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Comparative Study of Lane Detection Techniques

Pallavi V. Ingale*,
*(Department of Electronics & Telecommunications,
J.T.Mahajan College of Engineering, North Maharashtra
University, Faizpur, 425524, Maharashtra- India)

Prof. K. S. Bhagat**
** (Department of Electronics & Telecommunications,
J.T.Mahajan College of Engineering, North Maharashtra
University, Faizpur, 425524 Maharashtra- India)

Abstract: Many people die each year in roadway departure crashes caused by driver inattention. Lane detection systems are useful in avoiding these accidents as safety is the main purpose of these systems. Such systems have the goal to detect the lane marks and to warn the driver in case the vehicle has a tendency to depart from the lane. In the past few years, numerous approaches for lane detection were proposed and successfully demonstrated. This research work has proposed a noble method for lane detection system by using the hybrid median filter. The main objective of this paper is to improve the lane detection system using hybrid median filter. Lane detection is an important method in a number of intelligent automobile applications comprising the lane trip recognition and warning board, intelligent journey control and autonomous driving. Most of existing researchers has neglected the use of image filtering techniques. So in order to decrease the problems of the lane detection technique a new strategy is proposed which utilize the hybrid median filter thus improve the accuracy of the lane detection system. The performance evaluation has shown significant improvement over the existing methods.

Keywords: *Lane detection, Modified Hough transformation, edge detection, Hybrid median filter (HMF)*

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1. INTRODUCTION

With the rapid raise of urban traffic, the traffic safety becomes more and more significant. Leaving the lane causes about 30% of all accidents in the highway, and most of these are resulted from the distraction and fatigue of the driver. Therefore, a system that could provide a warning to drivers of a danger has a great potential to save a large number of lives. Systems that are designed to help the driver in its driving process are known as advanced driver assistance systems (ADAS). Many systems like adaptive cruise control, collision avoidance system, night vision, blind spot detection and traffic sign detection are a part of ADAS [1]. Lane departure system is also a part of this category. This system has a goal to detect the lane marks and to advise the driver in case the vehicle has a tendency to leave the lane.

Lane detection is the process to locate lane markers on the road and then present these locations to an intelligent system. In intelligent transportation systems [6], intelligent vehicles cooperate with smart infrastructure to achieve a safer environment and better traffic conditions. The applications of a lane detecting system could be as simple as pointing out lane locations to the driver on an external display, to more complex tasks such as predicting a lane change in the instant future in order to avoid collisions with other vehicles. Some of the interfaces used to detect lanes include cameras, laser range images, LIDAR and GPS devices [7].

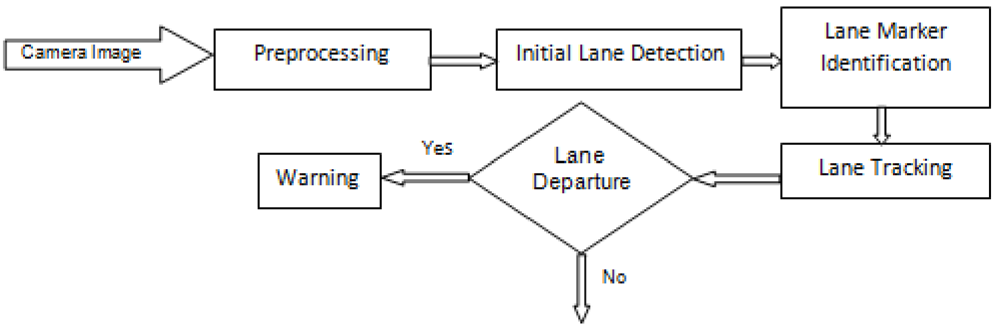

Figure.1. Block diagram of a simple Lane Departure Warning System (LDWS)

In many proposed systems [8], the lane detection consists of the localization of specific primitives such as road markings of the surface of the painted roads. Various challenges like parked and moving vehicles, bad quality lines, shadows of trees, buildings and other vehicles, sharper curves, irregular lane shapes, merging lanes, writings and other markings on the road, unusual pavement materials and dissimilar slopes causes problems in lane detection. There have been active research on lane detection and a wide variety of algorithms of various representations, detection and tracking techniques, and modalities have been proposed [9].

Figure 2: Challenges of Lane Detection [6]

Many approaches have been applied to lane detection, which can be classified as either feature-based or model-based [3]. Feature-based methods detect lanes by low-level features like lane-mark edges the feature-based methods are highly dependent on clear lane-marks, and suffer from weak lane-marks, noise and occlusions. Model-based methods represent lanes as a kind of curve model which can be determined by a few critical geometric parameters. The model-based methods are less sensitive to weak lane appearance features and noise as compared to feature-based methods. But the model constructed for one scene may not work in another scene, which makes the method less adaptive. Additionally, for best estimation of model parameters, an iterative error minimization algorithm should be applied, which is comparatively time-consuming [13].

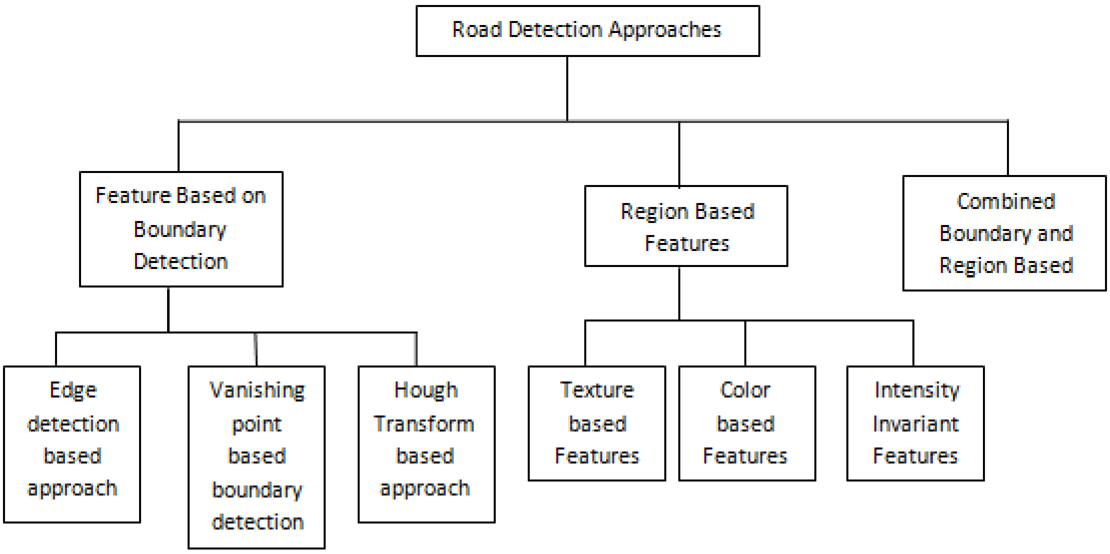

Fig 3. Classification of Road Detection Approaches

2. LITERATURE REVIEW

The objective of the literature review is to find and explore the benefits of lane detection algorithms and also what are the different problems in existing algorithms and techniques. The main goal of this literature review is to find the gaps in existing research and methods and also what will be the possible solutions to overcome these holes.

D. Pomerleau et al.(1996) [21] proposed the RALPH system, used to control the lateral position of an autonomous vehicle . It uses a matching technique that adaptively adjusts and aligns a template to the averaged scan line intensity profile in order to determine the lane's curvature and lateral offsets. B.M. Broggi et al.(1998) [22] prepared a GOLD system which uses an edge-based lane boundary detection algorithm. The acquired image is

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remapped in a new image representing a bird's eye view of the road where the lane markings are nearly vertical bright lines on a darker background. Specific adaptive filtering is used to extract quasi vertical bright lines that concatenated into specific larger segments. C. Kreucher et al (1998) [23] proposed in the LOIS algorithm as a deformable template approach. A parametric family of shapes describes the set of all possible ways that the lane edges could appear in the image. A function is defined whose value is proportional to how well a particular set of lane shape parameters matches the pixel data in a specified image. Lane detection is performed by finding the lane shape that maximizes the function for the current image. Y. Wang et al. (2004) [24] used B-Snake spline as a geometric model that can represent the road. Then he processed images with Canny/Hough Estimation of Vanishing Points (CHEVP) to extract the parameters needed by the geometric model. The obtained results were very robust and accurate. As in his paper, the algorithm can overcome the interference of shadows.

However, when the system detected the shadow of a tree trunk or a shadow of telegraph pole which has a uniform orientation, an unpredictable result occurred. M. Chen et al.(2004) [25] developed another system called AURORA which tracks the lane markers present on structured road using a color camera mounted on the side of a car pointed downwards toward the road. A single scan line is applied in each image to detect the lane markers. C. R. Jung et al.(2005) [26] used the edge detection, squares angular estimation, Hough transform to estimate lanes on a road. The results were obtained in his paper using his algorithm. The algorithm mostly runs good except when it comes to shadow or other interference on the road.

M. Aly (2008) [10] proposed an efficient, real time, and robust algorithm for detecting lanes in urban streets. The algorithm was based on taking a top view of the road image, filtering with Gaussian kernels, and then using line detection and a new RANSAC spline fitting technique to detect lanes in the street. This algorithm was able to detect all lanes in still images of urban streets under various conditions. This method has problems due to stop lines at cross streets, at cross walks, passing cars and confused writings. Z. Kim(2008) [9] presented a robust lane-detection-and-tracking algorithm to deal with challenging scenarios such as a lane curvature, worn out lane markings, lane changes, and emerging, ending, merging, and splitting lanes. The algorithm was based on random sample consensus and particle filtering. The algorithm was proposed to produce a large number of hypotheses in real time as compared to other algorithms.

O. O. Khalifa et al. (2009) [14] proposed a real time lane detection algorithm based on video sequences taken from a vehicle driving on highway. This algorithm showed a robust behaviour to lighting change and shadows. The lanes were detected using Hough transformation with restricted search area. It could be applied in both painted and unpainted road, as well as slightly curved and straight road in different weather conditions. This algorithm proved to be robust and fast enough for real time requirements as compared to other algorithms. Vehicles are assumed to move on flat and straight roads or with slow curvature. This algorithm does not work well on sharp curves and in presence of shadows. M. Meuter et al. (2009) [17] proposed a new robust approach for camera based lane recognition for lane detection and tracking system. This detection algorithm was combined with a tracking algorithm which combined two Extended Kalman filter using the Interacting Multiple Models (IMM) algorithm. The algorithm was linear in time and robust in the presence of noise and weak markers. The algorithm could be used to detect the position and the slope of the lane segments. S. Zhou et al. (2010) [18] proposed a road detection algorithm on the marked roads based on Geometrical model and Gabor filter. This algorithm can be used for Lane Departure Warning System or other auxiliary driving system. The lane geometrical model contained four parameters which were starting position, lane original orientation, and lane width and lane curvature. Gabor filter is adopted to estimate orientation in each pixel and to filter the image along the line of lane model. This algorithm can overcome the universal lane detection problems due to inaccuracies in edge detection such as shadow of tree and passengers on the road. As compared to other methods, the algorithm achieved high accuracy and was robust to the noise and other interferences such as shadow.

Q. Lin et al. (2010) [13] proposed a real time vision-based lane detection system to find the position and type of lanes in each video frame. In this method, lane hypothesis was generated and verified based on an effective combination of lane-mark edge-link features. During the searching process of lane mark candidates, an extended edge linking algorithm with directional edge gap closing is used to produce more complete edge links. The continuity of lane is estimated using a Bayesian probability model. In this algorithm, there were no special requirements for camera parameters, background models, or any other road surface models. Therefore, the algorithm was more adaptive to various road environments.

Z. Teng et al. (2010) [29] proposed an algorithm which integrated multiple cues, including bar filter which has been efficient to detect bar-shape objects like road lane, color cue, and Hough Transform. To guarantee the robust and real-time lane detection, particle filtering technique has been utilized. This algorithm improved the accuracy of the lane detection in both straight and curved roads. It has been effective on a wide variety of challenging road

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environments. This method fails for the lane tracking wh en it is to be applied to particle filter in the dashed lane situation.

F. Mariut et.al (2012) [5] proposed an algorithm that automatically emphasizes the lane marks and recognizes them from digital images, by the use of Hough transform. This method also detects lane mark's characteristics and has the ability to determine the travelling direction. A technique that extracts the inner margin of the lane is used to ensure the right detection of the lane mark. The algorithm works very efficiently for straight roads but fails in some cases of curved roads. N. Phaneendra et al. (2013) [20] proposed a vision-based lane departure warning system. The main goal of this model was to implement an image processing algorithm for detecting lanes on the road and give a textual warning on departure from the lane. The lane departure decision making is based on distance between lanes and the center of the bottom in captured image coordinate, which needed less parameters.

The lane detection performance has been improved by making use of Hybrid median filter with modified Hough transform, compared to the usual method of using Hough transform. The model proved to be efficient and feasible as compared to other systems.

3. LANE DETECTION MODEL

The general method of lane detection is to first take an image of road with the help of a camera fixed in the vehicle. Then the image is converted to a grayscale image in order to minimize the processing time. Secondly, as presence of noise in the image will hinder the correct edge detection. Therefore, filters should be applied to remove noises like bilateral filter, gabor filter, trilateral filter, Hybrid median filter. Then the edge detector is used to produce an edge image by using canny filter with automatic thresholding to obtain the edges. Then edged image is sent to the line detector after detecting the edges which will produces a right and left lane boundary segment. The lane boundary scan uses the information in the edge image detected by the Hough transform to perform the scan. The scan returns a series of points on the right and left side. Finally pair of hyperbolas is fitted to these data points to represent the lane boundaries. For visualization purposes the hyperbolas are displayed on the original color image [14].

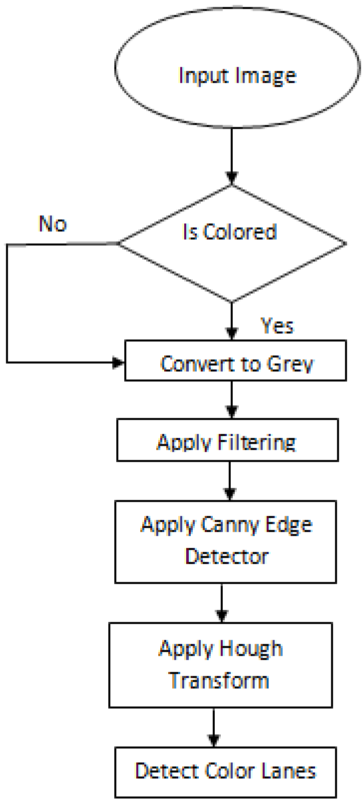

Figure 4: Traditional Algorithm of Lane Detection

The algorithm undergoes various changes and detection of patterns in the images of roads for detecting the lanes. Some of the images are shown in Figure 5-7. Figure 5a, shows the input image. Figure 5b represents the filtered image of fig 5a. In Figure 6a, the filtered image is converted to grayscale image for reducing the processing time. Then this image is segmented to binary image 6b. It is done to locate the lanes in captured image.

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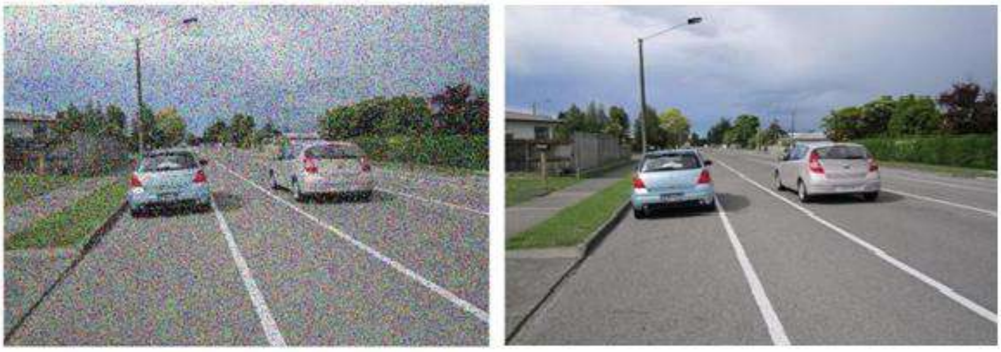

Figure 5: a) Input Image b) Filtered Image [16]

Figure: 6a) Grayscale Image b) Binary Image [16]

Figure 7a) represents the smoothed image and Figure 7b) shows the detected edges in the image with the help of canny edge detector.

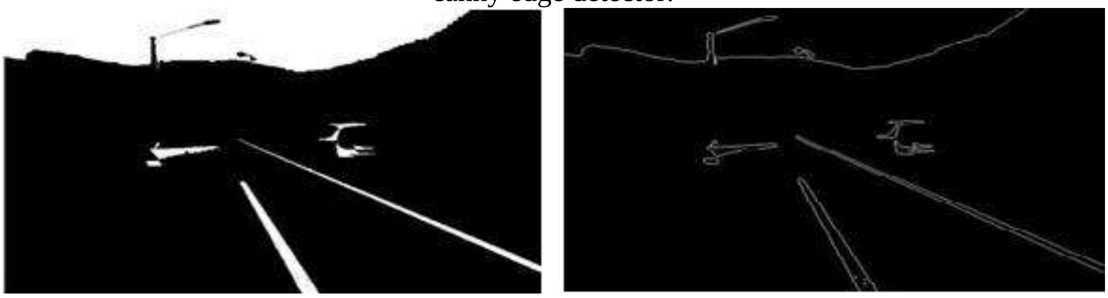

Figure 7: a) Smoothed Image b) Edge Detected Image [16]

Figure 8a) shows the smoothed image and finally the output image is represented in Figure 9b.

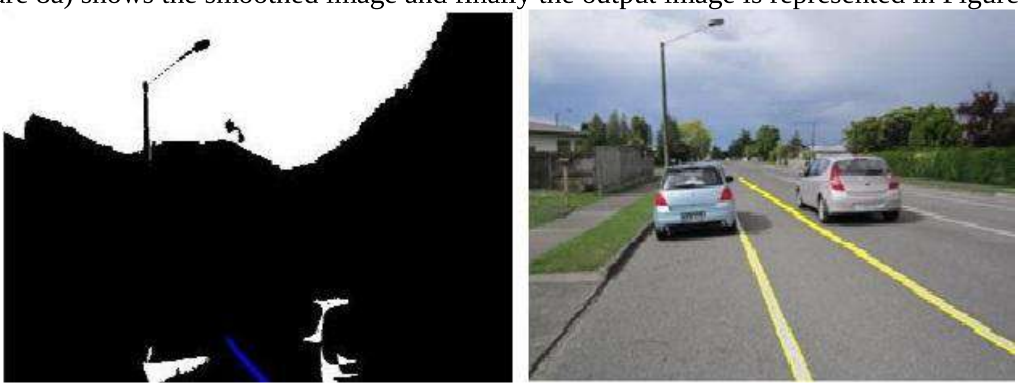

Figure 8: a) Smoothed Image b) Output Image [16]

4. PROPOSED LANE DETECTION MODEL

Lane detection is a complicated problem under different light/weather conditions. In this research work we analysis different cases: the images are captured from the crossover above the road, the lanes to be detected can be straight or curvy, at any time i.e. day or night and with any weather conditions good or bad. The lane markings can be solid or dash lines. Other than detecting the lane markers, the mid-line of each lane is also calculated to identify the position of the vehicle with respect to lane makings, which is useful for autonomous driving.

Fig. 9 is the flowchart of the lane detection algorithm, which is based on edge detection and Hough Transform. First the RGB road image is read in and converted into the grayscale image. Then image is passed to hybrid median filtering technique. Then we use the global histogram to find the road background gray and subtract it from the grayscale image to get img1. Edge operation is executed on img1 and lane marking features are preserved in img2. The key technology here is using Hough Transform to convert the pixels in img2 from the image coordinate (x, y) to the parameter space (ρ, θ) and then search in the Hough space to find the long straight lines, which are lane marking candidates. The candidate lines are post-processed: delete the fake ones, select one line from a cluster of closing lines as a lane marking. Finally the lane markings are sorted by their position in the road from left to right. Also the mid-line of each lane is computed to localize the lane.

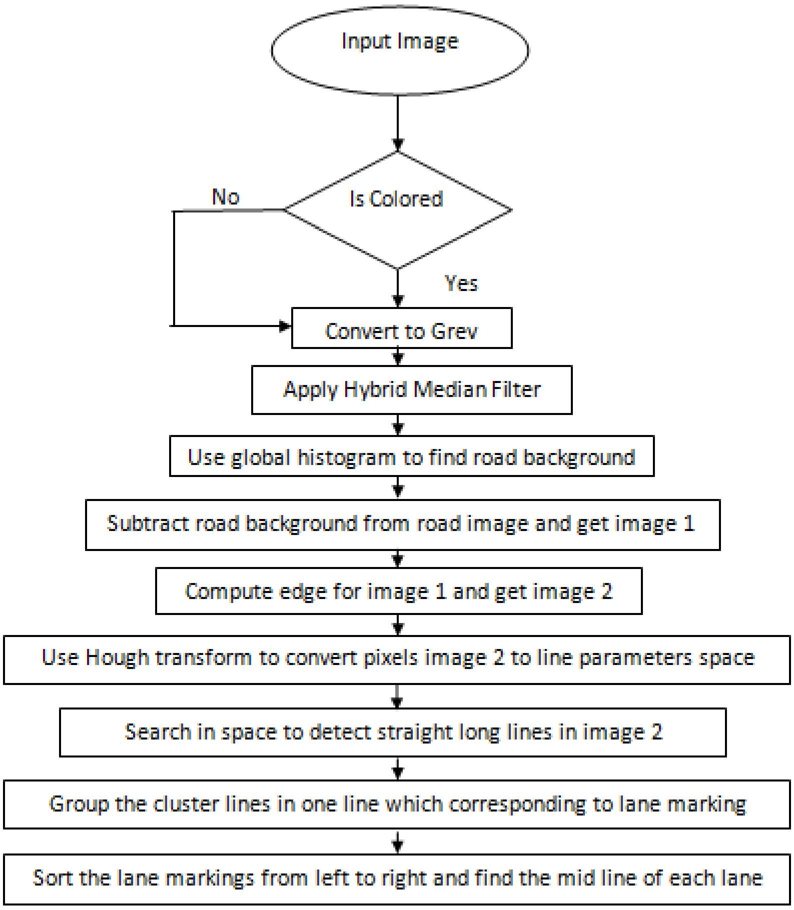

Figure 9: Lane Detection Algorithm with improved Hough Transform & Hybrid Median Filter

Step 1 Conversion from RGB to Grayscale Image

RGB images are composed of three independent channels for red, green and blue primary color components. So, for RGB to grayscale conversion, primarily we take three channel values of each pixel and make an average of those values which is the gray-level value for the corresponding pixel in the grayscale image.

Step 2 Filtering Technique

Next step is the noise removal of the images. Each image is passed through Hybrid Median Filter. Considering salt and pepper noise in the images, noise will be reduced by the proposed algorithm i.e. by using HMF. Comparison will be drawn among the existing and proposed techniques.

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Step 3 Find the road background and subtract it from the original image

The ideal case of the road scene is like Fig.10 solid white line is the lane boundary, white dash line is the lane separator and the double yellow solid line is used to separate two driving directions. Due to the perspective transform, the parallel lines in the road scene will converge to the vanishing point in the image.

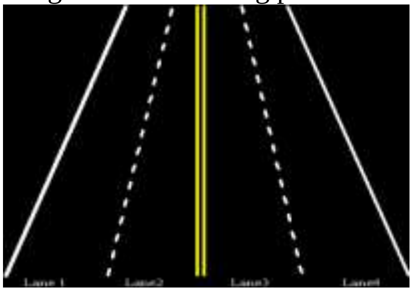

Fig.10 Ideal road geometry

However the road geometry is not so ideal in the real world. For example, in some road images, the lane boundaries are broken; there are vertical/horizontal scratches or other clutter on the road surface; the vehicles on the road will also affect the detection accuracy of the road geometry.

Step 4 Edge Detection

Edge detection refers to the process of identifying and locating sharp discontinuities in an image. There are many various edge detection algorithms developed such as Sobel, Robert, Prewitt and Canny. In this research work canny edge detection technique is used.

Lane edges are the objects of interest in this work. The features of interest are those that discriminate between lane markings and extraneous (non-lane) edges. Most features of the lane markings are preserved as edges, which is directly caused by the edge function of Matlab. But, if we use the edge function directly on the original image, much lane marking edge information is lost. Then we consider other pre-process methods to preserve the lane marking information before the edge operation. Background subtraction is a solution. Assume most of the pixels in the image belong to the road background. So we consider using the global histogram to find the road surface background gray. The grayscale around the histogram maximum is taken as the background gray. The result image is caused by subtracting the background gray from the original image. From the edge image we can find that the lane marking edge information is preserved.

Step 5 Hough Transform

The Hough transform is used in a variety of related methods for shape detection. These methods are fairly important in applied computer vision; in fact, Hough published his transform in a patent application, and various later patents are also associated with the technique. For implementation on an image, more often than not, the Hough Transform is performed after edge detection has been done. In this research work, this is done so that the Hough transform can separate out the straight edges of the lane markings from the other image data. So here we use it to detect the straight lines. Fig.3 is the fundament idea to convert each pixel in the image to parameter space. We define the origin of the image coordinate as the upper-left point. A count array [ρ] [θ]is constructed for each candidate line and some other array is constructed to record each line's start/end position. Since the lane markings are not close to the origin and they are not horizontal in the image (for autonomous driving application, the camera is mounted on the vehicle with front view), we only detect the straight lines with restriction $\rho>10$, $30<\theta<150$, and also the calculation time cost is reduced

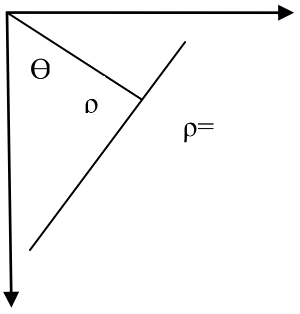

Fig.11 Hough transform for detecting straight lines

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Step 6 Search in the Hough space for the long straight lines

There are many straight lines detected by Hough Transform, now we search in the Hough space to find the long straight lines, which are lane marking candidates. The lane markings include more edge pixels than other lines in the image.

Step 7 Decide the lane markings and mid-line of each lane

There are many lines around the lane markings detected by the Hough Transform, also some lines, which are caused by the edges of vehicle queues, are counted as straight lines. We need to group the line cluster as one lane marking and delete other fake lines. First we sort the lines according to their position in the image from left to right. Secondly for each line group consisting of closing straight lines, select the most possible line as the lane marking and delete other fake lines (the distance between two lines and their count numbers are used as criteria to judge whether or not this line is a fake lane marking). Finally the mid-line of each lane is calculated from the sorted lane markings. The detection result for lane markings and mid-lines of each lane are calculated and the fake lines caused by the vehicle queue on the road are deleted

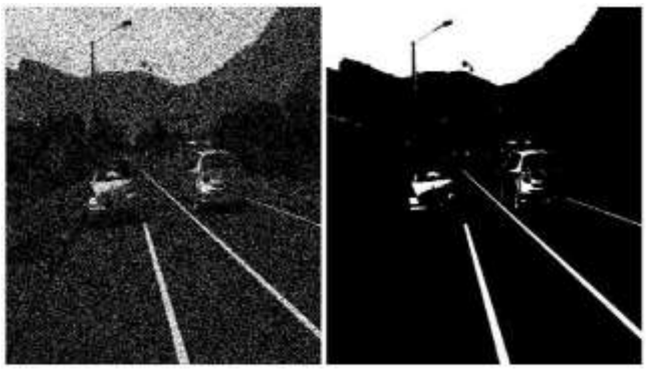
5. RESULTS AND COMPARISON

This section contains the results taken by implementing the proposed and existing algorithm. Figure 12 is showing the input noisy image which is passed to both the implemented simulations i.e. proposed algorithm and existing algorithm.

Figure 12. Input noisy image

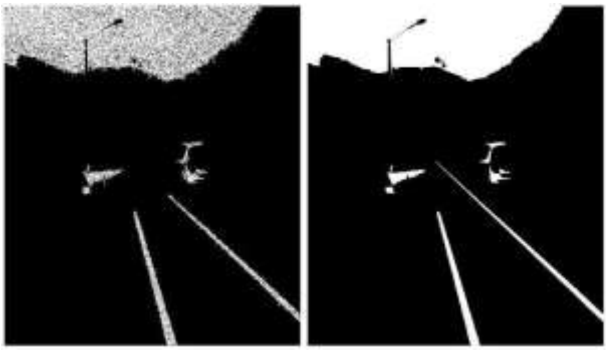
Figure 13. (a) Existing algorithm Filtered Image

a) Existing algorithm (b) Filtered Image
Figure 14 Gray scale image

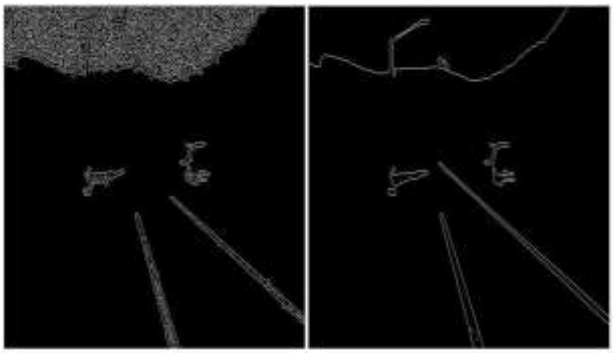


(a) Existing algorithm (b) Proposed Output
Figure 15 Binary image

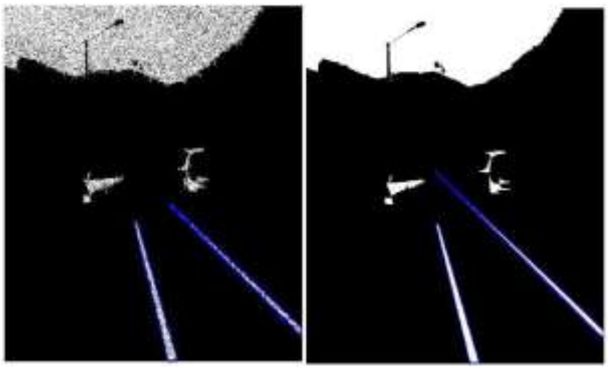
Figure 13 is showing the filtered image by using the Hybrid median filter. It is clearly shown that in image figure 13 (b) the image is quite sharper than that of the existing algorithm's output image. Figure 14 is showing the gray scale image for both the techniques. It is clearly shown that the existing algorithm result is seems to be inaccurate than that of the image shown in figure 14 (b) image i.e. output of the image filtered by the Hybrid median filter.



(a) Existing algorithm (b) Proposed Output
Figure 16. Smoothed Binary image



(a) Existing algorithm (b) Proposed Output
Figure 17. Edge detected image



(a) Existing algorithm (b) Proposed Output
Figure 18.Smoothed Binary image

(a) Existing algorithm (b) Proposed Output
Figure 19. Smoothed Binary image

Figure 4th i.e. fig 18 (a) has demonstrated the output of the Hough transformed without using the Hybrid median filter. It has been noticeably shown that the Hough lines are not as accurate as expected. Figure 5th i.e. fig 19 (b) has shown the Hough transformed output image using Hybrid median filter. The results are quite better than the image shown in figure 4th.The lane colorized image is shown in Figure 6th and 7th of fig 19 (a) and (b) respectively. The image shown in figure 6th is without Hybrid median filter so have some artifacts i.e. not visibility too accurate and even lanes are not properly detected. But image shown in Figure 7th is showing the smoothed image even the colorized lanes are properly shown. Thus proposed algorithm is quite better than the existing algorithm.

6. Conclusion and Future Work

The lane detection techniques play a significant role in intelligent transport systems. Driver support system is one of the most important features of the modern vehicles to ensure driver safety and decrease vehicle accident on roads. The system was investigated under various situations of changing illumination, and shadows effects in various road types. The system has demonstrated a robust performance for detecting the road lanes under different conditions. In this paper, lane detection methods have been studied. Also a real time vision-based lane detection method was proposed. Image segmentation and remove the shadow of the road were processed. Canny operator was used to detect edges that represent road lanes or road boundaries. A series of experiment showed that the lanes were detected using Hough transformation. From the above result, we find the algorithm works well for these cases. The key method includes: find the background gray range, hybrid median filtering, background subtraction, edge detection, Hough Transform, find the long lane marking candidates, sort the lane marking candidates, group the cluster lines as one line, delete fake lines and calculate the mid-line of each lane. The experimental results showed that the system is able to achieve a standard requirement to provide valuable information to the driver to ensure safety. The methods developed so far are working efficiently and giving good results in case when noise is not present in the images. But problem is that they fail or not give efficient results when there is any kind of noise in the road images. So in order to reduce these problems a new strategy is proposed which has improved lane detection system. The experimental results show the effectiveness of the proposed algorithm on both straight and slightly curved road scene images under different day light conditions and the presence of shadows on the roads. It is found that the proposed algorithm become even more powerful when noise is present in the input road images. In near future we will use the proposed algorithm in real time systems using the embedded systems. However some improvement in the HMF will also be done to improve the results even for high density of noise or disturbance in the image.

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