Study on Lane Boundary Detection in Night Scene

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Abstract—**Lane boundary detection is the most important component of Driving Assistance System which aims at keeping drivers safe. In this paper, a method combining the edge characteristics with brightness of lane is discussed for traffic scene at night. First images are preprocessed by dual thresholding algorithm in green channel. Then, the edge is detected by a fast method based on single-direction gradient operator. Finally, noises such as headlights of vehicles, reflected lights and street lamps are removed through filter template. Experiment results indicate that the proposed approach is adapted to night condition.**

I. INTRODUCTION

Lane detection is one of the key issues of intelligent vehicle. It provides lane information to both Autonomous Navigation System and Driver Assistance System. Naturally, it has attracted vast numbers of researchers' attention. Lane detection is mainly divided into lanes location and parameters extraction [1]. Edge information is one of the main methods of lane location. Ref. [2] used gradient orientation and gradient values to establish two-dimensional histogram for lane detection. Ref. [3] proposed a new edge detection method based on gray theory to recognize the edge. Thresholding has also been widely used in color and gray images for lane boundaries' location. Ref. [4] recognized the lane by empirical thresholding which was based on the difference between color components. Ref. [5] segmented the lane **boundary** based on the local histogram. The mathematical modeling is the based means to extract lane parameters [5], [6]. Otherwise, Hough transform and the improved algorithms are widely used for line extraction [7]. In addition, the B-Snake and other templates were also used in this area [8], [9], [10].

Lots of research has been done for lane detection. However, there are still many problems: complex, real-time, the expensive processing platform, sensitive to environmental changes and some other issues. While the night-time lane recognition faces even greater difficulties. It is difficult to see objects at night, especially in the wild. Road and lanes can only be seen by reflected car headlights, the street lamps or some other illuminants. The headlights of self-car are the only source of light on unstructured road. The lane detection algorithm proposed in Ref. [6], has discussed the night case. But the experimental images were captured on structure road, with street lamps and other auxiliary light source. Thus, the images were easy to process.

At night especially in the wild, head lights are the main light source. The brightness of lane boundary is more obvious than the road under the light. But when lane's position is away from the direct region of headlights, the brightness is decreased apparently. It would lead to serious noise if we use thresholding segmentation method to locate lane. The result of artificial thresholding segmentation is shown in Figure 1. The brightness of road in direct region is close to lane boundaries, so there are a lot of noises after segmentation. The brightness will have a significant change between road and lane boundaries. Therefore, many researchers use edge detection to find lane boundary position. However, edge detection method requires the road uniform, and the edge of other objects will be easily confused with lane boundary.

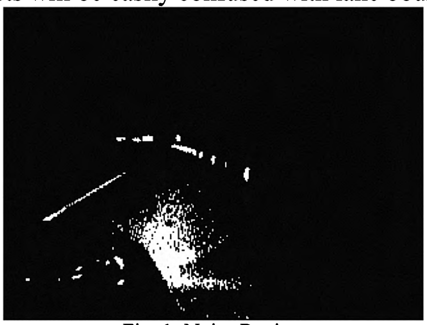

Fig. 1. Noise Region

In response to these issues, one method which combines gray-scale features and edge characteristics is present in this paper. At first, according to high and low threshold, non-lane region is excluded. Then a one- orientation gradient template is given to detect the road edge. By means of Morphological lane filter, exact lane position can be acquired through felting edge noise. Last, by Hough transform, lane boundary parameters can be acquired.

II. ACQUISITION OF CAMERA POSITION AND COLOR SPACE

Target's shape in the imaging space is determined by inside and external parameters of the camera. Meanwhile, information from imaging processing is influenced by different parameters. There are two main programs for installation of the camera in current experiment system. One is the location near to the rearview mirror, in the central axis line of the car. Another location is the side of the vehicle. Based on largest change of the lane slope, the camera is set up on the side of the vehicle, with optical axis parallel to the central axis surface. Efficient selection of color space confers a benefit on contrast between road and lane boundaries, which increases the accuracy of lane boundaries recognition. It shows that the contrast in G-channel of RGB color space is higher than other two channels in Fig.2. And it also shows

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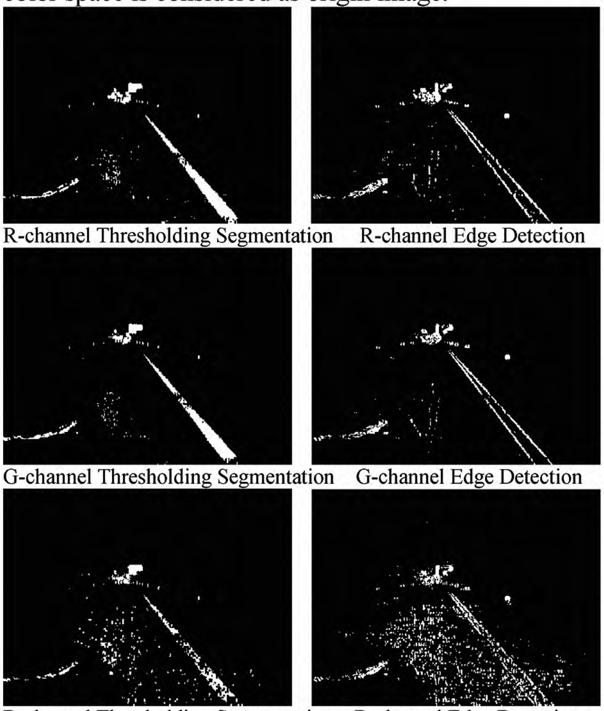
that the brightness is more uniform. So G-channel of RGB color space is considered as origin image.



R-channel Thresholding Segmentation R-channel Edge Detection

G-channel Thresholding Segmentation G-channel Edge Detection

B-channel Thresholding Segmentation B-channel Edge Detection

Fig. 2.Detection Results For Each Channel

III. LANE BOUNDARY LOCATION

A. Dual threshold based preprocessing at night

The complex external environment is often diverse and unknown. In traffic scenes, cars, road contour signs, road signs and some other things exist. The edges of those objects need to be removed. Brightness is the most important information in night-time image. The gray values of many noises, created by lights reflection, are significantly higher than the road and the line. In this paper, an empirical threshold is proposed to remove the pixels of reflective objects or light source. At the same time, it has a large number of dark regions in night-time image. The processing time will be shortened significantly by removing these regions. So a low-threshold should be set up. The brightness of the road would not be always the same under different surface materials of roads and lights with different power. Faced to this problem, an adaptive method is discussed to determine the low-threshold.

Setting l as the gray level of the image, N is the total of pixels in the sample area (shown in Fig. 3). n_i is the number of the pixels whose value is i . $p(i)$ is the probability gray value i appeared. The first moment of one dimension histogram μ_0 is calculated as the low-threshold.

$$p(i) = n_i / N$$

$$\mu_0 = \sum_{i=0}^{l-1} ip(i)$$

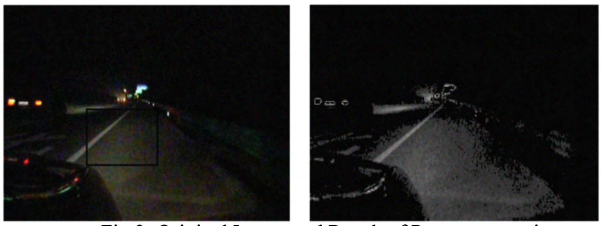


Fig.3. Original Image and Result of Pre-segmentation

B. Edge operator

Edge pixel is determined by gradient, which has a mathematical definition. The two important physical quantities of vector gradient are gradient magnitude and gradient orientation. For digital images, magnitude is calculated by edge operator. Different operators have a different number of templates. Every template corresponds to a particular orientation. And gradient orientation is determined by the dominant gradient magnitude. When the gradient and the orientation meet the assumption, the pixel is judged as the edge. Sobel and Canny operator are widely used in edge based lane detection. They all have 2-8 templates, which can express images in detail. But, the processing will not only spends a lot of time but also bring many noises. To remove these noises, an artificial threshold is necessary. Further, it makes engineering applications hard. In this paper, only the horizontal orientation template is used to calculate gradient magnitude. The template is $\{1,2,0,-2,-1\}$.

C. Threshold determining and edge refining

Using the 1×5 template operator to extract the edge will cause the expansion of edge region. Usually, only the extremums of the regions will be saved, so it can achieve the purpose of edge thinning. If the target information can be enlarged correctly, it would be very useful for lane parameters extracting. Therefore, it is worth emphasizing that we do not use the method only saving the area extremum. The expansion effect due to template operation is reserved to improve the robust of the following processing. In lane departure warning system, the inside edge of the lane attracts more interests. And the lane marking edge is required to be distinguished from road edge in the system. Fig. 4 shows the gradient orientations when lane locates in different regions. According to the characteristics, gradient is calculated as follow:

To each pixel in image, setting $p(x,y)$ as the brightness, setting $d(x,y)$ as gradient magnitude. If the pixel belong to left side,

$$d(x,y) = \begin{Bmatrix} p(x,y-2) + 2\times p(x,y-1) \\ -2\times p(x,y+2) - p(x,y+1) \end{Bmatrix}$$

Otherwise,

$$d(x,y) = \begin{Bmatrix} -p(x,y-2) - 2\times p(x,y-1) \\ +2\times p(x,y+2) + p(x,y+1) \end{Bmatrix}$$

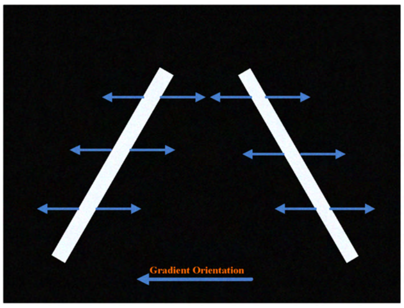


Fig. 4. Gradient Orientation

Only gradient reaching a certain threshold can pixel be determined as edge point. Artificial threshold can not adapt to changes of road scene. After pre-segmentation, the middle part of histogram is retained by dual threshold operator. The high-brightness class in histogram is corresponding to lane boundaries, while the low is corresponding to road. The distance between two classes is considered as gradient threshold Th . Otsu is a Clustering Method based on maximizing the difference between two classes [11]. Here, Otsu method is used to cluster the histogram data into two groups. T is the threshold which is calculated as follows:

$$T = ArgMax[d_0(t)(\mu_1(t)-\mu_t)^2 + d_1(t)(\mu_2(t)-\mu_t)^2]$$

Where,

$$d_0(t) = \sum_{i=\mu_0+1}^{t} p_i, d_1(t) = \sum_{i=t+1}^{L-1} p_i$$

$$\mu_1(t) = \sum_{i=u_0+1}^{t} id(i)/d_0(t)$$

$$\mu_2(t) = \sum_{i=t+1}^{L-1} id(i)/d_1(t)$$

$$Th = \mu_2 - \mu_1$$

The results of edge detection are shown in Fig.5.

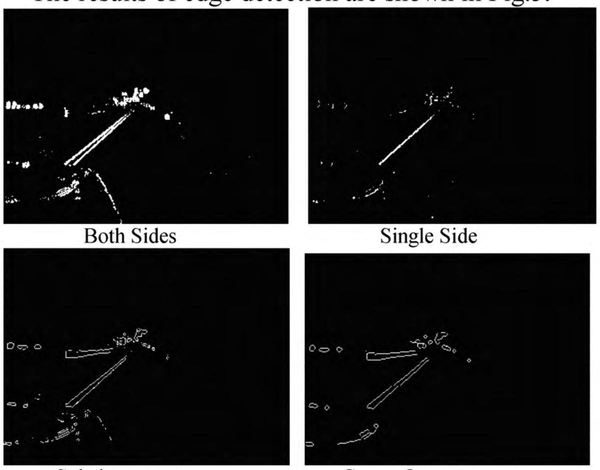


Fig.5. Edge Detection Result

D. *Morphological Filter*

The edge characters of headlight, car's edge, road contour sign and the non-uniform surface of the road will bring noises, which will influence lane detection accuracy. According to imaging rules, lines paralleling each other in the world coordinate system will converge to a point called the vanishing point in the image coordinate system. The position of vanishing point is fixed while Internal and external parameters of Camera is not changed any more. Based on this characteristic, here a filter is proposed. Defining the Fixed-point coordinates as $O(x_0, y_0)$, to any point $A(x, y)$. Then, calculate the slope K of a straight-line 'OA'. The filtering template is chosen according to the value of K. The candidate point will be considered as a lane point if the Template matching is successful. Template matching for every candidate point is unnecessary when there are few noises after edge detection. To each row, we consider that there are no noises if the number of candidate point is littler than three. While template matching is active when the number is larger than three.

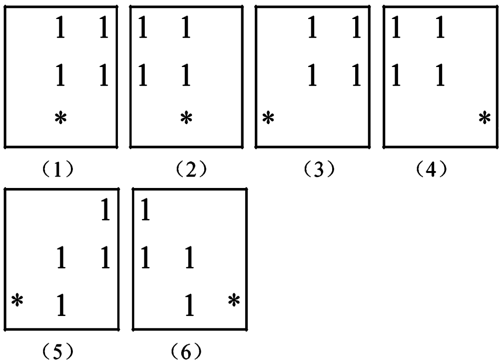


Fig.6. Filter template (*is the position of point A)

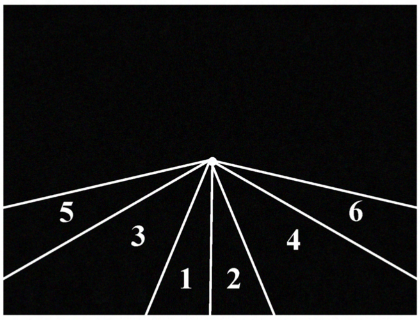


Fig.7. The Applicable Regions of Filtering Template

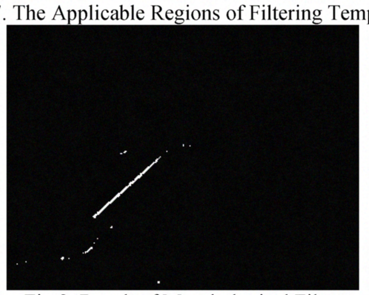


Fig.8. Result of Morphological Filter

IV. PARAMETERS EXTRACTION OF LANE

Getting Mathematical model to fit lane boundaries is the main method for parameters extracting especially for curve parameters. However, it is sensitive to noises. In night case, the lane boundaries can be approximated to straight-lines, cause of the limit field of vision. Therefore, in this paper, Hough transform, which is robust with noises, is used to extract parameters [12]. Hough transform is a kind of spatial transfer manner. In Hough space, a line can be represented as follows:

$$\rho = x \times \cos(\theta) + y \times \sin(\theta)$$

Where, variable ρ is the distance from the origin to the line along a vector perpendicular to the line. θ is the angle between the x-axis and this vector. The Hough function generates a parameter space matrix whose rows and columns correspond to ρ and θ values respectively. Then find the local peaks in matrix, and the location of each peak is just the parameters (ρ, θ) of each detected line. Fig.9. displays the result of parameters extraction by Hough Transform.

Fig.9. Result of Parameters Extraction

V. CONCLUSION

Lane detection is significant for Autonomic Navigation System and Driving Assistance System. Image is processed through threshold selection according to dual threshold. Gradient is calculated by horizontal direction template. Gray-scale features and edge characteristics are combined to detect lane boundary correctly. A special edge filter for lane boundary is presented. Experiment results show that this method is efficient for lane boundary detection in the night condition. And it is not sensitive to noise such as edge of headlight, rear-light, cars, road contour signs and so on. Because of its low complexity, the algorithm could be applied to embedded platform.

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