Smart and Interactive Features for Lane Detection

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Abstract

The advent of newer and more sophisticated automobiles has greatly pushed the performance limits in terms of speed and maneuverability. However, this has greatly increased the risk of driver losing control over their car, resulting in accidents. Many techniques have been proposed in the past that addresses this concern by limiting the movement of the car to a particular lane only. Practical implementation of such systems demands highly capable hardware like TDA3x which can perform real-time processing. The efficiently designed code helps the individual tasks to run and complete on a particular processor core independent of what the other core is doing. The main emphasis given in this paper is to implement the Lane Detection and Warning System (LDWS) on a Texas Instruments Driver Assist 3x (TDA3x) board with a frame resolution of (1920×1080p) at 2GHz, compared to the existing implementation that provide a resolution of just (480*270p) at 100MHz.The work proposed in the paper is to detect the lane for any range of camera height to road width ratio between [0.3 to 0.8] Since the standard ratio on Indian roads is approximately 0.524, the proposed algorithm would work well under the given idealistic road conditions in India.

Keywords: *Lane Detection and Warning System (LDWS), Canny edge detection, Hough transforms, Vanishing point estimates, Principal component analysis, TDA3x*

1.0 Introduction

There can be various reasons for an accident to occur on the road. There are also circumstances where the accident occurs due to sheer negligence on part of the person controlling the vehicle. To overcome this problem there is a need for an autonomous system designed and implemented inside the vehicle which work independent of the person controlling the vehicle. The advantage of having such setup of autonomous system inside the car is that they will be able to identify the errors committed by the driver and also predict the possible collisions. This will not only alert the driver on his mistakes, but also help him to overcome such mistakes by taking corrective actions, on-time.

Among the many applications that the autonomous systems can provide, implementation of Lane information detection (LID) is proposed in this paper. In this application (LID) camera is placed on the bonnet of the car captures the

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video frames, and then extracts the information related to the lane markings that are laid on the road. Based on the available information, the movement of the vehicle will be tracked, and a suitable warning shall be issued to the driver in advance. This will not only alert the driver, but also help to avoid the possible collision before it is too late to respond for the driver.

In the past, lot of research ideas were proposed by various authors in the field of vehicle safety. Detection of the lanes based on the fact that lines which are drawn on the road will be thick in nature; the individual lane markings have a non-zero width [1]. The work proposed [2] focus on increasing the processing speeds than on the accuracy of lane detect system by reducing the resolution of the captured image. Papers [3-4] focused on the noise aspect of the image to enhance the quality and also performed illumination adaptability for adjusting to various lighting conditions on the road. Authors in [5] highlights the specific bottlenecks in the existing techniques, such as the obstruction caused by the presence of vehicles, unclear markings of the lane, shadow obstructions due to buildings, etc. Authors [6] and [7] also worked on solving the issue of poor visibility of the lanes at hilly regions due to the dynamic weather conditions such as rain, fog, haze, etc that are prevalent. Work proposed in [8] perform lane detection based on vision processing, where techniques such as perspective mapping, deep neural networks, vanishing point estimates, and other mathematical models were used.

However, to implement the proposed idea in real time, there is a requirement for a suitable hardware which is capable of supporting the highly complex algorithms that takes up a huge computational time. Also, these kinds of applications demand for the use of highly optimized hardware that can allow the real-time processing of the captured images. Texas Instruments has developed a hardware called “TDA3x” whose whole purpose is to support the implementation of the Advanced Driver Assistance Systems (ADAS) applications. In this work, the entire operation of the lane detection and warning system is divided into smaller tasks, with each task allocated or made to run on a different processor. Thus, the efficiently designed code helps the individual tasks to run and complete on a particular processor core independent of what the other core is doing.

2.0 System Development

Real-time processing of the applications will be possible only when the hardware which it uses is capable enough to provide support for high speed processing. The work proposed in the paper used TDA3x hardware for implementation of lane info system. The figure 1 depicts the block diagram for the same. To implement the lane info system, an ISS OV10640 omni vision camera is used to capture the video frames which is then connected to the board via CSI2 interface. Also, the developed application code is dumped into the board by flashing it through a SD card. Hence, every time a code is modified, it needs to be re-flashed into the board. Here, the detected lanes and in turn the lane cross warning is displayed to the end user through the use of a HDMI LCD display.

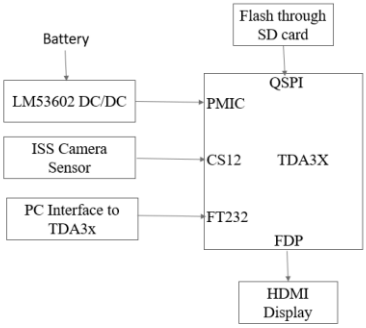

Fig. 1. Block Diagram of Lane Detection and Warning System (LDWS)

TDA3x board works on a supply of 12V. Since the car's battery can generate a voltage drop of 12V across its terminal, this lane info system can be easily setup inside the car.

2.1 Methodology adopted

This section gives details information about the methodology adopted for the proposed algorithm used for lane detection system. The fig. 2 depicts the flowchart of the steps that needs to be accomplished for the same.

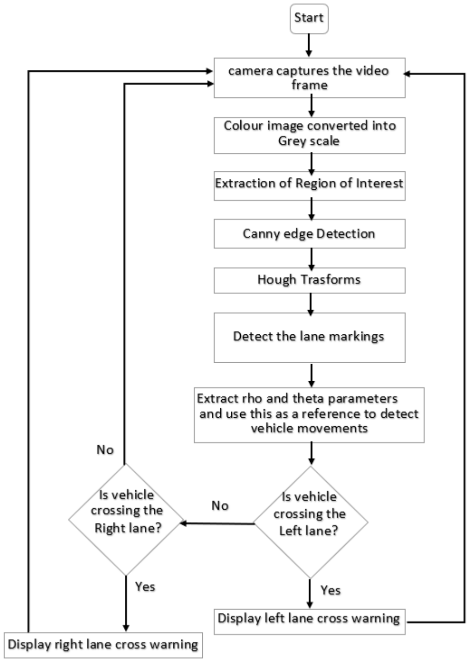

Fig. 2. Flowchart for the LDWS Lane Detection and Warning System (LDWS)

When a camera captures a video stream, it should be converted into a grey scale image as canny edge detection can only operate only on the monochrome images. The extraction of Region of Interest (ROI) boundary helps to limit the search area of the algorithm and hence eliminates any unwanted details from the captured image. Though canny edge detection helps to identify the lane edges in the input image, Hough transforms will help to generate a mathematical relationship between those edge points, be it a straight line, a parabola, or a circle. Hough transforms will also help to extract the polar equivalents of the obtained lane coordinates to help track the position of the lane with respect to the test vehicle. By incorporating all the algorithms mentioned above, any accidental lane drifts by the car can be easily identified and suitable action can be taken by the system.

2.2 Experimental details

The government bodies (RTO) who paint the lanes on the road will ensure that they always run parallel to each other. However, the way a camera looks at these lanes in reality will be quite different. As the camera is placed parallel to the road surface, the lanes in front of the car appears to look like a trapezoid, instead of a rectangle. As a result, the lane boundary near the camera appears to be thick, while it looks thin at the far end. The fig. 3 depicts this phenomenon.

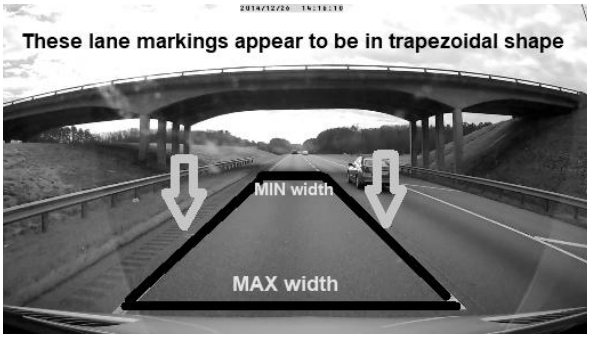

Fig. 3. Viewpoint of the camera

For the Lane Detection and Warning System (LDWS) to identify the trapezoid, the four extreme vertices of this trapezoid needs to be determined first. This is done by extracting the information of the lane points at the output of the Hough Transforms block. The fig. 4 depicts the pictorial representation of the trapezoid.

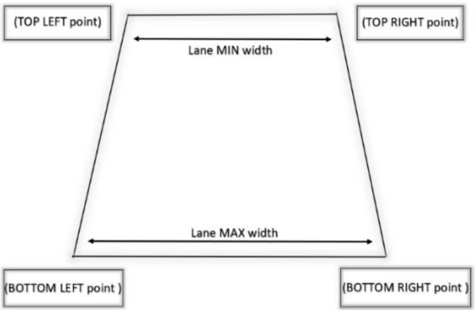

Fig. 4. Pictorial representation of the trapezoid

Once the 4 vertexes are obtained, 2-point formula can be used to generate the equation of a line and in turn identify the lane markings. Suppose that there exists any two points in space, (x_1,y_1)& (x_2,y_2). To extract the polar counterparts (rho and theta) from the given straight line, a perpendicular line has to be drawn from the origin to the line. This is shown in the fig. 5.

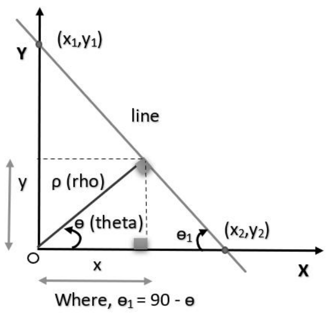

Fig. 5. Extraction of polar counterparts from a line

The pictorial representation of the lane under normal condition is shown in fig. 6. Here, "$ɵ_1$" denotes the angle subtended by the left lane while "$ɵ_2$" denotes the angle subtended by the right lane. Similarly, "ρ1" denotes the magnitude of the perpendicular to the left lane and "ρ2" denotes the magnitude of the perpendicular to the right lane. When the car is moving well inside the current lane, it is said to be in normal condition.

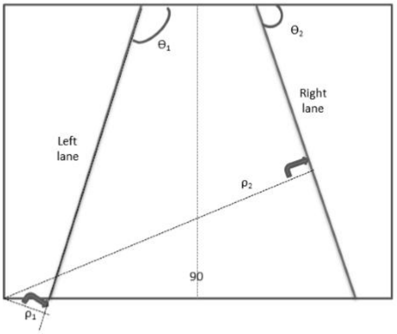

Fig. 6. Pictorial representation of the lane under normal condition

When the car drifts to the left, then the angles subtended by both the lanes will decrease, while magnitude of the perpendicular to the left lane increases and magnitude of the perpendicular to the right lane decreases. The fig. 7 depicts the above criteria.

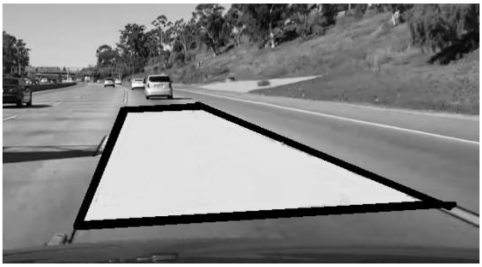

Fig. 7. Pictorial representation of the lane under left lane drift

Similarly, When the car drifts to the right, then the angles subtended by both the lanes will increase, while magnitude of the perpendicular to the left lane decreases and magnitude of the perpendicular to the right lane increases. The fig. 8 depicts the above criteria.

Fig. 8. Pictorial representation of the lane under right lane drift

The above concepts will be used to obtain the results for the proposed lane info system.

3.0 Results and Discussion

Based on the concepts that were discussed in the previous sections, screenshots of the obtained result are shown, followed by their detailed analysis. The fig. 9 depicts the screenshot of the detected lanes under normal condition.

Fig. 9. Screenshot of the detected lane under normal condition

The fig. 10 depicts the screenshot obtained during the left lane cross warning, and the fig. 11 depicts the screenshot obtained during the right lane cross warning.

Fig. 10. Screenshot obtained during left lane cross warning

Fig. 11. Screenshot obtained during right lane cross warning

The above experiment was also conducted by making use of a carboard sheet and a cello tape to mimic the lane markings on the road. The output was analyzed for various configurations of the camera parameters, and the resulting readings were tabulated, as shown in the table 1 and table 2. It is important to note that all these seven values are user configurable. Based on the parameters in table 1, the efficiency of the lane info system can be altered. This is because, when the car is moving inside the lane, it has some set of (Rho & Theta) values for the left and the right lanes.

Table 1. Lane cross warning results

Sl. No	Left theta (max, min) in degrees	Right theta (max, min) in degrees	Left rho (max, min)	Right rho (max, min)	Type of road (single/ double lane	camera angle w.r.t vertical axis	Lane cross warning results
1	130, 126	46, 45	140, 133	151, 150	Single	0	Left/right warnings correctly observed
2	130, 126	46, 45	140, 133	151, 150	Double	0	Left/right warnings correctly observed
3	130, 126	46, 45	140, 133	151, 150	Double	30 deg to the right	Left lane cross is detected with difficulty. Right lane cross is detected easily
4	127, 126	41, 40	140, 139	151, 145	Single	30 deg to the right	Left lane cross is detected with difficulty. Right lane cross is detected easily
5	127, 126	41, 40	140, 139	151, 145	Single	30 deg to the left	right lane cross is detected with difficulty. left lane cross is detected easily
6	127, 120	41, 39	149, 139	151, 150	Single	0	Left lane cross is detected with difficulty. Right lane cross is detected unreliably
7	130, 126	46, 45	140, 133	152, 150	Single	0	Left/right warnings correctly observed

Now, when the car tries to drift across the left/right lane, depending on the direction of the drift, even the (Rho & Theta) values also change.As a result, the algorithm continuously monitors the obtained values with the (MAX, MIN) threshold pairs that have been set by the user prior to the experiment. So, effectively the algorithm issues a left/right lane cross warning to the end user when the real time (Rho/Theta) values exceed the above threshold values.

The readings for various parameters of the camera is shown in Table 2. After analyzing the obtained readings from the table 2, it can be concluded that the performance of the proposed application depends on the relative difference between the height of the camera and the width of the road. As the ratio between these two values keep increasing, then it gets more and more difficult for the lane info system to detect the lanes correctly. At the same time, when the ratio gets too low of a value, then the lane markings on the road cannot be detected accurately. This is because, in both the cases, lanes in the captured image goes well beyond the processing range of the algorithm.

Table 2. Readings for various parameters of the camera [17]

SL. No	Height of the camera from ground (inches)	Width of the road (between the lane markings) in inches	Camera banking angle (wrt Horizontal axis) in degrees	Ratio between Camera height and road width	Result
1	3 (least height)	13.6	0 (parallel to the ground)	0.22	Lane detected
2	3	13.6	5 ↓	0.22	Lane detected
3	3	13.6	10↓	0.22	Lane detected
4	3	13.6	30↓	0.22	Lane not detected
5	10	13.6	0	0.73	Lane detected
6	10	13.6	20↓	0.73	Lane detected
7	15.8	13.6	0	1.161	Lane not detected
8	15.8	13.6	20↓	1.161	Lane detected
9	17	13.6	0	1.25	Lane not detected
10	17	13.6	20↓	1.25	Lane detected
11	3	25.3	0	0.11	Lane not detected
12	10	25.3	0	0.39	Lane detected
13	10	25.3	10↓	0.39	Lane detected
14	10	25.3	20↓	0.39	Lane detected
15	17	25.3	0	0.67	Lane detected
16	17	25.3	20↓	0.67	Lane detected
17	24.5	25.3	0	0.968	Lane not detected
18	24.5	25.3	15↓	0.968	Lane detected
19	30	25.3	0	1.18	Lane not detected
20	30	25.3	25↓	1.18	Lane detected
21	35	25.3	30↓	1.38	Lane detected

If at all, the user wants to still be able to detect the lanes correctly at higher ratios, then the camera needs to be titled downwards by a small angle such that it no longer is parallel to the road surface. The placement of the camera will remain universal across all the brands of the car until it satisfies a particular criterion that the ratio between the camera height and the road width remains within the range (0.3 to 0.8). The proposed system can work for cars of any dimension. When the ratio goes beyond 0.8, the algorithm can be still made to work by changing the camera angle. The very nature of the proposed system makes it scalable and also portable.

4.0 Conclusions

The existing techniques that implement the lane information detection on the Xilinx's Zynq-7000 APSoC platform supports only a resolution of (480×270p) at 100MHz [16]. Whereas, the TDA3x board used in the proposed work supports a full HD resolution of (1920×1080p) at 2GHz. Hence, the lane markings from the captured video streams will be sharper and the detected edges will be highly accurate. Also, due to the higher frequency of operation, there will be no cluttering of the video streams during run-time.

The speed of the vehicle should not matter until the lane markings are clearly captured by the camera. If the captured image of the camera appears blurred due to potholes, humps or even sudden jerks, or even due to the obstacle ahead of the test vehicle, then this algorithm will not be able to work as expected. The above work has not been tested for the application on a curved road. It has only been tested on a straight road. Hence, the lane info system may not be able to work on sharp bends (as seen on hilly roads). However, considering the fact that the regular highways in our country have relatively lower curve gradients compared to the hilly roads, algorithms mention in paper can work satisfactorily.

The authors would like to thank Mr. Ameermon V A, senior staff Engineer, Ignitarium Technology solutions Private Limited, for his constant support and encouragement throughout.

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