RESEARCH ARTICLE OPEN ACCESS

Lane Detection for Autonomous Vehicle

Dr Narapareddy Ramarao[1] B Vivek Bhat [2] Kartik Kulkarni[3] Ashley[4] Raban Akbary[5]
[1 2 3 4 5] *Department of Electrical and Electronics, BMSIT&M, Banglore-64*
Corresponding Author; Dr Narapareddy Ramarao

ABSTRACT
In recent years autonomous vehicle concepts has been evolving from 'maybe possible' to 'definitely possible'. These kinds of vehicles have two major tasks to accomplish that are, perceiving and processing the input data in order to navigate vehicle. Autonomous vehicles have the potential to improve safety by eliminating human error in driving. Research has been done to develop and implement path detection algorithms to detect and analyze the drivable path ahead of the autonomous vehicle. Some vehicles might use only cameras, whereas others might use a combination of cameras, LiDAR, GPS etc. One of the principal approaches is to detect road boundaries and lanes by using vision-based system on the vehicle. However, one of most challenging tasks regarding this approach is how to extract road center parameters, using vision-based input. The system acquires parameters using various input sensors installed on vehicle then applying algorithms hence, determining path coordinates to navigate autonomous vehicle. Research papers regarding path tracking methodologies suggest various approaches to solve the above-mentioned challenges have been analyzed and compared in this review report.

Keywords – Autonomous Vehicle, Digital Image processing, Lane detection, Path Detection Algorithms, Road Edge Detection

---

Date of Submission: 30-03-2019 Date of acceptance: 13-04-2019

I. INTRODUCTION

An autonomous vehicle is a self-driving car which is having sensors and various input devices installed in it to make it capable of gathering information of its environment parameters and navigating without human input. Various challenges are involved in lane detection due to variation in illumination caused due to different time of a day, weather and road textures. Also, shadows of trees, cars and other obstacles affects the lane markings and boundaries captured in the input image, further increasing the challenges. The performance of the algorithms is sensitive to these features. Hence, processing frame-by-frame, some algorithms fail or have few inconsistencies in their outputs. It is also found that in a constrained environment, it is easy for an autonomous vehicle to navigate and track the path, but it becomes difficult for the algorithm to process the same in real and dynamic world.

Literature survey related to autonomous vehicle technology is carried out; various methodologies for autonomous vehicle are taken into consideration. With respect to the above stated difficulties and drawbacks algorithm chosen should be efficient, possess high processing speed, low complexity, high computing efficiency, low memory requirement and easy implementation. Further, the algorithm should be flexible for future development and upgradation.

II. METHODOLOGIES

1. Asphalt Detection & Contour Tracing

Using asphalt detection algorithm [2], detection of asphalt (black/grey part of road) is done on which the vehicle is treading on, to get road edges, contour tracking algorithm is used. It is achieved in following process,

1.1 Region growing technique for segmentation

The idea behind simultaneous region growing technique is to choose a certain number of seed pixels (desired road pixels) in the image and start connecting the pixels in its neighborhood, as shown in figure 1.1 and 1.2, if they are similar to the seed pixels. This region grows only in the direction of the asphalt.

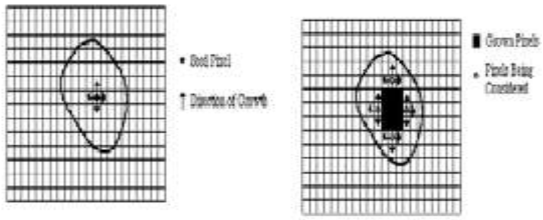


Fig**.1.1.1** Start of growing region and Growing process after few iterations

1.2 Texture detection

The texture segmentation is done by applying s and e filters which operate row-wise first and column-wise later, depicted in figure 1.2.1 & 1.2.2.

After applying the filter sparse noise is introduced in the image. In order to reduce noise, median filter is used.

Fig**. 1.2.1** EE filtered image

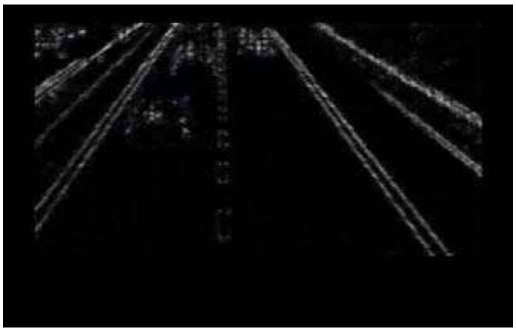


Fig. 1.2.2 SS filtered image

A supervised pixel classification is performed on these two channels. To compensate for errors and make texture more pronounced, a median filtering is applied on both images. [2] The convolution of the mask h[k,j] with the image x[r,c] signal is defined as given in equation (1).

$$\sum_{k=0}^{M-1}\sum_{j=0}^{M-1} h[k,j] * x[r-k,c-j]$$

Equation (1)

1.3 Merging two outputs

The simplest way to combine the information of region growing and texture analysis is to take the intersection of the output regions which have similar grey values. Finally, all the regions that are 8-connected (3x3 pixel kernel) and labeled similarly, obtaining the asphalt region, result is shown in figure 1.3.2.

Fig**. 1.3.1** Original image

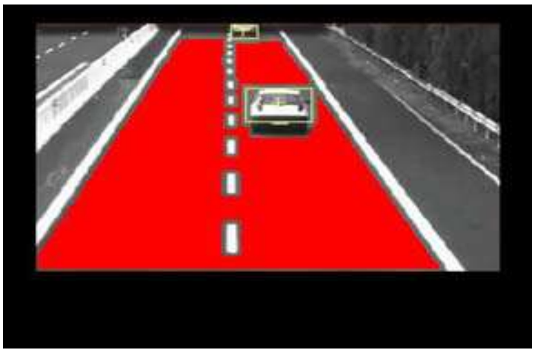


Fig.1.3.2 After asphalt Segmentation

1.4 Contour Tracing

It is applied to images in order to extract boundary pixels of a given pattern. The asphalt region is given a boundary to obtain road edges.

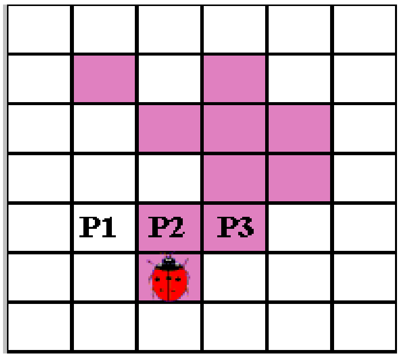


Fig. 1.4.1

In figure 1.4.1 it is shown that a pixel is selected on the asphalt as the starting pixel. It will keep on moving on its immediate left pixel until it reaches a pixel which isn't part of the asphalt.

Three pixels P1, P2 and P3 are selected and checked for desired grey value. The pixel having the desired grey value will the new starting pixel and it will be labelled as boundary pixel. In this way, the tracing of the boundary of the road is done.

Conclusion

In this method a framework of algorithms for autonomous vehicle with vision-based system is presented. Algorithms described here combine grey value difference and texture analysis techniques to segment the road from the image, contour processing algorithms are used to produce road boundaries. This system is economical as it only consists of a single camera mounted on the vehicle.

2. Fuzzy set theory

In autonomous vehicle navigation through path detection, primary goal is to achieve parameters of the road or path edge. This is done using the computer vision-based system installed on the vehicle. One of the attributes of those objects among color, texture, etc., edges is being the most widely used, since it determines shapes and contours which are useful features for vehicle guidance. Those features may be partially occluded or may be lying in poor uneven or varying conditions.

To counter the ambiguous input, fuzzy set theory is applied. The method is based on the fuzzy perception of the road edges from the gradient orientation image. Following is the process. In this the alignment of the camera that is mounted on the vehicle is set up with respect to the road or the path. Now parameters such as: -

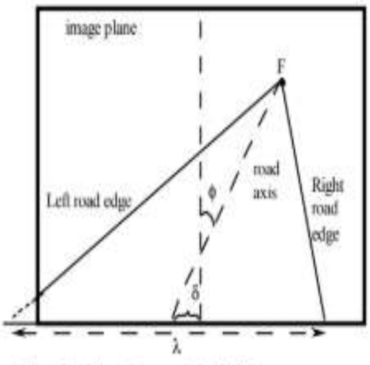


Fig. 2.1 Scene mode alignment

From the above given figure 2.1, the following parameters are explained:

1) Vanishing Point F: point is determined by the intersection of the road edges. Maybe inside the frame or outside it.
2) Orientation error φ: angle between the road axis and the vertical axis of the image plane.
3) Shift error δ: shift in pixels is measured at the bottom of the image plane between the image vertical axis and the road axis.
4) The path width λ: Pixels measured at the bottom of the image plane allows the evaluation of the physical path width.

Fuzzy Mapping Function – It is used for creating a gradient orientation image. It is used as a first step in the image processing. It takes in the input of the frame and according to the algorithm it sets a perception-based algorithm, on which the following output is shown:

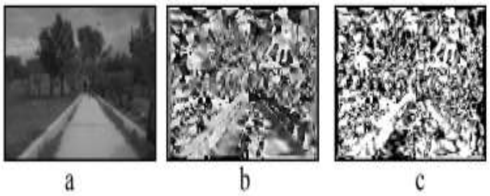


Fig. 2.2 Orientation

In 'a' the original image is fed. 'b' shows that that a gradient orientation image is formed. After that the orientation image in the perception domain is created.

Measure of fuzziness – Method adopts entropy to measure the fuzziness of the gradient orientation image. It usually involves using Shannon's function to measure the fuzziness of an image. The intensification operation is achieved by the mapping I(Θp) given as :-

$$I(\Theta_p) = \Theta_s = \begin{cases} \int_\theta 2\mu_\pi^2(\theta) & \text{for } 0 \le \mu_\pi(\theta) \le 0.5 \\ \int_\theta [1-2(1-\mu_\pi(\theta))^2] & \text{for } 0.5 \le \mu_\pi(\theta) \le 1 \end{cases}$$

Equation (2)

Using the equation (2), histogram is plotted, in figure 2.3, histogram is plotted using this function, in which it is set that way, in a particular duration of set it will increase and after that interval it will decrease and so on.

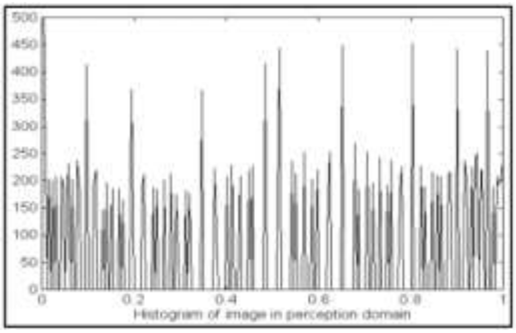


Fig.2.3 Histogram

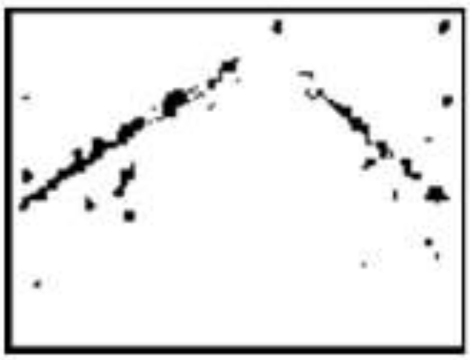


Fig. 2.4 Output

Now, to extract the left and right edges, the dominant linear features are separated and plotted using a particular set of variables.

Hence, in figure 2.4 we can see that road edges are obtained using which the central points of the road or the path can be calculated which is used for guidance of the vehicle.

Conclusion

This approach, the conventional number of edge levels are found to be reduced to minimum since the edge information obtained from the gradient direction image. Consequently, road edges may be easily determined by a simple search among the reduced set of edge levels. The papers show that there is significant decrease in the error over the time when compared to the classical approach which is simply based on the intensity of the domain.

3. Feature selection algorithm

Feature is one of most important factors for building a good classification system. For example, grey colour regions in the middle-bottom of the image are road. That is a feature useless by itself may be useful together with others. So, feature combination can provide correlation information of features. Utilizing these correlations may further improve the performance.

There are two kinds of algorithms for feature selection:

1) Feature selected by ranking: The features collected from training are ranked basis on a particular characteristic of it. Used as a principal or auxiliary selection mechanism.
2) The subset selection method: It includes, two subset methods. Wrappers and embedded method. Wrappers search for the required features in a brute force way, requiring massive amounts of computation. Embedded method uses process of training and machine learning.

3.1 Data collection and training

The paper suggests collecting various images with shadows, multi-coloured paved surfaces and poorly defined borders. The images are from several sets of data collected from a camera mounted on vehicle.

For training the algorithm, region of interest is selected manually that is labeled as road. A training set is created is which road region feature is labeled 1 and non-road region feature is labeled -1. Then, the features are combined according to the combine function using correlation between them.

3.2 Feature selection

Support Vector Machine is basically a classifier used for data feature selection. It is used for data mapping in a required plotting space. The data used for learning is placed in that space on which SVM algorithm is applied for classification. Now, the new data is fed to the already trained data set to get the data output.

This output refers to the plot where, the particular given region belongs to the road dataset or not (labeling as done previously). The classification accuracy of SVM classifier is based on different feature sets.

3.3 Road detection

The blue regions in Fig. 3.1 are the regions classified into the road.

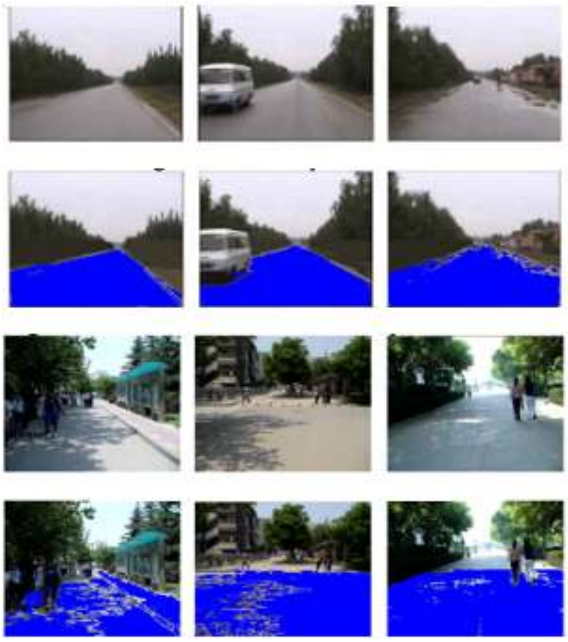


Fig. 3.1

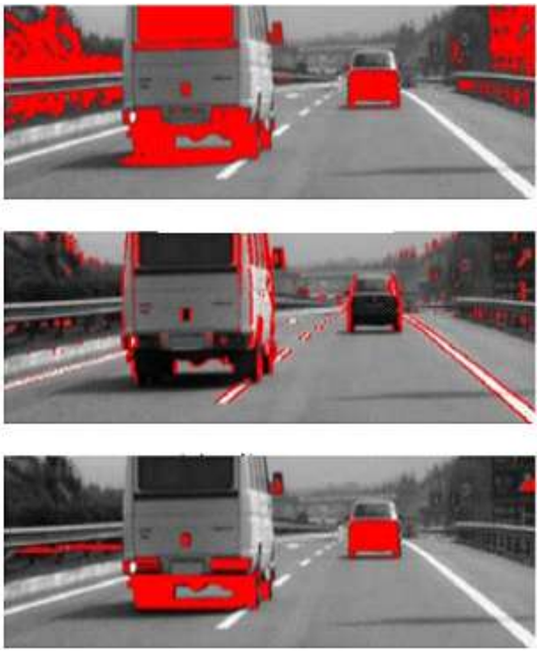


Fig. 3.2

Using SVM, various edges and grayscales changes can be, classified accordingly and marked for the desired outcomes which are depicted in figure 3.1 and 3.2.

	Frame	Vehicle	Hit	Hit Rate	False	False Rate
Scene 1	3184	5759	5701	98.99%	38	0.66%
Scene 2	2367	6324	6198	98.01%	65	1.04%
Scene 3	2683	3145	3012	95.77%	39	1.28%
Scene 4	2331	3678	3479	94.59%	56	1.58%
Scene 5	2712	8667	7943	91.65%	398	4.77%
Total	13277	27573	26333	95.50%	595	2.21%

Fig. 3.3 [19]

Above is the experimental data obtained [19]. The results obtained are having significantly high percentage of success rate.

Conclusion

Papers present a vision-based real-time vehicle detection approach. The key part of research papers is that it exploits the correlation of the features, combination functions are used to combine features. After that the selected features are weighted according to the power of its classification. SVM-based classifiers are used in the process of data training and after which the further image processing is done. One aspect where this method lacks is near shadows, when compared to other algorithms.

4. Canny edge detection & Hough transformation

The front view of the vehicle is captured using the vision system mounted on the vehicle. The video is converted into frames and each frame goes through pre-processing. It includes cropping each frame to our region of interest, conversion from RGB to grayscale and then applying noise reduction algorithm.

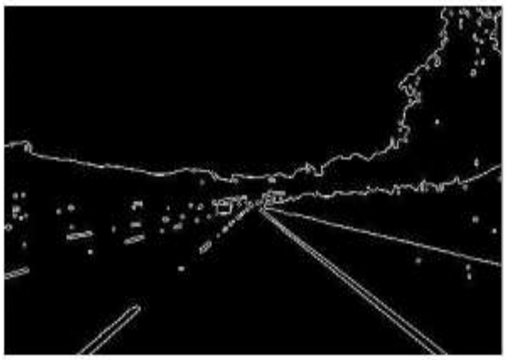
For edge detection, authors have used canny edge detection and Hough transformation. An edge is set of connected pixels that lie on the boundary between two regions. The pixels with high gradient values are the image edges where some of them correspond to road boundaries.

4.1 Canny edge detection

Many papers suggest that Canny edge detector for the reason that it is having a very desirable characteristic that it does not produce noise like in other approaches. The edge is represented as white and non-edges will be black. Pixels not having high gradient values will get suppressed. Further edges are sharpened by using hysteresis. It basically consists of high threshold that allows a group of pixels to be classified as edge points. A low threshold then determines which group of pixels will not be edge points and permits only those points that increments the connectivity of previously determined edge points.

If the gradient magnitude is less than the first threshold value then the pixel value is replaced by 0, otherwise replaced by 1.

Fig 4.1 Original image



Edge Detection by Canny

Fig. 4.2

4.2 Hough transform

Hough transform can used to detect straight lines, circles, ellipse and other shapes. Its function applied to the edges within the mask to extract the lane lines in the image.

In captured images since lanes are in the bottom half of image, a region of interest trapezoidal mask is created to ensure that none of other lines outside region of interest interfere with algorithm.

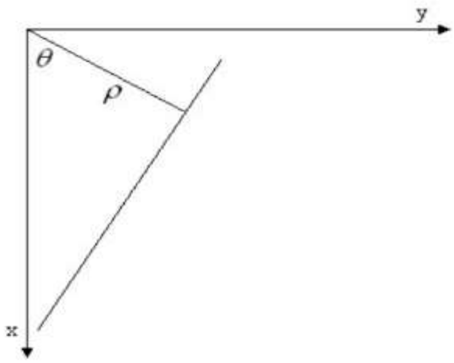


Fig. 4.2.1

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

for ρ $\pm\sqrt{\#rows^2 + \#cols^2}$

Equation (3)

Hough transforms searches for lines using the equation above given in figure 4.2.1The images are split in half yielding right and left side of the image. Each right and left sides are searched separately returning the most dominant line in the half image that falls within the 45-degree window. Horizon is calculated using left and right hough lines and projecting them on their intersection. These parameters obtained by these algorithms are then used for the vehicle guidance and proper navigation.

Conclusion

In this methodology, the input image from vision system is pre-processed, and canny operator is used for edge detection. It performs better than other edge detection algorithms but takes more computational time. Hough Transform was used to identify the lanes and determine the look-ahead distance and the lane angles. Experimental results have demonstrated that this methodology is fast, accurate, and efficient.

5. Lidar Application Based

LiDAR (light detection and ranging) enables self-driving car to pursue the information around it. It gives continuous 360 degree of visibility and also precise information. It is mounted on the vehicle, as a box which revolves around continuously, throws laser pulses. It measures how long it takes for the laser light to return to the sensor.

Planning Safe Trajectories: The safe planning of trajectories in local plane is done using LiDAR. Each revolution of the LiDAR generates a section cutoff surrounding. The data of each revolution is stacked upon one another to build 3-D map of the surrounding.

In research paper [20] it is mentioned that a road segmentation algorithm was developed to obtain road boundary points in the sensors path of the vehicle.

Object Detection: As LiDAR have become higher resolution and can operate on longer ranges it is used in object detection and tracking. LiDAR not only helps us to planning safe trajectories but it can also detect and track obstacles like car, pedestrians etc. Modern LiDAR helps us to differentiate between a person on bike and walking person. It is also capable, detecting at what speed and direction the obstacles are moving.

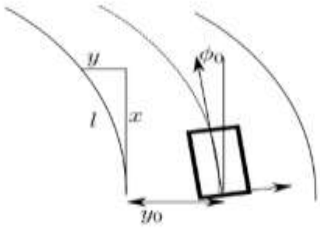


Fig 5.1 Clothoid Geometry

$$\phi(l) = \phi_0 + \int_0^l C(t)dt$$
$$= \phi_0 + lC^0 + \frac{l^2}{2}C^1$$

Equation (4)

$$x = x_0 + \int_0^l \cos\phi(t)dt$$
$$y = y_0 + \int_0^l \sin\phi(t)dt$$

Equation (5) [20]

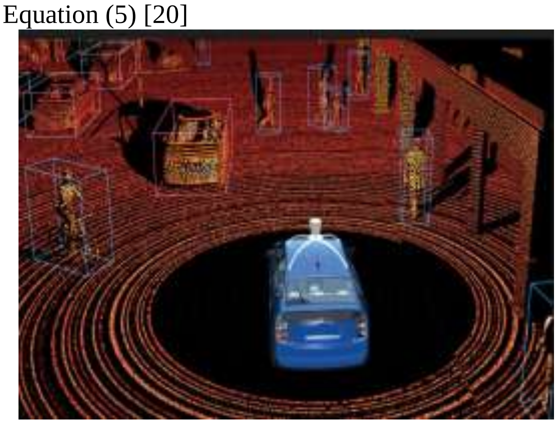


Fig. 5.2

Conclusion

Method mentioned in the research paper states that, it is very efficient despite the large rate of data collection from the sensor. It is capable of estimating the road surface edges without any assumption about road marking. LiDAR based method is particularly effective in structured environment. The combination of capability of LiDAR like navigation, mapping and high-resolution object detection has made the LiDAR a key sensor in autonomous cars today.

6. Machine Learning Using OpenCV

The autonomous vehicle will have a vision-based system. Computer vision algorithm that detects and tracks the boundaries of drivable regions appearing on input images. This makes the vehicle make use of dynamic input, frame-by-frame. Paper suggests that there are many other methods like hough transform and Least mean square method. They are quite susceptible to noise and have poor accuracy of lane identification. So, we use machine learning. It helps in getting outputs accurate for even the bends or turns in the road or path. OpenCV, works on machine learning algorithms. It requires a data set for its training.

To achieve identification of drivable region boundaries**,** the pre-processing [18] of the input video signal is done in following steps.

- Graying: - To improve the computation and remove redundant information and improve the processing speed.
- Image De-noising: - The noise reduction is done using various filters as suggested by the papers.
- Binarization: - Using Ostu threshold method as suggested by the author, distinguish the target object and the background.

The above process is depicted in figure 6.1.

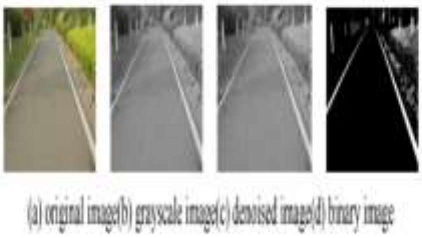


Fig. 6.1

Lane Recognition: The path or the roads that are employed have proper markings and have lanes too. In following steps, the OpenCV detects the lanes and hence the parameters required: -

1) It is trained for the road or path using videos/ frames already captured.
2) It will generate a dataset accordingly which will be used for the new recognition of the road.
3) New data is provided to OpenCV in which it detects the desirable parameters.

The following figure 6.2 depicts the process,

Fig 6.2

Research papers also suggest that, OpenCV can be used or clubbed with other algorithms such as Hough transform to have a better result.

III. CONCLUSION

Lane recognition system based on OpenCV is feasible, and this system may fully meet the design requirements, it has good effect in the practice. The algorithm, which set ROI, can greatly shorten the processing time. And when the ROI is set priority to optimization, not only the real- time performance of the system is improved, but also a high robustness is maintained. Even if the road information completely lost, papers suggest that the system performance is good, and has the practical value. Also, it can be installed at very low cost and is versatile in its use for practical and experimental uses.

REFERENCES

[1]. Farid Bounini, Denis Gingras "Autonomous Vehicle and Real Time Road Lanes Detection and Tracking" 2015 IEEE Vehicle Power and Propulsion Conference (VPPC) 19-22 Oct. 2015 Montreal, QC, Canada
[2]. Tolga Birdal, Aytül Erçil "real-time automated road, lane and car detection for autonomous driving" Published 2007.
[3]. Thomas Churack "Improved Road-Edge Detection and Path Planning For an Autonomous Sae Electric Race Car" 26th October 2015.
[4]. Larry S. Davis, Todd Kushner "Road boundary detection for autonomous vehicle navigation" 1 March 1986
[5]. Jasmine Wadhwa, G.S. Kalra and B.V. Kranthi "Real Time Lane Detection in Autonomous Vehicles Using Image Processing" Research Journal of Applied Sciences, Engineering and Technology 11(4):429-433 · October 2015
[6]. Khalid Bin IS, Adznan Bin Jantan "An Autonomous Vehicle Driving Control System" International Journal of Engineering Education 21(5):855-866 · April 2005
[7]. Kodi Balasriram, Manimozhi M "Curve Path Detection in Autonomous Vehicle using Deep Learning" May 2018 IEEE International Conference on Robotics and Automation (ICRA)
[8]. Suvarna Shirke, Dr.C.Rajabhushanam "A Study Of Lane Detection Techniques And Lane Departure System" Published in June 2018
[9]. Balakrishna Yadav Peddagolla, Santhosh Sivan Kathiresan, Nikhil S. Prabhu, Ninad C. Doshi, Mehrdad H. Zadeh, Ph.D., "On the Lane Detection for Autonomous Driving: A Computational Experimental Study on Performance of Edge Detectors" Published in July 2015, South African Transport Conference at Pretoria
[10]. Sukriti Srivastava Manisha Lumb Ritika Singal , LCET Katani Kalan "Improved Lane Detection Using Hybrid Median Filter and Modified Hough Transform" Published in 2016.

[11]. Ajit Danti, Jyoti Y. Kulkarni, and P. S. Hiremath "An Image Processing Approach to Detect Lanes, Pot Holes and Recognize Road Signs in Indian Roads" Published in Jan 2012
[12]. Guangqian Lu "A Lane Detection, Tracking and Recognition System for Smart Vehicles" Published 2014 in MSWiM
[13]. Young-Woo Seo, Ragunathan (Raj) Rajkumar "Detection and Tracking of Boundary of Unmarked Roads" 2011 IEEE International Conference on Robotics and Automation
[14]. George Henrique Rangel Costa, Fabiano Baldo "A method to automatically identify road centerlines from georeferenced smartphone data" Published 2011 in COM.geo
[15]. Sunil Kumar Vishwakarma, Akash, Divakar Singh Yadav "Analysis of Lane Detection Techniques using OpenCV" Conference: 2015 Annual IEEE India Conference (INDICON)
[16]. Gowdham Prabhakar, Binsu Kailath, Sudha Natarajan, Rajesh Kumar "Obstacle Detection and Classification using Deep Learning for Tracking in High-Speed Autonomous Driving" Published in 2017 IEEE Region 10 Symposium (TENSYMP).
[17]. M. Elarbi Boudihir, R. Nourine, D. Ziou "Visual Guidance of Autonomous Vehicle Based on Fuzzy Perception". January 1998
[18]. Xu Yang, Zhang Ling "Research on Lane Detection Technology Based on OpenCv" 2015 3rd International Conference on Mechanical Engineering and Intelligent Systems
[19]. Xin Liu, Bin Dai, Hangen He "Real-time On-Road Vehicle Detection Combining Specific Shadow Segmentation and SVM Classification" 2011 Second International Conference on Digital Manufacturing & Automation
[20]. Teddy Ort, Liam Paull, Daniela Rus "Autonomous Vehicle Navigation in Rural Environments without Detailed Prior Maps" 2018 IEEE International Conference on Robotics and Automation (ICRA)

Dr Narapareddy Ramarao" Lane Detection for Autonomous Vehicle" International Journal of Engineering Research and Applications (IJERA), Vol. 09, No.03, 2019, pp. 28-35