Survey on Various Traffic Monitoring and Reasoning Techniques

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Abstract. Traffic monitoring and surveillance is advancing in recent years. This paper proposes a survey on an overview of various traffic sensing, monitoring techniques. Several projects have been developed for the detection and tracking of vehicles on multiple scenarios. The vehicle monitoring results depends mainly on the camera positioning. This paper gives a detailed description on the different camera positioning and monitoring which includes straight roads and intersections. In this survey a detailed description is given on preprocessing techniques, vehicle detection and tracking methods. Finally paper concludes with the challenges and the future scope.

Keywords: Vehicle surveillance · Vehicle sensing · Monitoring · Vehicle tracking · Pre-processing · Shadow detection · Shadow elimination · Occlusions

1 Introduction

Computer vision technology has been improving rapidly in the past few years. One of its application around the world is vision based traffic monitoring. As the road traffic is being increasing day by day, our concern for the safety too is increased. Several Projects have been launched from the earlier 1990's on the vehicle monitoring and controlling. Still unfortunately many video surveillance systems existing are depending their works on humans. Vision based traffic monitoring has a wide range of applications in day to day life. Many systems have already been developed for the detection and tracking. Still the existing many vision based algorithms are not robust enough to do the automatic detection of these events [6]. The computer vision technology involves acquiring, processing, analyzing and understanding of the digital data acquired from the video cameras. Vision based traffic monitoring has a wide range of applications in a day to day life. Abnormal event detection is a major application, in which it involves accident detection, traffic violation, parking violation, zig zag driving etc. The main goal of the vision based traffic monitoring system is to act as a human eye that should detect the abnormal activities in road traffic and to give alert without any delays. Providing intelligence to the system could achieve this result, in spite of the huge amount of data and heavy processing (Fig. 1).

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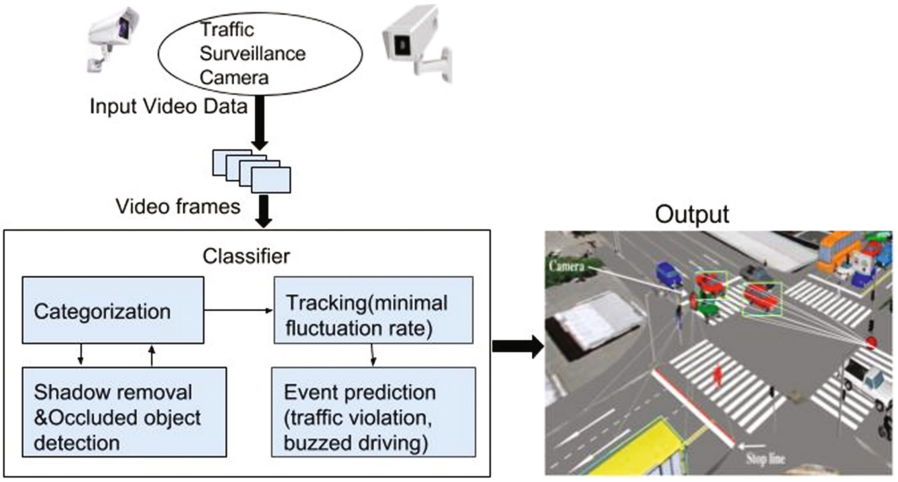

Fig. 1. Architecture diagram of vehicle tracking.

Our paper is organized as follows, Sect. 2 includes various vehicle sensing techniques till the recent technologies, then Sect. 2 gives a brief overview on various camera positioning and calibration techniques, Sect. 3 and 3.1 includes various traffic analysis and vehicle monitoring techniques on both straight road and on intersections, Sect. 3.2 gives a detailed description and various methods of pre processing. Section 3.3 includes the various vehicle detection counting and tracking algorithms. Section 3 represents the occlusion management technique available till recent. Section 3.4 gives a comparative study on the various techniques available for the vehicle tracking techniques in a detailed table (Table 1).

2 Vehicle Sensing Techniques

2.1 Infrared Detectors

There are two type of infrared detectors active and passive. They can actively work at both day and night times and detects vehicle position, class, count and speed. The advantages of these infrared detectors is that they can be easily mounted on the road sides and also multiple lane functioning can also be done, but the disadvantage is that they are very sensitive to extreme weather conditions like rain, blowing snow or snow where the visibility is less than 20 feet [11].

2.2 Microwave/Millimeter Wave Radar

Microwave detectors detect the presence, speed and velocity of a moving vehicle [9]. Operate by measuring the energy reflected by the target vehicle, in the field of view. Multi lane operation is available and also resistant to difficult weather conditions. The improper placement of the detectors will also affect the accuracy in the output.

2.3 Acoustic Detectors

Array of acoustic detectors are helpful in determining the presence of a moving vehicle. Advantage of these detectors are they are multilane functional and also passive [11]. But the slow moving vehicles and certain model vehicles are not detected [11]. Extreme cold temperature will also affect the output rate.

2.4 Ultrasonic Detectors

Ultrasonic detectors generates the high frequency sound waves that hits the target and measures the energy reflected from object by calculating the distance between the sending and receiving wave. It should be placed perpendicular to the target hence it could not detect the occluded vehicles [10].

2.5 Inductive Loop Detectors

Inductive loop detectors are the electrical conducting loop which are insulated that is embedded in the pavement [13]. They can detect the moving vehicles passing through the top of it. They are the widely used technology for vehicle detection in the United States [9]. They detects the speed, presence, gap and headway but the installation and maintenance require the cutting of pavement which will obviously decrease the life of the pavement [11].

2.6 Magnetic Detectors

Magnetic detectors are used for detecting the presence and the movement of vehicles. They are of active and passive type. Active type detects both the presence and the movement of the vehicle but the passive type detects only the movement. They can be used where the loops cannot be installed [11]. They work by producing a magnetic field and when a vehicle moves it cuts the magnetic field and the vehicle movement is detected. The advantage is that they can withstand the pressure caused by the traffic more than the loop systems and also they are resistant to extreme weather conditions [11].

2.7 Piezoelectric Detectors

They can get the presence of any vehicle that is being stopped with on it. They convert the pressure, force, acceleration, strain to electric energy using the piezoelectric effect. When a vehicle passes over it the piezoelectric material is being compressed and the voltage is produced. Which in turn detects the presence of the vehicle. It has the advantage of detecting the exact vehicle position and also the path of the vehicle movement. Vehicle speed can also be detected by placing the two of them in series [9]. The disadvantage is that the road has to be cut every time for the installation, and for the maintenance.

2.8 Acceleration Detectors

Acceleration detectors are used for traffic monitoring and vehicle detection. The system operates for a long period of time freestanding. The advantages of detecting the acceleration is that the movement of the vehicle can be obtained and hence can detect the vehicles that are moving against the traffic rules like increase speed, red light stopping, no left turns etc. [14]. They can be used to determine the car crashes, which is being applied in many car manufacturing companies.

2.9 Spread Spectrum Wideband Radar

It is an accurate range detector [9]. They are used for detecting the motion of vehicle. This sensor system has wide range of signals and it starts by looking at a single range and while the vehicle starts moving the range fluctuates, and hence the vehicle motion is being detected. The advantages of spread spectrum wideband radar is that the result is very accurate and occlusions are not a problem. We can get the additional information from the traffic [10] and also they are very cheap. The disadvantages involved in here is that they are single lane detectors.

2.10 Video Detectors

Video image detectors are widely being used. They have a wide range of data collection [11]. They can be installed easily on the road side or on the top bridges facing the front of the vehicle as well as the rear side. They can be used to detect the vehicle presence, vehicle movement and also the other information related to traffic flow. There are various advanced algorithms for processing the output from the video camera. They can be easily used for changing or adding new detection zones [11].

3 Traffic Analysis Methods

3.1 Vehicle Monitoring (Intersection and Straight Road)

Transportation has been increasing rapidly day by day and vehicles are all around. The monitoring of these vehicles are being done pretty easily from point to point with the emerging technologies around. The road types for monitoring has been divided to straight roads, intersections and curved roads. There are various algorithms developed for the monitoring in these areas. Many of the vehicle monitoring applications include getting the vehicle count, vehicle path, flow rates, density of vehicle, weight and length of the vehicle, class differentiation of the vehicle and the identity of the vehicle [3]. The monitoring in urban and highways vary in many perspectives. The urban area have low camera angle and high density of vehicles, hence occlusion is a main problem. Freeways are having wide angle camera focus and also homogenous vehicle flow [8].

3.2 Preprocessing Techniques

Video Input data is divided in to frames and then dispatched for preproessing. Preprocessing aims at the enhancement of image data, improvement of the features for the further processing and to exclude the misrepresentations. Image preprocessing uses the repetition in images for the processing [17]. Preprocessing is performed before feature extraction which corrects various fragments in the image that includes lighting changes [12], sensor variations, noise, geometric corrections, color corrections [16]. Image enhancement is another result of preprocessing which includes, sharpening, color balancing, scale-space pyramids, illuminations, blur and focus enhancement. The basic preprocessing techniques includes:

Image resizing
Image resizing is one of the preprocessing methods. Nearest neighbor interpolation method is one of it where the value of any non given point in a space is approximated. Seam carving is another image resizing method without the geometric constraints [18]. There by the image can be processed with minimum time consumption and occupying less memory space.

Image Normalization
Normalization is another preprocessing method. In an image the distribution of gray level/intensity varies. Also illumination variation contains non uniform contrast. Image normalization acts in the above mentioned scenarios. The pixel intensity values are affected by the normalization. Histogram normalization is one of the commonly used image normalization technique. The other various normalization techniques includes zero padding, track extension, resampling, smoothing, thereby can control the variation in the intensity of pixel values.

Image denoising/filtering and cropping
Gaussian noise is the default noise that occurs in an image while its been captured. The image denoising regains the image without the noises. Image smoothing is the widely used approach from the older days for the removal of noises. In traffic data the noises are more from weather conditions like fog, mist, rain etc. Level set approach is one of the gratifying noise removal approach, where the pixels are viewed as topographic maps. Another approach is motion of curvature, where the spikes of noises will disappear quickly. The advantage is that the boundaries will remain still sharp. The basic division of filtering methods include transform domain filters and spatial domain filtering methods [18].

Dimensionality reduction
Dimensionality reduction concerns with feature vectors. Down sampling is one of the method for dimensionality reduction, where taking the average number of block of pixels in a regular grid and removing the other pixels. Dimensionality reduction can be divided into feature selection and feature extraction. The other dimensionality reduction techniques include vector quantization, polynomial fitting, multi resolution decomposition, Hidden markov model, spectral methods, kernel methods, Principal component analysis, Kernel Principal component Analysis, Graph based kernel PCA, Linear Discriminant Analysis, Generalized discriminant Analysis. Hence from as a

result of this technique by averaging the values the most relevant datas are included for the further processing without the whole bulky data.

Brightness thresholding
Simple and effective way preprocessing method by dividing image into background and foreground. It works by converting grayscale image to binary image. By the application of brightness threshold the image can be distinguished into object of interest and the other part. Here the threshold value is set and the pixel value is calculated from the given image, if the pixel values is brighter than the threshold value then convert it to black or white depending on the condition. One of the disadvantage involved in thresholding is that the pixel intensity values are only considered and hence in case of pixels related to the neighbors are separated.

3.3 Vehicle Detection

After the preprocessing the particular target detection can be performed. Detection implicates locating vehicles on video frames. Vehicle detection plays a crucial role in Intelligent Transportation System which results in making a better system that acts more smarter, safer and integrated. Vehicle detection using video camera is a non intrusive form of detection which mainly involves motion segmentation and environment/background modeling [4]. Other processes like classification of vehicles, tracking vehicles and their behavior recognition depends on this. The vision-based vehicle detection which includes vehicle candidate localization, that involves more number of frames and the methods are classified into background subtraction, model based segmentation, feature based segmentation, motion-based segmentation, frame differencing [1]. Vehicle detection using multi cameras (stereo vision) as well as single camera where they are placed over the road and fixed. The system gives 90% accuracy with the stereo vision. Multi feature detection and 3D tracking methods are employed for the detection where the maximum spanning tree clustering algorithm is applied [19]. Various sturdy algorithms are developed for the detection of vehicles which resulted in less than 9% error rate.

Classifier algorithms acts smartly on the detection cases. The classifiers based on Histogram of Oriented Gradient (HOG) and Gabor have attained a better performance in accuracy rate and performance than Principal Component Analysis which is another classifier and others based on gradient and symmetry, but study shows that they have limitations under certain scenarios. The feature combination results better since Gabor and HOG fails in far range and the latter in middle range [5]. There are other detecting algorithms on the basis where detection is based on points. Point detectors are detectors that locates the interesting points in image which includes KLT detector, SIFT detector, Harris detector, Moravec's detector. With the supervised learning mechanism the detection can be performed automatically from different object views [6].

Shadow detection
For the proper detection of targets shadows in target objects should be detected and removed. Shadows results in serious problems in the processing of images. Shadows are falsely taken as foreground objects, they causes shape distortion in images,

produces error in vehicle counting and they also acts as occlusions [15]. Shadows are detected with many features like chromaticity, physical properties, intensity, textures, geometry, and temporal features. The various physical methods include kernel based, semi supervised, Gaussian mixture model, kernel based and various texture based methods like gabor filter, ratio-edge test, Principal Component Analysis (PCA) based, Gradient background subtraction, local ternary pattern MRF etc.

Line-based shadow algorithm is another approach proposed by Jun-Wei et al. [20] in automatic traffic surveillance system where the algorithm uses a group of lines to eliminate all the nonessential shadows. Automatic lane-dividing lines are proposed with the experimental results that showed the system is more powerful, accurate, and fast. Haar-like feature with Adaboost is an approach for the shadow detection where the Haar detector can be trained offline. Shadows are easily extracted using visual data.

3.4 Vehicle Tracking

Traffic surveillance includes a lot of functions like vehicle detection as well as tracking. Vehicle tracking is the important processing stage in surveillance. Tracking means trailing a particular target. There are a lot of advantages in tracking vehicles in traffic scenes like safety, security, reducing the crimes, and apart from these we can also keep track of the flow of vehicles and velocity. A lot of algorithms have been developed in the recent years for the efficient tracking. Brendan et al. [2] in their paper created a scene modeling for tracking, where the object is to be identified and the identity should be maintained in each frame. The tracking states are $S_T = \{S_1, S_2, \ldots, S_T\}$, from S_T portray the position, appearance, shape, velocity and the other object labels. One of the tracking algorithm is extended lucas kanade template matching algorithm with a speed accuracy of 2.3% for 95% of the vehicles in the varying lighting conditions [7]. False detection is an issue that highly affects tracking, temporal tracking method overcomes this false detection problem. Tracking should works effectively on the moving scenes huddles, numerous position changing objects, varying illumination conditions and the other different changes in the target sceneries. The tracking methods are categorized on the basis of:

Region based method
Here the parameters are regions of the data. In this method the ith frame and the i + 1th frame in together produce a conflict free association graph. They are sensitive to partial occlusions. The spatio-temporal information can also be used for deducing the regions. Region based tracking method handles only the object-level entities.

Model-based tracking method
This is used for the free-flowing traffic. A 3D model of object is created, and the result is highly accurate. They are used for classifying and tracking the moving objects in a crowded and undisciplined landscape. The model dwells with 3D geometrical portrayal of vehicles. Both the texture and edge information can be used as models. M-estimators are also included to impose shadows, occlusions and varying backgrounds which may result in false detection.

Contour and feature based tracking method
A rough contour of the object is gleaned from the first frame. The further contours can be created using kalman filter. The acceleration and velocity of the object can be obtained by this tracking method. This gave more robustness and could handle changing behaviors and varying lighting conditions. Tracking by extracting the features of the target objects is a form of unsupervised object tracking method.

Point tracking and silhouette tracking methods
Point tracking is another tracking method for shorter distance. It uses Kanade-Lucas-Tomasi (KLT) feature tracking algorithm. Here the objects are represented as points and tracked crosswise the frames. Silhouette tracking is another method that tracks objects that are in solid form. Silhouette extraction methods are available from earlier times like the subtraction method, background modeling etc. The other methods include parmish silhouette approach, silhouette mapping, spatio-temporal shape extraction from silhouette tracking. These methods are applied for objects with constant shape throughout.

Table 1. Comparison of recent tracking methods

Algorithm	Technique	Advantage	Shadow removal	Occluded Object Detection
Symmetric frame differencing target detection algorithm	Based on local clustering segmentation	Target detection and tracking	No	Partial
Mean shift tracking	Density estimation	Detect occluded targets	No	Partial
Contourlet transform tracking	spectrum data estimation	Real time tracking accuracy	No	No
Block-matching algorithm	Based on motion estimation	Reduced computation time	No	No
Compressive tracking algorithm	Application of kalman filter	High robustness and real time tracking	No	Partial
Optical Flow	Blob Analysis Method	Detect, track and count objects in real time	No	No
Markov chain monte carlo data association	Approximation of optimal bayesian filter	Multiple object tracking in dense scenes	Yes	No
Optimal unbiased finite memory filter	Adaboost using proposed feature	Outperforms kalman and other filters	No	Yes
K-shortest disjoint path	motion - based optimization on dual graphs	Accuracy rate of 99.4%	Yes	Yes
Kanade-Lucas-Tomasi	Applied to motion layers	High robustness	Yes	Yes

Kernel tracking
Kernel based tracking improves the robustness and accuracy of tracking. One of this is central component method in which the centroids of all the objects are taken for tracking multiple objects in single frame. In case of moving scenes Isotropic kernel-method is applied that regularizes the feature histogram based target representations. They successfully works with the moving scenes, occlusions, eloquent cameras, scale variations etc.

4 Challenges and Future Work

Vehicle surveillance is still a research area and lot of challenges arising. The weather condition and illumination changes are the major challenges that we are facing now a days. The fog, mist, rain or poor lighting conditions could make the view from the camera very poor and hence the tracking and detection can be disturbed. The occlusion is another major problem in tracking. The target vehicles may be partially or fully occluded which is very tough to be detected. In the case of reconstructions, 3D reconstructions has not yet achieved from the intersections. The vehicle motion pattern learning, trajectory prediction and vehicle tracking accuracy is still remaining as a challenge.

5 Conclusion

Video surveillance is an important topic in computer vision. It has got a lot of applications for the peoples in daily activities. Here the paper presents a literature survey on the complete vehicle surveillance top to bottom. Paper gives a brief review on the various vehicle sensing techniques from the earlier days. The input for the processing is the video data taken from the camera which is positioned in various places of the road. Hence the camera positioning plays a crucial role in the surveillance. This survey gives a detailed description on the various preprocessing techniques implemented so far and then the various detection and vehicle tracking techniques available. Accuracy of various implemented algorithms implementation results have been mentioned. Future works and challenges helps in gaining more knowledge and an encouragement for the future research.

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