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Performance Evaluation of Modified Hough Transformation for Lane Detection

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***Abstract*- among the various complex and challenging tasks of upcoming road vehicles, one is road detection or road boundaries detection. Many people die every year in roadway departure crashes caused by driver inattention in most of the cases. Lane detection systems are helpful in avoiding these accidents as safety is the major purpose of these systems. Such systems have the objective to detect the lane marks and to advise the driver in case the vehicle has a chance to depart from the lane. In this paper, after a brief overview of existing methods of lane detection and discovering their limitation of ineffective detection of curved roads, we present a novel lane colorization technique using modified hough transformation. The proposed technique can detect both the straight and curved roads very efficiently and enhance the results. Moreover, it also gives efficient results in sunny day, foggy day, and rainy day and at night time.**

***Keywords:* lane detection, Hough transform, intelligent transport systems.**

I. INTRODUCTION

Detecting and localizing lanes from a road image is an key component of many intelligent transportation systems. Lane detection is the process to locate the lane markers on the road and then give these locations as an input to an intelligent system. Lane detection is a considerable part of driver assistant system, and has been studied by many researchers [1-6]. Recent studies [7] have shown that the road fatalities have decreased over the previous years with the help of ITS, but the figure is still high enough. To decrease these fatalities, a system that provides a warning to the driver of the risk of road crossing has the potential to save a large number of lives. Number of approaches has been used till now for the lane detection. Some of them have received significant consideration since the 1980s [8-12]. Techniques used were from using monocular [13] to stereo vision [14], [15], with low-level morphological operations [12], [16] to using probabilistic grouping and B-snakes [17-19]. Though, most of these techniques were focused on detection of lane markers on straight roads, which is an easier task compared to lane detection in curved roads. Other approaches used a variety of models and techniques for lane detection, such as distance transform [20-21], perspective view [1] and processing bird's eye view [22], techniques that have higher computational costs. The other approach is a loose coupling among a detection detecting line segments, and a grouping of line segments using a Kalman filter or derivative [23-25]. Mc Call and Trivedi [11] used steerable filters to find lane segments. Various other vision-based approaches merge features of the lane with artificial intelligent technique such as neural network [22] or Bayesian probability theory [26]. Approaches can also be classified under three categories of feature based, region based and model based. Lanes are detected by using low-level features like lane-mark edges [27-29] in feature-based methods. These methods are very much dependent on clear lane-marks, and they suffer from weak lane-marks, noise and occlusions. Methods which represent lanes as a kind of curve model which can be determined by a few critical geometric parameters [30-31] are the model-based methods. As compared to the feature-based methods, the model-based methods are less sensitive to noise and weak lane appearance features. On the other hand, in the model-based methods, a very complex modeling process involving much prior knowledge is usually required. Furthermore, the model which is constructed for one scene may not work in another scene, which makes the model-based method less adaptive. For the accurate estimation of model parameters, an iterative error minimization algorithm can be applied, which is rather very time-consuming. Z. Teng [32] presented a feature based technique based on multiple cues like Bar filter, HT, colour cues and Particle Filter. This resulted in robust detection of lanes in various situations but failed in dashed lane situations. K. Ghazali et al. [33] proposed an algorithm which was based on H-Maxima and Hough Transform. The algorithm has high efficiency, ability to detect unexpected lane changes and good performance in straight and curved road conditions but failed to determine the farthest objects. R. K. Satzoda et al. [34] developed a Model- Based technique based on IPM and steerable filters. It was effective for embedded realization and adaptable to varying contextual information but fails in some environmental conditions. S. Fernado et al. [35] developed a technique on Mahalanobis distance and Gabor filter which is very robust but is very complex. Based on the previous work done in lane detection field, a method is developed in this paper to detect lane-marks by a modified Hough Transform. This technique of lane detection gives more accurate performance on lane detection of curved and straight roads as compared to other existing techniques.

II. OVERVIEW OF ALGORITHM

An image is captured initially by a camera and then the region of interest is extracted from the input image. Then this image is converted to the gray-scale image in order to

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minimize the processing time. Then the vertical histogram is drawn to estimate the mid lane of the segmented image. Then the magnitude image is processed to highlight the lane mark's margins from the image. Then the modified Hough Transform is applied to detect the lanes of straight and curved roads. Then the lane colorization is done.

A. Region of Interest

When the camera lens is directed parallel to the ground, the taken images can be divided into foreground and background fields. Selecting a suitable ROI will not only decrease the search area in images but also reduce the interference from irrelevant objects. The farthest away objects in the images which are generally above the horizon consist mainly of clouds, sky, hills or far distances objects; can be considered as region of less interest for lane detection purpose. The maximum region of interest lies from the bottom line of the image to around 17 meters in front of the vehicle, where all the essential objects are located, like lane markings, pedestrians and other vehicles. The region of interest is calculated on the basis of the dimensions of the image. Each side of image is reduced to select the particular size .

B. Gray-scale Conversion

To preserve the colour information and to segment the road from the boundaries of the lane using the colour information resulted in complications on edge detection and also it effects the processing time. Generally, the road surface can be made up of various colours due to shadows, diverse pavement style which changes the colour of the road surface and lane markings to form one image region to another. Therefore, the image is changed to gray scale as the processing of gray-scale images is minimal as compared to a colour image. It transforms a 24-bit, 3-channel, colour image to an 8-bit, single channel gray-scale image.

C. Gradient Image

The gradient image has the goal to highlight the lane mark's margins from the image. First, we generate the gradient image for the x-axis, using equation (1)

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

Then, the gradient image for the y-axis is generated using equation (2)

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

Using these gradient images, we generate the gradient image, represented as (3) and the magnitude image represented by (4)

$$\nabla J = (J_x, J_y) = \left(\frac{\delta J}{\delta x}, \frac{\delta J}{\delta y}\right) \dots\dots (3)$$

$$\|\nabla J\| = \sqrt{J_x^2 + J_y^2}) \dots\dots\dots (4)$$

D. Modified Hough Transform

It is known by the theory and various implements of Hough transform, that the classic Hough algorithm has heavy calculation burden resulted in ineffectiveness to satisfy real time request. To reduce computation cost, this paper uses prior knowledge, like ROI for better results. Moreover the classic Hough transform gives inefficient results for lane detection in curved roads. Therefore, we modify it for detecting both straight and curved roads efficiently. The pseudo code of modification of Hough Transform is as follows:-

1. Find (X,Y) boundary coordinates
2. Compute a simple estimate of the object's perimeter
   $$delta_{sq} = diff(boundary).^2 \dots (5)$$
   $$perimeter = sum\left(\sqrt{sum(delta_{sq}, 2)}\right) \dots (6)$$
3. Find the area calculation
   $$area = stats(k).Area \dots\dots (7)$$
4. Compute the roundness metric
   $$metric = \frac{4 * pi * area}{perimeter^2} \dots\dots (8)$$

III. EXPERIMENTAL RESULTS

In the experiments, the proposed approach has been implemented to test a wide variety of road images. The algorithm has been implemented in MATLAB. We tested our algorithm for many different marked roads. It successfully detected road lanes for both straight and curved roads. In this section, first of all, we compare the classical Hough transform with the modified Hough transform by showing their comparison through images. Then both techniques are compared on the basis of values evaluated by various parameters.

A. Results of Classical Hough Transform

Figure 3.1 shows the results of the straight lane image. It is clearly shown that all the lanes have been detected efficiently on straight roads.

It also shows the results of the curved lane image. It is clearly shown that the all the lanes has not been detected efficiently. And moreover it is also shown that no lane is detected in more curved road. So we can say the given technique is not so efficient for curved lane images.

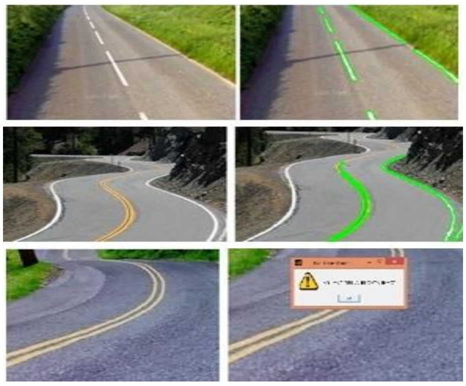

Fig. 3.1: Input images and their outputs.

B. Results of Modified Hough Transform

Figure 3.2 has shown the results of the straight lane image. It is clearly shown that the all the lanes has been detected efficiently.

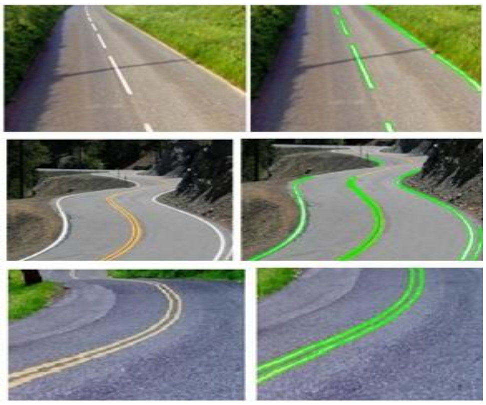

Fig. 3.2: Input images and their outputs

It also shows the results of the curved lane image. It is clearly shown that the all the lanes have been detected efficiently. So we can say that the proposed technique is very efficient for curved lane images.

Performance Evaluation

This section contains the comparison among the proposed and the existing lane detection algorithm based upon certain lane recognition metrics.

A. F-Measure

The F-Measure computes average of the information retrieval precision and recall metrics. The computed values are between 0 and 1 and a larger F-Measure value indicates higher classification/clustering quality. Table 3.1 has shown the comparison among proposed and the existing strategy based on F-measure. As the F-measure is more in almost every taken road image; therefore the proposed strategy has shown significant results over the available technique.

Table 3. 1: F-measure Analysis

Image	Old method	Proposed Technique
IMG1	51.7557	51.8065
IMG2	98.3758	98.3982
IMG3	62.9877	62.9904
IMG4	96.8174	96.8174
IMG5	99.6912	99.6959
IMG6	52.5398	52.5747
IMG7	67.8895	67.8895
IMG8	64.0087	64.2043
IMG9	98.9598	98.9598
IMG10	90.9218	91.0952

The graph obtained for F-measure of these images is shown in figure 3.3 below:

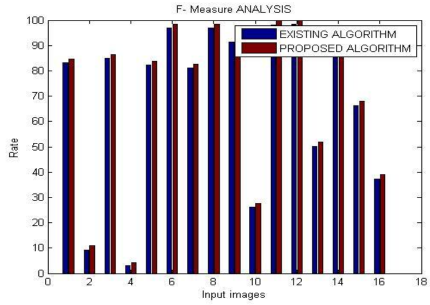

Fig. 3.3: F-measure Analysis

B. Geometric Accuracy

Geometric accuracy is the accuracy of a resulted image compared to the original image. Table 3.2 has shown the comparison among proposed and the existing strategy based on Geometric accuracy. As the value is more in almost every taken road image; therefore the proposed strategy has shown significant results over the available technique.

Table 3. 2: Geometric accuracy Analysis

Image	Old method	Proposed Technique
IMG1	0.5909	0.5913
IMG2	0.9839	0.9841
IMG3	0..6780	0.6781
IMG4	0.9687	0.9687
IMG5	0.9969	0.9970
IMG6	0.5969	0.5972
IMG7	0.7169	0.7169
IMG8	0.6861	0.6876
IMG9	0.9897	0.9897
IMG 10	0.9130	0.9146

The graph obtained for Geometric Accuracy of these images is shown in figure 3.4 below:

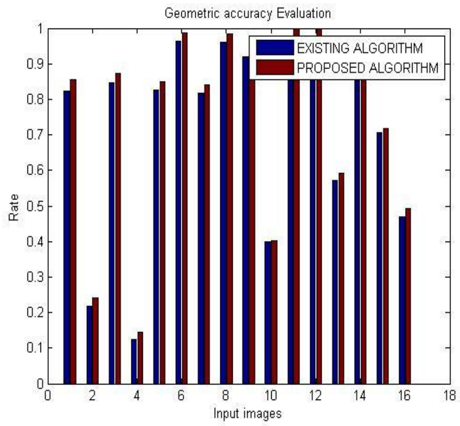

Fig. 3.4: Geometric Accuracy Analysis

C. Sensitivity

Sensitivity analysis is a way to predict the outcome of a decision if a situation turns out to be different compared to the key prediction(s). Table 3.3 has shown the comparison among proposed and the existing strategy based on Sensitivity.

Table 3. 3: Sensitivity Analysis

Image	Old method	Proposed Technique
IMG1	0.3491	0.3496
IMG2	0.9680	0.98841
IMG3	0.4597	0.6781
IMG4	0.9383	0.9687
IMG5	0.9938	0.9970
IMG6	0.3563	0.5972
IMG7	0.5139	0.7169
IMG8	0.4707	0.6876
IMG9	0.9794	0.9897
IMG 10	0.8335	0.9146

The values for Sensitivity Analysis of proposed Technique is better as compared to existing technique. So proposed hough is better as compared to classical hough. The graph obtained for Sensitivity Analysis of these images is shown in figure 3.5 below:

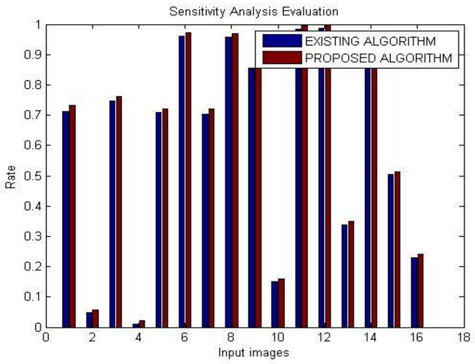

Fig. 3.5: Sensitivity Analysis

D. Bit Error Rate

The bit error rate (BER) is the percentage of bits that have errors relative to the total number of bits received in a transmission. Table 3.4 has shown the comparison among proposed and the existing strategy based on bit error rate (BER). As the BER is less in almost every taken road image; therefore the proposed strategy has shown significant results over the available technique.

Table 3.4: Bit Error Rate Analysis

Image	Old method	Proposed Technique
IMG1	32.5438	32.5206
IMG2	1.5982	1.5765
IMG3	27.0138	27.0124
IMG4	3.0845	3.0845
IMG5	0.3079	0.3032
IMG6	32.1851	32.1691
IMG7	24.3058	24.3058
IMG8	26.4659	26.3600
IMG9	1.0295	1.0295
IMG10	8.3227	8.1766

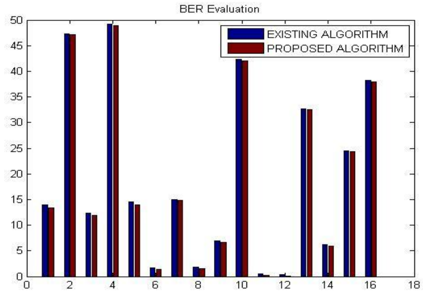

Fig. 3.6: Bit Error Rate Analysis

Figure 3.6 has shown the comparison among proposed and the existing strategy based on bit error rate (BER). As the BER is less in almost every taken road image; therefore the proposed strategy has shown significant results over the available technique.

E. Mean Square Error

Mean Square error is a risk function corresponding to the expected value of the squared error loss or quadratic loss. Table 3.5 has shown the comparison among proposed and the existing strategy based on Mean squared error (MSE).

Table 3.5: Mean Square Error Analysis

Image	Old method	Proposed Technique
IMG1	16.2719	16.2603
IMG2	0.7991	0.7883
IMG3	13.5069	13.5062
IMG4	1.5422	1.5422
IMG5	0.1539	0.1516
IMG6	16.0926	16.0845
IMG7	12.1529	12.1529
IMG8	13.2329	13.1800
IMG9	0.5148	0.5148
IMG10	4.1613	4.0883

The graph obtained for MSE of these images is shown in figure 3.7 below:

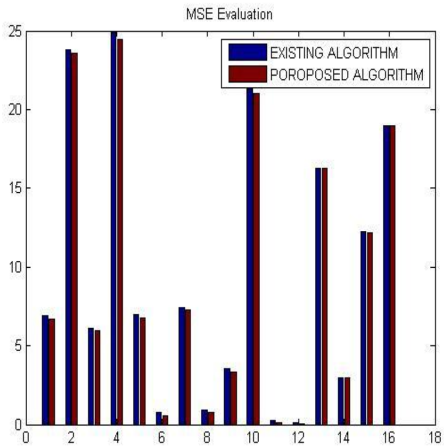

Fig. 3.7: Mean Square Error Analysis

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F. Peak Signal Noise Ratio

It is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Table 3.6 has shown the comparison among proposed and the existing strategy based on Peak Signal Noise Ration (PSNR).

Table 3.6: Peak Signal Noise Analysis

Image	Old method	Proposed Technique
IMG1	72.0329	72.0390
IMG2	98.2093	98.3282
IMG3	73.6505	73.6509
IMG4	92.4986	92.4986
IMG5	112.5144	112.6470
IMG6	72.1291	72.1334
IMG7	74.5680	74.5680
IMG8	73.8285	73.8633
IMG9	102.0293	102.0293
IMG10	83.8769	84.0307

The graph obtained for PSNR of these images is shown in figure 3.8 below:

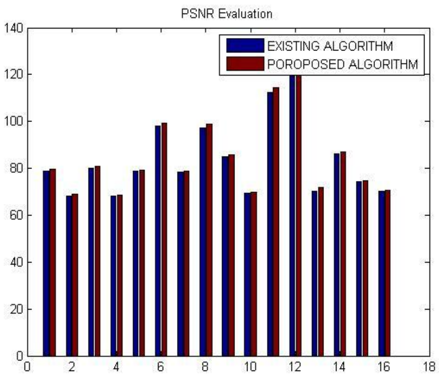

Fig. 3.8: PSNR Analysis

IV. CONCLUSION AND FUTURE WORK

The lane detection techniques play a significant role in intelligent transport systems. The most of the existing methods found to be very efficient for straight images but fail for curved images. This paper has proposed a new lane detection method by modifying the Hough transform to improve the lane detection rate for curved images. The comparisons has shown that the proposed method is very effective than the existing technique on the basis of some parameters. In near future we will integrate the proposed strategy with the guided image filter to enhance the results further.

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