A review on deep learning and non deep learning approach for lane detection system

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***Abstract*— Lane detection is one of the essential elements in road safety analysis. With the enhancement of technologies nowadays, the number of road accidents can be reduced by implementing a few preventive actions, one of it is by using a lane detection system. The authors review the recent deep learning and non-deep learning approach for lane detection system.**

Keywords—Deep Learning, Lane detection, Convolutional neural network, recurrent neural network, image processing

I. INTRODUCTION

Lane detection system is one of the ways to prevent unwanted incidents that will happen in the road especially highway. In Malaysia, as stated in [1] the statistic shows an increase of 11% of road incidents happen in 2020. The statistic is taken before the pandemic of Covid-19. A survey[2] from WHO also stated that more than 1.35 million people have died and around 20 to 50 million affected from injuries which lead disability due to their injuries Drivers who lose focus behind the wheel are more prone to collisions on the road. They tend to lose focus and get distracted while driving on the road due to fatigue, carelessness or the change in the driving scenario caused by a number of factors including the change in weather conditions including rainy and foggy weather. lane detection systems are very useful for the latest transportation technologies including the autonomous driving assistance systems (ADAS). In [3], it is reported that the real time driving scene understanding will become the future of the automotive industry. It is also reported that the willingness of both academia and industry to invest in developing the advanced driving scene understanding will make it more realistic to happen. There are many researches have been performed to improve the road experience especially regarding the lane detection. The lane detection yet still needs a lot of improvement to overcome challenges and to make it more convenient to the driver.

Lane detection usually use visual such as image and video to evaluate lane. The common lane detection process includes the pre-processing, feature extraction and lane detection and tracking. Pre-processing process include the process of determining the region of interest (ROI) as [4] stated that ROI important to lessen the detection of false lane and improve the computation efficiency. After raw image go through pre-processing step, the extraction of lane feature is done by various method such as deep learning and HT algorithm. There are many approaches can be used to extract and detect lane. The last step of the lane detection algorithm is tracking. Tracking is basically the algorithm predict the lane continuously.

In [5], it had been reported that the biggest lane detection obstacle is the difference in illumination and roads conditions. Thus, it is really important to come out with the lane detection system that can work in all kind of weather.

II. NON DEEP LEARNING APPROACH IN LANE DETECTION

A. Architecture

There are many methods used to detect lane. These methods have its advantage and disadvantage itself according to situation faced by the vehicles. The most important thing that need to be satisfy is the real-time situation and the robustness of the algorithm while facing unfavourable condition of the road which make it hard to detect the image of the lane. HSV colour space and lane shape feature is used in [6] to cater issues regarding various lane marking on the road. In [6], it is proposed that the algorithm include Progressive probabilistic Hough transform to decrease the processing time of the images. However, the suggested method cannot work well if the lane marker is not in good condition. It also less reliable when there is foggy weather or rainy weather happen. This is because the camera will failed detect HSV colour space and will reduce the performance of lane detection system.

In [7], the contour and feature of the lane is used to design cost- effective lane detection where the system is affordable for all. According to [7] , the designed algorithm used both contour and feature based tracking due to their high reliability when it comes to accuracy of the results. Feature based tracking make use of the uniqueness of the object to detect it. Tracking based on contour analysed the images for a certain colour.

In [8], algorithm designed is suitable on the smooth road. It also can function in the situation where the intensity of light is high. According to [8], the proposed system will detect lane boundary using lines using vision-based technologies. The Gradient and Hue saturation Lightness (HLS) thresholding is applied for detecting the lane. HSL will handle the situation when the road is to light or to bright

In [9], the similarity of PF and pixel of line boundaries used to maintain the robustness of lane localization on

various condition. According to [9], the algorithm will include the motion compensation is to overcome the impreciseness of camera due to sudden movement of the car that also improve the estimation of angle and location of the vehicle.

In [10], severe shadow that affect the performance of lane detection is cater by using Fuzzy Interference System (FIS). However, there is a limitation in this system where it difficult to get desired performance in the presence of complex traffic.

As the biggest problem of lane detection is it robustness under the different weather and road condition, [5] suggested to implied image classification and hybrid isomeric operator as main method in lane detection.

In [11], it has stated that optimizing image processing approach is used as algorithm as well improved Hough transform. In [12], the interest is more into designing cost effective image sensor lane detection. The algorithm that proposed put focus on controlling and detecting the lane. The result portrays some lane detection error and cross-track error after simulation are been done [12]. However, the error is still in the acceptable range.

By addressing the issues of robustness, [13]proposed to extract the feature of lane by two level. In [13], it is reported that the algorithm in the proposed lane utilises the modified Hough Transform to cater the small lane segment. According to [13], the proposed algorithm meets the requirement and manage to solve the robustness issue in term of inconsistence lightning and background clutter.

In [14], it has been reported that the algorithm will be included 3 feature that combine in one algorithm which is adaptive threshold, random sample consensus and lane classification algorithm. The algorithm with the aims to reduce the false positive rate error for the future research [14].

III. Deep learning approach in lane detection

A. Architecture

In [3], it has reported that the algorithm in the proposed lane detection will combine deep recurrent neural network (DRNN) and deep convolutional neural network (DCNN) by using a lot of frames sample of driving scenes. According to [3], RCNN is very useful in the lane detection system as it has ability to capture every information and save it through time. It is very good to predict the outcome as accurate as possible.

According to [15], large data set of highway been collected and algorithm using neural network is applied to detect lane. In [15], it has been reported that the algorithm is design by implementing the CNN to recognize the feature of the lane while considering real time parameter by running the required frame rate. According to [15], the used of camera, Lidar, Radar and GPS is utilized efficiently.

To cater the unfavourable condition such as sunlight's reflection or strong shadow , [15] designed the algorithm that utilize CNN to sense the 6 coefficients for both modelled right and left lane . Algorithm also tested in the high curvature lane such as at hill roads and manage to meet the expectation by manage to stay at the lane despite the condition of the test lane is unfavourable.

In [16],it has been reported that the algorithm proposed will include CNN for detecting the images of the lane. Based on[16], the use of extreme learning machine (ELM) in the CNN algorithm will produce accurate results while minimize the training data.

The difficulty to detect the small object by the Faster R-CNN although the method is promising in term of accuracy and time execution as discussed in [17].In [17], it is reported that modified Faster R-CNN algorithm that can solve the issue. The results show that proposed algorithm manage to increase the accuracy of the lane while being fast in the execution time.

In [18], the suggested algorithm designed can detect the lane in various road condition whether it structured or not The steps shown in [18] is :

- Keep only lane images while removing other images
- Extract the lane feature using convolutional auto encoder (CAE) method
- Fit the lane using hyperbolic model
- Tack the lane using particle filter

The algorithm is tested by simulation and the accuracy of the algorithm is above 90% for structured and unstructured roads.

According to [19], the ways the visual sequences distributed is important in the application that need the algorithm to understand the scene such as lane detection. In [19], the algorithm which is multi tasked CNN and RCNN is designed. Multi task CNN provide the information to model the lane while RNN will detect the lane boundaries without prior knowledge[19].

According to [20], the algorithms designed improve the processing time of the lane detection 2.7 times faster than CNN. The algorithm that proposed by [20] used visual deep learning named as space convolutional neural network (SCNN). In [20], vision, LiDAR and GPS sensor used to detect lane . Apart from that ,[20] presented sensor integration method named sensor-weight integration field (SWIF). The SWIF method will simplify the integration of data. SWIF will utilize information from LiDAR and GPS in term of obstacle and waypoint respectively[20].

In [21], the algorithm designed will solve issue of absent marking , shadow and dazzle light. The reason of this issue is [21]:

- The size of empirical receptive filed is small.
- Channel DNN not seen as importance feature.

According to [21],it is reported that the proposed algorithm to use attention module that put self-attention and channel together which is called (AMSC). In [21],AMSC algorithm produce by using parallel trainable coefficient.

According to [22], it is reported that comparison of method CNN to detect lane on the road with the method that proposed which is named robust DCNN is made. The method that the [22] compare is Spatial Temporal Method (STM), segmentation approach, structural analysis and robust DCNN method. The result of the experiment shown the proposed method has high accuracy under unfriendly condition. However, the algorithm failed to detect the lane if

the camera is unstable[22]. This algorithm cannot work well if the lane is too much worn out[22].

TABLE I
Summary of non-deep learning approach

Paper	Pre-processing	Lane detection	Tracking	Integration	Comment	Gap
[6]	HSV colour space and lane shape feature	PPH transform	none	Camera	Not complex method and can achieve less amount of processing time	less reliable when there is foggy weather or rainy weather happen
[7]	ROI	Hough transform	none	Camera	Cost effective image sensor	Processing speed unable to support system when vehicle is very fast
[8]	Noise removal, Cropped image, Thresholding	Perspective transform, Sliding window search	none	camera	Efficiently detect lane on smooth road	less reliable when there is foggy weather or rainy weather happen
[9]	Weight ROI	likelihood computation of line boundaries	PF	camera	Able to detect lane on various condition road	Not tested in unfriendly weather condition
[10]	Vanishing point detection, ROI	LSD and Canny Line detector	None	Camera	Efficient on severe shadow condition	Need to define fuzzy function and rule
[5]	ROI, Inverse perspective method	Sobel-Canny hybrid algorithm	None	Camera	Efficient for all weather condition	Can be improve by using deep learning algorithm RNN
[11]	Grey level conversion, ROI	Improved Hough Transform, Sobel edge detector	None	Camera	Able to detect lane on hilly terrain	Not tested in unfriendly weather condition
[12]	ROI, Inverse perspective mapping	Edge detection, RANSAC	none	Dashcam	Affordable cost	Unable to work well on complicated condition
[13]	ROI	Improved HT, Density based curve fitting	none	camera	Efficient for detecting lane	Cannot generate accurate result for large curvature lane
[14]	Averaging Image, IPM, ROI	Edge detection, Feedback RANSAC	Kalman Filter	Camera	Detect Multi lane road	Not tested in unfriendly weather condition

TABLE II
Summary of non-deep learning approach

Paper	Pre-processing	Lane detection	Tracking	Integration	Comment	Gap / recommendation
[3]	Cropped and resized	CNN, RNN	none	Camera	RNN can capture sequential spatial lane throughout time in the video and act as short term memory	Not tested in unfriendly weather condition
[23]	ROI, IPM	CNN	Sliding window detector	Camera	The accuracy is high	Not tested in unfriendly weather condition
[15]	ROI	Modified CNN	none	camera	Can perform well on high curvature, shallow puddle, sunlight reflection, and self-shadow condition	Not tested in unfriendly weather condition
[16]	Filtering and edge detection	ELCNN or RANSAC	-	camera	Less training time	Not tested in unfriendly weather condition
[17]	ROI	Faster R-CNN	-	Camera	Can detect small object	Not tested in challenging condition
[18]	Lane boundary extraction	CNN, CAE, Hyperbolic model fitting	Particle Filter	Camera	Suitable for detecting structured or unstructured road	Only in single lane road
[19]	ROI	CNN, RNN	None	Camera	RNN can capture sequential spatial lane throughout time in the video and act as short term memory	Not tested in unfriendly weather condition
[20]	ROI, Distance data, Absolute location	SSCN, SWIF	None	LiDAR, GPS sensor, camera	Efficient for urban road	Not tested in unfriendly weather condition
[21]	ROI	AMSC, CNN	none	Camera	Work well in both shadow and bright condition	Not tested in unfriendly weather condition
[22]	Grayscale conversion, Gaussian filter, ROI, IPM	CNN	none	camera	Efficient for detecting lane with high accuracy for all weather	Cannot function well if camera unstable, bumpy situation and when lane is faded
[24]	Gradient information	CNN, RNN	none	Camera	RNN can capture sequential spatial lane throughout time in the video and act as short term memory	Not tested in unfriendly weather condition

IV. Conclusion

In this report, the lane detection system of non-deep learning approach and deep learning approach are reviewed. The general process of lane detection from pre-processed, extraction of feature and tracking and reviewed. Most of lane detection system use camera as integration due to its reliability and cost effectiveness. Although lane detection system has been researched for long time, there are still many gap and leakage in the system. With the advance of technologies nowadays the lane detection system seems to be very promising to explore and developed as key to road safety analysis. There is no doubt that the system will benefit society as it to be implemented on ADAS and automotive industry.

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