ISSN: 2710-0588

Research on Lane Line Detection Algorithm based on Improved Hough Transform

Shuai Shao

School of Electrical Information Engineering, Northeast Petroleum University, Daqing, 163000, China

*Shao-Shuai@163.com

Abstract

In order to solve the problems existing in the traditional lane line detection algorithm, such as weak robustness and low accuracy, an improved Hough transform lane line detection algorithm is proposed. Firstly, the method preprocesses the road image, including gray transformation, histogram equalization, Gaussian filtering, image binarization and so on. Then the canny edge detection operator is used to detect the edge of the image to be processed, and an improved Hough transform algorithm is proposed. Simulation results show that the algorithm has stronger robustness and higher accuracy than the traditional algorithm.

Keywords

Line Detection Algorithm; Mproved Hough Transform; Image Preprocessing; Establishment of Lane Line Model.

1. Image Preprocessing

The road image preprocessing process is shown in figure 1.

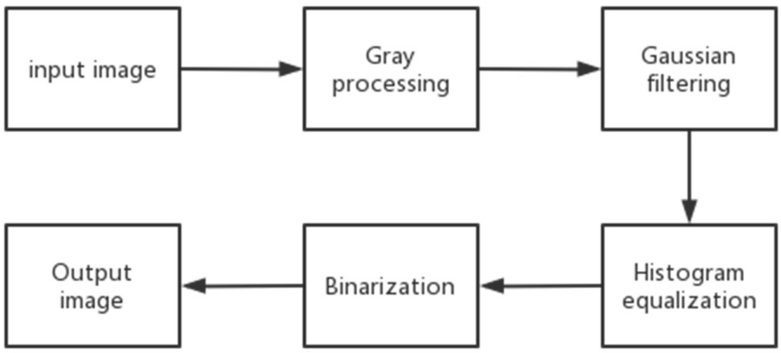


Figure 1. image preprocessing process

The color value of each pixel on the gray-scale image is also called gray-scale, which refers to the color depth of the midpoint of the black-and-white image. The range is generally from 0 to 255, 255 for white and 0 for black. The amount of road image information is large. The weighted average method is used to convert the road image into gray image, which will not change the initial characteristics of the road. The weighted average method gives different weights to the three channels R, G and B respectively. The expression is as follows[2]:

$$f(i,j) = 0.3R(i,j) + 0.59G(i,j) + 0.11B(i,j) \tag{1}$$

ISSN: 2710-0588

The process of transforming color image into gray image, that is, the process of transforming three-dimensional matrix into two-dimensional matrix, retains the information required by the experiment and shortens the time required for subsequent image processing, as shown in Figure 2:

Figure 2. gray scale diagram

The specific steps are as follows. The specific calculation method is as follows[3]:

$$T_j = \frac{f_{\max}(x, y) + f_{\min}(x, y)}{2} \quad j = 1 \tag{2}$$

Figure 3. binarization diagram

The gray value of the image is discrete, the discrete gray level is represented by rk, and the distribution of the image gray level is represented by the probability density function pr (R), then the following formula holds:

$$p_r(r_k) = \frac{n_k}{n} \tag{3}$$

Where 0 < rk < 1, k = 0,1,2 N-1, where the number of pixels with gray level is represented by nk, the gray level series is represented by K, the total number of pixels is represented by n, and the frequency is nk/ n.

The value of R can be changed in the [0,1] interval. The gray level of the image after equalization is expressed by s, and t (R) is the transformation function.

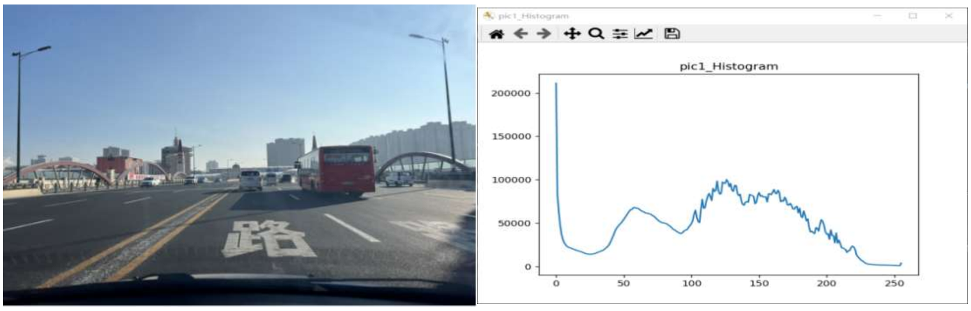
$$s = T(r) \tag{4}$$

ISSN: 2710-0588

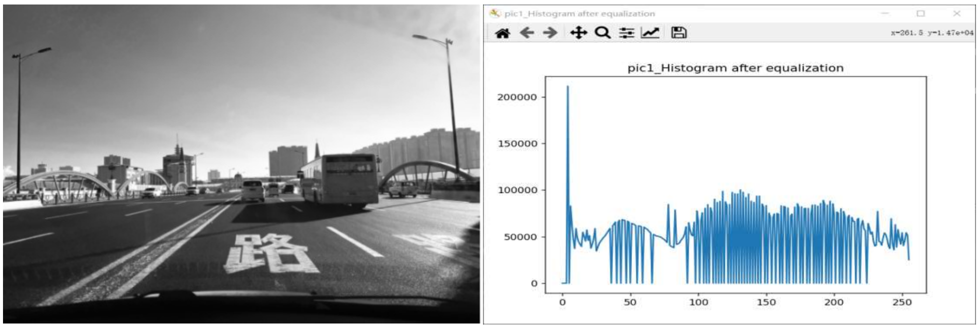
When the gray value in the image is a discrete value, the discrete form of the transformation function can be expressed as:

$$s_k = T(r) = \sum_{k=0}^{n-1} p_r(r_k) = \sum_{k=0}^{n-1} \frac{n_k}{n} \tag{5}$$

Histogram equalization is represented by sk. The process of gray level from input to output is the pixel mapping process from rk to sk. Combined with the above formula derivation, the enhanced lane line image can be accurately obtained, as shown in Figure 4 below.



(a)Original image (b)Original image histogram



(c)after histogram equalization (d)Histogram after equalization

Figure 4. effect diagram after histogram equalization

2. Image Edge Detection

Image edge detection algorithms include Sobel operator[5], Roberts operator, previtt operator and Canny operator. Compared with other operators, canny has clearer processing and more complete road edge extraction, which can meet the needs of experiments. There are four steps to implement Canny operator:

(1)In the first step, Gaussian filter is used to smooth the image.

$$\mathrm{g}(x, y) = h(x, y, \delta) * f(x, y) \tag{6}$$

(2)Find the gradient intensity in the image, where is the approximate gradient of pixels, is the gradient direction, is the convolution kernel of the corresponding weight, and is the image pixel matrix.

$$R = \left(R_x{}^2 + R_y{}^2\right)^{1/2} \tag{7}$$

ISSN: 2710-0588

$$\theta = \cot\left(G * I / G^T * I\right) \tag{8}$$

(3)It is necessary to suppress the non maximum value of gradient amplitude in order to solve the problem of boundary ambiguity.

(4)Set strong threshold boundary and weak threshold boundary. If the pixels in the image are larger than the strong threshold boundary, it is a strong boundary. If it is less than the strong threshold boundary and greater than the weak threshold boundary, it is a candidate weak boundary.

3. Improved Hough Transform Algorithm

Typically, the slope of the left lane line is negative and the slope of the right lane line is positive. The expression of slope can be expressed by equations (12) and (13):

$$k_l = \frac{y_a - y_b}{x_a - x_b} \tag{9}$$

$$k_r = \frac{y_c - y_d}{x_c - x_d} \tag{10}$$

In the above formula[9], (XA, ya), (XB, Yb) are the coordinates of the left edge point in the region of interest, (XC, YC), (XD, YD) are the coordinates of the right edge point in the region of interest. Taking the right lane line as an example, the coordinate points on the straight line of the region of interest in the initial image are as follows (14):

$$\begin{cases} X_c = x_c + R \cdot x \\ Y_c = y_c + R \cdot y \\ X_d = x_d + R \cdot x \\ Y_d = y_d + R \cdot y \end{cases} \tag{11}$$

If the car is in the middle of the lane, the slope of the lane lines on both sides also has a certain range. If the low slope threshold value is Ka and Ka is smaller than zero, and the high slope closing value is Ka and Ka is larger than zero, then the slope (KL, KT) of lane lines on both sides under normal and initial states needs to meet equations (15) and (16):

$$-k_a < k_l < k_A \tag{12}$$

$$-k_a < k_r < k_A \tag{13}$$

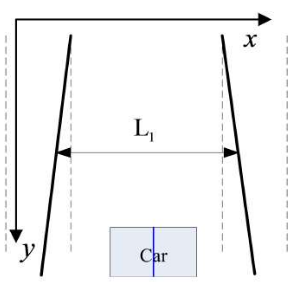


Figure 5. front view of lane image

ISSN: 2710-0588

The lane width of the left and right lane lines also has a certain range, as shown in Figure 7. The distance between two lane lines can be set according to the actual situation. Among the line pairs in the candidate image area, the line pair closest to the lane width can be found in the world lane image (road top view). In the case of the same ordinate, the line pair is usually the line pair with the shortest abscissa distance difference. When the ordinate is half of the ROI, the distance between the left and right lane lines is expressed as shown in equation (14) (15)[9]:

$$D_1 = u_2 x - u_1 x \tag{14}$$

$$D_2 = u_{2H} x - u_{1H} x \tag{15}$$

In the above formula, u1hx and u2hx are the abscissa of the left and right sides in the front view respectively, and u1x and u2x are the abscissa of the left and right sides in the top view respectively.

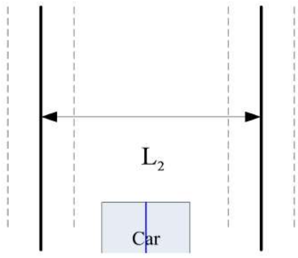


Figure 6. top view of road image

4. Result Verification and Analysis

The experimental video of this paper was collected by Dongfeng Peugeot car with iPhone 13 camera in Mudanjiang urban highway environment. The image processing system is a computer with CPU i58300h 2.3ghz and 16g memory. It selects a 120m video and extracts 800 images with 1290 * 720 pixels, including road images during the day and at night. Experimental image and video processing is installed in the computer with Python 3 7 and OpenCV. The average processing time of lane line detection per frame is about 35ms.

The experimental simulation results are shown in Figure 8. Under normal operation conditions, the algorithm in this paper can accurately fit the actual lane line, and predict the driving direction of the lane line in real time according to the abscissa of the vanishing point. The lane line can still be correctly identified and fitted under different environmental changes of night environment and pavement materials, with good accuracy.

(a)Strong daylight (b) Weak light during the day

ISSN: 2710-0588

(c)Vehicle interference at night (d)No vehicle interference at night

Figure 7. Result verification and analysis

Table 1. Comparison of verification results

algorithm	Average accuracy/%	Average time/%
Traditional Hough transform	75.6	0.058
Literature (10)	93.6	0.042
Algorithm in this paper	95.3	0.036

5. Conclusion

This paper preprocesses the collected structured road image through gray transformation, binarization and histogram equalization, and uses Canny operator with good detection effect to detect the edge of the preprocessed image. The traditional probability Hough transform is improved to adapt to the situation of many straight lines on the actual road.The results show that the algorithm can correctly fit and identify the lane lines under different working conditions, has good robustness and real-time accuracy, and has certain significance for practical production and application.

References

[1] Jiang Ze, Dong Yu rail detection algorithm based on Hough transform and Catmull ROM spline [J] Journal of graphics, 2018, 39 (6): 1078-1083.

[2] Guan Fangfang, Cheng Xiaosheng Adaptive edge detection of color image based on Canny value [. J] Development and innovation of electromechanical products, 2013 (6): 102-114.

[3] Yu Xiaojiao, Chen Xianfu High speed lane departure warning system based on Video [J] Microcomputer and application, 2016 (19): 21-24.

[4] Xu Jianjun, Huang Lida, Yan Limei, Yi Na. Insulator Self-Explosion Defect Detection Based on Hierarchical Multi-Task Deep Learning[J]. Transactions of China Electrotechnical Society, 2021,36 (07):1407-1415.

[5] Limei,LIU Yongqiang,XU Jianjun,et al.Broken string diagnosis of composite insulator based on Grabcut segmentation and filler area discrimination[J].Power System Protection and Control,2021, 49(22):114-119.

[6] Yi, Q. Wang, L. Yan, et al., A multi-stage game model for the false data injection attack from attacker's perspective. Sustainable Energy Grids & Networks 28 (2021).

[7] Na Yi,Jianjun Xu,Limei Yan,Lin Huang. Task Optimization and Scheduling of Distributed Cyber-physical System Based on Improved Ant Colony Algorithm. Future Generation Computer Systems, 109(Aug. 2020),134-148.

[8] Yang Zhao, Jianjun Xu, Jingchun Wu. A New Method for Bad Data Identification of Oilfield Power System Based on Enhanced Gravitational Search-Fuzzy C-Means Algorithm. IEEE Transactions on Industrial Informatics. VOL. 15, NO. 11, NOVEMBER 2019 5963-5970.

ISSN: 2710-0588

[9] Jing Han,Xi Wang,LiMei Yan, Aida Dahlak, et al. Modelling the performance of an SOEC by optimization of neural network with MPSO algorithm. International Journal of Hydrogen Energy, Volume 44, Issue 51, 22 October 2019, Pages 27947-27957.