Where Should I Park?
Real-time Detection of Parking Space Occupancy

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2023

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1 Abstract

In the face of escalating urbanization and its associated parking challenges, this paper proposes an innovative approach to enhance parking lot management and optimize space utilization, thereby mitigating urban parking difficulties. We initially experimented with the Yolo-Fastest V2 algorithm for real-time parking space detection. However, we observed that Yolo-Fastest V2 had shortcomings, particularly in terms of incomplete detection accuracy. This led us to develop a more robust approach using a modified ResNet model with transfer learning. This approach, diverging from traditional sensor-based methods, offers improved accuracy and cost-efficiency with less data need. Our comparative analysis between ResNet and YOLOv8 demonstrates the former's superior adaptability and performance in urban settings. This development significantly contributes to the smart city framework, improving parking efficiency and potentially easing traffic congestion.

Keywords: Urban Parking, Smart Cities, Deep Learning, Yolo-Fastest V2, ResNet, YOLO V8.

2 Project Background

Nowadays, rising vehicle numbers have exacerbated parking challenges. The quality of life in urban areas is increasingly impacted by traffic issues, particularly exacerbated by parking challenges. In addition, the search for parking spots contributes to congestion, further worsening the situation in cities and metropolitan areas (Carrasco et al., 2021). A common issue is time wasted searching for open spots, especially in urban areas with more vehicles than parking spaces. These problems stem from underutilizing available technologies. Oftentimes, parking spaces remain vacant due to poor management, leading to ineffective parking area use, traffic congestion, and jams.

Parking detection methods are mainly categorized into sensor-based and vision-based. Radar and sensors excel in adaptability and accuracy, yet susceptibility to false readings, expense, and complexity limits their use, especially in low-end lots. Vision, robust against interference and cost-effective, taps into existing infrastructure and leverages powerful convolutional neural networks (Xie & Wei, 2021), providing users with reliable guidance on available parking spaces. In a sensor-based setup, ultrasonic sensors are located in each parking space, relaying information to a display panel to guide the driver. However, this approach is hampered by substantial installation and maintenance costs. In contrast, vision-based systems offer clear advantages. Such systems eliminate the need for additional infrastructure and precisely identify empty spaces to help drivers navigate. Furthermore, vision-based approaches are particularly suitable for expansive outdoor environments, such as roadsides and residential parking lots, where deploying a large number of sensors is impractical.

Over the past decade, numerous studies have focused on creating an efficient automated parking slot occupancy detection system. While automated vehicle parking mechanisms exist, identifying vacant and occupied slots remains a key prerequisite (Dev et al., 2023). In the realm of car detection, deep learning has demonstrated remarkable advancements, surpassing traditional approaches. The use of deep learning-based methods for object classification has also garnered significant attention from researchers due to its consistently favorable outcomes (Naufal et al., 2020). Therefore, we use a variety of deep learning methods to detect the occupancy of parking spaces in the parking lot and compare their advantages and disadvantages, so as to improve the situation that the parking spaces are not fully utilized. This approach will power a strong parking occupancy detection system, capitalizing on the capabilities of advanced technology (Thakur et al., 2023).

3 Division of Roles & Responsibilities

Name	Role	Responsibility
Li Wenxuan	Group leader	Design overall program and write YOLO code for training and testing
Zhou Shipei	Group member	Preprocess data, write ResNet and parking space dectection code for training and testing
Tang Yujing	Group member	Employ OpenCV to display images in real-time while overlaying detection results
Zhang Xiang	Group member	Utilize the Yolo-FastestV2 model for car parking detection and parking space status assessment
Ma Jingchun	Group member	Summarize project contributions and analyze future technological developments
Xu Jianghui	Group member	Consult relevant literature and background description

4 Challenges & Solutions

Our main challenges were in achieving a rapid detection time while maintaining high detection accuracy. In practical application, this system needs to process real-time data. If it cannot meet real-time requirements, drivers won't receive timely updates. And if detection accuracy is low, there's a risk of misjudgment. Both scenarios significantly reduce the system's reliability.

In our initial attempt, we utilized the Yolo-FastestV2 model for car parking space and occupancy detection. This model maintains high computational speed in real-time scenarios, making it suitable for low hardware requirements. We employ a dataset called PKLot, comprising 12,416 images from various parking lots and weather conditions. By fine-tuning the Yolo-FastestV2 model and adjusting parameters to suit parking space detection features, the model exhibited promising predictive performance after 30 training epochs, as follows.

After that, we developed a real-time detection system. This system utilizes the OpenCV library to access the computer's camera, loads the pre-trained model, preprocesses captured images for inference, and finally employs OpenCV to display images in real-time while overlaying detection results. Practical

Table 1: Performance of FastestV2 after 30 training epochs

Parameters	Values
Accuracy	94%
Precision	84%
Recall	95%

results demonstrate that this real-time object detection system adeptly identifies parking spaces and vehicle information.

However, during the use of the Yolo-FastestV2 model, the problem of false detection and incomplete detection arose (as shown in Figure 1(b)), mainly attributed to the dataset's subpar quality. Consequently, we decided to explore alternative models suited for the task.

(a) (b)

Figure 1: (a)Good results (b)Incomplete detection of Yolo-FastestV2

Drawing on the experience with Yolo-FastestV2, we distilled this challenge down to a classification problem. This approach was justifiable given that in real-world applications, each car park has fixed parking spaces. As such, there is only a need to detect the car park's layout once, eliminating the necessity for intricate object detection tasks. Our primary challenge then became discerning whether a particular space is occupied or vacant. As a result, we employed a binary classification network to address this matter. Our overall approach is as seen in Figure 2:

Initially, traditional computer vision techniques are utilized to segment the images, identifying each individual parking space, and thus completing the parking space detection task. Through manual annotation, we generate labeled datasets of occupied and vacant parking slots. These images were then introduced as training data into a deep-learning classification network. The outcome was a binary classification network adept at detecting whether parking spaces are occupied or not. Ultimately, we superimposed these predictions onto the original image. The result provided the total number of parking spaces and the count of those available, achieving real-time parking space and occupancy detection.

The main process for parking space detection is shown in Figure 3. It begins with binarizing the image, thereby removing color information to produce a binary image. Subsequently, edge features are harnessed using Canny Edge Detection. A mask is then employed to demarcate the car park's boundaries. Finally, Hough Line Detection identifies all parking spaces, with segmentation processes revealing details of each individual space.

We extracted snapshots from the video and applied the image processing techniques to generate the dataset, which only contains nearly 500 photos. To assess the performance, we conduct a comparative experiment involving two models: ResNet He et al. (2016) and YOLO Terven & Cordova-Esparza (2023).

For the ResNet model, we employed transfer learning by fine-tuning a pre-trained ResNet trained on the ImageNet dataset using our own dataset. Similarly, for YOLO, it also serves as a binary classification

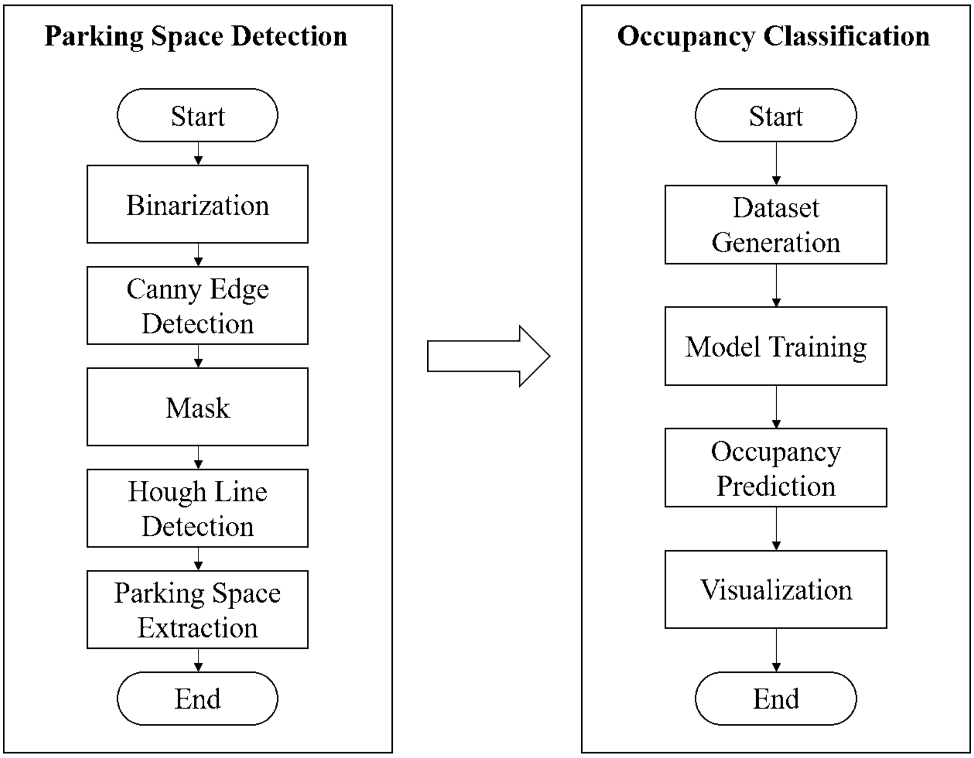

Figure 2: Overall Progress

model to determine whether the current parking space is available or not.

Our experiments were conducted on a server equipped with GPU RTX 3090(24GB) and 15 vCPU Intel(R) Xeon(R) Platinum 8358P. Figure 4 illustrates the accuracy, precision, and recall of both models.

Notably, the performance of both models exhibits a substantial degree of similarity, with ResNet slightly outperforming YOLO. The speed and accuracy of ResNet and YOLO are presented in the table below. From the Table 2, it can be observed that ResNet achieves higher accuracy compared to YOLO. Additionally, ResNet outperforms YOLO in terms of both training and testing time.

Table 2: Performance of ResNet + Transfer Learning and YOLO

Parameters	ResNet + Transfer Learning	YOLO
Training Time	5s/epoch	12s/epoch
Accuracy	98.7%	98.4%

From the table, it can be observed that ResNet achieves higher accuracy compared to YOLO. Additionally, ResNet outperforms YOLO in terms of both training and testing time. Therefore, we ultimately chose ResNet due to its superior accuracy and speed.

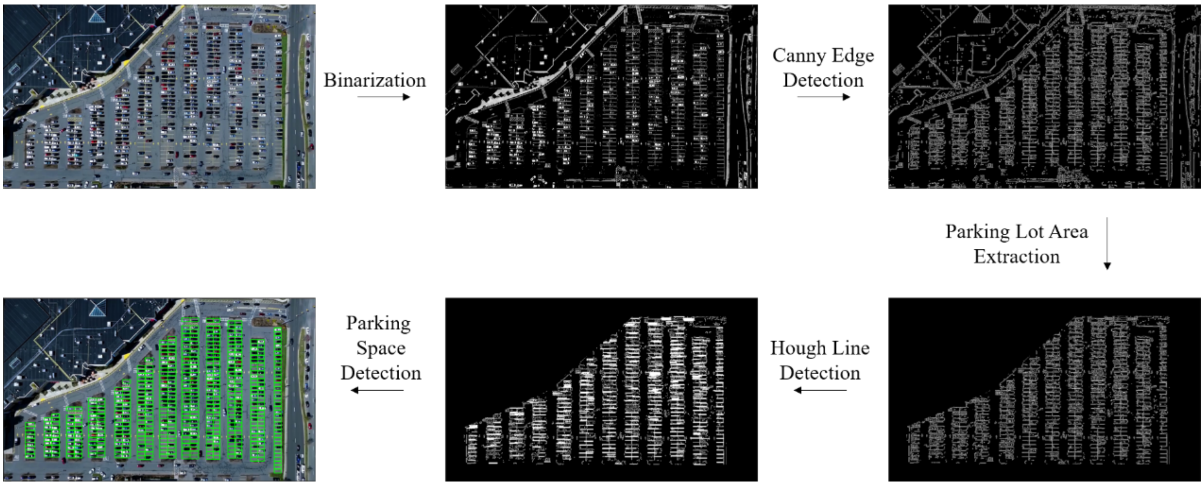

Figure 3: Parking Space Detection Progress

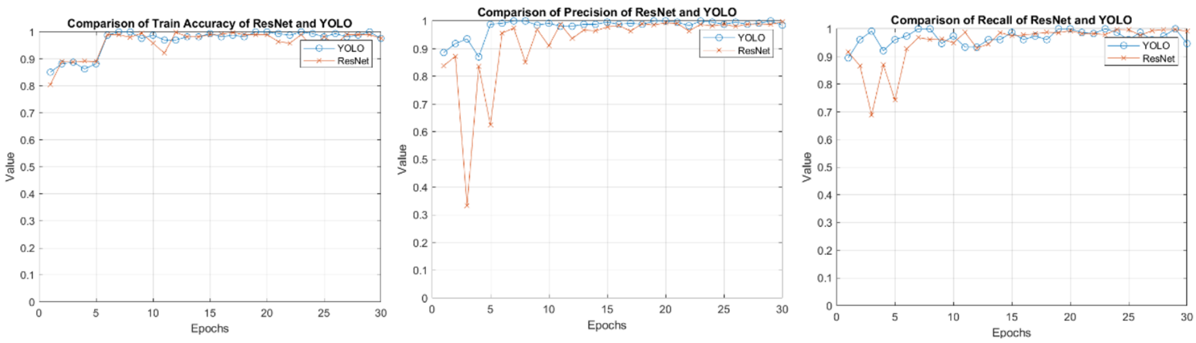

Figure 4: Evaluation of the Classification Network

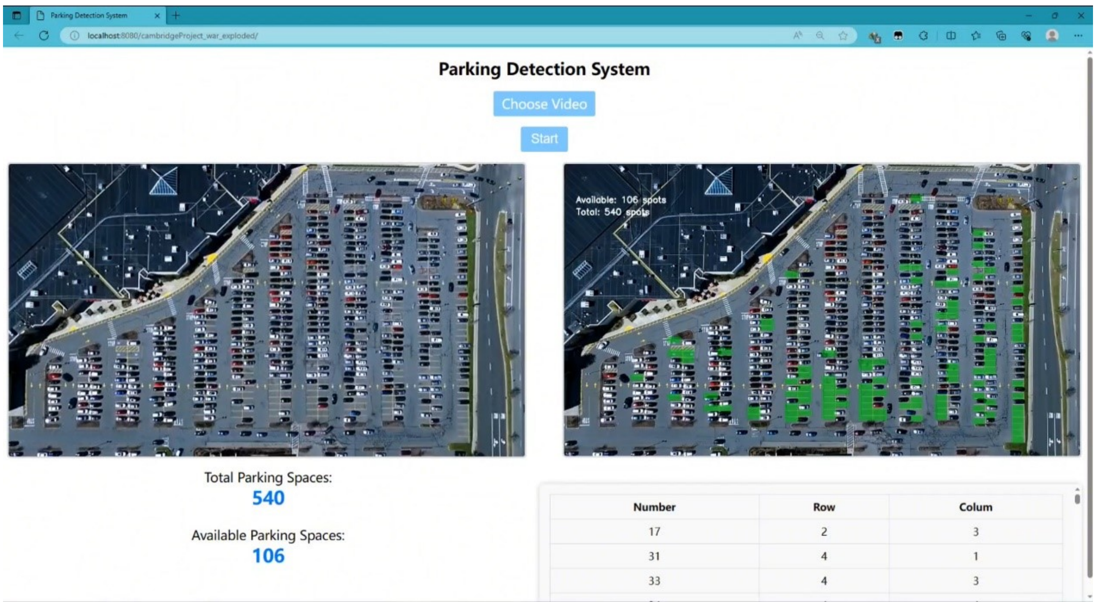

Figure 5: Graphical User Interface

Lastly, we utilized a Graphical User Interface (GUI) to showcase our results. By inputting video into the GUI, the system updates in real-time, automatically identifying the total number of parking spaces and the number of available spots and marking and outputting their respective numbers and coordinates on the video.

5 Contributions & Limitations

We developed a system that detects parking space occupancy in real-time. Our ResNet + Transfer Learning model boasts remarkable accuracy even with a minimal training dataset, and it trains at an impressive speed. Furthermore, we conducted comparative evaluations with the Yolo-FastestV2 object detection and YOLO classification algorithms. The results show that our method excels with the highest precision, combined with the shortest training and prediction time.

Our work offers real-time data on available parking spaces for car parks. This endeavor lays foundational work for the establishment of smart cities, significantly reducing the time taken to find parking and alleviating traffic congestion. By combining pretrained ResNet models with transfer learning, parking space detection algorithms gain significant benefits in various aspects.

1. Faster Convergence: Utilizing a pretrained ResNet model as an initial point for the transfer to the parking space detection task allows the model to possess feature extraction capabilities from the outset. This accelerates the convergence of the training process, saving time and computational resources.
2. Enhanced Feature Representation: Pretrained on ImageNet, ResNet learns rich image features. Applying these generalized features to parking space detection aids in capturing complex features of vehicles and parking spaces, thereby improving detection accuracy and stability.
3. Limited Annotation Data: Given the potential challenge of obtaining ample labeled parking data, transfer learning allows for the fine-tuning of the pretrained ResNet model on a smaller annotated dataset, overcoming data scarcity issues.
4. Improved Generalization: The strong generalization ability of a pretrained ResNet model helps the algorithm adapt to different parking space scenarios, lighting conditions, and scales, enhancing the algorithm's adaptability.
5. High-Precision Detection: ResNet's prowess in mitigating the vanishing gradient problem in deep networks, combined with its fine-grained image feature extraction, enables the model to accurately distinguish parking spaces from other objects in parking space detection tasks.

In summary, the integration of transfer learning and ResNet brings forth faster training speeds, superior feature representation, heightened generalization ability, and increased detection accuracy to parking space detection algorithms, effectively addressing the challenges of the task.

Nevertheless, limitations persist. Occlusion and shadows resulting from parked vehicles obstruct other parking spaces, posing challenges for computer vision in determining occupancy. Real-time demands are crucial, yet some mobile devices lack the necessary computational power, possibly falling short of real-time requirements.

In the future, one of our goals is to use our model in more and different kinds of situations. With a focus on finding cars in parking lots, we want to use our technology in many different ways. One interesting idea is to identify parking spaces that are different sizes for different kinds of cars. By using our experience in detecting vehicles, we hope to create a future where drivers can easily find parking spaces that are just right for their cars. This not only makes things easier but also makes better use of parking spaces, which is especially important in busy cities.

Also, we are dedicated to making the most of the potential of light models so that they can be easily integrated into mobile devices. The possibility of finding a parking spot in real-time while using navigation adds another level of ease for drivers and makes parking a breeze. Imagine mobile apps that tell drivers exactly where to park by giving them correct information about available spaces.

Author Contributions
Design overall program, preprocess data, and write code for training and testing: W.L. and S.Z.; Employ OpenCV to display images in real-time while overlaying detection results: Y.T.; Utilize the Yolo-FastestV2 model for car parking detection and parking space status assessment: X.Z.; Summarize project contributions and analyze future technological developments: J.M.; Consult relevant literature and background description: J.X.

Funding
This research received no external funding.

Research Guidelines
This study has followed the research guidelines of Deep Learning and Neural Networks, Cambridge Programme 2023.

Informed Consent Statement
Not Applicable.

Data Availability
Please contact the corresponding author for all reasonable requests for access to the data.

Acknowledgments
We would like to give our thanks to our faculty professors and teachers at Cambridge University for their guidance.

Conflicts of Interest
The authors declare no conflict of interest.

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