Traffic Surveillance and anomaly detection using image processing

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Abstract — **Today there is a huge increase in the use of automobiles on roads and highways which has increased the concern to monitor and regulate the traffic on roads and highways. This has led to proposal of new and efficient traffic surveillance systems. This research focusses on detecting direction anomalies in the traffic surveillance videos using basic Image processing techniques and algorithms. The direction of the detected vehicle is checked per frame and if there is a case of direction anomaly, concerned authority is informed.**

Keywords — Object detection, Background subtraction, Object tracking, Direction detection, Direction anomaly detection, Alert generation.

I. Introduction

Intelligent traffic management systems has become one of the dire necessity in today's world as the number of vehicles running on the roads are very high. Recently there was a survey conducted by Association for Safe International Road Travel, according to which nearly 1.2 Million people die every year in road crashes, leading up-to an average of 3,287 deaths per day. The figures mentioned above does not include the counts of the people who have been injured or are permanently disabled in road accidents. Apart from the personal and physical damage, road accidents also leads to loss of huge amount of money that can be used to tackle other pressing issues of the society. The main reason of such type of appalling result is that the current traffic surveillance systems are not up to the mark. In India the traffic surveillance is done manually by the traffic police, which leads to human error, resulting in such horrific results. Few developed countries are also using RADAR guns for traffic surveillance [1]. But there are few drawbacks as well, RADAR guns are highly expensive and only few developed countries can afford it. RADAR guns fails to detect and track vehicles in case heavy traffic. As RADAR guns uses the concept of Doppler effect, so it is prone to noise [1], [2].

In this paper we suggest methods that can be used in the surveillance of the vehicles. Developed Countries such as Switzerland, England, US and many other, have already adapted the new technology and are using it for the traffic surveillance. Every traffic or video surveillance process can be further subdivided into two parts [7].

A. Explicit event recognition.
   a. Object detection
   b. Object tracking
B. Anomaly detection

A. Explicit event recognition

Object detection: It can be defined as the process of differentiating the object from the background. There are several methodologies for object detection,

Background subtraction: In this process every pixel of the captured frame is being subtracted from that of the reference frame. The resultant image is segmented using a threshold value resulting in a logical image [1], [6].
Mathematically,
F(x, y): a pixel from the recently captured frame. B(x, y): a pixel from the background image.
F`(x, y): resulting pixel.
Threshold: Pre-decided threshold value.
Then,

If | F(x, y) - B(x, y) | >= Threshold
    Then, F`(x, y) == 1
Else
    Then, F`(x, y) == 0

This method of is based on static background which often fails in real environments as it fails to adapt the change in the ambient intensity [1].

Adaptive Background Subtraction: This method of object detection is the advanced version of background subtraction. In this method background image is not a static image i.e. it keeps updating itself after certain period of time [1], [6].
Mathematically,
New_bg: Updated background image.
old_bg: Old background image.
F: Current frame.
P: Percentage change, its value can vary depending on the application for which this process is being used. In traffic surveillance, as the vehicles on the highways generally moves very fast, thus the frame need to be updated very quickly, leading to small value of p.

New_bg = old_bg * P + F * (1 - P)

Since the background image is updating we also have to update the threshold value and that is given by the formula,

New_th = A* avg + B
New_th: Updated threshold value.
Avg: Average ambient intensity.
A & B are constants depending upon the application.
One of the major drawback of the method is if an object is present in the frame for a long period of time, then it will be treated as the background which can lead to false detection of objects [1].

Object tracking: It is the process of estimating the movement of the object. In order to successfully track the object we first need to apply some morphological techniques such as convex hull, shadow removal, erosion, dilation etc. There are several methodologies proposed for object tracking [7].

A. Point tracking
B. Silhouette tracking
C. Bounding boxes and centroid extraction

Point tracking: In this process we track the object by placing some interest point at the salient features of the object, and tracking those points across different frames [7].

Silhouette tracking: In this method we track the object based on the shape description of the object, the main aim of silhouette tracker is to find the object region in each frame by the means of the object model that is generated using the previous frame [7].

Bounding box and centroid extraction: The object is surrounded by a bounding box and the centroid is determined, centroid is further stored in lists which will be used for further processing such as tracking the movement of the object [1] [7].

B. Anomaly detection

The idea behind anomaly detection is to find anomalous events differing from the typical patterns. This paper revolves around finding direction anomaly of detected vehicles on highways.

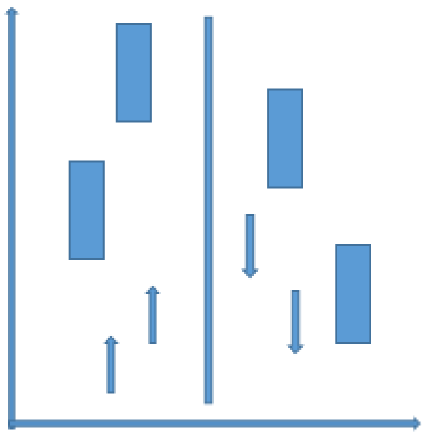


Fig.1. Lane-1 (right) vehicle moving towards the camera, Lane-2 (left) vehicle are moving away from the camera

II. DIRECTION ANOMALY

Highways in India are generally two-ways the divider, divides the entire road is into two halves and the vehicle moves in different direction in both the halves. In the fig.1. we can clearly see that vehicles are moving in different direction on both sides of the divider and any vehicle that is moving in opposite direction from the rest of the vehicles running in that lane will be treated as direction anomaly.

III. SYSTEM REQUIREMENT

The hardware used in the research work are listed below,

- Nikon D3400 DSLR Camera.
- Laptop/Desktop with Intel Core i5-2450M CPU @ 2.50GHz × 4, Windows 10
- MATLAB 9.0 R2016a.

Although the system designed is robust and is capable of yielding good results in different environments, but the image quality plays a vital role in image processing.

IV. METHODOLOGY

The entire methodology can be understood with the help of the fig.2. which is further explained in the following paragraphs.

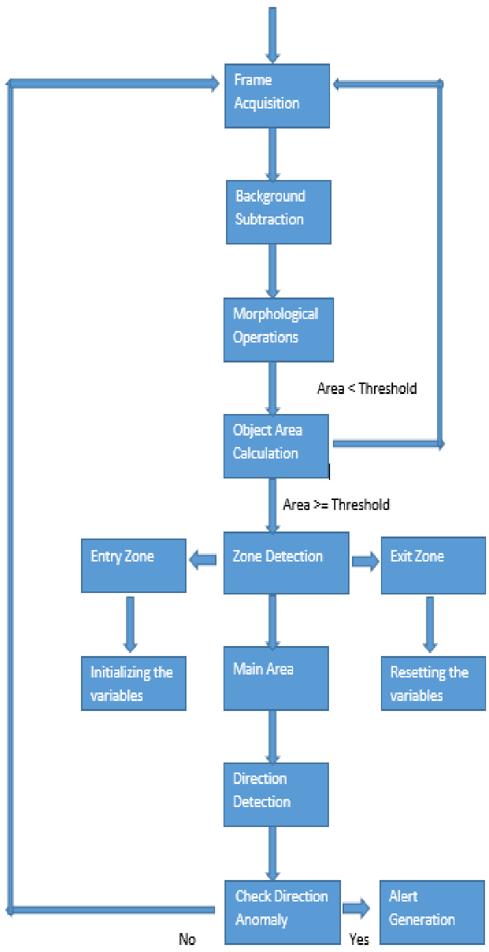


Fig.2. Flow Diagram

Frame acquisition: It is the process of acquiring single frame from the running video. So that it can be used for further processing.

Background subtraction: This process deals with detection of the object from the input video. As the first frame is taken as the reference frame and subsequent frames are subtracted from it. The resultant is threshold using a suitable threshold value resulting in a logical image [1], [2].

Morphological operations: Once successful identification of the vehicle is done, the resultant image is improved using some morphological operations. Convex hull, Opening, Closing and Hole filling algorithms were used for this purpose.

Opening and Closing operations were used for removing small object such as noise form the image.

Object area calculation: After applying morphological operations the area of the object is calculated and if the area is greater than a certain threshold area then only it can qualify as a valid object.

If Object Area >= Threshold
    Detected object is a vehicle.
Else
    False Object detected.

Threshold- Pre-decided threshold value.

Zone detection: Now the entire frame is divided into three regions [4].

a) *Entrance zone*: It is the region where we start tracking the object/blobs. As soon as a blob enters the entrance zone variables such as object area, object centroid are initialized which will be preserved until the object exits the exit zone [4].
b) *Main area*: It is the region where the actual tracking of the object takes place, here the centroid of the object is being tracked. Once the object is in the main area its direction information is being stored in arrays [4].
c) *Exit zone*: Once the object is in the exit zone, all the variables are cleared and the process repeats [4].

Direction detection: For direction detection the centroid coordinates of the vehicle is used, the process can be explained with the following example,

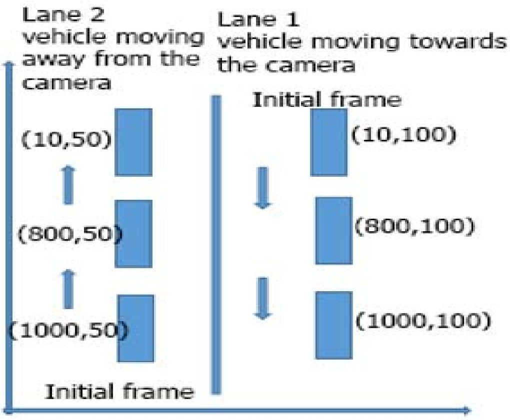


Fig.2. Direction detection of vehicles

For case-1, let the object centroid be (10, 100). For case-2, let the object centroid be (1000, 50).

Case-1: In 50th frame centroid of the detected object is (800, 100). In 100th frame centroid of the detected vehicle is (1000, 100). Then the direction of vehicle can be determined by, for 50th frame: $x_2 - x_1 = |800 - 10| = 790$, where, x_1 is x coordinate of centroid in background frame,
x_2 is x coordinate of centroid in 50th frame.

For 100th frame: $x_3 - x_2 = |1000 - 800| = 200$, where, x_3 is x coordinate of centroid in 100th frame, x_2 is x coordinate of centroid in 50th frame.
From the results, it can be inferred that the vehicle is moving towards the camera, as the centroid distance is decreasing frame by frame.

Case-2: In 50th frame centroid of the detected object is (800, 50). In 100th frame centroid of detected object is (10, 50). Then the direction of vehicle can be determined by, for
50th frame: $x_2 - x_1 = |800 - 1000| = 200$, where x_1 is x coordinate of centroid in background frame,
x_2 is x coordinate of centroid in 50th frame.

For 100th frame: $x_3 - x_2 = |10 - 800| = 790$, where x_3 is x coordinate of centroid in 100th frame,
x_2 coordinate of centroid in 50th frame. From the results, it can be inferred that the vehicle is moving away the camera as centroid distance is increasing frame by frame.

Anomaly detection: Any deviation from the normal standards will cause an anomaly. Anomaly detection is a two-step process,

a) *Lane Detection*
b) *Direction anomaly detection*

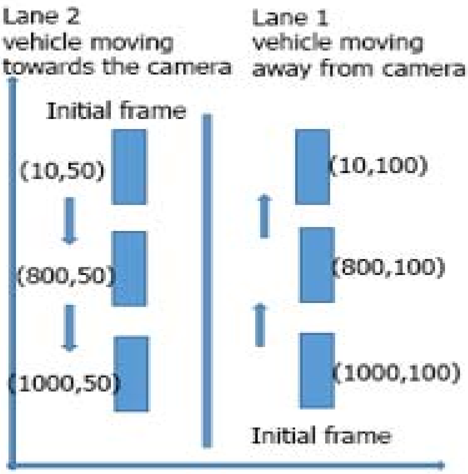


Fig.3. Direction anomaly detection

Lane detection: plays an important role while detecting the direction anomaly of vehicle. Preliminary method has been used for lane detection. The lane has been manually classified by dividing the road using the coordinate systems [3], [4].

Direction anomaly detection: Any deviation from the normal standards fixed by the government would result in an anomaly. As per our assumption, the vehicles on the left lane must move away from the camera while in the case below the vehicle is moving towards from camera and vice versa for the right lane[3], [5].

For case-1, let the object centroid be (10, 50), for case-2 let the object centroid be (1000, 100).

Case-1: In 50th frame centroid of the detected object is (800, 50). In 100th frame centroid of the detected object is (1000, 50). Then the direction of vehicle can be determined by, for 50th frame: $x_2 – x_1 = |800 - 10| = 790$, where x_1 is x coordinate of centroid of background frame,
x_2 is x coordinate of centroid of 50th frame

For 100th frame: $x_3 – x_2 = |1000 – 800| = 200$, where x_2 is x coordinate of centroid of 50th frame, x_3 coordinate of centroid of 100th frame. When the results are compared, the vehicle is moving in the left lane but towards the camera. In this case the distance obtained by subtracting the centroids is decreasing rather than increasing, which would be the case for a vehicle moving away the camera in the left lane. So we can infer that there is a direction anomaly and an alert message can be generated.

Case-2: In 50th frame centroid of detected object is (800, 100). In 100th frame centroid of the detected object is (1000, 100). Then the direction of vehicle can be determined by, for 50th frame: $x_2 –x_1 = |800 - 1000| = 200$, where x_1 is x coordinate of centroid of background frame, x_2 is x coordinate of centroid of 50th frame.

For 100th frame: $x3 – x2 = | 800 - 10| = 790$, where x_2 is x coordinate of centroid of 50th frame, x_3 coordinate of centroid of 100th frame. When the results are compared, the vehicle is moving in the right lane but away from the camera. In this case the distance obtained by subtracting the centroids is increasing rather than decreasing, which would be the case for a vehicle moving towards the camera in the right lane. So we can infer that there is a direction anomaly and an alert message can be generated.

V. RESULTS

The first step is extracting the reference frame from the video. Frame extraction is followed by Background subtraction. For this we subtract the background frame from all the subsequent frames,

Fig.4a. Background frame (top)
Fig.4b. Frame with vehicle (bottom)

Consecutive frames were subtracted from the above background frame (fig.4a). The fig.4b. consists of the frame where we have our desired object. After subtracting the above frame from the background image we ended up with the following image which is shown in fig.5a,

Fig.5a. Result of Background Subtraction (top)
Fig.5b. Region based separation (bottom)

After background subtraction, region based separation was done, so that only the road is detected and the objects on the either side of the road is not be detected. After region based separation, area calculation and area based filtration was done in order to remove those objects that do not qualify as a valid object. Some morphological operations were also performed on the resultant to have a complete structure of the vehicle. These are few of the morphological operations that we applied Convex Hull, Opening, Closing, Hole-Filling.

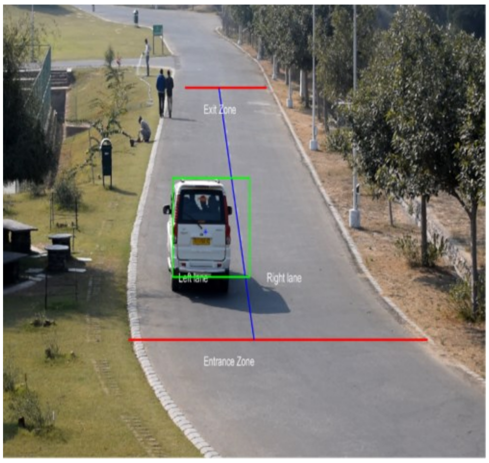
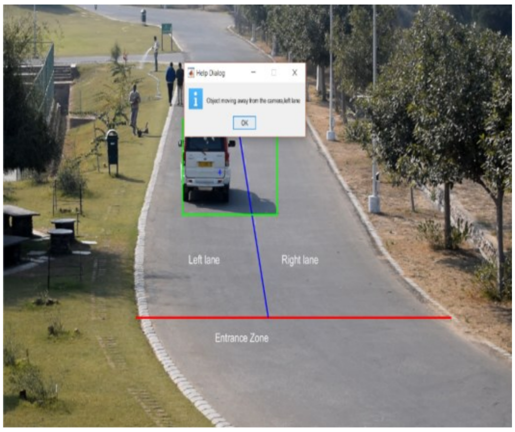


Fig.6a. Result after applying morphological operations (top),
Fig.6b. Bounding box vehicle (bottom)

After applying morphological operations the resultant image is shown in fig.6a. The next step is creating a bounding box around the vehicle for highlight the object of interest in the video and creating zones for the object to be tracked depicted in fig.6b. In order to find the direction of the object the centroid values of the object were monitored, depending on the increasing and decreasing centroid distance values the direction of the vehicle was determined and the resultant is shown in fig.7a.



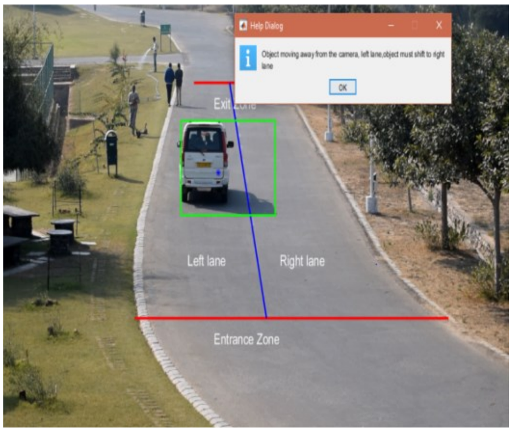


Fig.7a. Vehicle direction detected (top),
Fig.7b. Direction anomaly of the vehicle detected (bottom)

The lane in which the vehicle was moving was also determined with the help of coordinate values of the detected object. After direction detection, direction anomaly was checked. Depending on the behavior of the centroid distances we can easily determine the direction, once we have the direction of the object. Anomaly detection is an easy process of matching the obtained direction from the standard assumption, which is shown in fig.7b.

VI. CONCLUSION AND FUTURE WORK

In this paper we have proposed a system which can detect the direction of the vehicles moving in multiple lanes on highways. The proposed method is robust enough to yield accurate results in both daytime as well as night time. Although this research is a combination of various fields in the domain of vehicle detection. In future the focus shall be on implementing Trajectory analysis and Support Vector. Machines for direction detection of vehicle and direction anomaly detection. Currently the lane detection is done manually, it can further be detected using some advanced algorithms such as Hough transform which automates the entire process of lane detection. The current system fails to discriminate between the object and the shadow, in near future focus will be on implementing shadow removal techniques. So that the shadow doesn't play any role in the area detection of the vehicle.

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