An Image Processing Approach for Moving Vehicle Speed Detection by Speed Camera

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Abstract —
Traditionally, the technique used for speed detection of moving object is RADAR system. It uses RADAR gun for speed detection. The new technology which is being used is Speed Detection Camera System (SDCS) that is applicable as a RADAR alternative. In SDCS first the video is captured and several image processing techniques are used on the captured video either in online or offline mode. This makes SDCS capable of calculating speed of moving object by avoiding the problems in traditional RADAR. SDCS offers an inexpensive alternative to traditional RADAR. With the same accuracy or even better. SDCS process is divided into five successive phases; First phase is Pre-processing. Second phase is object detection uses background subtraction technique with a three frame differencing algorithm which ratifies the major drawback of using of using only adaptive background subtraction. The third phase is object tracking, which consist of three successive operations, Object segmentation, object labelling and object centre extraction. Fourth phase is speed calculation which is calculated from the number of frames consumed by the object to pass-by the scene. The final phase is Capturing object's picture, which captures the image of objects that violate the speed limit.

Key Words **—Background subtraction, Object labelling, Object tracking, thresholding.**

I. INTRODUCTION

The rate of accident is increasing very speedily in today's fast moving world, The over-speed of vehicles is one of the main reason for this. Speed detection of moving vehicle using speed cameras is one of the major steps taken towards this issue so as to bring down the rate of accidents and enhance road safety. As the single biggest cause of road accidents is speed most of the research is going on to detect speed of vehicle. Many speed detection instruments are available for moving vehicle speed detection. The need to use radar systems is growing in importance. This is not only for military applications but also for civilian applications. The latter includes (but not limited to) monitoring speeds of vehicles on high ways, sport competitions, aeroplanes, etc. The spread of use of radar systems is affected negatively with the high cost of radar systems and also with the increasing requirements on the accuracy of the outputs. This motivated the research on alternative technologies that offer both higher accuracy and be more cost effective. The field of image processing has grown considerably during the past decade. This has been driven by 1) the increased utilization of imagery in myriad applications, coupled with 2) improvements in the size, speed and cost effectiveness of digital computers and related signal processing technologies. Image processing has found a significant role in scientific, industrial, space and government applications. Nowadays many system are being replaced by the systems which uses image processing and gives better performance than former one. An SDCS system is one of these systems that can replace traditional radars.

II. LITERATURE REVIEW

Traditionally radar systems were used for many applications. It can be applicable in both military applications and civilian applications. The radar system has high cost of radar and less accuracy, also it requires line of sight connection between vehicle and radar equipment, so it is not able to become popular in traffic surveillance. There is another method for speed calculation which uses inductive loops, but this requires high maintenance and high installation cost, also it doesn't provide enough information about traffic parameters.

Therefore in order to overcome the limitations in existing methods, various techniques have been developed for vehicle speed determination using image processing. But the algorithm which is used in image processing may affect the output due to some contingent factors such as illumination changes, tree waving, camera noise etc. there are many work have been done for vehicle detection and speed measurement using image processing, some of these are reviewed here. The motion is derive in using equation of spherical projection to estimate the vehicle speed [4]. The algorithm is used for motion tracking is Lucas-Kanade-Tomasi. The various algorithms which are developed for vehicle detection and tracking has reviewed in [5].This paper is based on background subtraction. In background subtraction background modelling is most important. The various methods of moving vehicle speed detection are Inductive loops, RADAR gun, LASER Gun, Manual count [6]. The methods of background extraction from coloured image based on average value, median filter and common region [7]. Also running average, median algorithm, Mixture of Gaussian are developed, these are based on DCT [8]. Many times first frame or frame differencing is used for background subtraction. ROI extraction is used to remove misdetection of vehicle due to vehicle travelling from other lane, or other small movements such as tree waving [9]. The background is multiplied with ROI mask. So that vehicles are detected accurately. Furthermore thresholding and morphological operations are used to reduce noise. In thresholding selection of threshold value is based on various methods. The threshold value can be selected manually or automatically by using thresholding.

III. Proposed Method

This method is used for estimating the speed of moving vehicle which is coming towards camera by tracking the motion of vehicle through sequence of images. This system is mainly consists of the following steps shown in fig.1 Firstly, the video is converted into frames. The background subtraction is used for moving vehicle detection. The extraction of background without moving object is done by averaging all frames. The output of background subtraction is applied for thresholding and morphological operation. In object tracking centroid of object is tracked over multiple frames. Velocity is calculated using distance travelled by vehicle and frame rate of video. This system is helpful for traffic surveillance. Fig.1 shows block diagram for proposed method.

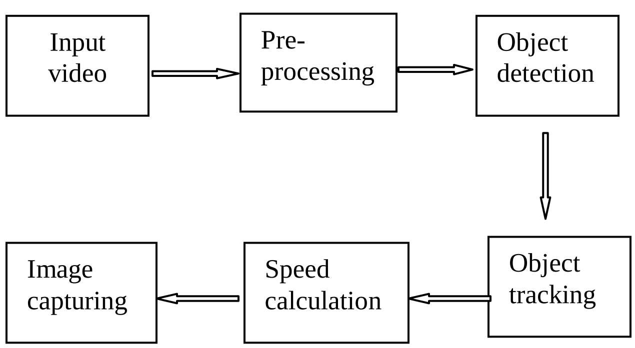


Fig.1 Flow diagram of SDCS system

III.1 Pre-processing

The video is recorded using mobile camera having pixels. In pre-processing the video has converted into the frames. The various parameters such as number of frames, frame rate, colour format, frame size are extracted. There are total 372 frames in this video. It has frame rate 30 frames per second. The frame size is of 640x480 pixels. Also at this stage the frames are converted into double data format i.e. required for future operation.

III.2 Object detection

Object detection technique is mainly based on combining an adaptive background subtraction technique with a three-frame differencing algorithm. This combination ratifies the major drawback of using only adaptive background subtraction. That is it makes no allowances for stationary objects in the scene that start to move. So here three steps are carried out to detect the object. These are;

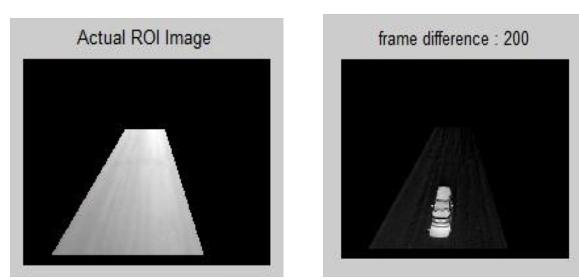
- Background extraction
- Thresholding
- Morphological operation

III.2.1 Background extraction

Background extraction is most important step in background subtraction. It is very difficult to get the image without any moving vehicle; while recording video on highway. For getting such image which is called as background model or background extraction is used. In this work, average of all frames pixel values, have taken because of this as result as shown in Fig. III.2.1.1

Fig III.2.1.1 Background model using averaging frames[2]

From background image ROI Extraction has done. In this method vehicle coming towards camera are tracked so that only one lane of road is considered as ROI. The extracted ROI is as shown in Fig. III.2.1.a.



(a)[2] *(b)[2]*

Each frame is then multiplied with extracted ROI. Before multiplication RGB frames are converted to Gray level. Because of this detection other unwanted movement such as waving trees, or any other movement is avoided, which is required to do to get accuracy in vehicle detection. The absolute difference of each instantaneous frame and background model after multiplying both with extracted ROI has taken to detect only moving vehicles. The result of this is as shown in fig.III.2.1.b.

III.2.2 Thresholding

Thresholding is one of the way for image segmentation. It converts grey scale image to binary scale. Selection of threshold value is very much important in thresholding. To separate foreground vehicle from static background thresholding is used here.

$$g(x, y) = \begin{cases} 0 & \text{for } f(x, y) < T \\ 1 & \text{for } f(x, y) >= T \end{cases}$$

Where g(x, y) is threshold image, T is the selected threshold value; f(x, y) is instantaneous frame. In this work, we got vehicle as object and some noise. The result of this stage is as shown in fig. III.2.2.1

Fig.III.2.2.1 Result of Thresholding[2]

III.2.3 Morphological operation

They are generally used to remove noise from imperfect segmentation. Morphological operations are especially suited for binary images. So they are performed on output image of thresholding. Here opening, closing and dilation are performed. Opening and closing is used to remove holes in the detected foreground. Dilation is interaction of structuring element and foreground pixels. The structuring element is nothing but a small binary image. In the process of dilation the size and shape determination of structuring element is very important. The results of these morphological operations are shown in fig.3.2.3.1 After this the selected object pixels are applied for connected component analysis.

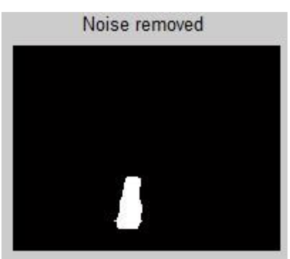


Fig.III.2.3.1 Results of Morphological Operations[2]

Connected component analysis is used to identify connected pixel region by scanning an image pixel-by-pixel. It is applied to binary and grey scale image. It has various connectivity i.e.8 pixel connectivity or 4 pixel connectivity. Here connected component analysis is performed on binary image with 8 pixel connectivity.

III.3 Object tracking

Tracking of detected objects frame by frame in video is a significant and difficult task. It is a crucial part of smart surveillance systems since without object tracking, the system could not extract cohesive temporal information about objects and higher level behaviour analysis steps would not be possible. On the other hand, inaccurate foreground object segmentation due to shadows, reflectance and occlusions makes tracking a difficult research problem.

Object tracking driven using three successive phases;

- Object segmentation
- Object labelling
- Object center extraction

III.3.1 Object segmentation

Object segmentation is based mainly upon the connectivity of the objects. For segmenting a foreground image into a group of objects we must assure that every object is being connected as one part, otherwise segmentation will not act in an appropriate way, this will result in excess objects count since the single object is being treated as many several objects.

We need to detect the area which surrounds the objects, since the objects are not connected, Later, this area can be treated as an excellent representative to the un-connected objects; i.e. this operation aims to map the object into a rectangle representing it.

This method is consists of successive iterations; each iteration consists of two main parts, horizontal scanning and vertical scanning.

The horizontal scanning starts from the top most left pixel at the foreground image F (0, 0) Then, it scans the foreground image horizontally. If no foreground pixel (white pixel) found then, it will mark the whole scan line. Else, if any pixel found to be a foreground pixel (i.e. colored in white) then, the scanner will skip this line and go the next scan line.

On the other hand, the vertical scanning starts also from the top most left pixel at the foreground image F (0, 0). But, it scans the foreground image vertically. If no foreground pixel (white pixel) found then, it will mark the whole scan line. Else, if any pixel found to be a foreground pixel (i.e. coloured in white) then, the scanner will skip this line and go the next scan line.

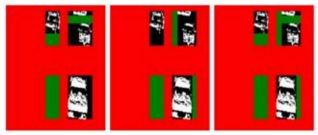
After the first iteration it is clear that we still need another iteration in order to give an accurate result, beside there exist false detected regions which will disappear after an additional iteration as shown below at figure (III.3.1.1)

The second iteration has separated the two objects at the same region shown at figure (III.3.1.2)and has discarded the false detected regions.

Since no more segmentation can be done, the third iteration is sufficient. Now comes another problem, how to determine the number of sufficient iterations to give an accurate segmentation?

(a) (b) (c)

Fig.III.3.1.1 1st iteration[1]



(a) (b) (c)

Fig. III.3.1.2 2nd iteration

III.3.2 Object labelling

Object labelling is an essential process in order to keep track of the moving object. This is because each object must be represented by a unique label while keeping in mind that the object shall preserve its label without any change. This is since the moment it enters the scene (at frame F_0) till it leaves the scene (at frame F_n)

The segmentation process held at the previous stage has guaranteed us a set of well separated regions representing the objects. Each region must be given a unique label because each region represents the object and preserve it till the object leaves the scene.

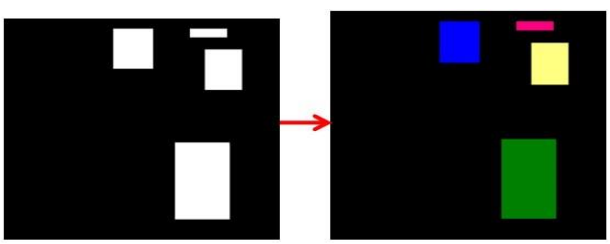


Fig.3.3.2.1 Labeling operation[1]

Figure III.3.2.1 clarifies the output of the segmentation process, it is clear that those regions representing the objects are well separated. At figure 3.3.2.1 labelling has given each pixel within the same region a corresponding label clarified by a certain colour.

III.3.3 Object centre exctraction

This point is the object centre extraction, it represents the whole object and can be tracked and mapped easily. In the next section, we discuss in details how can we track the centre and correct its label at some special cases in order to preserve the uniqueness of labelling. For the same object, figure III.3.3.1 shows the centre of each object which we are going to track at the next stage.

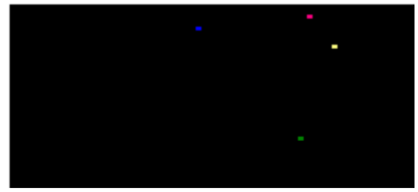
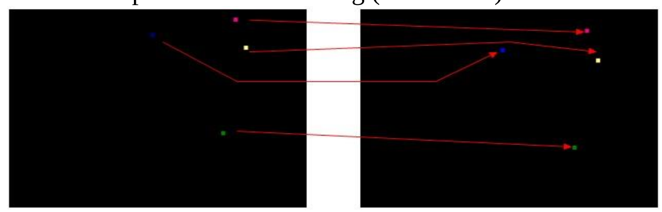


Fig.III.3.3.1 Center extraction [1]

a) Simple tracking:

In this case, the centres of objects, as shown in figure (III.3.3.2.a) representing the previous frame, have moved or shifted for a certain distance from there original position to next frame represented at frame fig.(III.3.3.2.b)

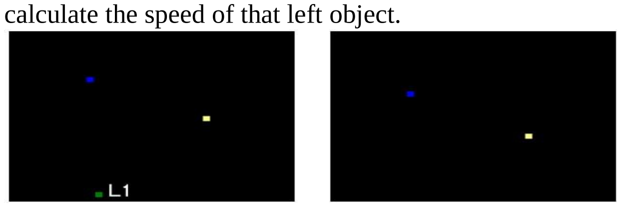


(a) (b)

Fig. III.3.3.2Tracking centers within two successive frames[1]

b) Object has left the scene :

When a label L1 (displayed at figure III.3.3.3.a marked with green), which exist at the frame I_{n-1}, disappears at the next frame I_n. This indicates that an object has left the scene, therefore the current frame In represents the last frame (F_n) for that green object and therefore the system need to calculate the speed of that left object.

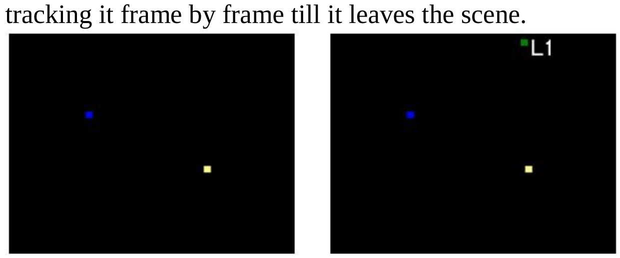


(a) (b)

Fig.III.3.3.3 Label disappears case[1]

- **c) Object has entered :**

When a label L (displayed at figure III.3.3.4.b marked with green) which does not exist at the frame I_{n-1} then appears at the next frame In this indicates that an object has entered the scene, therefore the current frame In represents the first frame (F_0) for that green object and therefore the system creates a record for that new object in order to keep tracking it frame by frame till it leaves the scene.



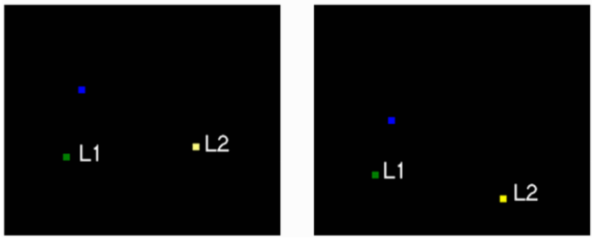
(a) (b)

Fig. III.3.3.4 Label appears case[1]

d) Object cross by another object:

Label L1 (displayed at figure III.3.3.5.a marked *ect* with green) is ahead of another label L2 (displayed at figure III.3.3.5.a marked with Yellow), at the next frame label L2 has become ahead of Label L1.

Those two labels will swap if this case left un-handled and will cause an error at the tracking process but since our tracking use each label history to correct the labelling therefore this swapping would never occur and objects L1 and L2 will preserve there labels as show at figure III.3.3.5.b



(a) (b)

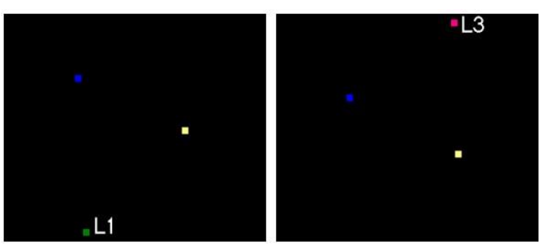
Fig. III.3.3.5 Label cross by another label case[1]

e) Object leaves and another one enters the scene:

If the number of objects at the last frame I_{n-1} equal the number of objects at the current frame then there may be no change has occurred but there may exist another case, if there is an object leaves the scene at frame I_{n-1} and another one has entered at the current frame then that is a special case which need to be handled.

In figure below, there are three objects in the two frames, but they aren't the same objects, in frame (a) there is an object labelled by one represented by the green colour (L1) (b) a new object entered to the scene, so it will be given a label four represented by the pink colour (L3) since the green object hasn't released its label yet.

Even if object left the scene it reserve certain label to avoid this reserving the system assigns labels for every object at a round robin fashion, consider figure III.3.3.6, at III.3.3.6.a the green object is still at the frame I_{n-2}, at the next frame In-1 (III.3.3.6.b) the green object has left the scene, at the next frame In (III.3.3.6.b) a new object has entered the scene, and since the label one (represented by the green colour) is not being used at the moment therefore the system will assign the label one to the new object instead of giving it a new label.



(a) (b)

Fig.III.3.3.6 Label cross by another label case[1]

IV. Speed Calculation

The frames track detected vehicle having match id . The total number of frames in which same object is present has calculated.

Total Frames Covered= frame n – frame 0

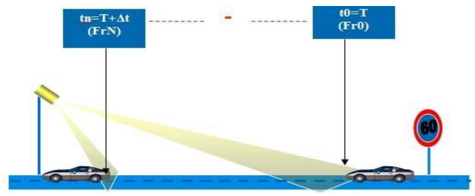


Fig.IV.1 Speed detection model[1]

Where, frame 0 is the first frame when object is entered in ROI and frame n is last frame when object passed away from ROI. Also the real world distance is mapped on the image. The count of total number of frames is then multiplied with duration of one frame which is calculated from frame rate of video. From this the total time taken by vehicle to travel and Distance is fixed it is measured in real world and mapped into image.

Speed=Distance/ (TF*Frame rate)

From distance and travelled time of detected vehicle, speed of that vehicle is determined from above formulae.

V. Image Capturing

The best position to capture a picture with good resolution to the object is that when the object is being at the center of the scene, therefore when the object is located around the center of the scene then the system stores the current frame as the object captured picture.

There exist a wide range of algorithms that work on improving the quality of any image captured from a video stream by capturing three or four consecutive frames from the processed video stream, the new enhanced frame or image is generated after then with better quality than the original one but it needs the video stream to have a high frame rate in order to capture the frames too close from each other. This technique is called video stabilization.

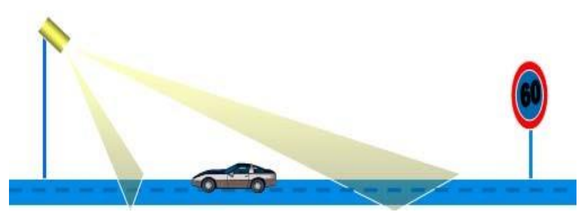


Fig. V.1 Object's picture capturing model[1]

After capturing the picture, the system marks the targeted object in the frame in order to differentiate between it and other moving objects within the scene.

VI. Conclusion

The proposed method gives better results as compared to previous techniques. Background subtraction is robust against illumination changes in real world. Also by extracting ROI the noise immunity is improved. As the distance is mapped on the image by calculating it from real world. So the calculated speed is approximated to actual speed.

SDCS system provides a software package specifically designed to manage a vehicle's traffic, that provides a number of benefits:

- SDCS is a cheap alternative system to the traditional radar system.
- SDCS is considered as a good application for some difficult image processing algorithms and theories (Object Motion Detection, Shadow Removal, and Object Tracking).
- SDCS doesn't need professional persons to deal with it as it has a simple interface and good design.

VII. References

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