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Obstacles detection method of vehicles based on image analysis

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Abstract—**In order to reduce the effects caused by complex environments and ambient light conditions, a fast, robust and effective obstacles detection method of vehicles based on image analysis of multi-feature is proposed. Firstly, regions of interest (ROI) which contain lanes, vehicles and few parts of interference background are extracted in the input image by detecting gradient feature in rows. Secondly, color segmentation is tackled in YCrCb image to reduce illumination effect. Then, lanes are detected in segmented image by Line Segment Detector (LSD) to obtain the accurate detected regions of obstacles. At last, Obstacles are detected based on an adaptive threshold. The experiment proves that the proposed method can detect obstacles with small calculating amount, high accuracy and robustness. It is suitable in practical engineering.**

Keywords—***Obstacles detection; Image analysis; Multi-feature; Region of interest; Line Segment Detector;***

I. INTRODUCTION

With economic developing in high speed, a huge number of vehicles have rushed into our life and people are much concerned about the traffic security problems. As vehicles run at high speed, traffic accidents which happen by operator's mistakes or lack of visual interference usually account for most fatalities. So, the Intelligent Vehicle Navigation research has become more and more important in driving assistance systems [1]. For Intelligent Vehicle Navigation, it is critical to detect obstacles in various environment conditions, which can provide significant basis for autonomous navigation of the vehicle. Consequently, the obstacle detection is an important part of the analysis of environmental information.

There are a variety of sensors which can be used to detect obstacles such as sonar, Infrared sensor, Laser range finder, and so on [2]. Among sensors mentioned, sensors based on image analysis are effective means to obtain the surrounding environment information. Compared with other methods, the advantages are that it belongs to passive measurement with superior concealment performance and lower price. Therefore, obstacles detection method of vehicles based on image analysis has been a research hotspot [3].

Over the past couple of decades, many researchers have paid much attention to the study of obstacles detection based on image analysis and numerous methods have been proposed. These methods can be roughly classified into two categories. The first kind of methods recover the three-dimensional structure of the scene according to the image information, and then performs the obstacle detection based on three-dimensional information of the scene such as optical flow method [4] and stereoscopic vision [5-6]. These methods can give feasible results. However, they have higher demands for imaging equipment and are more sensitive to light and noise. Meanwhile, the real-time performance is unsatisfied due to the large amount of computation.

The other kind of method is based on the assumptions of different characteristics of the obstacles and the lanes. By extracting features including edge, color, texture, obstacles can be distinguished from its background [7]. However, these methods are easily affected by the shadows, uneven light condition and interference background, which results in the lower accuracy rate of the detection results.

Above all, there are still serious problems to detect obstacles robustly which mainly caused by complex environments and ambient light conditions. What's more, due to the characteristic of high speed and high threat, accuracy and real-time are required, too. Therefore, how to guarantee the accuracy, robustness and real-time of the method is a critical problem [8].

In this paper, a fast, robust and effective method based on multi-feature analysis aiming to solve these problems is proposed. Firstly, in order to reduce the effect of complex environment, ROI which contains lanes, obstacles and few parts of interference background are extracted in the input image by detecting the variance of gradient in rows. Secondly, color segmentation is tackled in YCrCb color space in order to reduce the effect of uneven light conditions. Then, Lanes are detected by LSD to obtain the final detected regions [9]. At

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last, obstacles can be detected in detected regions by an adaptive threshold. The experiments prove that the proposed method can detect lanes with small calculating amount, high accuracy and robustness.

The rest of this paper is organized as follows. Section Ⅱ describes the flowchart of the proposed algorithm. Section Ⅲ shows each step of the proposed algorithm in detail. Section Ⅳ gives experimental results of the proposed algorithm and assesses it subjectively and objectively. Finally, Section V 5presents the conclusion.

II. FLOWCHART OF THE PROPOSED METHOD

The proposed lane detection method based on image analysis can be concluded as four steps. First of all, ROI are extracted by gradient features to reduce the interference effect; Secondly, color features are obtained by adaptive threshold segmentation in YCbCr space; Then, LSD is introduced to obtain the lanes. Finally, obstacles can be segmented by Otus threshold. The flowchart of proposed method is shown in figure 1.

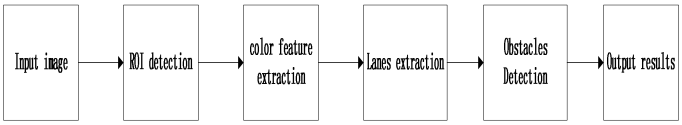


Fig. 1. Flowchart of the proposed method

III. OBSTACLES DETECTION BASED ON MULTI-FEATURE ANALYSIS

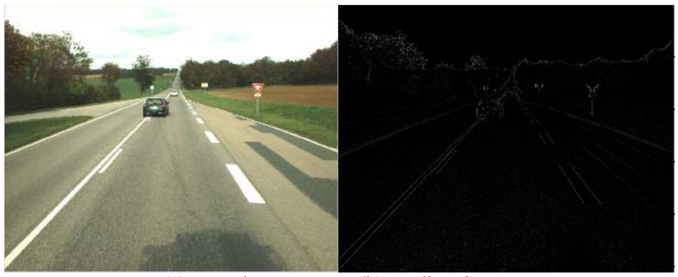
A. *ROI extraction by gradient features*

Generally, an input image is mainly composed of two parts, the lower part with lanes and obstacles the upper part with the sky, trees and other interference background. Therefore, the lower part can be concluded as ROI. In order to reduce the effect of complex redundant environment, it is necessary to find out ROI from the input image. According to previous experiments of image acquisition, when driving on uneven ground, the ratio of ROI will make great changes. At this time, if ROI and interference regions are simply divided in half of the row, there will be large amount of invalid regions, which leads to an undesirable and even false detection results.

The boundary between ROI and interference regions is often horizontal and its gradient change is obvious. Therefore, this paper puts forward an adaptive ROI detection method based on gradient features of the input image. By extracting and projecting gradient features in rows, the boundary between ROI and interference regions can be detected accurately and the following operations can be simply operated in ROI. It can not only reduce the following computation amount and achieve the demand of real-time requirement, but also suppress the interference caused by invalid regions [10].

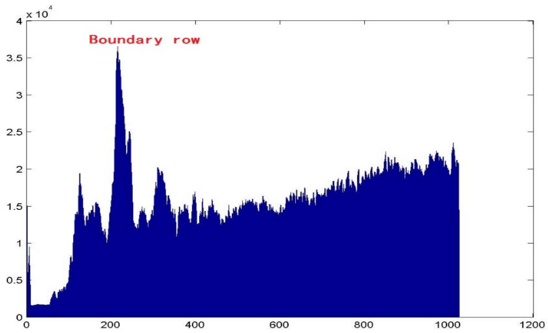
Gradient features of the input image can be extracted by Soble operator. As it is shown in Fig. 2(a), the intensity variation of boundary regions is obvious in horizontal direction, we just need to compute the gradient in 90 degrees. The filter model is shown in formula (1) and the gradient image is shown in Fig. 2(b). Then, each row of the gradient image is accumulated and the gradient image is projected to a single-dimensional array which presents the variance of gradient between rows. Result of the array is shown by bar chart in Fig. 2(d). At last, the row with the biggest change can be defined as the boundary between ROI and interference regions, which can be seen in Fig. 2(c).

$$G_{90} = \begin{vmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{vmatrix} \tag{1}$$



(a) Input image (b) gradient image

(c)detection result



(d) Gradient projection result

Fig. 2. Boundary detection by gradient projection

B. *Color feature extraction*

Results of lane detection methods based on color segmentation rely on the selection model of color spaces and thresholds used in segmentation. RGB model is simple and easy to realize. However, it can't work well in complex environment, because it is easily affected by the change of illumination [11]. Thus, when applied color segmentation to practical engineering, it is hard to detect lanes by means of

RGB model. In this paper, YCbCr color space is adopted. Here, Y, Cb and Cr represent brightness, blue chromaticity and red chromaticity, respectively. By separating information of brightness and chromaticity, it is robust to illumination. The YCbCr color space can be modeled from RGB color space as follows.

$$\begin{vmatrix} Y \\ Cb \\ Cr \end{vmatrix} = \begin{vmatrix} 0.299 & 0.587 & 0.114 \\ -0.168 & -0.331 & 0.500 \\ -0.500 & -0.419 & 0.500 \end{vmatrix} * \begin{vmatrix} R \\ G \\ B \end{vmatrix} + \begin{vmatrix} 0 \\ 128 \\ 128 \end{vmatrix} \tag{2}$$

As common used lanes are either white or yellow, there is no need to extract other color features. In order to separate white regions, high values in Y space are needed. Besides, points with high values in Cr space are selected to find out yellow regions, because yellow can be obtained by fuse green and red. In addition, the segmentation threshold should be adaptive for a better result. Therefore, given an input image I, the segmentation result can be defined as follows.

$$I(u,v) = \begin{cases} 1 & if \quad Y(u,v) > T_Y \ \& \ Cr(u,v) > T_{CR} \\ 0 & else \end{cases} \tag{3}$$

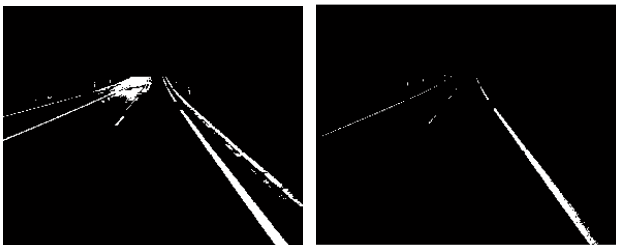
where u and v is the location of points; T_Y and T_{CR} represent the adaptive segmentation threshold used in Y and CR space, respectively. The two thresholds can be both defined as:

$$T = U(T) + k * S(T) \tag{4}$$

where T represents T_Y and T_{CR}, U denotes the operation of computing mean value, and S represents the operation of computing standard deviation. k is a correction factor (Here, k equals to 1.5).

Given the input image with uneven illumination, segmentation results of RGB model and YCbCr model are shown in Fig.3 (b) and Fig.3 (c), respectively. It can be concluded that result of YCbCr model contains less interference regions and this is especially obvious in regions near the boundary.

(a) Input image with ROI



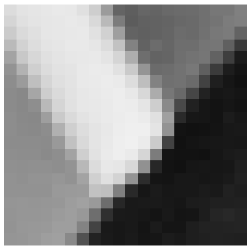
(b) Results of RGB model (c) Results of YCbCr model

Fig. 3. Results of RGB model and YCbCr model after segmentation

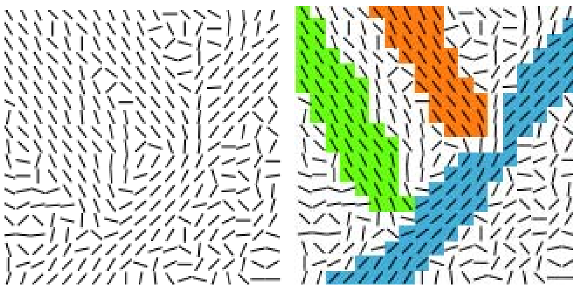
C. Lane detection based on LSD

Line detection is the critical step of lane detection. While applied the custom line detection methods (for example, Hough transform) to Lane detection, there exist problems in dealing with various environment conditions and determining whether a line is a lane boundary or an artifact. Here, LSD is adopted because it requires no parameter tuning and gives accurate and fast results [12].

Steps of LSD can be concluded as follows. Firstly, the level-line angle of each point is computed, which is perpendicular with its gradient angular. Secondly, as it is shown in Fig. 4, points are connected nearby with a certain threshold to establish level-line field and line support region. Then, line support region are fitting by rectangle and the main shaft of the rectangle can be obtained. By limiting the width, height, level-line angle and pixels number of the rectangle region, the number of false alarms (NFA) can be obtained. If its NFA is less than 1, this region is concluded as a line, else it is not.



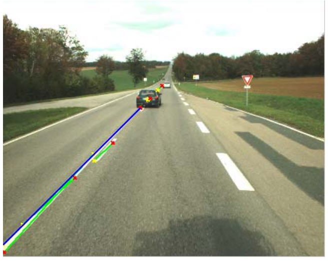
(a) Image



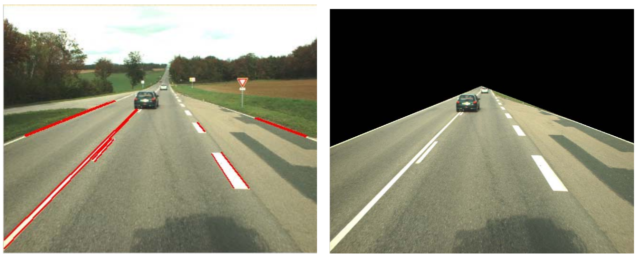
(b)Level-line Field (c)Line Support Region

Fig. 4. Line support regions

Detection results of Hough transformation and LSD are shown in Fig.5 (a) and (b). It is obviously that result of LSD is better, especially showing the existence of the right lanes and the completeness of the left lanes. In addition, final detected regions can be obtained by select leftmost lane and the rightmost lane, as it is shown in Fig.5 (c).



(a) Result of Hough transform



(b) Result of LSD (c) Final detected region

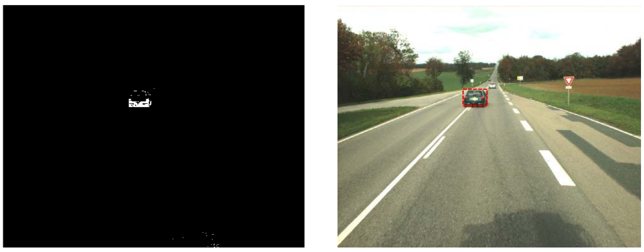
Fig. 5. Detection results of lanes

D. Obstacles detection based Otus threshold

The Otsu algorithm is a classical algorithm of image threshold segmentation method and it is widely used in image processing [13]. By keeping selecting different thresholds and computing variance of the two regions separated by thresholds, the optimal threshold can be obtained. As the final detected regions contain few part of interference background, it is easy to segment obstacles.

IV. THE EXPERIMENTAL SIMULATION AND ANALYSIS

To illustrate the effect of the method in this paper, the experiment is completed by using the test images (1024×1280) from database ROMA, which has been widely used by researchers around the world for lane detection algorithm. All images are tested within the lab environment (matlab2013a, Intel (R) Core ™ i3-2120CPU@3.30GH). Parts of detection results are shown in Fig.7. Images in Fig.7 (a) and Fig.7 (b) show the final segmentation results of the input image with shadows and uneven illumination, respectively. Conclusions can be drawn from Fig. 6 that the proposed method can effectively detect lanes and obstacles in various environment.



(a) Detection result of the image with shadow

(b) Detection result of the image with uneven illumination

Fig. 6. Final detection results of the proposed method

It is necessary to adopt various objective metrics to evaluate the detection performance further [14]. Here, accurate rate and consuming time in 100 frames are used to evaluating the performance between custom method (combined with edge detection and Hough transformation and Otus threshold) and the proposed method. Results are shown in Table 1. It is obvious that the proposed method has the higher accurate rate and consuming time. As the proposed method detects ROI to reduce following computation and select LSD as line detector, it reduces unnecessary computation. Meanwhile, it combined different features including gradient, color and line feature, it is more robust and accurate.

TABLE I. DETECTION PERFORMANCE COMPARISON OF MENTIONED METHODS IN IMAGE SEQUENCES

Methods	Table Column Head	
	Accurate rate	Consuming time/s
Custom method	91.5%	60.6
The proposed method	79.0%	37.1

V. CONCLUSION

A fast, robust and effective obstacles detection method based on multi-feature analysis is proposed to deal with problems in detection result in situations including complex environment and light conditions. The further analysis shows the proposed detection method is effective to detecting lanes and obstacles under complex background and the testing results demonstrate that it performs well with high with small calculating amount, high accuracy and robustness. The following work should be concentrated on how to guarantee the performance when there exist fast moving and occlusion.

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