Automatic Vacant Parking Places Management System Using Multicamera Vehicle Detection

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***Abstract*—— Managing vacant parking spaces efficiently is crucial for smart city applications. This paper tackles the challenge by introducing a deep neural network approach for detecting parking occupancy. For large parking areas, using a single high-mounted camera offers an effective way to monitor the entire space. To achieve this, we leveraged the well-known YOLO object detection model, which is recognized for its high precision and real-time speed. We propose a modified, lightweight version of the YOLO-v5 architecture tailored for parking management. Our model is designed to detect vehicles of various sizes, from large trucks to small cars, using a multi-scale learning mechanism. This approach enables the model to learn detailed, discriminative features across different scales. By optimizing the architecture, we reduced the number of trainable parameters from 7.28 million in YOLO-v5S to 7.26 million in our model while significantly boosting precision. Our model achieves a detection speed of 30 frames per second (fps) and outperforms the larger YOLO-v5-L and YOLO-v5-X versions, particularly excelling in detecting small vehicles, with a 33% improvement compared to YOLO-v5-X. Experimental results demonstrate that our approach is both efficient and accurate, making it a promising solution for managing parking spaces autonomously in smart cities.**

***Keywords*--It deals with smart parking management, parking occupancy detection, YOLO-v5 architecture, deep neural networks, smart cities, vehicle detection, cenital-plane camera, real-time object detection, multi-scale mechanism, tiny vehicle detection, deep learning applications, parking space optimization, computer vision, traffic optimization, machine learning models for parking, low-end terminals deployment, parking resource management, modified YOLO-v5 model, autonomous parking systems, and urban mobility solutions.**

I. INTRODUCTION

With the rapid growth of urban populations, managing city resources has become increasingly challenging. This has led to the concept of "smart cities," which focus on optimizing resource management and leveraging data to improve urban living. One of the key challenges in large cities is enhancing the driving experience, including better traffic control, effective surveillance, and smarter parking guidance systems. These improvements aim to make urban mobility smoother and more efficient.

One of the most frustrating and time-consuming tasks for drivers is finding a parking spot. It's estimated that drivers travel several extra kilometers each year searching for available spaces, which not only wastes time but also contributes to environmental pollution. Additionally, inefficient parking management in large lots, especially near popular spots, can worsen traffic congestion, creating a ripple effect of inefficiency and increased emissions.

Traditionally, sensors have been used in individual parking spots to detect availability. However, these solutions have their limitations. For instance, magnetometer-based sensors suffer from reduced battery life as accuracy demands increase, and modern vehicles often lack the ferromagnetic parts these sensors rely on.

Recent advances in computer vision and deep learning offer a more efficient alternative: smart cameras capable of monitoring multiple parking spots simultaneously. These systems provide a cost-effective solution to parking occupancy detection. While some studies have successfully tackled the problem of identifying available spots using images, many of these methods lack adaptability. A solution that works in one parking lot often doesn't translate well to another, making generalization a significant challenge.

Most current approaches classify parking spot occupancy rather than detecting vehicles directly. While this method can achieve good precision, it falls short in providing additional insights, such as information about road congestion, interactions between vehicles and pedestrians, or instances where a single car occupies multiple spaces. By using vehicle detection instead of spot classification, it's possible to gather richer, more actionable data that can significantly improve the overall parking management system in smart cities.

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II. RELATED WORK AREA

The work of **M. A. Merzoug, A. Mostefaoui, G. Gianini, and E. Damiani** titled "Smart connected parking lots based on secured multimedia IoT devices" focuses on integrating Internet of Things (IoT) technologies with multimedia systems to create efficient, secure, and smart parking solutions.

The work by **A. Farley, H. Ham, and Hendra** titled "Real-time IP camera parking occupancy detection using deep learning" focuses on leveraging deep learning techniques to analyze video feeds from IP cameras for parking occupancy detection.

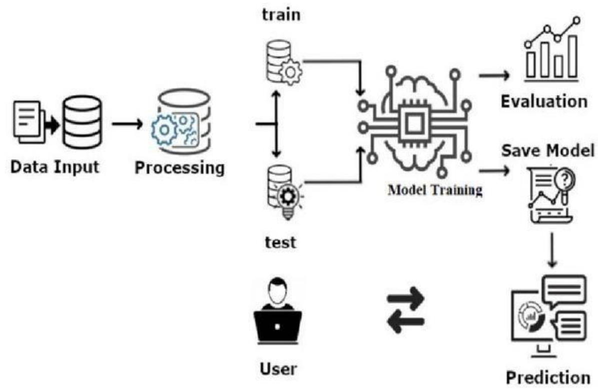
The work of **M. Farag, M. Din, and H. Elementary** titled "Deep learning versus traditional methods for parking lots occupancy classification" explores the effectiveness of deep learning techniques compared to conventional methods for detecting parking lot occupancy.

The work by **O. Cats, C. Zhang, and A. Nissan** titled "Survey methodology for measuring parking occupancy: Impacts of an on-street parking pricing scheme in an urban center" focuses on assessing parking occupancy in urban environments, particularly in the context of on-street parking and pricing schemes. While their research primarily addresses survey methods rather than technological solutions, it has relevant implications for systems like automatic vacant parking space management using multi-camera vehicle detection.

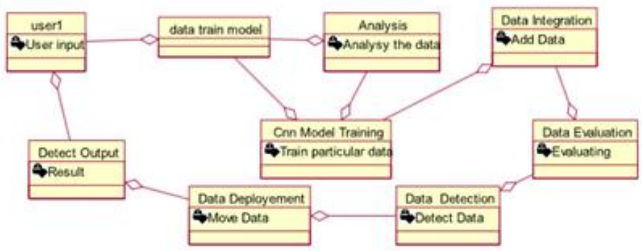
III. METHODOLOGY

Research methodologies employ an iterative approach to develop an effective system for parking occupancy detection via a modified YOLOv5 model. It entails an input consisting of preliminary dataset preparation, which organizes, preprocesses, and refines the data to train and analyse it. Later steps include data analysis, for which statistical methods and graph plotting techniques are used to glean desirable insights. The training of the CNN model uses Convolutional Neural Networks to process the image recognition and vehicle classification, while YOLO model training is focused on customizing the YOLO-v5 architecture for detecting parking occupancy and identifying different sizes of vehicles. Data integration is carried out by integrating diverse datasets into a single structure to enhance model efficiency. Evaluation and tuning will evaluate the performance of the model to optimize its parameter so as to achieve maximum precision on small vehicle detection after it is trained. It applies in data detection for object real-time detection and anomaly identification with real-time data deployment making the deployed model integrate all trained parameters to the real-life scenario hence offering a more scalable and efficient solution for managing smart parking application. This approach has underlined the efficiency in using computation power, accuracy, and flexibility for leveraging deep learning techniques towards addressing urban challenges.

SYSTEM ARCHITECTURE

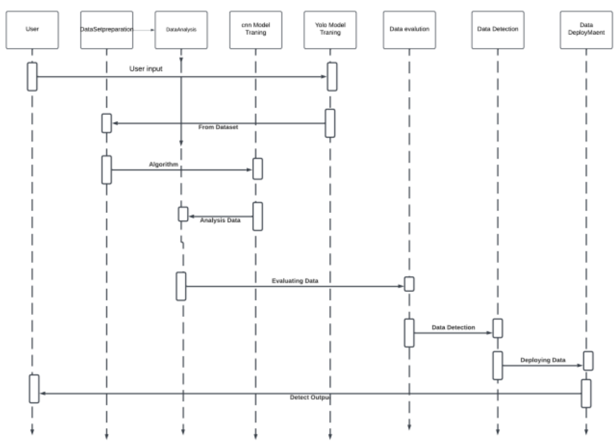


Class diagram



The diagram appears to be a process flow or system design diagram representing the pipeline for training and deploying a Convolutional Neural Network model. The diagram illustrates a complete lifecycle for training, evaluating, and deploying a machine learning model, emphasizing iterative refinement and data flow.

Sequence diagram



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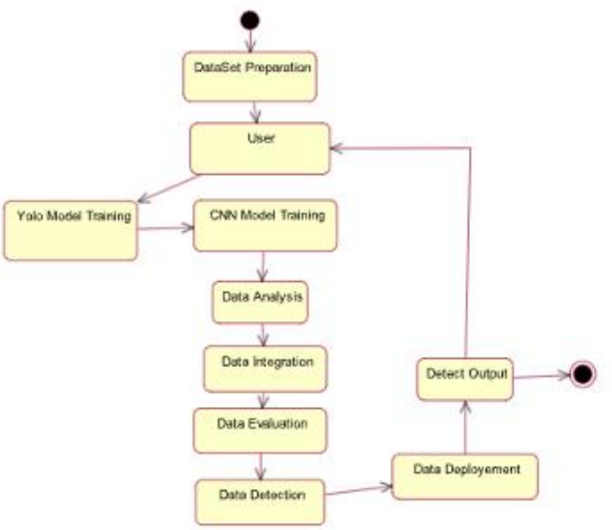
This diagram is a **sequence diagram** that outlines the process flow of a machine learning pipeline, from user input to model deployment. It is divided into several vertical lanes, each representing a key phase of the pipeline. The process begins with the **User** providing input, which is then passed to the **Dataset Preparation** stage, where the data is cleaned, selected, and made ready for analysis. In the **Data Analysis** phase, the dataset is analyzed to extract useful insights, ensuring its readiness for model training.

State diagram



This diagram represents a flowchart of a machine learning pipeline, showcasing the steps involved in training, evaluating, and deploying models. The process begins with **Dataset Preparation**, where raw data is collected and prepared for analysis. From there, the data flows to the **User**, who provides inputs or configurations to initiate the next stages of the pipeline.

IV. RESULT AND ANALYSIS

From the results and analysis of this paper, robust modifications made in the YOLOv5 model for the identification of small vehicles in huge parking spaces are highlighted. These include the following:

Improved Precision:
The modified YOLO-v5 model obtains a precision of 96.34%, which is significantly improved over the baseline YOLO-v5 model's 63.87%. This proves that the model works effectively in detecting tiny vehicles, which are smaller in size.

Efficient Model Design:
The proposed model reduces trainable parameters from 7.28 million (YOLO-v5-S) to 7.26 million while maintaining accuracy, making it computationally efficient.

Detection Speed:
The system operates at a detection speed of 30 frames per second (fps), ensuring real-time application viability.

Enhanced Performance:
The model outperforms YOLO-v5-L/X profiles in precision and improves the detection performance of tiny vehicles by 33% over the YOLO-v5-X profile.

Multi-Scale Mechanism:
Incorporating a multi-scale mechanism enables the model to learn discriminative feature representations across various scales, crucial for accurately identifying vehicles of different sizes in complex environments.

Adaptability and Scalability:
The model's adaptability to specific real-world parking scenarios and its scalability for use in different urban environments make it a practical solution for smart cities.

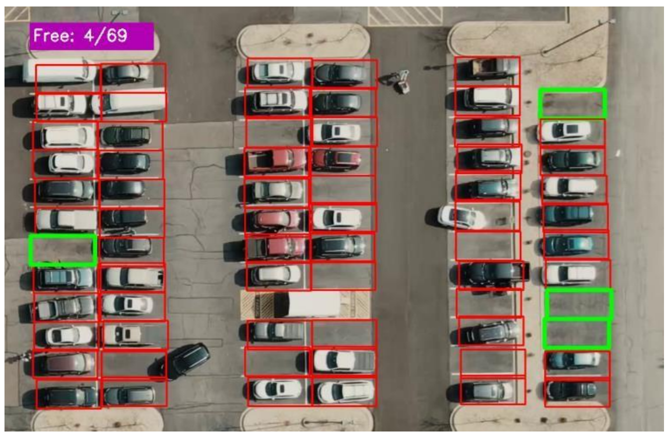
Future Potential:

The study emphasizes ongoing work on integrating this detection system into low-end devices such as NVIDIA Jetson Nano for efficient deployment in real-time parking management scenarios.

INPUT IMAGE

The image depicts an aerial view of a parking lot with rows of parked cars. The arrangement of the cars is organized in a grid-like pattern, with clear lines demarcating each parking space. Some spaces are occupied by cars, while others remain vacant. The overall scene is one of a busy parking lot with a mix of occupied and unoccupied spaces.

OUTPUT IMAGE



The parking lot was divided into a grid of parking spaces. Each space was outlined in red, indicating an occupied spot, or green, signifying a vacant spot. This color-coded system allowed drivers to quickly identify available parking spaces and find the perfect spot with ease.

V. CONCLUSION

In summary, we improved the YOLO-v5 model to better detect tiny cars in overhead parking lot images. Our modified model achieved higher accuracy (96.34% precision) than the original YOLO-v5 (63.87%). It also slightly improved overall performance while maintaining efficiency. We plan to further enhance this model by integrating it with a tracking system and deploying it on low-cost hardware for real-time parking monitoring.

VI. FUTURE SCOPE

The future scope of this project involves several advancements to enhance its impact on smart city applications. It can integrate with broader smart city ecosystems, including traffic management systems and autonomous vehicles, creating a seamless urban mobility experience. The system's adaptability can be improved for deployment on low-power edge devices like NVIDIA Jetson Nano or FPGAs, enabling real-time, on-site processing. Future enhancements could focus on robust detection under challenging conditions, such as varying lighting, weather, and occlusions, making it versatile across diverse environments. Additionally, integrating the system with payment, reservation platforms, and mobile applications can improve user convenience by providing real-time parking availability and reducing congestion. The data generated by the system can offer predictive insights for urban planning, optimizing parking facilities and resource allocation. Extending the framework to other applications, like traffic density monitoring and surveillance, and incorporating advanced AI techniques for better accuracy and efficiency, further broadens its utility. Finally, by reducing search times for parking, the project supports environmental sustainability, minimizing emissions and fuel consumption. These advancements position the system as a pivotal solution in addressing modern urban challenges.

VII. REFERENCE

[1] M. A. Merzoug, A. Mostefaoui, G. Gianini, and E. Damiani, "Smart connected parking lots based on secured multimedia IoT devices," Computing, vol. 103, no. 6, pp. 1143–1164, Jun. 2021.

[2] A. Farley, H. Ham, and Hendra, "Real time IP camera parking occupancy detection using deep learning," Proc. Compute. Sci., vol. 179, pp. 606–614, Jan. 2021.

[3] M. Farag, M. Din, and H. Elementary, "Deep learning versus traditional methods for parking lots occupancy classification," Indonesian J. Elect. Eng. Compute. Sci., vol. 19, pp. 964–973, Aug. 2020.

[4] T. Ridnik, H. Lawen, A. Noy, E. B. Baruch, G. Sharir, and I. Friedman, "TResNet: High performance GPUdedicated architecture," 2020, arXiv:2003.13630.

[5] C. Kumar B., R. Punitha, and Mohana, "YOLOv3 and YOLOv4:
Multiple object detection for surveillance applications," in Proc. 3rd Int. Conf. Smart Syst. Inventive Technol. (ICSSIT), Aug. 2020, pp.

[6] S. J. Faraji and M. J. Naozar, "Smart parking: An efficient approach to city's smart management and air pollution reduction," J. Air Pollut. Health, vol. 4, no. 1, pp. 53–72, Feb. 2019.

[7] S. Liu, L. Qi, H. Qin, J. Shi, and J. Jia, "Path aggregation network for instance segmentation," in Proc. IEEE/CVF Conf. Compute. Vis. Pattern Recognise., Jun. 2018, pp. 8759–8768.

[8] T. Lin, H. Rivano, and F. Le Mouël, "A survey of smart parking solutions," IEEE Trans. Intell. Transp. Syst., vol. 18, no. 12, pp. 3229–3253, Dec. 2017.

[9] G. Amato, F. Carrara, F. Falchi, C. Gennaro, C. Meghini, and C. Vairo, "Deep learning for decentralized parking lot occupancy detection," Expert Syst. Appl., vol. 72, pp. 327–334, Apr. 2017.

[10] H. Zhang, M. Cisse, Y. N. Dauphin, and D. Lopez-Paz, "Mixup:
Beyond empirical risk minimization," 2017, arXiv:1710.09412.

[11] O. Cats, C. Zhang, and A. Nissan, "Survey methodology for measuring parking occupancy: Impacts of an on-street parking pricing scheme in an urban center," Transp. Policy, vol. 47, pp. 55– 63, Apr. 2016.

[12] S. Ren, K. He, R. Girshick, and J. Sun, "Faster R-CNN: Towards realtime object detection with region proposal networks," 2015, arXiv:1506.01497.