INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

IJARIIT

ISSN: 2454-132X
Impact factor: 4.295
(Volume 4, Issue 1)
Available online at www.ijariit.com

A Review of UAV Video Processing for Estimation of Traffic Parameters

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ABSTRACT

Remotely sensed data using aerial video can be used to enhance existing methods and therefore to improve traffic surveillance. Traditional monitoring devices such as loop detectors, surveillance video cameras, and microwave sensors are usually placed at fixed locations to achieve a fixed surveillance coverage range. Aerial monitoring has helped the traffic planners and commuters to yield detailed information. Unmanned aerial vehicles (UAVs) are gaining popularity in traffic monitoring due to their low cost, high flexibility, and wide view range. The purpose of this technical report is to provide a survey of research, related to the application of UAV videos for traffic management.

Keywords: *Aerial Video, Traffic Flow Parameter Estimation, Traffic Image Analysis, Unmanned Aerial Vehicle.*

1. INTRODUCTION

The increase in the number of vehicles on roadway networks has led transport authorities to allow the use of technology advances. The aim is to evolve from solely providing roadway infrastructure to focusing on the needs of the traveling public, management and operations, and improved performance of the surface transportation system. This requires the precise and accurate collection of information about the state of the traffic and road conditions. The traditional technologies for traffic surveillance, including inductive loop detectors and video cameras, are kept fixed. While these detectors do provide useful information and data on the traffic flows at particular points, they generally do not provide useful data over large space. These sensors are usually placed at fixed locations, to achieve a fixed surveillance coverage range; this may not be cost-effective because a large number of these devices are needed for a single road segment. It is also difficult to use these sensors to provide other useful information such as vehicle trajectories, routing information, and paths through the network. Additionally, the maintenance of any of the fixed detectors leads to additional fees and would inevitably interrupt the normal traffic.

An aerial view provides better perspective with the ability to cover a large area. It has the properties of being both mobile, so that it may be deployed where needed to collect traffic data, and of capturing movements of individual vehicles in both time and space. When used along with traditional ground-based sensors, more absolute data can be collected for traffic monitoring and management. Satellites were initially considered, but the transitory nature of satellite orbits makes it difficult to obtain the right imagery to address continuous problems such as traffic tracking. Some authorities used manned aircraft for commercial usage and survey. But this approach was never cost-effective. Unmanned vehicles have advantages over manned vehicles as most of the functions and operations can be implemented at a much lower cost, faster and safer. UAVs (Unmanned Aerial Vehicles) may be employed for a wide range of transportation operations and planning applications. UAV equipped with a camera is considered to be a low-cost and flexible platform that can provide efficient data acquisition. UAVs may be employed for a wide range of transportation operations and planning applications: incident response, monitor freeway conditions, coordination among a network of traffic signals, traveller information, emergency vehicle guidance, track vehicle movements in an intersection, measurement of typical roadway usage, monitor parking lot utilization UAVs may potentially fly in conditions that are too dangerous for a manned aircraft, such as evacuation conditions, or very bad weather conditions. UAVs are programmed off-line and controlled in real-time to navigate and to collect transportation surveillance data. UAVs can view a large area of roadway network at a time and inform the base station of emergency or accidental sites. The difficulties involved in the aerial surveillance include the camera motions such as panning, tilting, and rotation. Also, the different camera heights largely affect the detection results.

2. UAV OVERVIEW

UAVs are semi-autonomous or fully autonomous aircraft that carry cameras, sensors, communication equipment etc. UAVs have been a topic of research for military applications since the 1950s. UAVs are broadly classified into rotary-wing and fixed-wing UAVs. Fixed-wing vehicles are simple to control, are well suited for wide-area surveillance and tracking applications and have high endurance, fixed wing vehicles have the advantage that they can sense image at long distances but it takes sufficient time to react because turning a fixed-wing vehicle takes time and space until the vehicle regains its course. The rotary-wing vehicles are also known as Vertical Takeoff and Landing (VTOL) vehicles as they have minimum launching time and space. Rotary wing vehicles have short range radars and cameras to detect traffic movement. The main disadvantage of this type of UAVs is that the rotary motion leads to vibration. Different UAVs have different payload weight carrying capability, their accommodation (volume, environment), their mission profile (altitude, range, and duration), and command, control, and data acquisition capabilities. A UAV system includes sensors and processing components on board and additional processing and displays at an operator controlled ground station. The cameras used may be standard visible light (electro-optical) or infrared (IR). As a result of rapid imaging in the video, moving objects can be detected from the static background and identify other changes between subsequent video frames even when the camera is itself moving.

3. METHODS

The main interest of all studies based on UAV videos for parameter estimation is to develop a low-cost traffic monitoring system that can automatically track vehicles and give traffic parameters from a moving surveillance platform even under heavy traffic conditions. In term of research objectives, previous studies in the area can be roughly divided into three categories. The first category is road detection. This category also includes road tracking for the autonomous navigation of UAV. The second category of relevant research is vehicle detection and tracking. The third category focuses on traffic parameter estimation from the processed videos.

3.1 Road Detection and Tracking

A common approach for road detection is to use information in a single frame. However, some object detection methods make use of the temporal information computed from a sequence of frames to reduce the number of false detections. UAV-based road detection and tracking are important because it can be applied to the vision-based navigation of UAVs [1]. It also helps to determine the region of interest (ROI) in a given video. In the literature of road detection and tracking, most approaches use the radiometry (texture) and/or geometry (structure) of roads. Among them, the combination of road colour and boundary information have achieved more robust and accurate results than using only one of them in road detection, as shown in the work [2], [3]. In general, region colour distributions or/and boundary structures are probably the most important information utilized for road detection.

Road detection can be broadly classified into three categories. Point detectors are used to find interesting points in images which are expressive texture in respective localities. Commonly used interest point detectors are Moravec’s detector, Harris detector, KLT detector, and SIFT detector. Object detection can be achieved by building a background model and then finding deviations from the model for each of the successive frames. This approach is called background subtraction. Different methods of background subtraction are Frame differencing, Hidden Markov models and Eigen space decomposition. Image segmentation algorithms separate the image into almost similar regions for further processing. Mean shift clustering, image segmentation using Graph-cuts (Normalized cuts) and Active contours are the common image segmentation methods.

The aim of a road tracker is to generate the trajectory of an object by locating its position in successive frames of the video. There are many methods of tracking; Point tracking, Kernel tracking, Silhouette tracking, and Feature Selection for Tracking. Point tracking is the similarity of detecting objects represented by points across frames. Objects detected in consecutive frames are represented by points, and the association of each point is based on the previous object state such as object position and motion. Deterministic approach and Statistical approach are the broad classifications of point tracking. Kernel tracking is done by computing the motion of the object from one frame to the next. Template and Density-based Appearance Model and Multi-view appearance model are methods of kernel tracking. Silhouette tracking provides an accurate shape description of the target objects. Silhouette trackers can be divided into two categories i.e. Shape matching and Contour tracking. Feature Selection for tracking plays an important role in the selection of proper features to track. Colour, texture, edges and optical flow are examples of some features.

In work [4], they proposed to represent road colour distributions using Gaussian mixture models (GMMs) from given sample images. A GMM is a parametric probability density function represents a weighted sum of Gaussian component densities. And then to determine road pixels in each frame by checking the probabilities of pixels that complies the GMMs. GraphCut-based road detection [5] method uses the GMMs to model image colour distributions, and structure tensors are employed to capture image edge features. Fast homography estimation [5] method gives the details on how to achieve a fast road tracking based on homography alignment to correct the drift problem caused by accumulation error in homography estimation, and give criteria on assessing tracking results. Learning both colour and gradient information from a sample image is proposed in [6]. Gaussian and gamma distributions are used to represent colour and gradient models. Those parts of the road, that are not being recognized automatically by using primary analysis, are being filled, if there are two sections of the road, that can bridge with straight line towards the road direction. In [7], the clustering technique based on prior hue and texture information is used to classify each image pixel into target and background, and then boundary lines are fitted to refine the desired region. In [8], [9], a simple intensity thresholding technique is used to obtain initial road regions, followed by refinements of local line segment detections, where the assumption is that roads intensities are very different from neighborhood regions and roads can be approximated locally by linear line segments.

3.2 Vehicle Detection and Tracking

Vehicle detection techniques keep on developing nowadays and existing techniques keeps on improving. This greatly aids in traffic monitoring, speed management and also in military and police. It uses numerous models: Feature primarily based on object detection, Support Vector Machine (SVM) classification, and Image Segmentation. The existing vehicle detection techniques are based on a large variety of techniques. The hierarchical model proposed in [10] which describes different levels of details of vehicle features and detection method based on cascade classifiers has the disadvantage of lots of miss detections. Vehicle detection algorithm based on symmetric property [11] of car shapes is prone to false detections. The high computational complexity of mean-shift segmentation algorithm is a major concern in the existing methods.

In work [12], a novel detection method using color transform model and edge map is discussed. The detection procedure is done in different stages. In the first stage a color transformation model is used to easily identify the vehicle pixels from backgrounds. An optimal vehicle classifier can be formed by using proper weights from a set of training samples. The verification of hypothesis is done by edges, coefficients of wavelet transform and corners. Hansen *et al*. [13] defined an affine model for the operation of motion detection. Background subtraction operation follows the stabilization operation for a dynamic video sequence. The next phase is binary classification which is carried out by SVM along with considering the features such as HOG and size. HOG features means histogram of oriented gradient which represents the object contours to an extent. Size features are considered for distinguishing the vehicles from the false alarms. The HOG features have the disadvantage of having high dimensionality. Work [14] introduces an extension of the HOG features to overcome the disadvantages by reducing dimensionality. This technique is known as boosting HOG feature. Adaboost classifier is used for this boosting HOG features and to translate the weak to strong classifiers. In work [15], a combination of Scale Invariant Feature Transform (SIFT), SVM and Affinity Propagation algorithm (AP) is used. SIFT is a technique which is invariant to rotation, scaling, illumination changes etc. The task is effective for the natural outdoor images. AP is used on the key points classified using SVM. This aids in the unsupervised clustering of the key points generated. Kanade-Lucas-Tomasi tracker (KLT) [16] exhibits frame to frame tracking. The KLT tracker tracks and generates a trajectory for the corresponding object features between a pair of images by calculating the displacement vector.

3.3 Parameter Estimation

The traffic stream includes a combination of driver and vehicle behaviour. A flow of traffic through a street of defined characteristics can vary both by location and time according to the changes in the human behaviour. The parameters can be mainly classified as: measurements of quantity (density and flow of traffic) and measurements of quality which (speed). Flow or volume is defined as the number of vehicles that pass a point on a highway or a given lane or direction of a road during a specific time interval. Density is defined as the number of vehicles occupying a given length and is generally expressed as vehicles per km. Speed is the quality measurement of travel as the drivers and passengers are concerned more about the speed of the journey. It is defined as the rate of motion in distance per unit of time. In [17], an automatic velocity estimation technique is described that makes use of features from KLT tracker. The paper [18] introduces specific methods for estimating speeds, travel times, densities, and queuing delays from aerial imagery. Mirchandani et al. in [19] and A. Angel et al. in [18] discussed the potential of collecting traffic data from aerial video footage; several parameters were able to be extracted, such as densities, travel times, turning counts, queue lengths etc.

4. CONCLUSION

The paper discusses relevant researches in the field of traffic flow parameter estimation from UAV videos. The main aim of this inspection is to find an ideal approach of nearly no false alarms and high detection accuracy. Aerial video processing for analyzing traffic flow mainly includes three steps: road detection, vehicle detection and tracking and parameter estimation. For road detection, the combination of road colour and boundary information has achieved more robust and accurate results. KLT tracker and SIFT are considered to be more convenient in-vehicle detection and tracking. The use of computer vision techniques and remote sensing information (such as photogrammetric applications or road construction and maintenance), for processing the aerial video footage has proved a great success.

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