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Advanced lane detection technique for structural highway based on computer vision algorithm

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ABSTRACT

Lane departure detection plays a vital role in the Advanced Driver assistive systems and it improves the vehicle's active safe driving. A wholesome lane detection method which is based on computer vision techniques, is introduced. The lane boundaries and its radius of curvatures and lane direction were detected from a stream of videos. This video footage was recorded from a camera mounted on the top of a vehicle. We have corrected the camera distortion in the input frame. HLS thresholding and sobel thresholding techniques are applied to the undistorted image for getting focus on the lane lines in the binary image. Then the resulted frame is warped to the bird's eye by applying the perspective transform. The respective lane line pixels are identified using sliding window search and then left and right lane lines are identified by fitting second-degree polynomials. The lane curvature and deviation from the lane centre are also computed after the identification of the lane. The identified lane boundaries are warped back onto the input image and the radius of lane curvature and vehicle position is calculated and displayed. Hence this technique is enforced using python programming language and for processing the images open CV is utilized. The obtained result illustrates how the proposed method accurately detects the lane line in different lightning conditions.

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1. Introduction

Road accident is most complex problem in the worldwide. In India almost a person dies of road accident in every four minutes. During the year 2013 nearly 1.37 lakhs individuals died of road accidents alone. Sixteen children die on Indian roads every day. These accidents are caused by improper construction of road, interruption of people and animals, slippery road and curved ones. Therefore, it is necessary to detect the lane marking in the road to avoid over speeding of the vehicles during turning in the curved road conditions and to reduce irregularities in the lane change and lane occupancy. The detection of lane using computer vision algorithms is designed for warning system. The necessity of the camera is increased as it can capture an environment in various directions with the boundless blossom of computer vision-based technology. In the proposed lane detection technique two important thresholding algorithms are employed such as sobel thresholding and HLS thresholding for the identification of lane line in the binary image. After distinguished the lane lines in the perspective transformed image, the complete path of the lane and the direction of curve is computed by using sliding window technique.

The radius of curvature of the lane and its distance from the centre was computed and the video was warped back onto the vehicle view. The system effectively detects the lane margins in the road, radius of curvature of the lane and its distance from the centre. The proposed system is best for narrow and crooked roads and also has the capability to work in different lighting conditions. By this several accidents will be reduced and also the welfare of human life and assets will be ensured. Qing Lin et al. [1] detect the position and sort of the lane inside the input frame with the aid of the usage of vision-based totally techniques. At first, this technique extracts the lane mark candidates within the input frame through using a prolonged edge link algorithm with a directional cease gap ultimate which produces more complex edge-

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hyperlink features. Candidate lane-mark edge hyperlink pairs are picked with complicated edge-link features that are orientation and width. By combining lane-mark and edge-link capabilities, lane speculation became generated. By using the Bayesian chance version which is based totally on lane-mark shade and edge-hyperlink length ratio the continuity of the lane is checked and the lane-departure version is built. This model detects the lane vicinity in real-time. The camera facilities and standard background is not available in this algorithm. Ninty two Percentages of detection rates for average of 50 m per frame is achieved through the technique of lane departure.

C. Ma, L. Mao et al. [2] uses Heuristic Search Methods to identify the lane boundary points by converting the original RGB image into Lab colour space and Heuristic Search technique narrowing the search region, this algorithm is powerful and compatible to the particular road conditions. But this algorithm doesn't work with the poor quality of images. J. Baili et al. [3] converts the ROI into YCbCr colour space and the edge detection is done by employing a horizontal differencing filter. The modified Hough transform algorithm sorts the edge point into lines. But the tracking mode has to be upgraded, on account of false detection in some cases of road lines especially when there is a modification in the road lane. J. Son et al. [4] Clustering Algorithm is implemented to detect the lane-line. Yellow and white lane lines are separated using illumination variance. The detection is poor if lane line is used to get damaged because of worn and it can be submerged by shadows.

Wenhui Li et al. [5] the detection of lane marking is executed by way of three phases. First, the ROI is bisected. Then the detection of lane lines by using applying Hough transformation on each subregion, after this section, we will get a collection of seed points. By detecting the slope we are able to estimate the sort of the lane. If, it was a curved lane rational cubic B-spline curves are employed inside the becoming of the lane. Extended Kalman Filter is implemented for the monitoring of lane line which produces an excellent lane detection result Changzheng Hou [6]. In this lane detection technique, the ROI is extracted from the input image and this is divided into 2 elements and it has sections in a single direction. Because of this, the system of fitting the curve turns into easier to achieve. The split areas are again divided into 3 or greater sections. Because of this, the areas end up tiny, with the aid of the use of this method lane cannot be accurately detected and the segmentation changed into additionally poor. The feature can accommodate multi shapes and not with geometrical land line algorithm. But this technique is liable to external factors and makes it lack of its robustness A. Kamble and S. Potadar. [7]. The road and divider edges are detected using canny algorithm the noises present in the edges are the barriers to detect the lane and it is removed by Hough transform algorithm. The distance for measuring gap is calculated using Euclidean distance. The combination of Euclidean distance and the PLSF algorithm provides improved accuracy under varying lighting conditions. Huval B, Wang T, Tandon S, et al. [8] present a lane-line detection algorithm on the basis of a fully convolution neural network (FCN). Because of not using the time-domain information for the detection of lane-line and this method doesn't have the universal applicability.

Kim J and Lee M. [9] initially, the edges in an image are calculated using a hat shape kernel after that the lanes are detected using the CNN combined with the random sample consensus. If there was a simple road condition, the lanes are simply detected by employing only the RANSAC algorithm. The proposed method accurately detects the lane even in complex road conditions. But the results are too dependent on the range of complexity of the input image. If a lot of noise present in the input image then the detection was slightly worse. H.Wang et al. [10] use a curve detection algorithm that supported an instantly-curve version that has higher applicability for the curve street conditions. The ROI is break up into 2 areas consisting of immediate place and the curve place. The instantly-curve mathematical version is also established simultaneously. The curve fitting method is used to identify the equation of the curve. The curves are identified and assumed instantly and reconstruction of lane line is detected. The disadvantage is foggy climate detect only near field of lane line and not far field. However, this algorithm assists the safety driving for the drivers in curved lines [11]. Gaussian filter is used to remove the noise and median filter is used to overcome the blurring image. The line is detected using Hough transform [12]. The shape and colour features are extracted to detect the lane clearly and covariance matrix is used instead of normal matrix to detect the RGB features. The edge detection is used to measure the shape features [13]. The colour image is converted to gray image and adaptive threshold is analysed from characteristics of the road [14]. Python language is used to find out effective solution. The linear SVM is used to detect the lane during day and night time [15]. The unwanted background is removed to segment effective foreground image; ROI is extracted using superimposing the gray image over the colour image [16]. The land is clearly detected using edge detection and it is applied in remote sensing area to segment the land fileds.

2. Lane detection of curved road with straight- curve model on vision

In this system, the lane detection established using a straight-curve model algorithm. At first, the ROI is extracted from the input image. The straight region is acquired by using Hough transform and curved region is acquired by least square curve fitting method. The curve model is built by relationship between straight and curve model.

2.1. Division of ROI

The input image was greyed and binarized. The each line of the input road image is accumulated. The difference value of pixel accumulation was calculated but adjacent of 2 adjacent rows. The 2 rows were obtained by performing subtraction between current row and previous row's calculation. Finally the extern search is applied to the difference values and the horizontal line position was founded out. Then the ROI was extracted.

2.2. Division of straight and curve region

For the division of straight and curve region, 2 approximations are made. The straight line matched to near field for the lane detection and curved line considered as far field of the detection system. That is lane which is in the near field of view was considered as straight line and lane which in the far field of region was approximated as curved region. The linear structure of straight and curve model are initiated by land line system of straight and curve surfaces.

2.3. Straight model resolving

The lanes in the near field of region are considered as the straight line and the mathematical equation for the straight line was expressed in equation (1).

$$y = kx + b \tag{1}$$

In the straight model resolving, equation (1) needs to be solved. The Hough transform has greater significance in the straight model resolving. The general representation of the Hough transform is expressed in parametric equation (2).

$$\mathrm{P} = x cos\theta + y sin\theta \tag{2}$$

The lane-lane is located on both sides of the vehicle. The Hough transform produced the slope values of the right lane and left lane that is connected with the linear model equations. $K = -1/\tan\theta$ and $b = \rho/\sin\theta$ can be obtained and the parameters of the linear model equation can be obtained.

2.4. Curve model resolving

The least-squares curve fitting method is used in the curve model resolving. The main motive of this method was minimizing the real and fitting value error to satisfy the data point. Depending upon this, the curve model equation parameters can be resolved.

2.5. The switching of a straight curve model

The driver is alerted before the vehicle reaches the curve. The threshold is set by solving residual error value which is calculated by difference between detected straight line and second lane line. When the error value is greater than threshold the driving mode automatically changes to straight line. The disappearance of straight and curved point is used to find the direction and angle of bending.

2.6. Determination of bending direction

By identifying the curve's vanishing point and relative position of the straight intersection, we can estimate the bending direction of the curve. It can be performed in 4 steps: (1) Hough transformation obtains linear equation and parameters. (2) The Bisecting position of the left and right straight line lanesis calculated, (3) The disappearing point of curve, meeting point of straight line and curve's direction are predicted. Leftward bending and rightward bending are calculated using bisected point of straight line (4) The bending direction is identified by numbering the pixel value of an intersection and inflection point of an image.

2.7. Disadvantages

If the slope of the lane is large, the obtained output will slightly deviate. Therefore, the recognition method desires to be stepped forward on this case. The near field recognition is identified accurately comparing to far field recognition in lane detection system Fig. 1.

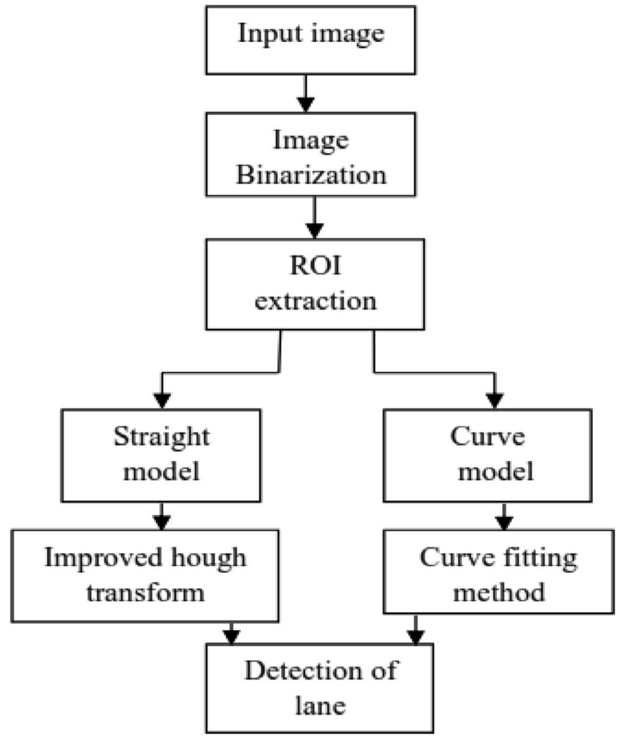

Fig 1. Lane detection using straight-curve model on vision.

3. Proposed method

The proposed lane detection technique is illustrated here used computer vision techniques to detect lane lines on a structural road captured employing a camera mounted at the front of a car. This technique makes use of the Open Source Computer Vision Library (OpenCV) throughout the detection process. The overall procedure of the proposed method is illustrated in the block diagram Fig. 2.The sobel thresholding and the HLS thresholding is employed here. It used the sliding window search to illustrate the lanes and curves on the road.

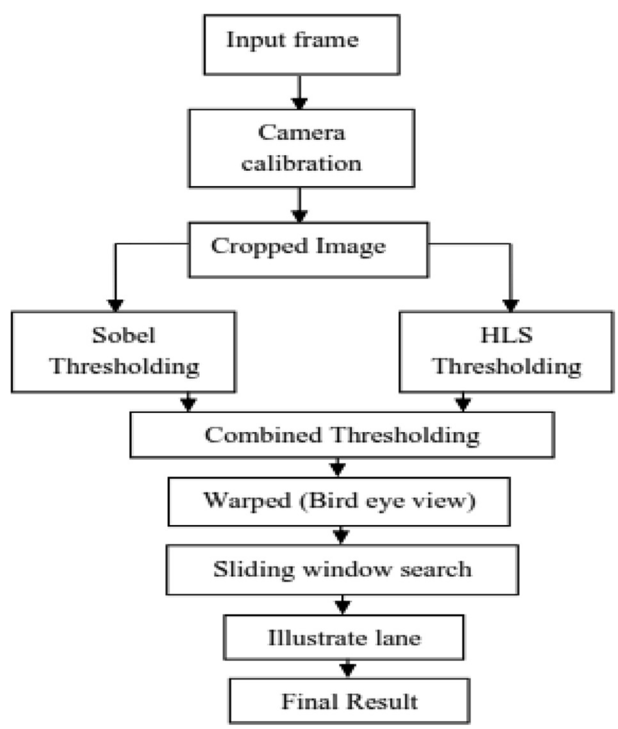

Fig 2. Proposed lane detection technique based on computer vision algorithm.

3.1. Camera calibration

The input video which is captured from the digital camera can be subject to some distortions. Those distortions are caused by the optical design of lenses and also by camera position relative to the object or by the location of the object within the image frame. These distortions can affect the accuracy of the lane detection process. We had to overcome those distortions to correctly detect the lane line in the image. The camera is calibrated to capture images of the check board pattern. The inside corners within the picture and it's a deviation from the expected measurement was calculated. By using this information distortion matrix and distortion coefficients are calculated to undistorted the calibration image is given in Fig. 3.

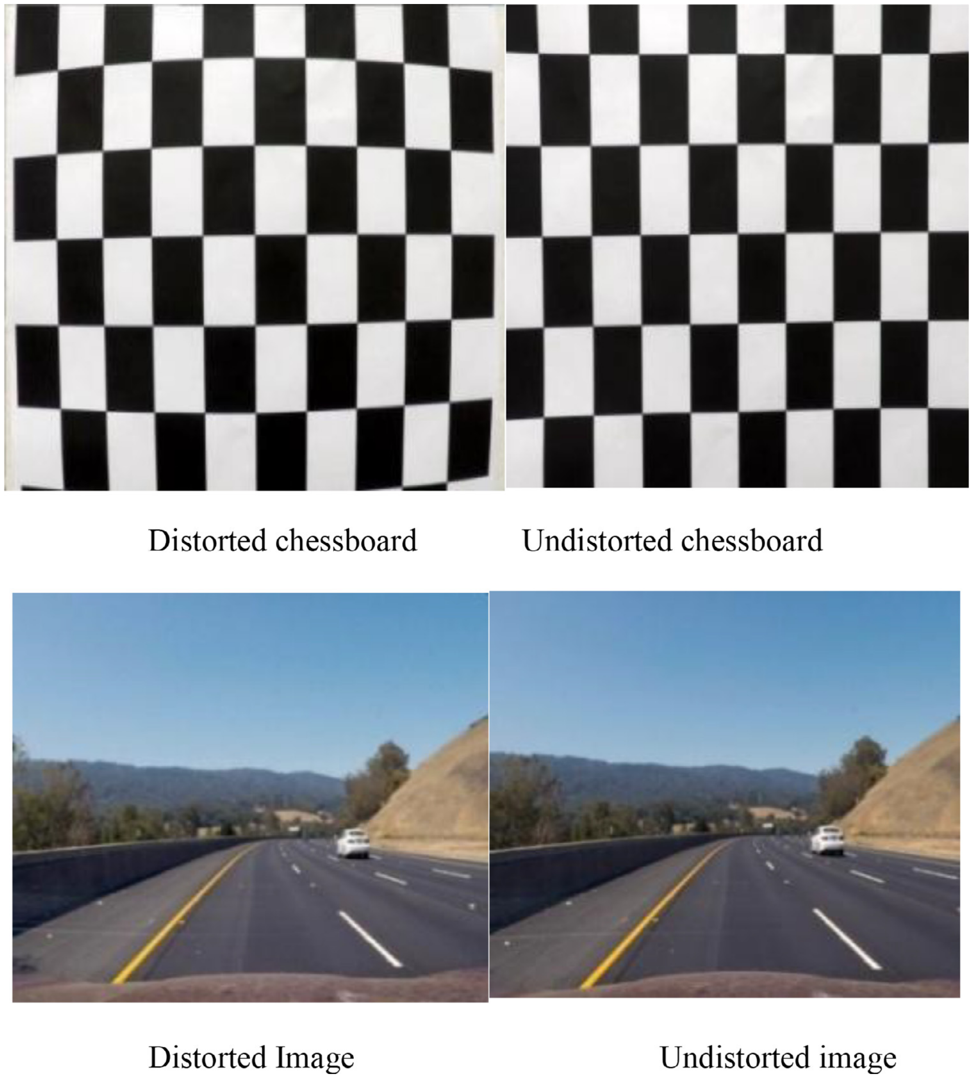

Fig 3. Images before and after fixed distortion.

3.2. Cropped image

Cropping can be described as the process of removing unwanted or irrelevant portions of a photo. Cropping also lets visually focus on the main subject. Cropping is helpful to bring attention to the main subject. In the determination of lane lines, we have to focus only on the areas where we are expected to see the lane lines. So, we go for a cropping operation. Which makes the overall process pipeline faster by performing further image processing only in the particular regions. The Fig. 4 illustrated the cropped image focusing on the region of lane lines.

3.3. Image thresholding

Thresholding is used to split a photograph into the smallest segments to outline limitations. It is a way to get a binary photo from a shade photo or greyscale image. The binary photograph reduces the complexity of the procedure of the reputation of the lane line from the photograph. It was greater efficiency in the pics with excessive contrast.

3.3.1. Sobel thresholding

When using a Sobel thresholding algorithm, it uses what is called kernel convolution. A kernel is a 3×3 matrix consisting of differently weighted indices. Sobel operator carried out the 2-D spatial gradient measurement on images. It was a pair of horizontal and vertical gradient matrices such as x and y axis. The image is processed in x and y directions separately. Here, the lane lines were proceeding only in the vertical direction so the y axis was more weighted. The result obtained after applying sobel thresholding is shown in Fig. 5. It reduces the impact of noise in an image.

3.3.2. HLS thresholding

It has three components such as hue, lightness and saturation. The HLS thresholding is very useful complex lightning conditions. The hue and saturation components contain total colour information. So it is very easy to extract the yellow and white lines from HLS transform image. The diminishing edges in the image are threshold by the lightness component. The output obtained after employing HLS thresholding is given in Fig. 6.

3.3.3. Combined thresholding

Then the final thresholding result is obtained by combining both the sobel thresholding and the HLS thresholding to improve the precision of the lane detection. The final output image after combining both the thresholding into one is shown in the Fig. 7. In which the lane line is distinguished from the cropped image.

Undistorted image Cropped image

Fig 4. Cropped image after removing unwanted portions.

Cropped image Sobel thresholding

Fig 5. Resulted image after applying sobel thresholding.

Cropped image HLS thresholding

Fig 6. Output obtained from HLS thresholding.

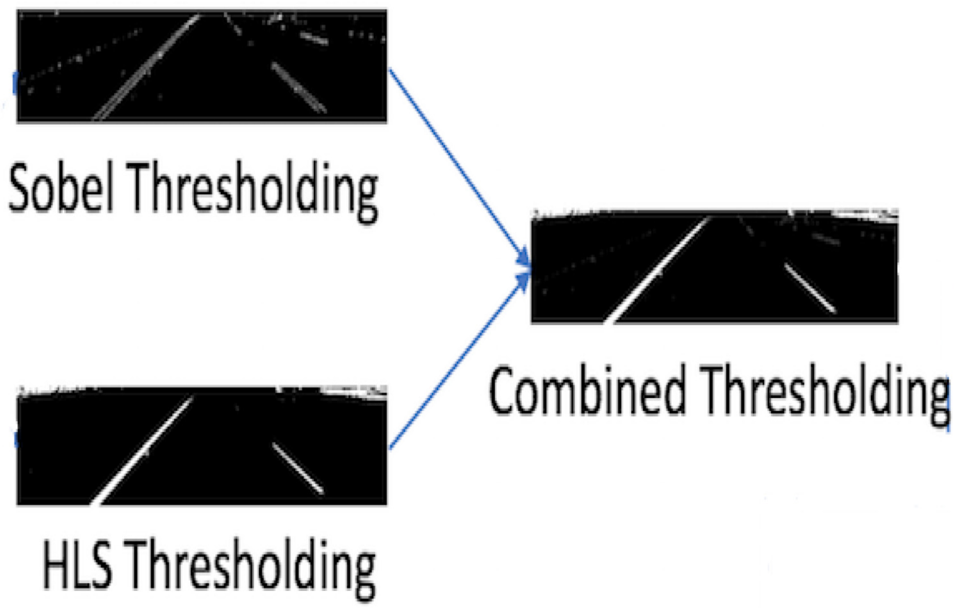

Fig 7. Final thresholding output after combining HLS and sobel thresholding.

3.3.4. Perspective transform

Images captured from cameras might subject to perspective distortion. The objects closer to the camera source appear as larger and smaller when they are further away is known as perspective distortion. The input image appears like the lane lines are converge each other after a distance but actually they are parallel to each other. To fix this, apply perspective transform which converts the 3D real world image into 2D bird's eye view, where the lane lines are always parallel to each other. By applying this, we can figure out the exact direction of the lane line in the image. The resulted output after applying the perspective transform is demonstrated in the Fig. 8.

3.3.5. Sliding window search

Since the lane traces are already detected in the earlier step, we understand the starting x function of the pixels from the bottom of the image which yields the lane. Here, one window on the pinnacle of different windows follows the lanes up the body. We average the x values of the pixels a good way to get the appropriate identification of the base point of the next window above. Here, one window on the pinnacle of other windows follows the lanes up the body. This manner is repeated over and over until we get the pinnacle of the lane. Fig. 9 represents the outcome of the sliding window search. In this way we've accumulated all the pixels which we're fascinated in, to compute the radius of curvature of each lane line. The second-order polynomial equation for the curve is expressed in equation (3).

$$f(y) = Ay^2 + By + C \tag{3}$$

The x and y positions are used to get the pixel values of left and right lane line. This search algorithm works faster and reduced more amount of process time.

3.3.6. Illustrate lane

The sliding window seeks easily diagnosed the lane starting from the pinnacle point of view. The illustrated lane is shown in Fig. 10. The green bins constitute the windows, blue and crimson-colored traces imply the lane.

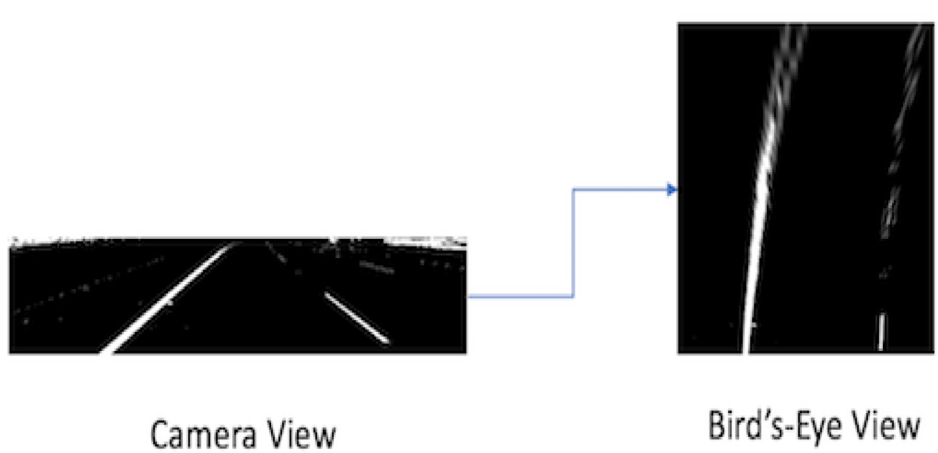

Fig 8. Output obtained after applying perspective transform.

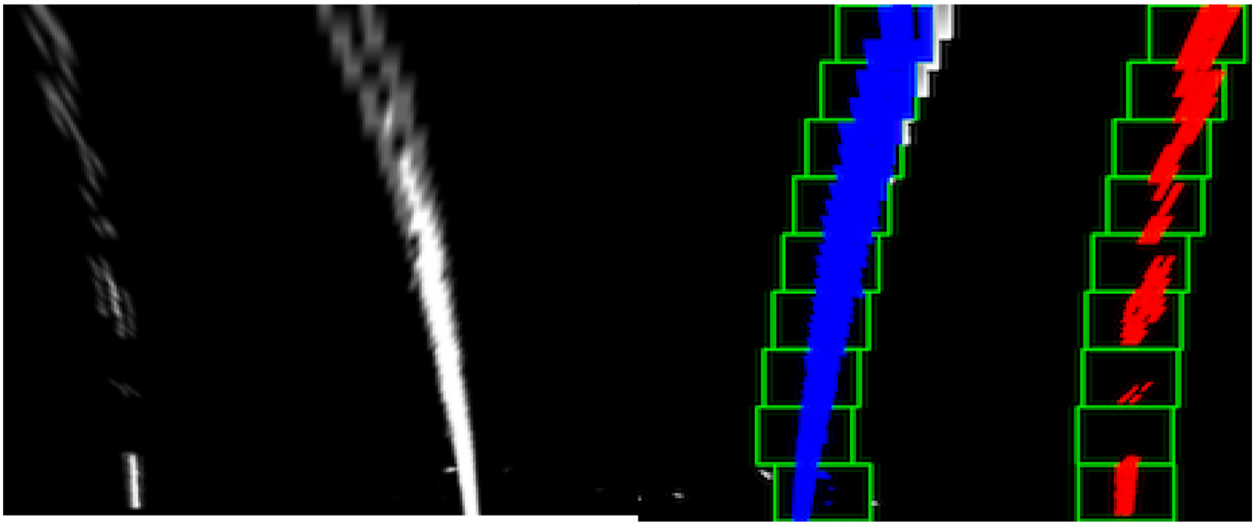

Fig 9. Sliding window search output.

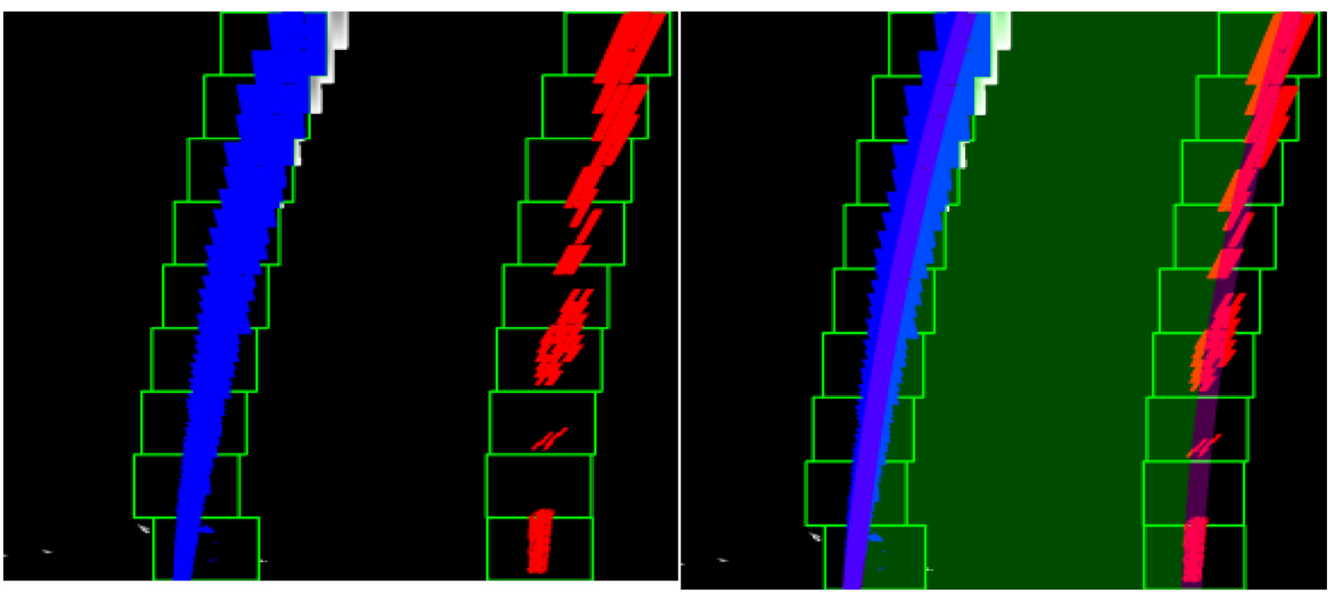

Fig 10. Illustrated lane from the resulted image of sliding window search.

The shaded lines are represented into the input image after that cropping operation is performed in the illustrated lane image. This was expressed in Fig. 11. Here the two pink lines denote the lanes and the space between them which was green in colour denotes the road surface.

Value of radius of curvature of the lane was calculated by measuring the radius of a smallest circle which is tangent to the lane line. The radius value would be very large for the straight lanes. The pixel space was converted into meters by clarifying the proper pixel height to the lane length and pixel width to the lane width ratio. Vehicle's distance from the centre of the lane was calculated by offsetting the average of bottom co ordinates of left and right lane lines and then subtracting the centre point as an offset and it was multiplied by lane's pixel to real world lane width ratio.

3.3.7. Unwarping to camera view

The rectified photograph has been warped returned on the check image for the identification of lane obstacles. That is converting the bird's eye view of the unique undistorted picture format. The process becomes executed body by body. The lane barriers are properly identified and warped returned into the undistorted check image, proven in Fig. 12.

4. Result

The proposed lane detection technique is executed in python programming language on Windows operating system environment. The OpenCV library is nothing but a python programming

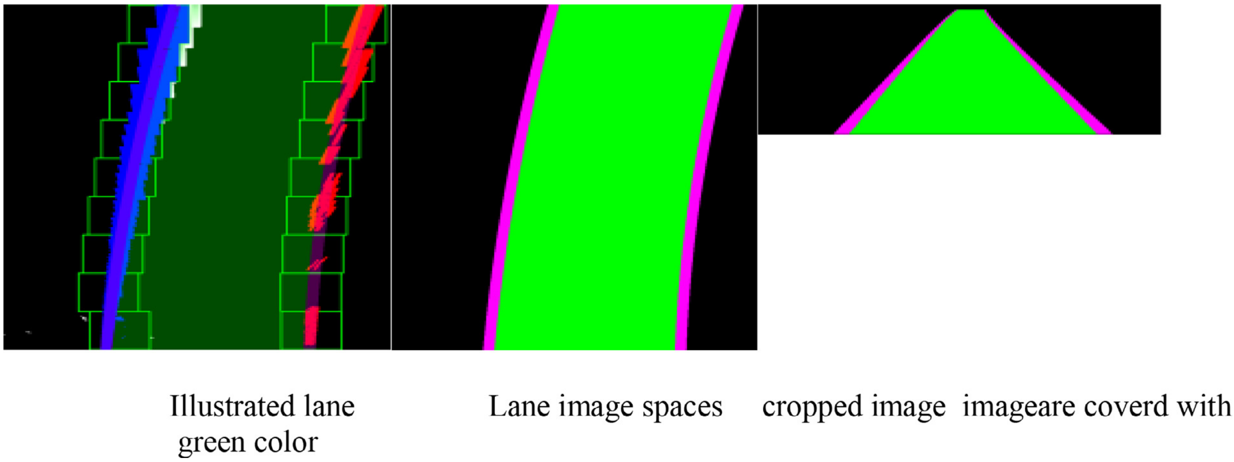

Fig 11. Illustrated lane image after cropping.

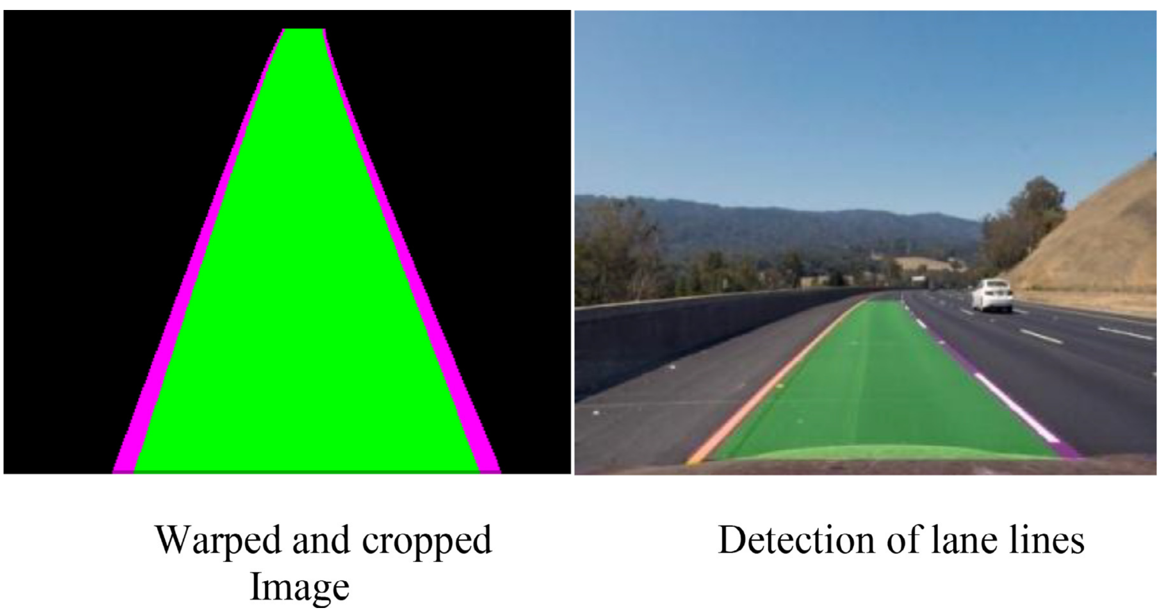

Fig 12. Final result of lane detection.

language. Spyder is a Scientific Python Development Environment (IDE) that is finely protected by the support of Anaconda. It is used here to support the implementation of lane detection algorithm.

The experimental result was expressed in Fig. 13 which shows the outcome of lane detection algorithm using sobel thresholding, HLS thresholding and sliding window search algorithms. This detection algorithm detects lane accurately in normal lightning condition and visualize the lane. The radius of curvature of the lane and its distance from the vehicle and the direction of curve are computed and visualized. This technique works well in normal lightning condition.

5. Conclusion

The proposed a lane detection technique using computer vision based algorithms which accurately detects the lanes and curve on the road and make prior warning to the drivers. So that many accidents can be avoided due to the overspeeding of vechiles on the curved regions of the road. We have implemented this algorithm by using python programming language. This technique uses multiple thresholding algorthims like sobel thresholding and HLS thresholding and uses sliding window technique to distinguish the lane in the road. It can be implemented in real time on the roads which having perfectly marked lane lines. This system can be embedded with any kind of hardware for the assistance of ADAS.

6. Future work

In future other relevant computer vision techniques can be applied to this system which is not covered by this project and the proposed system can be implemented to the embedded system for the real time detection of lane and curves on the road. This can be implemented in Autonomous vehicles for lane keeping assistance system.

Fig 13. Resulted output.

CRediT authorship contribution statement

K. Dinakaran: Conceptualization. **A. Stephen Sagayaraj:** Methodology, Software. **S.K. Kabilesh:** Writing - original draft, Writing - review & editing. **T. Mani:** Data curation, Resources. **A. Anandkumar:** Investigation, Validation. **Gokul Chandrasekaran:** Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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