Vertical Lane Line Detection Technology Based on Hough Transform

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Abstract. Lane detection technology is widely used in the field of automatic driving. In this paper, Hough transform is used to detect the vertical straight lanes of interest. Firstly, the edge features of the image are extracted by image preprocessing. Then, the region of interest in the image is delineated. Then, the region contour image is transformed by Hough transform to find the straight line segment in the image. Finally, the straight line end is filtered and simulated by least square method. Combine the linear equation and mark the lane line.

1. Introduction
The detection lane is simply to find out the lane on the road. Lane detection methods can be divided into traditional methods and in-depth learning methods. Compared with in-depth learning methods, traditional methods are simpler and the scenes applicable to lane are not complicated. At present, lane detection methods widely used at home and abroad are mainly divided into two categories: (1) lane detection based on road characteristics [1]; (2) lane detection based on road model. As one of the mainstream detection methods, lane detection based on road features mainly uses the difference of physical characteristics between lane and road environment to segment and process subsequent images, so as to highlight Lane features and realize Lane detection. This method has low complexity and high real-time performance, but it is vulnerable to road environment interference [2]. Lane detection based on road model is mainly based on different two-dimensional or three-dimensional road image models (such as straight line, parabola, spline curve, combination model, etc.) [3]. The corresponding methods are used to determine the parameters of each model, and then the lane line is fitted. This method has high accuracy for the detection of specific roads, but it has strong limitations, large computational complexity and poor real-time performance. The lane detection method based on deep learning [2] has good effect and robustness to different straight, curved and combined models, but it consumes a lot of GPU computing resources and is not necessary to use in some simple road conditions. In this paper, the traditional image recognition method is used to carry out experiments on the freeway, which is relatively simple and the curvature of the curve is not large.

2. Introduction of methods
In this paper, the traditional image processing method is used to detect the vertical Lane line. The flow chart of the method is shown in Fig. 1.
In the whole algorithm, the image is first preprocessed, which includes converting RGB image into gray image, then smoothing the edge by Gaussian blurring, and then inputting the processed image into Canny edge feature to get the edge feature of the image [4]. In order to reduce the interference of the background image edge outside the lane, this paper chooses ROI region of interest of a certain size, and then only Hough transform the ROI region of the image to find all the straight ends of the image. However, there may be many straight lines found, and they are not continuous. Therefore, it is necessary to filter and screen many straight lines. According to the slope of straight lines, the left and right lanes can be distinguished. At the same time, we can remove some straight lines with large slope difference from most straight lines. Finally, the remaining lines after screening can be fitted, and two straight lines can be fitted, which are left and right lanes respectively.

2.1. Canny edge feature extraction

Canny edge detection algorithm steps:

Gauss low pass filter is used to smooth the image in order to remove the influence of noise in the image. We can set up a Gauss convolution kernel $G(x, y, \delta)$, image convolution with Gauss smoothing filter:

$$S(x, y) = G(x, y, \delta) * I(x, y)$$  \hspace{1cm} (1)

Then the intensity gradient of the image is calculated. The magnitude and azimuth of the gradient, the magnitude and direction of the gradient are calculated by the first-order finite difference method.

$$G(x, y) = \sqrt{G_x^2 + G_y^2}$$  \hspace{1cm} (2)

$$\theta = \arctan(G_x/G_y)$$  \hspace{1cm} (3)

However, due to the existence of similar points around the local extremum, non-maximum suppression (NMS) is required.

Non-maximum suppression technique is used to eliminate edge error detection (which is not edge, but detected is the result of gradient magnitude image $M(x, y)$). Only the maximum value is retained. Strictly speaking, the maximum point in the gradient direction is retained. The obtained image is $N(x, y)$, and the specific process initializes $N(x, y) = M(x, y)$. For each point, find n pixels in the gradient direction and the anti-gradient direction. If $M(x, y)$ is not the largest point in these points, set the point at $N(x, y)$ to zero, otherwise, $N(x, y)$ will remain unchanged. $N(x, y)$ single-pixel width problem, additional edge points, missing edge points.
In order to detect whether the point is a local maximum along the gradient direction, it is usually simplified to use only four directions (0 degree, 45 degree, 90 degree, 135 degree). The width of $N(x, y)$ obtained is 1 pixel including the edge. Double threshold method is used to determine potential edges. Small thresholds are used to control edge connection, and large thresholds are used to control the initial segmentation of strong edges. Finally, the edge image is extracted and connected to the boundary to output the edge image.

2.2. Hough line detection

Hough transform is a feature extraction technique that aims to find imperfect instances of objects in a particular type of shape by voting program. The voting procedure is carried out in a parameter space in which candidates are obtained as local maxima in the so-called accumulator space, which is explicitly constructed by the algorithm used to compute Hough transform. The basic Hough transform is to detect straight lines (segments) from black-and-white images. The main advantage of Hough transform is that it can tolerate the gap in feature boundary description and is relatively free from image noise. The simplest Hough transform is to detect straight lines. We know that the equation representation of a straight line can be expressed by slope and intercept (this representation is called oblique intercept), as follows:

$$ y = mx + b $$

If expressed in parameter space as $(b, m)$, a straight line can be represented by slope and intercept. However, there is a parameter problem. The slope of the vertical line does not exist (or is infinite), which makes the value of the slope parameter $m$ close to infinity. To this end, in order to better calculate:

$$ r = x\cos\theta + y\sin\theta $$

Where $R$ is the distance from the origin to the nearest point on a straight line (others may record it as rho, and below can also regard $r$ as parameter rho), $\theta$ is the angle between the x-axis and the line connecting the origin and the nearest point. As shown in Figure 4.
Therefore, each line of the image can be correlated with a pair of parameters \((r, \theta)\). This parameter \((r, \theta)\) plane is sometimes called Hough space and is used for the set of two-dimensional straight lines.

2.3. Least square fitting

For curve fitting function \(\varphi(x)\), it is not required to pass through all data points strictly, that is to say, the deviation (residual) of fitting function \(\varphi(x)\) at \(x_i\) is not strictly equal to zero, that is, the contradictory equation system:

\[
e_i = \varphi(x_i) - f(x_i) (i = 0, 1, 2, \ldots n)
\]

In order that the approximate curve can reflect the changing trend of the given data points as far as possible, the deviation is required to be minimum according to some measure standard, that is, the minimum value of the following formula is required.

\[
\sum_{i=0}^{n} e_i^2 = \sum_{i=0}^{n} (\varphi(x_i) - f(x_i))^2
\]

This method is called least square method of curve fitting. In the final analysis, it is to find the minimum value of the upper formula.

3. Experiments

The experimental process is divided into four steps:

1. Input the original RGB image, gray the image, and use Gauss blur as shown in Fig. 5.

\[\text{Figure 5. Image preprocessing effect}\]
2. After canny edge feature extraction, the edge features of the image are extracted as shown in Figure 6.

![Figure 6. Canny edge feature extraction](image)

3. Delimitating ROI regions of interest, removing useless background information, and further processing ROI regions, where ROI is shown in Figure 7:

![Figure 7. ROI region](image)

4. Hough transform line detection in ROI area can get many straight lines, and then select the lines with little difference in slope to do least square fitting. Finally, two straight lines of left and right lanes in ROI area can be obtained, as shown in Figure 8.

![Figure 8. Least squares fitting of lane lines](image)

Finally, the recognized lane line is mapped to the original map and the recognized lane line effect map is obtained, as shown in Figure 9.
Figure 9. Lane detection effect map.

Figure 9 is a highway scene. Most of the lanes on the Gauss Highway are straight lines, and the slope of the curve is not large. Hough transform can detect the straight lines quickly, and it has a good effect when the lane scene is not too complex.

4. Conclusion
When the lane scene is not complex, Hough transform can be used to detect the lane straight line. First, the edge features of the image are obtained by pretreatment. Then all the lines in the image can be found by Hough transform. Finally, the linear equation of the left and right lanes can be determined and the lane line can be fitted by screening the straight lines and least squares fitting the straight lines.

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