Vehicle Pose Estimation Method for Lane Line Detection Through Monocular Camera

Xingxing Li*, Chao Duan, Yan Zhi, Panpan Yin, Ningxing Wang

Department of electronics and information engineering, Guangzhou College of Technology and Business, FoShan, 528138, China.

*Corresponding author e-mail: wsllx@jxstnu.edu.cn

Abstract. Lane detection algorithm is widely used in the field of driverless. In this paper, a lane detection method is proposed to estimate the vehicle's driving position and attitude. Firstly, a frame of image is transmitted from monocular camera. In this paper, each frame image is pre-processed. After Sobel edge detection, the x-direction edge features of the single frame image are obtained. Then, the region of interest in the image is demarcated, and the line segment in the image is found through Hough transform, and the line ends are filtered, and two are selected respectively for vehicle calculation. According to the position line and angle line of pose, the current angle of the camera is calculated by vanishing point, and then the homography matrix is obtained by using the external parameters of the camera, and the image is affine transformed, and the current position of the monocular camera is finally obtained.

Keywords: Lane detection algorithm, Sobel edge detection, Hough transform, x-direction edge features.

1. Introduction
In the field of unmanned driving, in order to keep the vehicle running on the designated line automatically, the vehicle needs to be able to get the position and angle of the current driving process in real time, and the vehicle terminal can adjust and correct the real-time state of the vehicle after getting the position and posture status. The information that vehicle can rely on can include lidar, camera image, infrared ray, etc [1]. This paper discusses the camera image, which contains the lane line in the process of driving. Through lane line detection, the current position and angle of the camera installed on the vehicle can be determined, which represents the current position and angle of the vehicle. Lane detection technology can be divided into traditional method and deep learning method. Compared with deep learning method, the traditional method is relatively simple and direct, which is suitable for single scene with simple background information. At present, lane detection methods widely used at home and abroad are mainly divided into two categories: (1) lane line detection based on road characteristics; (2) lane line detection based on road model. As one of the mainstream detection methods, lane line detection based on road features mainly uses the physical characteristics difference between lane line and road environment to segment and process subsequent images, so as to highlight Lane features and realize lane line detection. The traditional method has low computational complexity and is easily affected by the complex ground environment.
Lane detection based on road model is mainly based on different 2D or 3D road image models (such as linear, parabola, spline curve, combination model, etc.), the parameters of each model are determined by corresponding methods, and then the lane line fitting is carried out [3]. This method has high accuracy for specific road detection, but it has strong limitations, large amount of calculation and poor real-time performance. Deep learning method can adapt to different environment background, including curve straight road. At the same time, it can also adapt to different weather environment, such as rainy day, night, fog, sun exposure and other severe weather, but the algorithm will consume a lot of GPU computing resources, so it is not necessary to use it in some relatively simple conditions. In this paper, the traditional image preprocessing and manual features are used to process the road with straight lane.

2. Principle
In this paper, the monocular camera is used to collect the image, and each frame of the collected image is handed over to the algorithm for lane line detection. The flow chart of the method is shown in Figure 1:

![Flow chart of lane detection algorithm](image)

In the whole algorithm process, the image is first preprocessed, RGB image is transformed into gray image, and then the gray image is extracted by Sobel operator to extract the x-direction edge features of the image. After binarization, the edge of the whole image will be obtained. By removing some small areas, many indistinct burr edges will be filtered out. Then, the interest of the image is delimited artificially, and all the lines detected will be obtained by Hough transform on the edge features in the region of interest. Through filtering and fitting lines, the two angle lines that need to be involved in the calculation will be filtered out. The angle of the camera will be obtained by the way that the line vanishes in the image. In this paper, the homography matrix of monocular camera is constructed to make affine transformation of the image to ensure that the image is not affected by the camera angle. The lane location line is determined by keeping the front view angle. Finally, the best position line for two days is obtained through filtering and screening, so as to know the specific position of the vehicle currently driving in the lane line.

2.1. Sobel edge feature extraction
In this paper, Sobel operator is used for edge feature extraction. It can extract different gradients in X and Y directions respectively. It is a discrete differentiation operator, which is used to calculate the approximate gradient of image gray level. The larger the gradient is, the more likely it is to be the edge.

The function of Sobel operator combines Gaussian smoothing and differential derivative, also known as first-order differential operator. Derivative operator can obtain gradient image in X direction and Y direction by deriving in horizontal and vertical directions. The disadvantage of the method is that it is sensitive to noise, and the edge is easily affected, so it is necessary to denoise by Gaussian blur (smoothing). Operators enlarge the difference by different weights.

The Sobel gradient is calculated as follows:

Horizontal change: with an odd size kernel $G_X$ is convoluted. For example, when the kernel size is 3, the calculation results of $G_X$ are as follows:
Vertical change: with an odd size kernel $G_y$ is convoluted. For example, when the kernel size is 3, calculation results of $G_y$ are as follows:

$$G_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{bmatrix} * I$$  \hspace{1cm} (2)$$

On each pixel of the image, the approximate gradient is obtained by combining the above two results.

$$G = \sqrt{G_x^2 + G_y^2}$$  \hspace{1cm} (3)$$

Sometimes it is replaced by the following simpler formula, and the calculation speed is fast.

$$G = |G_x| + |G_y|$$  \hspace{1cm} (4)$$

In this scene, we use sobel edge detection algorithm and only get gradient in X direction. Compared with classical canny edge detection, canny has extracted gradient in X direction and Y direction, and added non maximum suppression, which makes canny detected edge in X direction is not as clear and direct as sobel line.

2.2. *Sobel edge feature extraction*

After Sobel edge extraction, Hough transform is applied to the edge feature image, and the parts with straight edge in the image will be detected. Because two parallel lines in 2D image must intersect at a point, this point is called image vanishing point. Using the vanishing point of the image, some lines that do not meet the conditions will be filtered [2].

![Figure 2 Geometric interpretation.](image)

Figure 2 is from the camera coordinate system to the world coordinate system, known extinction point and camera external parameters, according to formula (5).
The pixel coordinate of vanishing point is $V_z$. when the external parameter of the camera is $K^{-1}$, $r_3$ can be obtained, according to formula (6).

$$\alpha = \tan^{-1}\left(\frac{r_3(1)}{r_3(3)}\right), \quad \beta = \cos^{-1}(r_3(2))$$

(6)

The pitch angle $\beta$ and course angle $\alpha$ of the camera can be obtained.

### 2.3. Image warp and vehicle position calculation

Homography is a concept in projective geometry, also known as projective transformation. It maps a point (three-dimensional homogeneous vector) on one projective plane to another, and maps a straight line into a straight line. Assuming that the homography between two images has been obtained, the homography matrix $H$ can associate the two images.

$$\begin{pmatrix} u_1 \\ v_1 \\ 1 \end{pmatrix} = H \begin{pmatrix} u_2 \\ v_2 \\ 1 \end{pmatrix}$$

(7)

According to the following formula:

$$H = K(R + T \frac{1}{d}N^T)K^{-1}$$

(8)

The parameter $K$ is the external parameter of the camera, $T$ is the translation, $N$ is the unit normal vector in the camera coordinate system, and the distance from the first camera center (coordinate origin) is $d$, $R$ rotation matrix, so we can get homography matrix $H$. using homography matrix, we can affine the image back to any angle position. The lane line inclines because of the vehicle angle, and the lane line becomes inclined. Through the warp image, we can return to the positive angle, which is conducive to the calculation of vehicle position.

The selection of lane location line can fit the left and right lane lines respectively by straight line fitting. The current driving position of the vehicle can be known by calculating the distance between the image center point and the pixel center point of the lane.

### 3. Experiments

The experimental data used in this paper is the lane line image collected on the road. After Sobel edge detection and line extraction, the relatively pure lane line image can be obtained after filtering. After passing through the vanishing point, the elevation angle and heading angle of the camera can be calculated through the two longest lines on the left and right. After the change of warp, the image is shown in Figure 3.
Then, after the above-mentioned screening and filtering of the left and right lane line edge lines, the camera's current posture can be calculated, as shown in the following figure 4.

Figure 4 shows that the lane line is accurately screened out through the vanishing point information, and the current attitude information of the camera, including pitch angle and heading angle, is calculated. After radiative transformation, and combined with the lane line position information, the deviation of the camera from the center of the lane line can be calculated. Through the above calculated information, the vehicle position can be automatically corrected to make it in any position of the lane line.

4. Conclusions

In this paper, the camera position estimation algorithm is applied to lane recognition. Firstly, Sobel edge detection is used to obtain the x-direction edge features of a single frame image. Then, the region of interest in the image is demarcated. The line segment in the image is found through the line Hough transform of the contour image of the region. Then, two position lines for calculating the vehicle pose
are selected respectively. And angle line, using vanishing point to calculate the current angle of the camera, and then use the external parameters of the camera to calculate the homography matrix, the image affine transformation, and finally get the current position of the monocular camera, and through the vanishing point information to accurately screen out the lane line, and calculate the camera's current attitude information, including pitch angle and heading angle, and combined with lane line position information, the camera can be calculated. The deviation from the center of lane line can be effectively applied in practical engineering projects.

Acknowledgments
This work was financially supported by fund project, that is, Young Talents in Higher Education of Guangdong, China, (No. 2019KQNCX231).

References
[1] Liu Q, Yuan S, Li Z. A Survey on Sensor Technologies for Unmanned Ground Vehicles [C]// IEEE ICUS 2020. IEEE, 2020.
[2] Wu J, Xu G, Dong Z, et al. An Improved Tsai's Two-stage Camera Calibration Approach Using Vanish Point Constrain [J]. Geomatics and Information Science of Wuhan University, 2012, 37(1): 17-21. Kaiming H, Georgia G, Piotr D, et al. Mask R-CNN [J]. IEEE Transactions on Pattern Analysis & Machine Intelligence, 2017, PP: 1-1.
[3] Oeljeklaus M, Hoffmann F, Bertram T. A Fast Multi-Task CNN for Spatial Understanding of Traffic Scenes [C] IEEE International Conference on Intelligent Transportation Systems. IEEE, 2018.