Fuzzy C-Means and Modified Hough Transform based Lane Detection

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Abstract
Lane detection is one of the most prominent technology in large number of intelligent vehicles and is an important part of Advanced Driver Assistance Systems. It detects lanes without any proper knowledge of road geometry. This detection system is needed because due to increase in number of vehicles on road, accidents are increasing day by day. Moreover vehicular drivers are fully ignorant towards traffic rules. So we need a system that will help the driver by providing him exact path of lanes. In this paper Fuzzy C-Means and Modified Hough transform based lane detection algorithm is discussed. The proposed algorithm is designed and implemented using matlab. Straight as well as curved lane markings are detected with the help of this algorithm. Lanes in the presence of clutters like noise, shadow are also detected. Performance evaluation between existing and proposed technique is done on the basis accuracy, bit error rate, F-Measure etc.

Keywords
Lane Detection, Region of interest, Fuzzy C-Means, Modified Hough Transform, Canny operator

I. Introduction

In 1914, Henry Ford transformed the entire world by manufacturing bulk of automobiles and these automobiles completely changed our way of travelling. They became an integral part of our society and we all are dependent upon them. But the way coin has two sides there are pros and cons of automobiles. The economic cost of manufacturing and owing a vehicle can be ignored but there are various global effects which affect our everyday life and can't be ignored. Few of them are environmental impact, noise pollution, emission of greenhouse gases, congestion from road infrastructure etc. But the most stunning effect is the economic and social burden caused by accidents and fatalities. In 1999 alone about 750,000 people died globally in road related accidents, with an estimated cost of US $518 billion. In OECD countries, 1, 50,000 are killed every year [1].

There are various ways by which we try to tackle the burden of fatalities caused by road accidents. It includes implementation of strict road regulations, installation of radars, cameras, speed breakers etc to check over speeding vehicles. Automobile manufacturers are also trying to improve the design of vehicles by providing seat belts, air bags, ABS (Antilock Brake Systems), traction control system to reduce accidents and fatalities. But these are just primitive approaches and driver is considered as the most unreliable component in our vehicles. So we need to work in the field of computer vision to develop a system that will help in the detection of the lane while we are driving a vehicle. A passive approach needs to be taken this field which aims at completely removing the driver from our system by introducing smart functions in our vehicles. Lane detection and lane tracking are two important steps used in detection of lanes. Lane detection is concerned with recognition of lanes without any proper knowledge of road geometry while lane tracking algorithms detects lane edges frame to frame with proper knowledge of road geometry. Lane tracking is very easier to perform in comparison to lane detection. But before lane tracking, lane detection system is implemented. Detected lanes can be of various types like traffic lanes, express lane, reversible lane etc. There are two types of approaches used in lane detection. They are Feature Based Approach and Model Based Approach [2]. In feature based approach lane is detected by identifying low level features such as edges of lane etc. This approach can work properly only when our road is properly painted and fails in the absence of strong edges on road. It is highly insensitive to noise. Model based approach is highly robust to noise as it assumes the shape of lane by identifying various geometric parameters of road. These approaches includes various techniques like B SNAKE [3], RANSAC technique [4], SAPTIO Temporal Model [5], LANA technique [6], Violet technique, Classical Hough Transform [7] etc .All these techniques are used for the detection of straight lane markings and failed in case of curved lanes. Moreover lanes in the presence of clutter like noise, shadow are not detected. So in this paper we discuss an algorithm that helps in the detection of straight and curved lanes using fuzzy c-means as a segmentation technique and modified Hough transform. At last we evaluate the performance of classical Hough transform and proposed modified Hough transform based approach.

II. Proposed Algorithm

Framework of the required lane detection algorithm is as shown in figure1.In the detection algorithm initially an image is captured with the help of camera and then preprocessing is done in order to extract the region of interest of an image. After that gray scaling is performed so that processing time is reduced. Scaling and segmentation are performed to extract segmented image. First thresholding and then fuzzy c- means is used as a segmentation technique. To get estimation about the mid lane of a segmented image, Vertical histogram is constructed. Gradient magnitude of an image is found using prewitt operator to locate sharp edges of segmented image. Improved canny based edge detection and modified Hough is applied to detect and color lanes and finally its performance is evaluated. Various steps used for lane detection are as shown below:

A. Capturing of an Image

The input image used for processing is color image sequences and is taken with the help of camera placed near a moving vehicle's front view mirror. Camera takes the image of road along with the vehicles placed on road, roadside environment etc. All the images are taken in .jpg format.

B. Detect Region of Interest

Camera takes the image of entire road environment and these images are divided into two parts i.e. foreground and background fields. But we want to process only a selected part of an image. For this reason we calculate Region of Interest (ROI) of an image. It is that area where all the required objects are placed and is usually one third of the full frame.

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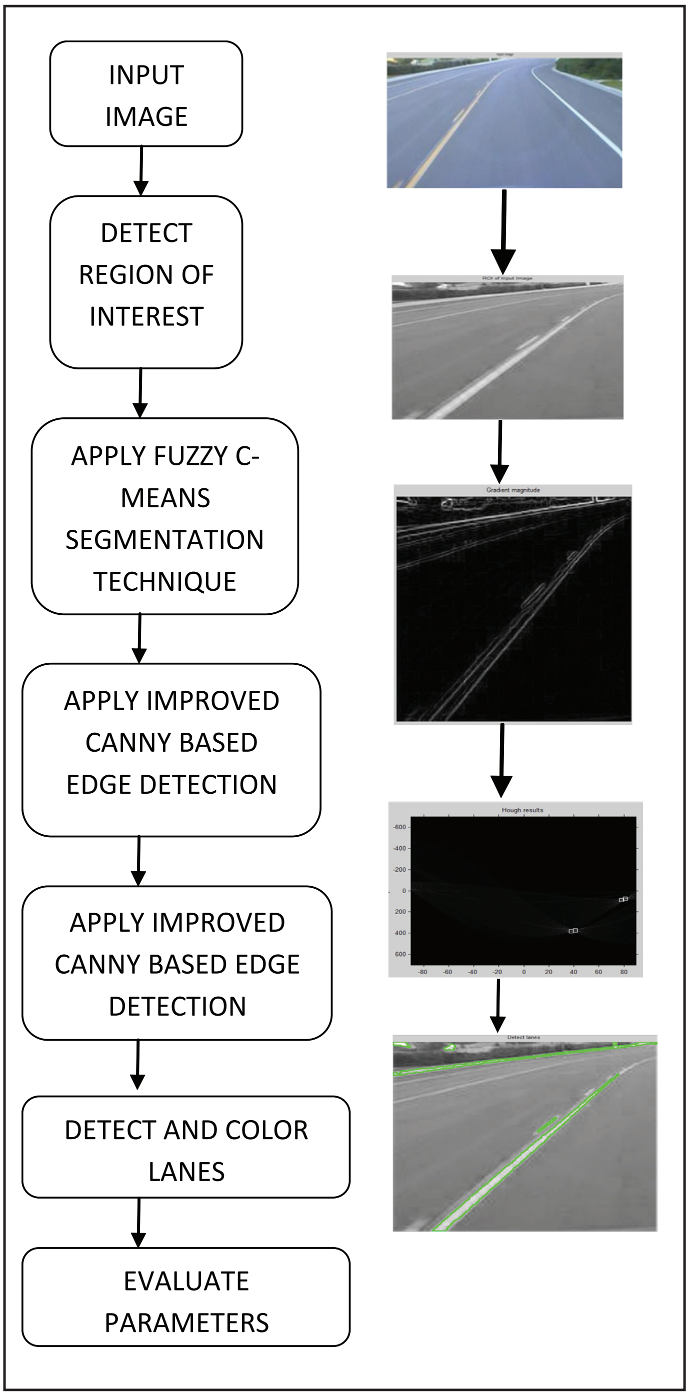

Fig. 1: Framework of Our Lane Detection Algorithm

All lane markings can easily be found in this area as it is 17 meters from the bottom line of an image. Farther points like hills, clutters are not included in ROI. With the selection of proper ROI, interference from irrelevant objects is decreased. In this algorithm ROI is automated, as all the images are of different dimensions. In automation maximum and minimum dimensions of an image are considered and then cropped to get the desired dimensions.

C. Gray Scaling of an Image

Before gray scaling resizing of an image is done as size is increased in order to enhance our image. Then gray scaling is performed. It refers to a process of conversion of colored image into black and white format. All the raw images from camera are in RGB color format where three color channels are assigned to each pixel i.e. one is used for red, one for green and one for blue. The value of these channels is combined to determine the actual color of the pixel. In RGB format, it becomes very difficult to make distinction among the various lane markings. Lot of complications arises on edge detection as well as processing time is also affected. We know that our road surfaces are made up of various colors, shadows are there, and pavement styles are different. All these things changes road color and lane markings vary from region to region. So gray scaling is performed and processing time of gray scale images is very less as compared to color images. In this, intensity of the pixel in the original image is reflected by each pixel. Low intensity values are assigned to dark pixels and high values are given to bright pixels. Here a 24 bit, 3 channel color image are transferred to 8 bit, single channel gray scale image. Different methods are used for gray scaling.

D. Segmentation of an Image

In this algorithm segmentation of an image is divided into two parts. But before segmentation scaling is done in order to brighten our image and get smoother images After that segmentation is performed which refers to the process of dividing an image into N parts and aims at locating objects such as curves and boundaries in an image. Here we are using two types of segmentation techniques i.e. Thresholding technique and Fuzzy C-Means technique. Thresholding is a very simple segmentation technique and it works by assuming a proper threshold value T. Depending upon the selection of threshold value, we use global thresholding technique. Fuzzy C-Means Technique falls under the category of theory based segmentation and involves clustering of data. Fuzzy C-Means clustering technique works in following steps [8]:

- Define a matrix $U=[u_{ij}]$ where u_{ij} is the degree of membership of x_i in the cluster j
  x_i is the ith element of the d dimensional measured data.
- Calculate centre vectors $C^k= [C_j]$ where k represents the required step.
- Update U^k, U^{k+1}
- Calculate distance (d_{ij}) between data points and centre as d_{ij} = sqrt (x_i - C_j) where i varies from 1 to n
- Also calculate u_{ij}.

If the magnitude of U (k+1)-U (k) is less than ε_u then stop otherwise repeat the above steps. Depending on distance between cluster centre and data points, membership values are assigned. Data points which are nearer to cluster centre have higher degree of membership than points that lies away from the centre. Membership and cluster centers are updated after every iteration and this process continues until we get the desired results. The advantage of FCM is that it is an unsupervised learning algorithm and converges to a finite set of iterations. With this segmented images are obtained

E. Gradient Magnitude of an Image

After thresholding, edge detection is used to find lane boundaries of an image. Here we are using 'Gradient Magnitude' to find the sharp edges of an image. We first sweep our image along x axis, then along y axis and then an image is combined to get the desired results. So the mathematical equation for gradient magnitude is as follows [9]:

The gradient magnitude for x axis is as given below

$$\frac{\delta I}{\delta x}(i,j) = \frac{1}{2}((I(i,j+1)- I(i,j)+ (I(i+1,j+1)- I(i+1,j))) \quad (1)$$

The gradient magnitude for y axis is as given below:

$$\frac{\delta I}{\delta y}(i, j) = \frac{1}{2}((I(i,j+1)- I(i,j)+ (I(i+1,j+1)- I(i,j+1))) \quad (2)$$

$$\nabla I = (I_x, I_y) = (\frac{\delta I}{\delta x}, \frac{\delta I}{\delta y}) \quad (3)$$

With the help of these equations magnitude is calculated as follows:

$$I=\sqrt{I_x^{2} + I_y^{2}} \quad (4)$$

Prewitt operator is used to calculate the gradient magnitude.

F. Applying Improved Canny Based Edge Detection

After finding gradient magnitude canny operator is improved. Improvement of canny operator is done by providing enhanced image to it.

G. Applying Modified Hough Transform

It is observed that classical Hough transform does not give accurate results for real time applications as its processing time is very high. So we need to modify it to effectively increase its performance. The steps used for the modification of Hough are as follows:

1. Calculate the inner margins of an image.
2. Then apply Hough code and calculate the results of basic Hough transform.
3. To modify Hough transform we start performing morphological operations on an image by first removing noise from an image and get the smoothed binary image.
4. We use various morphological structuring elements to enhance our image. Here a disk shaped structure is used. With the help of disk, circular nature of an object can be observed. Our road is curved so it can be easily detected. After structuring, we close an image so that all components can be connected.
5. Then we start tracing boundaries of an object and calculate (X, Y) boundary coordinates.
6. After that object's perimeter is calculated with the help of following equations:

$$delta_{sq}=\text{diff}(boundary)^2 \quad (5)$$

$$\text{Perimeter}=\text{sum}\ (\sqrt{sum(delta_{sq})} \quad (6)$$

7. Area is calculated as shown below:

   Area=stats (k).Area (7)
8. Compute the roundness metric

$$\text{Metric}=\frac{4*pi*area}{(perimeter)^2} \quad (8)$$

9. At last the required lane is detected.

III. Results and Discussions

With the help of different set of road images, we compare the results of both classical Hough transform and modified Hough transform. Then at last their performance is evaluated.

A. Results Obtained by Using Simple Segmentation Technique and Classical Hough Transform

Fig. 2 shows the result obtained for different road images. It is clearly visible that straight lane roads are easily detected. Roads with shadow are also detected but their detection is not accurate. Curved roads are not detected as shown below. So there was need to modify Hough for curved lane detection.

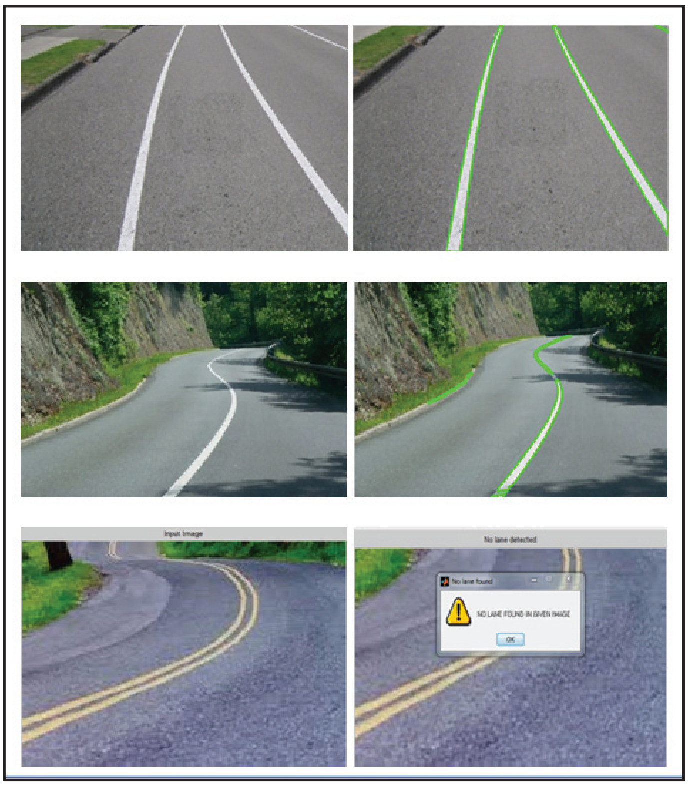

Fig. 2: Input Images and Their Outputs

B. Results Obtained by Using Fuzzy C-Means Segmentation Technique and Modified Hough Transform

By making improvement in the existing techniques all types of road images can be detected.Figure3 shows different input images and their outputs. It shows that all lanes whether straight, curved, lanes with shadow are detected accurately.

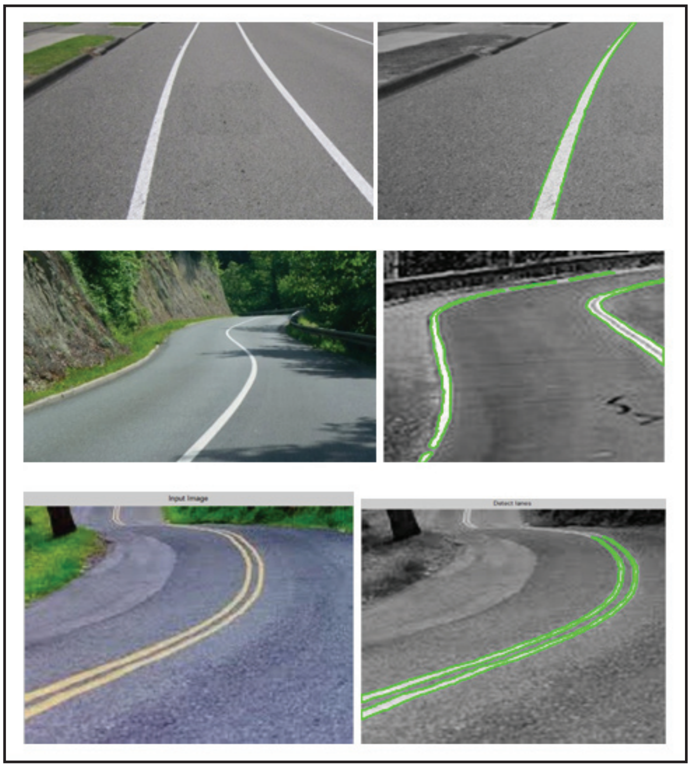

Fig. 3: Input Images and Their Outputs

IV. .Performance Evaluation

In order to evaluate the performance of existing and proposed algorithm various lane metrics are considered. For this we have taken 15 set of images in .jpg format.

A. Accuracy

Accuracy indicates how properly lane is detected by the algorithm and is calculated with the help of following formula.

$$\text{Accuracy}=\frac{\textit{No of correct assesments}}{\textit{Total number of assesments}} \qquad (9)$$

Table 1 shows accuracy values of both the techniques. It shows that accuracy is higher in proposed technique.

Table 1: Accuracy Analysis

INPUT IMAGE	EXISTING WORK	PROPOSED WORK
1	0.1197	0.4572
2	0.6780	0.7740
3	0.9520	0.9731
4	0.5969	0.9367
5	0.4903	0.9068
6	0.2012	0.2330
7	0.7126	0.7377
8	0.8675	0.9175
9	0.6761	0.8252
10	0.7850	0.9956
11	0.6736	0.7931
12	0.4466	0.7219
13	0.9065	0.9089
14	0.6011	0.8763
15	0.4583	0.5595

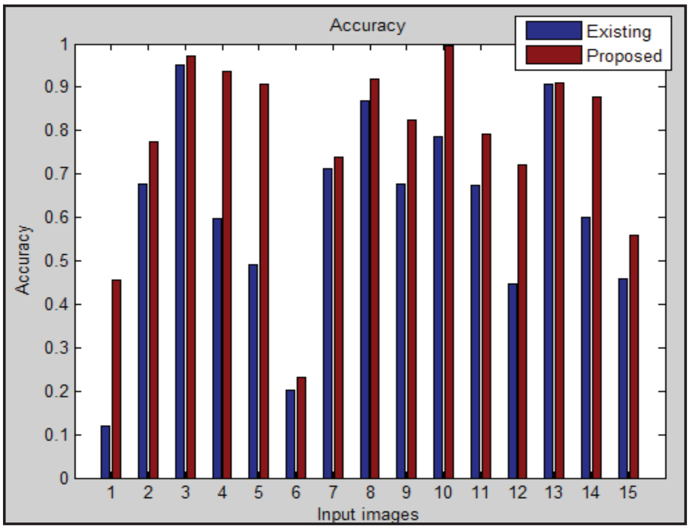

Fig. 4: Accuracy Analysis

It is seen from the graph in fig. 4. that the proposed technique has higher accuracy than the existing technique

B. Bit Error Rate

Bit error rate is defined as number of errors that occur in bits divided by the total number of bits transferred in a given period of time. According to need this error rate should decrease and should be minimum. Table 2 shows the bit error rate measurements for both the techniques

Table 2: Bit Error Rate Analysis

INPUT IMAGE	EXISTING WORK	PROPOSED WORK
1	49.2835	39.5502
2	27.0138	20.0426
3	4.6877	2.6491
4	32.1851	6.1262
5	37.9812	8.8886
6	47.9769	47.2378
7	24.6136	22.7887
8	12.3718	7.9066
9	27.1461	15.9564
10	19.1914	0.4372
11	27.3105	18.5489
12	40.0265	23.9407
13	8.9102	8.6965
14	31.9316	11.6023
15	39.4971	34.3505

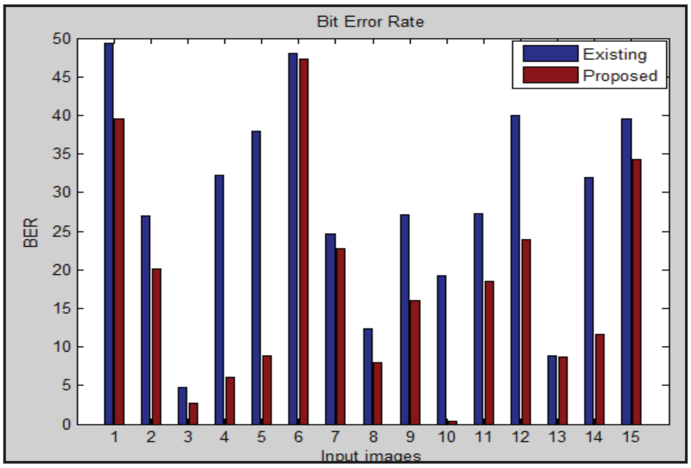

Fig. 5: Bit Error Rate Analysis

Fig. 5 shows a graph of bit error rate analysis. It is seen that the proposed technique has lower bit error as compared to existing algorithm

C. Recall

Recall is the measure of true positives that are currently identified in our algorithm. It also determines the sensitivity of our network. Recall is expressed with the help of following formula:

$$\text{Recall}=\frac{\textit{Number of true positive assesment}}{\textit{Number of all positive assesments}} \qquad (10)$$

Higher value of recall is required. As higher the value of recall better is the performance of our algorithm. Table 3 shows the values of recall for different 15 set of images.

Table 3: Recall Analysis

INPUT IMAGE	EXISTING WORK	PROPOSED WORK
1	0.0143	0.2090
2	0.4597	0.5991
3	0.9062	0.9470

4	0.3563	0.8775
5	0.2404	0.8222
6	0.0405	0.0552
7	0.5077	0.5442
8	0.7526	0.8419
9	0.4571	0.6809
10	0.6162	0.9913
11	0.4538	0.6290
12	0.1995	0.5212
13	0.8218	0.8261
14	0.3614	0.7680
15	0.2101	0.3130

Fig. 6 shows graphical representation of recall.

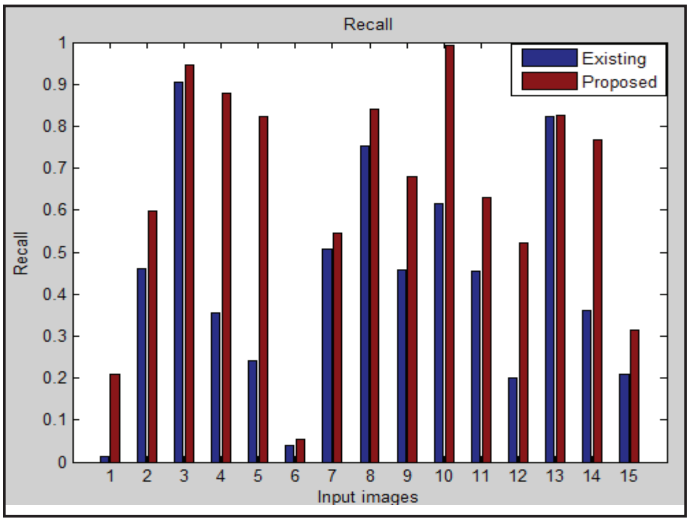

Fig. 6: Recall Analysis

D. Area under the Curve

It provides a way to measure the accuracy of our system. Table 4 shows the values of area under the curve for different 15 images.

Table 4: Area Under the Curve Analysis

INPUT IMAGE	EXISTING WORK	PROPOSED WORK
1	0.5072	0.6045
2	0.7299	0.7996
3	0.9531	0.9735
4	0.6781	0.9387
5	0.6202	0.9111
6	0.5202	0.5276
7	0.7539	0.7721
8	0.8763	0.9209
9	0.7285	0.8404
10	0.8081	0.9956
11	0.7269	0.8145
12	0.5997	0.7606
13	0.9109	0.9130
14	0.6807	0.8840
15	0.6050	0.6565

Graphical representation of area under the curve is as shown in fig. 7.

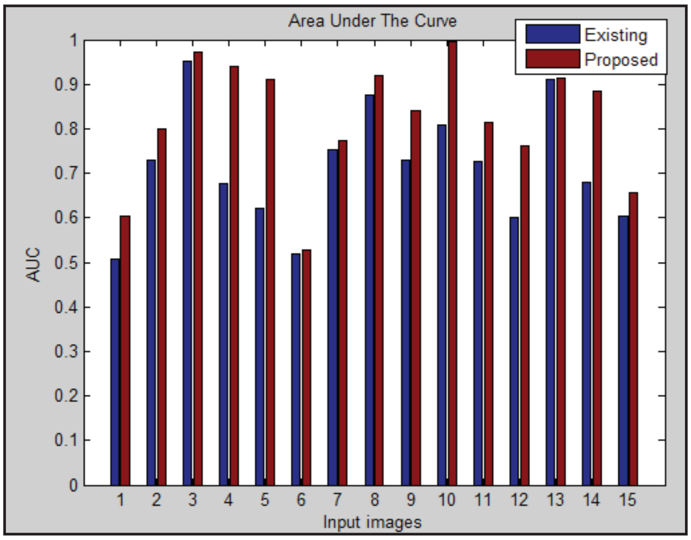

Fig. 7: Area Under the Curve Analysis

E. F- Measure

F Measure is used for computing the average values of precision and recall. Table 5 shows the different values of f measure for set of 15 different images. Higher value of f measure is desirable as higher the value of this parameter better will be clustering quality. Table 5. below shows that the proposed technique has higher value than basic algorithm.

F Measure is expressed with the help of following formula:

$$\text{FMeasure}=\frac{2.precision\ .recall}{precision+recall} \quad (11)$$

Table 5: F-Measure Analysis

INPUT IMAGE	EXISTING WORK	PROPOSED WORK
1	2.8254	34.5734
2	62.9877	74.9333
3	95.0817	97.2788
4	52.5398	93.4740
5	38.7586	90.2442
6	7.7778	10.4705
7	67.3501	70.4853
8	85.8815	91.4145
9	62.7390	81.0142
10	76.2508	99.5609
11	62.4286	77.2269
12	33.2598	68.5236
13	90.2182	90.4752
14	53.0888	86.8749
15	34.7187	47.6760

Graphical representation of f measure is shown in fig. 8. From the graph it is clearly illustrated that proposed technique is better than basic lane detection algorithm.

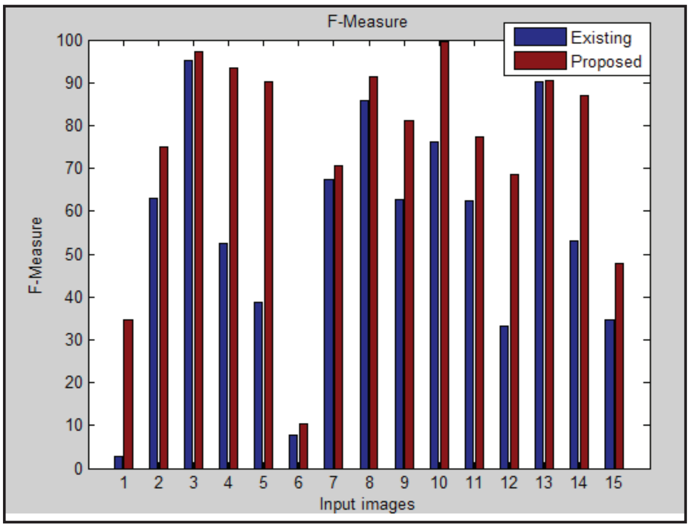

Fig. 8: F-Measure Analysis

V. Conclusion

In order to reduce accidents, vehicle manufacturers are increasing the security of vehicles by the introduction of lane detection systems in vehicular networks. It is being done because if we are aware of our lane, then we can easily move and accidents can be reduced. The previous methods of lane detection works only for straight road images and in the absence of clutters etc. But the proposed technique uses Fuzzy C-Means and Modified Hough Transform to improve lane detection algorithms and detect curved lane efficiently. The proposed technique shows higher accuracy and lower bit error rate as compared to existing algorithm. For improving the reliability of our algorithm in future, we can think of designing algorithm using filtering techniques. Various filters like weiner filters, bilateral filters can be used. Gabor filter can be used for improving results as well as these algorithms can also be implemented using embedded system.

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