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Feature-based efficient vehicle tracking for a traffic surveillance system☆

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ABSTRACT

This paper presents an efficient feature-based tracking system to detect vehicles in a number of challenging conditions like lighting, occlusion, and darkness. A novel approach for vehicle tracking is proposed using an unsupervised feature matching technique. The system is fully functional under varying conditions because most of the salient vehicle features are tracked from matching of features in different objects. A feature-based vehicle tracking is proposed for a real-time traffic surveillance system. By analyzing the features of vehicles and their corresponding matched features, salient discriminative features of vehicles are calculated. The tracking of target vehicles is performed from the calculation of winner pixels in the consecutive frames using an unsupervised feature matching. To increase the accuracy of vehicle feature classification, orientation of feature descriptor of target vehicles tracked in the video frames is taken into consideration. Experimental results show that features classification rates of 96.4% and 92.7% for different vehicle sets can be achieved using the feature of aspect ratio. The proposed method is compared with recent feature-based method and Kalman filter-based method that results into better detection performance. The method can track the target vehicle under different situations like rotation, scaling, illumination and many others requiring less computation and providing better accuracy.

1. Introduction

Detecting vehicles is still a challenging task for intelligent transportation systems (ITS) due to the extreme variability of targets, lighting conditions, occlusion, and high-speed vehicle motion. Since vision sensors provide more information than the conventional sensors, attention is being focused on developing traffic surveillance systems that are equipped with vision sensors. Vision sensors such as cameras, stereo vision cameras, and infrared cameras are being widely used to gather scene information because of their ever-growing ability in comparison with the conventional sensors [1]. These sensors can detect obstacles in the navigation path and can navigate in terrain environments [2].

The detection of moving objects in video sequences at different interval is one of the challenging tasks in computer vision. One of the video surveillance fields is the traffic image/video analysis which consists of moving vehicle detection and object segmentation in video sequences. For example, in intelligent surveillance systems, tracking of moving vehicles is particularly essential for detection of the object region by patterns of movement [3]. Numerous algorithms have been proposed for the tracking of objects in the area of vision science. For instance, global template-based tracking [4] and local feature-based tracking [5] are given for tracking the objects using templates and features. A number of tracking algorithms

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employ manually-defined models while in other tracking algorithms, the objects are trained in initial tracking stage [6]. These tracking algorithms did not work well due to a change in appearance and due to transformations of the target object.

A number of algorithms have been developed that separates the object from background and overcome the difficulties of change in object appearance [7]. In [8], a tracking algorithm is proposed to select object features using online boosting approach. Another semi-supervised boosting algorithm has been proposed in [9] to overcome the object drift problem. In addition, many moving vehicle detection methods were proposed in [10,11] to detect and segment the vehicles in dynamic scenes. In [12], an online gradient-based tracking algorithm has been proposed to select the object features. Multiple instances learning tracker has been presented for tracking of the objects using positive and negative sets of samples [13]. Another semi-supervised learning algorithm is given in [14] using structural constraints. In [15,16], various methods are illustrated to track the objects using Kalman filter, however these methods require more computations when applied to real-time applications. These systems suffer from camera calibration that can cause error in windy and noisy environment.

A local-feature point's configuration method using computer graphics (CG) model images is proposed for vehicle classification [17]. However, this technique requires high computations to collect real images of the target vehicles. Various feature-based algorithms are given in [18–21] for keypoint detection of object features. Scale-invariant feature transform (SIFT) method [18] has been proposed to obtain features invariant to image scaling and rotation, and partially invariant to changes in illumination and view. In [22], a subregion-based novel statistical method is presented to detect vehicles automatically that depend on local features of sub-region. In [23], a multimodal temporal panorama (MTP) method is proposed for real-time vehicle detection and reconstruction. Zhang [24] introduced a method for vehicle detection that depends on versatile movement of histogram. An object recognition system is introduced for augmented reality that requires high computations in offline-training phase [25].

1.1. Technical contribution in the paper

The main contribution in this paper is to perform an efficient vehicle tracking in traffic videos using object segmentation and feature matching. The aim of the proposed vehicle tracking method is to detect features of the vehicles by segmentation of the target vehicle. The feature matching is performed only on the segments of the vehicle object instead of searching the image database. The proposed scheme determines winning pixels in consecutive frames of the segmented image database. The large sets of features are reduced using an unsupervised neural network that detects the reduced form of target features which speed up the tracking process. The performance of the proposed vehicle tracking scheme is compared with SIFT method [18], and Kalman filter-based tracking method [15]. The simulation results show that the proposed approach detects vehicles in the challenging conditions like occlusion, illumination, and darkness and it provides higher accuracy in less computation. Furthermore, in the proposed scheme, the orientation of feature descriptor is taken into consideration and it also provides good feature classification rates of 96.4% and 92.7% for different challenging datasets.

1.2. Application and paper organization

The tracking of object can be applied to a number of location-based services (LBS) and to road network environment that detects user location in LBS regions. In [26], a dynamic path privacy protection method is proposed that depends on a specific geometry to detect a LBS region. This scheme can protect user identity, location information, and service content that can be efficiently used for continuous query services in traffic without having access to any cryptographic keys. In [27], a new scheme for dynamic obstacles collision is proposed from detection of obstacles that appear in the path of movement. It provides a new approach for obstacle avoidance and alarm security system in the industrial area to avoid robot collision from walls, peoples, and obstacles. The proposed tracking method can be applied to location-based methods to integrate with the security systems.

The rest of this paper is organized as follows. The vehicle segmentation along with feature extraction and SIFT method is introduced in Section 2. Then, the proposed vehicle tracking using feature detection algorithms are given in Section 3. The experimental results using real video datasets, and a comparison with recent tracking techniques, are given in Section 4. The concluding remarks with some future research are presented in Section 5.

2. Vehicle segmentation and feature selection

2.1. Vehicle segmentation

To obtain features of vehicles from the video sequences, vehicle segmentation results only features of the segmented vehicles. The segmentation of vehicles in dynamic scenes is a challenging task due to change in shape and color. A widely used approach is background subtraction that subtracts vehicle object from the input image. However, in practice, detecting vehicle in moving videos using background subtraction technique is not straightforward due to change in background and illumination change in the scene. Vehicle segmentation in motion scenario is still an unsolved problem; however, the main idea behind solving the vehicle segmentation is to separate the object from background using motion information (Fig. 1). The clusters of motion vectors in video frames are determined by an over-segmentation in the video frames. This results in smaller patches of vehicles and each patch is assigned to one of the cluster.

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