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Real-Time Vacant Parking Spot Detection Using Multi-Camera Technology

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ABSTRACT: In smart city applications, efficient management of vacant parking spaces is crucial. This study addresses the challenge by utilizing a deep neural network for parking occupancy detection. For large parking areas, a central plane camera positioned at a high vantage point is optimal for monitoring the entire space with a single camera. Leveraging the popular YOLO object detection model, known for its high precision and real-time speed, we propose a modified, lightweight deep object detection model based on the YOLO-v5 architecture. Our model is tailored to detect objects of various sizes, from large to tiny vehicles, by incorporating a multi-scale mechanism that learns deep discriminative feature representations at different scales. This modification reduces the number of trainable parameters from 7.28 million (YOLO-v5-S) to 7.26 million in our model, while improving precision significantly. The proposed model achieves a detection speed of 30 fps, outperforming the YOLO-v5-L/X profiles, and enhances tiny vehicle detection performance by 33% compared to the YOLO-v5-X profile. Experimental results confirm the efficiency and accuracy of our approach, making it a viable solution for automated parking space management in smart cities.

KEYWORDS: Smart City Applications, Parking Space Management, YOLO Object Detection Model, Deep Neural Network

I. INTRODUCTION

The ever-increasing city population has reached a point where the management of city resources has become a critical and important problem for large cities. In fact, to address the management of resources, the concept of a smart city has been coined for city resource data exploitation. One of the biggest challenges of large cities is the improvement and enhancement of driving experience traffic control, surveillance, or parking guidance, which can help improve the mobility experience in these cities. Following this objective, one of the most time-consuming processes for drivers is finding a parking spot. A driver will travel extra kilometers per year to find an available slot, which not only has a direct impact on the drivers time consumption but also on environ mental pollution.In addition, in large parking, where the most desired spots are usually concentrated, it will yield inefficient traffic, which will again contribute to worsening the problem. This problem was managed using sensors in each parking spot to detect the spot occupancy. However, magnetometer based parking sensors rapidly decrease the battery life with increasing accuracy requirements. In addition, modern vehicles often do not have ferromagnetic parts. Thus, the progress in computer vision and deep learning makes it possible to use smart cameras to control several parking spots and provide much cheaper solutions for the parking occupancy problem. In fact, the problem of finding available parking spots given an image has been addressed in several studies [5] [8].How ever, these techniques cannot be generalized, and even the adaptation of a specific solution to a different parking lot is not possible in many cases. Thus, vacant parking space detection based only on visual information remains a challenge for researchers. Most of these solutions use a simpler approach to determine the occupancy of each parking spot by detecting the availability of a parking spot through spot classification [9] [11] instead of localizing vehicles using object detection techniques and determining if their positions are over parking spots .Although these approaches can achieve good precision scores, they lack the possibility of extracting potential information about cars (i.e., road congestion, human interactions with cars, single car occupying two spots, etc.). Only by using a vehicle detection approach can we obtain information that cannot be obtained using a parking spot classification approach.

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II. LITERATURE SURVEY

S. C. K. Tekouabou et. al (2022)Smart cities are part of the ongoing advances in technology to provide a better life quality to its inhabitants. Urban mobility is one of the most important components of smart cities. Due to the growing number of vehicles in these cities, urban traffic congestion is becoming more common. In addition, finding places to park even in car parks is not easy for drivers who run in circles. Studies have shown that drivers looking for parking spaces contribute up to 30% to traffic congestion. In this context, it is necessary to predict the spaces available to drivers in parking lots where they want to park. We propose in this paper a new system that integrates the IoT and a predictive model based on ensemble methods to optimize the prediction of the availability of parking spaces in smart parking. The tests that we carried out on the Birmingham parking data set allowed to reach a Mean Absolute ErrorMean Absolute Error (MAE) of 0.06% on average with the algorithm of Bagging Regression (BR). This results have thus improved the best existing performance by over 6.6% while dramatically reducing system complexity.

M. A. Merzoug et. al(2021)In this paper, we present a smart connected parking lots solution to automatically count and notify drivers about empty parking spots in major cities. As its name implies, the proposed smart IoT system has two operating phases: (i) continuous counting of empty spots in the monitored far-apart parking lots, and (ii) instantaneous driver notification through a lightweight MQTT mechanism. This notification system relies only on information collected from the pre-installed multimedia devices (no other apparatus installation or maintenance such as ground sensors is required). To validate the proper operation of our solution, we have implemented a small-scale version of it and assessed its performance while considering different classical and lightweight deep learning techniques (MobileNetV2, ResNet-50, YOLOv3, SSD-MobileNetV2, Tiny-YOLO, SqueezeDet, and SqueezeDet pruned with ℓ1-norm). The experiments have confirmed the proper operation, efficiency, ease of deployment, and ease of extension of our system. They also confirmed that lightweight deep learning solutions are more adequate for small-sized resource-constrained embedded systems. They are more efficient in terms of inference time, size, resource consumption, and yield an accuracy that is close to that of classical solutions.

M. dos Santos de Arruda et.al(2021)This paper presents a Convolutional Neural Network (CNN) approach for counting and locating objects in high-density imagery. To the best of our knowledge, this is the first object counting and locating method based on a feature map enhancement and a Multi-Stage Refinement of the confidence map. The proposed method was evaluated in two counting datasets: tree and car. For the tree dataset, our method returned a mean absolute error (MAE) of 2.05, a root-mean-squared error (RMSE) of 2.87 and a coefficient of determination (R2) of 0.986. For the car dataset (CARPK and PUCPR+), our method was superior to state-of-the-art methods. In the these datasets, our approach achieved an MAE of 4.45 and 3.16, an RMSE of 6.18 and 4.39, and an R2 of 0.975 and 0.999, respectively. The proposed method is suitable for dealing with high object-density, returning a state-of-the-art performance for counting and locating objects.

Existing System

This work aims to develop real-time and lightweight vehicle detection for different vehicle scales based on advanced convolutional neural networks (CNNs) for large parking with a particular camera with a cenital plane view and many parking spots. This camera configuration is highly desired because locating the camera at high heights with a proper view of the parking allows the monitoring of the entire parking with just one camera (as shown in Fig. 1). Moreover, using such a system will have the capability to extract extra information about the detected vehicles, such as color, brand, trajectory, in future upgrades, if desired.

Proposed System

YOLO-v5 is a deep detection model that focuses on low parameters and high frames-per-second (fps) inference to be fit in low-end terminals, we must ensure that the changes in the model do not significantly affect this aspect.YOLO network contains many layers that connect with each other. The operations performed in each step can summarise the YOLO-v5 network into three different sections. The first section, the backbone (i.e., called cspdarknet [23]), is composed, in the case of Yolo-v5, of the most common operations in CNNs (e.g., convolutions, concatenations, maxpooling) and a simple forwarding mechanism that is constructed to extract multiple features for the next section. The concept of the backbone is a common and old topic in multiple deep learning networks of object detection and is used as a simple base network.

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System Architecture

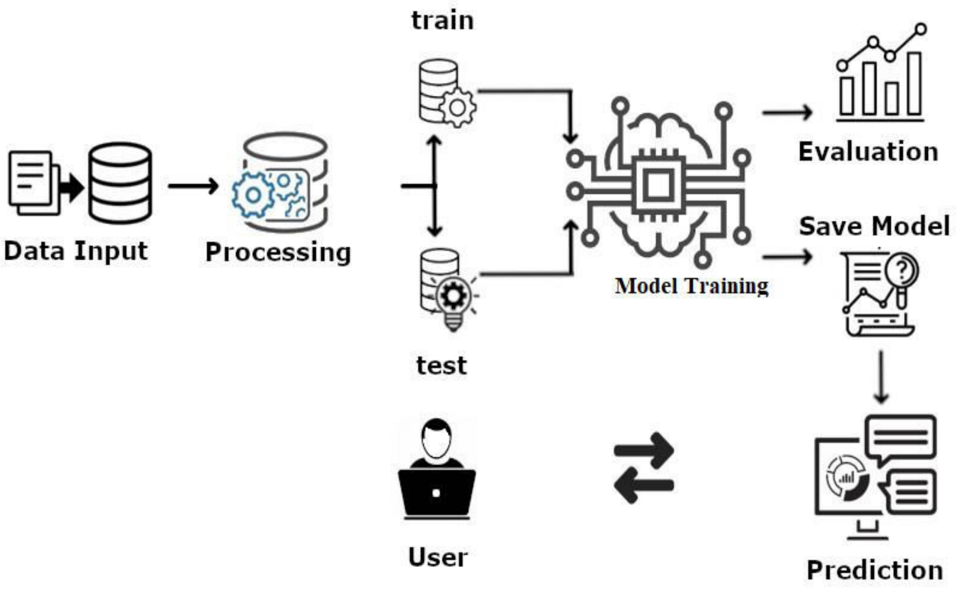

Fig 1: System Architecture

This figure provides a simplified overview of the machine learning process, which is often more complex in real-world scenarios. However, it captures the core steps and concepts involved in building and deploying machine learning models. The image depicts a typical Machine Learning Pipeline. It illustrates the steps involved in building and deploying a machine learning model, starting from data input to making prediction

III. METHODOLOGY

Modules:

1. Data Set Preparation:
This involves organizing and cleaning data to make it suitable for analysis or training models.

2. Data Analysis:
Analyzing data to gain insights or make decisions based on statistical methods and visualization techniques.

3. CNN Model Training:
Training Convolutional Neural Network (CNN) models, which are commonly used for image recognition and classification tasks.

4. YOLO Model Training:
Training You Only Look Once (YOLO) models, a type of object detection model used in computer vision applications.

5. Data Integration:
Combining data from multiple sources or formats into a unified dataset for analysis or modeling.

6. Data Evaluation & Fine-Tuning:
Assessing the performance of models or algorithms and making adjustments to improve their accuracy or effectiveness.

7. Data Detection:
Using trained models to identify or detect objects, patterns, or anomalies within data.

8. Data Deployment:
Implementing models or solutions into operational environments for real-world use, often involving software development and deployment processes.

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IV. IMPLEMENTATION

Convolutional Neural Network. It's a type of artificial neural network primarily used for analyzing visual imagery. Imagine it as a specialized architecture inspired by the biological processes in a human brain that helps computers understand and interpret visual data. CNNs use a mathematical operation called convolution, which involves passing a filter or a kernel over the input image to extract different features. These features could be edges, shapes, textures, or more complex patterns. By using multiple convolutional layers along with pooling layers to reduce dimensionality and prevent overfitting, CNNs can learn hierarchical representations of the input data.

V. EXPERIMENTAL RESULTS

This Paper is implements like application using python and the Server process is maintained using the SOCKET & SERVERSOCKET and the Design part is played by Cascading Style Sheet.

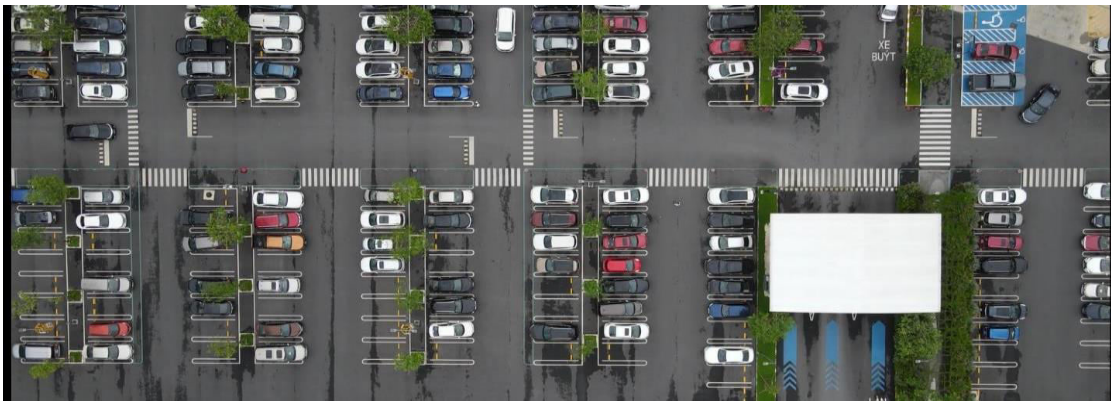

Fig 2: Parking Lot Aerial

The Snapshot Represents An Aerial View Of A Parking Lot With Clearly Marked Parking Spaces, Some Of Which Are Vacant. This Setup Can Be Integrated Into A Multi-Camera Vehicle Detection System For Managing Vacant Parking Spots.

Fig 3: Birds eye view of parking

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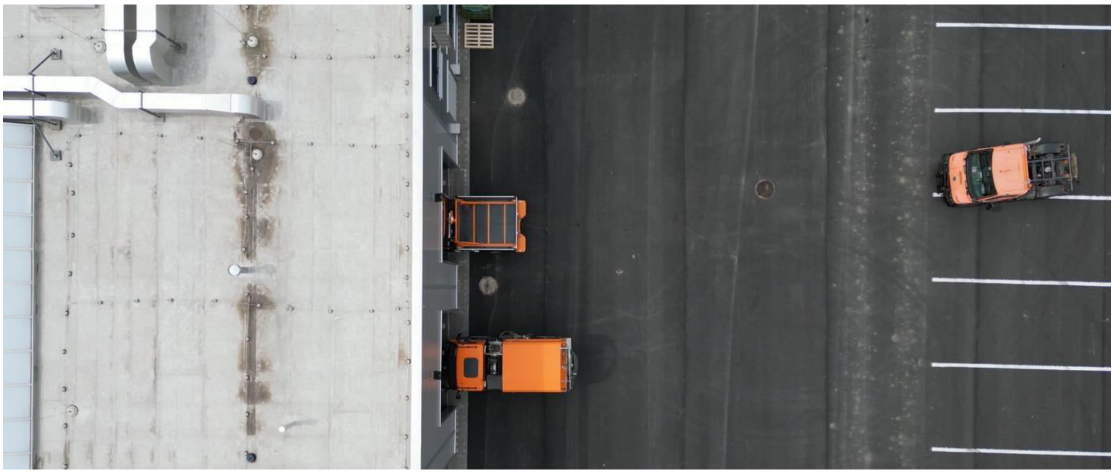

Fig 4: Top – Down view of Parking Lot

The snapshot depicts a section of a parking lot or facility with several service vehicles (likely maintenance or cleaning vehicles). In the context of a vacant parking place management system using multi-camera vehicle detection, the scene offers the following insights.

Fig: 5 Aerial View

The image appears to show an aerial view of a parking lot, with some vacant and occupied spaces. In the context of parking management using multi-camera detection, here are key insights on how such a system might operate.

VI. CONCLUSION

In this study, we proposed a reliable modification of the YOLO-v5 model targeting tiny car objects from a cenital view. Using a multi-scale module and channel/spatial attention mechanisms, the modified version outperformed the original YOLO-v5 for this specific application with a precision of up to 96,34% compared to a precision of 63,87% with the baseline YOLO-v5 model. The proposed model also slightly improved the Recall and mAP values while maintaining the same number of trainable parameters. In addition, the adapted variation yields a decrease in speed compared to the small and medium profiles of the YOLO-v5 network, although it exceeds the large and extreme profiles. On the other hand, the single-branch solution outspeeds the Yolo-v5 small profile and was almost as precise as the multi-branch solution. Ongoing work aims at developing a reliable tracker based on the developed detector. Future work aims to use

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the developed detector and tracker in low-end terminals, such as a Field-Programmable Gate Array (FGPA) or an NVIDIA Jetson Nano Developer Kit for real-time parking monitoring.

VII. FUTURE ENHANCEMENT

Tiny Vehicle Detection using YOLO and Multi-Scale Convolutional Neural Networks, is a smart system designed to spot vehicles accurately and quickly. It's like having a super-fast eye that can recognize cars, trucks, and other vehicles on the road. This system has been improved to work even better than before. It can spot vehicles in different lighting and weather conditions and even if they're partially hidden. Plus, it's small and doesn't need a lot of computer power, making it handy for all sorts of devices, from smart phones to smart cameras on roads.

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