Detection of Vehicle Speeding Violation using Video Processing Techniques

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***Abstract*—Due to their excellent development skills and low cost, detection of car speeding violations using video processing techniques is known to be one of the better applications for Traffic Speed Control (TSC). These systems apply video processing techniques to camera outputs to obtain the required information. This work describes a method for measuring speed of the vehicle depending on motion data. This paper offers a new motion detection-based vehicle speed measurement method. Unlike the methods that are based on features which rely on the characteristics of vehicles such as license plates or windshields, the proposed methodology can find a vehicle's speed by evaluating its operating features for a specific areas of interest (ROI) with unique dimensions.This proficiency allows for real-time computation and outperforms feature-related methods. Vehicle identification, tracking, and measuring of speed are the three main modules in this system. The compound-off-Gaussian background subtraction procedure detects every moving object when it enter into its ROI.Then using morphological changes, the unique parts of these materials become integrated filled forms and some limited filtration functions produces the most likely objects to be a vehicle. The identified vehicles are then monitored by using the bulb tracking method and their displacement in successive frames is determined which will be used in the final speed calculation module. A photo of the car, its associated speed, and the detection time are all included in system releases. In comparison to existing speed measurement techniques, experimental findings show that the proposed technique has reasonable precision.**

Keywords— Vehicle Detection, Gaussian Background Subtraction, Speed Measurement

I. INTRODUCTION

Transportation is inextricably linked to our day to day activities and plays a crucial role. The authorities' reaction should not be limited as the demand for transportation in metropolitan areas grows. Only for the purpose of constructing new infrastructure or widening existing roads.Over time, it has encountered a number of important problems, such as car accidents, air pollution etc. Hence, progression in transport systems is needed to maintain balance between the demands of society and current transport resources. This progression is done by Traffic Speed Control (TSC) [2]. Traffic related issues are managed by using TSC services during the past three decades with better performances. One advantage in TSC is that here the transport facilities are integrated with cutting edge technologies. This advantage strengthens them to the extent to be used to track traffic flow, detection of violations and improving motives [4-5]. The Video Pace TSC approach, which operates by using the output of video cameras, has, therefore, been of great interest to researchers in the use of video-based systems over the past decade[6], leading to the rapid increase of transport planning and transport engineering applications[7]. There exist several applications of TSC such as measurement of speed of vehicle, estimation of traffic density, classification of vehicle etc., Among all these applications measurement of speed based on vehicle is the one that helps in identifying violations. Cameras have become an integral part of the system, because of its less maintenance costs, broad vision and improved documentary evidence[8].The images which are captured in cameras are processed by using computer vision based techniques. Speed is described as how fast a moving vehicle is moving over at a particular time. It is calculated by using the movement distance and time elapsed from one main parameter to another. Average speed and instantaneous speed are the two main categories of speed. Average speed tells how far a vehicle travel in a given time interval. Whereas instantaneous speed tells the correct speed at one particular time. In this proposed work,the term speed refers to the exact speed at which a vehicle moves at a particular time. Motion based method and feature based method are the two main methodologies used in vehicle detection applications. In Feature based method features such as light, license plate, wheels are detected in each frames. This method provides excellent accuracy with high computational cost due to their consistent feature and high probability of filtering non-vehicle objects [20]. Whereas in Motion based method all the moving objects are considered and treated as the unique

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object in this work vehicle object is taken. As this method do not depend on features it has low computational cost. Filtration method is used in motion based method to filter non vehicle items in the Region of Interest to overcome the drawback of lack of features.

II. RELATED WORKS

The main aim of vehicle detection systems is to identify vehicles from the non-vehicle things such as road surfaces , peoples, animals etc.,. The identified vehicles are then monitored for many reasons such as traffic assessment, vehicle numbering and measurement of speed [21]. In [22] a completely automated traffic monitoring system which uses motion tracking technique to detect vehicles is proposed to monitor the Transport Commissionerate and State Transport Authority(TNSTA) monitoring mechanisms. Considering the benefit of self-measurement, the effectiveness of the system is mainly depends on the accurate identification of lanes for detecting and monitoring vehicles. A 3 Dimension based vehicle tracking method which is based on the probability hypothesis which is used for challenging shots is proposed in [23]. Here the moving vehicle's width as well as length is calculated by using background subtraction methodology. Finally third dimension is calculated by employing homograph matrix to the bubble objects. The main drawback of this methodology is that the misclassification possibility of vehicle type is high by its size.

In [24] Ant-R-Graph (AOG) based vehicle detection methodology which deals with the multifacetedvehicle problem in video display is proposed. The difference between large and small vehicle is identified by using visual features for large vehicles , contours & margins for smaller vehicles.AOG framework is used in another system for detecting vehicle in the congested traffic condition[25]. Here windscreen is used as a parameter for detection. mainly in hidden traffic conditions. Each and every vehicle terminal which is presented on the map is converted into discrete part of the Active –Pace Model and windscreen. The vehicle terminal is used near a bandwidth transformation mechanism that matches the vehicle parameters which is provided as input. In [26]lag analysis method is used for identification , classification of the type of vehicle, counting the number of vehicles in the displayed video frame. This method has the advantage of using less computation power by monitoring the vehicles in group under a congested traffic condition. YOLO V3 algorithm is used for object detection in [26]. In [27] Deep Convolutional Neural Network is used for parking space detection which provides high accuracy. Vehicle routing problem is solved by using clustering algorithm in [28].

A novel tracking system is provided in [27] for rear view type of vehicles with a different color and layout, based on the localization of light and license plate. Identified vehicles will then be monitored by a sophisticated kalman filtration system suitable for low framerate videos. In [28] the relative-discrimination histogram of the oriented gradients is used in addition. A method for measuring speed at low light levels was proposed in, which would locate and connect vehicle headlights. Integration of the various vehicle's headlights is the most important challenge for this system which is accomplished by using cross contact technique and pinhole methodology.Licensing plate reading (LPR) simulation model for speed measurement and monitoring is done in using Elsaq technique for telescopic systems by defining the pon, height and angles of the camera. In a methodology for measuring the speed of the vehicle and the corresponding time for calculating vehicle speed is recommended in stereo-vision systems depends on license-plate detection. OCR and CNN techniques are used to identify license-plate characters in this system**.**The main purpose of all the methodologies provided in the literature survey is to provide a system that can perform almost efficiently in traffic disruption conditions, Whereas the proposed system seeks to alleviate this challenge by providing the Region of Interest engraved on every vehicle.

III. PROPOSED METHOD

The approach presented in this paper is aimed at measuring instantaneous speed by monitoring the driving characteristics of vehicles by using the video output from a stationary camera. This methodology focus on urban areas due to the low speed of vehicles. The proposed methodology does not depend on the physical features of the vehicle such as Number-plate or head/tail light because of which the computational time is reduced since there is no need for matching of the display features. Identified vehicles are further examined in successive frames in order to calculate the speed associated with it. It is determined by inspecting the number of frames a vehicle has taken to cross the pre defined area. The proposed methodology consist of five different steps as it is depicted in the Figure 1. Some presumptions are taken into account in this system such as fixing a camera in one specific height which is used to detect the speed of the vehicle, light condition and road surfaces. All the five steps used in the proposed system is further explained in the remaining sections of this paper.

A. Preprocessing

Initialization and calibration of the variables used in the system is done as the first step. Video frames which are provided as RGB values are converted into gray scale in order to reduce the number of processing channels.Then the Region of Interest is to be specified in order to filter the unwanted parts which do not provide any input from the frame.

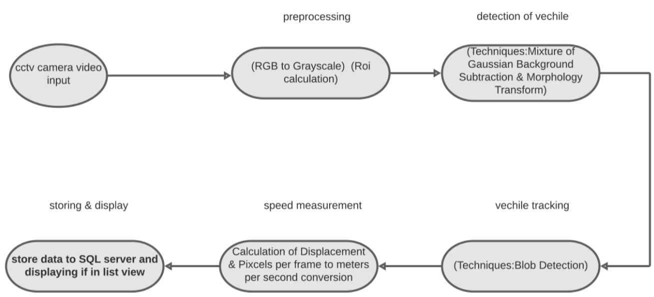

Fig.1. Flowchart of the proposed method

This ROI area should be large enough to cover the entire vehicle area, making it the most suitable place to plant the area where the vehicles will appear - ie. Paths- It should be noted that allROI should be placed on the same roadway.

B. Vehicle Detection

The next step of the proposed method is to identify vehicles within the ROI by using its operating status. Object which are in movement is detected by one of the most famous technique called background subtraction. In this work each law is compared to a standard law –i.e. Difference between frames in background view and binary view format. Pixels which are different while comparing with the reference pixels are separated and treated as parts which are moving. This method is very much ductile even to small changes such as movement of the leaves , unusual light changes etc.. can also be taken as movement. In order to overcome this problem the reference law should be changed and it is also provided in one extension of background subtraction technique as Cassian background subtraction technique. In this method a collection of frames are taken instead of a single frame. They are more likely to belong in the background scene than a gateway time in the scene. Here, if the value of pixel does not change for a period of time, it is taken as a dominant pixel. The Fig. 3 differentiate background subtraction method with the cassian background subtraction method.

Fig.2. Sample of ROI

Due to differing view in various frames, the overall form of the moving vehicle in the last binary picture consists of several separate components, as seen in Fig 3. Each moving area is represented by motion vectors in certain methods, such as optical flow, and then a group of vectors is collected as a unit by uniformity analysis [15].Image transformations are used in the proposed method to present an object as a vehicle for the detection process. This improvements are done by a couple ofmathematical operations which included two inputs, such as a binary image and a kernel images[14]. Opening function and closing function is used in between various image transitions. Fill-holes system, are filled with pre-defined pixels within the attached-elements of an object because of its brightness and adjacent factors[13].

Fig.3. Background subtraction sample output

Opening and closing function used in the detection module is used to represent the vehicle as filled shape as shown in Fig 4. The term bubble in this paper is used to represent the moving object.ie., the object moving within the Region of Interest. The bubbles are not depend upon the physical features of any vehicle. So it can represent any moving objects like animal, pedestrians moving in the street. In order to overcome this drawback and to extract non vehicle material 3 filtering techniques such as maximum bubble, threshold and path filters are proposed in this work.

Fig.4. Output of vehicle detection module

Maximum bubble filtration block identify the biggest bubble within the ROI, which is the most probable case of a vehicle. In Motion-based speed measurement of vehicle using intelligent traffic systems , ROI is chosen according to the calibration value as an area in which the vehicle exist. Hence by disposing small bubbles, the chance of selecting the area with vehicle increases.As the vehicles crossing in the current lane have alarge bump area, and any othervehicle with a partially noticeable bump is discounted. Thresholding filtration is a output of using bubble filter, maximum and minimum threshold value for the given system is defined by using on the portion of ROI region size.

For example, if the highest bulb detected is smaller in size than a normal vehicle size or if the ratio of height from the width of the object is smaller in size than the pre-defined threshold, then these bulbs should be discarded. Therefore, by using this filter system as a next continuous filter,the two wheelers and human beings will be filtered out, and only bubbles with optimal vehicle sizes will be on display for further processing

Trajectory filtration used since the size of the bubble that emerges is higher than the minimum threshold, in some situations, such as many pedestrians walking towards each other, this may not go unnoticed by the last two types of filters. Hence, the path filter takes the displacement of bubbles into account in continuous frames to offset non-vehicle objects. since pedestrians usually walk across the crosswalk they are categorized as non-vehicular objects. So, the location of each and every bubble is saved to get its path. where the resulting bubble is not considered a vehicle due to the inappropriate path. Finally, only moving bubbles that could be a vehicle will be kept in the binary frames and sent to the monitoring step for further processes.

C.Vehicle Tracking

Release of the detection of vehicle step –i.e. The knob-movement of the vehiclewithin the ROI must be monitored in successive frames. The monitoring process can be done using a variety of techniques. In the proposed system as soon as the vehicle enters the ROI it has to be monitored else it is to be name as vehicle IIT. Then a frame counter is used to provide the number of frames in which the vehicle is present within the variable ROI. As long as a vehicle bubble with the same vehicle ID is found within the ROI, the tracking process is protected by the horizontal centroid of the bubbleand the displacement pixels is calculated in between two consecutive frames. The magnitude o fthe displacement is not stable because of capture-related factors, effect of the camera and changes in bubble shape. In order to provide calculation results for displacement, these factors are to be taken into account in the form calibration factor. Because of this reason, a regression threshold parameter is used that operates differently in various parts of the ROI. At last, the average value of the displacements, the number of dptotal and frames is sent to the process of measuring speed. Displacement is calculated in pixels based on the Equation(1).

$$dp_i = |posi - pos_i - 1| \times pc \quad (1)$$

The displacement amount in frame i is dpi and the PC calibration constant is compared to the previous frame. In addition, Posey and Posey-1 are horizontal bulb centroids of the frame i and i-1, respectively. This step is continued till the vehicle remains within ROI. The average value of the displacement is calculated without this region by using Equation (2):

$$dp_{total} = \sum_{frame=i}^{n+i} dp_i / n \quad (2)$$

D. Speed Measurement

At this point, two important values are needed to generate the vehicle speed , displacement value and the elapsed time duration. Instantaneous velocity is calculated over a particular period of time and it is represented as displacement vector. Two different mapping function is used for converting displacement vector into real world scale. KM/h-pixels is converted to meters and frame/second. The size of ROI is represented in pixels and calibration constant value is represented in PC. The value for pixel density is calculated by using Equation 3.

$$ratio = dp_{total}/ROI_{Height} \quad (3)$$

The ratio in meters per pixel of the ROI represents the average area. Thus, the displacement is calculated as follows in measurement of vehicle speed using motion – based technique.

$$displacement\ (m) = dp_{total} \times ratio \quad (4)$$

Where as time-related factors such as frame counters and FPS, are calculate as time in seconds. So, the elapsed time is calculated using Equation 5.

$$time\ (s) = Frame\_counter/fps \quad (5)$$

Finally, the speed of vehicles in km / h is computed by using the Equation (6):

$$Speed\left({}^{km}/_{h}\right) = (displacement \times 3600)/(time \times 1000) \quad (6)$$

The average of all vehicle's instantaneous speed within the ROI is the final speed. There is no drastic difference among average and instantaneous speeds Since the displacement of vehicles is few meters within the ROI.

E.Violation Detection

Since different types of roads have different speed limits, the final vehicle speed computed should be compared with the optimal speed limit. Therefore, an image of the vehicle for detecting a speed violation should be captured as evidence along with the speed and time in the ROI. In metropolitan areas, the speed limit is fixed as 50-70 km / h, while in highways it is given 90-120 km / h depending on the capacity and type of road.

IV. EXPERIMENTAL RESULTS

In this part of the paper, the performance of the proposed methodology based on detection and accuracy of the measured speed is provided. The input video data and output of the computer is a set of images of the vehicles provided along with the relative computer speeds and time to receive the image. Additional information like framecounter and vehicleID is stored in XML format for further processing. Computer with the following configuration 4GB DDR3 RAM on Intel Core 2 Duo 2.66 GHz system is used for video analysis. The rest of the result section is categorized as follows: Dataset is explained in Section – IV-A. Then in Section IV-B criteria for performance of detecting vehicle and speed measurement is provided. It is done for vehicle detection as well as speed measurement separately in section IV-C and IV – D respectively.

A. Datasets

To evaluate the performance of the proposed system, two datasets in video format is contributed an by educational institutions have been used. The first includes five H264 videos from the Federal University of Technology of Faraday (FUTP), which summarize the different lighting and condition of weather in Table 1. The database is captured by using a five megapixel image sensor with the resolution of 1920 × 1080 and 30.15 fps Every single video has its own relative ground true value for vehicle speeds which is calculated by using a high-precision system based on induction loop detectors, accurately measured and validated by the BrazilianNational Measurement Agency. The next data set is an actual video used by the authors of this work with the contribution of KonguEngineering College(KEC), including a 30-minute colour video with a resolution of 1920 × 1080 and 30 fps . To extract the data, a five-megapixel low-cost camera is placed on the front gate of Kongu Engineering College campus,which capturesthe vehicles which are passing during daylight hours. A vehicle with a constant speed was repeatedly ignored in the view of the camera and its actual speed given by the vehicle's travel control system was saved for future testing. The reason for using this database is to explore the proposed method's performance with low FPS actual status video. The low motion effect caused by the low FPS vehicle seems to be disconnected, leading to the loss of details, which is taken as a challenge to the vehicle detection, monitoring and speed measurement system. Table 1 shows the characteristics of FUTP and KEC databases with their respective vehicle speed limits.

TABLE I. Characteristic of FUTP and KEC datatset

Dataset	**File name**	**#frames**	**#Vehicles**	**#Available Vehicle Speed**			
				0-19	**20-39**	**40-59**	**60-79**
Federal University of Technology of Paraná [24]	Set01_video01	6918	119	111			
				3	26	82	0
	Set02_video01	12053	223	198			
				6	43	147	2
	Set03_video01	24301	460	418			
				5	77	320	6
	Set04_video01	19744	349	317			
				11	108	195	3
	Set05_video01	36254	869	795			
				32	256	498	9
Kongu Engineering College	Gate 9_video01	1152	31	31			
				11	13	7	0
Total	-	100422	2051	1870			
				78	1255	517	20

B. Evaluation Criteria

This section introduces the main criteria for subsequent tests presented in sections IV-C and IV-D. The tests are analyzed on the basis of three main criteria:

- **Sensitivity**: The fraction of data associated with the whole set of outcomes recovered is referred to as sensitivity. The most often utilized statistical measure of performance for relative evaluation is sensitivity.Hit or True Positive (TP) refers to data that is correctly classified, while False Negative (FN) refers to data that is misclassified as irrelevant. As a result, the sum of the TP and FN values yields the overall findings.
- **Mean Squared Error(MSE)**:An error indicates the difference between the actual and predicted data in the tests.
- **Variance**: This factor is the square deviation of a random variable from its mean.

C. Vehicle Detection

The important reason for doing this test is to get the effectiveness of the proposed methodology of vehicle detection provided in Section III-B. Therefore, the ROI position was changed depending on the characteristics of each database for system calibration. To execute this test, the sensitivity factor is defined as the number of actual vehicles in the database correctly detected by the computer. Table 2 provides the analysis results of vehicle detection technique. As shown in Table 2, The accuracy in vehicle detection is in acceptable range in most of the cases. The classification of non vehicle objects is reduced in the proposed system since it is not depend on the physical features and it can't able to detect it from the frames. Hence the system is provided as appropriate motion detection and nonvehicle material filtration within the pre-defined ROI.

TABLE II. Accuracy of Vehicle Detection

Dataset	**File name**	**#vehicles in dataset (total)**	**#detected vehicles (TP)**	**Sensitivity percentage (TP/total)**
Federal University of Technology of Paraná [23]	Set01_video01	119	114	95.79%
	Set02_video01	223	212	95.06%
	Set03_video01	460	442	96.09%
	Set04_video01	349	329	94.26%
	Set05_video01	869	843	**97.00%**
Kongu Engineering College	Gate 9_Video1	143	135	94.41%
	Gate 9_Video2	139	97	69.78%
	Gate 9_Video3	264	233	88.25%
	Gate 9_Video4	275	251	91.27%

D. Speed Measurement

The accuracy of measured speed for the proposed method is calculated by performing speed measurement test. Here both the measured speed as well as actual speed of the vehicle is provided as a floating point value. Hence possibility for equal value is very less. Therefore, to compare the values, the acceptable speed limit in this study is be defined as [-3, +2] km / h based to the US standard acceptable limits. Therefore the calculated speed is considered to be optimal if the difference between the calculated and actual velocities is within the defined range. If the difference is less than the defined limit then it will come under lower category else in higher category.The following section explains the results analysis of the speed measurement using the proposed method. This test is only performed on FUTP and KEC databases. The accuracy of the measured speed is analysed by using two different statistical criteria such as sensitivity and analytical accuracy. Sensitivity is defined as the percentage of the data which is classified accurately among all the available data in the database. Whereas analysis accuracy also does the same job with MSE and variance as additional parameters..The difference between actual and measured results. under appropriate lighting and weather conditions, is within the ideal range for more than 94% of vehiclesby usingthe proposed method for the FUTP database.In addition, the figure 6 presents the distribution of actual and measured speed minus errors at 11 km / h. Errors within [-3, +2] km / h are proven with patterned bars.

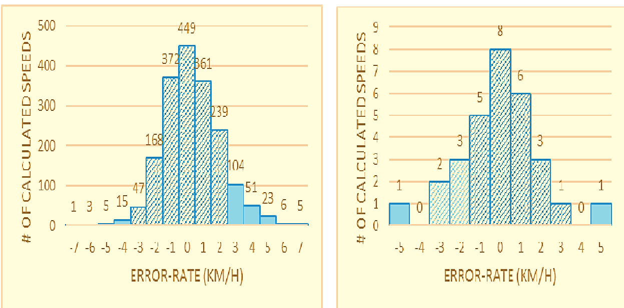

Fig.6. Distribution of speed measurement error

V. CONCLUSION

As part of intelligent transportation systems, this paper presents a video-based vehicle speed measurement system for transportation applications. The recommended method uses road camera output films to generate detected vehicle images, as well as their estimated speed and detection time. This approach is made up of motion detection methods which consist three parts such as Vehicle detection, tracking and speed measurement. The mix-off-Gaussian background subtraction method and image modifications are employed in the detection phase. The bubble tracking technique will then be used to monitor the discovered items, and their displacement will be compared to the previous frame. For speed measurement, average displacements within the area of interest were used.Furthermore, the suggested method does not rely on the vehicles' visual characteristics and instead analyses their operating parameters to detect them inside a pre-defined area. The method was evaluated using two separate real-world datasets, with the final results confirming a detection rate of more than 94 percent and a speed measurement rate of more than 94.8 percent for vehicle detection and speed measurement, respectively.

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