2019 IEEE 3rd Advanced Information Management,Communicates,Electronic and Automation Control Conference (IMCEC 2019)

Lane-line Detection Algorithm for Complex Road Based on OpenCV

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***Abstract*—In order to meet the requirements of the high accuracy and timeliness of lane line detection for the autonomous vehicle camera, a fast detection algorithm based on the combined gradient and color filtering of lane line pixel for the interest model was proposed. Firstly, based on the high contrast between the lane line and the surface of the structured road, the algorithm uses Sobel edge detection operator to detect the edge information of the lane. Then, according to the white and yellow color features of the lane line, the pixel of the lane line is extracted by filtering these two colors in the color space. Finally, a relatively stable lane line extraction method is obtained based on combining the edge gradient and color filter in the region of interest model.Experiments show that the algorithm has high accuracy, fast speed and good robustness, and can meet the requirements of lane line detection under complex road conditions.**

Keywords—Opencv; edge detection; color filtering; lane line extraction

I. INTRODUCTION

According to the world health organization, 1.24 million people die in traffic accidents every year, and the figure could reach 2.2 million by 2030. Autonomous vehicle could save millions of lives by dramatically reducing the number of traffic accidents. The unmanned vehicle carries out data collection through cameras, radars and other sensors, and relies on the intelligent driving instrument based on the computer system in the vehicle to achieve the purpose of unmanned driving. Among them, Lane line identification is an important part of unmanned vehicle, which is directly related to the safety performance of unmanned vehicle.

At present, there are many researches on lane line detection methods at home and abroad, which are mainly divided into feature-based and model-based methods. [2] some methods enhance the contrast between lane line and road by adjusting the CCD brightness, gain and exposure time，then, the seed points of image is selected and classified，after this, Hough transform is performed on the seed points. [3] there are also methods use circular curve lane line model and density-based Hough transformation for lane line recognition. [4] some researchers also adopted the boundary tracking detection algorithm based on fuzzy clustering to realize lane line recognition when identifying the interested area of lane. However, because the collected lane line image is affected by light, wear, vehicle shade and tree shadow, it is still a big challenge to accurately detect the lane line.

Therefore, a fast detection algorithm for lane line pixels based on combined gradient and color filter of region of interest is proposed. First, the algorithm uses Sobel edge detection operator to detect the edge information of the structured road based on the high contrast between the lane line and the road surface. The second basis is the color characteristics of the lane line. Generally speaking, there are only two colors of the lane line, white and yellow, so we can filter these two colors in the color space to extract the pixel of the lane line. Then, in the region of interest model, a relatively stable lane line extraction method can be obtained by combining edge gradient and color filter.

II. PRETREATMENT

A. Camera calibration

There are two main types of camera distortion, radial distortion and tangential distortion. Radial distortion is caused by the fact that when light passes through the camera lens, the light at the edge will be bended more or less, so there will be distortion in the imaging of objects at the edge. Tangential distortion is mainly caused by the fact that the lens is not parallel to the imaging film or sensor. Therefore, it is necessary to calibrate the vehicle camera before lane line detection.

Generally, the distortion is corrected by 5 parameters, that is $D=(k_k, k_2, k_3, p_1, p_2)$。The correction formula of radial distortion is as follows:

$$x_{corr}=x_{dis}\,(1+k_1 r^2+k_2 r^4+k_3 r^6) \tag{1}$$

$$y_{corr}=y_{dis}\,(1+k_1 r^2+k_2 r^4+k_3 r^6) \tag{2}$$

The correction formula of tangential distortion is as follows：

$$x_{corr}=x_{dis}+[2p_1 x_{dis} y_{dis}+p_2(r^2+2x_{dis}^2)] \tag{3}$$

$$y_{corr}=y_{dis}+[p_1(r^2+2y_{dis}^2)+2p_2 x_{dis} y_{dis}] \tag{4}$$

Where (x,y) is certain point of the original image, x_{dis} and y_{dis} represent distorted coordinates; x_{corr} and y_{corr} represent the restored coordinates; k_1 , k_2, k_3 represents the radial distortion parameter; p_1 , p_2 represents tangential distortion parameter; r represents the distance from the corrected coordinates to the center of the image, and the correction parameters are obtained by the API of open CV. The reason why the checkerboard diagram is used is that it is easier to

978-1-7281-0513-0/19/$31.00 ©2019 IEEE

calculate the point coordinates. In general, it is necessary to take more pictures of the checkerboard diagram at different view angles, find the corner coordinates of each checkerboard diagram and its corresponding undistorted corner coordinates, and calculate the parameters for correction.After the calibration, the image taken by the camera is closer to the real situation, and the "distorted straight line" caused by the distortion is corrected.

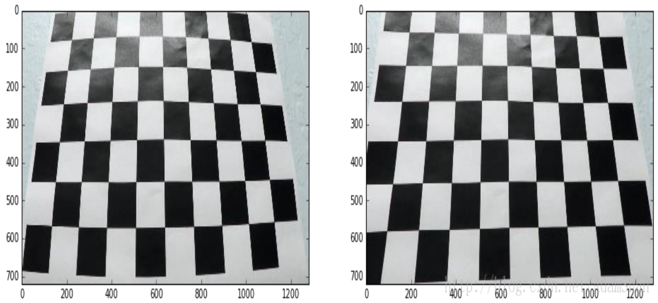

Fig. 1. Contrast image before and after camera correction

B. *Area of interest*

Through the analysis of the lane images collected by the vehicle camera, it is found that the collected images include the houses on both sides of the lane, trees, pedestrians, the sky ahead and other data information, which basically does not contain the lane information. If the collected images are processed directly, not only the complexity of detection algorithm will be increased but also the efficiency of lane detection will be reduced. Therefore, these irrelevant information may also interfere with the accurate extraction of lane lines. Therefore, it is necessary to filter out the interference information and extract the effective lane area of interest before lane line detection.

Perspective transformation is the projection of an image onto a new view plane，which also known as the projection mapping. This paper uses perspective transformation to gain a more intuitive perspective, and get ROI in a new perspective. The area of interest not only effectively reduces the amount of data processing, but also eliminates the interference from the sky ahead and trees and houses on both sides of the road.

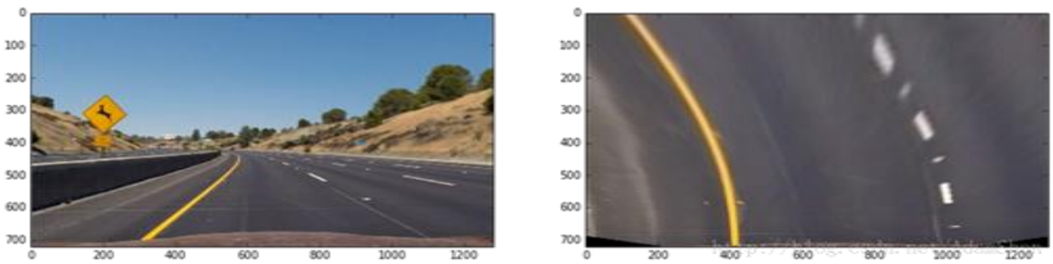

Fig. 2. Perspective transformation of ROI

III. IMAGE PROCESSING

A. *Edge detection*

Structured road lane lines have obvious features of high contrast, so the method based on edge detection can easily extract the edge features of lane lines.

This paper introduces a method based on the first derivative of brightness. The edge character in the image is calculated by the sobel operator, which contains two sets of 3×3、3×3 matrices, respectively are transverse and longitudinal, then make a convolution with the image plane to obtain the horizontal and longitudinal brightness differential approximations respectively. If A represents the original image , G_x and G_y represent the image detected by horizontal and vertical edges respectively, the formula is as follows:

$$G_x = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} * A \quad (5)$$

$$G_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{bmatrix} * A \quad (6)$$

The x-direction sobel operator tends to detect the vertical edge, while the y-direction sobel operator tends to detect the horizontal edge. In the real detection, lane lines are usually vertical lines, and we hope to filter the certain horizontal lines. Therefore, in this paper, the x-direction sobel operator is used to detect the edge of the image.

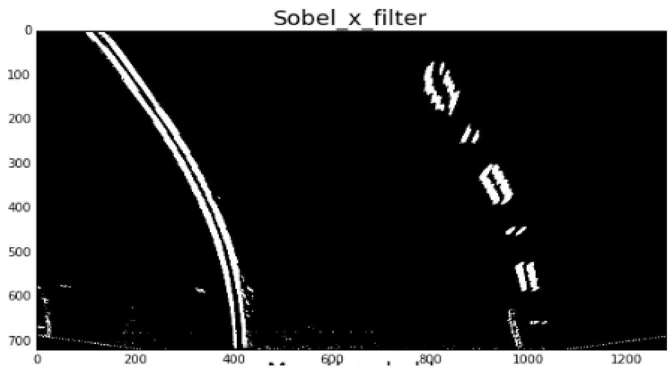

Fig. 3. Edge detection results of lane line by sobel operator in direction X

B. *Color threshold*

HSL is a method to represent points in the RGB color model in cylindrical coordinate system, namely Hue, Saturation and Brightness. Compared with RGB, HSL geometric structure based on Cartesian coordinate system is more intuitive.

Another basis for lane line detection is the color characteristics of the lane line. Generally speaking, there are only two colors of the lane line: white and yellow, so we can filter these two colors in the HSL color space to extract the pixel of the lane line.

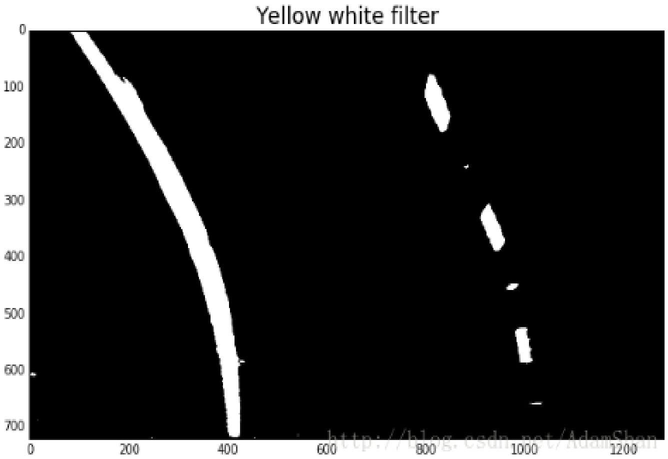

Fig. 4. Detection results of lane line by color threshold

C. Obtained lane line pixels by combining edge and color filtering

By combining edge and HSL color filter, a relatively stable lane line extraction method can be obtained, and the influence of ambient light, road background and other vehicles on lane line detection can be reduced.

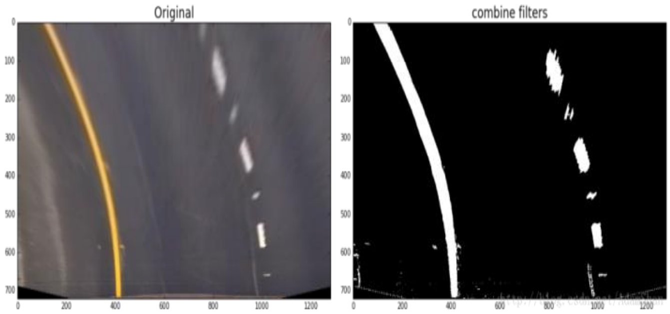

Fig. 5. Combined edge and color filtering detection result of lane line edge

D. Sliding window and polynomial fitting

After extracting lane line pixels, two curves were used to fit these pixels. Before fitting operation, lane line pixel needs to be determined. The sliding window method is used in this paper.

First, determine the approximate location of two lanes line, accumulate the pixels in the image along the y axis, identify the photo with the data peak, which will be the possible lane line area, then use sliding window from the bottom up, calculate the non-zero pixel point inside the window, if the number of pixels is greater than a certain threshold, then the average of the points can be used to be the center data of a next sliding window.

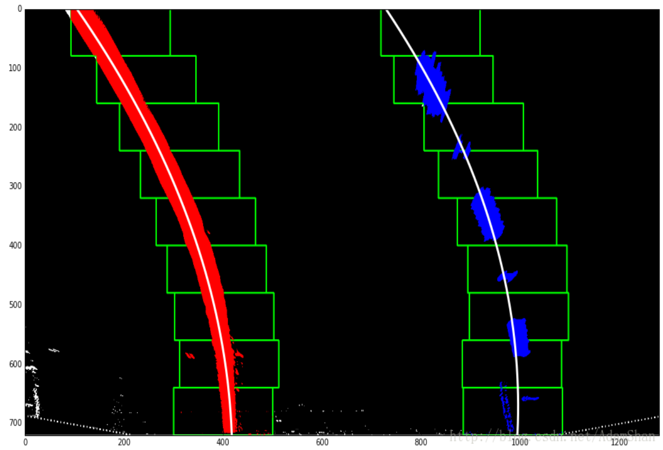

Fig. 6. Detection results of sliding window

IV. RESTORE TO THE ORIGINAL PERSPECTIVE

The fitted curve was restored to the original perspective using perspective transformation and realize the lane line detection.

Fig. 7. Lane line detection result by restoring to the original perspective

V. CONCLUSIONS

In this paper, combined edge method and color filter are used to detect the lane line, sobel operator and HSL geometric structure are also introduced. The lane line is extracted by sliding window and polynomial fitting, and the real lane line is restored by perspective transformation. The test results of Open CV platform show that the algorithm has better real-time performance and anti-interference performance, it can well detected the lane line of its dotted line and the solid line, realize the real-time line marking in the video image, this test method effectively avoid the light, wear, car shade and trees shadow effects on the lane line image. Amount of calculation and robustness of algorithm are highly optimized, this method can be also applied to the safety assistant driving system, or autonomous vehicle system.

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