

Road Lane Tracking Based on Monocular Vision

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Abstract

Lane tracking and detection is a complex problem due to the versatility of road conditions in which the road stream of images is analyzed. In this paper, an algorithm was developed to obtain a robust real-time lane tracking under a sudden appearance of obstacles such as vehicles and shadows. The method starts with applying Gaussian filter to grey scale images. Then, ROI is defined by finding the lowest mean of all rows in the image. Canny edge detector followed by Hough Transform are applied to the ROI to acquire lines. The information of lines in a sequence of frames are stored to predict the lane position. This method was tested on 1700 frames in different situations and proved its robustness.

Keywords— lane detection, Hough Transform, canny edge detection

I. INTRODUCTION

Lane detection systems that are used for driver assistance to produce an active guidance in different driving situations, hence, they are gradually integrated into vehicles to increase their safety. Moreover, these systems are growing more and more in their level of sophistication to realize full autonomy driving in the coming decades. The development of these systems stands on two main fields which are road and lane detection and obstacle detection under variance conditions.

This paper is dedicated to undertake lane detection where color and texture of the lane markings provide main indications for driving. The importance of these markings is in the information that assists driving by supplying the details of the road such as, how many lanes are present, are they straight or curved, and so forth. The problem difficulty arises from the variations present in, first, type of markings and their color (solid lines, dashed lined, circular reflectors and their color). Second, the type of road the car is travelling on such as off-road, highways, city streets, sub-urban and vehicles that block the lanes markings. Third, time of driving whether its day or night. And forth, articulates that can affect the appearance of the markings such as,

shadows and water reflection and blurry image due to rain. Therefore, lane detection process is challenging and requires robust algorithms and techniques that can deal these various situations aforementioned. Since all of the conditions discussed in this paper are uncontrollable, many methods were developed to tackle them based on the type of sensor (radar, camera, GPS and laser scanners) used to obtain the information of the road. For instance, visual sensor (cameras) capture number of images in short time which are manipulated to extract the required information which are used to perform the lane detection process. On the other hand, GPS sensor has a more robust performance in foggy weather which cameras cannot afford [5]. In this project we are more interested in working with processing visual input from a camera installed in center line of a car to provide the images which are going to be used in the lane detection practice.

II. PROBLEM STATEMENT

detailed information of the latest lane detection methods were presented in [7] which shows a progress in various conditions of lane types, nonetheless, the constant need of high reliability lane tracking and detection systems in circumstances where shadows and curves and other artifacts are still affecting the tracking is still calling for more research to be done in this area to fulfill this need. Therefore, a study has to be conducted on how to improve lane tracking in the presences of shadows based on the latest state-of-art techniques.

III. LITRATURE REVIEW

When lane detection systems were developed, they were constructed to increase the safety of driving on road since the most significant reason of accidents is drivers being misled by road lanes [2]. Therefore, many vision based lane detection algorithms were created to deal with different sort of problems while detecting lanes, for example, occurrence of shadows, whether, color of lane, type of lane (solid line, dashed, or circular reflectors) and change in lighting [10], [7]. One approach described in [2] paper was to use a pair of hyperbolas fitted to the edges of a lane where those lanes are extracted by Hough Transform and the edges were detected via Canny edge detector. This approach can be used at painted and unpainted roads also at curved and straight roads with accuracies of above 80% in smooth or congested roads. Unfortunately, the canny Hough estimation of vanishing points method is sensitive to threshold selection and is also sensitive to illumination and shadows present in the road.

Locally adaptive soft-voting (LASV) is one novel algorithm based on road vanishing point estimation. This vanishing point is then used to detect two dominant edges to segment the road. Gabor filter is then used to estimate texture orientation which is brought to a better accuracy by taking the confidence in the orientation then it is normalized. At some situations like bright sky or unstructured roads, Gabor filter results in poor magnitude response which is then enhanced by applying soft-voting (Figure 1) scheme. Through the process where only pixels of local voting whose

confidence is high are used. This procedure leads to a greater accuracy and lessens the computational complexity [9].

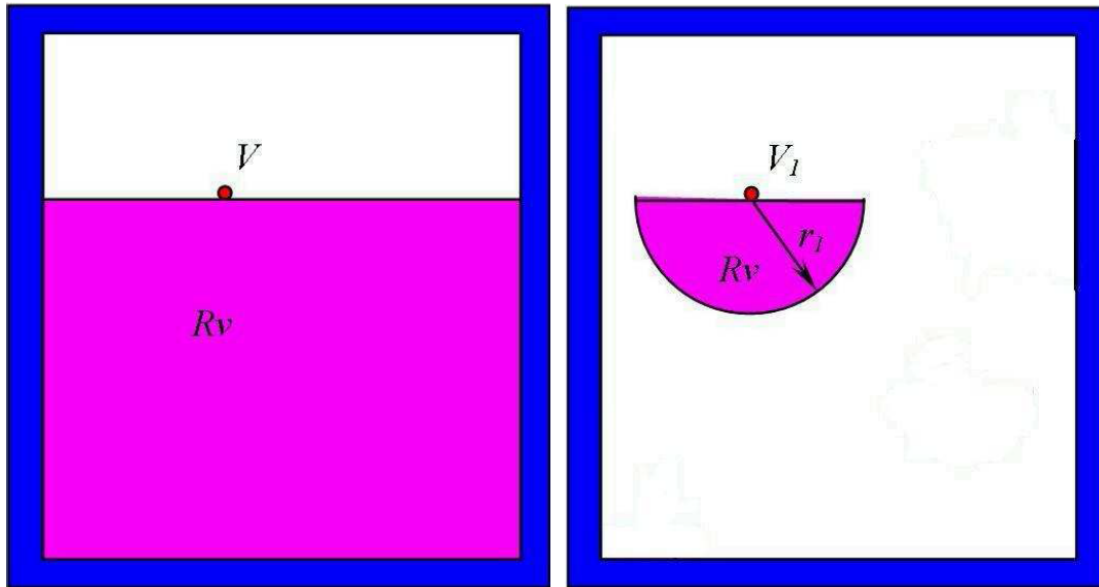


Figure 2: the blue boarder pixels are eliminated from voting. Also pixels out of the threshold radius of confidence are excluded from voting

In the method of [2] the accuracy of lane detection was affected by vehicles congestion on the road. The lane markings are blocked by the moving vehicles on the road which cause outliers in the in the lane detection process. To eliminate such an error [4] has proposed (Figure 3) that lane markings in the case of vehicle obstacles can be extracted using colored images in such a way that it is not affected by change in lighting or similarity in color between the car and the lane color. For cars that have the same color as the markings, information of shape, size, and movement can differentiate a lane from a car by using a moving vehicle elimination procedure followed by lane recognition procedure. A similar method was developed by [13] which estimates the motion parameters from two successive images. The road plane parameters are then estimated by extracting feature points in the road then the 3d positions are calculated by triangulation and refined by least median of squares (LMedS). The road region is then found from the warped previous image and the current image differences calculation. These methods face a great deal of error in textureless images.

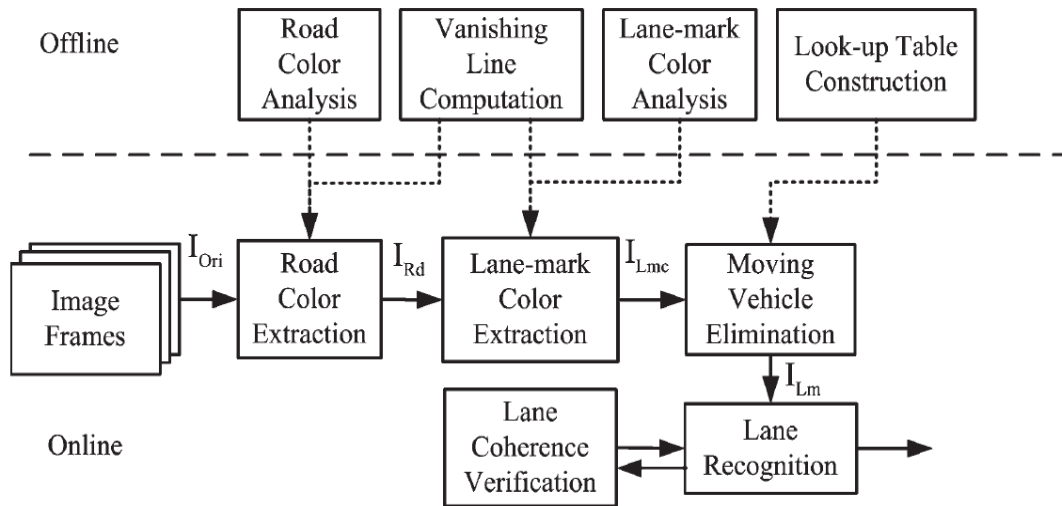


Figure 4: overview of the system

Another artifact is Shadows presences in videos can be suppressed by the analysis of images in HSV color space combined and other colorspace. This method of shadow detection improves object segmentation and object feature computations that are essential for vision based control systems. SAKBOT system was developed by Cucchiara, Grana, Piccardi, Prati, & Sirotti. (2001) proves that choosing the right colorspace (such as LAB, HSL and YCbCr...etc) for analysis is crucial to perform image segmentation in the presence of shadows. Furthermore, Katramados, Crumpler, & Breckon. (2009) in their paper used colorspace fusion with edge detecting filter (Soble filter) to eliminate shadow and water artifacts. They combined channels of (HSL, LAB and YCbCr) to derive four illumination invariant features for image segmentation, where shadows are present, using temporal memory model that resulted in shadow-free image. [1] Proposed a different method of image segmentation that is based on “growing region” (Figure 5) where a number of seeds are in a fixed position of the imaged assumingly “the road”. this method is called advanced driver assistant system “ADAS” and capable of preserving road limits and curves. These color space transformation methods were used to suppress the presence of shadows in images since the main source of sharp edges produced in roads is due to shadows. It is noticed that all these techniques relies on the fact that hue information still exist in the shadowed areas.

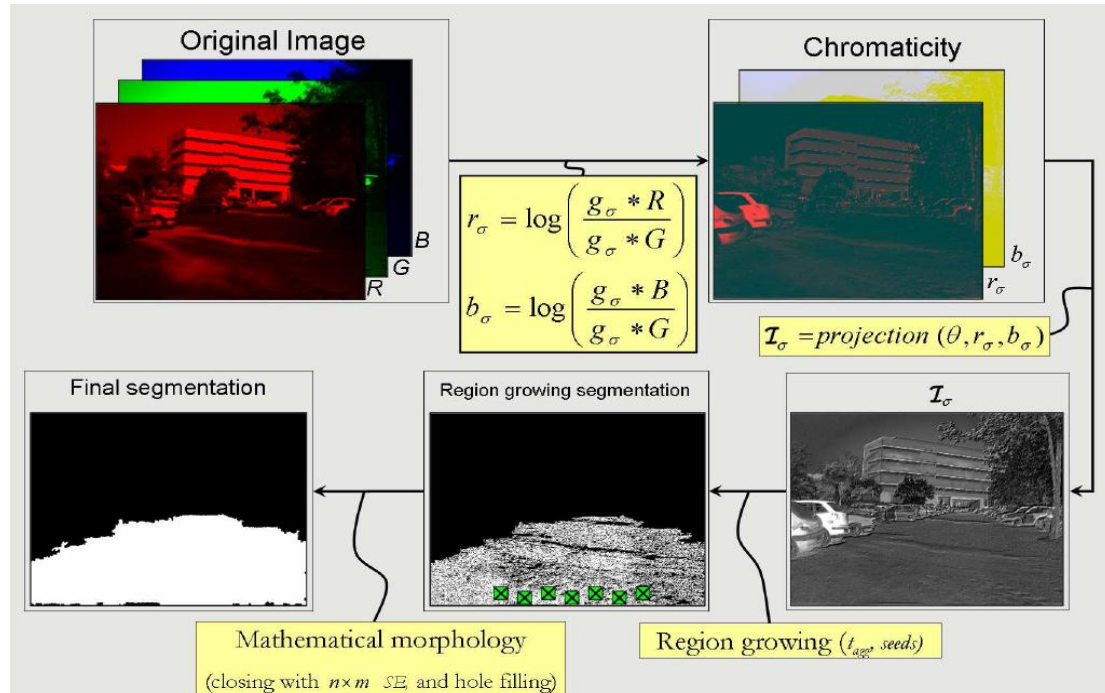


Figure 6: growing region segmentation method with the seven seeds shown.

To reduce the number of calculations required, Region of interest on the image is a method that discards unwanted image parts by the use of features extraction on the ROI. [14] have performed image segmentation using minimum spanning tree where road area and non road area can be extracted using histograms of RGB colorspace assuming the biggest segment is the road segment which is also presumed to be the lower part of the image (the ROI). After cutting the upper part of the image, canny edge detector and Hough transform are applied to the road segment using some threshold. Vanishing point is then detected using voting procedure for the pixels that lay on the vanishing belt. The result obtained was good enough to perform real-time processing in autonomous vehicle vision system in presences of shadows and other unwanted artifacts. Another ROI segmentation method was used in [12] work where multiple ROIs were defined and checked gradually for lane detection. In this method, there are 6 horizontal ROIs lay in the lower part of the image, which is with high probability the road, and each of these ROIs is then goes through marking detection process gradually starting from the lowest part of the image. Each ROI section parameters can give basic information of the road whether left lane detected or right lane or both and each scenario is then related to logic where it estimates the lane shape from the image.

Extraction of features is applicable once image parts are determined. These features are needed to help improve estimation of both tasks road and lane detection. Different features are selected and examined based on set of assumptions that are taken by the machine trainer. In the following content are some elaborations on the

features that were used to do the lane and road estimation. Speaking of distinction features, shape of the lane is subject to change, from dashed line through continues lines. Moreover, the color may alter, white, yellow, cyan or orange. To reduce the effect of such of changes in color and shape of road markings, Steerable filters provide high performance in detecting bots dots, road marking as well as painted line road markings. This method is preferable due to its robustness to shadows and light changes [11]. It has remarkable properties that increase robustness for lane detection in variant lighting changes. Convolution of the filter with an image is separated into two components, X and Y, to speed up processing of the image. In addition, in order to see the response at a specific angle or to examine the response of all angles at one time, finite number of angles is needed to be identified for a specific steerable filter [10].

IV. LANE DETECTION AND TRACKING

In this section, the lane detection and tracking is going to be explained by using gray scale method and edge detection and will examine the results by using this method. The Hough based detection includes the four parts as shown in the gray block diagram Figure 7.

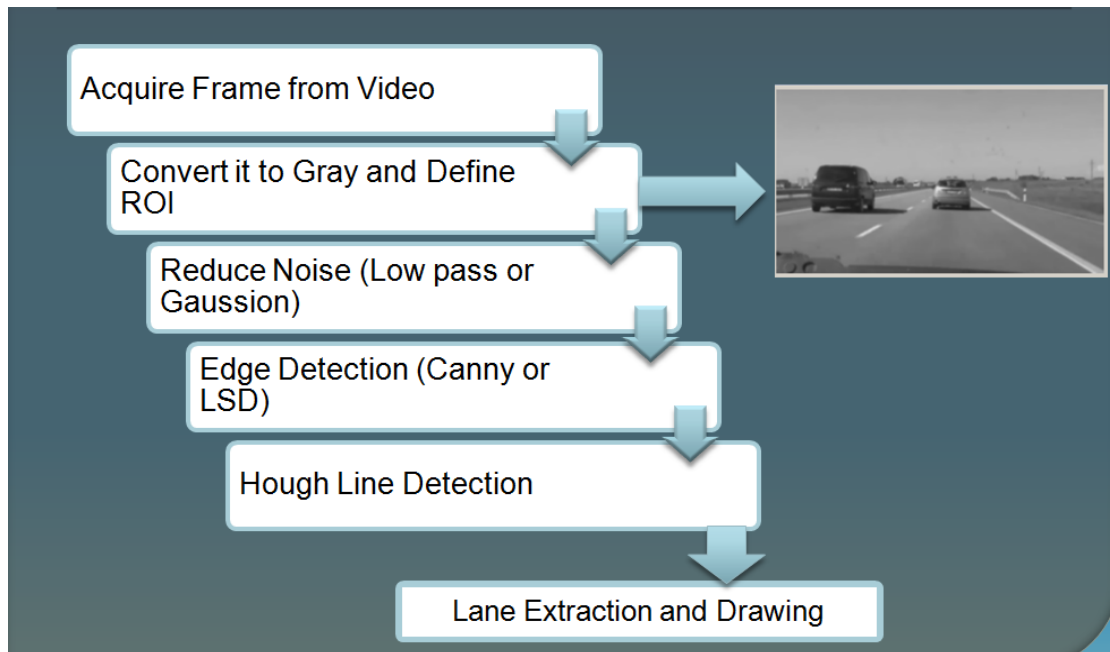


Figure 8: An overview of the overall system algorithm

A. *Defining and Conversion of ROI into Gray Scale*

In this step, the images that are captured are converted into gray scale images to reduce the number of computations so that it meets real-time processing requirements.

Moreover, gray scale images are less sensitive to scene conditions which boost the robustness of the algorithm. The camera is positioned in such a way that the vanishing point of the road should be placed on top of the ROI, therefore, the bottom part of the image contains all the information that need to be processed. on the other hand, the upper part of the image posses unwanted information so it's cropped (Figure 9). As a result, the algorithm becomes faster and consumes less memory while processing.



Figure 10: The result of row lowest mean ROI detection.

The method followed to specify which part of the image is considered as upper and lower is called row lowest mean. row lowest mean calculates the lowest mean of all pixel rows in various scenes which is suggested by [15] in their paper.

B. Canny edge detection

By applying lowest row mean, ROI of the image is found. Now, a gray scale cropped image is obtained where only the road part of the image exists. The objective of this procedure is to collect all the lines present in the ROI including the lane lines. To achieve that an edge detector is applied which is in this case Canny edge detector. Canny edge detector takes the gradient vector of an intensity image since lane boundaries have high contrast in the image and this feature yields high values of gradient vector. Many edge detection methods are based on the same basics but Canny edge detector offers better results due to its double thresholding and hysteresis threshold properties. Hysteresis threshold and double threshold suppresses pixels that are not interpret an edge, therefore, it produces very good edges that are close to the true ones. One drawback to canny edge detector is that it's very sensitive to noise and

to solve this problem Gaussian filter is applied to the gray image before applying canny filter to refine the results.

C. *Extracting line segments*

In order to attain straight lines of an image, Hough line transform is utilized. The input to Hough line transform is the output image of canny edge detector where all the lines in the image produced by the canny edge detector is realized as a point in Hough space and the reverse is true.

A data set of lines is available including horizontal lines. To get rid of irrelevant line segments we sort the lines based on their angle. The ROI of the image is split into two sides: the right side and the left side. The line segments angles in the right side has to lie between 25~70 and between -25~ -70 for the left side. Therefore, the rest of the lines that are out of these two ranges are excluded. The angle of the line is calculated using the following equation:

Each line segment s_i , ($i = 1, \dots, k$) is defined as

$$s_i = \{x_i^1, y_i^1, x_i^2, y_i^2, \theta_i\}, \quad (i = 1, \dots, k).$$

$$\theta_i = \frac{180}{\pi} \times \arctan\left(\frac{y_i^2 - y_i^1}{x_i^2 - x_i^1}\right), \quad (i = 1, \dots, k).$$

Since the line segments are now represented in terms of angle range, another parameter is needed to full describe the line segment and this parameter is taken to be Y-axis intercept or C constant from the line equation. C is calculated from the following equation:

$$C = y - x \left(\frac{y_i^2 - y_i^1}{x_i^2 - x_i^1}\right), \quad (i = 1, \dots, k).$$

The information of each line segment that wasn't excluded in the process is then stored for the last step.

D. *Clustering and lane drawing*

Based on orientation and position information, a K-means cluster was constructed to find the local maxima of segments. K-means cluster was chosen for its ease of interpretation, simplicity of implementation and quick convergence. Moreover, even if the number of instances is high, this cluster still offers a computationally acceptable performance. The clustering process is applied for both left side and right side segments. The output of this is three sets of line segments where one of these sets

owns the majority of lines are assumed that it belongs to the lane. A median filter is then applied to that set to extract the line that lies in the middle of the lane; hence, all other outlier lines are removed. Finally, the candidate line is drawn as shown in figure.

One advantage of this method of lane tracking is that the algorithm stores the data of a number of previous frames, then, it predicts the position of the lane whenever the needed data are missing. Situations like covered lane markings by vehicles, faded lane markings or even the presences of shadows which adds to its robustness. Figure 11 shows a summary of the algorithm on one frame.

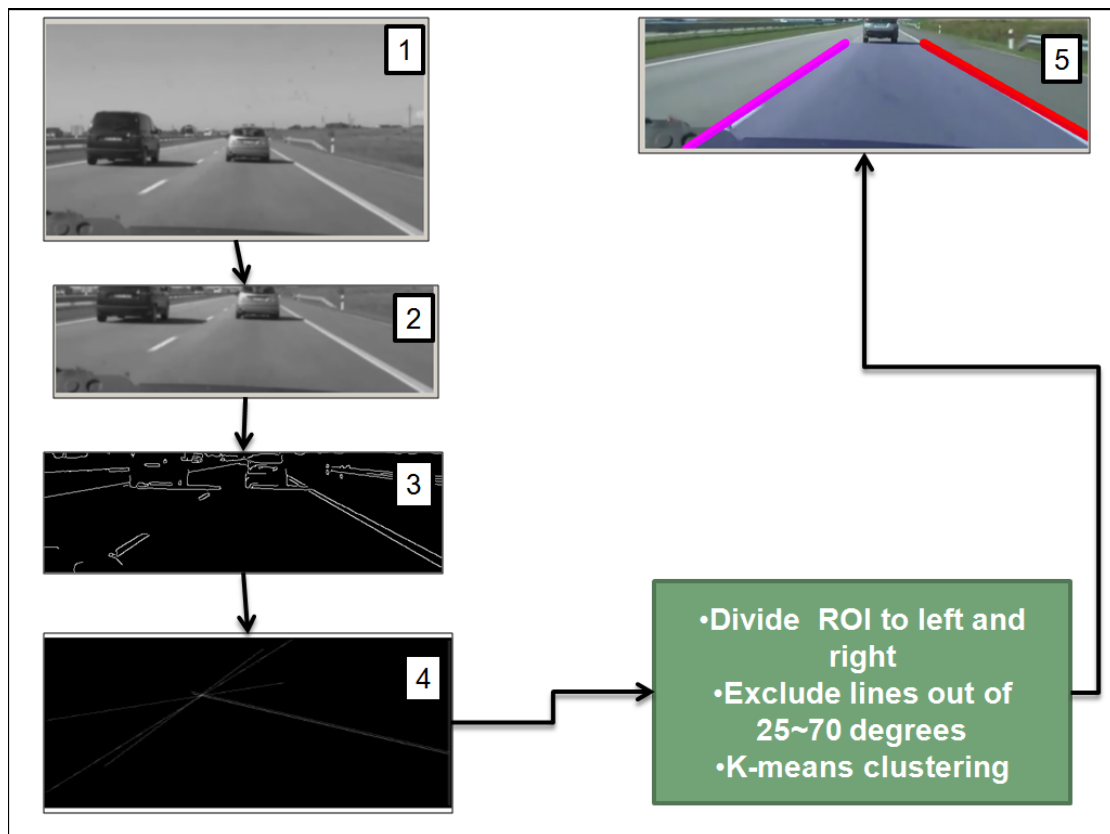


Figure 12:flow of image manipulation (1) RGB image converted to gray image (2) based on row lowest mean (3) Canny image (4) hough transform of the canny image (5) final result.

V. RESULTS

The proposed algorithm was coded in visual studio 2010 c# with EMGU libraries and experimented on data set from Nuigalway Car Laboratory. The experiments were conducted on a notebook of intel i3 2. 13GHz with available RAM 2/4 GB memory. The data set were qualitatively evaluated based on the proposed algorithm since there is no common ground of evaluation is available.

Below are images taken from the data set tested that demonstrate the system is working in different situations. The total number of tested images is 1700 image. 150 frames were tested on road sections where discrete shadows are present and the system has showed 96% accuracy. The rest of the results are shown in Table 1. However, there are some situations where the system was not able to detect the lane such as sharp curves and heavy rain. Figure 13 & 8 show some tested frames in various situations.

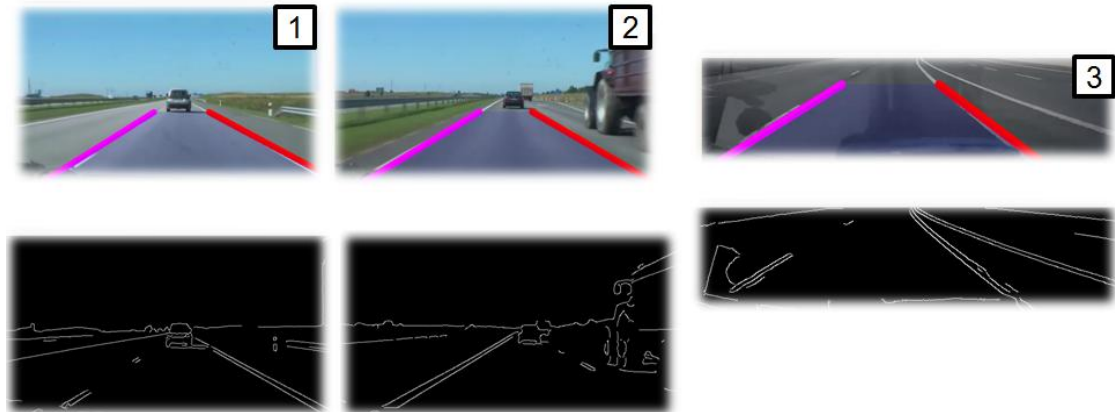


Figure 14: some results of the testing data set (1) straight highway with no obstacle (2) straight highway with obstacle (3) curved highway.

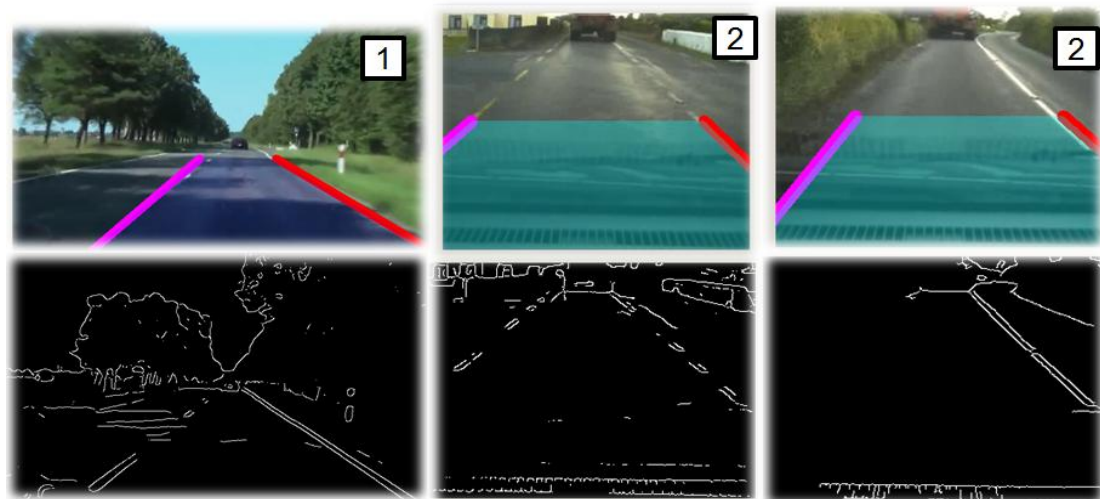


Figure 15: (1) partially shaded road (2) faded away line markings (3) poor lane markings.

VI. CONCLUSION

The evaluation and comparison of different methods of lane detection is vital to obtain the performance benchmark to recognize the limitations of each algorithm. However, in lane detection texts, assessing the algorithms outcomes is rather complicated due to the fact that there is no agreed upon criteria to standardize the

testing of algorithms. The vast majority of papers provide only a qualitative feedback of their work (good, bad, successful...etc), on the other hand, there is no basis in evaluation of the algorithms used since the performance metrics and the data sets are different from system to another; therefore, no quantification of the outcomes is possible. The availability of data with well defined assessing criteria can provide an outstanding boost to machine learning, lane and road detection research, hence, algorithm improvement.

The main focus of lane and road detection is to realize a fully autonomous vehicle which is still in its early stages. The main challenges of the development of fully autonomous vehicles are: a high reliability lane detection system and to be able to analyze more information of the road. For example, in the literature review, the majority of systems dealt with detection of roads that has one lane or two lanes at most. However, understanding multiple lanes detection problem and being able to identify merges and splits of lanes is required to accomplish advanced fully autonomous vehicles. In order to tackle the second challenge a mixture of algorithms with different assumptions has to be utilized. These algorithms should operate in parallel to attain closed loop control attributes. Another suggestion is to use these algorithms serially starting with less complex ones and applying the more complicated algorithms when needed. Apart from developing more reliable algorithms, utilizing the powers of machine learning can achieve more accurate results and reduce the amount of work required. Information can be gathered of the road by taking the sensor feedback under supervision where the data has to be interpreted by a classifier which was used by [3] as a part of the DAPRA challenge.

VII. RECOMENNDATIONS

To achieve better results, we can use line segment detector (LSD) instead of using canny edge detector along with Hough Transform. The advantage of LSD is that it can perform better than canny edge detector in various situations, moreover, it reduces the time needed for performing the computations, and thus, it's a more robust method of line extraction. The recommended method of line extraction couldn't be implemented in the proposed algorithm.

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