
Literature Review Application of YOLO Algorithm for Detection and Tracking

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ABSTRACT

A vehicle tracking system is a computer program that utilizes devices to monitor the position, movement and condition of a vehicle or fleet of vehicles. Multi-vehicle tracking on highways has significant research interest and practical value in building intelligent transportation systems. Nevertheless, traffic road video frames consist of various complex backgrounds and objects. Detection and tracking are very challenging because foreground to background switching occurs frequently. One-stage algorithm approaches such as YOLO and its various variants have been proven to be accurate for detecting vehicles. Meanwhile, the SORT, DeepSORT, ByteTrack and other algorithms can be combined in YOLO. The aim of this study is to highlight existing research on the application of YOLO and its variants in detecting and tracking vehicles, especially in traffic management. The journals used are limited to 2019 – 2024 and the journal sources consist of Hindawi, IEEE, MDPI, Research Gate, Science Direct, and Springer. Based on the research that has been reviewed, the YOLO variant algorithm approach has been successfully applied in the field of vehicle monitoring to support smart cities. In addition, many new model combinations and improvements have been proposed, proving that this algorithm has a big influence in the field of computer vision.

Keywords: Tracking; Detection; YOLO; Smart City; Vehicle

1. INTRODUCTION

In recent years, advances in sustainable intelligent transportation have emphasized the importance of vehicle detection and tracking in real-time control of road traffic flow (Luo et al., 2020). A vehicle tracking system is a computer program that utilizes devices to monitor the position, movement and condition of a vehicle or fleet of vehicles. Generally, this system has become a primary requirement in the current era for almost all types of vehicles, including land, sea and air. Of course, this system is equipped with sophisticated tracking technology (Sivaraman & Trivedi, 2013).

Detecting and counting the number of vehicles on urban roads and highways (such as cars, trucks, buses, motorbikes, or ambulances) as well as collecting statistical data about traffic flow is a very important task (Khorramshahi et al., 2022). With more and more vehicles on the road, traffic jams are becoming a frequent problem. Therefore, it is important to carry out tracking in the vehicle system in order to reduce the level of congestion in road traffic. This tracking aims to find traces of vehicles and calculate their number accurately, especially when traffic is heavy. In this way, traffic jams on the highway can be reduced.

Multi-vehicle tracking on highways has significant research interest and practical value in building intelligent transportation systems. However, the traffic road video frame consists of various complex backgrounds and objects. Pre-tracking detection is very challenging because foreground-background switching occurs frequently. As a result, a large number of low-confidence detection boxes are available. In addition, the conditions for vehicle movement are very different. Advances in deep learning approaches have been widely adopted to be applied as intelligent systems for monitoring vehicle activity on highways and urban roads (Djenouri et al., 2022; Li et al., 2022; Zhang, Guo, et al., 2022). One-stage algorithm approaches such as YOLO with its various variants have been proven to be accurate for detecting vehicles, while the SORT algorithm (Bewley et al., 2016), DeepSORT (Wojke et al., 2018), ByteTrack (Zhang, Sun, et al., 2022) and others can be combined with YOLO (Kalliomäki, 2019; Neupane et al., 2022).

Various studies have conducted experiments with tracking and locating moving cars using video monitoring. Video monitoring systems typically combine stationary and moving objects. Objects in the video system can be

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identified, thereby enabling automatic detection and monitoring of moving traffic in the video frame (Kumar et al., 2023b). This research aims to review the literature on the results of several studies that apply a combination of the YOLO algorithm with a tracking algorithm which is implemented as an intelligent traffic monitoring system. Various models and datasets used will be evaluated in this research.

2. LITERATURE REVIEW

Vehicle detection and tracking is one of the important domains in the development of intelligent traffic monitoring systems on highways and cities. Detection of various types of passing vehicles has been proposed as a solution to congestion problems, apart from that, tracking vehicles is also an important part. Several research results apply a combination of object detection algorithms with moving object tracking, including T, Bui et al (Bui et al., 2024) proposed the YOLOv5 algorithm with the DeepSORT algorithm to detect and track vehicles on traffic roads. They improved the YOLOv5 algorithm by applying the Attention-based Intra-scale Feature Interaction (AIFI) module introduced to detect vehicles more quickly and accurately, then optimized the Kalman Filter (KF) algorithm in deep sort to increase the accuracy of vehicle state prediction by using width to replace the length-width ratio of the vehicle prediction box in the original KF algorithm. From the test results, the proposed algorithm achieves significant accuracy based on average accuracy values (mAP) of 7.7%, 15.5%, and 14.2% respectively, while the tracking algorithm achieves an increase of 14.84% and 9.62%. This research aims to highlight existing research on the application of YOLO and its variants in detecting and tracking vehicles especially in traffic management, as well as suggested improvements and method improvements applied to increase the accuracy of the proposed model.

3. METHOD

The research methodology is illustrated in Figure 1 where the stages carried out are discussion of the research topic, then data collection is carried out. The journals used are limited to 2019 – 2024 and the journal sources consist of Hindawi, IEEE, MDPI, Research Gate, Science Direct, and Springer.

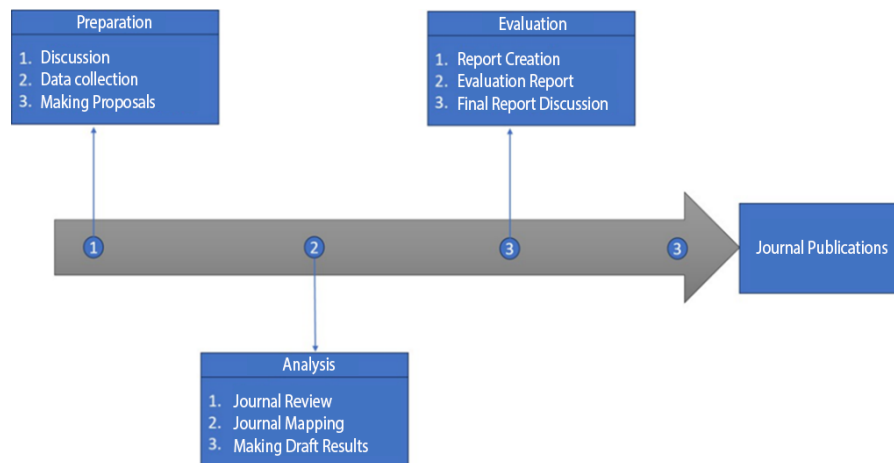


Figure 1 Research Methodology

4. RESULT

With the emergence of deep learning methodologies, object detection is an important part of computer vision that has undergone great progress. The ability to find and identify the right objects in digital images has had a significant influence in various fields, one of which is the application of vehicle detection on highways. This evolution in object detection shows the power of contemporary technology and opens the door to new innovations and efficiencies. In this section, we will describe the application of the YOLO variant model in its implementation and development in various aspects. The initial goal of the YOLO model is to design an algorithm model that is able to recognize and detect objects quickly without reducing its accuracy. This can be realized and developed from time to time with various shortcomings in each version. However, along with its development, the shortcomings of each version of the YOLO model have been worked on and improved to a better level. Apart from that, the success in

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implementing the YOLO model on conventional GPUs also provides great benefits for various parties. The YOLO algorithm was first created by Joseph Redmon in 2015 (Redmon et al., 2016), is a real time object detection system based on CNN (Convolutional Neural Network), then in 2017, Joseph Redmon and Ali Farhadi released YOLO v2 which has increased accuracy and speed algorithm (Redmon & Farhadi, 2017) and version 3 was born in 2017 (Redmon & Farhadi, 2018) to improve object detection performance. In the last decade, YOLO variants have continued to develop until now YOLOv10 has been released by Ultralytics (A. Wang et al., 2024).

Object tracking is a computer vision technology that serves as a core module in many video analysis systems. Therefore, object tracking requires the ability to link detected objects between video frames. This task is more difficult than object detection, which simply aims to find the location of the desired object in an image and produces a list of bounding boxes as output. In the last decade, the application of the YOLO algorithm has been proven to be accurate in vehicle tracking with a high level of accuracy. The application of YOLO for vehicle tracking has been proposed in various versions, such as (Al-qaness et al., 2021; Rahman et al., 2020; Song et al., 2019; J. Wang & Simeonova, 2019; Y. Zhao et al., 2020) using YOLOv3 for vehicle tracking. Various combinations and improvements were proposed by researchers such as the application of the Kalman filter (J. Wang & Simeonova, 2019), Deep Sort (Y. Zhao et al., 2020), centroid tracking (Rahman et al., 2020), KFC (Çintaş et al., 2020), CKFA and MVTA (Sudha & Priyadarshini, 2020). Then (Bin Zuraimi & Kamaru Zaman, 2021; Choi et al., 2024; Jin et al., 2023; Liu & Zhang, 2021; H. Park et al., 2022; S. Park et al., 2022; Tak et al., 2021; Vuong et al., 2022; J. Zhao et al., 2022) proposed the YOLOv4 approach with various enhancement techniques and different datasets. In addition, the implementation of YOLOv5 (Kumar et al., 2023a; Lin et al., 2023) and YOLOv8 (Neamah & Karim, 2023; Shao et al., 2024; Sharma et al., 2023; Xing et al., 2023; Yasir et al., 2024) has succeeded in increasing vehicle tracking accuracy significantly.

Vehicle tracking using Manned Aerial Vehicles (drones) is emerging as a promising technology for environmental and infrastructure monitoring, with widespread use in various applications (Lin et al., 2023; Rodríguez-Rangel et al., 2022; Tak et al., 2021; Talaat & El-Sappagh, 2023; Vuong et al., 2022; N. Zhao et al., 2024; Zou et al., 2023). Many such applications require the use of computer vision algorithms to analyze information captured from attached cameras. In particular, Road Traffic Monitoring systems (is a domain where the use of UAVs is receiving significant interest (Daramouskas et al., 2023). In traffic monitoring applications, UAVs can carry out vehicle monitoring, without the need for embedded sensors in the car and can be used in desired areas at no cost additionally (Shao et al., 2024; Xu et al., 2024). In research (J. Wang & Simeonova, 2019) applied YOLOv3 on drones to overcome the problem of maneuvering vehicles that cannot be fully tracked using traditional camera settings so that vehicles cannot be tracked efficiently, but this model still requires high complexity and greater resources (Liu & Zhang, 2021).

Increasing the accuracy of YOLO has also attracted a lot of interest by researchers resulting in new models, such as (Azimjonov & Özmen, 2021) developing a new bounding box (Bbox) based vehicle tracking algorithm on YOLO. The results of the proposed method have increased the accuracy of the YOLO+CNN+Bbox method by around 13.25% to obtain 99.63%. This method is better than the previous method, but there is some low accuracy from the Kalma Filter Box. Tak S et al (Tak et al., 2021) used a deep learning-based approach (YOLOv4) for image processing for vehicle detection and vehicle type classification where lane-by-lane vehicle trajectories are estimated by matching the locations of detected vehicles with high-definition maps. Then, (Deo & Palade, 2022) proposed YOLOv4 for detecting camera objects and RTDE switching tracker for tracking plus LiDAR sensor fusion for in-depth variation of tracking algorithm performance in sensor fusion. Furthermore, Zhao J et al (J. Zhao et al., 2022) proposed YOLOv4_AF to achieve a better balance in object detection and classification and obtain better performance results for vehicle classification detection. Zhao N (N. Zhao et al., 2024) proposed a new CMCA-YOLO model specifically optimized for parking lot surveillance scenarios.

DISCUSSIONS

Real-time vehicle tracking is a very important technology in building smart cities. Vehicle tracking in traffic video scenes aims to find and track one target object throughout the input video, while all other objects are ignored. In research (Jin et al., 2023; Kavitha & Chandrappa, 2021; Lin et al., 2023; J. Zhao et al., 2022), example images of target objects are usually provided as input, apart from videos. Otherwise, the first frame of the input video annotated with a bounding box enclosing the target object can be used as the target image. This target image is used as a template in tracking when searching for this object in other frames of the video. Typically, the target object can be any class that does not need to know the class of the object used during training. In other words, vehicle tracking works with invisible categories of objects. Research (Song et al., 2019) proposes a vehicle detection and counting system using

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YOLOv3 sourced from CCTV cameras on unobstructed roads using three classes, namely cars, buses and trucks. The combination of the YOLO algorithm with Deep Sort produces better accuracy for detecting and tracking vehicles in a variety of different data sources, such as (Y. Zhao et al., 2020) applies the YOLOv3 algorithm for vehicle extraction and detection while Deep Sort is useful for tracking, then (Liu & Zhang, 2021) proposes YOLOv4, (Kumar et al., 2023a; Lin et al., 2023) uses YOLOv5 and YOLOv8 implemented by (Sharma et al., 2023).

Based on the description of the results of previous research, the YOLO variant algorithm approach has been successfully applied in the field of vehicle monitoring to support smart cities. In addition, many new model combinations and improvements have been proposed, proving that this algorithm has a big influence in the field of computer vision.

5. CONCLUSION

Computer Vision has an important role to play in the future of intelligent transportation systems and traffic monitoring, so exploring better solutions is critical. Monitoring the condition of the road network is fundamental to efficient traffic management. A simple but effective algorithm for counting vehicles per lane in UAV imagery has been described to expand its applicability to real-time applications, such as UAV, Camera, video and CCTV based traffic monitoring. In particular, deep learning techniques with the YOLO algorithm approach can be used to improve various aspects of the network. In addition, the speed of development of the YOLO variant has proven that this algorithm produces high accuracy and can be applied in various other fields. However, its accuracy is greatly influenced by the object detection distance and complex background and is not effective in detecting small objects. Research on transplant optimization for large models is still in theoretical research and fails to be combined with specific scenarios for application implementation and finally YOLO performance is inadequate when performing small object detection on satellite videos.

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