Detection of Traffic Violations using Moving Object and Speed Detection

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***Abstract* –-** Manual and legacy technology is used to detect over speeding in developing countries like India. This process can be easily automated by leveraging the powers of image processing and machine learning. Moving object detection is one of the crucial tasks in image processing because of its important role in many real-world applications. Vehicle speed detection can be achieved by employing image and video processing methods to determine vehicular speed. In this work, we propose a novel approach for vehicle speed detection based on an integrated approach to detect moving objects in video sequence frames as opposed to the most commonly used RADAR and LIDAR devices for traffic law enforcement. Video data is collected and analyzed for speed in real-time without any sensor calibrations, thereby removing any hardware dependency/requirements. A Haar classifier has been trained and integrated into the application for detecting the vehicles. To make the detection more robust, we adopt an efficient object detection system by training the classifier on 1500 positive images. Each detected car is treated as an individual moving Region of Interest (ROI). Moving vehicles are segmented out by using frame-subtraction and masking techniques. The algorithm tracks the time taken by the car to cover a pre-determined distance in order to calculate its speed. This application can be used by the traffic police to automatically detect the speed of each car and note down any license numbers from the video stream in cases of over speeding.

***Keywords* –** Haar Classifier, Image processing, object detection, VASCAR

I. INTRODUCTION

Owing to the high traffic accident rate in India, speed regulations have become the need of the hour. Traffic management and enhancing road safety, can be one way of avoiding road accidents. On the other hand, another approach to prevent road accidents is to deter civilians from over speeding by penalizing such people in the form of fines. In order to identify such cases, the traffic department makes use of hardware-based speed detection systems which requires the physical presence of the traffic officials at the time of over speeding. While effective, such methods are limited by the fact that there are numerous cases which often go undetected.

Some researchers are working to develop sensor technology in networks that provide consumers with traffic information, thus reducing the number of traffic breaches. Many researchers often use global positioning systems in combination with sensors that operate on RADAR or even digital cameras to determine vehicle speed and volume of traffic flow on the roads to monitor over speeding. Significant resources have been spent on the calibration of Large-Scale Traffic Control Systems operations, which is both costly in terms of monetary value time and energy.

Speed monitoring technologies such as RF transceiver, automatic braking systems, camera-based speed recognition and electronic RFID tracking have been introduced in order to reduce the number of road accidents. However, current strategies to reduce accidents are still not effective.

Intelligent speed adaptation providing efficient monitoring for its operator, registration and recording of the vehicle speeds that exceed the speed limit, is therefore an essential priority. In this work we suggest an automated, lightweight speed detection system for real time video surveillance using image processing that can be used by law enforcement.

The paper is organized as follows. The following section elucidates the important existing work done in fields concerning Image Processing, Object detection and tracking. The proposed application is elucidated in section 3, which discusses design methodologies and algorithms employed in this work.

II. LITERATURE REVIEW

One of the most fundamental and critical tasks in computer vision is to detect moving objects along with their video sequence movement. This provides the basis for a variety of automated applications in a range of domains, including monitoring, increased reality and movement capture. Object monitoring is a key component of the IVS or Intelligent Video Surveillance program and can further be replicated for other suspicious activity detection systems. There are ample methods and algorithms for object tracking, which are the basis for implementing an IVS with a mean shift algorithm [1].

Nearly every vehicle detection system comprises two basic stages : (1) a generation of hypotheses, hypothesizing the position in the picture of potential vehicles and (2) hypothesis verification (HV), verification of the assumptions [2]. The aforementioned paper presents a motion-based approach for generating hypotheses. Motion-based methods measure the presence of the vehicle using the relative movement between the sensor and the scene obtained through optical flow measurements [3]. It also works on designing and implementing highly adaptive algorithms and systems based on field-specific road, vehicle, and control knowledge in real time [4]. Automated tracking and motion detection is a challenging task in traffic monitoring. Cheng et al. proposed a digital image correlation-based, high-precision vehicle tracking algorithm [5]. Experiments carried out by Cheng et al. have shown that the approach works well in long-range monitoring. With the scaling value of the tracking device, the high-precision relative speed can be determined.

For some computer vision implementations, object recognition is a crucial step. These included three-dimensional reconstruction, compression, medical imaging, augmented reality, image reconstruction and monitoring [6]. In any traffic management system, it is the first and foremost step. Pawar et al . describe a variety of target detection techniques [7]. The classification of vehicles in the traffic flow is considered complicated because of the similarity in the appearance of many vehicles. A large variety of models and theories of traffic flow have been developed over the past 50 years [8]. The models can be described as follows:

1. Continuous, Discrete, Semi-discrete, which represent the scale of the variables
2. Deterministic, Stochastic, which represent the processes
3. Microscopic and highly detailed, Mesoscopic and medium detailed, Macroscopic and low detailed, which represent the level of detail [9].

Rahmaniar et al. introduced a new and efficient technique for the detection of moving objects in the environment in real time by unmanned aerial vehicles [10]. In order to estimate the camera movement and hence to stabilize the image sequence, the first two successive frames are found. Then, the moving object candidate is detected in regions of interest of the objects. This is the image in the front. In addition, moving objects, based on the motion vectors, in the foreground and the background are classified as the dynamic and static objects. These techniques have surpassed many state of the art techniques, as this technique achieves the speed of measurement as 47.08 frames per second and also maintains a high precision of 94%.

The standard or current system for monitoring or calculating vehicle speed is through the use of RADAR instruments and other variants such as the continuous G-factor, series and acceleration median. The constraints of this device or models are that it is not as precise and is expensive. Furthermore, it does not capture images over long distances. For speed estimation, various techniques have been used. A combination of Gaussian techniques for speed estimations is proposed by Dhulavvagol et al. [11]. The objective is to identify vehicles from the recorded video in order to estimate and quantify the speed of the vehicles. This is done by taking the centroid into account in each instance of a frame and size.

In order to detect high speed vehicles in the Vehicle Ad Hoc Network, Nayak et al. propose a Position Based Algorithm for High Speed Car Detection (PHVA), using a vehicle cloud server, used as computing as a service [12]. A vehicle's speed is measured by the algorithm based on data received directly from the road side units (RSUs). When the vehicle is covered by this RSU, the RSU receives time, position, and other information on a vehicle. The information received will then be forwarded to the Cloud Server. The Cloud Service measures the average speed of the vehicle in a given lane based on information collected from the nearby RSUs. The measured speed is compared to the speed allowed on the road. If a speed that is higher than that permitted is detected, then the Cloud Server increments the speed violation for that vehicle. Appropriate action will be taken on this high-speed vehicle according to the frequency of the violation and the Certification Authority.

A crucial step for traffic safety applications is the automated regulation of vehicle speed by sensing speed sign labels from speed boards on the roadside. In addition, the driver will be notified of the changes in the speed limit with an alarm message [13]. Thus, the driver is informed. In a situation where, even after the warning sign the driver does not lower the limit, the authorities are informed. Automatic control of the speed of the vehicle by detecting the speed signs labels from speed sign boards, which are laid on the road side is a critical step for traffic surveillance applications. Furthermore, necessary steps must be taken to alert the driver by sending a caution notification [13]. When the driver does not lower the speed even after the sign of caution, details of the vehicle are notified to the authorities.

III. PROPOSED METHOD

The proposed work is structured as a three-tier application. The first module is the input acquisition module. It deals with the capture of video data via CCTV services followed by remote transfer to the computer where the proposed application is executed. This work is tailored to work for traffic video data, consequently, the input for the scope of this work is restricted to traffic surveillance videos.

During the process of streaming the input video, each stream is captured using cv2.VideoCapture() method of OpenCV and each frame is treated as an individual image on which the tracking algorithm is applied.

The Image Detection and Segmentation module follows the Image Acquisition module. This module consists of extracting the different ROI's, elimination of any background if present and pre-processing steps.
The preprocessing steps are as follows:

1. Convert the color video frame to grayscale. This is done because images in RGB format increase complexity of the algorithm as the additional information provided by the three-color channels are not of any use to the algorithm. It also reduces the amount of noise in the image frame.
2. Gaussian blurring is performed to remove high-frequency noise which aids in contour detection which is performed in a later stage.
3. Apply fastNIMeansDenoising() method provided by OpenCV to remove remnant noise which uses an underlying Non Local Means denoising algorithm.

After the preprocessing steps have been applied, Segmentation is carried out. Segmentation is the process of partitioning an image into chunks of pixels called image objects, thereby simplifying the process of analysis. The classifier is then used to carry out the object detection in each frame. The flow of events is depicted in Fig. 1.

The last module is the speed calculation module. We implement a robust and well-known algorithm called VASCAR to estimate the speed for each vehicle.

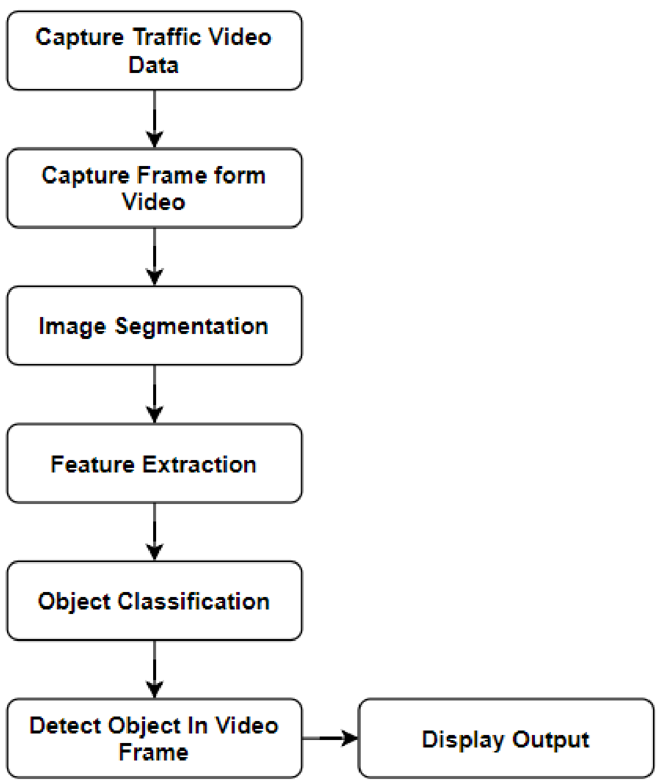


Figure. 1 Proposed architecture for Object Detection

3.1 Image Detection and Segmentation

The first step in the algorithm is to capture each frame from the input surveillance video. After the video frame has been captured, we first apply the above preprocessing steps to reduce the background noise and any noise which might be incurred during image processing stages.

3.1.1. Generating the Haar Classifier

We employ the Haar Cascade Algorithm to carry out object detection and segmentation. We further treat each detected object as a different ROI in each frame, on which we operate independently.
Haar Cascade is an object detection algorithm that is based on machine learning proposed by Paul Viola and Michael Jones in their paper "Rapid Object Detection using a Boosted Cascade of Simple Features" in 2001 to recognize objects in an image or video.

The first step is to collect positive and negative training images. These images form the basis for training of the classifier. We define a positive image as any image which contains our object of interest in the foreground. A negative image is any image which does not contain the object of interest. We need a good corpus of positive and negative images to guarantee good accuracy in object detection. We use 1500 positive images and 2000 negative images.

The positive and negative images are first separated into different folders, following which they are cropped to similar sizes and resolutions. We then carry out the Haar cascade file generation using the positive and negative images by running a batch file which generates the Haar classifier.

3.1.2. Working of Haar Classifier

The Haar Classifier is a machine-based learning technique, where a cascade function is trained on both positive and negative images. Following this the cascade is then used on test images to detect the object of interest.
The algorithm is composed of four separate stages:

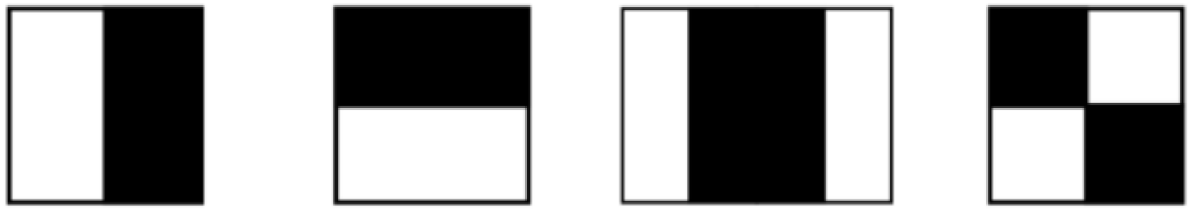
1. Selection of Haar Feature
2. Integral Image Creation
3. Adaboost Training
4. Cascading Classifiers

Collecting the Haar Features is the first step. A haar feature makes use of neighboring rectangular regions in a detection window at a given location, finds the sum of the intensities of pixels in each region. Finally it finds the difference between the sums between white and black regions.

There are 3 basic haar like features which are used :

1. Edge Features are used to detect edges
2. Line Features are used to detect lines
3. Four Rectangle Features detect slanted lines

Sum of pixels of all black subregions are subtracted from sum of pixels occupied by the white subregions. This difference in pixels is referred to as convolution kernels.



(1) (2) (3) (4)

-1	-1	5
-1	-1	5
-1	-1	5

5	5	5
-1	-1	-1
-1	-1	-1

-1	5	-1
-1	5	-1
-1	5	-1

5	-1	-1
-1	5	-1
-1	-1	5

Figure 2. Visual and Matrix representation of Edge (1 and 2), Line (3) and Four Rectangle Features(4)

Viola and Jones suggested an effective method for calculating the number of pixels from a rectangular region in linear time by adding the concept of integral images. Integral images refer to those images where the pixel value at a specific point can be found from the sum of pixel values located before the current pixel at any (x, y) position.

The integral image for the entire source image is only computed once. Every integral pixel value holds the sum of all pixel values above and to the left of the pixel. The number of pixels within a rectangle is determined by referring to the respective integral image values of the corner pixels of the rectangles and performing three basic operations on them.

At a base resolution of 24x24 pixels there can be more than 160000 features to choose from. Hence in the feature selection stage we use the Ada-boost algorithm which selects the most promising features and uses them in the training process. The features selected by the Adaboost algorithm are called weak learners and can be as high as 2500 in number. The weak learners are selected if they perform better than random guessing.

A window of the target size is placed over the test image under consideration during the detection process. Haar features are measured from every subsection in the image. This difference is then compared against a threshold value which has been determined earlier, which separates ROI from non-objects of interest.

Due to each haar feature being only a slow classifier, we use multiple haar features to identify an individual with sufficient precision. Therefore, the weak learners are grouped into multi stage cascade classifiers which in effect function as a strong classifier. The Cascade classifier is a multistage algorithm. In each stage of the classifier, a region is identified as either positive region or negative region by the current position of the sliding window. Positive means an object was located while negative means no objects were detected. In case we have a negative label, the region will be full labelled as complete, and the detector will shift the window to the next location. If the label is correct, the classifier will pass the region on to the next level. If the final stage classifies the area as valid, an object at the current position is detected by the detector.

1.1.3. Usage of Haar Cascade in the Application

The Haar Classifier is then used to detect all the objects in each frame. If the one or more object of interest is detected, we draw a bounding box around it to signify a vehicle in the frame. The is then written to the output video, allowing us to visualize the detected object. Since this procedure is done on a per frame basis, the detection of vehicles appears in the video output.

1.2. Speed Estimation

The final Stage is to evaluate the speed of each moving car in the video stream and create alerts for those that are travelling above the set speed limit. We employ a well-known algorithm called Visual Average Speed Computer and Recorder (VASCAR) to do a simple speed detection. We apply this algorithm on each ROI which was identified in the detection stage.

Effective use of the VASCAR process, is achieved if we know beforehand the accurate measurement of displacement between exactly 2 reference points on the path being captured in the video stream. When a car crosses the first point of reference, we start a timer which is specific to that vehicle. Similarly, when the vehicle crosses the second reference point, we stop the timer and calculate the time difference, i.e. the time taken by the vehicle to move from the first reference point to the second.

We then use the simple formula for speed calculation to estimate the speed for each moving vehicle:

$$Speed = Distance/Time \tag{1}$$

This must be done on a per vehicle basis to effectively track the speed of each car. Finally, we compare the estimated speed of each car to the threshold speed. In the event of over speeding we highlight the required ROI, hence allowing the law enforcement to note down the license plate number and take effective action.

IV. RESULTS AND DISCUSSION

4.1. Performance Metrics

The results of the experiment are measured with accuracy, recall, precision and F-measure as metrics. Precision is the fraction of the relevant instances among the instances retrieved, while recall is a fraction of the overall number of relevant instances retrieved.

Let TP, FP, TN, and FN represent the number of true positives, false positives, true negatives and false negatives, respectively.

The results obtained are:

Table 1. Experimental results

	Predicted Positive	Predicted Negative
Actual Positive	32	3
Actual Negative	2	30

Where, TP = 32, TN = 37, FP = 2, FN = 3

4.1.1. Recall

The precise definition of recall is the ratio between the true positives and the sum of true positives and false negatives. True positive data points are categorized as true points(positive) by the model, which signifies that they are correctly classified and false negatives are those data points where the model categorizes as false(negative) but are actually positive (incorrect). In the proposed work, false positives would be when the model marks an object as a car when it is not so, or the model falsely identifies something as a car. True positive would be when the model rightly classifies a car as a car. A true negative would be when the model categorizes a car as positive object while a false negative would occur when the model fails to identify a car as a positive data point.

Eq. (2) depicts the formula for recall.

$$\begin{aligned} Recall &= TP/(TP + FN) \\ &= 32/(32 + 3) \\ &= 0.92 \end{aligned} \tag{2}$$

4.1.2. Precision

Precision can be defined as the ratio between true positives and the sum of the true positives and false positives is defined as precision. Eq. (3) depicts the formula for precision.

$$\begin{aligned} Precision &= TP /(TP + FP) \\ &= 32/(32 + 2) \\ &= 0.94 \end{aligned} \tag{3}$$

4.1.3. Accuracy

Accuracy is generally defined as the percentage of correctly classified objects, i.e. the percentage of correctly detected vehicles. Eq. (4) depicts the formula for Accuracy.

$$\begin{aligned} Accuracy &= (TP + TN)/(TP + TN + FP + FN) \\ &= (32 + 37)/(32 + 37 + 2 + 3) \\ &= 62/67 \\ &= 0.92 \end{aligned} \tag{4}$$

4.1.4. F1 Score

In certain cases, it might be required to maximize either precision or recall at the expense of the other. The F1 score is the metric we obtain when both precision and recall are taken into account and is defined as the harmonic mean between the two metrics. Eq. (5) depicts the formula for F1 score.

$$\begin{aligned} F1 &= 2 * (Precision * Recall) / (Precision + Recall) \\ &= 2 * (0.94 * 0.92) / (0.94 + 0.92) \\ &= 2 * (0.8648) / (1.86) \\ &= 0.92 \end{aligned} \tag{5}$$

Thus, the overall, the application achieved is an accuracy of 0.92, precision of 0.94, recall of 0.92 and F! score of 0.92. These are obtained using the aforementioned formulas.

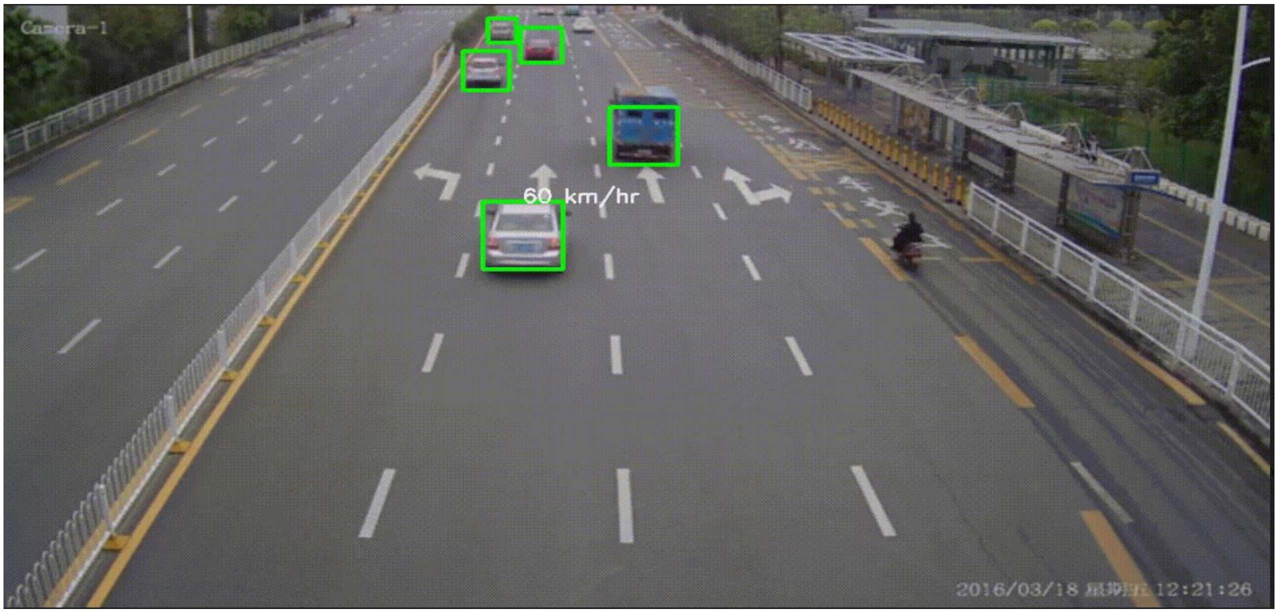


Figure 3. Detection of Vehicles with Speed estimation

4.2. Comparison with state of art techniques

Object tracking is a primary objective of any video surveillance system which can be translated or further modified for other surveillance based systems or other requirements. We compare our findings with other state of art techniques based on the accuracy metric which is the commonly used metric among all techniques. There are many approaches and state of art techniques for object tracking, from which mean shift algorithm was used by Mathur et. al. which obtained an accuracy of 0.939 [1]. Motion based method of hypothesis generation was employed by Sivaraman et. al to ascertain the location and presence of a vehicle by means of leveraging the relative motion between sensor and background [2]. An accuracy of 0.936 was obtained. Pawar et al. provide a plethora of techniques for object detection and explore methods to overcome the problem of similarity in appearance of different vehicles while obtaining an accuracy of 0.910 [7]. Dhulavvagol et al. propose a combination of Gaussian techniques for speed estimation and obtained an accuracy of 0.8 [11]. The proposed method obtains an accuracy of 0.928. This shows that the proposed method works in line with the state of art techniques and performs better in some cases. Table II depicts a comparison between the various state of art techniques available today and the work proposed. Although the proposed work calculates the precision, recall and accuracy, only accuracy is compared as it is a common measure among the other state-of-art methodologies.

Table 2. Comparison chart between proposed method and state-of-art methods based on accuracy

Proposed By	Method	Accuracy
Mathur et. al. [1]	Intelligent Video Surveillance	0. 93

Sivaraman et. al. [2]	Vehicle Detection by Independent Parts	0. 93
Pawar et. al. [7]	Morphology Based Detection	0. 91
Dhulavvagol et. al [11]	Vehicle Tracking and Speed Estimation	0.80
	Proposed Method	0.92

V. CONCLUSION

The use of high-resolution cameras has surpassed conventional sensor-based speed detection techniques. Thus, this research work is the result of an innovative technology integrated with a video monitoring system for speed detection and the enforcement using automatic number plate recognition. The system identifies moving objects on the road, extracts its other parameters, labels all its related elements, which essentially helps to obtain the speed of the vehicle using different python functions, based on the image's geometry and camera position. The system works well to assess the level of both local and highway traffic. The system uses various image processing methods such as background subtraction, binary image formation, gray scale image formation, etc. It can further be enhanced by using OCR technique for license plate identification. Another future enhancement would be to detect two-wheelers in addition to the 4 wheelers which it currently detects. Based on the results obtained, the research work is proven that it can be used as a real time solution for commercial traffic control systems.

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