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Review on Autonomous Vehicle Lane Detection, Tracking and Departure Warning Systems Using Digital Image Processing

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ABSTRACT

Autonomous Vehicles, as the important part of an Intelligent Transportation Systems as an (ITS) which uses an Advanced Driver-Assistance Systems as an (ADAS) algorithms for better and safer driving through automating, adapting and enhancing the vehicle systems. As a result, it will have a great impact on transportation in the near future it could navigate route drive autonomously in urban and highway scenarios using maps, GPS, video sensors and so on. Autonomous vehicle lane detection, tracking and departure warning system are one of the applications of ADAS which will help in detecting lanes autonomously throughout the road and generates a warning alarm when a vehicle going out of the lane marking. In this review paper, we will study different methods of image processing, feature extraction, classification, pattern matching, thresholding, filtering etc in brief. Initially, some pre-processing methods are using for the lane feature extraction and later for road lane marking detection. Then a warning should be given depends on vehicle departure by using other methods. We are having the aim to present a brief picture of the past research efforts through comprehensive discussions.

***Keywords*: Lane Detection, lane departure, lane tracking, Digital Image Processing, region of interest as an (ROI), feature extraction, pattern matching.**

I. INTRODUCTION

With the improvement in the mass of vehicles, the amount of car accident victims has risen yearly. .Many accidents are caused by an absence of knowledge of driving states due to driver carelessness, inattention or visual interference. An Advanced driver-assistance system an (ADAS) is regarded as an important technology to reduce such accidents. Autonomous systems like this are used to guide the driver in vehicle driving procedure. For this it is providing applications as lane detection, tracking and departure warning system, ACC, BCI etc. It is used to automate, develop, adapt and intensify vehicle systems for better driving safety and this automated ADAS applications is used to reduce road destructiveness, by decreasing the human faults. Safety features are meant to avoid collisions, accidents, and crashes by extending technologies that warn the driver to possible obstacles or to avoid crashes and collisions by implementing Protection and taking over directional command of the vehicle. Adaptive features may automate illumination, present an adaptive cruise control application (ACC) and collision avoidance (CA), incorporate traffic warnings (ITW), connect to Smartphone, alert the driver of other vehicle or dangers, lane line departure warning application, automatic lane centering, automatic blind

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spots detection. Lane line detection and line tracking are considered as a basic module for ADAS. In addition, information about the lane detection used to detect nearing vehicles and obstacles.

Digital Image processing: Digital image processing facilitating the many complex algorithms, and hence, can generate both more advanced execution at mere operations, and the implementation of operations which would be challenging by analog methods.

In today's computer science arena, a digital image and signal processing (DIP and DSP) methods would be used in various computer algorithms to do processing on digital signals and images. As a range of the digital image and signal processing having lots of mileage over analog image and signal processing. It provides a significantly wider array of algorithms which can be implemented on the data and can reduce and eliminate difficulties such as the noise and signal malformation while processing. Since situational images are marked over two dimensions and multi-dimensions and this may be represented in the sort of multidimensional systems.

II. CLASSIFICATION OF METHODS OF LANE DETECTION, TRACKING, AND WARNING

Different terms of Digital image processing: Feature extraction, Patter recognition, classification etc.

Smart Vehicles have the potential to better road safety, minimize traffic jam and boost the efficiency of transportation by using these techniques. They would be able to recognize their next environment, interact with other traffic things, and could travel autonomously in highway and urban scenarios using video sensors, maps, GPS and so on.

A. Different image processing methods are given below:

a. Thresholding
b. Segmentation
c. Feature Extraction
d. Edge Detection
e. Noise Removal
f. Classification and Pattern Matching

III. DIFFERENT METHODOLOGIES OF LANE DETECTION, TRACKING, AND DEPARTURE WARNING SYSTEM

Christopher Rasmussen et al. [1] in 2002, presented a methodology of feature extraction which describing results on collective information from a color and texture image cues and laser range-finder are used to segment unstructured asphalt, gravel, and smut roads as input data to various autonomous vehicle system. An amount of laser and camera pictures were captured at frame-rate on a diversity of rural roads, catering to correlate the various image features like a histogram of color and response of Gabor filter with laser features like smoothness and 3-D height. Based on some neural network training on feature vector which is clustered by road, the set of road models was generated. In first step, the classification of the novel road image is done, and in a further step

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a suitable next-stage classifier was being decided for segmentation of individual pixels, by this high rate of precision is achieved on arbitrary images. And these segmented images are combining with the laser limit data and the vehicle's navigation information were used for 3-D maps for finding path.

Joel C. and Mohan M. Trivedi et al. [2] in 2006, presented a methodology feature extraction for various Driver-assistance systems was observed driver intention, warn drivers for lane departures, or assist in vehicle driving are all being actively considered. These driver-assistance objective leads to the progress of the novel approach “video-based tracking and lane estimation” (VioLET) system. The system is created using steerable filters for sturdy and reliable lane-marking detection. Steerable filters provide an efficient method for detecting circular-reflector markings, solid-line markings, and segmented-line markings under varying lighting and road conditions.

They were support in supplying robustness to difficult shadowing; illuminations turns from tunnels and overpasses, and road-surface irregularities. They are effective in lane-line marking extraction due to the calculation of only three deferrable convolutions, they can extract comprehensive lane markings. Curvature identification is made more effective by consolidating both vehicle-state information and visual signs (lane texture and lane markings). The evaluation of analysis design of the VioLET system is represented through various quantitative metrics over a variety of test cases on a large test data path using a novel instrumented vehicle. A justification for the range based on metrics past studies with human-factors terms and extensive ground surface testing from different road conditions, times of day, and driving and weather scenarios is also explained. In designing process of this system, a comprehensive and up-to-date analysis of the past work in lane tracking and detection research was performed. In addition to it, a methods comparison, detecting the differences, similarities, and exceptions among methods where and when a variety of methods are most useful, was explained.

J. Wang, Y. Wu, Z Liang, and Y. Xi et al. [3] in 2010, presented the methods of thresholding and canny edge detection for lane detection which is mainly concentrated on the processing rate of a system. They proposed a new road edge detection algorithm of Random Hough Transform as an (RHT) which is principally implemented on Region of Interest as an (ROI). The algorithm comprises the primary road edge determination furthermore the follow-up borders tracking. Initially, for edge detection, they used the HT; in the route tracking, And further RHT applied to the ROI of the image to improve in computational speed road edge discovery. Pre-processing the road image by converting from RGB to gray image, then after applying a pair of thresholding methods for higher image pixel clarity. And achieving canny edges of the lane line while employing the Sobel operator. Initial boundaries of the road are detected by HT (Hough Transform). RHT was further used to track and detect road lane lines.

Amol Borkar, Monson Hayes, Mark T. Smith et al. [4] in 2011, presented a methodology which is pre-processing the camera images, lane markings appear as lines are most of the thin and covering horizontal space. Consequently, feature extraction becomes tough since features of line changes as a function of distance from the camera due to the effects of perspective. So the image is undergoing the IPM which is Inverse Perspective Mapping also known as geometric transformation to remove the consequences of perspective. The taken images

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are modified to appear as birds-eye view with lane marking now seems as almost parallel lines. In addition, the thickness of those lines remains constant in the different IPM image. Pre-processing is inferred next reforming the different IPM image from RGB to grayscale and then it is filtered out using Normalized Cross Correlation (NCC) by using of thresholding method. The polar Random Hough Transform is used to fit lines through detected features and parallel line detection.

Raghuraman Gopalan, Michael Shneier, Tsai Hong, Rama Chellappa et al. [5] in 2012, presented a pattern matching and classification methodologies which was applied on road scenario analysis challenging dilemma that has an applications in autonomous navigation of vehicles. They have addressed these issues through a training based method using visual data inputs from a camera installed in front of an every vehicle. They proposed the following steps, first is, choosing the features of pixel-hierarchy of the lane marking in the nearby area; second is, a sturdy boosting algorithm to extract the associated contextual features for recognizing lane markings and; filter the particle to track it. Then they have examined the effectiveness of their algorithm on challenging night-time and daylight road video progressions.

Yue Dong, Liangchao Li, Jintao Xiong, Jianyu Yang et al. [6] in 2012, presented a real-time approach as a lane-detection and lane-tracking system which is using segmentation technique which was differs it from the previous ones in the different ways: firstly it uses an effective algorithms to deal with the nearest two lanes as a left and right, in situation where in the typical road with a multiple lanes line on it leads to difficulty in forming appropriate departure warning. Secondly it separately detects the right and right lane markings, whereas numerous past work uses a fixed-width lane model. As a result, it would be dealing with the challenging different scenarios such as merging or splitting lanes effectively even if one lane is gone, detecting number of lane lines which are not required, so as a result it issued false warning. Third is, the lane detection and tracking in a single algorithm, and there is more to be used than the information from a single image that can effectively deal with lane changes, such as emerging, ending, merging, that split or motivating lanes. Here images are converted from RGB to gray for efficient image pixel extraction by canny edge recognition method and it is performed in bottom to top manner.

Vijay Gaikwad and Shashikant Lokhande, et al. [7] in 2015, proposed an image preprocessing technique of PLSF i. e. (Piecewise Linear Stretching Function) basically on ROI (Region of Interest) of color lane images which are approximately 40% of the images. For improvement in contrast level of ROI, the input RGB image is converted grayscale image. Initially, the normalized grayscale values for pixels in the scale of [0, 1] are calculated which are further processed for gray values using equation as follows,

(1)

Where, , and , are the gray values.

Then further ROI is segmented into left (L) and Right(R) sub region which is equivalent to the binary image. Further, by applying HT (Hough Transform), the lane features are extracted and lane detection is carried out. For this, the below equation is used,

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(2)

Where, is the width of ROI.

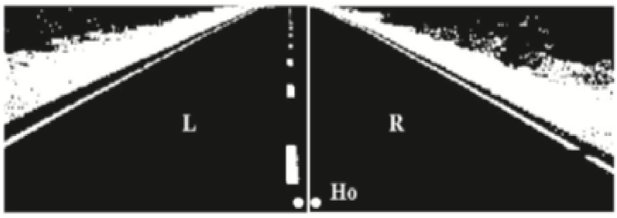

Figure 1. (a)Selecting. (b)Segmentation of the ROI (Region of Interest) in the equivalent binary image into the left (L) and right (R) sub regions, where Ho is Hough origin located in each sub region [7].

On the basis of the Euclidean distance between HT origin and the midpoint of the extracted lane lines, the departure warning will issue and they are of four types: No Departure, left Departure, Right Departure, and Danger.

Maurício Braga de Paula and Cláudio Rosito Jung et al. [8] in 2015, presented a method for road lane extraction and classification using a front-mounted camera. Initially, lane edges are distinguished by implementing a linear–parabolic road lane picture, and planned on-the-fly camera calibration. Further, by applying an adaptive smoothing transition to lessen noise while keeping adjacent edges separated and combinations of local maxima-minima of the gradient are used as signs to recognize lane markings. At last, a Bayesian classifier relied on composites of Gaussians is used to differentiate the lane markings there at each frame of a video data as, solid dashed, dashed, solid, double solid or dashed solid.

Chung-Bin Wu, Li-Hung Wang, Kuan-Chen Wang et al**. [9]** in 2018, presented an efficient method of lane identification and departure warning system by using minimum complexity block-based method. Relied on the lane lines in the surrounding of the vehicle, a parameterized ROI is calculated. For lane feature extraction and region of interest, the author has converted an image from RGB to YCbCr, which reduces the time for image processing by using the following equations,

$$I(x,y) = [0.9996 - 0.5608\ 0.41 \quad (3)$$

The lane markings which are in the ROI are having different luminance and chrominance in various environmental conditions, so for accuracy purpose, the pixel intensity is enhanced by applying the adaptive and effective thresholding method for lane detection.

$$L_i \quad (4)$$

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Where luminance in the ROI, ROI average has W and H as the width and the height of ROI of particular (x, y) pixels respectively and Y is luminance.

$$\{ \quad I(x, \quad 0 \tag{5}$$

Where and are the thresholds under different environmental conditions.

To reduce the burden of computation, the ROI is separated in non-overlapping sized blocks for calculation of block angles and block gradients by using two simplified masks methods. And it is calculating based on the next equation,

(6)

Where is the addition of the differences between the pairs of corresponding pixels and is the distance among the pairs of corresponding different pixels.

The driving conditions are classified into four classes as a No lane departure (NLD), leftward lane departure (LLD), rightward lane departure (RLD), and vehicle across a lane marking (VALM), to easier the lane detection and lane divergence warning system execution based on lane lines detection results.

Peijiang Chen, Junhao Jiang et al. [10] in 2018, presented a method which is essentially based on machine vision theory and the algorithm design of lane lines departure warning system and it is depends on the angle of input image processing. The algorithm mainly uses the matrix properties of the digital image to reduce the speed of processing. An adaptive image cutting technique based on a threshold value is combined with the image preprocessing, which efficiently removes the irrelevant parts and upgrades the speed of the algorithm. Based on the snipped images, the feature points of the lane line are derived by the edge enhancement, median filtering, edge extraction, binarization, and other preprocessing methods. Finally, the Hough transform and other analytic geometry methods are used to get the lane line and issue lane departure warning.

Yasin YENİAYDIN, Klaus Werner SCHMIDT et al [11] in 2018, presented a work which introducing robust and effective vision-based lane recognition method. It is removing noise efficiently. First of all two binary images derived from the region of interest of gray-scale images which was obtained from the pre-processing of the real-time image. Then those two binary images are merged by a novel neighborhood AND operator. For parallel lines, an image is changed to Bird's Eye View (BEV) by IPM (Inverse Perspective Mapping). After applying of Gaussian probability density functions is set to the left and right regions of histogram images got from the BEV. Finally, a polynomial lane model is estimated from the recognized regions efficiently.

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TABLE I : SUMMARIZED WORK RELATED TO LANE DETECTION AND DEPARTURE WARNING

Year	Author	Lane Identification Method	Classifier	Lane Detection	Lane Departure Warning	Dataset	Lane Detection And Departure Warning
2002	Christopher Rasmussen [1]	Smoothing, laser data range filter	Gabor filter, color histogram	Neural network, least square fit	-	Real time image sequence in rural area at ARMY demo project-III	-
2006	Joel C. McCall and Mohan M. Trivedi, [2]	Thresholding, smoothing	Steerable filter, BEV using IPM	VOiLET	-	Real time video sequence (various road conditions)	Good performance -
2010	J. Wang, Y. Wu, Z Liang, and Y. Xi [3]	RGB to grey, binarization, thresholding	ROI, histogram equalization, polarization	RHT and HT	-	Real time video sequence (15 f/s)	-
2011	Amol Borkar, Monson Hayes, Mark T. Smith[4]	RGB to grey	Normalised cross correlation, BEV using IPM	PRHT	-	Real time video sequence (2000 various frames)	-
2012	Raghuman Gopalan, Tsai Hong, Michael Shneier, Rama Chellappa [5]	Pixel hierarchy based feature extractor, spatial context descriptor	Outlier-robust boosting method	Robust boosting algorithm	Learning based method, Hough transform, Kernel discrimination analysis	Real time video sequence (various road conditions)	-
2012	Yue Dong, Jintao Xiong, Liangchao Li, Jianyu Yang [6]	RGB to Grey	Canny edge detection, sobel operator	Removing noise, point pixel searching based method	Point searching based method	Real time video sequence(0.12 s p/f, frame size is 640*480 pixels)	Correct Lane Detection - Over 91%
2015	Vijay Gaikwad and Shashikant Lokhande, [7]	Piecewise linear stretching function	ROI, thresholding	HT	Thresholding the Euclidean distance between lines	Real time video sequence (various lighting and road condition)	Correct Lane Detection - 97%
2015	Maurício Braga de Paula and	O-the-fly calibration, smoothing	-Bayesian classifier based	Gradient of lines	-	Real time video sequence	Correct Lane Detection -

	Cláudio Rosito Jung [8]		Gaussian function				96%
2018	Chung-Bin Wu, Li-Hung Wang, Kuan-Chen Wang [9]	RGB to YCBcr, Avarage Thresholding	Block Angle, ROI, Block Gradient, NLD, LLD, RLD and VALM	Gradient of block in L, ML, MR and R	Thresholding	KITTI and Caltech Lanes (Straight and Curved lanes)	Correct Lane Detection-95.70%, Lane Departure-98.85%
2018	Peijiang Chen , Junhao Jiang [10]	RGB to Grey, Novel Neighbourhood AND Operator	ROI, BEV, IPM	Gaussian Probability Density Function	-	Cordoval (solid, dashed, worn out and curved lanes)	-
2018	Yasin YENİAYDIN, Klaus Werner SCHMIDT [11]	Image cutting, median filtering, binarization	Edge extraction, enhancement	HT, RHT, Least square method, analytical geometric Method	Algorithm based on Angle between Parallel lines	Image	No Departure

IV. COMPARISATION OF METHODS OF LANE DETECTION, TRACK, AND DEPARTURE WARNING

In our review paper, Table I will give us the detail idea of different methods of feature extraction, classification, noise removal etc. for lane detection, tracking, and departure warning. By using these methods the features are extracted from the various type of images and videos. In most of the paper, the input is obtaining in real time from the front-facing camera of the vehicle. [7][9][5] In our survey we obtain the lane detection lowest accuracy of 91% [6] using Sobel operator, pixel-based searching and highest accuracy of 97% [7] using HT, ROI classification, PLSF methods and lane departure accuracy of 98.85% using thresholding method.[9]

V. CONCLUSION

In our review paper, we have studied the previous different image processing methodology by different authors thoroughly and it is very much helpful for us to choose an appropriate method for lane detection and lane lines departure warning efficiently throughout the road. As well as it is efficient in changing weather conditions, shadows on the road, condition of a road and much more. In a further paper, we will be using different methods of image processing and implemented to obtain an efficient result as well. And Based on this detection a necessary warning will issue to help the driver while driving a vehicle.

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