Edge Based Tracking for Traffic Surveillance

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Abstract

This paper investigates on tracking vehicles based on edge detection. The main application studied in this paper is Velocity Detection which is still a challenge in traffic surveillance. By using several samples of normal road, a reference image is created and objects are determined from edge detection. Some new noise filtering techniques proposed for this method described as well. The method tested on several real road movies which contains known velocities. The result of method compared with a well-known intensity based object tracking method and comparison results presented.

1. Introduction

Video sensors become particularly important in traffic applications mainly due to their fast response, easy installation, operation and maintenance, and their ability to monitor wide areas. Research in several fields of traffic applications has resulted in a wealth of video processing and analysis methods [1].

The project's aim is to determine velocity of vehicles in inter-city roads. The result of this project could help Police Forces to monitor highways. The system is intended to be flexible, easy to use, vision-based and be able to track cars and report speed of vehicles which are visible in the scene.

Till now, several studies have focused on vision-based approaches for traffic surveillance. Some of researchers have used windows for counting vehicles and detecting velocity [2].

In the other hand, several studies have done on tracking vehicles to determine traffic parameter, e.g. velocity, acceleration, volume and etc [3-5]. Some other works focused on object and people tracking which of course would be useful for tracking vehicles as well [6-9].

Background subtraction has been used in several approaches till now. Generally speaking, most of them used background subtraction for detecting objects [2-9] and specially vehicles [1-5]. However, other approaches, e.g. wavelet transform [10, 11], used for object detection too, they are not suitable for online traffic monitoring.

Technically, this paper focused on vehicle tracking based on edges and concentrated on velocity detection as main application and accuracy check. In the next section, related work reviewed. Next, proposed method described in details. Result of proposed method on real world movies described after that. Finally, paper concluded in the last section.

2. Related works

Point features have strong characteristics and this makes it relatively easy to localize them and to find correspondences between frames. This makes point-based systems robust to large, unpredictable inter-frame motions [12].

Most of applied researches used intensity or color features to determine motion and objects [3-9]. In the other hand, edge or line features was very useful too. Line features and their descriptor (intensity gradient) are stable under a very wide range of lighting conditions and aspect changes [12].

Cucchiara and Mello proposed a rule based traffic monitoring system which is using fusion of intensity and edge features for tracking [14]. Although they mainly focused on reasoning part, but tracking part of their paper is still interesting. They used intensity based subtraction for determining temporal activities and edges for spatial features.

Javed et. al proposed a hierarchical approach for tracking objects in video [13]. They used color based subtraction for determining motion (like others) and approved the result by edge based subtraction. This way, they tried to remove some noises created by quick illumination changes.

Rosten and Drummond used edge features for image registration and tracking under difficult conditions, i.e. camera movement and shaking [12]. They mainly used edge as helper feature to overcome varying illumination situations.

Background subtraction techniques use a reference image or a model as background, and they subtracts current image from it. So, illumination changes make result of subtraction unfaithful. Some studies used complex strategies to determine features which are constant during illumination changes, e.g. chromaticity [6, 15]. Some others improved their models to be stable during these kinds of changes [6-8]. Additionally, normalizing image before subtraction was seems to be useful too [9].

Still authors did not receive any satisfying results from real world movies. In the contrary, edge subtraction would result to more stable silhouette in varying illumination conditions [12].

3. Edge Based Tracking

The proposed method is based on subtracting current frame from a reference frame and extracting object information. However, this kind of tracking is completely known approach [3], but using edge feature alone is completely fresh. Figure 1 shows a total view of velocity system.

As described in the figure, this velocity system builds upon a tracker, real world mapping and velocity detector. Authors proposed this framework in [16]. Here a new tracking method based on edge features is described.

3.1 Background Acquisition

Since the tracking system is going to be used in urban freeways and inter-city roads, assuming a clear road for background reference would be impossible. This problem has solved in several researches before.

The background image is specified either manually, by taking a vehicle-less image, or dynamically, by forming a mathematical or exponential average of successive images [1]. Some people used median [4] or average intensity value of available samples for background image, while some others modeled pixels as normal distribution and classified pixels as stationary and non-stationary [6-8].

However, still there is not any pure edge base background modeling method proposed. Most of methods like [17] assumes given clear background for further process, created their edge based background reference based on created intensity based model [12, 13] or did not count on edge background at all [14].

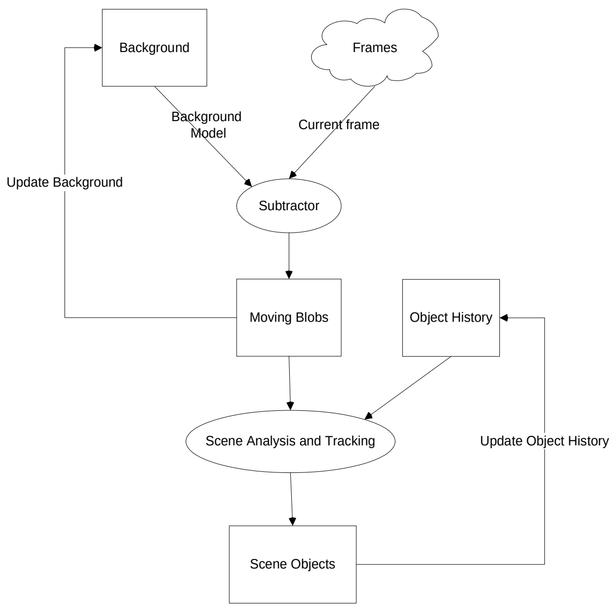


Figure 1 Tracking System Architecture

While vehicles are inevitable from the scene, 20-60 seconds of video is used as background sample. Nevertheless, as the distribution of noise and non-stationary objects could not be assumed as normal, a threshold implied to create reference image.

First all samples is being reviewed to count how many times a pixel determined as edge and how many times it did not. To make it visual, in figure 2, each pixel which has detected as edge in all pixels marked as white and pixels which did not detected as edge at all marked as black. Other pixels are colored proportionally based on (1).

$$C_{(x,y)} = \frac{\sum_{k=0}^{N} I_{(x,y,k)}}{N} * 255 \tag{1}$$

While $I_{(x,y)}$ would be 1 if (x, y) is detected as edge in k th sample and 0 otherwise; N is number of samples. $C_{(x,y)}$ would be a fuzzy representation of edge availability in this particular pixel. In Figure 2 $C_{(x,y)}$ used as gray level color of this pixel for visual representation of edges. Value of N assumed as 1500 for all results proposed during rest of this paper.

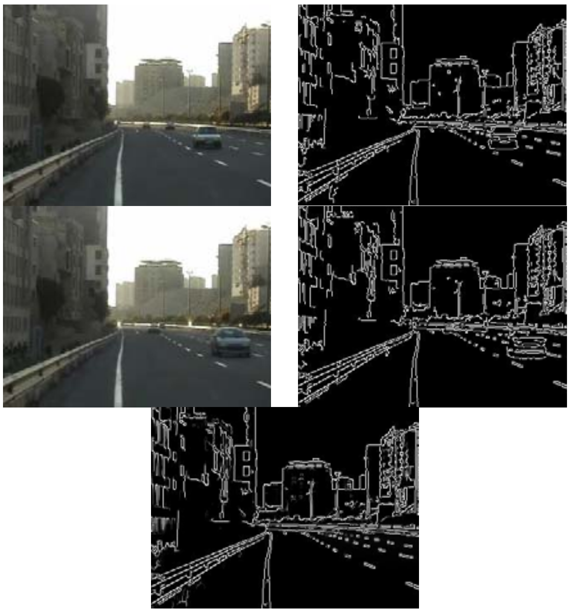


Figure 2 Real road and created fuzzy background

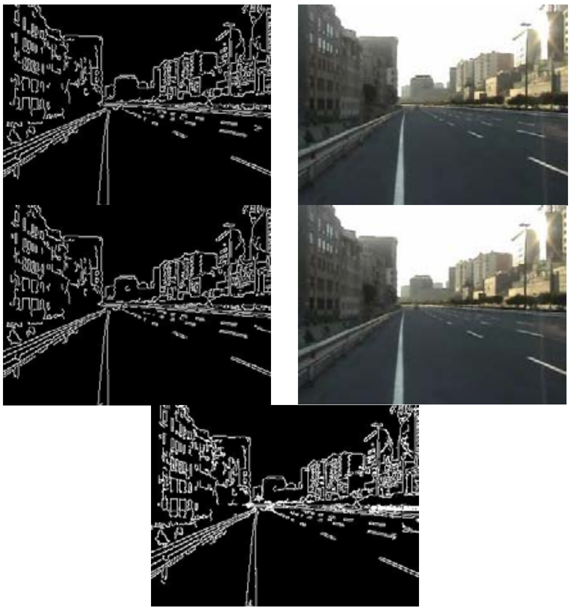


Figure 3 Static scene and created edge model based on OR operation

For motionless scenes, making background model is straightforward. One can simply make a reference image by logical OR of all available samples. The OR operator is necessary because of noises and effect of illumination changes which could make some edges disappears shortly. For example, some test frames of a static scene and created edges for that is viewed in Figure 3.

For dynamic scenes, a threshold is used to categorize stationary and non-stationary edges. Equation (2) is illustrating the use of threshold here.

$$\begin{cases} C_{(x,y)} > \tau & \text{Stationary} \\ C_{(x,y)} < \tau & \text{Non-stationary} \end{cases} \qquad (2)$$

The decision is based on the fact that, if the object was not stationary, e.g. a vehicle or a bird, it should not appear in more than few samples. Figure 4 illustrates background images generated by different values of Threshold.

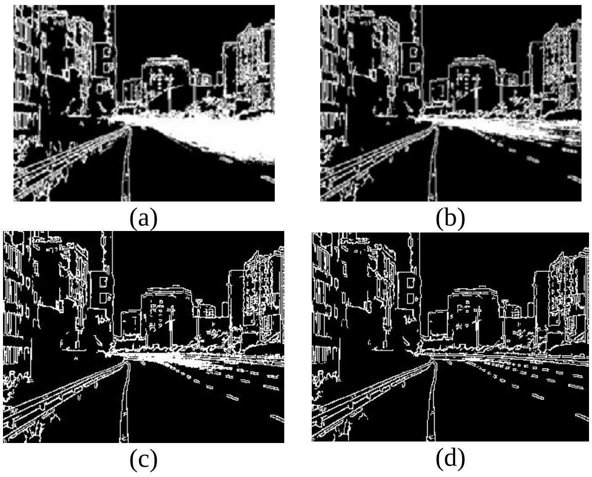


Figure 4 Background model generated by using different thresholds. (a) Threshold=1, (b) Threshold=5, (c) Threshold=9 and (d) Threshold=24.

As shown in the figure, the higher the threshold chosen, the more clear background image would be created. However, clear background creates noisy silhouette because noisy edges could not be filtered. In the other hand, little threshold values creates image which contain nothing but noise like figure 4(a). In the following of paper value of 9 assumed for threshold value as it shown better results.

3.2 Tracking method

Tracking algorithms are highly dependent to their background model. Till now, several approaches are proposed for tracking. Very first methods used simple subtraction of current frame from background. Gaussian distribution was used for both model and subtraction [6, 7 and 13]. Horparast et. al used complex categorization based on chromaticity and brightness for detecting shadows, moving objects and static objects [15]. Javed et. al proposed their method using subtracting current frame from reference and applying edge subtraction on result image [13]. In this section, details about subtraction, noise filtering and object extraction parts presented.

The proposed method is based on following edges which appeared currently but did not appear in reference image. However, edges which existed in background and are not appeared in current image, considered as noise. This assumption might create some invalid results when human tracking or object tracking in normal application concerned. However, roads have solid patterns, and there is not any edge in main road except edges which created by lane lines. Figure 5 shown result of such subtraction.

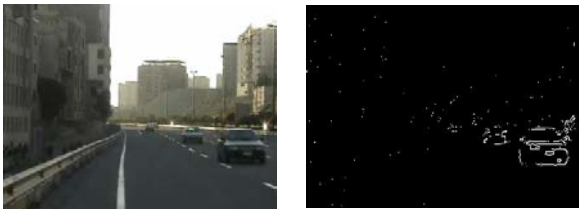


Figure 5 Sample silhouette created

As it could be seen, there are some noises in silhouette which should be ignored. Median filter [8] and morphological operations are common ways for reducing noise which are not useful in this method. Since edge features are robust during illumination changes, only outliers should be removed in this stage. So, neighborhood has been applied to remove extra points. Each pixel which has not more than two active neighbors has classified as noise and deleted from silhouette. Result of such filtering presented in Figure 6.

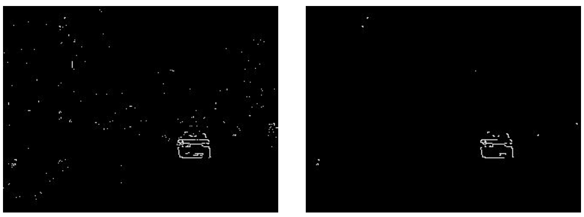
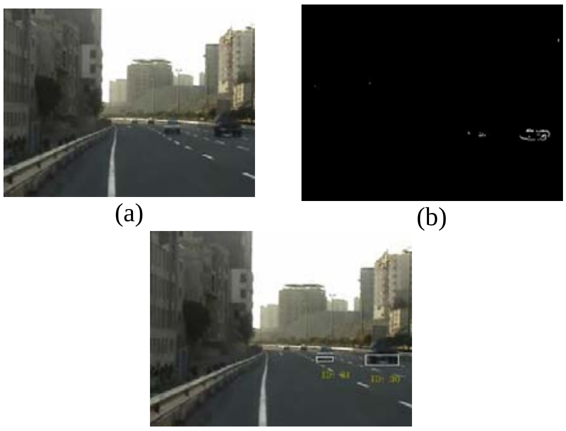


Figure 6 Result of neighborhood filter

As soon as clear silhouette created, remaining task is object extraction. Object extraction has two parts, spatial and temporal. The object should extract from current frame and then compared to results of later frames for identification.

For spatial part, contours of silhouette extracted firstly. Next, small regions are deleted at very fist level and near blobs merged to create complete object.

Because of noises which created by compression, grabbing and processing some edges are missed in some frames. For having more robust results, history of three last frames is used for optimizing current results. In fact, edges of three last frames are added to result of current frame for having better results. Set of images which illustrates this are presented in figure 7.



(a) (b)

(c)

Figure 7 Progress of tracking. (a) Original frame, (b) Result of subtraction after noise filtering (c) detected objects

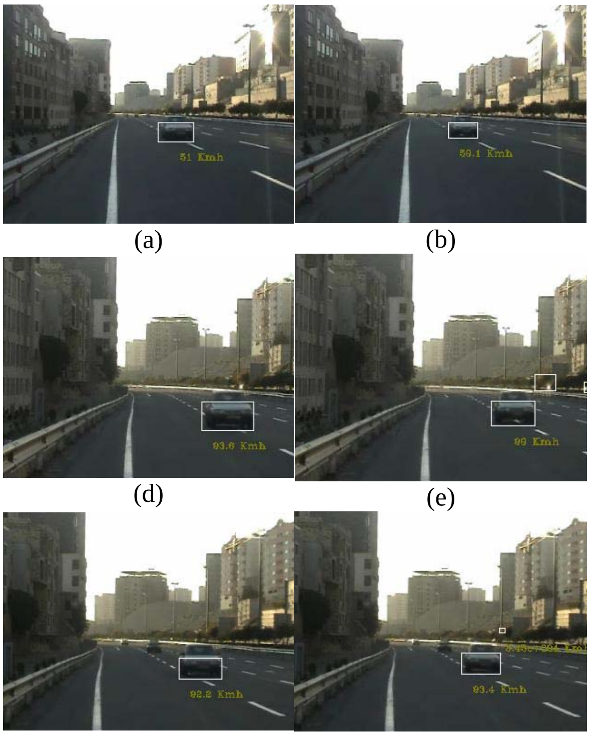
4. Experimental Results

Object tracking has been used in several applications including traffic surveillance. Based on result of target tracking, statistics of vehicles, traffic volume, occupancy, headway, mean speed and several other parameters could be measured. In this paper, mean velocity of vehicle has been focused.

The proposed algorithm determines objects in scene and extracts boundary rectangles for them. Using inverse perspective mapping, position of vehicle in real world determined. Right lower corner of boundary rectangle used for object positioning in presented results of this section.

Mean velocity of each vehicle is result of dividing moving distance of object by time. For testing algorithm on real circumstances, some movies were required containing known-speed vehicles. For this purpose, a car used to drive with different speeds and result movie used for creating report.

For comparison of proposed method and recent researches, intensity-based object tracking with Gaussian-like background model proposed in [8] (which named W^4) has been used. Algorithm Results on real world movies presented in Figure 8.



(a) (b) (d) (e) (f) (g)

Figure 8 Comparision between proposed method and W^4. (a), (d) and (f) are results of presented method for a car moved with speed of 60, 80 and 90 respectively. (b), (e) and (g) are results of W^4 method generated on respective movies.

Proposed method did not detect invalid objects; however W^4 method detected several invalid objects in non-road area which is effect of illumination change. However W^4 results on first movie was better, for other movies proposed method have better income. A comparison between results has been presented in Table 1.

Table 1 Result comparison

	Edge-based	W^4	Known Speed
1st movie	51	59.1	60
2nd movie	83.6	98	80
3rd movie	92.2	93.4	90
Avg. Error	3.31	6.11	N/A
Accuracy	91.83%	90.74%	N/A

As it could be seen from table, result of proposed method was better in two experiments and worse in one. Formula which is used for calculating average error and accuracy are presented in (3).

$$\sqrt{\sum (R_e - R_l)^2} \qquad \text{Average Error}$$

$$\frac{\sum \frac{|R_e - R_l|}{R_e}}{n} \qquad \text{Accuracy} \qquad (3)$$

Which R_e and R_l are expected results and algorithm results respectively. n is number of test which is 3 here.

5. Conclusion and Feature work

We have presented a new method for tracking objects in solid background, which widely useful for vehicle tracking in roads. The method is based on detecting edges of current frame and subtracting it by reference image edges. The method has been used for detecting velocity of vehicles. Results of proposed algorithm compared with a well-known intensity based object tracking method presented.

Tracking of wheels location might have better results of tracking of lower down edge of boundary rectangle. By the way, updating background model through long run is another important challenge which are been investigated by authors to achieve more robust and reliable velocity detection system.

10. References

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