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Techniques to Estimate Vehicle Speed

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Abstract: The velocity of the vehicle is calculated using the video frames that are captured from the video taken from a digital camera which is fixed on the road. Three techniques are implemented and compared. First technique is based on normalized cross correlation approach. Second technique is based on frame differencing approach and the third technique is based on optical flow.

Keywords: Normalized-Cross Correlation, Frame Differencing, Optical Flow, Horn Schunck

I. INTRODUCTION

Managing the traffic is one of the critical issues of the modern society. The increase in automobiles (four wheelers) from 2005 to 2035 is 13 times i.e. 35.8 million to 236.4 million vehicles and with two wheelers the increase is 6.6 times i.e. 35.8 million to 236.4 million vehicles [1]. Finance Minister P. Chidambaram in the budget 2014-15 has given relief to the automobile industry by reducing the excise duty on SUVs from 30% to 24% and for small cars, motorcycles, scooters and commercial vehicles from 12% to 8% [2]. The National Highways in the India accounted for 30.1% of the total road accidents and 37.1% of the total number of persons killed in 2011 [3].

Intelligent transportation systems are becoming more significant day by day due to their advantages of saving lives, money and time. Collecting traffic information, such as lane width traffic volume (the number of travelling vehicles per time period through a position in a lane), traffic density (the number of total vehicles in a given area at a given time) and vehicle speed, these are the key part of intelligent transportation systems, and such type of information is used to manage and control traffic. It focuses on vehicle speed since reducing speed can help to reduce accidents and deaths.

II. EXISTING SPEED ESTIMATION TECHNIQUES

A. Radar Detectors

The technology that law enforcement agencies uses to measure the speed of a moving vehicle. It uses Doppler radar to beam a radio wave at the vehicle, and then infer the vehicle's speed by measuring the Doppler effect-moderated change in the reflected wave's frequency. Radar guns can be hand-held, vehicle mounted or mounted on a fixed object, such as a traffic signal [4]. Its disadvantages are its high cost, less accuracy and the radio interference.

(a)

(b)

Fig. 1 (a) Radar Detector [5] and (b) Lidar Detector [7]

B. Lidar Detector

Lidar detector is another device which is designed to detect (observe) the infrared emissions of law enforcement agencies lidar speed detection devices and warn motorists that their speed is being measured [6]. When measuring the speed with Lidar, the delay is measured between individual infrared pulses from the transmitter to the vehicle and back to the receiver. Its limitation is that it cannot be used while a car is in motion because it requires the operator to actively target each vehicle. It also requires a precipitation free environment.

C. Vision Based System

Vision based vehicle speed measurement is one of the most convenient methods available in speed detection. A novel algorithm is given for estimating vehicle speed from two consecutive images in [8]. Its principles are both images are transformed from the image plane to the 3D world coordinates based on thee calibrated camera parameters. Second, the difference of the two transformed images is calculated, resulting in the background being eliminated and vehicles in the two images are mapped onto one image.

Finally, a block feature of the vehicle closest to the ground is matched to estimate vehicle distance and speed. Vehicle speed measurement for accident scene investigation in [9] shows the characteristics of accident scene by including the information of lane marks and background model is estimated and used for motion detection.

Vehicle speed detection based on video at urban intersection in [10] calculates the vehicle velocity by the width of the detection zone and the time it takes for the target vehicles to drive into and depart from the detection zone. Vehicle velocity estimation for traffic surveillance system in [11] calculated the speed of the vehicle based on the displacement of the vehicle's centroid. Most of these vision-based speed estimation methods estimate the average traffic speed over a period of time with error rate of over 10% compare with the reference value. Such error rate is considered large for any practical use. The errors due to day-night transition or general weather changes could be large unless updating is frequent enough, which needs to trade-off with computational complexity.

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III. SPEED ESTIMATION USING NORMALIZED - CROSS CORRELATION

Suppose we have a template f and image g such that template f is smaller than image g. We have to find out where this template f best matches within the area of given image g. Cauchy – Shwartz [12] has given an inequality to measure the similarity measure between template f and image g. Such similarity measure is termed as cross-correlation matrix.

$$\iint_A f(x,y).g(x+u,y+v)dxdy \leq (\iint_A f^2(x,y).\iint_A g^2(x+u,y+v))dxdy$$

Whenever we perform a match measure of template f inside every region of g, we perform shift on f on every possible location in given image g. In the above equation, u and v are the shift components along x and y direction respectively. Now to measure the similarity measure using cross correlation the R.H.S should be constant. But the problem here is that we cannot directly use the cross correlation function to measure the similarity measure because though $\iint f^2(x,y)\,dx\,dy$ is constant but $\iint g^2(x+u, y+v)\,dx\,dy$ depends upon the shift u and v. So we have to go for normalized cross correlation. Normalized cross correlation is given by

$$C_{fg} \;/\; [\iint_A g^2 (x + u, y + v)\, dx\, dy]^{½}$$

Where $C_{fg} = \iint_A f(x,y).g(x+u,y+v)dxdy$

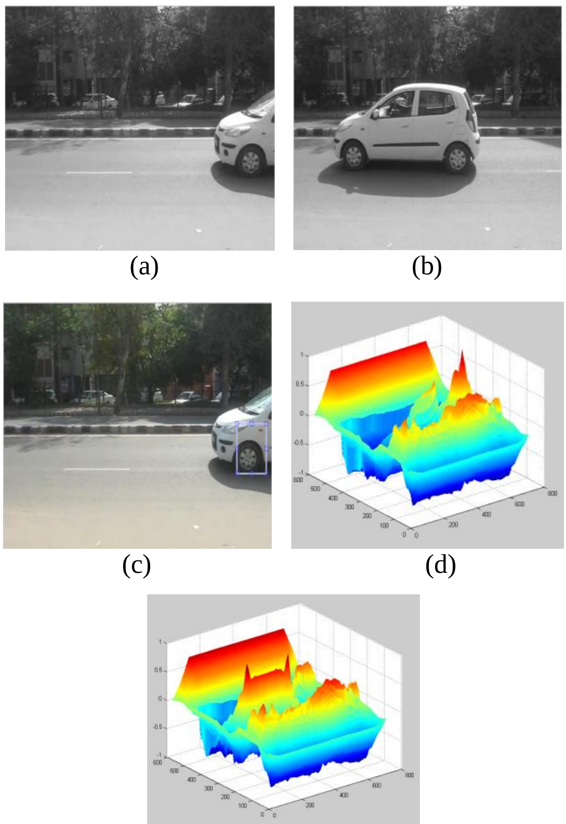

Fig. 2 (a) Reference Frame, (b) Frame X where velocity is needed to be estimated w.r.t reference frame, (c) Template extracted (d) Surface plot of normalized cross correlation between template and reference frame, (e) Surface plot of normalized cross correlation between template and Frame X.

We match the template in both the frames of the car to get the best match in both frames. Surface plot show us the place where the template is best matched. We store that value in the form of displacement in X direction and displacement in Y direction.

The displacement of the vehicle between the reference frame and frame X is calculated by performing normalized cross correlation between the template and the reference frame and the template with the frame X.

TABLE 1.Speed Estimation using Normalized Cross Correlation

S. No	Frame X	Reference Frame	Speed(km/h)	Error
1	19	14	45.90	12 %
2	20	15	36.58	7 %
3	21	16	38.79	3 %
4	22	17	38.28	4 %
5	23	18	37.60	6 %
6	24	19	37.43	6 %
7	25	20	46.41	13 %

The difference in the position of the best match of the template with the reference frame and the frame X gives us the flow.

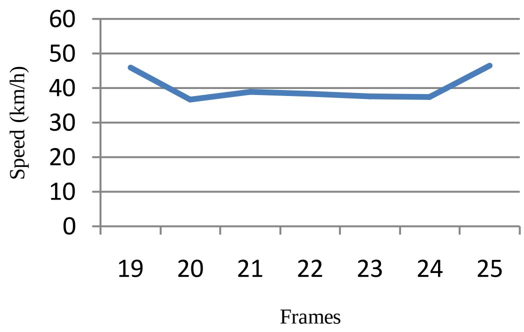

Fig. 3 Graph showing the speed in different frames using normalized cross-correlation approach

III. SPEED ESTIMATION USING FRAME DIFFERENCING APPROACH

Frame Differencing is a technique in the fields of image processing and computer vision wherein an image's foreground is extracted for further processing for example object detection. Frame difference (absolute) at time $t + 1$ is

$$D(t+1) = | V(x,y,t+1) – V(x,y,t) |$$

The background is assumed to be the frame at time *t*. This difference image would only show some intensity for the pixel locations which have changed in the two frames. Though we have seemingly removed the background, this approach will only work for cases where all foreground pixels are moving and all background pixels are static. A threshold "Th" is put on this difference image to improve the subtraction.

$$V(x,y,t+1) – V(x,y,t) > Th$$

This means that the difference image's pixels' intensities are 'thresholded' or filtered on the basis of value of Th.

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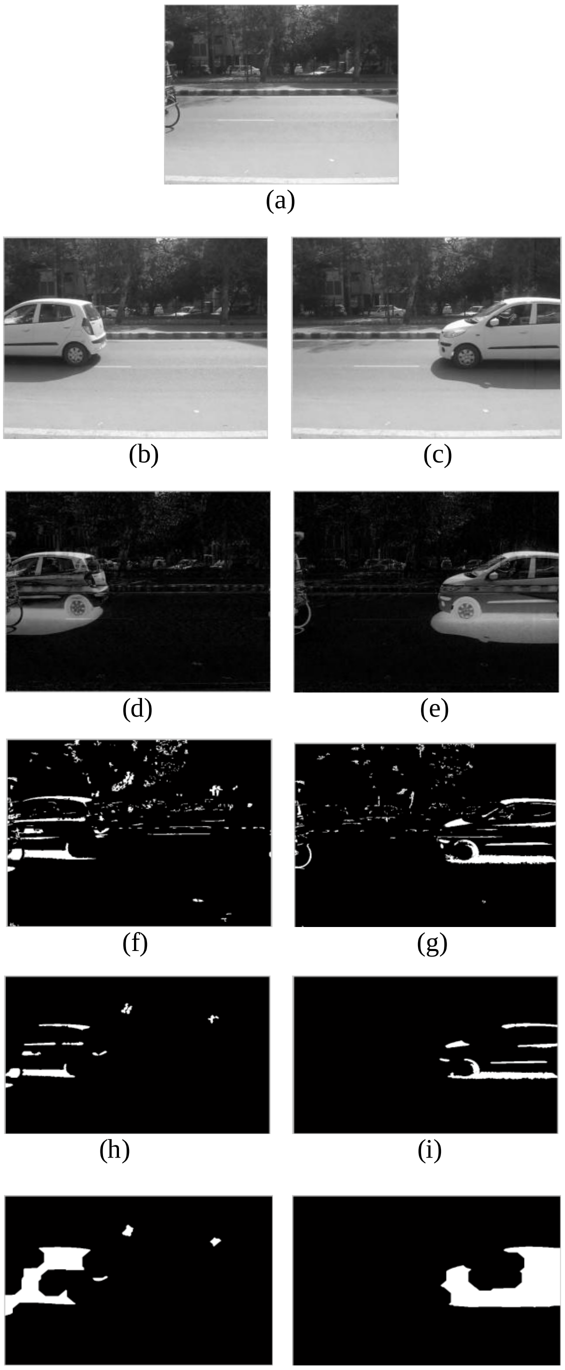

Fig. 4 (a) Background Frame, (b) Frame X, (c) Frame Y, (d) Result of Frame Differencing between Background frame and Frame X, (e) Result of Frame Differencing between Background frame and Frame Y, (f)-(g) Thresholding operation is applied to convert the grayscale image to binary image, (h)-(i) Morphological operation is performed on the binary image to remove small unwanted structures, (j)-(k) Morphological closing is performed to join the disconnected components. After getting the grayscale images we need to convert it into binary images for further calculation. It is converted using thresholding operation. After conversion we get the binary image but with small unwanted structures. Such small structures are removed by using morphological operation. Now to calculate the displacement we need to calculate the centroid of the resultant image. But the problem is that we have many separated parts of the object. To combine such parts we perform morphological closing which joins the disconnected components. After joining the disconnected components we may still left with few disconnected small components. Therefore we calculate the centroid of the largest part which discards the small components.

TABLE 2.Speed Estimation using Frame Differencing & Centroid Approach

S. No	Frame	Reference Frame	Speed(km/h)	Error
1	19	14	33.58	16 %
2	20	15	29.83	25 %
3	21	16	44.39	10 %
4	22	17	53.68	24 %
5	23	18	46.93	13 %
6	24	19	32.64	17 %
7	25	20	36.74	8 %

In this approach error rate is more than 10 %. Sometimes lots of motion or disturbance in the video may alter the results.

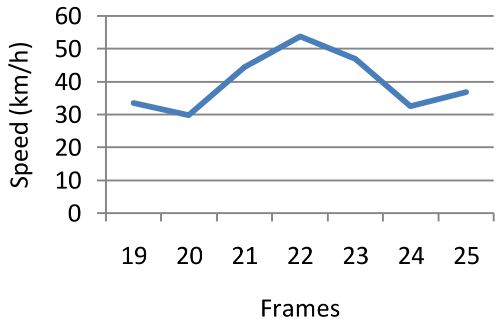

Fig. 5 Graph showing the speed in different frames using frame differencing & centroid approach

IV. SPEED ESTIMATION USING OPTICAL FLOW

Optical flow is the dispersal of apparent velocities of movement of brightness patterns in an image. Optical flow can arise from relative motion of objects and the viewer [13]. The Optical Flow System object estimates object velocities from one image or video frame to another. It uses either the Horn-Schunck or the Lucas-Kanade method [14].

Two equations are given by Horn-Schunck which calculates the flow vector in horizontal direction as well as in vertical direction. For every pixel (x, y) we have a flow vector (u, v). The pixel intensity in image I_2 is equal to the pixel intensity in image I_1. The image intensity is the function of time and space. To calculate the flow vectors Horn-Schunck has given the following two equations:

$$u = u_{avg} - I_x \left(\frac{u_{avg} I_x + v_{avg} I_y + I_t}{{I_x}^2 + {I_y}^2 + \lambda} \right)$$

$$v = v_{avg} - I_y \left(\frac{u_{avg} I_x + v_{avg} I_y + I_t}{{I_x}^2 + {I_y}^2 + \lambda} \right)$$

Here I_x, I_y and I_t are the spatiotemporal image brightness derivatives.

TABLE 3. Speed Estimation using Optical Flow

S. No	Frame	Reference Frame	Speed(km/h)	Error
1	19	14	43.50	8 %
2	20	15	40.33	1 %
3	21	16	40.30	1 %
4	22	17	42.62	6 %
5	23	18	41.09	2 %
6	24	19	41.07	2 %
7	25	20	37.13	7 %

This approach is best among all the three approaches.

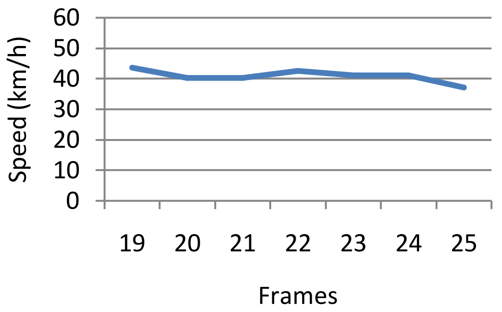

Fig. 6 Graph showing the speed in different frames using optical flow

V. CONCLUSION

All the three methods i.e. normalized cross correlation, frame differencing and optical flow are implemented and the speed is estimated. The percentage error shows that the method of normalized cross-correlation and optical flow generate better result. These methods are good in daylight condition but in the night the results may vary. The change in the shape of the object may also affect the results.

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BIOGRAPHIES

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