Lane Detection Algorithms for ADAS

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Date: 14.03.2021

Abstract—Over the last decades, lane detection is playing a significant role to promote the modern technology of Advanced Driver Assistance Systems (ADAS). A robust and accurate solution for detecting the lane is an integral part of achieving the goal of self-driving cars. In the meantime, various types of algorithms are being applied to enhance the performance of detection. Notably, vision-based, deep learning and evolution-based algorithms are showing an immense improvement. This paper briefly explains and compares the several state-of-the-art lane detection algorithms that give a promising performance in real-time. Finally, the limitation of current developing algorithms and the future upcoming artificial society, computational experiment based on the parallel system (ACP) approach have been discussed.

Index Terms—Lane Detection, Computer Vision, Deep Learning, Convolutional Neural Network (CNN), Evolution Algorithms, Artfical Society and Computational Experiment Based On Parallel System (ACP), Advanced Driver Assistance Systems (ADAS).

1 Introduction

SAFETY driving and accident reduction, thus saving many precious lives, is one of the great interests in the context of the Advanced Driver Assistance Systems (ADAS). Considering this aspect, the lane identification system is the spine of ADAS and the most highly challenging and complex tasks for future automated vehicles. Following the long-term lane detection research, great success has been achieved in reducing road accident fatalities. For the last decades, many vision-based [1]–[4] and deep learning-based [5]–[8] algorithms have been researched for human visual understanding based on the lane markings of a road. The ultimate objective of visual technology is to identify the lane from the road image and help the driver to control the lane change involuntarily. Consequently, it is mandatory to make a robust and accurate solution that can detect lane in real-time. Image processing is a common technique for almost all vision-based lane detector algorithms and resembles the same frameworks [9]–[14]. After the revolution of deep learning technology, researchers are trying to make an advanced solution that will be more effective and optimize low computational resources. One of the finest and fruitful ways to create a powerful and flawless advanced solution is a multi-level integration process that combines and integrate with other object detection systems by using multi-modal sensors. This emerging methodology has already been proven and it can be possible to improve the performance of the lane detection system [15]–[17].

2 General Architecture Of Lane Detection

Image processing, detecting, and tracking of a lane position is the main segment of the vision-based technique for lane detection. Among those aspects, the most crucial part is the lane detection process involving extracting feature and model fitting (see Figure 1). The most popular methods of the pre-processing image are to identify the region of interest (ROI), converting grayscale or different color format image, vanishing point detection (VPD) algorithm, noise reduction and blurring, bird's eye view by applying inverse perspective mapping (IPM). ROI is the utmost focal point of the researchers between these methods because it can remarkably amplify the performance of computational efficiency and lane detection accuracy [19],[20]. After completing the pre-processing steps, feature extraction or model fitting technique is applied for detecting the lane or boundary. Hough transformation [10],[21] algorithm is a very effective way of feature extraction but only for the straight lanes. On the other side, the model fitting technique is used for detecting the curve lanes by applying the random sample consensus (RANSAC) [22]. At last, after getting the expected outcome of lane detection, a tracking-based algorithm such as Kalman [22] or Particle [23] filter is used to monitor the lane position.

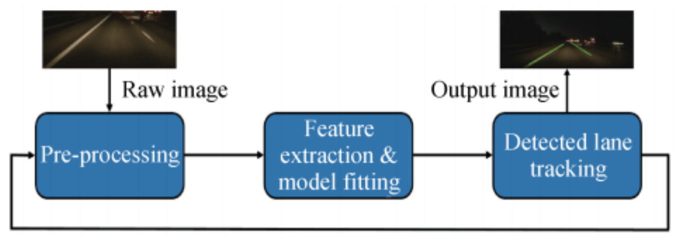

Fig. 1. General architectural design of lane identification system [18]

3 Vision-based Algorithms

By applying the vision-based technique, lane detection is categorized as a feature-based and a model-based method [18].

3.1 Feature-based methods:

The feature-based procedures depend on the colour, texture and edge-based extraction. For example, Gold system states that the edge-based boundary of the lane detection algorithm is applied and then the output image is remapped into a bird's eye view [1]. An adaptive filter method is used to identify and separate the vertical line segments to make a long line. The LOIS system uses a deformable template approach [2]. "[. . .] detection is performed by finding the lane shape parameters that maximize the function for the current image" [11, P.83]. A spatial feature based on the combination of a Hough Transformation algorithm was proposed by Collado that can detect the lane and classify the method for creating the bird-view image [24]. In [25], multiple lanes were calculated by using IPM and a clustered particle filter for tracking based on the lane features. Furthermore, by applying the colour format transformation, the lane can be detected easily but it is not a robust solution. In [26], the FPGA based algorithm for real-time has been proposed. By applying gradient amplitude features and improving the Hough Transformation, the DSP has designed. In LaneRTD algorithm, it applies grayscale conversion, Gaussian Filter to remove incorrect edge detection and Canny edge detector for automatic thresholding. Then identify the region of interest (ROI) and Hough transform is used for detecting straight line segments and separating with the left and right lane group. Finally, the line segments are extrapolated [3].

3.2 Model-based methods:

There are different types of model-based methods are available for lane detection. Among them, spline models were given best result for any kind of curved shape lines. For example, In the Catmull-Rom model, a VPD technique is applied by using a combination with the Hough transform and likelihood method. A multi-resolution is also applied to get an accurate result [27]. The B-snake model can detect lane boundaries and make any form of arbitrary shape by using a control point set. The CHEVP algorithm is applied for giving an initial position [9]. Another model called Parallel-snake has also been proposed. A balloon force is applied from the middle of the road that amplifies the double snake towards the lane boundaries to regain the parallel properties. After that, a Kalman filter is used to optimize parameters. [28]. In the past few years, the RANSAC algorithm has shown better performance to calculate the parameters of a lane model. Borker [22] proposed a model where a linear model and RANSAC algorithm have been used for detection and also a Kalman filter for noise reduction. Moreover, another model [29] is proposed for both the straight and curve line fitting in a lane which is developed by applying a ridge featuring and RANSAC. Further, a hyperbola-pair model with RANSAC was also used for lane fitting [30]. Bounini et al. introduced an algorithm where the line model was fitted by a least-square method that could reduce the computational cost in the simulation environment by identifying a dynamic ROI [31]. Niu et al. proposed a two stages curve fitting method that can detect a lane by applying an upgraded Hough Transform and DBSCAN algorithm [32].

4 Deep Learning-Based Algorithms

From the last decade, deep learning technology is getting more attention from all sectors. Some researchers tried to bring an accurate result compared to a vision-based approach. According to the report, after applying the Convolutional Neural Network (CNN), the accuracy rates up to 90% has improved [33]. This report has been done by applying the CNN model on point clouds data. A gradual-up sampling technique was introduced in this CNN which improved the output accuracy rate and reduced the computational cost. In [15], a solution for lane detection that deep based CNN implicit with the recurrent neural network (RNN) was brought by Li et al. A pre-processed ROI image was fed by CNN. This model has two output. The first one is to get the lane classification discretely. If the classified data gives the lane markers properly, then the second output will be the successive calculation for localization and data orientation. It was also proved that despite the vehicle obstacles, RNN can identify the lane and make a connection. Moreover, In [6], A CNN called "DeepLanes" has been proposed. It can understand the position of the side lane by an end-to-end detection system. Li et al. proposed a solution called "spiking neural network (SNN)" [34] based on the human neuron system. The edge-based image extraction is done by SNN and Hough Transform is used for lane detection. Besides, the "LaneNet" [7] architecture was developed in two stages. One is to classify the edge as pixel-wise and another is only for localization. Recently, Redmon et al. introduced the "PointLaneNet" model which was developed by inspiring YOLO [35] architecture. This model works for end-to-end training and detect the lane in real-time. It predicts the position simultaneously and makes line classification within a network. It also proposed a structural representation of the lane line based on the deep neural network (DNN) [8].

5 Discussion

From the discussion of the above algorithms, model-based methods have acquired a better performance than feature-based ones. Nevertheless, due to the endless iterator of the RANSAC outer boundary, the computational cost is excessively high. Moreover, it is comparatively a complex implementation process.

On the other hand, various types of deep learning-based solutions have improved efficiency and accuracy drastically. Apart from these, heuristic or evolution-based algorithms, such as a multi-agent model, ant colonies, and directional random walking method have also used for lane detection [36]–[38].

The above-mentioned algorithms are more robust and effective than vision-based algorithms. However, the higher computational cost with a large dataset is a big issue for hardware-based memory. Therefore, the parallel system based ACP approach [18] can be an expected solution to the near future [39],[40].

6 Conclusion

In this paper, an overview of the lane detection algorithms for ADAS has been reviewed. The vision-based and deep learning-based algorithms have been discussed and compared according to their performance. Although deep learning technology has brought significant prosperity in this area, yet it is very difficult to say the outcome has been matured. Even, there is still needed to research about decreasing the computational resources. Considering these aspects, the emerging technique of the parallel system based ACP approach is showing the potentiality for future endeavours.

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