A Comparision of Image Processing Techniques for Vehicle Velocity Estimation

Syed Farooq Ali,
SST,UMT
Lahore, Pakistan
farooq.ali@umt.edu.pk

Adnan Abid
SST,UMT
Lahore, Pakistan
adnan.abid@umt.edu.pk

Muhammad Asim Butt
SEN,UMT
Lahore, Pakistan
asim.butt@umt.edu.pk

Abbas Raza
SST,UMT
Lahore, Pakistan

Aijaz Khan
SST,UMT
Lahore, Pakistan

Adeel Asghar
SST,UMT
Lahore, Pakistan

Ahmad Kamal
SST,UMT
Lahore, Pakistan

***Abstract*— Monitoring the velocity of a vehicle is an important activity in managing the traffic. Several techniques have been developed to estimate the velocity of a vehicle. The field of computer vision offers different ways of estimating the velocity of a vehicle. This paper presents computer vision based three different techniques to estimate the velocity of a vehicle using video processing. We also compare these methods from different perspectives. As an auxiliary contribution we have also prepared video data set to evaluate and compare the accuracy of these systems.**

Keywords*— Computer Vision, Background subtraction, traffic monitoring techniques, Motion vectors, vehicle detection, vehicle tracking,, vision velocity algorithms, Image processing

I. Introduction

Traffic surveillance systems are widely used nowadays for performing various tasks including vehicle count, traffic congestion, detecting suspicious vehicles, crime control, traffic rules violation, over speeding etc., The study of such various tasks are used to reduce the road accidents.

The techniques presented in this paper have been motivated by the extensive use of surveillance cameras for traffic problems. All the techniques developed in this research paper are based on single video camera to automatically calculate the speed of the vehicle hence reducing the road accidents caused by over speeding.

Speed limits are used to improve road traffic safety, road accidents and to reduce the environmental impact of road traffic including vehicle noise, vibrations and emission [16]. The World Health Organization (WHO) identifies speed control as one of various measurements that can contribute to reduction in road casualties. According to the WHO estimates around 1.2 million people were killed and 50 million injured on the roads around the world in 2004. It was estimated that around 1.25 million people were killed and several millions were injured in road accidents in 2013 [17]. Due to this high number of road accidents, it becomes the leading cause of deaths in adults of 15-29 years of age and ninth cause of death for all ages worldwide. It is important to note that 32,675 people died and 2.3 million were injured in crashes in 2014. It is estimated that road accidents caused the death of around 60 million people during the 20th century around the same as the number of World War II casualties.

The moving object detection is an important task in the image sequences of the area which is under surveillance. Detection of moving object is necessary for surveillance applications. The moving object detection is the initial step in velocity detection. The aim of moving object detection is extracting moving objects in video sequences with back-ground which can be static or dynamic. After the moving object is detection, then different techniques and algorithms as described in this paper can be used to calculate the velocity of the vehicle. Various factors including camera noise, tree waving and illumination changes can affect the output of the algorithms

The rest of the article has been organized in the following manner: Section 2 presents the relevant literature; our proposed methodologies to compute velocity have been presented in Section 3; the data set for the evaluation of our approaches is presented in Section 4; the comparison of the proposed approaches has been presented in Section 5. Whereas, the article has been concluded in Section 6

II. Literature Review

Monitoring traffic conditions has been a great topic of interest in past. Researcher tested and devised various ways to improve the monitoring of traffic conditions. John L. Barker Sr. and Ben Midlock invented a radar velocity gun in 1947.

Later on, in early 1960s Lidar technology was introduced to detect the velocity of objects using laser technology. In 1979 sensors were developed to estimate the velocity of objects or vehicles [7].

In the early 2000, a new technique was proposed in US patent to detect the embodiment parts of the vehicle [6]. Later in 2006, a technique known as Embedded Vehicle Velocity Estimation System using an Asynchronous Temporal Contrast Vision Sensor was proposed in which object detection was done by sensing the shadow of newly arrived object in frame [15].

In this article, we present three different approaches based on computer vision, which involve *imaginary lines (IL)*, *background subtraction (BS)*, and *motion vectors (MV)*. The technique of motion vectors is motivated by the paper published in 2006. This paper gives extensive knowledge on vehicle detection during day and night scenarios and under various environmental conditions [10].

III. Methodology

The following algorithms have been implemented to acquire the required goals of the research:

A. Imaginary Lines

In this method, velocity of the vehicle is calculated using the formula v= d/t, where 'v' denotes velocity,'d' means distance and 't' signifies time. The purpose of using this technique is to count the frames. The count starts from the frame where car has been detected and count goes to the exiting frame (where the car exits). Since the camera is reading the frames in constant velocity of 60 frames per second, the entry and exiting frames can be taken as initial and final frames. To determine how to detect a car has entered the frame, two imaginary lines have been programmatically introduced in all the video frames as shown in Fig. 1; one at the right end of the frame and one the left end of the frame.

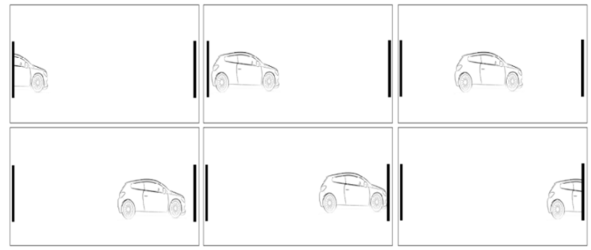

Fig. 1. Imaginary Lines

Whenever a car cross through the right side line, pixel values at that point change and the frame counting function is triggered and this function continue to track the frame number until change is detected in the pixel values of the left side line. Now the time variable can be calculated by counting the frames between initial and final frame using frame difference approach. Both distance and time values has been acquired which can then be used to estimate the velocity. Following are the formulas that have been used for this technique.

- Frame difference = existing frame number – entry frame number
- Velocity = distance/ time

B. Background Subtraction

This technique is applied when there is a need to extract necessary information from video frames. Essentially the frames are converted to binary images and then subtracted to get pixel difference. This pixel difference shows that a car has entered the frame hence altering the pixel values. This change in pixels triggers the frame calculation from this frame which continues to calculate up till the frame pixels match the initial frame pixel; it means the car has left the scene as shown in Fig. 2. It is necessary to reduce noise in the image before frame calculation starts because we need to calculate frames in which only car is moving not the frames in which other things like leaves or clouds are moving so thresholding of -0.5 has been applied to detect the car and neglecting other small pixel changes like camera movement or leaves movements.

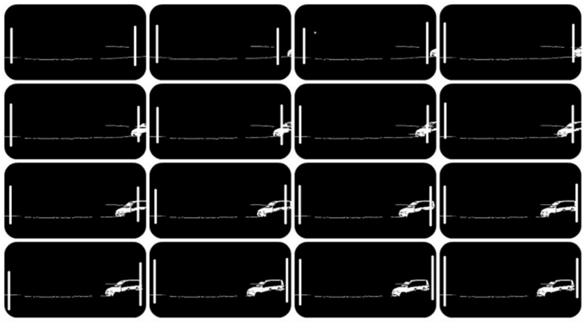

Fig. 2. Background Subtraction

C. *Motion Vectors*

In this approach, the frames are divided into blocks. These blocks then serve as referenced segments which are searched in the consecutive frames. This approach takes the first frame that has no car in it and initializes blocks; each block is then searched in the next frame as illustrated in the Fig. 3. When a car enter a frame, the pixel values in that block changes which means the reference block (keyblocks) in that point will not be found in this updated frame, hence this means that a car has been detected. This initiates that frame calculation need to be calculated from this frame. As the car constitutes of more than one blocks so all these blocks will be searched and the frame calculation will stop when all these reference block has been detected again which means that the car has left the scene.

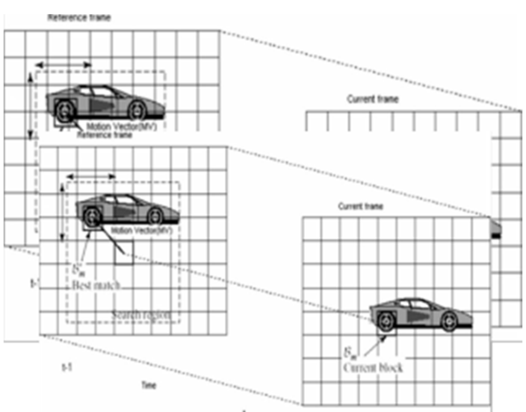

Figure 3: Motion Vector

If two or more cars enter the frame, the reference blocks will continue to be searched until the frame matches the reference frame, so this technique can estimate the velocity if there are more than one car occur in the frame. This is a brute force tactic hence it relies on heavy computation of tracking moving object in frames. In this technique, both frames are divided into blocks and every block in reference frame is searched in current frame. If certain block is located in same location in both frames that means there is no motion in that block.

Following diagram describes the key steps of each technique, in which IL represent Imaginary Lines, BS is used for background Subtraction, and MV denotes Motion Vector

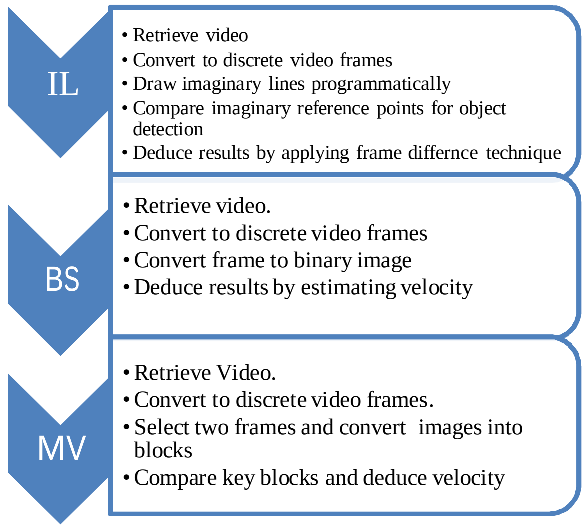

Fig. 4. Key steps of each technique

D. *Hybrid Approach for Multiple Cars*

For detecting the velocity of multiple cars, we implemented the hybrid approach, in which we use imaginary lines, background subtraction and blob analysis to estimate the velocity of multiple cars.

The biggest challenge in multiple cars is to keep a track of cars entering and leaving the scene. For example, Car A enters the frame followed by Car B. But then Car B overtakes Car A and leaves the frame earlier. Now it is difficult to keep track of car entering and leaving the scene. This problem is catered in this approach.

In this approach, in addition to the two imaginary lines (defined at both sides of each frame) as shown in Fig. 5, a feature vector for each car is generated when it enters the scene. Similarly, one more feature vector is generated when car exits the scene. Now feature vectors of car exiting the scene is matched with all the feature vectors of cars entering the scene. The maximum match will help to determine the specific car e.g., if Car A enters the scene followed by the Car B. The feature vector for Car A and B entering the scene is generated i.e., FV_{AEnter} and FV_{BEnter}. Now suppose Car B overtakes Car A and leaves the frame earlier. In order to determine which car is leaving the scene, its feature vector is generated and matched with feature vector of Car A and Car B entering the scene i.e., FV_{AEnter} and FV_{BEnter}. It matches more with FV_{BEnter} hence it shows that the Car leaving the scene is Car B. Therefore, it helps to determine the amount of time the Car B stays in the scene that helps us to calculate the velocity of Car B. That's how this approach can be successfully used to detect velocity of multiple cars.

Whenever a car enters the imaginary line, distortion is created on imaginary line, which will consequently result as a trigger. From this trigger, we can wait until the car completely passes the imaginary line, restoring it into its original form. As soon as the line restores we can crop out certain section of frame in which possibly car would be present.

Now we have a relatively small sub frame which have newly arrived car in it. Background subtraction is used to subtract this frame from our reference frame that gives us the sub frame containing only the shape of our car. Now feature vector comprising of mean pixel value and total number of pixels is generated from this sub frame.

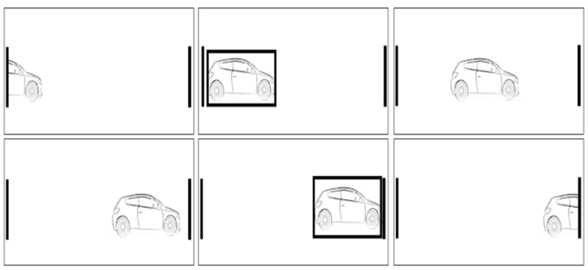

Fig. 5: Hybrid Approach

Now that whenever exiting imaginary line is distorted, it means the car is leaving the scene. Hence, we do the same as above but here we do not wait for the line to be restored. We just crop out the sub frame and repeat the feature extraction procedure as mentioned above, hence new feature vector is generated for a car exiting the scene.

IV. DATA SET& EXPERIMENTAL SETUP DETAILS

In this paper, following data set has been arranged in order to obtain extensive and efficient results of all the methodologies involved. Data set consists of different videos. For each video, video camera is kept at a constant distance from the road to take a fix camera view of road, which is 0.013716km (45 feet). Details of data sets are described in the following table.

TABLE I. DATA SET

Video Category	**Very Slow**	**Slow**	**Medium**	**Fast**	**Very Fast**
Velocity Limit	1-15 km/h	16-30 km/h	31-50 km/h	51-60 km/h	61-80 km/h
Total Videos	3	4	3	3	3

V. EXPERIMENTAL RESULTS

The results of this paper have been summarized as follows:

TABLE II. RESULTS

Velocity Variant		**Very Slow**	**Slow**	**Medium**	**Fast**	**Very Fast**
Velocity Limits		1-15 km/h	16-30 km/h	31-50 Km/h	51-60 km/h	61-80 km/h
No. Videos		3	4	3	3	3
Imaginary Lines (%age Accuracy)		81	80	83	79	77
Background Subtraction (%age Accuracy)		74	75	76	68	66
Motion Vectors (%age Accuracy)		88	90	91	88	86
Hybrid Approach	**Car A**	86	87	87	88	83
	Car B	89	91	89	92	90

TABLE III. COMPUTATION TIME

Methodology	**Imaginary lines**	**Background Subtraction**	**Motion Vectors**
Time In seconds	0.439s	(Without Noise Filters) 8.20s (With Noise Filters) 0.1221s	1.095s

Note: Above time representing approximate time for the computation of single frame.

These experiments were done on a machine with following specifications.

System Specification
- Processor i3: model m380
- Ram 4 gb (3gb usable) 667MHz DDR3
- Level-3 Cache

O/S specification
- Windows 7 32bit

VI. CONCLUSION

In this article we have presented three different algorithms based on computer vision to estimate the velocity of a vehicle. We have evaluated and compared these approaches in terms of accuracy and performance.

The results reveal that *motion vectors* based approach is the best approach.

In future, this work can be improved to estimate the velocity of a vehicle on a two way road, and in the dark.

ACKNOWLEDGEMENTS

This research is funded by the ICT Grant scheme (FRGS) – Grant No.FrGS/1/2011/FKEKK/TK02/1-F00114, LAHORE.This research is conducted at University of Management and Technology. We would like to express our gratitude to the ICT and RTC for the funding.

REFERENCES

[1] Y. Zhang, C. Geng, D. Yao, L. Peng, "Real-time Traffic Object Detection Technique Based on Improved Background Differencing Algorithm", *The 12th World Conference onTransportation Research*, pp. 1-11, July 2010.

[2] L. A. Alexandre, Aurélio C. Campilho, "A 2D Image Motion Detection Method Using a Stationary Camera".

[3] M. S. Temiz , S. Kulur, S. Dogan, "Real Time Velocity Estimation from Monocular Video", *International Archives of thePhotogrammetry, Remote Sensing and Spatial InformationSciences*, pp. 427-432, 2012.

[4] T. Kowsari, S. S. Beauchemin, J. Cho, "Real-time Vehicle Detection and Tracking Using Stereo Vision and Multi-View AdaBoost", *14th International IEEE Conference on IntelligentTransportation Systems*, pp. 1255-1260, 2011.

[5] Y. Fumio, L. Wen and T. V. Thuy, "Vehicle Extraction And Velocity Detection From Digital Aerial Images" *IEEEInternational Geosciences and Remote Sensing Symposium*, pp. 1134-1137, 2008.

[6] G. R. Arash, D. Abbas and R. K Mohamed, "Vehicle velocity detection in video image sequence using CVS method" *International Journal of the Physical Sciences*, Volume 5 (17), pp. 2555-2563, 2010.

[7] H. A. Rahim, U. U. Sheikh, R. B. Ahmad, A. S. M. Zain and W. N. F. W. Ariffin, "Vehicle Velocity Detection Using Frame Differencing for Smart Surveillance System" *10th InternationalConference on Information Science, Signal Processing andtheir Applications*, 2010.

[8] Y. Fumio, S. Daisuki and M. Yoshihisa, "Use of Digital Aerial Images to Detect Damages Due to Earthquakes" *The 14thWorld Conference on Earthquake Engineering*, October 2008.

[9] Y. Fumio, L. Wen and T. V. Thuy, "Automated Extraction of Vehicle and their Velocity from Digital Aerial Images", *Proceeding27th Asian Conference on Remote Sensing*, 6p, 2007.

[10]Mehrubeoglu, M. and McLauchlan, L., E.F. (2006), "Determination of traffic intensity from camera images using image processing and pattern recognition techniques", Proc. SPIE-IS&T Electronic Imaging, SPIE Vol. 6063, 60630Q-1 -60630Q-12.

[11]S. S. S Ranjit, H. S. D. S. Jitvinder, K. C. Lim and A. J. Salim, "Motion Analysis for Real-Time Surveillance Video via Block Pixel Analysis Technique" *Proceedings of 2011 InternationalConference on Signal, Image Processing and Applications*, pp. 60-64, 2011.

[12]An, X., Qin, X. and Bao, H., E.F.(2006), "Automatic and robust classification of independent motions in video sequences", Proc. SPIE-IS&T Electronic Imaging, Vision Geometry XIV, SPIE 6066, 60660B-1 – 60660B-8.

[13] Li, Y., Yin, L., Jia, Y., and Wang, M., E.F.(2008), "Vehicle velocity measurement based on video images", Proc. 3rd International Conf. Innovative Computing Information and Control, pp.439-442.

[14] Guolin Wang, and Deyun Xian Jason Gu ―Review on Vehicle Detection Based on Video for Traffic Surveillance‖ Proceedings of the IEEE International Conference on Automation and Logistics Qingdao, China September 2008

[15] Chen, Peijiang. "Moving object detection based on background extraction."Computer Network and Multimedia Technology, 2009. CNMT 2009. International Symposium on. IEEE, 2009.

[16] (2016, July 19). Speed Limit [Online]. Available: https://en.wikipedia.org/wiki/Speed_limit

[17] (2016, July 15). Epidemiology of motor vehicle collisions [Online]. Available:https://en.wikipedia.org/wiki/Epidemiology_of_motor_vehicle_collisions