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Real-time Vehicle Detection and Speed Estimation System

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Abstract - Vehicle detection and speed estimation are important factors in road safety management. This module is important in the monitoring system because the citizen's safety is the primary priority. Object tracking in video surveillance is of great interest to many researchers, which is an important application and emerging research area in machine learning and image processing. This paper proposes a vehicle detection and speed estimation system to estimate the speed of a vehicle using image processing. The background subtraction method is used to detect the vehicle efficiently. Experimental and theoretical analyses are used to calculate the efficiency of the suggested approach.

Keywords: Vehicle Detection, Background Subtraction, Speed Estimation, Image Processing

1. INTRODUCTION

In town planning, speed measurement is very significant. Due to their ease of installation and operation, video-based intelligent surveillance systems are the most widely utilized approach in this industry, therefore image processing and computer vision techniques are employed to monitor and estimate a vehicle's speed. Vehicle count, vehicle speed, vehicle image, and other parameters can be extracted using an intelligent traffic surveillance system. Traditionally, speed measurement approaches have relied on hardware, such as radar speed measurement, laser speed measurement, and so on. The radar system has not gained popularity in traffic monitoring due to its expensive cost and lack of precision. A line-of-sight connection between the vehicle and the radar equipment is also required. Various methods have been used. To overcome the limitations of previous technologies, many strategies for determining vehicle speed using image processing have been developed. Video cameras have proven to be an effective technique for gathering and analyzing traffic data thanks to recent technological advancements in computer vision and image processing. Video-based surveillance systems are more sophisticated and robust because the information that is associated with image sequences presented in a video allows us to identify and classify vehicles in the most effective manner. In video surveillance systems, image processing is commonly used for its various applications. Vehicle detection using image processing has gained much attention in recent years due to rapid advancements in modern computer vision and traffic surveillance techniques**.** Video sequences are used in image processing to track moving objects, extract characteristics, identify traffic intensity, estimate vehicle velocity, and so on. The purpose of this project is to use image processing to create automatic vehicle detection and speed estimation system. Video is used as an input in this system, and background removal is employed to recognize cars.

2. LITERATURE SURVEY

Wei Hou *et al.* [1] proposed a technique for constructing a vehicle video analysis system for the detection and tracking of autos on the road using the moving object library and the data structure in the computer vision library. To overcome the problem of target deformation and partial occlusion, the CAMSHIFT method was applied. The background was created using the Gaussian Background model. These tests confirmed that a threshold of 20 is the best value for vehicle detection.

DONGYANG ZHAO *et al* [2] present a method for vehicle tracking and speed estimation based on aerial videos. The vehicle detection is performed using the YOLOv3 network. In the tracking process, a tracking-by-detection method is designed to track the traffic vehicles. In speed estimation, the relationship between the pixel distance and the actual distance satisfies the exponential function. The error in the vehicle speed estimation becomes larger due to the fact that the mapping rate is increasing.

Genyunan Cheng *et al.* [3] proposed a method based on a KNN algorithm background modeling to extract moving targets and apply the centroid distance matching method to achieve target tracking, so as to calculate vehicle speed. Experimental result shows that the relative error of the speed detection can be controlled at about 5% and meet the real-time requirements of video monitoring speed detection.

S. M. Sunny *et al.* [4] proposed a technique to show how the activity is followed and distinguished by its speed and an accident detection algorithm is used with immediate emergency calling facilities. A kit is developed to coordinate all these S. M.

Sunny *et al.* [4] proposed a technique to show how the activity is followed and distinguished by its speed and an accident detection algorithm is used with immediate emergency calling facilities. A kit is developed to coordinate all these capacities in it and tried in a genuine environment. From picture contrasts the speed of the vehicle is recognized, and the over-speeding vehicle's number plates are identified through OCR Tesseract. Dense-Net engineering is utilized for the location of mishap and the result has been checked and in 80% of cases, an adjusted discovery was affirmed.

Shengnan Lu *et al.* [5] present a unique method for accurately estimating vehicle speed from video sequences. Abandon the idea of feature tracking for speed estimation but adopt a new analysis strategy without feature extraction instead. The proposed method is the inverse process of the traditional method for vehicle speed estimation. It considers the feature differences among the images with different speeds and constructs the mapping relation with the extreme value corresponding to the vehicle speed. Besides, make use of the shadow beneath the vehicle as to the tracking point, which is considered the ground truth speed. According to the findings of the experiments, the suggested system has an average inaccuracy of 0.3 km/h, with 99.4 percent of the estimation speed falling within the error range (- 2 km/h, 2 km/h). For actual application, the system proves to be reliable, accurate, and real-time.

C. Ranjeeth Kumar *et al.* [6] proposed a method in which, the feature value of the samples is combined with bat optimization to select a feature from a large scale feature pool which is having Haar nature. Support Vector Machine is combined with a local binary pattern to track the rectangles between thresholds with a confidence value for classification. The interference area between moving objects and vehicles is removed by using another classifier called Enhanced Convolutional Neural Network (ECNN) classifier. Higher values of accuracy can be obtained by using the proposed support vector machine with the feature selection (SVM-FE) model when compared to the existing methods. The proposed ECNN with SVM scheme attains 93.63% of accuracy whereas existing methods such as CNN, and CNN with SVM attain 84.88% and 89.08%, respectively.

For a real-time vehicle object recognition approach, KEYOU GUO *et al.* [7] used multi-scale feature fusion. The learning rate-adaptive adjustment approach was utilized to replace the traditional and fixed learning rate in the model training process to develop a vehicle multi-object detector. The upgraded SSD detector has a detection time of 55.6 MS, which is faster than other classic detection methods at the same resolution, according to the experimental results.

Suraiya Parveen *et al.* [8] created a simple and efficient motion detection system that allows users to interact with machines and access and retrieve data from the internet on a PC. This proposed model is beneficial because it is both effective and user-friendly. In this scenario, a basic interface is created for the customer to select the important area to be explored, i.e. the region of interest, and image processing techniques are then applied to the photographs to calculate vehicle count and classify the vehicles using machine learning algorithms.

Shriharsha S. Venia *et al.* [9] presented a vision-based system for distinguishing, tracking, and inspecting automobiles. From a given input video, the framework might be used to detect, count, and follow vehicles, and then characterize the recognized vehicles. This system demonstrates that a roadway vehicle counting and classification model can achieve over 93 percent accuracy and a 25 FPS speed for vehicle detection, counting, and classification.

Valanukonda Lakshmi Padmini *et al*. [10] suggested a method for detecting helmet use among motorcycle riders based on machine learning. Motorcycles and their helmets are identified using an object detection-based algorithm. This research work has suggested a way to improve driving safety metrics, which in turn deploys a time-efficient approach to manage traffic regulations, with an 87.6% model accuracy rate.

3. PROPOSED METHODOLOGY

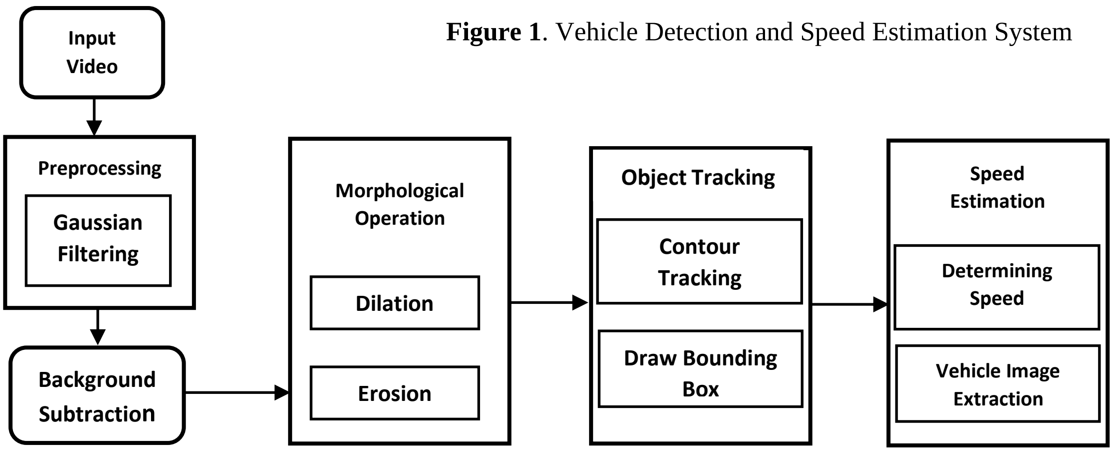

Figure 1. Vehicle Detection and Speed Estimation System

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The system has gone through three stages of development. The detection of a vehicle was the initial stage. Machine learning was used in the second stage to track the car using the OpenCV package. The final stage entailed calculating vehicle speeds. As input, a video from the camera is used. To get a moving object, each frame goes through an object detection process.

I. **Pre-processing** – Pre-processing is heavily dependent on the feature extraction method and input image type Stream of frames are extracted from the input video. Gaussian filter is used to remove noise and reduce details. Each frame is pre-processed to adjust the contrast and to remove the noise. In the process of using the Gaussian Filter on an image, define the size of the Kernel/Matrix that would be used for demising the image. The values inside the kernel are computed by the Gaussian function, the Gaussian function is

$$G(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{x^2}{2\sigma^2}} \quad (1)$$

In OpenCV, the *Gaussianblur()* method of the **imgproc** class object is used to perform the Gaussian filter.

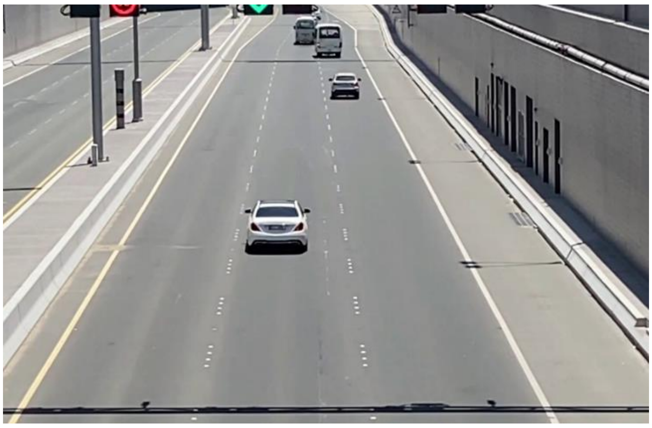

Figure 2. Pre-processed Input

II. Background Subtraction - After pre-processing, foreground objects are extracted by using the background subtraction method. Background subtraction is a widely used approach to detect moving objects in a sequence of frames from static cameras. Background subtraction (also known as Foreground detection) is a computer vision algorithm that tries to distinguish foreground objects from the background. In this method, the pixel difference between the current frame and the background frame is calculated. In OpenCV, the *BackgroundSubtractor* object is used to form the foreground mask. Background modeling consists of two main steps, In the first step, an initial model of the background is computed, while in the second step that model is updated in order to adapt to possible changes in the scene.

III. Morphological Operation - Morphological operations apply a structuring element to an input image, creating an output image of the same size. In a morphological operation, the value of each pixel in the output image is based on a comparison of the corresponding pixel in the input image with its neighbors. Morphological operations are simple transformations applied to binary or grayscale images. In cases like noise removal, erosion is followed by dilation. The *morphologyEx()* of the method of the class Imgproc is used to perform these operations. Erosion removes white noises, but it also shrinks objects. Dilate is used to increase the object area.

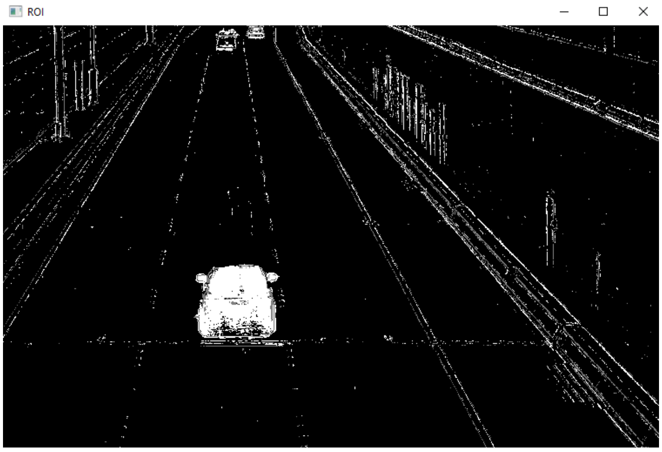

Figure 3. Background Subtracted Input Image

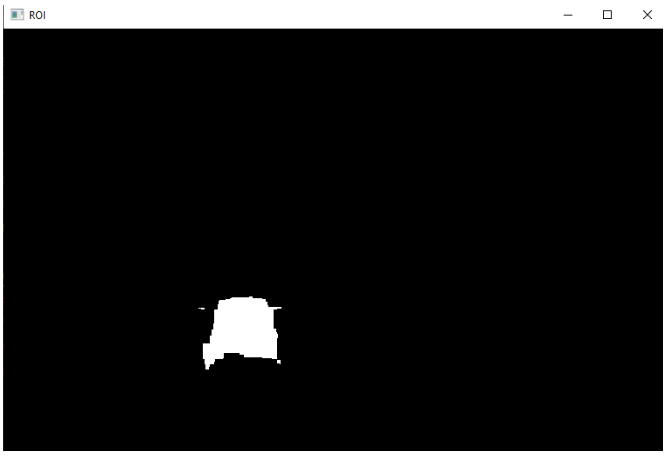

Figure 4. Morphological Operated Image

IV. Object Tracking - Object tracking is the process of locating an object or multiple objects in a video file. In object detection and tracking we have to target an object and track that object in consecutive frames of a video file. The detector identifies the

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vehicles in a given frame of video and returns a list of bounding boxes around the vehicle to the tracker. Contours help in shape analysis, finding the size of the object of interest, and object detection. OpenCV has a *findContour()* function that helps in extracting the contours from the image. The feature detection process is used in the vehicle detection procedure. The retrieved features are tracked over a series of frames. The tracker uses the bounding boxes to track the vehicles in subsequent frames.

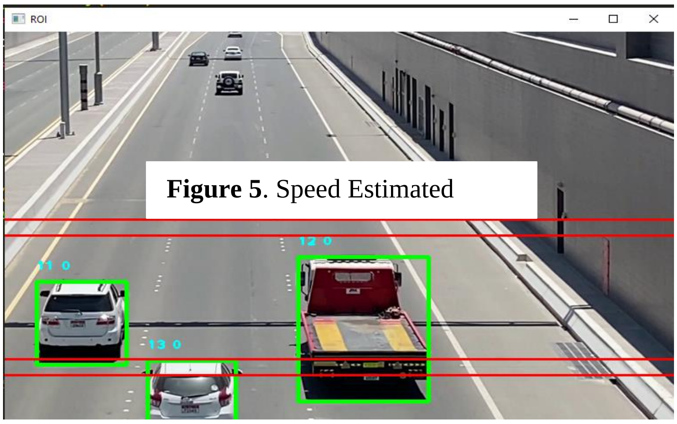


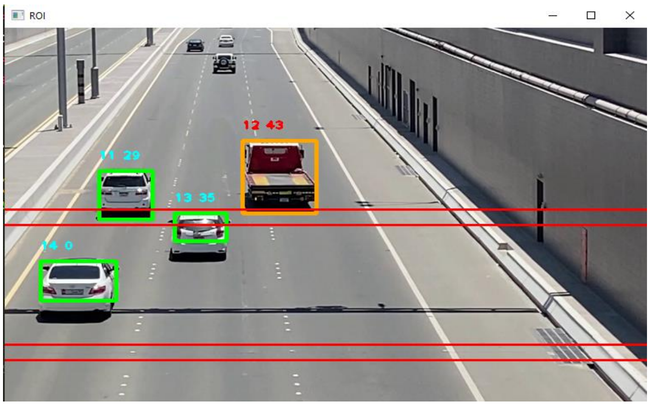
Figure 5. Speed Estimated

Figure 5. Vehicle Tracked Image

V. Speed Estimation - The speed of a vehicle can be estimated when a tracked vehicle covers a segment of the road. The time difference between the positions of a vehicle is calculated. The region of interest is mapped on a frame. The timer starts when the vehicle enters the region of interest, and the timer ends when the vehicle exits the region of interest. In order to achieve vehicle speed estimation based on image processing, it is necessary to determine the mapping ratio between pixel distance and actual distance**.** The distance between pixels is calculated using the Euclidean formula,

$$\text{Distance} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (2)$$

The total time is taken by the vehicle to travel and distance is fixed and is mapped from the real world into an image. By using contour detection image of a vehicle that drives above the speed limit is extracted.



4. EXPERIMENT AND RESULTS

The experiment system platform in this paper is based on the Windows 10 operating system and uses python and OpenCV for programming. The input video is served to process, video converted into frames, and then morphological operation performed on the frames and background subtraction method detects the moving object in series of continuous frames and creates the bounding boxes for each detected object. In order to achieve vehicle speed estimation based on image processing, it is necessary to determine the mapping ratio between pixel distance and actual distance.

Table 1. Experiment Result Table

Test No.	Resolution & FPS	Duration	Light	Detected Vehicles	Total Number of Vehicles	Error
1	1920*1080 30fps	00.02.46	Medium	56	58	3.45 %
2	1280*720 25fps	00.00.29	Weaker	8	7	13 %

From the experimental analysis, it is evident that vehicles were detected at an accuracy rate of about 96.55%, and 87% for low visibility of video. The data in the table shows that overall detection error decreases as resolution increases.

The conclusions were summarized as follows:

a) Surveillance camera should be installed at the top of the road, that is, the camera facing the front of the car. In this complete and stable vehicle information can be captured.
b) The intensity of light affects the detection accuracy. For some black or dark cars, the reflective condition is more serious.

Time is calculated as the vehicle enters the ROI. Initially, the speed is calculated using the formula. If (x1, y1) is the centroid of the vehicle in the first frame and (x2, y2) is the centroid of second frame, the distance between pixel can be calculate with Euclidean distance formula, and add timer for each vehicle when enters the ROI then

$$\text{Distance travelled} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

Speed = Distance travelled / Time taken

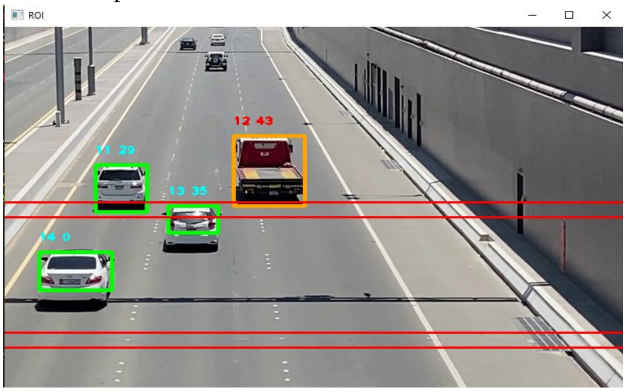


Figure 6. Output

5. CONCLUSION

This study proposes a simple and effective motion detection and speed estimation method. To recognize cars, the suggested method employs background reduction and contour detection. In comparison to earlier strategies, the proposed strategy produces better outcomes. In the real world, background removal is resistant to variations in illumination. This project can predict vehicle speeds and save vehicle information. The experimental results show that the relative inaccuracy of vehicle detection can be managed and that the video monitoring speed estimation system can meet real-time requirements. The research presented here shows how an image processing technique can be used to determine vehicle speed. The temporal difference between the position of a vehicle in a region of interest is calculated in speed estimation.

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