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Double Lane Line Edge Detection Method Based on Constraint Conditions Hough Transform

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***Abstract*—This paper proposes a lane detection method based on the constraint Hough Transform double edge extraction. Firstly, the image of the road is grayed out and dealt with the lane line area extraction process based on the lane width feature and color feature. For grayscale images, the Canny edge detection operator is used to obtain the lane line edge information. Then the lane line features are extracted through the lane line edge information and the lane line area information. For the straight lane line, the Hough transform based on the polar angle and polar radius constraints is used to obtain the double edges of the lane lines, and straight line points are used to determine the end points and starting points of the straight lane lines to complete the straight line fitting. For the curve, the near-field part is a straight line, the far-field is a curve, and the straight part adopts the detection method of the straight lane line, and the characteristic points of the curve are searched in the lane line characteristic diagram. Finally, the curve is fitted by a parabola. Experiments show that the lane detection using the double-edge extraction method is fast and accurate.**

Keywords*—Hough transform, double edge extraction, lane detection

I. INTRODUCTION

With the rapid development of science and technology, the development of the transportation industry is also booming. However, with the development of the transportation industry and the replacement of various vehicles such as automobiles, the potential safety hazards have become more and more serious. In China, traffic safety accidents caused by vehicle lane departures account for about 50%.China is still one of the countries with the highest traffic accident death rate in the world, and the national accident mortality rate exceeds 15%[1].The relevant data proves that before the accident, the driver is reminded to pay attention to the lane deviation and make appropriate operations to avoid more than 60% of accidents[2].The road lane line identification technology is the core and most basic function in the vehicle safety auxiliary system. Therefore, it is of theoretical and practical significance to study the identification method of road lane lines.

The detection of lane lines is a hot topic in the field of computer vision. At present, there are two kinds of lane line detection methods proposed by scholars at home and abroad: model-based and feature-based. The model-based method [3] is mainly used to extract the lane line by matching the feature point of the driveway line and the geometric model of the lane line. The feature-based method [4] is mainly detects lane lines through some low-level features such as gradients, directions, and gray values of the lane line edge points. Ma et al. [5] proposed a lane detection method based on K-means clustering based on CLELAB color features. Yang et al. [6] proposed a lane detection and recognition algorithm based on RGB space. Yi et al. [7] proposed a lane detection method based on edge distribution and feature clustering. The method adopted a variable window to count the local gray threshold of the lane line and extract the effective lane line edge with the image gradient. Cao et al. [8] proposed the establishment of pavement reflection model to process the image so as to weaken the other information points of the road. Liu et al. [9] proposed a lane detection method based on the surface water reflection model and the symmetry feature.

II. EXTRACT LANE LINE FEATURES

A. Extract Lane Line Image Region of Interest

Since the picture including the lane line is captured by using a CCD installed in front of the vehicle. According to the size of the picture, this paper divides the lane line image into three parts: near field, far vision field and sky area. As shown in figure 1: the near vision field area and far vision field area contain lane line information, and the sky area contains no important lane line information. The sky area accounts for 5/12 of the entire image, and the area of the near-field field is approximately twice that of the far-field.

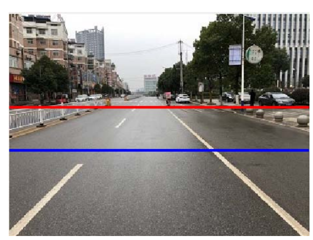

Figure 1 Regional division of road images

B. Extract Lane Line Area Based on Lane Line Lolor Feature

In the RGB image, the values of the R and G components of the white lane line and the yellow lane line are significantly higher than the R and G values of the road surface and the background. Therefore, according to the R, G components of the lane line image, it is possible to determine which pixel

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points in the image are the pixel points included in the lane line, and determine the color of the lane line through the B component. In this paper, according to the color characteristics of lane lines, the points that match the color characteristics of lane lines are selected.

In order to extract the road line area features correctly according to the color features of the lane lines, the feature color function formulas 1 to 4 proposed in this paper are as follows.

$$IM(i,j)=\begin{cases}255\ , & R(i,j)\geq(0.2R_{\min}+0.8R_{\max})\ \&\& \\ & G(i,j)\geq(0.2G_{\min}+0.8G_{\max}) \\ 0, & others\end{cases} \quad (1)$$

$$G(i,j)=\begin{cases}255, & R(i,j)\geq G(i,j)\geq B(i,j) \\ & \&\& IM(i,j)>0 \\ 0, & others\end{cases} \quad (2)$$

$$\begin{aligned}Gray(i,j)=R(i,j)+G(i,j)-2*B(i,j)+ \\ 0.3*8*\left|R(i,j)+G(i,j)\right|\end{aligned} \quad (3)$$

$$GM(i,j)=\begin{cases}128\ , & Gray(i,j)\geq 0.8*Gray_m \\ 255, & 2*Gray_{avg}<=Gray(i,j)<=0.8*Gray_m \\ & \|\ G(i,j)=255 \\ 0, & others\end{cases} \quad (4)$$

In formula 1, $IM(i,j)$ represents the initial color feature value at the pixel(i,j) in the image. $R(i,j)$ represents luminance value of the R component and $G(i,j)$ represents luminance value of the G component. $R_{\max}$, $R_{\min}$, $G_{\max}$, and $G_{\min}$ respectively represent the maximum value of the R component, the minimum value of the R component, the maximum value of the G component, and the minimum value of the G component, of the current row.

In formula 2, $G(i,j)$ represents the color feature value at the pixel(i,j) in the image.

In formula 3, $Gray(i,j)$ represents the color feature transition value, which is determined by each channel component value of the current pixel point.

In formula 4, $Gray_{avg}$ represents the average of the color feature transfer values in the current row, and $Gray_m$ represents the maximum value of the transfer value of the color feature in the current row. and $GM(i,j)$ represents the final color feature value of the pixel(i,j) in the image $GM(i,j)$ is jointly determined by $G(i,j)$, $Gray(i,j)$, and $Gray_{avg}$, $Gray_m$.

C. Get the Edge of the Lane Line

Edge detection [10] is to find the edge of the image region by analyzing the grayscale jump. In this paper, Canny [11] edge detection operator is used to filter out edges that meet the characteristics of lane lines. The Canny edge operator has a ratio of 1:2 for high and low thresholds, 0.3 for high thresholds, and 0.15 for low thresholds.

D. Extract Lane Line Features.

For the near-field part, when the pixel point $IME(i,j)$ whose pixel value is not zero appears in the lane line edge image, then scanning of the lane line area image IMC current pixel point $IMC(i,j)$ and its surrounding eight pixel points. When the nine pixel points in the lane line area image satisfies formula 5, then the pixel point $IME(i,j)$ is considered as the lane line edge pixel point.

$$\begin{aligned}&IMC(i,j+1)+IMC(i,j)+IMC(i,j-1)\\&+IMC(i-1,j+1)+IMC(i-1,j)+IMC(i-1,j-1)\\&+IMC(i+1,j+1)+IMC(i+1,j)+IMC(i+1,j-1)>0\end{aligned} \quad (5)$$

$$\begin{aligned}&IME(i,j-5)+IME(i,j-4)+IME(i,j-3)\\&+IME(i,j-2)IME(i,j-1)+IME(i,j)\\&+IME(i,j+1)+IME(i,j+2)+IME(i,j+3)\\&+IME(i,j+4)+IME(i,j+5)>0\end{aligned} \quad (6)$$

III. DETECTION OF STRAIGHT LANE LINE

The range of polar angles in the traditional Hough transform [12] is chosen from 0° to 180°. The polar angle range used in this paper is -90° to 90°. The steps for detecting the straight line based on the constraint condition Hough transform are as follows:

Step 1: Quantize (ρ, θ) into equally spaced small grids by combining the polar Angle and the polar radius.

Step 2: Build a two-dimensional additive matrix A1. Each value of the matrix represents a small grid, and the value represents the number of grids passing through (ρ, θ).The pixels of the near-field part of the edge image are sequentially traversed, and the pixel points whose pixel value is not 0 are mapped as a sine curve of ρ-θ space. As long as the curve passes through the small grid, the corresponding value of the accumulation matrix is incremented by one.

Step 3: Find the largest four groups (ρ, θ) in A1 by traversing the accumulation matrix A1.

After obtaining the four largest groups (ρ, θ), the starting and ending coordinates of the two edges of the left and right lane lines are determined by θ. Straight line detection results is shown in Figure 2.

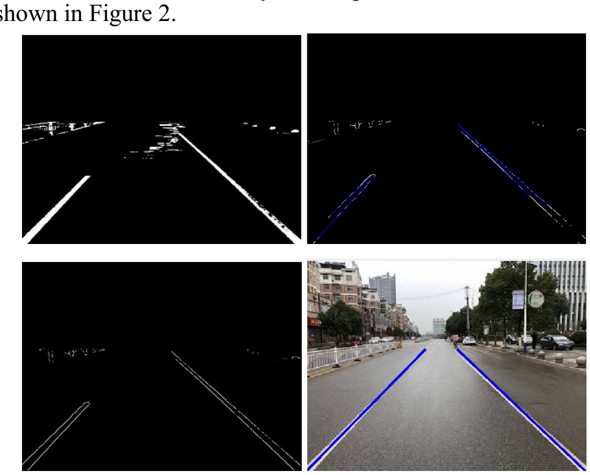

Figure 2 Detection of straight lane line

IV. CURVE DETECTION

A. *Straight-parabolic model*

Straight-parabolic model Formula is shown in formula 7, the intersection of the straight line segment and the curve segment is the deviation point of the lane line model.

$$x = a + by + cy^2 \tag{7}$$

$$x = \begin{cases} a + by, & y \le y_m \\ c + dy + ey^2, & y > y_m \end{cases} \tag{8}$$

In the formula 8, y_m represents the ordinate of the departure point, a and b represent the parameters of the straight line, c, d, e represent the parameters of the curve. a, b, c, d, e satisfy the formula 9, formula 10. Formula 11 can be obtained from these two fomulas.

$$a + by_m = c + dy_m + ey_m^2 \tag{9}$$

$$b = d + 2ey_m \tag{10}$$

$$\begin{cases} c = a + \dfrac{y_m}{2}(b - d) \\ e = \dfrac{1}{2y_m}(b - d) \end{cases} \tag{11}$$

B. *The choice of deviation point of the curve and the judgment of deviation direction*

By extending the left and right lane lines, we first find the intersection point between the left lane line and the far field of vision of the near vision field AL, the intersection point between the right lane line and the far field of vision of the near vision field AR. Then find the intersection point between the left lane line and the far-field ALF, the intersection of the right lane line and the far-field ARF. This article selects point AL as the deviation point of the left lane line, and point AR as the deviation point of the right lane line. As shown in Figure 3, the curve area is divided into four areas II I, II II, II III, II IV, and there are overlapping areas in the areas II II, II III.

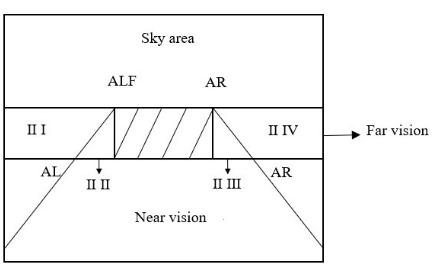

Figure 3 Regional division of the far vision field

C. *Extract the -curve feature point*

When the lane line is curved to the left, the initial point of the left curve is AL. The ordinate of AL is ALY, and the abscissa of AL is ALX. An ordered empty set RLI records abscissa of the left-curve feature point, and an ordered empty set RLJ records ordinate of the left-curve feature point. Search steps of the left corner feature point is:

Step 1: From the point (ALX, ALY-5) which is five lines above point AL, to the left. When encountering a lane line feature point where the pixel point is not 0, the abscissa of the point is stored in the set RLI, the ordinate is stored in the set RLJ. The abscissa of the current point is restored in m. Then step goes to 2. If 10 pixels are searched and no point of which pixel is not 0 are found, m is set to ALX then step goes to 3.

Step 2: The scan point is moved to the fifth line above the current line. According to the value recorded by m. If the pixel value of AM is not 0, the abscissa of the point AM is stored in the set RLI, the ordinate is stored in the set RLJ, and the abscissa of the point AM is recorded in m, then step goes to 2. If the pixel value AM is 0, step goes to 4.

Step 3: The previous line of the current line is scanned. According to the value recorded by m, it is first judged whether or not the pixel value of the point AM at the abscissa of the current line is not 0. If the pixel value of the point AM is not 0, the abscissa of the point AM is stored in the set RLI, and the abscissa of the point AM is recorded in m, then step goes to 2. If the pixel value AM is 0, step goes to 4.

Step 4: AM is regarded as the starting point. First, fifteen feature points to the left of AM are searched. When encountering a lane line feature point of which pixel is not 0, the abscissa of the point is stored in the set RLI, the ordinate is stored in the set RLJ, and the abscissa of the point AM is recorded in m, then step goes to 2. If 15 points have been scanned or the points on the left side of the AM have been scanned, and there is still no point of which the pixel value is not 0, step goes to 5.

Step 5: AM is regarded as the starting point. First, fifteen feature points to the right of AM are searched. When encountering a lane line feature point of which pixel is not 0, the abscissa of the point is stored in the set RLI, the ordinate is stored in the set RLJ, and the abscissa of the point AM is recorded in m, then step goes to 2. If 15 points have been scanned, and there is still no point of which the pixel value is not 0, step goes to 3.

After the processing above, the set RLI contains the abscissas of all left-curve feature points, and the set RLJ contains the ordinates of all left-curve feature points. Search steps of the right corner feature point is similar to the steps of the left corner feature point.Use the least squares method to complete the curve fitting. Figure 4 is the curve fitting effect.

Figure 4 Detection of curve lane line

In Table I and Table II, the ordinate range is (200,294). The standard deviation of the left lane line is 1.62094. The standard deviation of the right lane line is 1.599393.

TABLE I. THE DEVIATION OF THE LEFT LANE LINE

i	x_i	y_i	$x_i^{'}$	$\triangle x$	$\triangle x^2$
1	6	204	5.72	-0.28	0.0784
2	25	209	21.382	-3.618	13.08992
3	41	214	35.974	-5.026	25.26068
4	55	219	49.496	-5.504	30.29402
5	67	224	61.948	-5.052	25.5227
6	78	229	73.33	-4.67	21.8089
7	87	234	83.642	-3.358	11.27616
8	94	239	92.884	-1.116	1.245456
9	101	244	101.056	0.056	0.003136
10	107	249	108.158	1.158	1.340964
11	112	254	114.19	2.19	4.7961
12	116	259	119.152	3.152	9.935104
13	119	264	123.044	4.044	16.35394
14	121	269	125.866	4.866	23.67796
15	123	274	127.618	4.618	21.32592
16	124	279	128.3	4.3	18.49
17	124	284	127.912	3.912	15.30374
18	124	289	126.454	2.454	6.022116
19	125	294	123.926	-1.074	1.153476
$\sum_{i=1}^{19} \triangle x = 1.052$			$\sum_{i=1}^{19} \triangle x^2 = 246.9787$		

TABLE II. THE DEVIATION OF THE RIGHT LANE LINE

i	x_i	y_i	$x_i^{'}$	$\triangle x$	$\triangle x^2$
1	145	204	145.4965	0.4965	0.246512
2	166	209	168.183	2.183	4.765489
3	192	214	189.9195	-2.0805	4.32848
4	214	219	210.706	-3.294	10.85044
5	237	224	230.5425	-6.4575	41.69931
6	255	229	249.429	-5.571	31.03604
7	270	234	267.3655	-2.6345	6.94059
8	283	239	281.0307	-1.9693	3.878142
9	297	244	297.2572	0.2572	0.066152
10	311	249	312.5337	1.5337	2.352236
11	323	254	326.8602	3.8602	14.90114
12	335	259	340.2367	5.2367	27.42303
13	348	264	352.6632	4.6632	21.74543
14	360	269	364.1397	4.1397	17.13712
15	371	274	374.6662	3.6662	13.44102
16	381	279	384.2427	3.2427	10.5151
17	392	284	392.8692	0.8692	0.755509
18	403	289	400.5457	-2.4543	6.023588
19	414	294	409.2722	-4.7278	22.35209
$\sum_{i=1}^{19} \triangle x = 0.9594$			$\sum_{i=1}^{19} \triangle x^2 = 240.4574$		

V. EXPERIMENTAL RESULTS AND ANALYSIS.

This experiment algorithms are all based on compiler implementation Matlab2016 software environment. The image resolution is 640 * 480. Figures 2 and 4 are showing the effect of straight line lane detection and curve detection on the captured image. After an analysis of 1000 straight-line image processing, the average time for processing an image is 64.5ms. For curves, after analyzing the image processing of 500 bends, the average time for processing an image by the algorithm is 86.5ms. In the 1000 straight lane line pictures, 985 lane lines were correctly identified and the recognition rate was 98.5%. In the 500 Curve lane line images, 470 lane lines were correctly identified, and the recognition rate was 94%.

VI. CONCLUSIONS

This paper proposes a lane-line detection and identification method based on constraint Hough transform double-edge extraction. The method extracts the lane line area of the road image in the RGB color space, using Canny operator to obtain edge image of road image. The lane line feature image is obtained from the edge image and the lane line area image. The inner and outer edges of lane lines are extracted by using the constraint Hough transform of the extracted lane line feature image. Straight lines are determined by determining the starting point and end point of the straight line of the lane line through analyzing the inner and outer edges of the lane line. On the basis of accurately detecting the straight lane line, the bending direction of the curve is determined, and the characteristic points of the curve are extracted. Finally, the curve recognition is completed by least-squares fitting. This method shortens the image processing time by constraining the range of polar angles of the Hough transform.

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