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A	Sylvia Gil, Ruggero Milanese, and Thierry Pun, "Feature selection for object tracking in traffic scenes," SPIE Vol. 2344, Intelligent Vehicle Highway Systems, pp. 253–266 (1994)	December 29, 1994

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Eric A. Pepper

EXHIBIT A

Feature selection for object tracking in traffic scenes

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ABSTRACT

This paper describes a motion-analysis system, applied to the problem of vehicle tracking in real-world highway scenes. The system is structured in two stages. In the first one, a motion-detection algorithm performs a figure/ground segmentation, providing binary masks of the moving objects. In the second stage, vehicles are tracked for the rest of the sequence, by using Kalman filters on two state vectors, which represent each target's position and velocity. A vehicle's motion is represented by an affine model, taking into account translations and scale changes. Three types of features have been used for the vehicle's description state vectors. Two of them are contour-based: the bounding box and the centroid of the convex polygon approximating the vehicles contour. The third one is region-based and consists of the 2-D pattern of the vehicle in the image. For each of these features, the performance of the tracking algorithm has been tested, in terms of the position error, stability of the estimated motion parameters, trace of the motion model's covariance matrix, as well as computing time. A comparison of these results appears in favor of the use of the bounding box features.

Keywords: traffic scenes, motion detection, Kalman filter, tracking, feature comparison.

1. INTRODUCTION

Computer vision techniques can be useful in traffic control in order to increase safety and obtain road state information of monitored areas. For instance, the possibility to extract complex, high-level road information such as congestion, accident or fluid traffic allows to efficiently plan a path through the road network, to quickly bring rescue where needed or to deviate the traffic. In order to extract this type of information it is first necessary to segment moving objects from the scene. In this way, vehicles can be counted, and their trajectory, as well as their velocity and acceleration can be determined. Moreover, statistics can be collected from kinematic parameters in order to make a classification between safe, fluid, congestioned or dangerous state of traffic.

One of the major difficulties of monitoring traffic scenes, along with the real-time requirement, is the variety of light conditions of outdoor scenes. Indeed, the system should be reliable day and night, even though at night only vehicle lights are visible. Weather conditions also bring additional difficulties, such as the presence of the vehicle shadow in sunny days (shadows can prevent from correctly segmenting nearby vehicles) or a change in the contrast between the road and the vehicles when raining (a wet road is darker and generally dries irregularly). Thus, it is necessary to have a system able to adapt to these different lighting conditions by exploiting different visual features according to their reliability under such conditions. This paper presents a comparison of the ability of different features to be recovered and tracked, in an image sequence.

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1. Part of this research was conducted while the first author was a visiting scholar at the International Computer Science Institute, Berkeley, California, thanks to a grant from the Swiss National Fund for Scientific Research (4023-027036).

Surveillance of urban and highway scenes has been widely studied in the past five years, thus providing a large amount of literature. One of the most popular methods, called model-base tracking, uses a 3-D model of a vehicle and is structured in two steps: (i) computation of scale, position and 3-D orientation of the modeled vehicle, also called pose recovery, and (ii) tracking of the vehicle by fitting the model in subsequent frames by means of maximum-a-posteriori (MAP) techniques[1] or Kalman filters[2, 3]. The vehicle model being quite detailed (3-D model including the shadow), model-based tracking provides an accurate estimate (or recovery) of the vehicles 3-D position which might not be needed for most applications. A simplified model of the vehicle is proposed in [4] where it is represented through a polygon, with fixed number of vertices, enclosing the convex hull of some vehicle features. This model dramatically reduces the vehicle model complexity. In [4] Kalman filters are used in order to track the vehicle's position as well as its motion using an affine model which allows for translation and rotation. The fixed number of polygon vertices, however, allows little variations on the objects shape. Some improvements on this point are proposed in [5] through the use of dynamic contours instead of polygons with a fixed number of vertices. Cubic B-splines are fitted on a set of control points (vertices) belonging to the target and so providing a smooth parametric curve approximating its contour. In this case, a Kalman filter is used in order to track the curve in subsequent frames with a search strategy guided by the local contrast of the target in the image, i.e. with no use of the motion information. In the context of traffic scenes, especially in the case of highways, vehicle's motion should be a powerful cue in order to direct the search for the target position in subsequent frames. Another system that combines active contours model with Kalman filtering has been presented in [6]. In this case, the use of separate filters for the vehicle position and other motion parameters (affine model: translation and scale), has been shown to provide better results.

In consideration of this previous work, the approach described in this paper is based in the following points. First, advantage is taken from the simplicity of the targets profile (man-made vehicles), which can be well approximated by simple geometric models such as convex polygons; no restriction on the vertices number should be needed. Motion information in terms of an affine model (translation and scale) is used, as well as local contrast, in order to locate the vehicle in subsequent frames, by means of two separate Kalman filters. Finally, multiple features are tracked in the same image sequence and their performances are compared in terms of robustness, CPU time, and error measures. The rest of this paper is organized in the following way: Section 2 presents a motion detection system which discriminates between static background and dynamic objects and provides a set of binary masks coarsely representing the moving objects. Once moving objects are isolated, their mask shape is refined until their boundary accurately matches their contour (Section 3). After the mask refinement is accomplished, a set of features, such as the mask contour, the pattern describing the target itself, and its center of gravity, are computed for each vehicle, in order to be tracked in subsequent frames (Section 4). In section 5, the tracking procedure is described. Results are presented in Section 6, followed by a discussion. Finally, conclusions are presented in Section 7.

2. THE MOTION DETECTION SYSTEM

The goal of the motion detection module is to perform a segmentation between static and dynamic regions in an image sequence by providing a set of binary masks which coarsely represent the shape and the position of the moving objects. The method is required to be fast since it represents a preprocessing step for motion computation and tracking. For this purpose, it operates on low-level data such as spatio-temporal derivatives or image differences rather than an optical flow information.

2.1 Related work

Motion detection has been studied in different contexts such as video coding, surveillance, or traffic control. Differential methods are based on the substraction of subsequent frames in order to get rid of the constant background and process only the moving regions of the image. An example of this method is described in[7]: after performing the difference between successive frames, a 2-D median filter is applied on the difference image in order to smooth the mask boundaries; finally small regions are eliminated. This strategy is strongly affected by the aperture problem, when moving objects contain large regions of uniform gray-level. In this case, part of these objects are considered static and the resulting masks, despite the median regularization, appear oversegmented. A related approach, called the background method, aims at reconstructing the background using the spatial and temporal derivatives. When an accurate approximation of the background is available, it is subtracted from each frame in order to enhance moving objects. The background image has to be updated to account for

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