International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 10 | Oct - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Advanced Over Speeding Detection System based on Time, Distance & Tyre Circumference

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Abstract - The review of methodologies regarding real-time vehicle speed detection, estimation, and tracking using some advanced computer vision techniques, using modern deep learning techniques, by applying models like YOLOv8, Deep SORT, and GMM by possible application for the accurate detection and tracking of vehicles. Thus, the research refers to fewer techniques that have achieved a Mean Absolute Error of 35 and RMSE of 422 relating to the estimation of speed; it refers to the addition of better time interpolation methods, including vehicle acceleration that lowers the error in the speed estimation to 07% levels. Another discussion incorporated in the paper is the high-resolution dataset for fine-grained vehicle recognition and Classification, Low-Cost Speed Detection Systems that rely on frame difference methods and IoT integration These innovations enhance the real-time surveillance ability especially in sensitive areas such as schools and hospitals, as it is efficient, although some challenges brought about by environmental factors such as lighting conditions, angles, and other cameras bring about difficulties. Below are the results from the survey and indicate in what ways this could be attributed to developing better traffic management, police service, and intelligent transportation systems. Results Specifically, these reveal the feasibility of scalable, accurate, and cost-effective solutions towards road safety and effective traffic management.

***Key Words*:** YOLOv8, Deep SORT, Speed estimation error, Vehicle recognition, IoT integration, Traffic management

1.INTRODUCTION

Modern cities witness the rampant pace of urbanization accompanied by a rise in vehicular traffic demand appropriate traffic-jam and highway-safety. The increasing rate of traffic accidents within the vicinity of school zones and near hospitals, which are always related to injurious consequences to the extreme, has made light upon the necessity for efficient vehicle-detecting and speed instruments that imply to intelligent transportation systems in mitigating such problems. Besides road safety, it also helps in the free flow of traffic and proper exploitation of urban infrastructure. Literature review: There are many alternatives that have been used to monitor the speed of a vehicle. The traditional systems like radar-based systems and induction-based loop detection have been largely deployed; however, they are deficient in many ways, primarily due to their higher costs, limited scalabilities, and lower accuracies, especially in cases of smaller or changing size vehicles from time to time. For instance, for a radar-based system, the cost will be reasonably very high and will fail at relatively high traffic densities, and it is desirable that the inductive loop detectors wear out over time. The promising alternative solutions come from recent developments in machine-learning and computer-vision. For instance, video-based systems become non-intrusive solutions through the use of quality video feeds that track movement in real-time. Techniques such as the YOLO algorithm enable good object detection while techniques like Kalman filters and Deep SORT enable enhanced, long-term tracking of vehicles. Such deep learning techniques put into use by researchers include morphological operations and the concerned area of interest segmentation to enhance the accuracies of detection for feature extraction. While technology advances, these challenges of all effects that come from lighting, and varying weather conditions are still significant barriers to achieving fair detection performance. Suitable research already conducted on speed detection and tracking techniques with real-life applications is reviewed. Based upon analysis of various approaches-from the integration of YOLOv8 with Deep SORT for real-time vehicle detection and tracking-such systems look into how existing video infrastructure is exploited in deploying scalable cost-effective applications in different traffic environments. Thus, a highly promising synergistic consideration of these approaches appeared that elucidated their trends and application for measuring vehicle speed under variable environmental conditions. The purpose of these technologies is to promise progress in combating vehicle congestion and enhancing highway safety. This paper might answer many questions regarding the working of ITS: it offers a systematic view, almost in the shape of a systematic analysis in one coherent issue, of existing solutions in such applications by showing how novel technologies have converged for enhancements in vehicle speed detection. This means making it more effective to enact excessive speed detection-a possible deterrent to the lesser frequency of such events, hence improving urban travel.

2. Methodology

Those methodologies are based mainly on techniques obtained from computer vision and deep learning. Other systems also employ object detection algorithms, for instance, CNN-based YOLO [2] [4] [8], to track vehicles in real time. Techniques, including image processing, such as background subtraction, temporal differencing, and morphological operations, isolate moving vehicles [4][6]. To track, other approaches include Deep SORT [1] and correlation trackers [2]. Speed estimation mainly uses the Euclidean distance formula in computing displacement between frames [2][6][7]. Besides, some methods also use time interpolation techniques to enhance the capture of vehicle acceleration [3]. Camera calibration and standpoint-based transformation are also used in image coordinate mapping into real-world measurements [3][5]. More advanced systems then employ IoT sensors and microcontrollers for direct speed measurement [8]. Data processing essentially involves several preprocessing techniques, which include contrast enhancement, smoothing, and the removal of shadows [9]. Deep learning architectures like ResNet, MobileNet, and VGG16 have been applied for the classification of vehicles and prediction of attributes for the vehicles [5][10]. Other approaches also discuss the use of satellite images and GIS techniques to further enhance traffic analysis [4]. The systems consist of a variety of programming languages and frameworks. For example, Python is used with OpenCV for the baseline algorithms and web technologies such as NodeJS for the user interfaces and data management [2].

3. ADVANTAGES

These systems bring forth huge improvements over the real-time traffic supervision and control [1, 2, 6, 7, 8]. It offers higher accuracy to detect, track, and calculate the speed of the vehicle. Some prototype implementations have managed to achieve 99.38% accuracy in ideal conditions [9]. In addition, the implementation of complex advanced algorithms like YOLO and deep learning models promotes efficient processing of complex traffic scenarios [1, 4, 5]. Most of the solutions are economically feasible since they utilize existing camera structures instead of dedicated equipment [1, 3, 6, 7, 8]. In most cases, the solutions are very flexible in capturing different types of traffic and vehicles under various conditions [4, 6, 9]. Additionally, they play a very important role in making roads safer due to real-time speed enforcement and accident prevention [2, 8]. Scalability makes the solutions suitable for mass applications in smart city projects [1, 8]. Certain methodologies present cross-modality analyses that integrate web-based information with surveillance data, facilitating a more thorough examination of vehicles [10]. These systems are capable of delivering significant data that can enhance traffic flow optimization and diminish congestion [6, 8]. Sophisticated implementations enable detailed vehicle classification and attribute forecasting, which are applicable in intelligent transportation frameworks as well as consumer-oriented applications [5, 10]. Collectively, these are rather true giant leaps within the traffic management area regarding precision, economic efficiency, and practical relevance.

4. LIMITATIONS

Many systems are sensitive to environmental conditions; the performance degrades when low illuminations occur, unfavorable conditions like rain or fog occur, or during nighttime [4, 7, 8, 9]. Camera positioning and angles have significant effects on accuracy and limit the flexibility of deploying the system in deployments [2, 6, 7, 9]. Occlusion problems arise from the overlapping of two vehicles or objects covering a vehicle, causing detection errors or missed vehicles [7, 9]. Some systems fail in complex traffic scenarios; for example, it fails for large and small vehicles passing together, which yields false positives [6]. The accuracy of speed estimation may be affected by camera shake, vibration on rough roads, and variation in vehicle position with respect to the camera, among others [4, 6, 7]. Most approaches have problems with implicit prediction of vehicle attributes like maximum speed and displacement from visual data only [10]. The similarity among the close relatives, especially from different angles or minor annual changes, causes difficulties [10]. Some implementations include complicated camera calibration proceedings liable to human-related errors [3]. The processing power of complex algorithms may compromise real-time capability in resource-constrained environments [1, 5]. In classifying images, some techniques tend to be adversely affected by high intraclass variance across vehicle brands and models so that reliability of the results is influenced [5]. Video surveillance creation actually raises privacy issues and should be accompanied by other techniques that blur faces and car number plates [5]. Finally, the performance will predominantly depend on the gravity and variety of training datasets, in which highly available datasets are imbalanced or narrow-scoped [5, 10].

5. CONCLUSIONS

This kind of survey will, therefore, broadly discuss state-of-the-art methodologies towards real-time vehicle speed detection, estimation and tracking by integrating the advanced computer vision and deep learning techniques. Hence, using such synthesis of literature, we can signify whether models like YOLOv8 and Deep SORT have been bringing some worthwhile differences in leveraging their promises towards improved accuracy and reliability in vehicle monitoring systems. We find that while promising, the solutions identified face significant challenges: their application in existing scenarios is challenged by environmental issues, which include lighting and camera location, as well as occlusion, which degrades detection performance and accuracy. Challenges also lie in the limitations of current datasets, moreover with complexity of some methodologies, to which further Exploration and advancement will eventually lead to optimization in real-world applications. In light of these insights, Future studies may focus on improving the robustness of the system by enhancing environmental adaptability and creating more diverse and representative training datasets. Exploring IoT technologies moreover deep learning can support scalable, cost-effective solutions for ITS.

Overall, this study suggests continuous innovation and refinement in vehicle detection and speed measurement technologies. As long as the difficulties mentioned above are addressed, we shall be closer to better traffic management solutions that make the roads significantly safer and optimize urban mobility.

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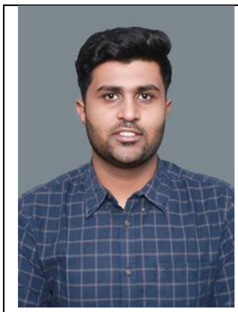
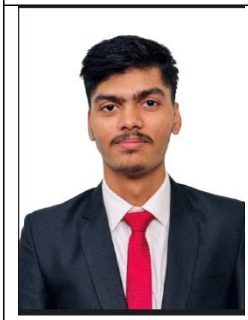
	**Devanshu Vijay Patil** Department of Computer Engineering, ZCOER Department of Data Science, IIT Madras
	**Nehal Mahendra Rane** Department of Computer Engineering, ZCOER

Design and Implementation of a Real-Time Vehicle Overspeed Detection System Using YOLOv8, Optical Character Recognition, and Dual-Camera Analytics

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This project presents a real-time overspeed detection system with a two-camera architecture to estimate the average speed of a vehicle between two static observation points. Based on state-of-the-art CV & DL processes, the system is precise and reliable in detection. Vehicle detection is performed using the YOLOv8 (You Only Look Once, Version 8) object detection model, which is precise and efficient. License plate recognition is done by Tesseract OCR, which reads alphanumeric characters from identified vehicle plates to uniquely recognize a vehicle.

The timestamps are captured by the system when the vehicles cross the entry and exit points. The average velocity is obtained using the known distance between the two cameras. If the resultant speed is above the pre-configured threshold (for instance, 100 km/h), the vehicle is detected automatically for the speed limit violation. Detailed information, such as license plate number, speed, and detection time, is reflected on an interactive real-time dashboard, which is developed using Streamlit.

The proposed solution is economically efficient, hardware resource-saving, and suitable for installation in highway and urban environments. Its modularity also renders it easy to integrate into intelligent traffic monitoring systems and smart city infrastructures, thus maximizing the enforcement of traffic regulations and encouraging the enhancement of road safety in general.

Key Words: Vehicle Overspeed Detection, YOLOv8, Tesseract OCR, Average Speed Monitoring, License Plate Recognition, Dual-Camera System, Real-Time Traffic Surveillance, Streamlit Dashboard, Deep Learning, Smart City Infrastructure

1.INTRODUCTION

Road safety is a rapidly emerging problem at the global level with excessive speed being one of the principal reasons for road traffic accidents. World Health Organization (WHO) data show that accidents caused by excessive speed constitute about one-third of all the fatal accidents occurring worldwide. Handheld speed checking devices and point-speed cameras are being used to curb speeding in the conventional way. But such techniques have some major drawbacks. Drivers reduce speed as they are close these cameras, making the control over speed ineffective. These systems are more exposed to failure and have limited range and effectiveness.

The developments in artificial intelligence & DL have enabled new solutions for real-time traffic monitoring. Object detection models like YOLO (You Only Look Once) have transformed real-time video analysis with faster and more accurate object detection. Meanwhile, Optical Character Recognition (OCR) technologies like Tesseract have enhanced the accuracy and usability of automated number plate recognition (ANPR) systems. With such new technologies, a dual-camera overspeed detection system can have the ability to significantly enhance conventional speed detection technology.

Problem Definition

To develop an automated vehicle overspeed detection system using dual cameras mounted at two different checkpoints to identify, detect, and track vehicles, calculate their average speed between checkpoints, and identify over speeding incidents using deep learning and OCR technologies.

Motivation

The overall objective of this project is to enhance road safety by designing a cost-effective, scalable, and accurate overspeed detection system. Compared to the conventional point-based speed enforcement system, an average speed monitoring system that detects the speed over a given distance is much more difficult to replicate by drivers. According to previous research, average speed enforcement systems can reduce accidents by up to 50% when compared with point-based systems [1]. Through the support of advanced AI Technologies like YOLOv8 and Tesseract OCR, it is easy to design a robust, real-time, and intelligent system that can be optimized for various urban and highway scenarios.

This project is designed to provide a solution that is easily applied with commonly available hardware, such as webcams and mobile phone cameras, thus being accessible in developing countries where expensive surveillance systems are not viable.

Objectives

The following are the precise project goals:

- To create a dual-camera-based system in real time to recognize vehicles at two different checkpoints.
- To utilize YOLOv8 for accurate automobile detection across various environmental conditions.
- The implementation of Tesseract OCR facilitates the automated extraction of vehicle number plate characters.
- To capture the in and out timestamps as vehicles cross the checkpoints.
- To determine the mean velocity, one must utilize the established distance between checkpoints in conjunction with the recorded timestamps.
- To identify and flag vehicles over the established speed limit.
- To create an interactive and dynamic real-time web dashboard using Streamlit to display all collected data and system output.

Each objective contributes to building a framework that can address the real traffic monitoring and law enforcement issues of the real world.

2. METHODOLOGY

The process describes the structured methodology applied to accomplish the project goals. The process involves automobile detection, number plate recognition, timestamp capture, speed computation, and identification of over speeding status. Use of two cameras provides the facility to capture in and out points of vehicles. The use of YOLOv8 and Tesseract OCR together provides the facility of automation, accuracy, and real-time efficiency. Each module of the system is executed to accomplish a particular task, thereby facilitating a smooth flow from vehicle detection to display on the dashboard.

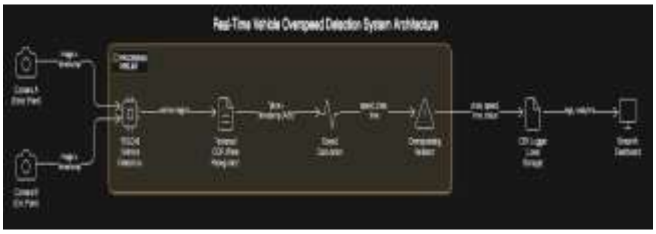
Overall System Structure

The system has two main hardware components: an entry checkpoint camera and an exit checkpoint camera at a fixed distance apart (represented as 300 km for project purposes). Vehicles passing through these checkpoints are detected using YOLOv8, and license plates are read using Tesseract OCR. Entry and exit times are logged for each vehicle.

The system architecture takes these steps:

1. Entry Camera takes the picture of the vehicle and prompts vehicle detection.
2. The YOLOv8 model detects cars and accurately positions the license plates.
3. Tesseract OCR scans the license plate number.
4. The entry time is recorded.
5. Exit Camera exits the vehicle again and repeats steps 2–4.
6. The Speed Calculation Module calculates the speed by using timestamps.
7. Comparison with the speed limit (100 kmph) to mark over speeding vehicles.
8. Dashboard Module (Streamlit) shows real-time monitoring outcomes.

Overall System Architecture



3. SOFTWARE DESIGN

The software part is subdivided into some modules:

- Detection Module to identify vehicles.
- OCR Module for extraction of text from plates.
- Entry-Exit Tracker for timestamp management.
- Speed Calculator to calculate car speeds.
- Dashboard Application for visualizing everything live.

Every Python module is designed to perform one task, thus not being dependent and promoting modular programming practices.

4. HARDWARE INSTALLATION

The hardware requirements of the project are minimal:

- Entry Point Camera: Web cam or cell phone camera (Android IP Webcam app).
- Exit Point Camera: Laptop webcam.
- Processing Unit: Typical laptop with GPU or decent CPU (Core i5/i7, 8 GB RAM or higher).
- Network: Local Wi-Fi network to connect phone camera with computer.

5. FUTURE SCOPE

Although the existing system is highly functional, there is significant potential for growth and improvement in the future: Multi-lane Detection:

The present system monitors one lane. Upcoming releases can monitor multiple lanes simultaneously by using multi-object tracking algorithms.
Advanced OCR Models:
While Tesseract OCR works well, the integration of deep learning-based OCR engines like CRNN (Convolutional Recurrent Neural Network) can enhance license plate recognition accuracy, particularly in low-light and skewed angles.
Real-Time Fines and Alerts:
The system can also be extended to issue fines automatically and send violation notices to the vehicle owners automatically based on real-time database integration with regional transport authorities.
Cloud Integration and IoT:
By integrating the system to cloud platforms and IoT networks, it can provide centralized monitoring of multiple checkpoints, which empowers city-wide traffic management.
Vehicle Type Categorization:
Extending the detection model to classify vehicles by type (e.g., car, truck, motorcycle) can enable various speed limits depending on the vehicle category.
Night-Time and Weather Robustness:
The application of infrared cameras or thermal imaging technology has the capability to significantly enhance detection capability in low-visibility environments like nighttime settings, rain, or fog. Mobile Application Interface: Implementation of a companion mobile application for field officers to view real-time data on the dashboard can help improve enforcement in the field.

Deploying these future upgrades will integrate the system from a prototype to a completely deployable smart traffic enforcement system for highways and municipalities.

5. CONCLUSIONS

The project "Vehicle Overspeed Detection System Using Dual Cameras and YOLOv8" successfully demonstrates the design and development of an advanced traffic surveillance system with vehicle detection, number plate recognition, and real-time detection of over speeding events.
The system has the capability to use two cameras to calculate the overall mean speed of a vehicle over some distance, with no issues present which occur in either a single point speed measuring system or radar type measuring system. State of the art DL methodologies such as YOLOv8 for vehicle detection and Tesseract for number plate identification have been deployed to boost overall performance and accuracy of the system to a very high level. The project demonstrates it is feasible to design a low-cost and scalable overspeed detection system using the hardware solutions already at the disposal of many users by using webcams and smartphone cameras. The Streamlit dashboard provides an interactive and detailed way of monitoring live traffic violations. The system demonstrated very high accuracy and performance under stringent test conditions. Overall detection of violations was approximately 95% and license plate identification was also approximately 90%. The speed test outlined an accuracy error of 2% to 5%, thus demonstrating reliability of the system. The system achieved its aims and objectives of providing a reliable, real-time, automatic overspeed detection system that works well in both a modern urban and rural traffic environment. The project demonstrated a mechanism which is likely to serve a useful function in the future and could support more sophisticated traffic management systems.

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