Lane Detection Algorithm Based on Road Structure and Extended Kalman Filter

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ABSTRACT

Lane detection still demonstrates low accuracy and missing robustness when recorded markings are interrupted by strong light or shadows or missing marking. This article proposes a new algorithm using a model of road structure and an extended Kalman filter. The region of interest is set according to the vanishing point. First, an edge-detection operator is used to scan horizontal pixels and calculate edge-strength values. The corresponding straight line is detected by line parameters voted by edge points. From the edge points and lane mark candidates extracted above, and other constraints, these points are treated as the potential lane boundary. Finally, the lane parameters are estimated using the coordinates of the lane boundary points. They are updated by an extended Kalman filter to ensure the stability and robustness. Results indicate that the proposed algorithm is robust for challenging road scenes with low computational complexity.

KEYWORDS

Extended Kalman Filter, Lane Detection, Road Models, Vanishing Point

1. INTRODUCTION

Advanced driver assistance systems are gradually being incorporated into vehicles. They can either alert the driver in dangerous situations or take an active part in the driving. They are expected to become more complex towards full autonomy during the next decade. One of the main bottlenecks in the development of such systems is the perception problem. Road, lane and obstacle detection (Huang et al., 2009; Hillel et al., 2014) are important vision perception problems. In this paper lane detection is considered. The main perceptual cues for human driving include road color and texture, road boundaries, and lane markings. Autonomous vehicles are expected to share the road with human drivers. It is unrealistic to expect the huge investments to construct and maintain special infrastructure only for autonomous vehicles. Autonomous vehicles will therefore most likely continue to rely on the same perceptual cues that human drivers do (Aly, 2008; Xiao et al., 2015).

The road and lane detection generally includes the following five modules. They are image pre-processing, feature extraction, road or lane model fitting, temporal integration, and image-to-world correspondence (Meng et al., 2010; Xu et al., 2011). A lane departure warning system was proposed

DOI: 10.4018/IJDCF.2020040101

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by Lee (2002) to estimate the subsequent direction of lane through an edge distribution function and direction changes of vehicle movement. It failed on roads with curved and dashed lanes. Wang et al. (2004) provided an initial position for a B-snake model, then the lane detection problem can be changed into the problem of control points to determine a spline curve following a road model. Mechat et al. (2013) detected the lane using a support vector machine (SVM) based method. In this method, the model of the lane was defined by a Catmull-Rom curve, and the standard Kalman filter was adopted to estimate and track the parameters of control points. Shin et al. (2015) extended a particle-filter-based approach for lane detection, also addressing challenging road situations. Kortli et al. (2017) proposed a method based on Gauss filter and Canny edge detector to extract lane boundaries based on color information. Although this system worked properly on a lot of different conditions, there were still some problems for blur lane marks and complex road surface. Lee et al. (2017) proposed a real-time lane detection algorithm using a simple filter and Kalman filter that can be implemented in an embedded system. Even though this method was invariant against various illumination changes, it was still difficult to handle several extreme conditions such as strong light reflection, blur lane marks, low sun angle situations and lane cracks. Pan et al. (2017) proposed a dual-stage detecting strategy, which consisted of a fast Hough transform based road detection method and a reliable vanishing point-based method. However, an evaluation method was needed to judge the detection result of two stages. The lane detection modules currently provide stable results in general, but their performance under special conditions is still a research topic; those conditions might be defined by strong sunlight, hard to identify lanes, shadows caused by trees or other objects, sidewalks, zebra crossings, or text logos on the road.

In view of this, a lane detection algorithm is proposed by combining a road structure model with an extended Kalman filter. Considering the characteristics of the lane and according to the roadway geometry, a new lane model is proposed which enhances the stability and anti-jamming of the lane-detection system. The parameter space is defined to accommodate the algorithm for the lane model. Due to algorithmic developments in the area of Hough transforms (Xu et al., 2015), there is good progress to improve the processing speed. The extended Kalman filter is used to estimate and track the lane, which is the major factor for improved accuracy in the proposed lane detection. The effectiveness and robustness of the algorithm is demonstrated in this paper.

The structure of this paper is as follows. Section 2 reports about the used road model. Section 3 describes the lane detection algorithm based on road structure and extended Kalman filter. Section 4 informs about the experiments and the performed evaluation. Section 5 concludes.

2. THE PROCESSING OF BASIC LAYER

The estimated parameters of the lane detection in this paper are related to the lane shape and the posture of the driving vehicle. These parameters involve lane width, the shifting of vehicle, pitch angle, horizontal angle and lane curvature, etc. Figure 1 shows the flowchart of the proposed lane detection algorithm. The parameter estimation is divided into two parts. The first part is the posture of the camera and the road environment information obtained from the in-vehicle camera. The second part estimates the parameters of the road using the road lane information.

The flowchart of the algorithm in this paper begins with reading a frame of image. The adaptive edge detection operator based on the scan line is used to extract the image edge points from the R channel of the image. The region of interest of the algorithm is selected. The image pixel coordinate system is mapped to the road plane coordinate system. The edge points are voted in custom parameter space to get candidate lines. The geometrical characteristics and spatial continuity of the lane are collected. The non-lane lines can be excluded using lane information in the image pixel coordinate system and lane road plane coordinate system. The inner-boundary points and extended Kalman filter are combined to estimate and update lane model parameters.
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