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A lane-departure identification based on LBPE, Hough transform, and linear regression

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Abstract

This paper presents a lane-departure identification (LDI) system of a traveling vehicle on a structured road with lane marks. As is the case with modified version of the previous EDF-based LDI approach [J.W. Lee, A machine vision system for lane-departure detection, CVIU 86 (2002) 52–78], the new system increases the number of lane-related parameters and introduces departure ratios to determine the instant of lane departure and a linear regression (LR) to minimize wrong decisions due to noise effects. To enhance the robustness of LDI, we conceive of a lane boundary pixel extractor (LBPE) capable of extracting pixels expected to be on lane boundaries. Then, the Hough transform utilizes the pixels from the LBPE to provide the lane-related parameters such as an orientation and a location parameter. The fundamental idea of the proposed LDI is based on an observation that the ratios of orientations and location parameters of left- and right-lane boundaries are equal to one as far as the optical axis of a camera mounted on a vehicle is coincident with the center of lane. The ratios enable the lane-related parameters and the symmetrical property of both lane boundaries to be connected. In addition, the LR of the lane-related parameters of a series of successive images plays the role of determining the trend of a vehicle's traveling direction and the error of the LR is used to avoid a wrong LDI. We show the efficiency of the proposed LDI system with some real images.

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1. Introduction

Machine vision is expected to contribute greatly to the development of vehicle safety and in turn the reduction of traffic accidents caused by driver's inattention, mistake or lack of experience. However, machine vision has showed limited success because it does not achieve an appropriate reliability in natural outdoor environments. To make machine vision systems practical, robustness is required. This paper presents a machine vision system capable of identifying lane departure (LD) of a traveling vehicle with minimum false alarms and miss-detections on roads with lane marks. The LD identification (LDI) determining whether or not a traveling vehicle deviates from its lane is conducted with lane-related parameters composed of the orientations and positions of lane boundaries in an image.

An important observation is that if the optical axis of a CCD camera and the center of lane nearly coincide as shown in Fig. 1A, the angles θ_l and θ_r, and distances ρ_l and ρ_r, which are defined in Fig. 1B for both of left- and right-lane boundaries, have the values as $\theta_l/\theta_r \approx 1$ and $\rho_l/\rho_r \approx 1$. If the optical axis deviates far from the center of lane, θ_l/θ_r and ρ_l/ρ_r deviates in accordance from the value of 1. When the optical axis of a CCD camera approaches the left boundary, θ_l and ρ_l decrease at the same time while θ_r and ρ_r increase. Conversely, when the optical axis approaches the right boundary, θ_r and ρ_r decrease and θ_l and ρ_l increase. The basic idea of the proposed LDI system is based on this observation. Fig. 2 shows a typical phenomenon where as a vehicle deviates from its traveling lane as shown in Figs. 2A and D, the orientation and position of lane boundaries change at the same time. The two columns on the left of Fig. 2 illustrate the LD to the left side and show that θ_l and ρ_l decrease as the vehicle approaches the left-lane boundary as shown in Figs. 2B and E. The two columns on the right depict LD to the right side and show that θ_r and ρ_r decrease as the vehicle approaches the right-lane boundary as shown in Figs. 2C and F. Therefore, the proposed LDI system focuses on measuring the orientation and position of lane boundaries to determine whether or not the LD occurs.

To realize the new LDI system, some constraints with respect to camera installation on a vehicle are required such that the optical axis of a camera mounted on a vehicle is as close as possible to the centerline of the car-body as illustrated in Fig. 1C, and as parallel as possible to the road surface. Such constraints are deeply related to setting of the ROI shown in Fig. 1B.

Our previous edge distribution function (EDF)-based LDI system [1,18] was also based on such similar observations. However, in LDI, we only used the departure measure ξ defined by $\xi = (\theta_1 - 90°)/(90° - \theta_2)$ where angles θ_1 and θ_2 are defined as shown in Fig. 1B. The departure measure ξ is equal to the ratio θ_l/θ_r. The EDF-based method has a weakness such that when a vehicle travels at the center of lane in a curved lane with broken lane marks, a big difference between the angles θ_l and θ_r occurs abruptly, the ratio θ_l/θ_r deviates in accordance from the value of 1,