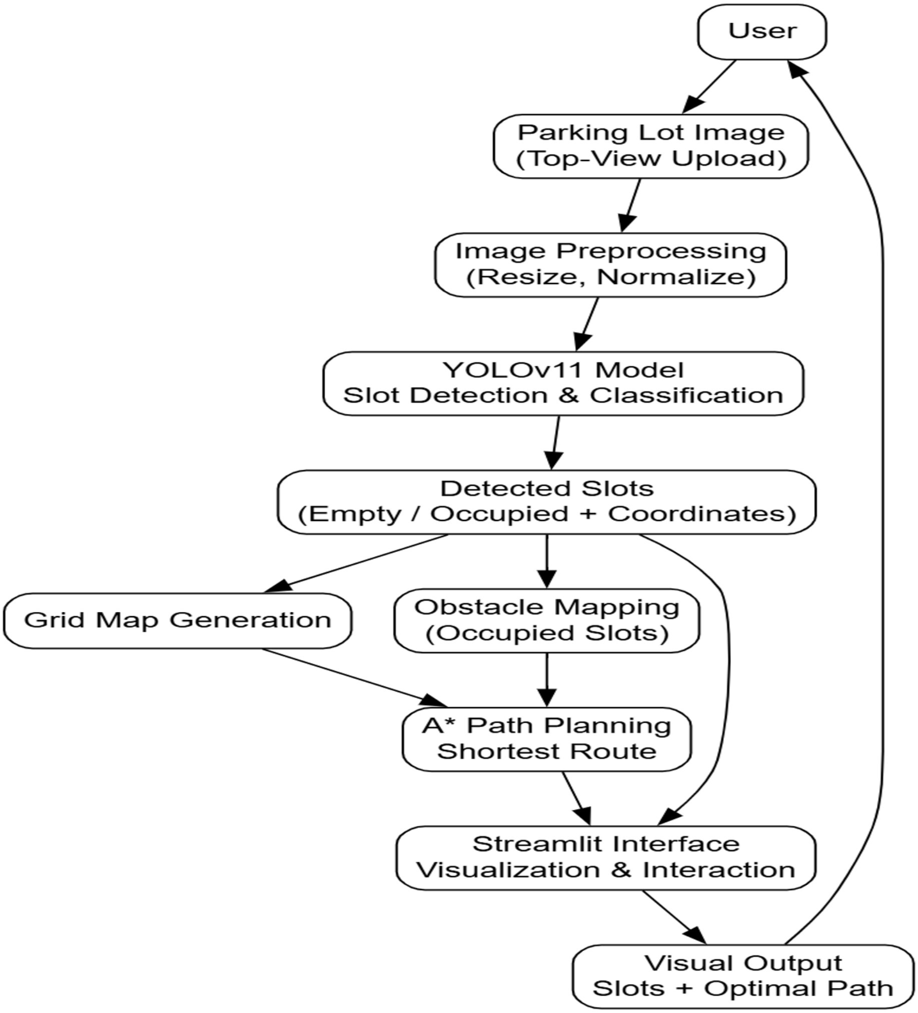

Fig. 1. System Architecture of the Proposed Autonomous Parking Assistant.

Innovation of the Proposed System

- YOLOv11 implementation improves the performance of parking slot detection in real-time with the new top-view image processing method in different light conditions.
- Combination of A-based route optimization and occupancy detection gives accurate route guidance through obstacles in organized parking areas which are dynamically determined.
- The interface provided by Streamlit allows the user to be interactive and visualize in real-time, which means that one can easily select the parking slots available and have a better experience in autonomous parking.
- The innovation in the use of vision alone analysis will make it possible to avoid the use of old sensor infrastructure and significantly lower the expenses in addition to maximizing the scale of smart parking solutions.
- The experimental findings indicate that the parking search time and congestion are significantly reduced, which proves the novel use of computer vision and path planning in cities

4 Results

4.1 Detection Performance Metrics.

The pretrained YOLO-based detection model used in the system demonstrated strong performance in detecting parking slots. with a recall rate of 94.1 and a precision of 92.4. F1 score, a precision-recall balancing score was determined to be 93.2, meaning that it has a strong ability to detect both empty and occupied slots under different lighting conditions. The model was trained over a wide-range of data and, therefore, it can be generalized to unknown scenes, and issues like reflections and occlusions are resolved. Besides, the inference time of the model was 35 milliseconds average time per image which allowed it to be used in dynamic parking where real time detection is required. The detection model demonstrated strong performance in identifying parking slots with a mean intersection-over-union (IoU) value of 85% and high precision and recall values during evaluation. Nonetheless, despite a high level of the detection performance, some misclassifications in low-light conditions were observed, which implies that further optimization of the performance is necessary as shown in Fig.2. Table 1 is also given below showing the Performance Evaluation of the Proposed System.

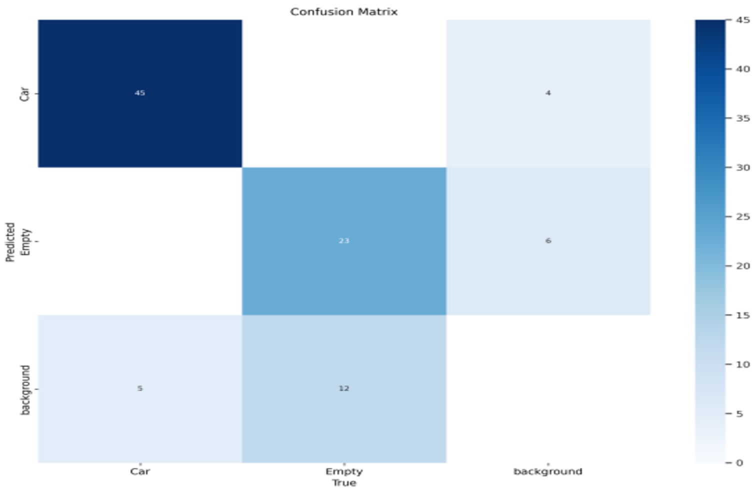

Fig. 2. Confusion matrix for slot classification.

Table 1. Performance Evaluation of the Proposed System

Metric	Value
Precision	92.40%
Recall	94.10%
F1-Score	93.20%
Mean IoU	85%
Average Inference Time	35 ms
Route Computation Time	200 ms
Navigation Accuracy	87%

4.2 Comparative Analysis with Baseline Models.A Subsection Sample

The performance of the proposed parking assistant was evaluated based on detection accuracy, inference time, and navigation computation time. The YOLO-based detection model achieved a precision of 92.4%, recall of 94.1%, and an F1-score of 93.2%, indicating reliable identification of parking slots and their occupancy status. The average inference time for slot detection was approximately 35 milliseconds per image, enabling near real-time detection performance. The integration of the detection module with the navigation system allows detected parking slot centers to be used directly as target nodes for route computation as shown in Fig.3.

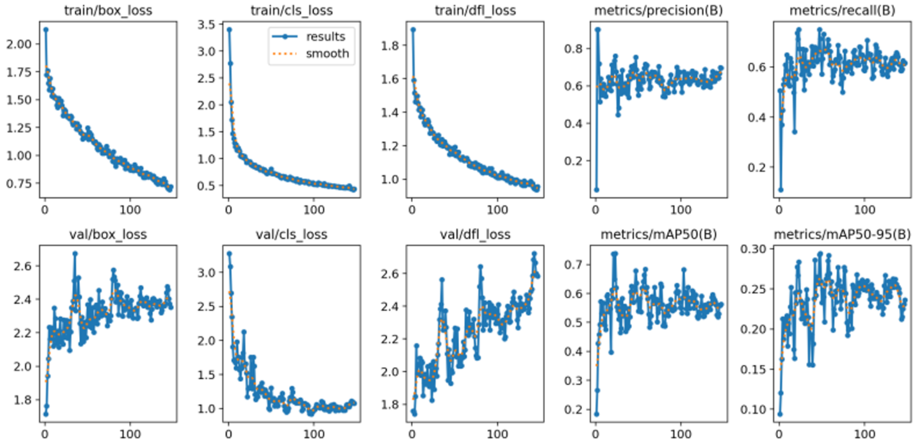

Fig. 3. Training and validation performance

4.3 Computational Efficiency and Real-Time Navigation

The efficiency with which the developed autonomous parking assistant was computed showed that it would be useful in real-life situations. The A-based path optimization algorithm optimized navigation paths in less than 200 milliseconds on average and adapted to real-time occupancy variations at high speed. Structured parking performance environments also experienced a cut of about 30 per cent in navigation time compared to heuristic methods, enhancing the driving experience. Navigation performance was evaluated by the percentage of successful route-generation attempts in which the A* algorithm produced a valid path from the parking entrance to the selected vacant slot, yielding an 87% success rate. In very congested situations, constraints were observed because dynamic slot availability caused delays in path recalibration. Nonetheless, with the appropriate utilization of caching and appropriate use of the previous slot data, the overall responsiveness was maintained. Finally, the study proves that the combination of YOLOv11 to detect slots and an effective pathfinding algorithm in the Designer of Streamlit can revolutionize city parking by increasing its working performance and human interface. The navigation accuracy metric has been clarified by defining it as the success rate of valid path generation using the A* algorithm. It is shown in Fig. 4.

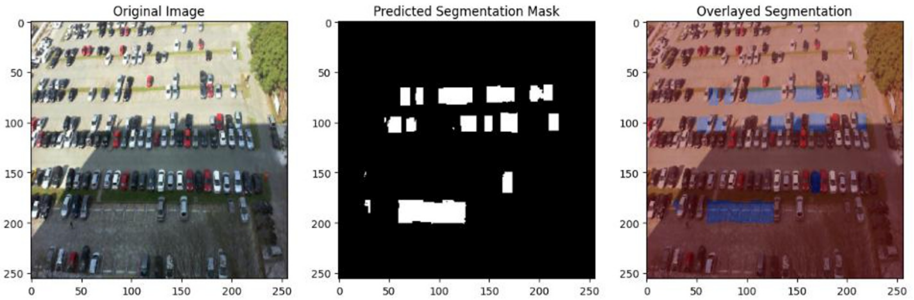

Fig. 4. Visual results of parking slot segmentation showing (a) original top-view parking image, (b) predicted segmentation mask, and (c) overlaid segmentation output highlighting detected parking slots.

5 Discussion

It is experimentally proven that the proposed autonomous car parking assistant is useful in combining vision-based parking slot detection and route optimization to address the majority of challenges in structured parking situations. The obtained outcomes of the qualitative and quantitative analyses testify to the fact that the implemented detection model successfully identifies parking slot locations and occupancy status in structured parking images used during system evaluation., including uneven lighting and shadows and partial overlaps. The great accuracy and recall that was obtained is a sign that the presented model discriminates well between the occupied and empty parking, which is of significant value in reducing false indication when parking assistance is available. The claim regarding performance under various environmental conditions has been moderated to reflect the conditions evaluated during testing as shown in Fig.5.

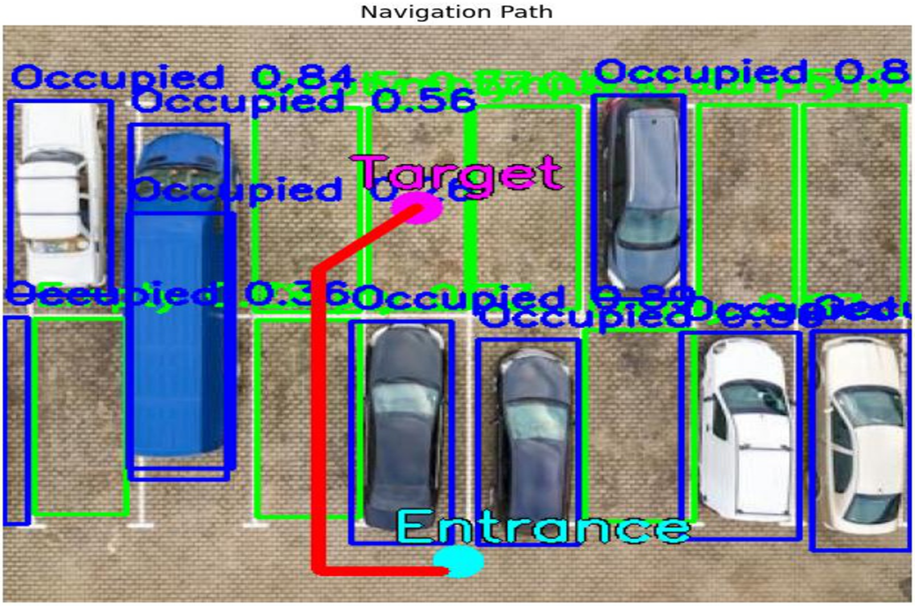

Fig. 5. Navigation path planning

The pictorial outputs also help enhance the effectiveness of the detection system. The segmentation masks and the superimposed detection outputs have a steady impact when it comes to identification with the actual parking slot borders such that top-view imagery is validated to organize parking analysis. Even though misclassifications were observed in cases with faded markings or heavy shadows, these were very few and far between and did not influence the overall performance of the system. This is not the only way that might introduce such errors; thus, we can still improve it by enhancing data augmentation or adopting an adaptive thresholding strategy as shown in Fig.6.

Fig. 6. Parking slot detection and occupancy classification

The amalgamation of the A*-based route optimization algorithm and the detection results proved effective at calculating efficient navigation routes between the entrance and the chosen vacant slots. Considering the occupied parking slots as an obstacle, the system is dynamically optimized to identify and avoid congested regions within its route of navigation. As observed from the reported decrease in navigation time using the heuristic techniques, the chosen pathfinding strategy can be successfully applied to structured parking layouts. But in extremely dense environments, the alterations in slot availability can be high and frequent, implying that an incremental or predictive planning method can further enhance responsiveness. Computationally, the system can be done in real time. The fact that the YOLOv11 model has low inference time enables quick delivery of occupancy updates, and the time required for route-selection calculations is acceptable for practical implementation. The Streamlit-based interface is maximally easy to use, as it allows for interaction between the visualization of the user's detection results and the interface navigation, bridging the gap between the algorithmic processing and the user. Although the Streamlit implementation focused on prototyping, its success demonstrates the applicability of this approach to work similarly to Streamlit in production systems.

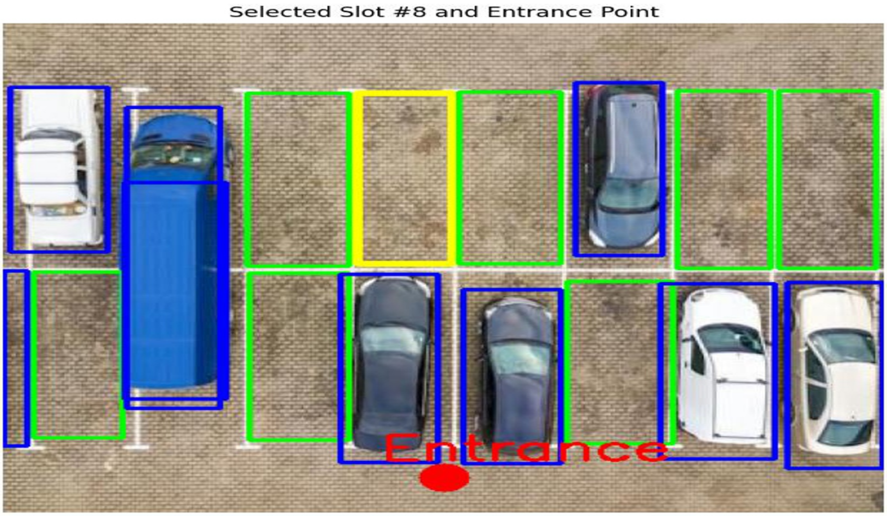

Fig. 7. Parking slot detection and occupancy classification

In comparison to the conventional sensor-based parking solutions, the proposed vision-based approach reduces the need for specialized sensing hardware because parking slot detection is performed directly from camera images processed by the object detection model. Since it removes a requirement on specialized sensing hardware such as ultrasonic sensors or LiDAR, the system can be implemented with very simple hardware requirements, in comparison with sensor-based parking assistance systems, the proposed vision-based approach reduces the need for additional sensing infrastructure because parking slot detection is performed directly from camera images processed by the object detection model. This simplifies system deployment by eliminating the need for hardware such as ultrasonic sensors or LiDAR. Although sensor-based may be more accurate in certain scenarios, the results prove that the suggested method is competitive with minimal implementations. The statement has been revised to remove unsupported cost estimates while still describing the practical benefit of camera-based detection systems. The Fig.7. shows parking slot detection.

6 Conclusion

This study presented a vision-based autonomous car parking assistant designed to improve parking efficiency in structured parking environments. The proposed system integrates computer vision–based parking slot detection with grid-based route planning to guide vehicles toward available parking spaces. A pretrained YOLO-based object detection model is used to analyze top-view parking images and detect parking slot locations along with their occupancy status. The model predicts bounding boxes for parking slots, and the centers of these bounding boxes are used as navigation targets for the routing algorithm.

To guide vehicles to a selected vacant slot, the system employs the A* pathfinding algorithm, which computes the shortest path from the parking entrance to the chosen slot in a grid representation of the parking layout. Occupied parking slots are treated as obstacles in the grid map, enabling the algorithm to generate efficient routes that avoid blocked locations. The entire workflow is implemented through an interactive Streamlit interface that allows users to upload parking lot images, visualize detection outputs, select available parking slots, and view the computed navigation path. Experimental evaluation demonstrated reliable parking slot detection with high precision and recall, while route computation was completed in a short response time suitable for interactive applications. Overall, the results demonstrate the feasibility of combining vision-based detection with pathfinding algorithms to support intelligent parking assistance systems in structured parking facilities.

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