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Lane Detection in Structural Road by Using Linear ModelMethod

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Abstract: In order to make sure that intelligent vehicles can work safely and efficiently in complex traffic environment, this paper proposes an effective lane detection method based on linear model in structural road. Firstly, an image preprocessing method using steerable filters is presented. To determine the lane direction during the initial lane detection phase, the images are divided into subareas and the algorithm of edge distribution function(EDF)issued. Secondly, a searching method based on orientation-priority is proposed, which reinforces those potentialroad lines while degrading otherwise edge features.Finally, lane markings are fitted using random sampleconsensus and the detection accuracy is improved. Experimental results under a wide variety of typical but challenging conditions have shown that Lane detection in structural road by using linear model method with steerable filters can detect lanes accurately and stably, which also has high efficiency and greatly reduces execution time.
Keywords: Lane Detection, Steerable Filters, Lines Fitting

I. INTRODUCTION

The robustness and stability of lane detection is vital for advanced driver assistance vehicle technology and even unmanned technology. At present, although many papers have proposed various methods to detect the lane, thecomplexity and uncertainty of road conditions has led to that there is still room for improvement of existing methods local. Challenges include: shadows cast from trees, other vehicles and buildings, invisible or defect lanes, highlight, strange lane shapes and bad quality lines and so on(Fig.1)[1][2].

Before we extract directly lane feature points in the lane road images, Bertozzi and so tended to reverse perspective view of the road image in order to coordinate conversion to take full advantage of parallel geometric information of the lane line. This method has advantage in locating accurately, however,it hastorely onspecialized hardware and has a large amount of computation.This article does not use this method.

Currently methodsof lane line feature points extraction are mainly divided into two categories: methods based on areacolor texture and method based on gradient feature[3][4].Approach based on area color texture distinguishing lane area from the road surface is recognized as a problem of binary classification. Literature[3]uses RGB or CIE color space classification method to learnmean and variance parameters of road surface region and the lane area, however, the statistical parameters ofthe color need to change dynamically to adapt to thechanging lighting and shadows conditions and other factors[5][6].

This work usesan effective lane detection method based on linear model in structural road by using steerable filters to preprocess the images, followed by a searching method based on orientation-priority for removing pavement shadows cast from trees and buildings and lanedefects interferencecan effectively reinforce those potential road lines and improve lane lines visibility while degrading otherwise edge features. The method cangreatly improve the algorithm robustness to meet therequirements of safety and real-time of vehicle driving.

The paper is organized as follows:sectionII gives a detailed description of the image preprocessing. Section III presents the RANSAC method to fit lane markings, which is followed by experiments and results in section IV. Finally, a conclusion is given insection V.

Fig.1 Challenges of lane detection in structural streets

II IMAGE PREPROCESSING

2.1 Steerable Filter

Steerable filters can be seen as a combination of a pair of base filters which can response to any directional inputs. This paper chooses the first order derivative of a two-dimensional Gaussian function as the base filters:

$$G(x,y) = \exp(-(x^2 + y^2)) \quad (1)$$

$$G_1^{0^\circ} = \frac{\partial}{\partial x}\exp\left(-(x^2 + y^2)\right) = -2x\exp(-(x^2 + y^2))(2)$$

$$G_1^{90^\circ} = \frac{\partial}{\partial y}\exp\left(-(x^2 + y^2)\right) = -2y\exp(-(x^2 + y^2))(3)$$

Where Eq.(1) is Gaussian function, Eq.(2) is respect for 0degree directionbase filter and Eq.(3) is respect for 90 degree directionbase filter. Combining Eq.(2) and Eq.(3) can get output waves in random direction:

$$G_1^{\beta} = G_1^{0^\circ}\cos\beta + G_1^{90^\circ}\sin\beta(4)$$

Where β is the direction angle of steerable filters.

We do not know the initial direction angleat the beginning, so we need to use EDF method obtain the β. The Eq.(5) shows gradient equation of a grayscale image:

$$G\left(I(x,y)\right) = \left(\frac{\partial I}{\partial x},\frac{\partial I}{\partial y}\right)^T \approx (D_x, D_y)^T(5)$$

Where D_x is the gradient of x direction while D_y is the gradient of y direction, both are obtained by using Sobel. According to Eq.(5) we can get gradient magnitude and angle：

$$\left|G\left(I(x,y)\right)\right| = \sqrt{D_x^2 + D_y^2} \approx |D_x| + \left|D_y\right| \quad (6)$$

$$\beta(x,y) = \arctan\frac{D_y}{D_x} \quad (7)$$

According to Eq.(6) and Eq.(7), we can get the initial direction angle. However, we only use edge distribution function to determine the lane direction during the initial lane detection and the restarting phase when the algorithm does not work, because method EDF has large amount of calculation[7][8].

2.2 A searching method based on orientation-priority

In order to reduce execution time, this paper detects the left and right lane line independently and simultaneously.

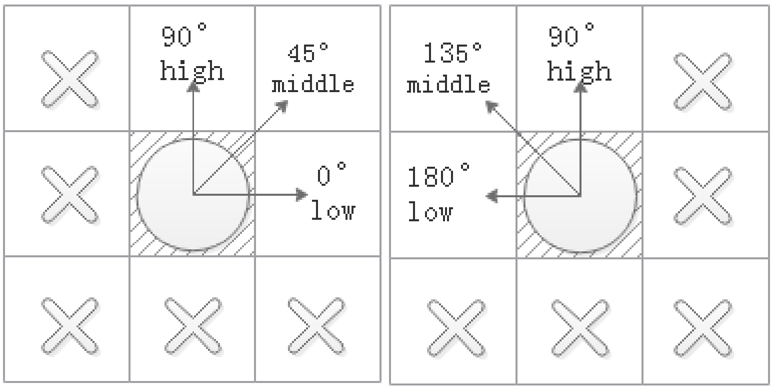
For purposes of illustration, the work takes the left lane search rules as an example. As shown in Fig.2(a), one feature point in the left lane was defined three priority directions: 90 degree directionhas the highest priority, followed by 45 degree, and 0 degree direction has minimum priority. Search rules are as follows:

2.2.1 Starting at the bottom left-hand corner, the method scans grayscale of left lane line from left to right, from bottom to top in line-by-line. If the current pixel is detected as an edge point, it will be set as the starting point in the initialization segment. Otherwise, continue to scan until it finds the edge points, then proceed to the next step.

2.2.2 Analyzing the current point in three directions exists an edge point or not. Begin from 90 degree direction, followed by 45 degree direction, and 0 degree direction in the last. If no satisfactory edge pointsare foundin the three directions, go directly to the next step; if eligible edge point is found,record the coordinates of the point and move to the new edge point to repeat the search process. Not end the search processuntil no point can be found to meet the conditions. End the search of this segment andproceed to the next step.

2.2.3 Repeat step 2.2.1 to traverse all the edge points in entire image, then end the search of candidatesegments in the left lane line.

Search Rules of right lane lines are similar to what is said above, shown in Fig.2(b).



(a) **(b)**

Fig.2 Search rules schematic

After completion of search elements,you will obtain the candidatesegments of n. Each candidatesegment includes m coordinate points, which length of the record is on behalf of the number of pixels of the line segment. By setting the threshold line, you can get an ideal lane recognition image[4].

III. THE LANE LINE FITTING BASED ON LINEAR MODEL

In the structure roads such as highways and urban roads, the lane lines imaging in an image is similar to the linear model, so it is proposed to use linear models to fit lane curves using feature points .In order to eliminate influence to the lane line fitting by anomalies point, this study uses the RANSAC (random sample consensus) method. This method divides extracted feature points into interior point and outliers, using an iterative manner to exclude some outliers thatcan notadapt to the lane line model.

RANSAC method[9] randomly selects k feature points to form a linear hypothesis each time, and then checksthat how many other feature pointsfall on the line or within a certain distance ε. In the last, select thestraight line which has the maximum amount of interior points as the target lane line.Take the log of Both sides of its iterations Eq. (8), we can get Eq.(9):

$$1-p=(1-w^k)^s \quad (8)$$

$$s=\frac{\log(1-p)}{\log(1-w^k)} \quad (9)$$

Where: w represents the probability of selecting a game point from the data set, p represents the probability of which a point randomly selected from data set is an interior point after s iterations.

Usually, due to intra-office points are far more than the number of outliers, there is less iterationsif the value of p, k is certain. Under various environmental conditions, there are more interior points are formed as well as signal contrast is clearer in near view of lane condition. Therefore, giving preference to choosing k feature points in near view fieldcan improveRANSAC performance, improve the accuracy of the lane line fitting as well as further reduce iterations during the initial stage. Fig.3 shows the results of feature points extraction and straight line fitting.

Fig.3lane detectionresults under different weather conditions

IV. CONCLUSION

This paper presents an effective lane detection method based on linear model in structural road, using steerable filters for image preprocessing. During the initial lane detection phase, EDF method is used to determine lane direction. This method not only has takenlane directional characteristic into consideration but also ensures the algorithm's real -time.In order to apply information accepted in image preprocessing period better, we adopt a searching method based on orientation-prioritytoreinforce thosepotential road lines while degrading otherwise edge features by checking left and right lines separately but simultaneously.

Then we use RANCAC to fit all valid points into straight lines, which greatly improves the real-time and robustness of algorithm. After a variety of conditions experimental tests, the proposed lane line search algorithm based on the linear model has been verified that it can complete lane line identification stably in various environmental conditions and successfully meet the requirements of safety and robustness of intelligent vehicles driving.

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