Real Time Lane Detection for Autonomous Vehicles

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Abstract

An increasing safety and reducing road accidents, thereby saving lives are one of great interest in the context of Advanced Driver Assistance Systems. Apparently, among the complex and challenging tasks of future road vehicles is road lane detection or road boundaries detection. It is based on lane detection (which includes the localization of the road, the determination of the relative position between vehicle and road, and the analysis of the vehicle's heading direction). One of the principal approaches to detect road boundaries and lanes using vision system on the vehicle. However, lane detection is a difficult problem because of the varying road conditions that one can encounter while driving. In this paper, a vision-based lane detection approach capable of reaching real time operation with robustness to lighting change and shadows is presented. The system acquires the front view using a camera mounted on the vehicle then applying few processes in order to detect the lanes. Using a pair of hyperbolas which are fitting to the edges of the lane, those lanes are extracted using Hough transform. The proposed lane detection system can be applied on both painted and unpainted road as well as curved and straight road in different weather conditions. This approach was tested and the experimental results show that the proposed scheme was robust and fast enough for real time requirements. Eventually, a critical overview of the methods were discussed, their potential for future deployment were assist.

Keywords
Driver Assistance System, Lane detection, computer vision, intelligent vehicles

I. INTRODUCTION

In intelligent transportation systems, intelligent vehicle cooperate with smart infrastructure to achieve a safer environment and batter traffic conditions.

Although, a more convincing reason to build intelligent vehicles is to improve the safety conditions by the entire or partial automation of driving tasks. Among these tasks, the road detection took an important role in driving assistance systems that provides information such as lane structure and vehicle position relative to the lane. However, the most compelling reason for adding autonomous capability to vehicles that to ensure the safety requirement. Vehicle crashes remain the leading cause of accident death and injuries in Malaysia and Asian countries claiming tens of thousands of lives and injuring millions of people each year. Most of these transportation deaths and injuries occur on the nation's highways. The United Nations has ranked Malaysia **30th** among countries with the **highest** number of fatal road accidents, registering an average of 4.5 deaths per 10,000 registered vehicles [1]. Therefore, a system that provides a means of warning the driver to the danger has the potential to save a considerable number of lives. One of the main technology involves in these takes computer vision which become a powerful tool for sensing the environment and has been widely used in many application by the intelligent transportation systems (ITS) In many proposed systems[2], the lane detection consists of the localization of specific primitives such as the road markings of the surface of painted roads. This restriction simplifies the process of detection, nevertheless, two situations can disturb the process: the presence of other vehicles on the same lane occluded partially the road markings ahead of the vehicle are the presence of shadows caused by trees, buildings etc. This paper presents vision- based approach capable of reaching a real time performance in detection and tracking of structured road boundaries (painted or unpainted lane markings) with slight curvature, which is robust enough in presence of shadow conditions. Road boundaries are detected by fitting a parallel hyperbola pairs to the edges of the

lane after applying the edge detection and Hough transform. The vehicle is supposed to move on a flat and straight road or with slow curvature.

II. RELATED WORK

Safety is the main objective of all the road lane detection systems due to the reason is that most of the vehicle road accident happens because of the driver miss leading of the vehicle path. Therefore, currently many different vision-based road detection algorithms have been developed to avoid vehicle crash on the road. Among these algorithms the GOLD system developed by Broggi, it uses an edge-based lane boundary detection algorithm [3]. The acquired image is remapped in a new image representing a bird's eye view of the road where the lane markings are nearly vertical bright lines on a darker background. Specific adaptive filtering is used to extract quasi vertical bright lines that concatenated into specific larger segments. Kreucher C. propose in [4] the LOIS algorithm as a deformable template approach. A parametric family of shapes describes the set of all possible ways that the lane edges could appear in the image. A function is defined whose value is proportional to how well a particular set of lane shape parameters matches the pixel data in a specified image. Lane detection is performed by finding the lane shape that maximizes the function for the current image. The Carnegie Mellon University proposes the RALPH system, used to control the lateral position of an autonomous vehicle [5]. It uses a matching technique that adaptively adjusts and aligns a template to the averaged scan line intensity profile in order to determine the lane's curvature and lateral offsets. The same university developed another system called AURORA which tracks the lane markers present on structured road using a color camera mounted on the side of a car pointed downwards toward the road [6]. A single scan line is applied in each image to detect the lane markers. An algorithm destined to painted or unpainted road is described in [7]. Some color cues were used to conduct image segmentation and remove the shadow. Assuming that the lanes are normally long with smooth curves then theirs boundaries can be detected using Hough transformation applied to the edge image. A temporal correlation assumed between successive images is used in the following phase. Three-feature based automatic lane detection algorithm (TFALDA) [8] is primarily intended for automatic extraction of the lane boundaries without manual initialization or a priori information under different road environments and real-time processing. It is based upon similarity match in a three dimensional (3-D) space spanned by the three features of a lane boundary starting position

direction (or orientation), and its gray-level intensity features comprising a lane vector are obtained via simple image processing. LANA algorithm [9] was based on novel set of frequency domain features that captures relevant information concerning the magnitude and orientation of spatial edges extracted by 8*8(DCT). The hyperbola-pair model is deformable template, and is developed on the base of Kluge's work [10]. The origin model is suitable for single-side lane markings firstly, but in the work by Wang and Chen [11]. It was emphasized that some parameters of the model was the same, if the lanes were parallel on the same road. The considerable feature is also used in our algorithms, to form an extended equation to fit the road shape.

III. ENVIRONMANTAL VARIABILTY

In addition to the intended application of the vision lane detection system, it is important to evaluate the type of conditions that are expected to be countered. Road markings can vary greatly not only between regions, but also over nearby stretches of road. Roads can be marked by well-defined solid lines, segmented lines, circular reflectors, physical barriers, or even nothing at all. The road surface can be comprised of light or dark pavements or combinations. An example of the variety of road conditions can be seen in Fig. 1, some roads shows a relatively simple scene with both solid line and dashed line lane markings. Lane position in this scene can be considered relatively easy because of the clearly defined markings and uniform road texture. But in other complex scene in which the road surface varies and markings consist of circular reflectors as well as solid lines the lane detection will not be an easy task. Furthermore, shadowing obscuring road markings makes the edge detection phase more

Figure1. Different road scene

complex. Along with the various types of markings and shadowing, weather conditions, and time of day can have a great impact on the visibility of the road surface as shown in Figure 1. All these circumstances must be efficiently handled in order to achieve an accurate vision system.
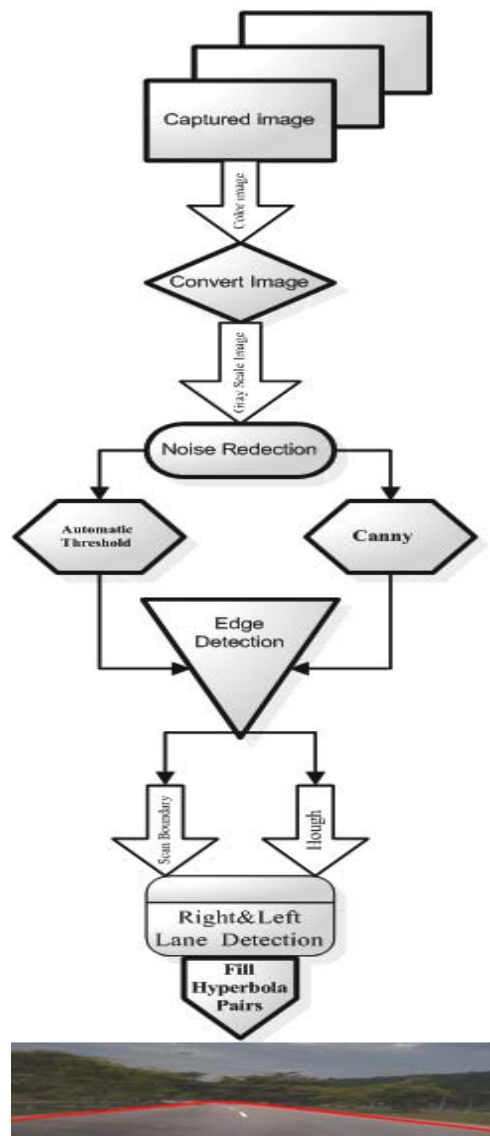
IV. OVER VIEW OF OUR ALGORITHM

Figure 2. Algorithm over view

A CCD camera is fixed on the front-view mirror to capture the road scene. To simplify the problem, we assume that it is setup to make the baseline horizontal, which assures the horizon in the image, is parallel to the X-axis. Otherwise, we can adjust the image using the calibration data of the camera to make it. Each lane

boundary marking, usually a rectangle (or approximate) forms a pair of edge lines. In this paper, it was assumed that the input to the algorithm was a 620x480 RGB color image. Therefore the first thing the algorithm does is to convert the image to a grayscale image in order to minimize the processing time. Secondly, as presence of noise in the image will hinder the correct edge detection. Therefore, we apply (F.H.D.) algorithm [13] to make the edge detection more accurate. Then the edge detector is used to produce an edge image by using canny filter with automatic thresholding to obtain the edges, it will reduce the amount of learning data required by simplifying the image edges considerably. Then edged image sent to the line detector after detecting the edges which will produces a right and left lane boundary segment. The projected intersection of these two line segments is determined and is referred to as the horizon. The lane boundary scan uses the information in the edge image detected by the Hough transform to perform the scan. The scan returns a series of points on the right and left side. Finally pair of hyperbolas is fitted to these data points to represent the lane boundaries. For visualization purposes the hyperbolas are displayed on the original color image. The algorithm structure is shown in Figure 2.

A. Image Capturing

The input data is a color image sequence taken from a moving vehicle. A color camera is mounted inside the vehicle at the front-view mirror along the central line. It takes the images of the environment in front of the vehicle, including the road, vehicles on the road, roadside, and sometimes incident objects on the road. The on-board computer with image capturing card will capture the images in real time (up to 30 frames/second), and save them in the computer memory. The lane detection system reads the image sequence from the memory and starts processing. A typical scene of the road ahead is depicted by Figure 1. In order to obtain good estimates of lanes and improve the speed of the algorithm, the original image size was reduced to 620x480 pixels by Gaussian pyramid.

B. Conversion to Gray Scale

To retain the color information and segment the road from the lane boundaries using the color information this proved difficulties on edge detection and also it will effect the processing time. In practice the road surface can be made up of many different colors due to shadows, different pavement style or age, which causes the color of the road surface and lane markings to change from one image region to another. Therefore, color image are converted into grayscale. However, the processing of grayscale images becomes

minimal as compared to a color image. This function transforms a 24-bit, three-channel, color image to an 8-bit, single-channel grayscale image by forming a weighted sum of the Red component of the pixel value * 0.3 +Green component of the pixel value * 0.59 + Blue component for the pixel value *0.11 the output is the gray scale value for the corresponding pixel[12].

C. Noise Reduction

Noise is a real world problem for all systems and computer vision is no exception. The algorithms developed must either be noise tolerant or the noise must be eliminated. As presence of noise in our system will hinder the correct edge detection, so that noise removal is a pre requisite for efficient edge detection with the help of (F.H.D.) algorithm [13] that removes strong shadows from a single image. The basic idea is that a shadow has a distinguished boundary. Removing the shadow boundary from the image derivatives and reconstructing the image should remove the. A shadow edge image can be created by applying edge-detection on the invariant image and the original image, and selecting the edges that exist in the original image but not in the invariant image and to reconstruct the shadow free image by removing the edges from the original image using a pseudo-inverse filter.

D. Edge Detection

Lane boundaries are defined by sharp contrast between the road surface and painted lines or some type of non-pavement surface. These sharp contrasts are edges in the image. Therefore edge detectors are very important in determining the location of lane boundaries. It also reduces the amount of learning data required by simplifying the image considerably, if the outline of a road can be extracted from the image. The edge detector implemented for this algorithm and the one that produced the best edge images from all the edge detectors evaluated was the 'canny' edge detector [14]. To find the maxima of the partial derivative of the image function I in the direction orthogonal to the edge direction, and to smooth the signal along the edge direction. Thus Canny's operator looks for the maxima of :

$$G_\sigma = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left[-\frac{x^2+y^2}{2\sigma^2}\right] \qquad (1.1)$$

Where

$$n = \frac{\nabla G * I}{|\nabla G * I|} \qquad (1.2)$$

Figure 3. Canny detection

It was important to have the edge detection algorithm that could be able to select thresholds automatically however, the automatic threshold that is used in the default Canny produced far too much edge information. Making a slight modification to the edge detected produced by canny has given more desirable results. The only changes necessary were to set the amount of non-edge pixels to the best value that gives more accurate edges in different conditions of image capturing environment. The canny edge detector also has a very desirable characteristic in that it does not produce noise like the other approaches

E. Line Detection

The line detector used is a standard Hough transform [8] with a restricted search space. The standard Hough transforms searches for lines using the equation shown in Figure 4:
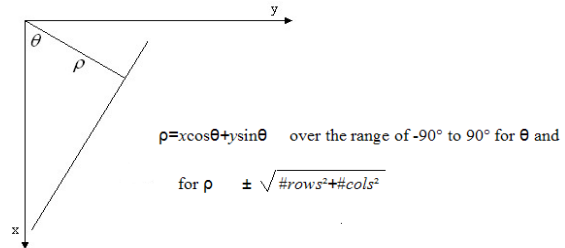

$\rho = x\cos\theta + y\sin\theta$ over the range of -90° to 90° for θ and

for ρ $\pm \sqrt{\#rows^2 + \#cols^2}$

Figure 4. Hough Transform

When in reality we can reject any line that falls outside a certain region [15]. For example a horizontal line is probably not the lane boundary and can be rejected. The restricted Hough transform was modified to limit the search space to 45° for each side. Also the input image is split in half yielding a right and left side of the image. Each the right and left sides are searched separately returning the most dominant line in the half image that falls with in the 45° window. The horizon is simply calculated using the left and right Hough lines and projecting them to their intersection. The

horizontal line at this intersection is referred to as the horizon.

F. Lane Boundary Scan

The lane boundary scan phase uses the edge image the Hough lines and the horizon line as input. The edge image is what is scanned and the edges are the data points it collects. The scan begins where the projected Hough lines intersect the image border at the bottom of the image. Once that intersection is found, it is considered the starting point for the left or right search, depending upon which intersection is at hand. From the starting point, the search begins a certain number of pixels towards the center of the lane and then proceeds to look for the first edge pixel until reaching a specified number of pixels after the maximum range. The range will be set to the location of the previously located edge pixel plus a buffer number of pixels further
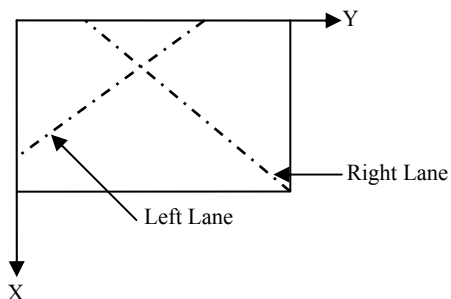

Figure 5.   Image coordinates

For the starting condition, the search will already be at the left- or right-most border, as shown in Figure 5 .so the maximum range will be the border itself. The extra buffer zone of the search will help facilitate the following of outward curves of the lane boundaries. The lane points are organized into two lists expressed as $L(l)$ and $L(r)$

$$L^{(l)} = \{(u_1^{(l)}, v_1^{(l)}), (u_2^{(l)}, v_2^{(l)}), ..., (u_m^{(l)}, v_m^{(l)})\} \qquad (1.3)$$

$$L^{(r)} = \{(u_1^{(r)}, v_1^{(r)}), (u_2^{(r)}, v_2^{(r)}), ..., (u_m^{(r)}, v_m^{(r)})\} \qquad (1.4)$$

Figure 6 shows the lane boundaries detection.

G. Hyperbola Fitting

The hyperbola pair fitting phase uses the two vectors of data points from the lane scan as input. A least squares technique is used to fit a hyperbola to the data. One hyperbola is fit to each of the vectors of data points; however, they are solved in simultaneously due to the fact that they are a pair model. The parameters of the two hyperbolas are related because they must converge to the same point, due to the geometry of the roadway as shown in Figure7. The formula for expressing the lane boundary as a hyperbola [11], given the road boundary point (u, v) in image plane:

$$u = \frac{k}{u - h} + b(v - h) + c \qquad (1.5)$$

u and v are the x- and y-coordinate in the image reference frame, h is the Y-coordinate of the horizon in the image reference frame, and k, b and c are the parameters of the curve, which can be calculated from the shape of the lane.
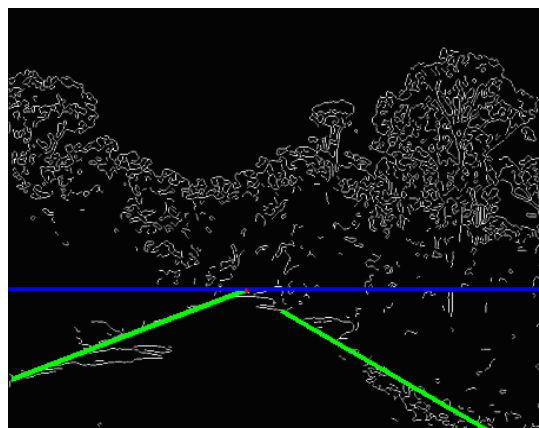

Figure 6. Lane boundary detection

Figure 7. Hyperbola fitting

V.   EXPERIMENTAL RESULTS

In this paper, the algorithm was implemented in a HP Intel ® Core TM (2) 2.0 GHz computer using Matlab 7.1. A database including a growing number of

image and video frames is set up for the experiment .All these images are taken in highways and normal roads, dashed markings, straight and curved roads in different environmental conditions (sunny, cloudy, nighttime, shadowing, rainy). Figure 8 illustrates the performance of the system under different road conditions. Additionally, in Figure 9 we can observe that the lane boundaries are successfully extracted, which indicate the robustness and real-time performance of the algorithm. However, still some problems did not solved yet such as sharp curves in the foreground of the image and the accurate detection of the lanes under heavy rain also the captured frames are not that stabile due to the vehicle movement and therefore, we need to improve the algorithm to overcome these problems.
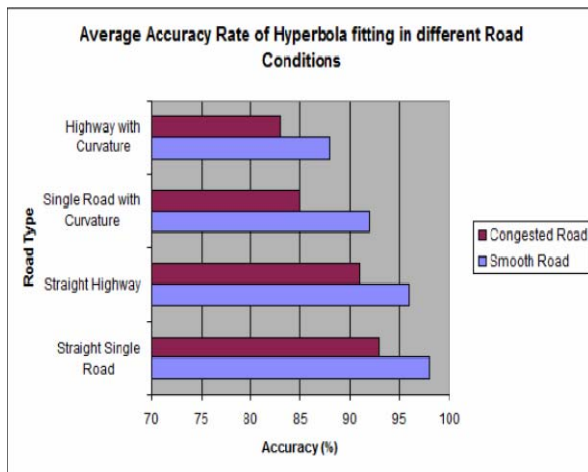

Figure 8. Average accuracy rates of lane detection in different road conditions.

VI.   SUMMARY AND CONLUSION

In this paper, a real time lane detection algorithm based on video sequences taken from a vehicle driving on highway was proposed. As mentioned above the system uses a series of images. Out of these series some of the different frames used are shown in the lane detection algorithm, (F.H.D.) algorithm conduct image segmentation and remove the shadow of the road. Since the lanes are normally long and smooth curves, we consider them as straight lines within a reasonable range for vehicle safety. The lanes were detected using Hough transformation with restricted search area. The proposed lane detection algorithm can be applied in both painted and unpainted road, as well as slightly curved and straight road as shown in Figure 9. There remained some problems in the lane detection due to shadowing and the Hough line and horizon overlaid,

then in the lower left edge with the lane boundary points overlaid and in few cases lane scan fails to track the correct lane.
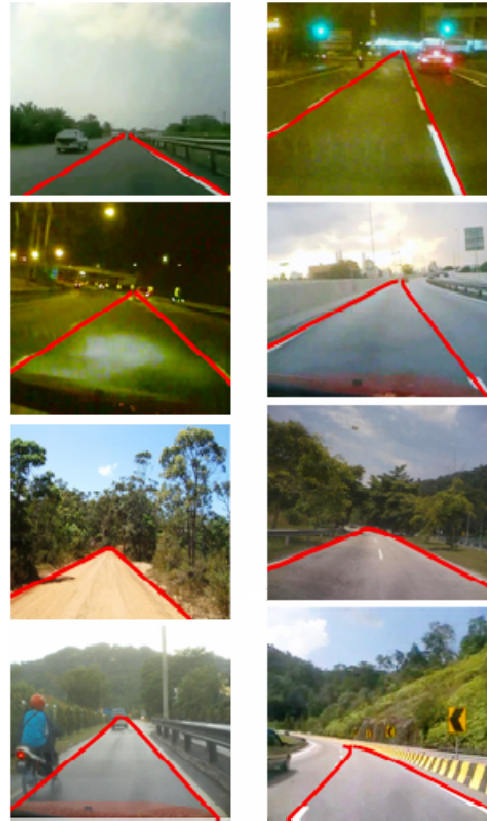

Figure 9. Road lane detection in different scene

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