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Lane Estimation by Particle-Filtering Combined with Likelihood Computation of Line Boundaries and Motion Compensation

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Abstract— **Roads are exposed to various kinds of noise, lighting conditions and weather; thus, robust lane localization is difficult. Our paper presents an algorithm for a probabilistic estimation of lane information and solves the problem by the combining particle-filtering (PF) with likelihood computation of pixels on line boundaries using Gaussian-like functions. Additionally, because a pitch or an abrupt yaw motion of the camera makes lane estimation imprecise, motion compensation is added to the estimation. Thus, the algorithm provides precise lane information to a driver assistant or autonomous driving system. The results of experiments show that the algorithm is well adapted to various lane conditions.**

I. INTRODUCTION

Obtaining precise lane information has been a challenging issue for driver assistant systems (DAS) as well as autonomous driving systems (ADS) [1]. To meet this objective, robust detection and localization of lane boundaries are essential tasks. Accordingly, the success of lane estimation largely relies on the robust extraction of lane boundaries [7, 24]. Many related studies based on computer-vision technologies and machine-learning algorithms combined with tracking methods have been conducted. Although their performance is satisfactory, maintaining robustness while generating precise lane information remains a challenge [2, 10]. Reasons for this challenge are as follows: 1) lane boundaries are often corrupted by various natural environment noises; 2) lane-boundary localization in images becomes ambiguous near the vanishing-line; and 3) lane estimation is affected by camera motion.

First, we clearly define the lane as a path for vehicles and the lane boundary as a lane border. Therefore, each lane has left and right boundaries, which are typically marked by a dotted or solid line and painted with a white, yellow or blue color on a paved road surface. Lane boundary types are single- or double-lines. In this paper, we refer to the lane boundary as a line.

This paper assumes that lines are lighter than background road surface and that lines in the three-dimensional (3D) space can be modeled by a two-dimensional (2D) curve. Accordingly, in places where these two assumptions are invalid, the proposed algorithm can produce inaccurate lane information. Aside from situations related to these assumptions, our algorithm copes with other noisy conditions using particle- filtering (PF)-based estimation combined with the following approaches: (1) extraction of line-boundary candidate pixels; (2) likelihood computation of the candidate pixels via pixel- grouping and Gaussian-like functions; (3) region of interest (ROI) weighting; (4) two-step PF [2, 3], and (5) camera motion compensation.

Our work contributes three main points. First, we compute the likelihood of a pixel that depicts the degree to which it is on the real line boundary. This likelihood computation gives rise to “maximum effect” for suppressing pixels that are not from the line boundaries without extra post-processing. This likelihood is exploited in estimating lane information via PF. Many existing methods have relied on binarization in selecting pixels from lane boundaries. Binarization simply divides features into positive and negative groups and largely depends on threshold values that are extremely affected by the image ambiguity, mainly caused by line markers. Second, we introduce ROI-weighting which prohibits fluctuations in lane localization, because ROI indicates the area where we anticipate the current lane’s left and right lane boundaries to be. In contrast, many lane detection methods, including the recent deep learning-based approaches [24], exhibit difficulty in localizing lines, owing to artifacts on the road surface, such as arrows, letters, and curbs. Such artifacts have similar properties to lines and frequently show more distinctive contrast to the background road surface than do lines. Double-line lane boundaries are also impediments to localization. Consequently, an extracted line fluctuates, leading to unstable steering-control for a lane-keeping or lane-centering systems [20]. Third, the estimated lane information is affected by camera motion (e.g., a pitch or abrupt yaw motion). Accordingly, we reflect the motion influence in estimating lane information. Generally, PF shows an effective tracking performance [2]. However, it does not track the lane well under abrupt motions. Therefore, our proposed motion compensation complements the PF.

Additionally, the two-step PF enhances lane-detectability and shortens processing time by reducing the search space of particles compared to a single-step PF [4].

The remainder of this paper is organized as follows: Section II presents related works about lane detection. In Section III, we describe the proposed algorithm. In Section IV, experimental results are shown. Our conclusion and plans for future work are

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