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Deep learning based highway vehicles detection and counting system using computer vision

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Abstract

In the field of highway management, intelligent vehicle detection and counting are becoming increasingly significant. City planners have been fighting the issue of traffic analysis for years. To analyze traffic and streamline the process, intelligent methods are being created. The type of vehicles and the number of vehicles in an area over some arbitrary time period may be taken into account. Over the years, humans have created a variety of mechanisms, because the vehicles are come in different sizes, it is still difficult to identify them, which can directly impact the accuracy of vehicles count. In the field of vision research, computer vision is one of the most often used applications for traffic scenarios. A variety of computer vision applications, including object detection and categorization, have proven that deep learning techniques like Convolutional Neural Networks (CNNs) greatly outperform conventional approaches. Hence in this work, deep learning-based highway vehicles detection and count system suing computer vision is presented. Vehicles on the highway can be efficiently detected by this technique. YOLOv3 (You Look Only Once Version 3) is a real-time object detection technique which is used to detect vehicles in real-time. Precision, recall and real-time rate are measured to evaluate the performance of this system.

Subject Classification: *Primary 68T07, Secondary 68M25.*

Keywords: *Highway vehicles detection, Deep learning, Convolutional neural network, You look only once (YOLO).*

1. Introduction

The vehicle has replaced other modes of transportation as the primary means of daily transportation in today's world of extraordinarily rapid

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economic development. With an increasing number of automobiles on the road, concerns with traffic safety and congestion are becoming increasingly prevalent [1]. In the field of traffic management and surveillance, vehicle detection and classification is a challenging action.

Intelligent Transportation Systems can use vehicle detection and classification, which is a growing area of research in vehicle surveillance systems. In vehicle surveillance system, identifying the make and model of a vehicle is crucial for traffic monitoring. Vehicle and its model identification is a challenging process because of intra-class variability, view-point variation, and changing lighting conditions. In order to track the movement of a specific target across the entire video stream, this object recognition and identification in the recorded video tries to detect the moving vehicle in individual video frames.

The process of identifying a vehicle entails profiling or classifying it according to its type and color as well as detecting and following it along the road. In order to identify all traffic actions committed by each moving vehicle on the road, all tracked vehicles activity must be analyzed. Highway traffic management, planning, and prevention of frequent traffic congestion, traffic law violations, and

deadly traffic accidents all benefit greatly from real-time highway traffic monitoring systems

As a result, the decision to use bouncing boxes and mass testing for vehicle testing is informed. These methods frequently ignore issues including obstruction, shadows, an unsteady camera, the camera's base state, and a disorganized base. Vehicle counting offers a practical answer to many traffic-related issues [2]. The fast development of deep learning, Computer Vision (CV) methods have been utilized in the visual-based ITS services successfully. Hence in this work, Deep learning-based highway vehicle detection and counting system using computer vision is presented.

2. Literature survey

Apeksha P Kulkarni, Vishwanath P Baligar [3] Presents Real Time Vehicle Detection, Tracking and Counting Using Raspberry-Pi. A computer vision model is used to monitor traffic movement, and it improves visibility of the road by utilizing one or more photographs. In industries where cost-effective traffic management systems are created, this approach is seen as a cost-effective solution.

Genyuan Cheng, Yubin Guo, Xiachum Cheng, Dongligang Wang, jiandong Zhao [4] Provides concurrent vehicle speed recognition based on

capturepicture. The video image feature matching vehicle-based target approach and other K-Nearest Neighbour (KNN) algorithm-based background subtraction methods are used to detect vehicle targets and get initial vehicle features in order to reduce algorithm complexity and achieve high accuracy.

Xiangdi Liu, Yunlong Dong, ZelinDeng [5] Customize your car by using many cameras and tracking context on the road. The development of a Deep Learning-based, two-step algorithmic framework that comprises vehicle identification and re-identification. The effectiveness of this approach has been demonstrated by a large body of experimental data, and the Beijing-Hong Kong-Macao Expressway has successfully implemented an intelligent control system based on this control system.

Zillur Rahman, Amit Mazumder Ami, Muhammad Ahsan Ullah [6] Presents YOLO and Centroid Tracking-Based Real-Time Wrong-Way Vehicle Detection. Images from the on-road surveillance cameras are used to illustrate the vehicle's wrong direction detection system. YOLO's centre of gravity tracking algorithm can successfully follow moving objects and is quite accurate at detecting things.

P. Nagaraj Raj Varshith Reddy Mohammed Sabeehuddin, SriChandana Reddy, V Santhosh [7] presents a system for counting and identifying vehicles based on video. System accuracy can be increased by using advanced picture segmentation and Artificial Intelligence procedures.

Mohammed HazimAlkawaz, Maran Tamil Veeran, Omar Ismael Al-Sanjary [8] Demonstrates a robust algorithm-based vehicle tracking and reporting system. The Global Positioning System (GPS), the most popular and widely used technique of real-time tracking, is used by this system. This involves that users can direct security cameras to track a car or other item and watch and view it from anywhere.

AryuantoSoetedjo, I KomangSomawirata [9] Suggests combining detection and tracking techniques to improve the performance of on-road vehicle detection. In order to enhance the recall of on-road vehicle identification, this analysis indicates a combination technique of detection and tracking.[16]

Boris A. Alpatov, Pavel V. Babayan, Maksim D. Ershov [10] provides a system for the discovery and including of vehicles for traffic surveillance in real time. To ensure traffic control and safety, road condition study work has been taken into consideration. Road marker detection methods were developed to progression images from a fixed camera. The urbanized vehicle recognition and counting method is implemented and experienced on an embed stage of elegant cameras.

Xiao-Feng Gu, Zi-Wei Chen, Ting-Song Ma, Fan Li, Long Yan [11,13] Deep Neural Networks are used to recognize and track vehicles in real time. This model allows for the immediate retrieval of vehicle candidates, vehicle probabilities, and their coordinates. This type is a real-time, the precise vehicle detector, which makes it excellent for computer visualization applications, according to the experimental data.

Huang Guan, Wang Xingang, Wu Wenqi, Zhou Han, Wu Yuanyuan [12] Suggests a Vehicle Detection and Tracking System for Lanes in Real Time. This analysis indicates a brand-new and efficient lane-vehicle recognition and tracking technique to accomplish instantaneous and dependable foremost vehicle localization.

While conventional machine vision techniques can identify the car more rapidly, they struggle when dealing with complicated environments, [14,15]slow-moving cars, brightly-lit photos, or images with recurring background motion. The proposed work includes deep learning-based highway vehicle identification and counting system is described in this work as a solution to these problems and as a means of providing real-time vehicle recognition and counting.

3. Proposed System on Deep Learning Based Highway Vehicle Detection and the Counting System

In this analysis, a computer vision-based system for counting and detecting highway vehicles is provided. The block diagram of presented Deep Learning-based computer vision method for highway vehicle detection is shown in Figure 1. Grayscale in digital images denotes that each pixel value simply carries information about the brightness of the light.

In specifically, a gray-scale picture is substituted for the colour (RGB) backdrop image of the car-free road and the current frame in the movie. Then, for every pixel in the present frame, the grey intensity of the background picture is subtracted (x, y). The absolute result is present at the same spot in a different image known as the difference image. Processing a particular Region of Interest is the next stage (ROI). The thresholding process produces a binary picture as the result.

CNNs are classification-based systems that can transform input images into organized data arrays and find patterns throughout. The fundamental idea of the first two generations of YOLO algorithms is incorporated into the YOLOv3 algorithm. For the detection job, a further

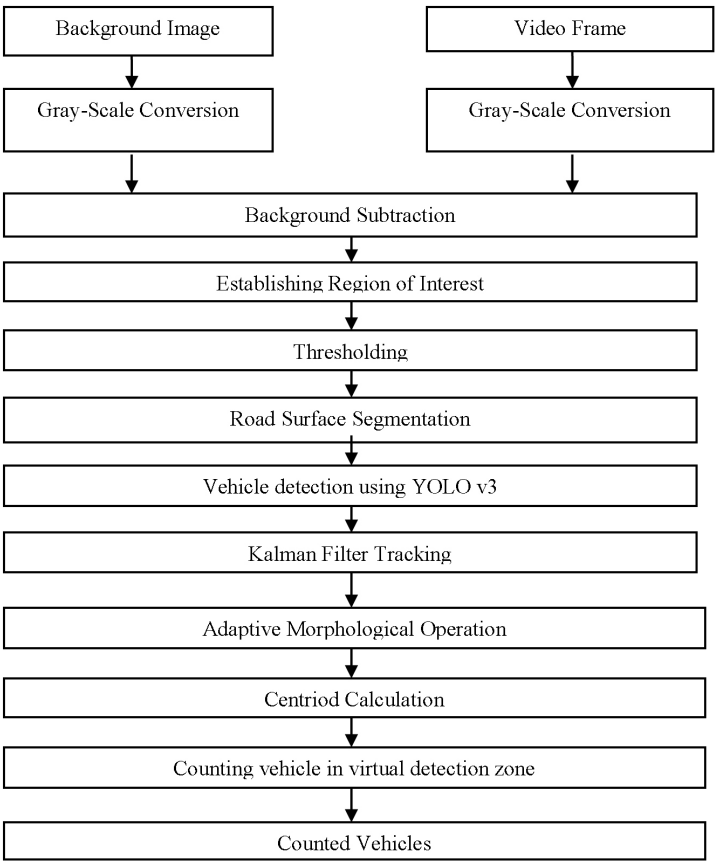


Figure 1

The Block Diagram of Deep Learning Based Vehicle Detection and the Counting System

53 layers are placed on top of it, making a total of 106 layers in the whole convolutional architecture.

After obtaining vehicle outlines, the virtual detection zone is established and used to count the cars. In this method, the virtual detection zone's height is fixed at 21 pixels. Each foreground object's centroid is determined and tracked. Then, its location is examined. If it reaches the virtual detection, its status will be set to 1 (counted), indicating that it has been counted once and won't be counted again in the ensuing frames. In this manner presented system detects and counts the vehicles on a highway in real time.

4. Result analysis

This section implements a computer vision-based system for counting and detecting highway vehicles that is deep learning-based. The open CV (Computer Vision library is used in the implementation of this system. The highway surveillance camera is fixed at a height of 12 meters on the side of the road. For the experiments many scenarios, high definition videos and photographs of highways were utilized. Vehicle object detection is performed using the YOLOv3 network. The quantitative assessment of detection and counting is reviewed and contrasted with advanced methods. Precision and recall are two quantitative performance criteria that are analyzed. In an experiment, the precision of vehicle detection is evaluated. The precision is expressed as the percentage of correctly detected vehicle pixels (true positive, or TP) out of the total number of correctly detected object pixels (TPs and false positives, or FPs).

$$\text{Precision} = \frac{TP}{TP+FP} \times 100 \tag{1}$$

Recall is the proportion of correctly identified vehicle pixels to the total number of vehicle pixels, including the number of false negative pixels (FN), and is expressed

$$\text{Recall} = \frac{TP}{TP+FN} \times 100 \tag{2}$$

The terms TP, FN, and FP, respectively, stand for the percentages of true positives, false negatives, and false positives.

The real time rate is used to evaluate how quickly the offered system operates. It is determined as the ratio of the time required for the system to process a video to the time the original video played and is expressed as

$$\text{Real time rate} = \frac{\text{system running time}}{\text{video running time}} \tag{3}$$

Where the video running time is the amount of time needed for the original video to play and the system running time is the amount of time needed for the system to process a video. With a lower real time rate number, the system completes the calculations more quickly. When the real time rate number is less than or equal to 1, the input video can be processed in real time. Figure 2 displays the broad highway image along with the image of the detected vehicles.



Figure 2 (a)

Broad highway image along with the image of vehicles

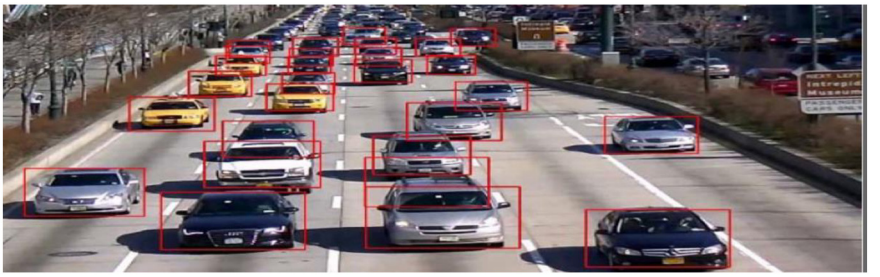


Figure 2 (b)

Broad highway image along with the image of the detected vehicles

The table 1 shows the performance evaluation of the Deep Learning based highway vehicle detection and counting system in different time scenarios. The table 2 shows the exactness, summon up and real time metrics evolution.

Table 1

Accuracy Evaluation in Different Scenarios

Different Time scenarios	Total number of vehicles	Number of counted vehicles	Accuracy (%)
Scenario1	238	233	97.89%
Scenario 2	156	152	97.15%
Scenario 3	205	201	98.05%

Table 2

Performance Comparison

Differentvehicle detection methods	Precision (%)	Recall (%)	Real time rate
Vehicle detection using ML algorithms	89.63	88.76	1.98
The Deep learning based on vehicle detection and the counting system	96.74	95.46	1.1

The performance of deep learning-based vehicle detection and counting system is compared with earlier vehicle detection method using ML algorithms. Compared ML based algorithms, deep learning-based vehicle detection and the counting system has better performance in terms of precision (96.74%) recall (95.46%) and real time rate (1.1). The Figure 3 shows the precision and recall parameters performance comparison for different vehicle detection and counting systems. The x-axis represents different approaches for vehicle detection and counting whereas Y-axis represents recall and precision values in terms of percentage.

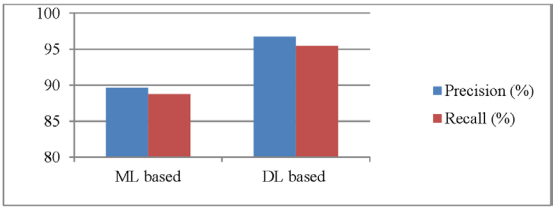


Figure 3

Performance Comparative Graph for Precision and Recall Metrics

Compared to ML based vehicle detection method, presented DL based vehicle detection and counting system has high precision and recall. The Figure 4 shows the accuracy comparison in different time scenarios.

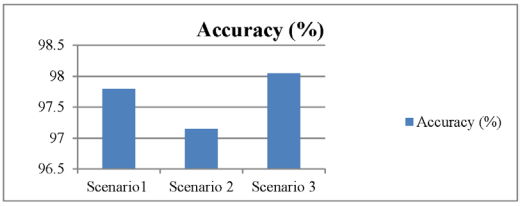


Figure 4

Accuracy Comparative Graph

From Figure 4 it is clear that the DL based highway vehicle detection and counting system has effectively detected and counted the vehicles in different real time scenarios and it has better counting accuracy than earlier vehicle detection and the counting methods. Hence presented Deep Learning based highway vehicle detection and the counting system using computer vision has better performance than earlier methods. This system has detected and counted the vehicles in real time with more accuracy.

5. Conclusion

In this work Deep Learning-based highway vehicle detection and counting system suing computer vision is presented. Finding foreground objects in each video frame using the background subtraction approach is the first step in achieving the objective. Then, computer vision techniques are used to reduce noise and improve foreground objects, such as thresholding, flooding filling, and morphological operations. To detect and count vehicles, each zone is separated into the area of interest. To accurately detect and count vehicles, YOLO v3 and kalman filtering methods are used. The next step is to extract the foreground objects contours and determine their centroids. Finally, this approach detected and counted the vehicles on highway. Precision, recall, and counting accuracy are used to evaluate how well this system performs. Compared to ML models, DL-based highway vehicle recognition and counting systems using computer vision has better performance in terms of precision, recall, and real-time rate.

References

[1] Janak D. Trivedi, Sarada Devi Mandalapu, Dhara H. Dave, "Vision-based real-time vehicle detection and vehicle speed measurement using morphology and binary logical operation", *Journal of Industrial Information Integration*, Volume 27 (May 2022), 100280,doi.org/10.1016/j.jii.2021.100280.

[2] Mohana, Rahul Kejriwal, Ritika H J, Arpit Arora, "Artificial Intelligence (AI) Enabled Vehicle Detection and counting Using Deep Learning", 2022 International Conference on Computer Communication and Informatics (ICCCI-2022), DOI: 10.1109/ICCCI54379.2022.9740929.

[3] Apeksha P Kulkarni, Vishwanath P Baligar, "Real Time Vehicle Detection, Tracking and Counting Using Raspberry-Pi", Proceedings of the Second International Conference on Innovative Mechanisms for Industry Applications (ICIMIA 2020), 978-1-7281-4167-1.

[4] Genyuan Cheng, Yubin Guo, Xiachum Cheng, Dongligang Wang, Jiandong Zhao, "Real-time detection of vehicle speed based on Video image", 2020 12th International Conference on measuring Technology and Mechatronics Automation (ICMTMA), 2157-1481/20, 2020 IEEE.

[5] Xiangdi Liu, Yunlong Dong, Zelin Deng, "Deep Highway Multi-Camera Vehicle Re-ID with Tracking Context", 2020 IEEE 4th Information Technology, Networking, Electronic and Automation Control Conference (ITNEC 2020), 978-1-7281-4390-3/20.

[6] Zillur Rahman, Amit Mazumder Ami, Muhammad Ahsan Ullah, "A Real-Time Wrong-Way Vehicle Detection Based on YOLO and Centroid Tracking", 2020 IEEE Region 10 Symposium (TENSYMP), 5-7 June 2020, Dhaka, Bangladesh, 978-1-7281-7366-5/20.

[7] P. Nagaraj Raj Varshith Reddy Mohammed Sabeehuddin, SriChandana Reddy, V Santhosh, "A Video based Vehicle Detection, Counting and Classification System", *Alochana Chakra Journal*, ISSN NO:2231-3990,Volume IX, Issue V, May/2020.

[8] Mohammed HazimAlkawaz, Maran Tamil Veeran, Omar Ismael Al-Sanjary, "Vehicle Tracking and Reporting System using Robust Algorithm", 2019 IEEE 7th Conference on Systems, Process and Control (ICSPC 2019), 13–14 December 2019, Melaka, Malaysia, 978-1-7281-1826-0/19.

[9] AryuantoSoetedjo, I KomangSomawirata, "Improving On-Road Vehicle Detection Performance by Combining Detection and Tracking Techniques", 2018 3rd Asia-Pacific Conference on Intelligent Robot Systems, 978-1-5386-7226-6/18, DOI: 10.1109/ACIRS.2018.8467217.

[10] Boris A. Alpatov, Pavel V. Babayan, Maksim D. Ershov, "Vehicle Detection and Counting System for Real-Time Traffic Surveillance", 7thMediterranean Conference on Embedded Computing MECO'2018, Budva, Montenegro.

[11] Xiao-Feng Gu, Zi-Wei Chen, Ting-Song Ma, Fan Li, Long Yan, "Real-Time Vehicle Detection and Tracking using Deep Neural Networks", 2016 13th International Computer Conference on Wavelet Active Media Technology and Information Processing (ICCWAM-

TIP), 978-1-5090-6126-6/16, 2016 IEEE,**DOI:** 10.1109/ICCWAM-TIP.2016.8079830.

[12] Huang Guan, Wang Xingang, Wu Wenqi, Zhou Han, Wu Yuanyuan, "Real-Time Lane-Vehicle Detection and Tracking System",Chinese Control and Decision Conference (CCDC) (2016).

[13] Kumar, A. et. al.," Improving the visual quality of a size deterministic visual cryptography scheme for Grayscale Images", *Journal of Discrete Mathematical Sciences and Cryptography* 25:4, pages 1113-1123 (2022).

[14] Sharma, H. et. al. "Commutative encryption-based video encoding technique with high-efficiency & video adaptation capabilities", *Journal of Discrete Mathematical Sciences and Cryptography*, 24:8, 2207-2219 (2021), DOI: https://doi.org/10.1080/09720529.2021. 2011099.

[15] Pasupathy, Vijayalakshmi, and RashmitaKhilar "Advancements in deep structured learning based medical image interpretation" *Journal of Information and Optimization Sciences* 43.5 : 1131-1138 (2022).

[16] Abdulghani, Farah A., and Nada AZ Abdullah. "Hybrid deep learning model for Arabic text classification based on mutual information", *Journal of Information and Optimization Sciences* 43.8 : 1901-1908 (2022).

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