

A Recognition Algorithm of the Structural Road Based on Piecewise Linear Model

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Abstract. In order to improve the accuracy and real-time of structured road recognition algorithm, this paper puts forward a recognition algorithm of the structural road based on piecewise linear model. Firstly the original image was the initial region of interest division and pretreatment, using an improved Otsu algorithm and mathematical morphology processing image segmentation, eliminate noise and split out of the way images of the original image. Finally get the final road recognition image with a piecewise linear model. Environment through VC++6.0 simulation, it proves that this method has good accuracy and real-time.

Keywords: road recognition; improved Otsu algorithm; mathematical morphology; piecewise linear model.

1. Introduction

Road recognition is an important part of the Intelligent Vehicle navigation system, the experts and scholars do a lot of research on it in recent years^[1]. Due to the complexity of the road environment, accurate and reliable identification of the road ahead is particularly important to the autonomous navigation system. There are many identification methods for this problem, generally can be divided into the method based on characteristic^[2] and the method based on model^[3]. Because of the complexity and variability of unstructured road, this paper mainly aimed at the road identification of structured road. In order to enhance the anti-jamming capability of the noise, road and environmental factors, improve the structural road recognition accuracy and real-time performance. Aiming at this problem, this paper presents structured road recognition which algorithm based on piecewise linear model.

2. Road Recognition Algorithm

2.1. Road constraint assumptions

Although structured road has a certain characteristics, but because the actual environment differ in the road, there does not exist a general road recognition system. This article introduced some prior knowledge as constraint conditions before the road recognition algorithm processing: road shape assumptions, road width assumptions, region of interest assumptions, road characteristics consistency assumption. They can not only effectively improve the robust of the road recognition algorithm, but also can improve the system real time through the assumption simplifies road recognition data quantity.

2.2. The initial region of interest division

Region of interest divided by reducing road detection area to simplify the image redundancy information, which plays an important role in improve the real-time of the visual navigation system. Structured road has more regular boundary and clear lanes, paved areas and non Road area has obvious distinction between the borders. Road images collected by the CCD camera, the road region is mainly concentrated in the lower area of the image, upper portion generally includes the sky, trees and other irrelevant information, thus for the

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division of regions of interest provides premise. In order to better segmentation threshold selection, to ensure reliability, must try to eliminate the interference of the sky. At the same time it also simplifies the image information, facilitates the real time of the system improved.

As the area of the sky brightness value is higher than a fixed threshold and blue components are significantly larger than the other two, do row operations on the road image and calculate for each column satisfy the definition of the nadir, which is the region of the lower edge of the sky. Finally find the maximum of the point set, taking this point to do the horizontal dividing lines to separate the image for a ground regional and area of the sky, below this line as the initial region of interest, as shown in figure 1.

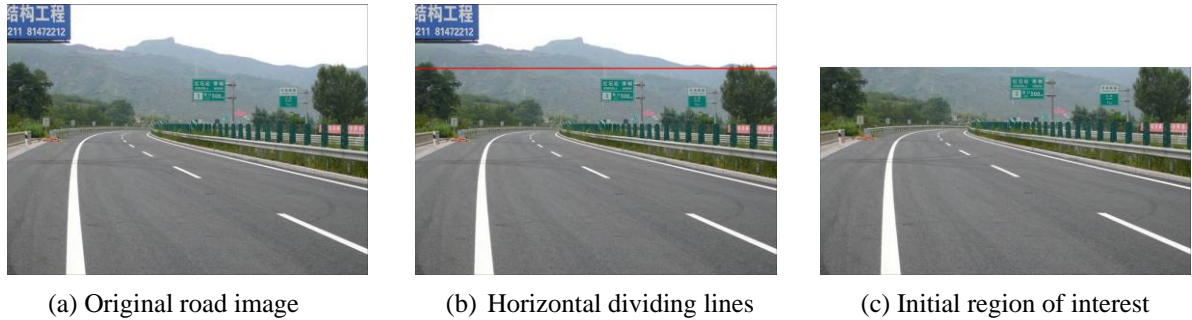


Fig.1: The initial region of interest divided

2.3. Image preprocessing

Intelligent vehicle navigation systems in the physical environment of the image acquisition process often will be the impact of various factors, not only the conditions of the system itself, as well as the interference of outside environmental conditions. Thus, in this case the collection to the original image preprocessing becomes very necessary.

Due to the presence of noise and other interference, do the image gray-scale processing and filtering processing firstly. This paper uses a 3 * 3 window median filter. This method is a local average smoothing technique, pulse interference and impulse noise suppression effect good points.

2.4. The improved Otsu method

Image preprocessing, image quality has improved, but the image also contains trees, shadows and other interference. This paper adopts the Otsu method for image segmentation. Otsu method^[4] put forward by the Japan Otsu in 1978, also known as Otsu threshold segmentation method. It is deduced based on discriminate analysis of the basis of the principle of least squares, the use of category variance as the criterion variance between two classes and classes within the minimum variance of gray value, select the most optimal threshold.

The traditional Otsu method for image segmentation, they often result in segmentation errors, which will reduce the segmentation accuracy. For this shortcoming, this paper presents a segmentation algorithm based on improved Otsu method. First, do the piecewise linear transformation with the filtered image, the transformed image using the Otsu threshold segmentation.

Piecewise linear transformation is intended to highlight the target of interest or gray range, relative inhibition of those not interested in gray interval. Will the original image for the initial the interested region divided, pretreatment, edge enhancement, and finally in figure 1 using the traditional Otsu method and the improved Otsu method for image segmentation, as shown in figure 2 below.

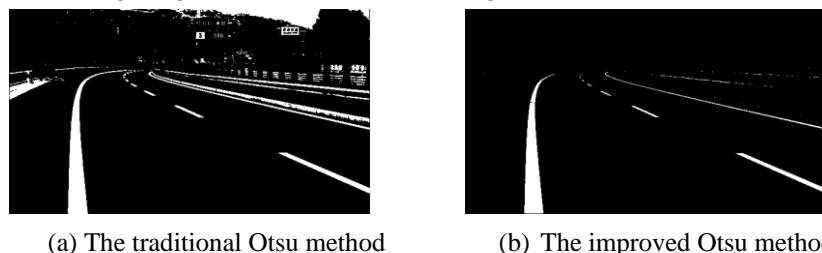


Fig. 2: Otsu segmentation

Through the figure 2 can obviously get improved Otsu image segmentation results are greatly enhanced, a greater level of segmentation from non road area. For the next step of lane recognition provides a good premise.

2.5. Mathematical morphology

Mathematical morphology is set theory method to describe the science of the target geometry. It is the use of a certain form of structural elements to extract the digital image corresponding to image recognition of shape. The application of mathematical morphology can simplify image data, to maintain their basic shape characteristics, and to remove extraneous structures.

The morphology of the basic operation mainly has four: corrosion, dilation, open and close.

Due to the shadow, shade, road logo line loss and other factors, the binary images of road after the improved Otsu segmentation, road edges may be discontinuous, the edges of the road line is not continuous, roads and non-road region boundary line may not be closed, and there is a certain amount of random noise, this will interference the next road recognition. In order to make the road area closed and continuity, this paper uses the opening and closing operation mathematical morphology on the road after the image segmentation, shown in figure 3.



Fig. 3: Image after morphological processing

Using the open operation, closing operation can effectively eliminate the background in spots, the small hole, the edge of the road zigzag shape, making the road edge for a closed region.

2.6. Road recognition based on piecewise linear model

In this paper, the structural road is mostly a straight line or curve, and curvature of the smaller features. Especially the high speed highway design has a certain standard, the turning curve has strict regulations. As known from table 1 that the road curve is moderate, not too fast corners. So in the general case, the structured road can often be approximated to a straight line. But when the larger of the bend curvature in some special cases, a single linear model is often not applicable. In order to better apply to a variety of circumstances of the structural road, this article uses the piecewise linear model to identify the lane.

Table. 1: Edge detection operator contrast

Speed (km/h)	120	100	80	60	40
limit turning radius (m)	650	400	250	125	60
normal turning radius (m)	1000	700	400	200	100

Through using the piecewise linear model, the lane line is divided into a number of segments, each segment is approximately linear path, using linear model for each sub road matching. At the end of each subdivision line connected to the lane line. When the number of lane division is larger, the lane is closer to the true path, the results is more accurate.

The acquisition of the road image size is 640*480. Set divided after the initial region of interest divided image size is 640 *h. The establishment of the coordinate system as figure 4. After threshold of road images for two value image, road logo line pixel value is 1, other regional pixel value is 0. To the left lane detection as an example, the first frame road image from image lower left corner as a starting point, along the x-axis direction, from left to right pixel scan. Started the first scan from the 0 line (when y=0), when first encountered a pixel value to a positive jump (pixel values from 0 to 1) record the point coordinate as (m_{l1}, y_{l1}) . Scanning continues until the first encountered the pixel value is negative jump (pixel values from

1 to 0) record the point coordinate as (n_{l1}, y_{l1}) , as shown in figure 4.

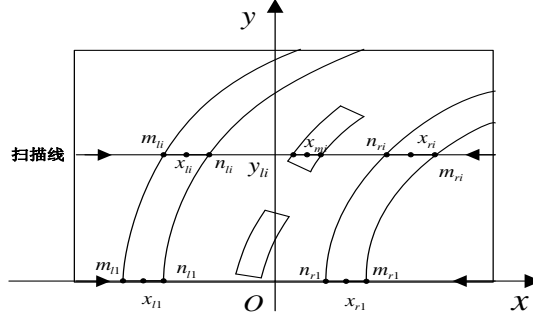


Fig. 4: Lane recognition principle

By the following formula:

$$x_{l1} = \frac{(m_{l1} + n_{l1})}{2} \quad (1)$$

The midpoint coordinate of line 0 is (x_{l1}, y_{l1}) . Along the y-axis direction, each w pixel values along the x-axis is the direction of a pixel scan, In order to obtain the midpoint $(x_{l1}, y_{l1}), (x_{l2}, y_{l2}), (x_{l3}, y_{l3}), \dots, (x_{lz}, y_{lz})$. Among them,

$$z = \left[\frac{h}{w} \right] \quad m > 0 \quad (2)$$

The image height h than the number of pixels interval w on adjacent scan lines, their ratio and the whole is the midpoint of the number z .

In order to seek the left lane in the first straight section to section i linear equations respectively:

$$\begin{cases} y = a_{l1}x + b_{l1} \\ y = a_{l2}x + b_{l2} \\ \vdots \\ y = a_{li}x + b_{li} \end{cases} \quad (3)$$

Similarly from the lower right corner of the image as a starting point, along the x-axis negative direction, from right to left pixel scan. We can obtain the right lane line of the straight line equation.

Search between the left lane and the right lane and get the midpoint of the midline as $(x_{m1}, y_{l1}), (x_{m2}, y_{l2}), (x_{m3}, y_{l3}), \dots, (x_{mz}, y_{lz})$, Similarly we can obtain the midline of each segment equation.

As the road environment existence deviation, interference is likely to produce many interference lane recognition. If we do not improve it, mistaken identification may occur, resulting in the failure of the algorithm. In order to improve the robustness and accuracy of the recognition algorithm, the algorithm for line detection and adding a failure judging condition:

(1) The design of structured good roads and construction are stringent industry standards, such as lane width is $0.21m$, lane width is $3.75m$. Thus it is concluded that the same lane line scanning points m_{lz} and n_{lz} , as well as the same line of the left, the right lane line two points n_{lz} and n_{rz} , through the coordinate conversion they sought in the world coordinate system the actual distance. The width of the lane line $L \approx 0.21$, lane width $D \approx 3.75$. If the detected L and D value is not in the certain scope, it can determine the line scanning point of failure.

(2) The structure of the road curvature is moderate, a stretch of road lines can often be approximated by a straight line, the adjacent segment of straight line segments with a slope of approximately equal.

$$\frac{y_{i+1} - y_i}{x_{l(i+1)} - x_{li}} = \frac{y_i - y_{i-1}}{x_{li} - x_{l(i-1)}} \quad (4)$$

(3) The system collected road image continuity in time and space. When the intelligent vehicle is

traveling at 120km/ h speed in actual road, assuming the frame rate is 30f/s camera to capture images, each collected an image car about moving forward distance is 1m, before and after the two images the location of the lane or less. So we can use the previous image frame of road information on the next frame image road recognition. Definition 30 on both sides of the lane of an image pixel values within the search area of the lane line of the frame shown in figure 5.



Fig. 5: Lane line search area between adjacent frames

3. Test results and analysis

In the test, the size of the BMP image is 640*480. In VC++6.0 programming environment to achieve the above algorithm. Piecewise linear model is shown in figure 6. Because of the right lane partially missing, using the piecewise linear model to connect 2 adjacent right lane line midpoint, approximate simulated occluded portion of the lane, as shown in figure 6(a). To a certain extent, can effectively improve the vehicle, shadow, rain and snow and other interference on the lane recognition effect . At the same time through the w size changes can be controlled by a piecewise linear model fitting precision. Be adjusted according to the needs on the ground, w value of the system in order to meet the real-time and accuracy of the system. Figure 6 for $w = 18$, y-axis positive direction every 18 pixel images one-by-pixel scan.

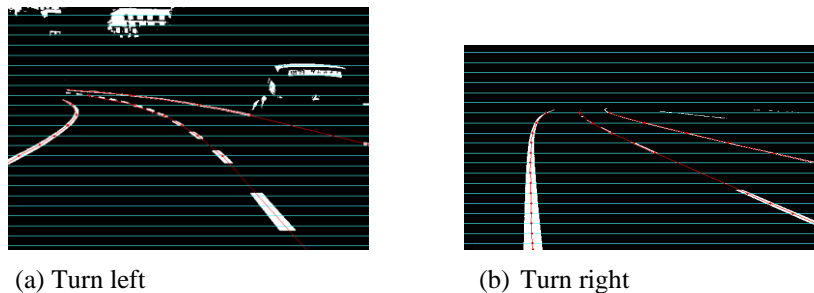


Fig. 6: Piecewise linear model

4. Conclusion

In this paper, the Intelligent Vehicle navigation system video image of the structured road to identify problems, propose a road recognition algorithm based on piecewise linear model and the experimental simulation. Experimental results show that this method has good accuracy, timeliness and robustness, and can basically meet the identification requirements of the structure of the road. However the experiment found that road as it off, often due to occlusion caused by false identification.

5. References

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