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Development of a vision-based lane detection system considering configuration aspects

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Abstract

Vision-based lane-sensing systems require accurate and robust sensing performance in lane detection. Besides, there exists trade-off between the computational burden and processor cost, which should be considered for implementing the systems in passenger cars. In this paper, a stereo vision-based lane detection system considering sensor configuration aspects such as field of view (FOV), span pixels, resolution, etc is developed. An inverse perspective mapping method is formulated based on the relative correspondence between the left and right cameras so that the 3D road geometry can be reconstructed in a robust manner. The selection rule of the sensor configuration and specifications is investigated for a standard highway. Based on the selected sensor configurations, it is shown that sensing region range on the camera image coordinate can be determined for the best lane-sensing performance. The proposed system is implemented on a passenger car and its real-time sensing performance is verified experimentally.

Keywords: Lane detection; Vision sensor; Camera configuration; Camera calibration

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1. Introduction

Lane-sensing systems based on vision sensors are regarded promising because they require little infrastructure on the highway except clear lane markers. These systems are believed to inform the driver of the possible lane departure accident and, if necessary, to override the driver's steering command. However, the feasibility of these systems in passenger car requires accurate and robust sensing performance in lane detection. In addition, trade-off between the computational burden and processor cost should be considered for the real-time image processing in passenger cars.

The image processing algorithms are basically composed of image acquisition process and inverse perspective mapping. The image acquisition process can be considered as a transform from the 3D world space to the 2D image plane. Conversely, inverse perspective mapping is an inverse transform from the 2D image plane back to the 3D world space by removing the perspective effect. The inverse perspective mapping is usually indeterminate because some of the 3D information is lost during the image acquisition. To overcome these limitations, various image processing algorithms [1–13, et al.] have been developed for vision cameras. For instance, 3D lane edge is detected solely based on the vision image [1–4, et al.], but the image processing algorithms can be very complicated. In order to reduce the computational burden and to apply the vision-sensing techniques in highway maneuvering, road geometry models have been utilized and their parameters are estimated to monitor the lane marker locations [5–9].

The lane-sensing systems using single camera are effective on planar roadway [5,6], but have limitations in non-planar roadway. In order to extend the lane-sensing systems to non-planar road geometry, several schemes with a single camera [7] or stereo cameras [2,9, etc.] are adopted for reconstructing the 3D road structure. In this case, robustness and image processing time become very important from the implementation perspective. For instance, robust vision-sensing systems have been developed considering adverse weather condition, poorly structured road, etc. [10–12] and speed in image processing time [12,13].

Moreover, the performance of the vision-based lane-sensing systems depends on several problems, such as, camera specifications, camera configuration, calibration data [14–16] and lane marker monitoring algorithms [17]. In particular, selection of the camera specifications and configuration is very important so that lane markers on the image plane can be detected in accurate and robust manner and that the cost of the lane-sensing unit is minimum without over-design in lane-sensing systems. The previewed region in front of the car and the sensing range in the image plane needs to be decided by considering the field of view (FOV) and resolution of camera, camera geometry and sensing environment (curvature range, lane marker type, etc.). However, these configuration aspects have not been investigated in designing the lane-sensing systems in the literature.

In this paper, a vision-based lane detection system considering the configuration aspects of vision sensors is developed. With a set of stereo cameras, an inverse perspective mapping method is developed based on the relative calibration between