A Hyperbola-Pair Based Lane Detection System for Vehicle Guidance

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Abstract—**Developing on-board automotive driver assistance systems aiming to alert drivers about driving environments, and possible collision with other vehicles has attracted a lot of attention lately. The ability to perceive, or sense, the surrounding environment is essential to driving and thus to the development of autonomous self-guided vehicles However, the time requirements of an autonomous vehicle's vision system are very demanding, and require careful selection of high speed algorithms for implementation. This paper presents a recent vision-based on-road lane detection system. Our focus is on systems where the camera is mounted on the vehicle rather than being fixed such as in traffic/driveway monitoring systems. Real time image sequences are used as inputs, which after being processed are used for lanes detection. The lanes are detected using Hough transform and fitted to a hyperbola model. The proposed lane detection algorithm can be applied on both painted and unpainted road as well as curved and straight road. Finally, a critical overview of the methods was discussed, the assessment of their potential for future deployment were highlighted. 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.**

Index Terms— **Lane detection, computer vision, intelligent Vehicles, Visual Guides**

I. Introduction

The main motivation behind having driver assist systems is to make driving safer. An autonomous intelligent vehicle has to perform a number of functionalities. Segmentation of the road, determining the boundaries to drive in and recognizing the vehicles and obstacles around are the main tasks for vision guided vehicle navigation. 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 danger has the potential to save a considerable number of lives. Among the tasks that need to be conducted by driver assist systems, lane detection has an important role in providing information such as lane structure and the vehicle position relative to the lane. The most prevalent methods used to carry out these functions involve camera-based systems relying on computer vision and image processing. In many proposed systems [2], lane detection consists of the localization of specific primitives such as the road markings of the surface of painted roads. Although this restriction simplifies the process of detection, two situations can disturb the process: the presence of other vehicles on the same lane and the partial occlusion of road markings ahead of the vehicle due to 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 remainder of the paper is arranged as follows: Section II highlights some recent driver assist systems, Section III provides an overview of the proposed algorithm, Section IV provides results for various experimental conditions and Section V concludes and presents directions for future work.

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II. Related Work

There are currently many different vision-based road detection algorithms developed to avoid assist drivers on the road. Among these algorithms the GOLD system developed by Broggi 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. [4] propose 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 designed for 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. This considerable insight is also used in our algorithm, to form an extended equation to fit the road shape.

III. OVERVIEW OF ALGORITHM

The algorithm described in this paper is quite unique as it uses a combination of scan boundary lines and Hough transform to fit a hyper bola pair model. Hyperbola pair models are rarely used, with most of the lane detection in literature being conducted by polynomial or template based models.

In our system, a CCD camera is fixed on the front-view mirror to capture the road scene. The algorithm first converts the image to a grayscale. Next, due to the presence of noise in the image, we apply the F.H.D. algorithm [13] to make edge detection more accurate. After this, the edge detector is used to produce an edge image by a threshold canny filter. The edged image sent to the line detector after detecting the edges which will produce the right and left lane boundary segments. 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 Fig. 1.

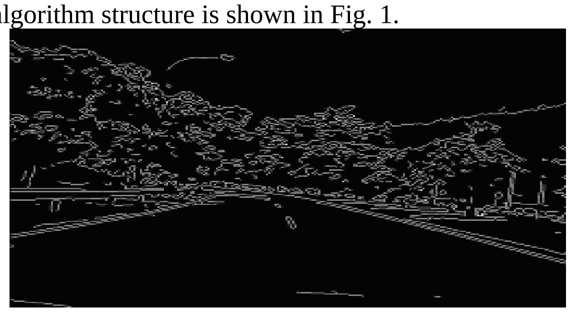

Fig. 2: Canny edge detection.

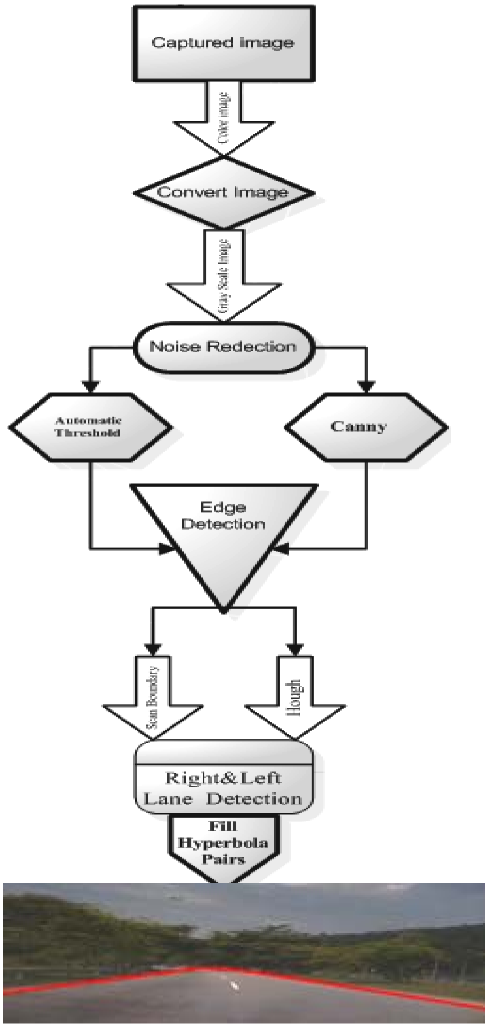

Fig. 1: Algorithm Structure

A. *Noise Reduction and Edge Detection*

As presence of noise in our system will affect edge detection, noise removal is very important. The F.H.D. algorithm [13] has been shown to remove strong shadows from a single image. The basic idea is that since shadows have a distinguished boundary, removing the shadow boundary from the image derivatives and reconstructing the image should remove the entire shadow. 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. Shadows are eliminated by removing the edges from the original image using a pseudo-inverse filter.

Lane boundaries are defined by sharp contrast between the road surface and painted lines or some type of non-pavement surface and obviously form edges in the image. Thus, a Canny edge detector [14] was employed in determining the location of lane boundaries. It also reduces the amount of learning data required by simplifying the image considerably as shown in Fig. 2.

B. *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 Fig. 3.

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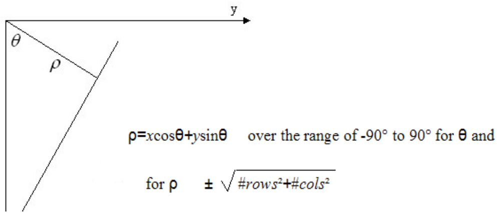

Fig. 3: Hough Transform.

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 and each side is 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.

C. 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.

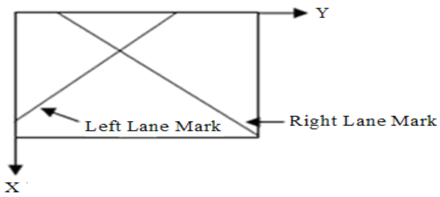

Fig. 4: Lane borders on image.

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. For the starting condition, the search will already be at the left- or right-most border, as shown in Fig. 4, 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 (Fig. 5).

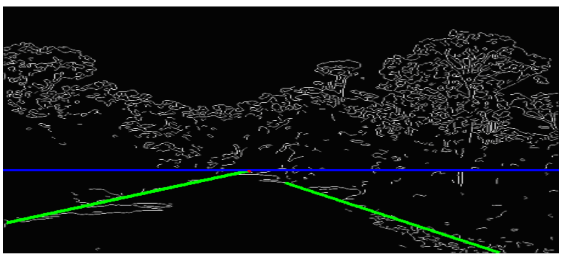

Fig. 5: Horizon and detected boundaries.

D. 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 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 Fig. 6.

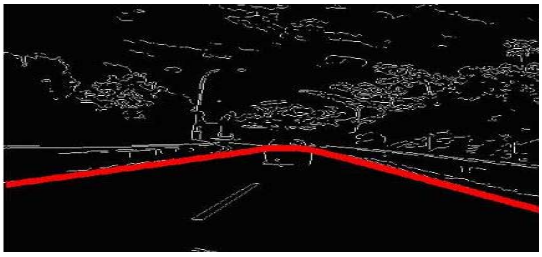

Fig. 6: Hyperbola pair fitted on lane boundary.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

In this paper, the algorithm was implemented in a HP Intel ® Core TM (2) 2.0 GHz computer using Matlab 7.1. All video was recorded at highways and normal roads, dashed markings, straight and curved roads in different environmental conditions (sunny, cloudy, nighttime, shadowing, rainy). There are numerous results of performance interest, relating to image resolution (Table 1), performance on single/multi lane roads during day (Table 2) and night (Table 3).

Table 1: Resolution and processing time

NO	Input Image resolution	Processing Time	Detection rate
1	128 by 128	20ms	65%
2	160 by 160	26ms	69%
3	314 by 235	33ms	73%
4	448 by336	38ms	87%
5	640 by480	46ms	89%
6	800 by600	1.1s	94%
7	1024 by768	1.8s	96%

Table 2: Lane detection during day

Road Type	Day			
	Frames	Success	Fail	Accuracy
Highway	120	102	18	85%
Single Lane	120	110	10	91.6%
Multi Lanes	120	97	23	80.8%

Table 3: Lane detection during night

Road Type	Night			
	Frames	Success	Fail	Accuracy
Highway	120	94	26	78%
Single Lane	120	100	10	83.3%
Multi Lanes	120	81	39	67.5%

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It is quite clear from the tables, and it is reasonable to expect that high resolution images, although offering the best detection rate, exponentially increase the processing time required (Fig.7). An appropriate trade-off between processing time and image resolution seems to occur at a resolution of 640x480, and it is at this resolution that the remainders of the experiments were conducted.

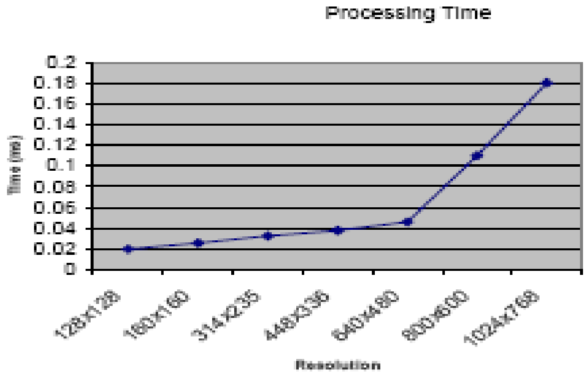

Fig. 7: Resolution and processing time.

Furthermore, it can be concluded that multi-lanes offer a greater difficulty for detection, especially at night. The greatest accuracy achieved in either night or day is for single lanes rather than highways, as its likely that the left and right lane scan search produces inaccurate results due to the distance of the lane boundaries from each other, given the fact that a lane on a highway is wider than a lane on a single lane road.

The accuracy of the hyperbola pair fitting model was also evaluated (Fig. 8).

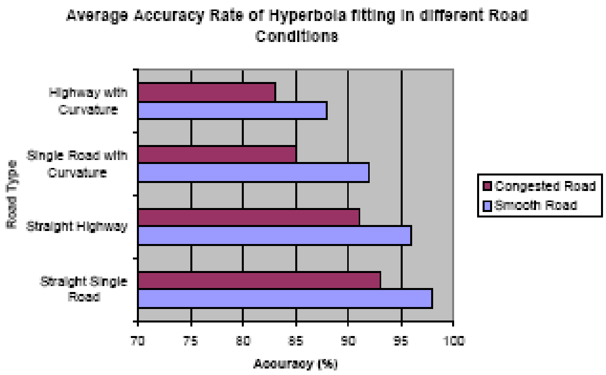

Fig. 8: Hyperbola pair model accuracy.

Since the model is of paired hyperbolas, it can be considered correct, if both hyperbolas have the same parameters. Obviously, the accuracy of the model will depend on the hyperbola model's robustness under different road curvature conditions. This is reflected in the results of Fig. 8, and it can be concluded that the model is fairly robust in dealing with curvature, with a 15% decrease in accuracy on curved roads. However, this would not be expected from an ordinary polynomial or template-based system.

V. SUMMARY AND CONCLUSION

In this paper, a lane detection for vehicle guidance based on video sequences taken from a vehicle driving on highway was proposed. The frames out of the video sequences are processed using an image processing algorithm that has been described in this paper. The algorithm uses noise and shadow removal technique to eliminate disturbances that would cause inaccuracies. Since lanes are normally long and smooth curves, we consider them as straight lines within a reasonable range for vehicle safety. The lanes are detected using Hough transformation with restricted search area and then cast into a hyperbola pair model. The proposed lane detection algorithm can be applied in both painted and unpainted road (single/multi lane marking), as well as slightly curved and straight roads. The results of several experiments were obtained and analyzed which provide an insight into the inherent trade-off between processing time and accuracy in the algorithm. The proposed hyperbola-pair model's robustness was discussed with different road curvatures. Additionally, the success of the system during day and night conditions was also experimented. There remain some short-comings primarily in the lane detection due to shadowing and Hough line horizon overlaying with the lane boundary points. This overlay largely depends on the camera orientation although an algorithm to tackle this problem can be considered as a future direction of this work.

VI. ACKNOWLEDGMENT

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