Journal of Education for Pure Science- University of Thi-Qar
Vol.12, No2 (December, 2022)
Website: [jceps.utq.edu.iq] *Email: [jceps@eps.utq.edu.iq]*

DOI: http://doi.org/10.32792/utq.jceps.12.02.13

Suggest a Mathematical Model to Measure the Speed of Vehicles Via Video

hana aqeel musaid Prof .Dr. Kadhim Mahdi hashim

[1] University of Thi-Qar, College of Education for pure Sciences, Department of Computer Science.

Imam Ja,afar Al-Sadiq University.
Received 16/07/2022 Accepted 14/8/2022 Published 01/12/2022

Abstract:

Identification of vehicles violating a certain speed by measuring the speed of vehicles in a non-intrusive manner with low cost and good results is very important, as it directly contributes to helping the traffic police instead of using radar, lidar or other expensive devices, the use of video analysis to estimate the speed of vehicles involved in traffic accidents is becoming increasingly common. In most cases, the estimate is based on in situ reference measurements or data derived using photogrammetry techniques.

In this research, the suggested method estimates the average vehicle speed via computing the distance between consecutive tires using the "Pixel Image Scale Coefficient" and converts the results to accurate measurements. Using an installed camera or a mobile phone device at video frames per second (fps of 30 frames per second, a mathematical function to identify the speed of a passing vehicle predicated on its motion pattern vector and transform that speed from measurements of pixels in succeeding frames to realistic measurements is presented. Three steps were used in this work to implement the technique: In the first stage, a vehicle is distinguished from other objects utilizing artificial intelligence, particularly the Aggregated Channel Features(ACF) vehicle detectors algorithm. In the second step, automobiles are monitored by tracking successive video frames and then the third step, which is the working core of this The research, is to calculate the speed of the detected vehicles in successive video frames through the proposed mathematical equation that mainly depends on the product of the obtained Euclidean distance, and then convert this result to what is proportional to the realistic measurements of speed, which really is km/h.

The project work was produced on a 64-bit system with an Intel Core i7 processor using Matlab R2021a. The software was used to analyze a series of locally captured movies that were used as the data source for a data set used to calculate the average vehicle speed. The proposed program's results were compared with the established driving velocity in order to verify the findings. A simulation of a vehicle moving at a known speed was employed. The mistake rate as a result of the vehicle speeds varied from 1 to 5 km/h.

Keywords: ACF, Euclidean distance, fps.

Introduction 1.

Many people live in apartment complexes or communities where driver inattention is common, where pedestrians enjoy walking, take their children to school or walk to work in the morning, they may all be run over by dangerous and fast-moving cars driven by careless drivers, this is caused by ignoring safety and speeding at dangerously high rates. In these cases, we feel helpless with those drivers who ignore speed restrictions and don't pay attention to pedestrian paths and school areas as well as bumps and they speed up at them as if they are trying to get some fresh air. In fact, there is a possibility What he did towards these people to deter them from these violations and help people defend themselves and protect our families by providing video footage of the cars, their speed and location, and being able to arrest these rogue miscreants in the neighborhood and prosecute them, this is done by working on a system to measure the speed of vehicles through a video camera [1].

One of the most important components of traffic surveillance systems is vehicle speed measurement, speed measuring systems can be categorized into two groups based on how they are used Depending on whether their methodology is active or passive, an active system monitors how a signal is altered as it travels through the air. A sensor system based on an induction-coil loop, a radar, or a camera may be used to estimate the speed of a passing vehicle by laser Some of these systems, on the other hand, are costly and require substantial calibration or maintenance [2].

In a passive mode Sensors frequently work together, and it focus on passive optical video systems. Video-based Due to technology developments in cameras and computing devices, systems have become more prevalent. become more effective, accessible, and dependable [3]. Furthermore, the fair cost-effectiveness of these systems makes them appealing. they're quite competitive with conventional methods [4].

Advanced traffic data analysis is an important part of today's sophisticated transportation systems. This study describes a video-based vehicle speed measuring system that is based on a mathematical model that uses a movement pattern vector as an input variable [5].

There are most popular ways to measure the speed of vehicles:

Law enforcement officers have used a variety of speed measurement devices throughout history, all of which differed substantially in terms of ease of use and accuracy. Currently, police forces measure speed using many different devices:

- RADAR: is an acronym for ""Radio Detection and Ranging"" is the most widely used technique of speed limit enforcement. As a result, many consumers opt to buy radar detectors, which can detect when a speed-detecting radar is approaching. The device is used to reduce the likelihood of the driver getting pulled over, the transmission of electromagnetic waves as they reflect off a moving object is measured using this method of speed clocking. When a wave is reflected, its frequency shifts, and the radar uses this difference to calculate speed. The Doppler Effect, often known as the Doppler Shift, is a change in frequency[6].
- LIDAR**:** (light detection and ranging) systems use an infrared light wave that is emitted at frequencies that allow the beam to be focused onto a small target region. Because the range of these devices is limited by the windshield glass, they are primarily employed outside of the police car. Speed is measured by dividing the distance by the time of the laser's light pulses (S=D/T),

according to the principle underpinning laser speed detection technology. While it is feasible to detect the laser beams emitted by LIDAR, the equipment that do so are restricted in their efficacy, which is why many law enforcement officers choose this device[7].

- Speedometer clocks: are the least technologically advanced type of speed measurement and have generally been supplanted by more efficient technologies. However, because they are the least expensive means of clocking speeders and report quite correctly, they are still utilized in some places[8].

Most of these methods will not have a high cost or the accuracy of the results is not good, so our proposed method was used because it is characterized by low cost and good accuracy of results.

2. Related Works:

There are some researches that presented methods and techniques for measuring the speed of vehicles, and these works are presented. Mohamed Rehan Karim et al. [9] offer a new method for estimating the speed of the vehicles. The camera's calibration was based on geometrical calculations that were directly supported by references. While camera calibration for precise data may be achieved, reliable speed prediction remains a challenge. The developed system can be expanded to handle more traffic applications. The average inaccuracy in detecting vehicle speed was 7km/h, and the experiment was run at various resolutions and video sequences. And Jozef Gerát et al. [10] proposed a vehicle speed measuring system that combines an improved optical low approach with Kalman filter tracking to overcome the problem of overlays with static foreground objects while also improving speed identification. In addition, Gaussian mixture model foreground detection was integrated with DBSCAN clustering to create a more exact object representation. Based on findings, they can conclude that combining optical flow and Kalman filter approaches produces rather acceptable results, even when the image quality supplied by industrial cameras is poor. In the same context Wang Liang et al. [11] presents the notion of virtual loops in video and proposes a new approach for detecting the speed of virtual loops in video. First, in their procedure, by manually setting the distance between all pixels, you may get the true distance between all of them. In the first frame, identify and track relevant locations; then, in the second frame, identify and track the rear. Vehicles on virtual loops are assigned to the back position. linked to a number of frames; finally, determine the vehicle's speed based on the position of the back. The simulation results suggest that this is the case. approach can properly calculate the instantaneous speed in real-world applications, measurement precision exceeds 95%. complies with the standards of the department of traffic supervision and confirms the availability and logic of the data. Adi Nurhadiyatna et al. [12] provide a real-time video processing approach for estimating vehicle speed. Principal elements vehicles are classified using principal component analysis (PCA). Kalman filter is used to keep track of and identify passing traffic. real-time vehicle tracking The vehicle's speed can then be increased. The Euclidean distance technique was used to calculate the value. Speed The precision acquired from ten video data sets is in the percentages ranging from 63 to 99.5 percent. And Diogo C. Luvizon et al. [13] offer an innovative approach for estimating vehicle speed from footage collected on city streets. There system uses text detection to find passing vehicle license plates, which are then utilized to choose stable features for tracking. For perspective distortion, the tracked characteristics are subsequently filtered and corrected. The vehicle speed is calculated by comparing the tracked features' trajectory to known real-world measurements. For license plate detection, the system achieved a precision of 0.87 and a recall of

0.92 in studies conducted on movies collected under real-world situations. In nearly 75 percent of the cases, vehicle speeds were assessed with an average error of 0.59 km/h, staying within the +2/-3 km/h range set by regulatory agencies in numerous nations.

3. Aggregated Channel Features (ACF):

Unconcluded photos of the front, rear, left, and right sides of the cars are used to train the returned ACF Object Detector object. Vehicle Detector ACF (model Name) provides a vehicle detector that has been pre-trained using the model supplied in model Name. Unobstructed views from the front, rear, left, and right sides of cars are used in a 'full-view' model. A 'front-rear-view' model only takes photos from the vehicle's front and back sides[14].

4. The proposed system:

The proposed method includes three main steps; Initially, cars are distinguished from other objects using artificial intelligence through convolutional neural networks (CNN) and specifically the ACF vehicle detector algorithm. Secondly, the cars are tracked by tracking successive video frames. In the third step, the car's speed is calculated through the proposed mathematical equation as a mathematical model to measure the speed. As shown in fig. 1.

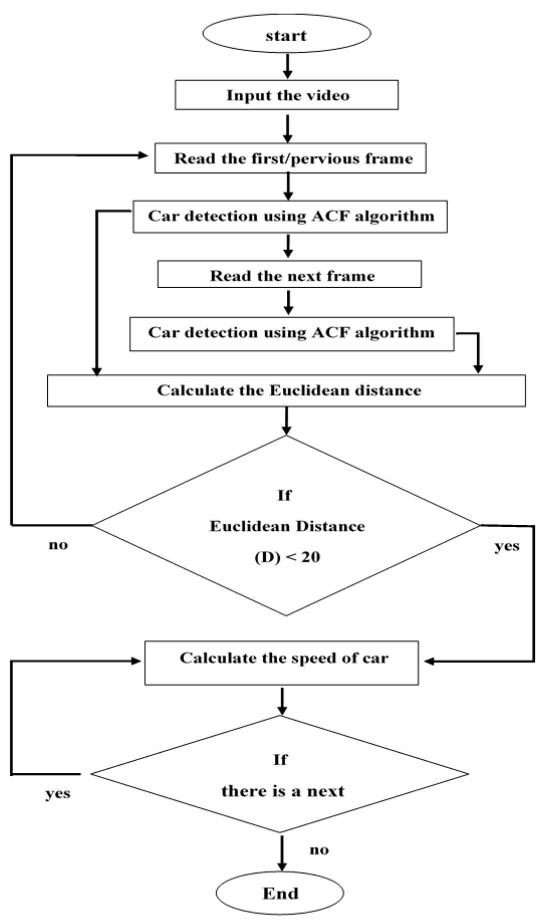

Fig. 1: The proposed system.

5. Vehicle detector

Model of vehicle detector, either 'front-rear-view' or 'full-view.' A 'full-view' model employs training images of unobstructed views of cars from the front, rear, left, and right sides. A 'front-rear-view' model only takes photos from the vehicle's front and rear sides as shown in paragraph 3. When vehicles are discovered, they are surrounded by a box to identify them. It is possible to identify dozens of vehicles in the image and surround them with boxes, as well as display the prediction percentage that the detected object is a vehicle, as shown in the fig. 2.

Fig. 2: Detected vehicle and scores.

5. Car tracking:

After reading the input video and identifying the cars in it, each car is tracked by tracking the location of the car, and that happens when the first frame is read, then the next frame, and the Euclidean distance is found between the arranged pairs of the values of the location of the upper left corner of the box surrounding the car when it was determined, and then the values are switched The first frame is in the subsequent frame and the subsequent frame is in the new frame that is being read. If the value of the resulting Euclidean distance is less than 20, this means that it is the same car and in this case the frames are moved in succession and thus we can track the vehicles during successive frames.

```
if number (new box) ~=0 && number (old box) ~=0

   for I=1: size (new box, 1)

   [D, ind] =  distance(old box, new box(i,:), 'Euclidean', 'Smallest', 1);

if D<20

    X = new box(i,1) – old box(ind,1);
    Y = new box(i,2) – old box(ind,2);
```

6. The speed calculator:

The step of calculating the speed of the vehicle is the most important and main part of this proposed system. It mainly depends on calculating the speed during successive frames in the video for each car, and then converting this value into real world measurements.

The first step is to enter the first frame of the video and identify the car from other objects and surround it with a square after distinguishing it, then the same process we perform on the subsequent frame as mentioned and benefit from it in the process of tracking the car, where we perform a subtraction process between the squares surrounding the same car and automatically the points raised will represent the beginning Each square is the upper left corner of the square, as in the following:

X = new box(i,1) – old box(ind,1);
Y = new box(i,2) – old box(ind,2);

After that, the squares of each of x and y are summed and the square root of this result is found, which represents the result of the distance between these points in pixels.

Distance(D)= sqrt(X^2 + Y^2);

Actual Distance Mapping Relationship – Pixel Coordinates, Speed is the ratio of distance to time, and the time taken by each frame in a typical image of video sequences is a fixed value (frame cycle of video sequences with 30f/s frame frequency). By building a coordinates relationship between distance and frame number, you can retrieve the distance/speed of the vehicle frame as a unit based on the varied locations of a few frames back in the distance space.

Speed is distance over time.

Actual speed= (((D/ 45) *1000/100)/ 1000)* 6* 60* 60

The actual speed of the car is obtained by converting the measurement of distance in pixels, by multiplying the result by the value 1000. Since the videos on which the program was applied had a frame rate equal to 30 f/s, and to make the result of executing the program better, one frame was taken out of every 5 consecutive frames and displayed and worked on, so the result was multiplied by the value 6, which is divided by 30/5 to get the output per second Then convert it to the minute by multiplying it by 60 and finally converting it to the hour by multiplying the result by 60, so that the result of this equation is the distance within the kilometer per hour, which is the required output.

7. Results and discussion:

To validate the method, a simulation was performed with vehicles traveling at known speed. The camera was installed in a fixed position, on a tripod, at a height of 5 m. The scenes were recorded using a

(Mobile phone (real me 6, Android v.10, Ram 8) camera, with a recording frame rate of 30 frames per second.

The application of the method produced speed estimates for each selected video footage. The results were close to the control speeds, with a swing deviation between (1 km/h- 5 km/h).

In case number one, it was agreed with the car driver to drive it at a speed of 70 km/h, but the speed that was recorded after applying our proposed method is 71 km/h, meaning that there is a deviation of approximately 1 km/h, an increase in the resulting speed, as in the fig. 3.

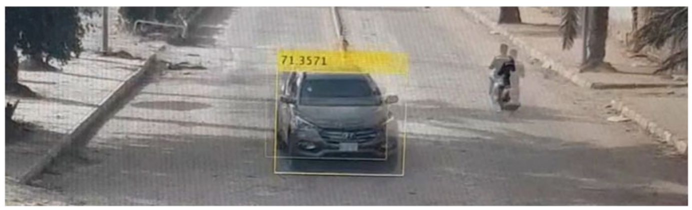

Fig. 3: Test result for the first case.

In case number two, it was agreed with the car driver to drive it at a speed of 100 km / h, but the speed that was recorded after applying our proposed method is 95 km / h, meaning that there is a deviation of approximately 5 km / h, a decrease in the resulting speed, as in the fig. 4.

Fig. 4: Test result for the second case.

In case number three, it was agreed with the car driver to drive it at a speed of 80 km/h, but the speed that was recorded after applying our proposed method is 76 km/h, meaning that there is a deviation of approximately 4 km/h, a decrease in the resulting speed, as in the fig. 5.

Fig. 5: Test result for the third case.

In case number four, it was agreed with the car driver to drive it at a speed of 80 km/h, but the speed that was recorded after applying our proposed method is 76 km/h, meaning that there is a deviation of approximately 4 km/h, a decrease in the resulting speed, as in the fig. 6.

Fig. 6: Test result for the fourth case.

In case number five, it was agreed with the car driver to drive it at a speed of 90 km/h, but the speed that was recorded after applying our proposed method is 88 km/h, meaning that there is a deviation of approximately 2 km/h, a decrease in the resulting speed, as in the fig. 7.

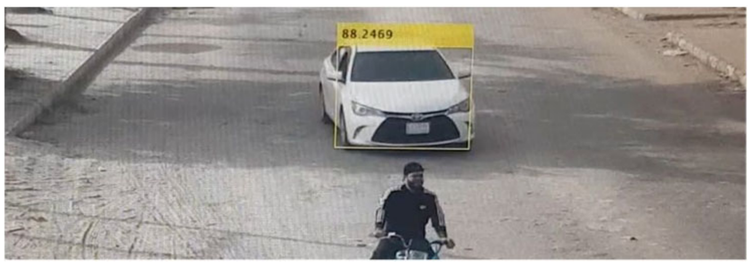

Fig. 7: Test result for the fifth case.

The application of the proposed method produced speed estimates for each detected frames. The results were approach to the control speeds, with a maximum deviation of 5 km/h. As shown in the following table (Table 1).

Results: Vc = vehicle control speed, Ve = vehicle speed estimate using the proposed system.

Table 1: Results and deviation amount.

Cases	Vc (Km/h)	Ve (Km/h)	Deviation (km/h)
Case1	70 Km/h	71 Km/h	1
Case2	100 Km/h	95 Km/h	5
Case3	80 Km/h	76 Km/h	4
Case4	80 Km/h	76 Km/h	4
Case5	90 Km/h	88 Km/h	2

By comparing these results that we obtained with the results of research in the same context to measure the speed of the car, different techniques were adopted, for example, in the research [15] offer a method for estimating the speed of the vehicles. The camera's calibration was based on geometrical calculations that were directly supported by references. While camera calibration for precise data may be achieved, reliable speed prediction remains a challenge. The average inaccuracy in detecting vehicle speed was 7 km/h, and the experiment was run at various resolutions and video sequences. Show in (table 2).

Table 2: The experimental results of the speed detection system.

Real speed (Km/h)	X_1 (pixel) (x, y)	X_2 (pixel) (x, y)	$\Delta x = X_1 - X_2$ (pixel)	Δx (m)	Error	System detection speed (Km/h)
40	(64,76)	(74,69)	12.2	0.81	0.03	38.6
50	(63,47)	(79,42)	16.76	1.12	0.01	50.4
60	(64,79)	(85,84)	21.58	1.44	0.07	64.7

The prominent negative in the aforementioned work is that it depends on the longitudinal path of the cars and calculating their speed, and this represents a strong weakness, because the cars in this case are more vulnerable to the process of blockage by other cars, which affects the result for calculating the speed, as well as it does not include cases in which the car is in a state of rotation when turn what.

8. Conclusions:

Use a non-intrusive and inexpensive system to estimate the speed of the car is an alternative very well to using radar or LIDAR devices, which are characterized by their high cost. To help the traffic police, the police detect the traffic of vehicles that exceed the specified speeds, and to facilitate the diagnosis of these speed-violating vehicles based on video. The method presented in this research was an effective way to measure the speed of cars, as it was based on provided a mathematical function to detect the speed of the passing car based on the vector of its movement pattern and convert this speed from measurements of pixels in successive frames to measurements of the real world. Acquiring the dataset of car videos locally with a smartphone device at video frame rates of 30 fps was an important step to compare the speeds generated by the proposed software with the real ones. In this work, the proposed method was implemented using three important steps: First, the vehicle was identified from other objects using artificial intelligence, specifically the ACF vehicle detector algorithm, which was very effective in the detection process as a result of its dependence on the overall features of the front or rear of the vehicle, and secondly, tracking Cars by tracking successive video frames, and this method was characterized by its simplicity and effectiveness, and. Finally, the speed is calculated through a mathematical equation organized in proportion to the video pixels to simulate the real speed.

This research can be developed in future works by adding a step after performing the speed calculation process, which is to identify the license plates of cars violating a certain speed, which are set as a threshold, and the license plates of speed-violating vehicles are retrieved in a violation file, in order to help the traffic police to identify the cars that exceed the specified speed easily and quickly.

References:

[1] A. Rosebrock, "OpenCV Vehicle Detection, Tracking, and Speed Estimation," *Pyimagesearch*, pp. 1–74, 2019, [Online]. Available: https://www.pyimagesearch.com/2019/12/02/opencv-vehicle-detection-tracking-and-speed-estimation/.

[2] T. Kumar and D. S. Kushwaha, "An Efficient Approach for Detection and Speed Estimation of Moving Vehicles," in *Procedia Computer Science*, 2016, vol. 89, pp. 726–731, doi: 10.1016/j.procs.2016.06.045.

[3] J. Lan, J. Li, G. Hu, B. Ran, and L. Wang, "Vehicle speed measurement based on gray constraint

optical flow algorithm," *Optik (Stuttg).*, vol. 125, no. 1, pp. 289–295, 2014, doi: 10.1016/j.ijleo.2013.06.036.

[4] E. C. Neto, S. L. Gomes, P. P. Rebouças Filho, and V. H. C. De Albuquerque, "Brazilian vehicle identification using a new embedded plate recognition system," *Meas. J. Int. Meas. Confed.*, vol. 70, pp. 36–46, 2015, doi: 10.1016/j.measurement.2015.03.039.

[5] S. Javadi, M. Dahl, and M. I. Pettersson, "Vehicle speed measurement model for video-based systems," *Comput. Electr. Eng.*, vol. 76, pp. 238–248, 2019, doi: 10.1016/j.compeleceng.2019.04.001.

[6] S. L. Jeng, W. H. Chieng, and H. P. Lu, "Estimating speed using a side-looking single-radar vehicle detector," *IEEE Trans. Intell. Transp. Syst.*, vol. 15, no. 2, pp. 607–614, 2014, doi: 10.1109/TITS.2013.2283528.

[7] E. Simley, L. Y. Pao, N. Kelley, B. Jonkman, and R. Frehlich, "LIDAR wind speed measurements of evolving wind fields," *50th AIAA Aerosp. Sci. Meet. Incl. New Horizons Forum Aerosp. Expo.*, no. July, 2012, doi: 10.2514/6.2012-656.

[8] M. Mitchell, "the Development of Automobile," *Visible Lang.*, vol. 44, no. 3, pp. 331–366, 2010, [Online]. Available: http://epublications.bond.edu.au/cgi/viewcontent.cgi?article=1555&context=hss_pubs.

[9] M. R. Karim and A. Dehghani, "Vehicle speed detection in video image sequences using CVS method," *Int. J. Phys. Sci.*, vol. 5, no. 17, pp. 2555–2563, 2010.

[10] J. Gerat, D. Sopiak, M. Oravec, and J. Pavlovicova, "Vehicle speed detection from camera stream using image processing methods," *Proc. Elmar - Int. Symp. Electron. Mar.*, vol. 2017-Septe, pp. 201–204, 2017, doi: 10.23919/ELMAR.2017.8124468.

[11] L. Wang and J. Song, "The speed detection algorithm based on video sequences," *Proc. - 2012 Int. Conf. Comput. Sci. Serv. Syst. CSSS 2012*, pp. 217–220, 2012, doi: 10.1109/CSSS.2012.62.

[12] A. Nurhadiyatna, B. Hardjono, A. Wibisono, W. Jatmiko, and P. Mursanto, "ITS information source: Vehicle speed measurement using camera as sensor," *2012 Int. Conf. Adv. Comput. Sci. Inf. Syst. ICACSIS 2012 - Proc.*, pp. 179–184, 2012.

[13] D. C. Luvizon, B. T. Nassu, and R. Minetto, "Vehicle speed estimation by license plate detection and tracking," *ICASSP, IEEE Int. Conf. Acoust. Speech Signal Process. - Proc.*, pp. 6563–6567, 2014, doi: 10.1109/ICASSP.2014.6854869.

[14] "Load vehicle detector using aggregate channel features - MATLAB vehicleDetectorACF." .

[15] C. N. E. Anagnostopoulos, I. E. Anagnostopoulos, I. D. Psoroulas, V. Loumos, and E. Kayafas, "License plate recognition from still images and video sequences: A survey," *IEEE Trans. Intell. Transp. Syst.*, vol. 9, no. 3, pp. 377–391, 2008, doi: 10.1109/TITS.2008.922938.