An Improved Lane Detection and Tracking Method for Lane Departure Warning Systems

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ABSTRACT

Lane detection and tracking are very crucial treatments in lane departure warning systems as they help the vehicle-mounted system to keep its lane. In this context, the authors’ work aims to develop vision-based lane detection and tracking method to detect and track lane limits in highways and main roads. The authors’ contribution focuses on the detection step. By exploiting the fact that, in an image, the road can be formed by linear and curvilinear portions, the authors propose two types of appropriate treatments to detect the lane limits. The authors’ method offers high precision rates independently of the painted lane marking’s characteristics, of the time of acquisition and in different weather conditions. Besides the challenges it overcomes, the authors’ method has the advantage of operating with a timing complexity that is reasonable for real-time applications. As shown experimentally, compared to three leading methods from the literature, the authors’ method has a higher efficiency.

Keywords: Driver Assistance System, Lane Departure Warning, Lane Detection, Lane Tracking, Morphological Filtering, Parametric Model

INTRODUCTION

The accidents caused by involuntary lane departure continue to represent an important part of accident-prone traffic conditions. Seeing the importance of their application, many vision-based lane departure warning systems have been developed (e.g., Mobileye\(^1\) and Valeo\(^2\)). Their main objective is to assist the driver by discharging him/her from some tasks. According to the Federal Motor Carrier Safety Administration\(^3\), regardless of the importance of the proposed systems, they present some limitations to track the lane limits (LL). These limitations may be due to a lack or poor quality of lane markings (LM), poor visibility, dirty windshield or also to an operating windshield wiper. Accordingly, their introduction in the market is very low (Kulmala, 2010).

To avoid accident-prone situations, our suggested lane departure warning solution is based on two main steps: lane detection and

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lane tracking. The realization of the two steps mentioned above is relatively easy when the texture of the road is uniform and when the lane presents very clear markings. However, they become non-trivial particularly with the presence of obstacles that cover LM, the presence of different LM, the effects of weather conditions and the time of acquisition. Their difficulties get further accentuated in cases of windshield wiper movements and abrupt or unexpected actions of conductors, which are likely to distort the result of the two steps.

In this paper, we are interested in highways and main road. The vehicle carrying the single camera is initially approximately aligned with a straight portion of the road. The tilt of the camera must be adjusted so that the horizon lies roughly in the middle of the acquired frame. Our contribution consists in proposing a method that ensures the detection and the tracking of the lane limits under different conditions: (i) under different weather conditions, (ii) under illumination change, and (iii) in the presence of an operating windshield wiper. To realize this, we apply a morphological filtering, the Hough transform, the parabolic fitting and the kalman filtering techniques.

The remainder of this paper is organized as follow: the second section describes the common steps of typical lane detection and lane tracking processes while detailing the existed techniques of every step in the literature. The section following details our proposed approach. The section after presents a set of experimental evaluations and compares the performance of our approach with existing propositions. The last section concludes by summarizing the main contributions of the present work and outlines future research works.

RELATED WORKS

The aim of lane detection and tracking based on image processing is, first, to locate in a sequence frame the lane limits of the road in which the vehicle is engaged and, then, to track these limits in the remaining frames.

The acquired images are, first, pre-processed in order to reduce the noise always caused by the sensors (Min, Liu, & Xu, 2006; Wennan, Qiang, & Hong, 2006; Ming-Dar, et al., 2008), to reduce the execution time based on the processing of a region of interest (Min, Liu, & Xu, 2006; Lim, Seng, Ngo, & Ang, 2009), or also to reduce the perspective effect of the lane by applying the inverse perspective mapping (Juan, Hilario, de la Escalera, & Armingol, 2005; Zu, 2006). The second step extracts the approximate pixels of LM either by detecting their edges (Min, Liu, & Xu, 2006; Ming-Dar, et al., 2008; Chih-Hsein & Chen, 2006; Haiping, Ko, Shih, Kim, & Kim, 2007), or by detecting their regions throw image segmentation (Lim, Seng, Ngo, & Ang, 2009; Serge, Michel, & Xuan, 1989; Chao, Mei, & D, 2010). The third step, the lane detection step, determines effective limits on an acquired image, based on the approximate pixels retained in the second step. Various lane detection methods are proposed in the literature and can be grouped in two categories: model-based approach (Min, Liu, & Xu, 2006; Wennan, Qiang, & Hong, 2006; Ming-Dar, et al., 2008; Romuald, Roland, & Frédéric, 2000) and feature-based approach (Ming-Dar, et al., 2008; Zu, 2006; Craig & Zou, 2007; Jan Pablo & Özgün er, 2000) (see Table 1). Finally, the last step, the lane tracking step allows the continuous detection within all the video sequence by updating, in every frame, the last detected limits. This step is required to minimize the noises and the execution time. Different methods were proposed to carry out this tracking step, they can be broadly classified in two approaches: deterministic-based approach (Liu, Dai, Song, He, & Zhang, 2011; Min, Liu, & Hu, 2006; Yue, Teoha, & Shenb, 2004; Muhammad, Arshad, Irfan, & Yahya, 2007) and stochastic-based approach (Ming-Dar, et al., 2008; M, A, & N, 2007) (see Table 2).

The tracking step allows controlling the lateral navigation of the vehicle through a lane departure warning module. In this context, Citroën was the first in Europe to offer such a module on their 2005 C4, C5 and C6 models. This system uses infrared sensors to monitor
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