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Enhanced Fuzzy based Hough Transform for Lane Mark Detection

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ABSTRACT- Lane Detection plays an important role in Intelligent Transportation system and Advanced Driver Assistance Systems. Lane detection is an important aspect of autonomous vehicles. It is also a preventive measure for road accidents. Hough Transform technique uses the edge map obtained from segmentation to detect the lane marks. The threshold value used to segment the image can either be static or dynamic. The overall objective of this paper is to improve the lane detection algorithm using adaptive segmentation and filtering techniques. It has been found that the value used to segment the road image containing lanes has been taken statically. To overcome this, a new lane detection method with an adaptive segmentation value has been proposed. This approach has the ability to boost the lane colorization in efficient manner by utilizing the Additive Hough Transform algorithm with optimized segmentation and filtering techniques. Various parameters like Accuracy, F-measure, Mean Square Error are used for calculating the effectiveness of this technique. The proposed technique yields accurate results as compared to existing techniques.

KEYWORD

ROI; Hough Transform; Otsu; K-means; FCM; Additive Hough Transform; Lane detection, JTF

1. INTRODUCTION

Roads are one of the finest modes of transportation among all modes of transportation. Due to the negligence of drivers, road crashes are continuously increasing day by day. Localizing lane marks painted in the road image is called Lane detection. The major objective of lane recognition is to detect as well as recognize the lane marks painted on the road and then provide these locations to an intelligent system. In intelligent transportation systems, intelligent vehicles cooperate with smart infrastructure to achieve a safer environment and better traffic conditions.

Advanced driver assistance systems (ADAS) are the systems that are designed to assist the driver in its driving process. Lane departure warning system is a part of ADAS whose objective is to detect the lane marks and to warn the driver in the case when the vehicle has tendency to depart from the lane. Many techniques have been made to detect and locate the lane marks. Hough Transform is the most commonly used technique for lane detection but the limitation of Hough Transform is its time complexity to calculate the parameter values. Based on the previous work done in lane detection field, a method is proposed in this paper to detect and localize the lane marks by using Improved Hough Transform based on adaptive segmentation and filtering techniques. This technique yields accurate results in lane detection of straight or curved roads even in the presence of noise present in the image

2. LITERATURE SURVEY

Road safety is the major concern of all the lane detection systems. Most of the road accidents happen when the driver departs from the lane. The Hough Transform (HT) developed by Poly
Hough in 1962 is the most commonly used technique to detect the lane marks. Many varieties and applications to detect the lane lines can be found in the literatures: Yu et al. have proposed a lane detection technique that uses the Hough Transform with a parabolic model under various road and weather conditions. A multi- resolution strategy has been employed to improve the Hough Transform but the method is computationally tractable and less prone when the noise is present in the image [1].Tseng et al. have proposed a lane detection algorithm that uses Geometry information and Hough transform but the algorithm was time-consuming and also failed when the lane boundaries intersected in a region which is a non-road area [2]. Kim et al. have presented robust lane detection and tracking algorithm based on random sample consensus and particle filtering [3]. An algorithm to detect the painted as well as unpainted roads has been designed by Khalifa that uses Hough Transform for line extraction [4]. Borkar et al. have proposed a lane detection algorithm that is suitable for detecting the lane marks at night. Low resolution Hough Transform has been employed to detect the straight lanes [5]. Wang et al. have used the ideas of region of interest and Random Hough Transform to detect the road edges [6]. Lakshmi et al. have proposed the color segmentation procedure to detect the white and yellow colored lanes on the road [7]. Mariut et al. have

proposed a method that detects the lane marks using Hough Transform and has the tendency to determine travelling direction of the vehicle [8]. Ghazali et al. have proposed an algorithm for detecting unexpected lane changes. The algorithm uses H-maxima approach and improved Hough Transform is applied on the near-field of view to detect the straight lines [9]. Phaneendra et al. have proposed an accident avoiding system that uses Hough Transform to detect the left and right marks and determines the position of the vehicle with respect to these marks and gives a warning message whenever the vehicle departs from the
lane [10]. Cho et al. have proposed a lane recognition algorithm that uses multiple region of interest. Hough transform with applied accumulator cells has been applied to detect the lane marks in each region of interest [11]. Yi et al. have discussed the existing lane detection techniques and the benefits and limits of existing lane colorization problems. It has been found that most of the existing researchers have used the Hough Transform algorithm for lane detection and also neglected the overheads of existing techniques. The limitation of Hough Transform is its time complexity to solve trigonometric functions to evaluate parameter values. To reduce the limitations of existing researchers, the author has proposed a modified approach for lane detection called as Additive Hough Transform that accelerates the HT process in computationally efficient manner and making it suitable for real-time lane detection. The algorithm randomly selects two points in the image space and solves them using additive property to obtain a point in the parameter space [13]. After surveying the literature, it has been found that most of the existing researchers have used the Traditional Hough transform that is capable for detecting straight lines only and static threshold is used to segment the image to obtain the edge map. In order to reduce the limitations of existing researchers, a new strategy has been proposed in this paper that consists of enhanced Hough Transform using adaptive segmentation techniques.

3. OVERVIEW OF ALGORITHM

The proposed algorithm works in two steps – pre-processing and post-processing. Pre-processing is low level image processing that deals with images from the camera and generate useful information for detection parts. It includes filtration, ROI selection and gray scale conversion. Initially the road image is captured by the camera and a region of interest is extracted from input image in order to reduce the search area and to save computational time.
Then the gray scale conversion of the image is done to reduce the processing. Post-processing consists of two steps. In first step, image segmentation is done to obtain an edge map which is used as an input by Additive Hough Transform. In second step Additive Hough Transform is applied to detect the lane marks.

3.1 Region of interest

The road image is captured by the camera that is mounted in front of the vehicle. The region of interest is extracted from the original image by cropping the road image. It increases the speed and accuracy of the lane detection algorithm. The maximum region of interest mainly lies in the bottom half of the road image where all the necessary objects such as lane markings, pedestrians and other vehicles are present. On the basis of the dimensions of the image, the region of interest is calculated by reducing each side of the image.

a. Gray-scale Conversion

The RGB image is converted into gray- scale format. Gray-scale conversion transforms a 28 bit, 3 channel RGB color image into 8 bit, one channel and gray-scale image. Generally, road surface can be made up of various obstacles such as shadows, tire skids, oil strains, diverse pavement style which changes the color of the road surface and lane markings to form one image region to another. Due to this, the image is converted into gray scale.

b. Image Segmentation

Image segmentation is an important step in image analysis and object recognition. It divides an image into meaningful structures. Lane detection algorithm uses edge map of the image to detect the lanes. The proposed algorithm consists of clustering based image segmentation technique that is used to segment the road lane image. Fuzzy based segmentation technique divides the road image using an adaptive threshold value which results in better lane detection.

3.3.1 Fuzzy based segmentation

The fuzzy c-means (FCM) algorithm is a clustering algorithm. It was developed by Dunn and Bezdek. The aim of FCM algorithm is to find an optimal fuzzy c-partition by evolving the fuzzy partition matrix iteratively and computing the cluster centers [12]. In order to achieve this, the algorithm tries to minimize the objective function:

$$J_{FCM} = \sum_{i=1}^{N} \sum_{j=1}^{C} \mu_{ij}^{m} (\|x_i - v_j\|)^2 \quad (1)$$

Where m is any real number greater than 1, u_{ij} is the degree of membership of x_i in the cluster j, x_i is the ith data, v_j is the center of the cluster. Membership μ_{ij} is given by:

$$\mu_{ij} = \Sigma_{k=1}^{c} \left[\frac{\|x_i - v_j\|}{\|x_i - v_k\|}\right]^{\frac{2}{m-1}} \quad (2)$$

c. Hough Transform

Hough Transform (HT) is an efficient tool for detecting straight lines in an image, even in the presence of noise and missing data. The basic principle of the Hough Transform is that every point in the image has infinite number of lines, which pass through it but with a different angle. The goal of the transform is to identify the lines that pass through the most points in the image. These are the lines that most closely match the features in the image. Hough transform algorithm uses an array, called an accumulator, to detect lines. The dimension of the accumulator is equal to the number of an unknown Hough transform parameters. The ρ parameter represents the distance between the line and the origin, and the parameter θ represents the angle of the vector from the origin to the closest point on the line. A count (initialized at zero) in Hough accumulator at point (ρ, θ) is incremented for each line it considers.

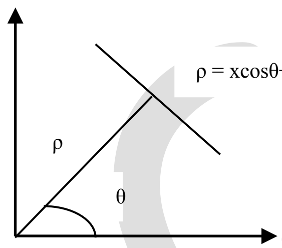


Fig.1 Hough transform for detecting straight lines.

Hough transform is unsuitable for real time applications because high computational time incurred by conventional Hough voting attributed to trigonometric functions and multiplications applied to every edge pixel.

d. Additive Hough Transform

From the various implementation of Hough Transform, it is known that the classic Hough algorithm has heavy calculation burden resulted into ineffectiveness to satisfy real-time request. Therefore, we modify it for detecting both straight and curved roads efficiently as well as for calculating more than one edge point. The idea is to select two points and solve them using the equations (11) and (12).

$$\theta_i = \tan^{-1}\left((x_i - x_{i+1}) \middle| (y_{i+1} - y_i)\right) \quad (3)$$

$$\rho = x_i \cos\theta_i + y_i \sin\theta_i \quad (4)$$

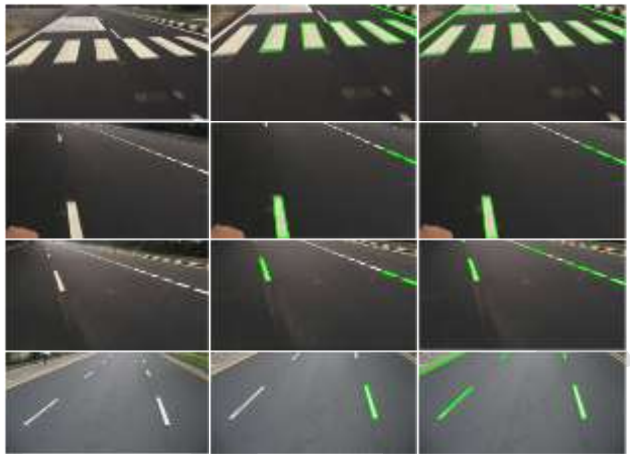
The corresponding accumulator units are set to zero in the parameter space. If the points exist in the parameter space the corresponding accumulators count plus 1. If not, the points are inserted into the parameter space.

4. EXPERIMENTS & RESULTS

We have performed the experiments in MATLAB under Hp computer having Intel(R) Core™ i5 processor, 32 bit windows 7 operating system, 4.00 GB RAM and RADEON Graphics. A database of 15 road images has been collected This technique has been implemented on a number of images acquired along the roads with different illumination conditions in different situations such as single/double lane marks, supplementary road marks etc.

4.1 Detection of lane marks using Hough transform and Additive Hough Transform:

Hough Transform and Additive Hough transform techniques have been applied on different test images. The lane detection results of the following four different test images on applying these techniques are shown in Fig. 2. In Fig.2, column (a) represents the original images captured by the camera, column (b) represents the lane detected images obtained on applying the Traditional Hough Transform technique and column (c) represents the lane detected images on applying AHT Hough Transform technique. From subjective evaluation it is evident that more lines are detected by AHT as compared to HT.



(a) (b) (c)

Fig.2 (a) Input Image; (b) Traditional Hough Transform lane detected image; (c) Additive Hough Transform lane detected image.

Performance Evaluation:

Performance Evaluation table shows the analysis of lane detection techniques using different parameters such as Geometric Accuracy, F-measure and MSE. The average values of parameters of conventional and new techniques have been calculated to analyze the performance. Also to evaluate the performance of HT and AHT, the average values of Accuracy, F-measure and MSE are evaluated for 15 images containing lanes. The average values of these parameters are shown in Table1.

a) Accuracy

Accuracy is the major requirement of the lane detection techniques. Geometric accuracy is the accuracy of a resulted image compared to the original image. In Table 1, Accuracy value obtained by HT and AHT techniques for 15 road images containing lane marks is shown. From table values, it is clear that highest value of Accuracy is obtained by AHT as compared to HT.

b) F-measure

F-measure parameter is used to compute the average of information retrieval precision and recall matrices. In Table 1, F-measure value obtained by HT and AHT techniques for 15 road images containing lane marks is shown. From table values, it is clear that highest value of F-measure is obtained by AHT as compared to HT.

c) Mean Square Error

Mean Square Error is a risk function corresponding to expected value of squared error loss or quadrate loss. It is a measure of image quality index. The large value of MSE means the image is a poor quality image. In Table 1, MSE value obtained by HT and AHT techniques for 15 road images containing lane marks is shown. From table values, it is clear that smaller value of MSE is obtained by AHT as compared to HT.

From experimental results and performance measures, it is vivid that results of AHT are more accurate as compared to HT. Therefore AHT yields more accurate lanes as compared to HT technique.

Table 1 Performance evaluation of Accuracy, F-measure and MSE after applying Traditional Hough Transform and Additive Hough Transform techniques on different images.

IMG.	ACCURACY		F-MEASURE		MSE	
	HT	AHT	HT	AHT	HT	AHT
1	0.6802	0.6985	80.3241	83.0168	0.3014	0.2934
2	0.3821	0.4628	62.8943	65.1264	0.5502	0.5328
3	0.8235	0.8468	93.7263	95.8267	0.6215	0.0582

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4	0.9017	0.9543	88.1497	90.3047	0.1986	0.1560
5	0.9254	0.9400	96.1005	97.2471	0.0198	0.0192
6	0.9368	0.9487	95.3286	97.0041	0.1024	0.0628
7	0.8553	0.8696	94.9982	97.9587	0.0816	0.0507
8	0.7616	0.7739	91.2109	92.6112	0.1590	0.1365
9	0.8259	0.8926	83.1478	86.2476	0.2517	0.2369
10	0.8016	0.8374	93.2108	94.8521	0.8014	0.6145
11	0.9385	0.9398	87.8435	90.0690	0.1727	0.1465
12	0.9632	0.9759	93.4792	95.2341	0.1285	0.1009
13	0.9112	0.9235	95.2116	97.6785	0.0242	0.0211
14	0.6973	0.7241	90.5387	93.5899	0.0957	0.0729
15	0.8714	0.9234	81.0978	83.8427	0.3014	0.2764
Avg.	**0.8183**	**0.8474**	**88.4841**	**90.7073**	**0.2540**	**0.1852**

4.2 Improved Hough Transform using Fuzzy based segmentation:

Additive Hough Transform (AHT) technique uses an edge map obtained by image gradient processing method as an input for lane detection. The threshold value used to segment the image is taken statically. Therefore adaptive threshold value is required to improve the results further. The Additive Hough Transform technique is applied with Fuzzy Segmentation algorithm. The segmentation results obtained by image gradient processing and Fuzzy segmentation based techniques are shown in Fig.3. From visual perspective, it is clear that the segmentation results of Fuzzy are more accurate than gradient processing method. In Fig. 4, the lane detection results of AHT by using gradient processing and Fuzzy segmentation are shown.

(a) (b) (c)

Fig.3 (a) Input Image (b) Gradient processing Segmented Image (c) Fuzzy Segmented Image.

(a) (b) (c)

Fig.4 (a) Input Image (b) AHT lane detected Image (c) Fuzzy based HT lane detected Image.

From the experiments, it is clear that Fuzzy based Hough Transform yields better lane detection results as compared to AHT technique.

4.2.1 Fuzzy based Hough Transform:

Fuzzy based Hough Transform technique is implemented on the road images containing lane marks. The improved lane detection results are obtained by Fuzzy based HT as compared to AHT technique. Fig. 5 shows the lane detection results of original image obtained by using AHT and Fuzzy based HT techniques.

(a) (b) (c)

Fig.5 (a) Input Image (b) AHT lane detected Image (c) Fuzzy based HT lane detected Image.

Performance evaluation Table 2 is showing the comparison and complete analysis of AHT and Fuzzy based HT techniques. From the table values, it is clear that the results of Fuzzy based Hough transform technique are more accurate as compared to AHT technique.

Table 2 Performance evaluations of Accuracy, F-measure and MSE on applying AHT and Fuzzy based HT techniques on road images.

IMG.	ACCURACY		F-MEASURE		MSE	
	AHT	Fuzzy based HT	AHT	Fuzzy based HT	AHT	Fuzzy based HT
1	0.6985	0.7537	83.0168	86.5893	0.2934	0.2204
2	0.4628	0.9881	65.1264	99.4013	0.5328	0.0119
3	0.8468	0.9700	95.8267	99.1657	0.0582	0.0157
4	0.9543	0.9998	90.3047	98.4624	0.1560	0.0300
5	0.9400	0.9780	97.2471	99.9972	0.0192	0.0010
6	0.9487	0.9768	97.0041	98.8407	0.0628	0.0220
7	0.8696	0.9633	97.9587	98.8259	0.0507	0.0232
8	0.7739	0.9594	92.6112	98.1054	0.1365	0.0367
9	0.8926	0.9693	86.2476	97.9298	0.2369	0.0406
10	0.8374	0.9500	94.8521	98.4313	0.6145	0.0307
11	0.9398	0.9693	90.0690	97.4172	0.1465	0.0500
12	0.9759	0.9832	95.2341	98.4284	0.1009	0.0307
13	0.9235	0.9535	97.6785	99.1508	0.0211	0.0168
14	0.7241	0.9859	93.5899	97.6178	0.0729	0.0465
15	0.9234	0.9843	83.8427	99.2892	0.2764	0.0141
Avg.	**0.8474**	**0.9590**	**90.7073**	**97.8435**	**0.1852**	**0.0393**

From subjective analysis and performance measures, it is observed that Fuzzy based HT technique gives more accurate lane detection results than AHT technique.

4.3 Enhancement of Fuzzy based Hough Transform using filtering techniques:

Lane detection technique has to locate the lane marks in the presence of noise present in the road image. The noise can be reduced by using different filtering techniques i.e. median filter, mean filter and JTF (Joint Trilateral Filter). Therefore the results of Fuzzy based HT technique are further enhanced by using filters so that it can give more accurate lane detection even in the presence of noise in the road image. In Fig. 6, 7, 8, lane detection results of Fuzzy based HT using mean, median and JTF filters are shown.

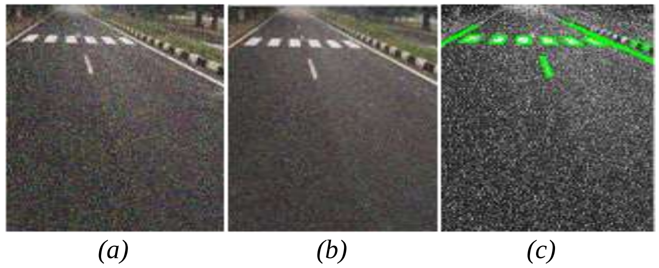


Fig.6 (a) Input Image; (b) Mean Filtered Image; (c) Fuzzy based HT lane detected image with Mean Filter.

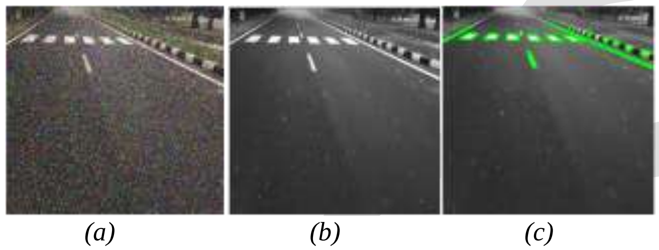


Fig.7 (a) Input Image; (b) Median Filtered Image; (c) Fuzzy based HT lane detected image with Median Filter.

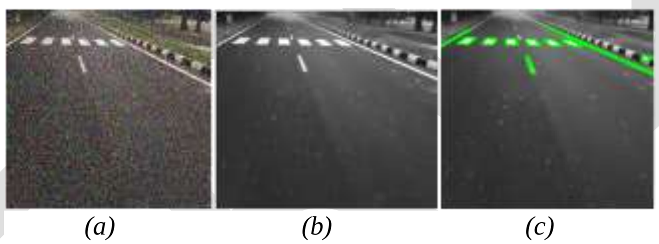


Fig.8 (a) Input Image; (b) JTF Filtered Image; (c) Fuzzy based HT lane detected image with JTF Filter.

From visual analysis, it is clear that the more accurate lanes are detected by Fuzzy based HT with JTF as compared to Mean and Median filter. To analyze the performance of these techniques, the various performance evaluation parameters such as Accuracy, F-measure and MSE are taken. Table 3 is showing the average accuracy value obtained by Fuzzy based HT with mean, median and JTF filters. Table 4 is showing the average F-measure value obtained by Fuzzy based HT with mean, median and JTF filters. Table 5 is showing the average MSE value obtained by Fuzzy based HT with mean, median and JTF filters. From table values it is clear that highest values of accuracy, F-measure and least value of MSE are obtained by Fuzzy based HT with JTF as compared to mean and median filters.

Table 3 Performance evaluations of Accuracy on applying Fuzzy based HT technique with mean, median and JTF on road images.

Image	Accuracy		
	Fuzzy based HT with		
	Mean filter	Median filter	JTF filter
1	0.7582	0.7796	0.7843
2	0.9886	0.9896	0.9902
3	0.9735	0.9798	0.9839
4	0.9985	0.9992	0.9998
5	0.9786	0.9832	0.9948
6	0.9775	0.9789	0.9800
7	0.9645	0.9768	0.9889

8	0.9598	0.9625	0.9720
9	0.9699	0.9708	0.9799
10	0.9529	0.9584	0.9683
11	0.9710	0.9785	0.9875
12	0.9849	0.9893	0.9969
13	0.9580	0.9599	0.9682
14	0.9872	0.9896	0.9979
15	0.9862	0.9886	0.9978
Average	0.9606	0.9656	0.9728

Table 4 Performance evaluations of F-measure on applying Fuzzy based HT technique with mean, median and JTF on road images.

Image	**F-measure**		
	Fuzzy based HT with		
	Mean filter	**Median filter**	**JTF filter**
1	86.9385	86.9650	87.5149
2	99.6385	99.7862	99.9156
3	99.8162	99.9358	99.9713
4	99.2068	99.2367	99.9996
5	99.9980	99.9985	99.9989
6	98.9210	98.9742	99.0852
7	98.9268	98.9776	99.2786
8	98.4638	98.6674	98.9987
9	98.9175	98.9326	98.9886
10	98.4510	98.5572	98.9791
11	98.8138	98.9567	99.2197
12	98.8710	98.9245	98.9518
13	98.9998	99.0016	99.1276
14	99.6275	99.7742	99.8916
15	99.3210	99.4325	99.5874
Average	98.3274	98.4081	98.6339

Table 5 Performance evaluations of MSE on applying Fuzzy based HT technique with mean, median and JTF on road images.

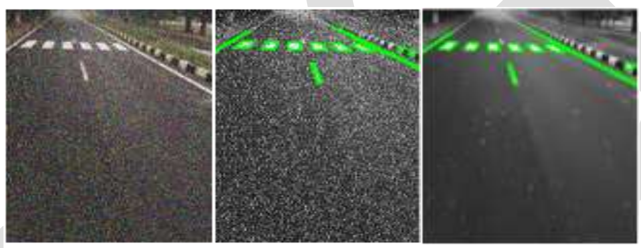
Image	**MSE**		
	Fuzzy based HT with		
	Mean filter	**Median filter**	**JTF filter**
1	0.2196	0.1963	0.1802
2	0.0107	0.0102	0.0095
3	0.0143	0.0134	0.0117
4	0.0291	0.0275	0.0196
5	0.0009	0.0008	0.0005
6	0.0205	0.0197	0.0098
7	0.0225	0.0207	0.0185
8	0.0342	0.0327	0.0291

9	0.0400	0.0389	0.0310
10	0.0301	0.0293	0.0197
11	0.0490	0.0478	0.0372
12	0.0304	0.0287	0.0207
13	0.0149	0.0132	0.0112
14	0.0459	0.0432	0.0399
15	0.0136	0.0124	0.0108
Average	0.0383	0.0356	0.0299

From subjective analysis and performance measures it is vivid that Fuzzy based HT with JTF yields more accurate lane detection results as compared to other filters namely mean and median filters.

4.3.1 Enhanced Fuzzy based Hough Transform using JTF:

In this part of experimental results, Fuzzy based HT technique without filter and Fuzzy based HT with JTF are implemented on the images containing noise such as salt and pepper noise. The enhanced lane detection results are obtained by Fuzzy based HT with JTF as compared to Fuzzy based HT technique. In Fig. 9, the enhanced lane detection results obtained by Fuzzy based HT and Fuzzy based HT with JTF are shown. In Table 6 and 7, the average Accuracy, F-measure and MSE values obtained by Fuzzy based HT without filter and with JTF are shown.



(a) *(b)* *(c)*

Fig.9 (a) Input Image; (b) Fuzzy based HT lane detected image without filter; (c) Fuzzy based HT lane detected image with JTF.

Table 6 Performance evaluations of Accuracy and F-measure on applying Fuzzy based HT without and with JTF filter on different images.

Image	**Accuracy**		**F-measure**	
	Fuzzy based HT (without filter)	**Fuzzy based HT with JTF filter (proposed technique)**	**Fuzzy based HT(without filter)**	**Fuzzy based HT with JTF filter (proposed technique)**
1	0.7537	0.7843	86.5893	0.7843
2	0.9881	0.9902	99.4013	99.9156
3	0.9700	0.9839	99.1657	99.9713
4	0.9998	0.9998	98.4624	99.9996
5	0.9780	0.9948	99.9972	99.9989
6	0.9768	0.9800	98.8407	99.0852

7	0.9633	0.9889	98.8259	99.2786
8	0.9594	0.9720	98.1054	98.9987
9	0.9693	0.9799	97.9298	98.9886
10	0.9500	0.9683	98.4313	98.9791
11	0.9693	0.9875	97.4172	99.2197
12	0.9832	0.9969	98.4284	98.9518
13	0.9535	0.9682	99.1508	99.1276
14	0.9859	0.9979	97.6178	99.8916
15	0.9843	0.9978	99.2892	99.5874
Avg.	0.9590	0.9728	97.8435	98.6339

Table 7 Performance evaluation of MSE on applying Fuzzy based HT without and with JTF filter on different images.

Image	**MSE**	
	Fuzzy based HT (without filter)	**Fuzzy based HT with JTF filter (proposed technique)**
1	0.2204	0.1802
2	0.0119	0.0095
3	0.0157	0.0117
4	0.0300	0.0196
5	0.0010	0.0005
6	0.0220	0.0098
7	0.0232	0.0185
8	0.0367	0.0291
9	0.0406	0.0310
10	0.0307	0.0197
11	0.0500	0.0372
12	0.0307	0.0207
13	0.0168	0.0112
14	0.0465	0.0399
15	0.0141	0.0108
Avg.	0.0393	0.0299

From visual analysis and performance measures, it is observed that Fuzzy based HT with JTF results in better lane detection even if the noise is present in the image. Therefore Fuzzy based HT with JTF yields more enhanced lane detection results as compare to existing techniques.

5. CONCLUSION

The lane detection technique is an essence of Intelligent Transportation Systems. It has been found that the value used to segment the image in lane detection algorithm is taken as static. To overcome this limitation, we have introduced a modified Hough approach that uses adaptive segmentation technique such as Fuzzy based segmentation to enhance the segmentation results which in turn results in better lane detection. Also different filtering techniques such as mean, median and JTF have been integrated with the proposed algorithm so that it can efficiently yield more accurate lanes even if the noise is present in the image. From quality measures, it has been analyzed that the value obtained by Fuzzy based HT technique with JTF is more efficient than HT and AHT techniques. Fuzzy based Hough Transform with JTF filter yields more accurate lane results for straight as well as curved images than other techniques. Therefore, the proposed technique is capable to detect straight as well as curved lanes.

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