International Journal of Computers, Communications & Control
Vol. I (2006), No. 4, pp. 93-99

Obstacle Detection in Cluttered Traffic Environment Based on Candidate Generation and Classification

Qing Li, F.C. Sun

Abstract: A novel method to detect vehicles is presented in the paper. Assumption of the vehicle is made using the geometrical features of the vehicle rear by the statistical histogram. Then hypothesis is verified using the property of the shadow cast by the car according to a prior acknowledgement of traffic scene. Finally, the vehicle detection is realized by hypothesis and verification of objects. The experimental results show the efficiency and feasibility of the method.

Keywords: objects hypothesis, objects verification, statistical histogram, vehicles detection

1 Introduction

The statistics of traffic accidents show that drivers have to face threats mainly from other vehicles. It is very significant to detect preceding vehicles in real time for keeping safe distance and avoiding collision. At the same time, vehicles detection is the precondition of safe driving and primary requirement of driver assist systems, active safety systems and automatic vehicles[1]. Many methods based on vision are used to detect vehicles, such as according to symmetry, shadow, texture, horizontal/vertical edge, color, stereo vision, depth, movement, template, view point, information fusion and parallax. We mainly detect preceding vehicles, including all vehicles running along same direction, even in other lanes, by vision sensors. Furthermore, head-on vehicles shall not be considered because we emphasize on systems for structural road where contrary lanes are separated by rail fence. A method based on objects assumption and verification for vehicle detection is suggested in the paper. Firstly, vehicles assumption is made by statistical histogram according to geometrical features. Secondly, the assumption is verified according to prior acknowledge. Lastly, the vehicles detection is realized. The experimental results show the method is valid and feasible.

2 Object assumption

The colorful video is gathered and conversed into frames of images. The images are preprocessed in the procedure of objects assumption. Then the potential vehicles are located in the whole image by several standards according to features of vehicles.

A.Finding Edge Features in the Image

Firstly, the object area is found approximately by camera calibration. Secondly, the color space is transformed in order to utilize color information effectively. Firstly, the horizontal gradient, the vertical gradient and the characteristic gradient are calculated in different color channel. In order to detect vehicles on the road, some features of vehicles are analyzed, including symmetry and edges. Vehicles mainly consist of horizontal structure, especially when they are observed from the rear. Though other horizontal structures exist in the road scene, the areas can usually be marked and their physical feasibility can be judged. Some experiments show horizontal edges are useful cue to confirm area of interest where vehicles appear possibly. In order to obtain horizontal edge response I_h and vertical edge response I_v, a direct edge filter is used. The input image is masked by two $n \times n$ template. The values of I_h and I_v is compared to obtain an edge response map I_r [2].In fact, man-made objects have more obvious edge response than natural objects. The value I_r is relatively distinct for vehicles, so it is regarded as a basic feature to detect vehicles(Fig.1)(Top: horizontal addition of the vertical histogram; bottom: horizontal lines representing vehicle (overlapped on the original image)).

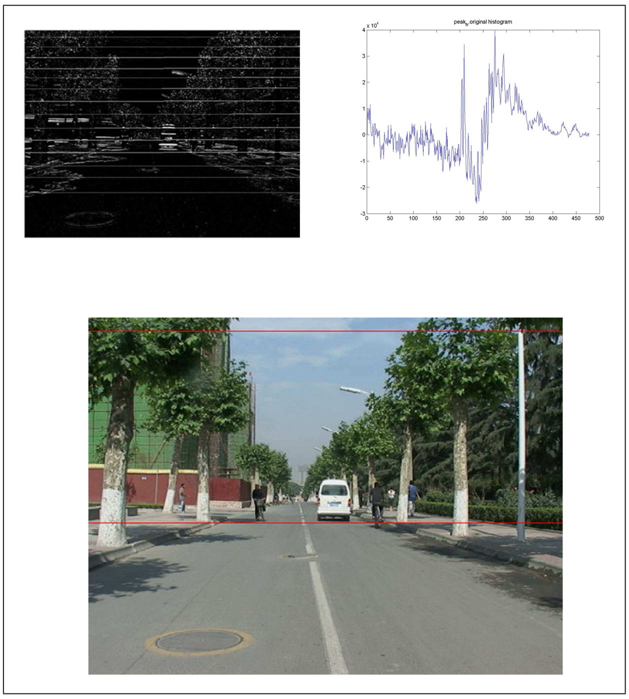

Figure 1: Object location in the vertical direction

B. Statistical Histogram Process

Firstly, we shall determine the possible location of vehicles in the vertical direction. The statistical histogram is formed by adding values of the edge responding map in a line and smoothed. The shift mean is used to smooth the curve in the paper. The potential vehicle is located by the local maximum of the smoothed curve. It is the most important to find and detect peak for segmenting the maximum of the histogram. Some methods are suggested to choose obvious mode. By examining the steepness or area of the peak value[3], the peak value will be detected. If it is not enough steep or big, the peak will be deleted[4]. The road surface is supposed as flat. The vehicles on road show symmetrical shape and certain ratio of high to width.(0.8-1.2).The ratio is set to 1.0 in the paper. The other feature is the size of vehicles in the image. The object will be far from the driver if the size is very little and will not be considered. The width of object responds the distance between the object and the driver. The smallest car far from 100 meter responds the width of 30 pixels. If the imaging width of the object is over 30 pixels, the distance will exceed 100 meters. Usually, the distance of 100 meters is enough to respond for drivers of the speech of vehicles is below 120 km/h.

Though the approximate position of vehicles can be determined by the above work, the imaging size of vehicles can't be solved and more work will be finished. The possible position locates the middle bottom of vehicles in Fig.2(top: vertical addition of the horizontal histogram; bottom: vertical lines located(overlapped on the original image) and possible position of vehicles). The area of interest of position (u_0,v_0) is as $A(u,v), u \in (u_0 - h_1, u_0 + h_2), v \in (v_0 - v_1, v_0 + v_2)$ (Fig. 3). The vertical edges of vehicles is searched in the area of interest $A(u,v)$. The statistical histogram of the area of interest is formed by the edge gradient in the vertical direction. The peak value of the left edge and the right edge of the vehicle can be found by the method. The peak value just near the candidate point is chosen if many peak values exist. No vehicles exist in the area of interest if only one peak value exist. The symmetry distance is introduced and obtained by calculating the mean square error of gray value g_{left} and g_{right}[5].

$$SD = E[(g_{left} - g_{right})^2] \tag{1}$$

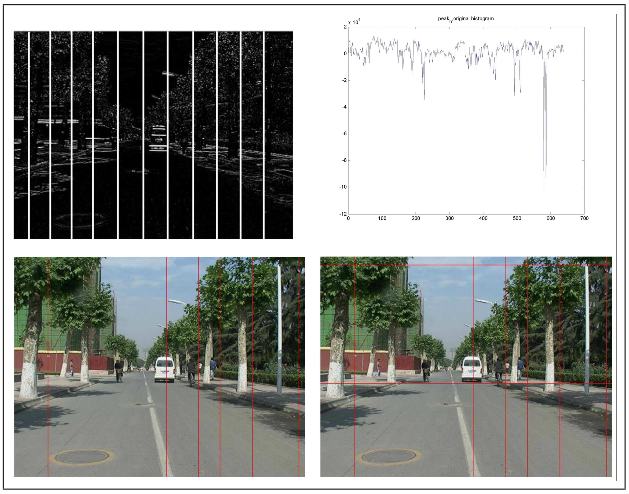

Figure 2: Object location in the horizontal direction

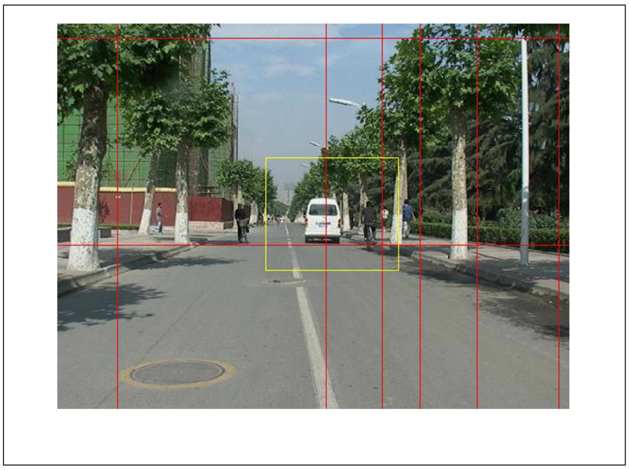

Figure 3: The area of interest determined.

If the *SD* is below a certain value, the obstacle more possibly exist(Fig.4). The area with maximum is defined as candidate area of vehicles(Fig.5).

3 Assumption verification

Even a potential object meets three standards, the assumption would be further verified because of weak grouping condition to seek potential vehicles. The object is verified based on shadow. Many methods are used to detect vehicles by utilizing the shadow below vehicles[6][7][8].

4 Experiment

Different types of vehicles are detected in the different road and weather condition. The variational P_r/P_R, P_g/P_G and P_b/P_G are illustrated in Fig.6 when the bar box moves. The different areas detected

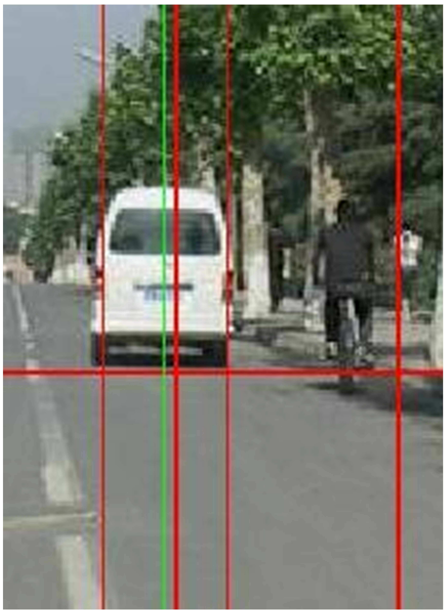

Figure 4: The vertical edges of the vehicle being located in the area of interest

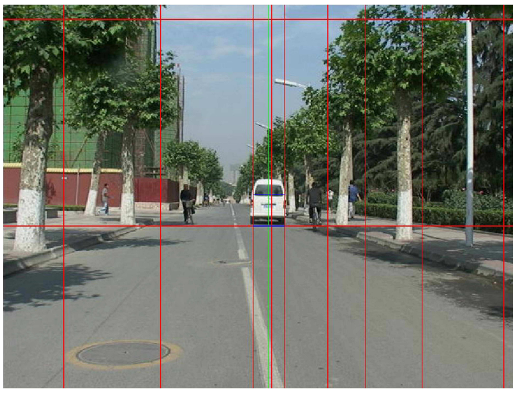

Figure 5: The candidate object

by object assumption and verification are showed in Fig.7. The position of preceding vehicles can be determined by combining with lane detection in Fig.8.

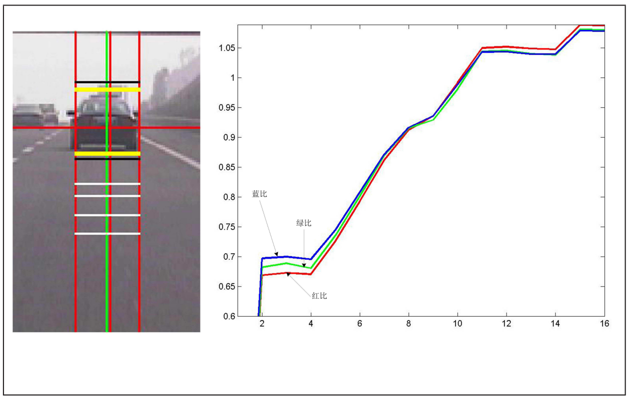

Figure 6: Blue ratio, green ratio and red ratio in the vertical candidate area

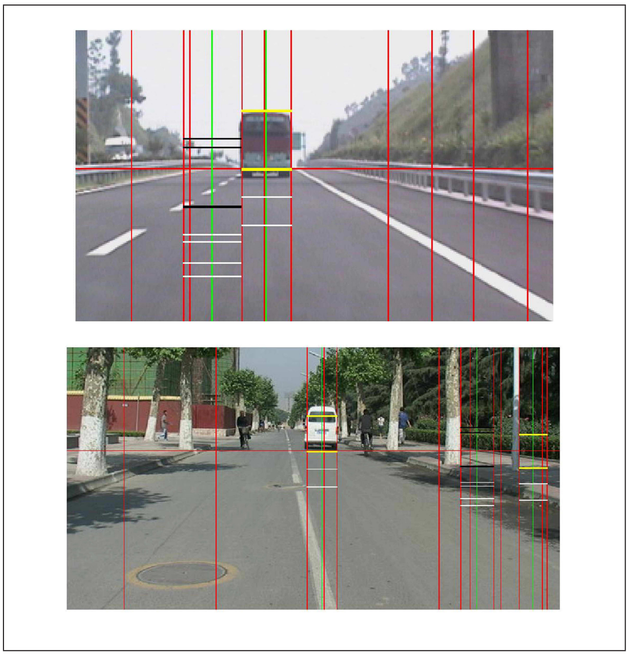

Figure 7: The different areas detected by object assumption and assumption verification

5 Summary and Conclusions

Because size, shape and color of vehicles are different, it is very challenging to detect vehicles by optical sensors. Additionally, surface of vehicles relies on their pose and is affected by ambient objects. It is difficult to control complicated outdoor environment. The method is composed of object assumption and assumption verification. Horizontal edge and symmetry of vehicle rear is used to seek candidate vehicles in assumption. Shadow is used to verify vehicles in verification. Experimental results show feasibility of the method.

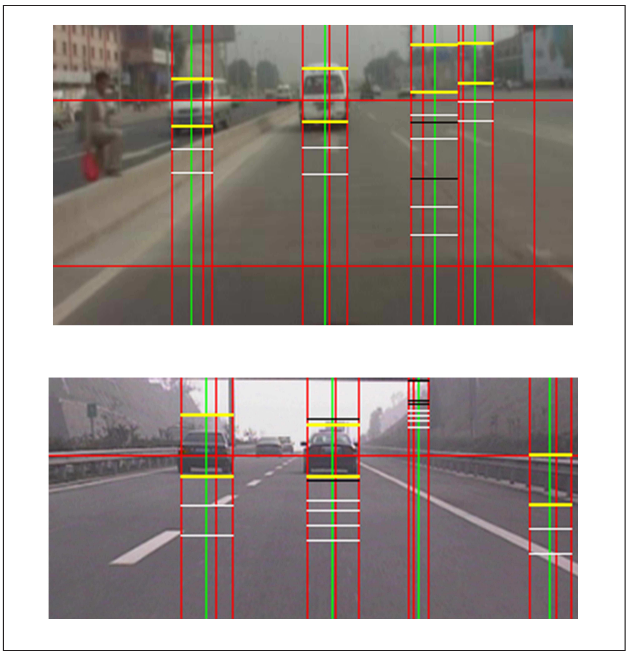

Figure 8: Some results of vehicle detection

6 Acknowledge

This work was jointly supported by the National Natural Science Foundation of China (Grant No: 60334020, 60321002, 60474025, 60504003 and 90405017), the National Excellent Doctoral Dissertation Foundation (Grant No: 200041), the National Key Project for Basic Research of China (Grant No: G2002cb312205) and the Specialized Research Fund for the Doctoral Program of Higher Education(Grant No: 20050003049).

References

[1] M. Bertozzi, A. Broggi,A. Broggi,A. Fascioli,Vision-based intelligent vehicles: state of the art and perspectives, *Robotics and Autonomous Systems*, Vol. 32, pp. 1-16, 2000.

[2] N. Matthews, P. D. Charnley, C. Harris, Vehicle detection and recognition in greyscale imagery, *Control Engineering Practice*, Vol. 4, pp. 473-479, 1996.

[3] D. C. Tseng, C. H. Chang, Color segmentation using perceptual attributes, *Proceedings of IEEE International Conference on Image Processing*, pp. 228-231, 1992.

[4] H. D. Cheng, Y. Sun, A hierarchical approach to color image segmentation using homogeneity, *IEEE Transactions on Image Processing*, Vol. 9, No. 12, pp. 2071-2082, 2000.

[5] H. Mori, N. M. CharkariY, T. Matsushita, On-line vehicle and pedestrian detections based on sign pattern, *IEEE Transactions on industrial electronics*, Vol. 41, No. 4, pp. 384-391, 1994.

[6] M. Y. Chern, B. Y. Shyr, Locating nearby vehicles on highway at daytime based on the front vision of a moving car, *Proceedings of Robotics and Automation*, Vol. 2, pp. 2085-2090, 2003.

[7] S. Kyo, T. Koga, K. Sakurai, S.OkazakiM, A robust vehicle detecting and tracking system for wet weather conditions using the LMAP-VISION Image Processing Board, *Proceedings of IEEE International Conference on Intelligent Transportation Systems*, pp. 423-428, 1999.

[8] S. Nadimi, B. Bhanu, Physical models for moving shadow and object detection in video, *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 26, No. 8, pp. 1079-1087, 2004.

Q. Li, F.C. Sun
Tsinghua University
Department of Computer Science and Technology
Beijing, China
E-mail: qli@mail.tsinghua.edu.cn

Received: November 10, 2006