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Lane Detection System for Autonomous Driver Assistance

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Abstract: Saving lives and reducing road accidents is of great interest while driving at high speeds on freeways. Traffic accidents have a vast majority of fatalities worldwide; hence, lives safety on roads is an important area of interest since decades. The most complicated tasks of future road vehicles are successful lane detection. Lane detection locates lane markers on the road and presents these locations to intelligent system. Intelligent transportation cooperates with infrastructure which provides a safer environment and better traffic conditions. Vision system is one of the basic approach which helps to detect lanes and road boundaries. Currently, camera based systems using computer vision and image processing are used to detect lanes. There are large number of vision based systems which are developed during the last two decades for vehicle control, collision avoidance and lane departure warning. Detecting lane becomes difficult problem because of the varying road conditions and weather conditions that one encounter while driving. This paper describes the implementation of two algorithms with their results using Raspberry Pi. The Raspberry Pi is a low cost, credit-card sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse. It is a capable little device that enables people of all ages to explore computing, and to learn how to program in languages like Scratch and Python. It's capable of doing everything you'd expect a desktop computer to do, from browsing the internet and playing high-definition video, to making spreadsheets, word-processing, and playing games.

Keywords: Lane detection, intelligent vehicle, PLSF, Laplacian filter, Canny Edge detection, Hough transform, Raspberry Pi.

1 INTRODUCTION

Around the world, high rates of fatality from traffic accidents are seen. As vehicles travel at high speeds on ways, the distraction consequences are tragic. Driver's safety has always been an area of interest for research [5]. With the higher speed and compact sizes of complex electronics, vehicles give rise to Driver Assistance System after being integrated with intelligent devices [2]. Vision based machine systems plays a crucial role in providing safety for the advanced driver assistance systems of today's and future automobiles [6]. The major component of Driver Assistance System is Lane detection system.

Lane detection is the localization of primitives such as the road markings of the surface of painted roads [1]. Lane detection can be defined as locating painted lane markings (white or yellow) or boundary markings on the road surface with very little or no prior information of the road geometry [4]. The lane detecting system has application varying from pointing out lane markings on an external display to complicated activities such as lane change to avoid collisions [2].

Lane detection systems also has an ability to detect sudden or unexpected lane changes which could help a driver to avoid accidents [3]. This system continually monitors the position of a vehicle within the lane which prevents froml lane departure caused by driver distractions, fatigue, or driving under some influence. Vision-based systems for lane detection uses one or more cameras looking out of the front. Input data is in the form of video or image sequence, after which the features are extracted as the desired lane markers. Lane detection concentrates on applications namely lane change assistance(LCA), lane departure warning(LDW) and blind spot monitoring. It is one of the fundamental component required by autonomous vehicles which enable to independently drive on roads in different environments [5].

Machine vision methods is acknowledged as most powerful and efficient module in the automatic traffic 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].

The organization of this paper describes the various lane detection algorithms along with their comparison in Section 2 under heading "Lane Detection". Further the two algorithms along with the results are described in detail in Section 3 under heading "Lane Detection Systems".

2 LANE DETECTION

Road safety is the essence of the lane detection systems. Most of the road accident occurs due to the miss leading of the vehicle path. Numerous techniques have been developed to detect and extract lanes in an automobile which avoids accidents.

Input is the color image taken by a camera fixed on the moving vehicle. Memory stores the images captured and processing is done by the lane detection system.

2.1 Different Techniques

Ddifferent vision-based road detection algorithms have been developed to avoid vehicle crash on the road. Among them some are discussed below.

2.1.1 Real Time Lane Detection for Autonomous Vehicles

It [1] converts the image to gray scale and minimizes processing time. Noise is required to be eliminated as it hinders the correct edge detection. F.H.D. algorithm is used for efficient edge detection that removes strong shadows from a single image. Canny edge detector along with automatic thresholding gives the best edge images that determine the location of lane boundaries. Hough Transform produces a left and right lane.

Horizon is the horizontal line at the intersection of left and right line segments. Lane boundary scan takes input as edge image, Hough lines and horizon which gives the result as series of points on right and left side. Further, two hyperbolas are fitted which represent the lane boundaries. Finally the result is reflected on the original color image.

2.1.2 A Layered Approaach To Robust Lane Detection At Night

This technique [2] starts with cropping which removes the irrelevant objects such as sky, street lights etc where original image is cropped into a Region of Interest (ROI). Color image is converted into a gray scale image and then temporal blurring extends dot lines and gives the appearance of long and continuous line.

Adaptive threshold extracts the lane markers and divide the image into left and right halves. A low resolution Hough transform (LRHT) is applied on both halves that detects lane. The matched filter and Gaussian kernel determines noisy Gaussian in search window and book keeping strategy provides best lane marker estimates.

2.1.3 Robust Lane Detection and Tracking with RANSAC and Kalman filters

The extension to the second technique [2], where initially the color image undergoes gray conversion and then temporal blurring with the Inverse Perspective Mapping (IPM) is done that converts the camera image to the bird's eye view. Later adaptive threshold changes IPM image where binary image is generated and split into two halves.

Now, a low-resolution Hough transform is calculated on each half and also a 1D filter is passed at each sample which gives the center of each line. RANSAC is applied which fits the through inliers while rejecting outliers. Linear Least Square Estimation (LSE) fits line on inliers. Kalman filter predicts line parameters and mapped back to give the result.

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

A problem that arises in previous approach is detecting pair of parallel lines generally separated by a fixed distance. Here [4], parallel nature of lines detects the lane markers. Initially, Inverse Perspective Mapping is applied and the IPM image is further changed from RGB to grayscale.

Normalized Cross Correlation (NCC) filter is used and binary image is obtained by the thresholding. The Polar Randomized Hough Transform (PRHT) 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

An integration of approaches in [2] and [3], which initiates with temporal blur, converts the dashed line appearance to a continuous line. Pixel wise transformation transforms average image into gray image and IPM is applied. Adaptive threshold applied converts IPM image to binary image. A low resolution Hough Transform (LRHT) gives the highest scoring lines which are then sampled at sampling columns gives points of 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 eliminate outliers and Linear least squares estimation (LSE) finds the best fit to the inliers. 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 RGB image is converted to grayscale image and normalized to range [0,1]. PLSF used, improves the contrast level of the image and new output gray values are obtained from the normalized gray values. PLSF is further converted to binary image. The image is cropped and ROI is selected which is 40% of the original image. The left and right sub regions are obtained by ROI segmentation. The ends of the edges are calculated by applying the Hough transform.

2.1.7 Lane Detection Using Median Filter, Wiener Filter and Integrated Hough Transform

This system compares two filters i.e. median and wiener used to remove noise from images. System initiates with the grayscale image conversion from the color image to reduce preprocessing time. Median and Wiener filters reduce noise as the correct edge detection will be disturbed

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due to the noise present. Canny edge detector generates an edge image further sent to the line detector for detecting the left and right lane boundary. Lane boundary scan scans the edge image information detected by the Hough transform.

2.2 Conparison of Different Lane Detection Algorithms

The comparison of the different lane detection algorithms described above is tabulated in a table below.

TABLE I
COMPARISON OF ALGORITHMS

S.No.	Algorithm	Merits	Demerits
1	Real Time Lane Detection for Autonomous Vehicles	Highways and normal roads, dashed markings, straight and curved roads sunny, cloudy, nighttime, shadowing, 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 LANE DETECTION SYSTEMS

Till now, large numbers of algorithms are developed for lane detection keeping in mind the safety of life. This paper mainly focuses on the two algorithms that are implemented for detecting lane using Raspberry Pi as a hardware and Python, Opencv as software.

Raspberry Pi 2 Model B has following specification:

- QUAD Core Broadcom BCM2836 CPU with 1 GB RAM
- 40 pin extended GPIO
- Micro SD slot
- Micro USB power source
- 4 USB ports, Full size HDMI, 4 pole stereo output and composite video port, DSI display port.

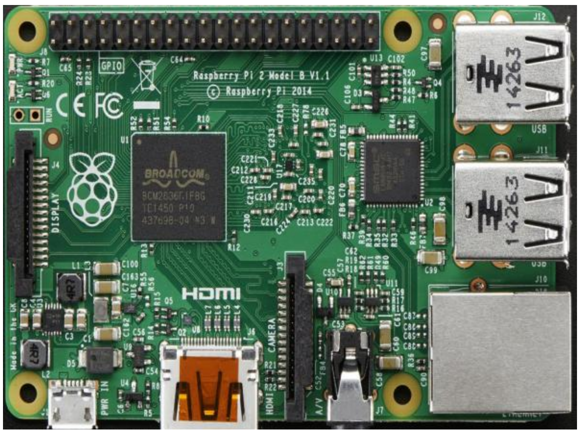

Fig. 1 Raspberry Pi2 Model B board

3.1 Lane detection for Advanced driver assistance

This algorithm uses a new contrast stretching technique named as piecewise linear stretching function (PLSF). The steps of the algorithm are as follows which are detailed in different steps:

Step 1: Input Image
Step 2: Gray Conversion
Step 3: ROI Image
Step 4: PLSF for Lane Images

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Step 5: Canny Edge Detection
Step 6: Hough Transform
Step 7: Output Image

3.1.1 ROI Image

The input color image is initially converted to gray scale image. The gray image is further converted to a cropped image where the region of interest is selected from the gray image which is 50% of the total gray scale image.

Fig. 2 Gray Image

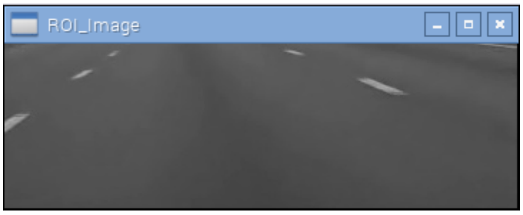

Fig. 3 Region of Interest

3.1.2 PLSF for Lane Images

The PLSF is used to improve the contrast level of the ROI image. PLSF technique shows a significant improvement on the contrast level of input image which also enhances the lane detection rate. The PLSF function provides better performance on variety of different lane markings.

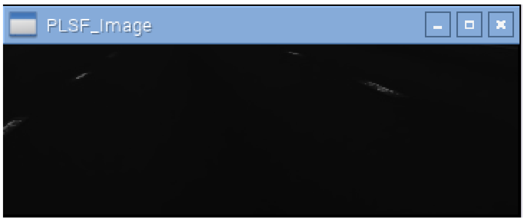

Fig. 4 PLSF Image

3.1.3 Canny Edge Detection

The sharp contrast between the road surface and painted lines are edges in the image. The edge detector determines the location of lane boundaries. Canny edge detector is used in this algorithm which produces binary edge image.

Fig. 5 Canny Edge Image

3.1.4 The Hough Transform

The Hough Transform detects lane by estimating the parameters "theta" (θ) and "rho" (ρ). The pixels lying on the lane marking follows $\rho = x \cos \theta + y \sin \theta$, where (x, y) are coordinate values of a pixel, θ is the angle between the x-axis and the normal line, and ρ is the distance between the origin and the fitted line. The range of θ is between 0◦ and 90◦.

Fig. 6 Lane Detected Image

3.2 Lane detection system using Laplacian filter

This algorithm uses an additional filter called the Laplacian filter which provides better edge sharpening results. The steps incorporated in the algorithm are mentioned below along with the description.

Step 1: Input Image
Step 2: Gray Conversion
Step 3: ROI Image
Step 4: Laplacian filter
Step 5: Canny Edge Detection
Step 6: Hough Transform
Step 7: Output Image

3.2.1 ROI Image

The input color image is initially converted to gray scale image. The gray image is further converted to a cropped image where the region of interest is selected from the gray image which is 50% of the total gray scale image.

Fig. 7 Gray Image

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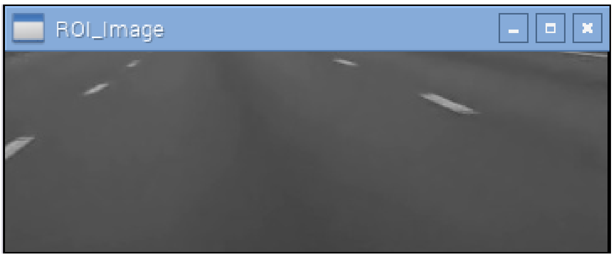

Fig. 8 Region of Interest

3.2.2 Laplacian Filter

Laplacian is a derivative operator which use highlights intensity discontinuities in an image and deemphasizes regions with slowly varying intensity levels. This produces grayish edge lines.

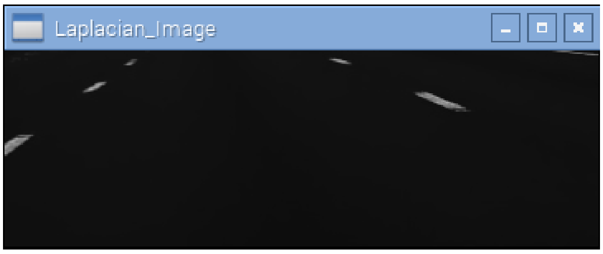

Fig. 9 Laplacian filter Image

3.2.3 Canny Edge Detection

Canny edge detector is also used in this algorithm which produces binary edge image.

Fig. 10 Canny Edge Image

3.2.4 The Hough Transform

The final detected lane results using Hough Transform detects in this algorithm is shown below.

Fig. 11 Lane Detected Image

4 CONCLUSION

There are numerous algorithms and techniques to implement lane detection system which can be further incorporated into forming a new intelligent transportation system such as lane departure system, collision avoidance system etc. The algorithms described in this paper are both implemented on raspberry pi using open cv libraries and python language. The lane detection algorithms are implemented on the input video which is converted into frames. The experimental results are observed for both the algorithms. Different algorithms focus 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.

S.No.	Algorithm	Speed of Actual Video (Frames per second)	Speed of Processed Video (Frames per second)	Frame	Threshold	Detection Performance		Accuracy
						Lines Present per Frame	Lines Detected per Frame	
1	PLSF	200/16.26 = 12.30	10/20.71 = 0.48	1	200(200), 255(255)	6	6	100%
				2		7	7	100%
2	Laplace of Gaussian		10/17.11 = 0.58	1	30,255	7	5	71.40%
				2		7	5	71.40%
3	Sobel x		10/20.12 = 0.49	1	30,255	6	5	83.30%
				2		7	7	100%
4	Sobel y		10/20.40 = 0.49	1	30,255	7	7	100%
				2		7	6	85.71%

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