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Comparative study of Lane Detection Algorithms A Review

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Abstract: Reducing road accidents and saving lives is of great interest while driving at high speeds on freeways. Traffic accidents account for a vast majority of fatalities worldwide; consequently, improving public and drivers safety on roads has become an important area of interest for many years. Among the complex and challenging tasks of future road vehicles is lane detection. Lane detection is locating lane markers on the road and presenting these locations to intelligent system. Intelligent vehicle cooperate with smart infrastructure to achieve a safer environment and better traffic conditions. To detect lanes and road boundaries, using vision system on the vehicle is one of the principal approaches. Camera based systems relying on computer vision and image processing is one of the most desirable methods used to carry out these functions. There are large numbers of vision based systems for vehicle control, collision avoidance and lane departure warning, which have been developed during the last two decades. Lane detection is a difficult problem because of the varying road and weather conditions that one encounter while driving. This paper shows comparative study of various lane detection algorithms with merits and demerits.

Keywords: Lane detection, intelligent vehicle, Hough transform.

1 INTRODUCTION

Around the world, high fatality rates from traffic accidents are evident. As vehicles commute at high speeds on freeways, the consequences of a distraction can be tragic. Driver's safety has always been an area of interest to research [5]. With the increased speed & smaller sizes of complex electronics, intelligent devices are beginning to be integrated with vehicles giving rise to Driver Assistance System [2]. Machine vision systems play an important role in providing safety features for the advanced driver assistance systems of today's automobiles [6]. Lane detection is a major component of Driver Assistance System.

Lane detection consists of the localization of specific primitives such as the road markings of the surface of painted roads [1]. Lane detection can be described as a problem of locating painted lane markings (white or yellow) or boundaries markings on the road surface with little to no prior knowledge of the road geometry [4]. The applications of a lane detecting system could be as simple as pointing out lane locations to the driver on an external display, to more complicated tasks such as predicting a lane change in order to avoid potential collisions with other vehicles [2].

Lane detection systems are systems aimed at aiding the driver of the vehicle. The ability of lane detection system to detect sudden or unexpected lane changes when there is traffic in the lane a driver is moving into could help a driver to avoid collisions [3]. Lane detection system continually monitors the position of a car within a lane. This could be used to avoid collisions due to unintentional lane departure caused by driver distractions, fatigue, or driving under the influence of a controlled substance.
Vision-based lane detection systems involve the use of one or more calibrated cameras looking out of the front windshield. Data in the form of video or an image sequence are acquired, after which they are analyzed to extract features that closely correspond to the desired lane markers. Lane detection is of much interest to many applications such as lane change assistance(LCA), lane departure warning(LDW) and blind spot monitoring to name a few, as they strongly rely on a good-quality lane detector as a building block to make their assessment of the situation. In addition, it is one of the fundamental modules required by autonomous guided vehicles that enable them to independently drive on roads in urban environments [5].
Machine vision methods have been acknowledged as a powerful and efficient module in the automatic control community. The recognition of complex situations in a given image is the main problem that limits the use of machine vision systems. The identification of road lanes is a challenging task, particularly in the presence of poor lighting conditions. Robust lane detection and lane departure techniques must be used to minimize the problems of poor lane detection in the presence of different environmental and illumination conditions [6].

2 LANE DETECTION

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. Numerous techniques have been developed to detect and extract lanes in an automobile. Among these some of them are discussed with their positive and negative scenarios of road and weather condition. All the techniques illustrated use color image as an input data which has been taken by a camera fixed on the front of a moving vehicle. The images captured are stored in the memory and the lane detection system fetches the image from memory and start the processing.

2.1 Different Techniques

Currently many different vision-based road detection algorithms have been developed to avoid vehicle crash on the road. Numerous techniques have been developed to detect and extract lanes in an automobile. Among these some of them are discussed with their positive and negative scenarios of road and weather condition.

All the techniques illustrated use color image as an input data which has been taken by a camera fixed on the front of a moving vehicle. The images captured are stored in the memory and the lane detection system fetches the image from memory and start the processing.

2.1.1 Real Time Lane Detection for Autonomous Vehicles

This technique [1] converts the image to a gray scale to minimize processing time. Here the image size was reduced to 620x480 pixels by Gaussian pyramid in order to get good results and improve algorithm speed.

In the system developed, either the noise should be eliminated or tolerated as it hinders the correct edge detection. For efficient edge detection, F.H.D. algorithm is used that removes strong shadows from a single image. Canny edge detector along with automatic thresholding (slight change in the amount of non-edge pixels) is used to produce the best edge images which determine the location of lane boundaries and reduce the data to be further analyzed. Hough Transform is used as a line detector that produces a left and right lane boundary in a restricted search space. Horizon is the horizontal line at the intersection of left and right line segments.

The inputs for lane boundary scan are edge image, Hough lines and horizon. This scan gives the result as series of points on right and left side and then two hyperbolas are fitted to these data points which represent the lane boundaries. Finally the result is reflected on the original color image for the visualization.

2.1.2 A Layered Approaach To Robust Lane Detection At Night

Another technique [2] starts with step of cropping where original image is cropped into a Region Of Interest (ROI) which removes the irrelevant objects such as sky, street lights etc. This process enhances the speed (due to reduction in image size) and accuracy (due to elimination of objects outside the ROI). In the preprocessing step, color image is converted into a gray scale image. By using temporal blurring the traffic lanes (dashed lines and sometimes appear as a dot) are extended and gives the appearance of long and continuous line. This blurring also reduces noise in the image. On the average image obtained, the average threshold is applied to extract the lane markers and split the image into left and right halves. Further, a low resolution Hough transform is applied on each half to find the straight line corresponding to lanes. The matched filter and Gaussian kernel is used to determine noisy Gaussian in the search window and book keeping strategy gives the best estimate of lane marker.

2.1.3 Robust Lane Detection and Tracking with RANSAC and Kalman filters

It is an extension to the second technique [2], where initially the color image undergoes grayscale conversion and temporal blurring along with the Inverse Perspective Mapping (IPM) which changes the camera captured image to a bird's eye view. Further adaptive threshold is applied to the IPM image where the binary image is generated and split into two halves. A low-resolution Hough transform is computed on each half and a 1D filter is applied at each sample to find the center of each line. RANSAC is applied to data points which fits the model through inliers and reject outliers. Linear Least Square Estimation (LSE) is used to fit the line on inliers. Kalman filter is then used to predict line parameters and then the line estimated is mapped back to the camera perspective to give the result.

2.1.4 Polar Randomized Hough Transform for Lane Detection using loose constraints of Parallel Lines

In the previous approach, there exists a problem in detecting a pair of parallel lines generally separated by a fixed distance. In the fourth technique [4], the lane markers are detected using the parallel nature of lanes. Initially, the camera image undergoes geometric transformation known as Inverse Perspective Mapping and then the IPM image is converted from RGB to grayscale. Further the resulting image is filtered using Normalized Cross Correlation (NCC) and the thresholding is done which converts the image to binary image. The Polar Randomized Hough Transform is applied to the binary image and the road center is mapped to the image along with the search window which determines the parallel lines in the image.

2.1.5 A Novel Lane Detection System with Efficient Ground Truth Generation

It is an integration of approaches discussed in second [2] and third [3] technique initiates with the temporal blurring which gives the appearance of a continuous line instead of dashed line in the image. Further the image undergoes pixel wise transformation which transforms average image into grayscale image and then IPM is applied to the image. The adaptive threshold is applied which converts the IPM image to the binary image. A low resolution Hough Transform is applied to the image that gives the highest scoring lines which are sampled at the sampling columns produces sampled points of only one line in the grayscale image. Temporal smoothing leads to the Gaussian-like shape in 1D within yellow window. Template matching with Normalized Cross Correlation is performed using a collection of predefined templates inside the search windows centered at each sample point. The pixel with the largest correlation coefficient that exceeds a minimum threshold is selected as the best estimate of the center of the lane marker. RANSAC is performed to eliminate outliers by fitting a mathematical model to a set of observed data which contain outliers. Linear least squares estimation (LSE) is used to find the best fit to the inliers. Finally, Kalman filter track and smooth the estimates of parameters based on the measurements.

2.1.6 Lane Departure Identification for Advanced Driver Assistance

In this system, an input color image is converted to grayscale image and then normalized to range [0,1]. PLSF is used to improve contrast level of the image and the new output gray values are calculated from the normalized gray

values. After PLSF the image is then converted to binary image. PLSF enhances the lane detection rate and provides better performance.
Initially from the image, ROI is cropped and approximately only 40% of the original image is selected. The ROI is segmented and divided into left and right subregion. On each subregion, the Hough transform is applied and the endpoints of the edges of the lane segments from the midpoint of which a perpendicular line connects to the Hough origin.

2.1.7 Lane Detection Using Median Filter, Wiener Filter and Integrated Hough Transform
This system shows a comparison of two filters i.e. median and wiener which used to remove noise from the images for lane detection system. This system initiates which the grayscale image conversion from the color image to reduce preprocessing time. Median and Wiener filters are used to reduce noise as the correct edge detection will be hindered due to the noise present. Canny edge detector along with the automatic thresholding is used to generate an edge image which is sent to the line detector that detects the left and right lane boundary. Lane boundary scan uses the information in the edge image detected by the Hough transform to perform the scan. The scan returned a series of points on the right and left side.

2.2 Comparison of Different Lane Detection Algorithms
Different lane detection algorithms meet the specific conditions as per the scenarios to be encountered. For example, there may be different road conditions, weather conditions to be considered before the implementation and in accordance with those conditions the system is developed. So, the system designed incorporating particular conditions may not fulfill other conditions considered for different system. Hence, on the basis of these scenarios there are algorithms which have certain road and environment conditions resulting in their own merits and demerits. These merits and demerits are described in the Table I.

TABLE I COMPARISON OF ALGORITHMS

S.No	Algorithm	Merits	Demerits
1	Real Time Lane Detection for Autonomous Vehicles	Highways and normal roads, dashed markingstraight and curved roads sunny, cloudy, night time,shadow-ing, rainy	Sharp curves in the image, heavy rain. Less stable images captured due to vehicle movement
2	A Layered Approach To Robust Lane Detection At Night	Isolated highways and metro highways in the presence of both light and moderate traffic	Age, lack of maintenance of roads, bright illuminations from street lights, other vehicles detected as lanes and presence of neighboring lanes on multi-lane highway
3	Robust Lane Detection And Tracking With RANSAC And KALMAN Filter	Active toll plaza, presence of other road markings, busy highways and busy city streets	Bumper, poor road maintenance
4	Polar Randomized Hough Transform for Lane Detection Using Loose Constraints Of Parallel Lines	Variations in illumination, road surface, marker quality, traffic	Age of roads, shadows, presence of neighboring vehicles, surface irregularities
5	A Novel Lane Detection System With Efficient ground truth generation	Normal highway, dark highway, road patterns, urban street, other vehicles present, navigational information, toll plaza, on ramp	Worn markers and cracks, lens flare, step ramp on truck, effects of bumps
6	Lane Departure Identification for Advanced Driver assistance	Normal lighting conditions (presence of continuous and dotted lines) Poor lighting conditions (watery road, rainy condition, fog, under tunnel, shadow, nighttime)	Driver is too negligent about warnings and vehicle moves to cross boundary
7	Lane Detection Using Median Filter, Wiener Filter and Integrated Hough Transform	painted and unpainted road, as well as slightly curved and straight road	under heavy rain

3 CONCLUSION

There are numerous algorithms and techniques to implement lane detection system which can be further incorporated into forming a new system such as lane departure system, collision avoidance system etc. Each algorithm focuses on detecting lane by considering conditions to overcome specific constraints for e.g. shadow, night time, different weather conditions etc. Therefore, each implementation technique has its own merits and demerits. There could be various areas in which the system can be further improved which make a better, error free and efficient system.

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