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Overlap Vehicle Detection by Tracking Horizontal Lines

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Abstract

This paper presents a vehicle detection method which can divide overlap vehicles. The proposed method detects vehicles by finding vertical planes above a road plane. At first, two horizontal line segments adjacent vertically are detected in the present frame. Then, corresponding line segments are searched in the previous frame by a correlation matching. If the motion of these horizontal line segments satisfy the constraint of the vertical plane, it is estimated that a plane between these line segments is a part of vertical surfaces on a vehicle. These vertical planes are merged if horizontal line segments on these planes satisfy the motion constraint of the vertical plane. Each merged region provides an individual vehicle. The proposed method can divide overlap vehicles because the back surface on each vehicle is detected as the different vertical planes respectively. Experimental results for real road scenes under a traffic jam show the effectiveness of the proposed method.

1. Introduction

A lot of traffic surveillance systems using a TV camera have been developed to reduce a traffic jam and a traffic accident. It is important for these systems to detect vehicles individually and track them in image sequences. The frame differential method or the background image subtraction method is generally used because they can easily realize video-rate processing. However, these methods have a problem that multiple vehicles are wrongly detected as a single one if vehicles look like overlapping one another in a traffic jam.

Several methods dealing with overlap of vehicles have been proposed. Kuboyama[1] proposed a method to measure heavy traffic in a tunnel by using L-type model composed of a horizontal edge and a vehicle's side view. However, this method cannot detect vehicles whose side view is not visible. Although Anbai[2] proposed the method to separate overlap vehicles by using a graph partitioning algorithm, this method needs the moment when each vehicle is observed separately. The method[3] utilizing Spatio-Temporal Markov Random Field Model has been proposed to track occluded vehicles robustly. However, this method has a problem that it cannot divide overlap vehicles which enter the field of view at same speed.

When a camera is installed at a low position, vehicles often overlap in images from beginning to end. In order to cope with this situation, this paper presents the method to divide vehicles which have already overlapped with each other when they entered the field of view. If a tilt angle of a camera is small, it can be determined whether a plane is vertical or horizontal by examining motion of two horizontal line segments existing on the plane. The proposed method detects vertical surfaces on a vehicle by using this principle. Overlap vehicles are divided into individual ones because the back surface of each vehicle is detected as the different vertical planes respectively. In this paper, it is assumed that a traffic monitoring camera takes a vehicle's image from behind.

2 Vertical Plane Detection

Vertical planes on vehicles are detected by using the obstacle detection method described in [4]. We assume that the origin of the image is set to the vanishing point of the road and the camera is fixed so that the vanishing line can become horizontal in the image. A lot of surveillance cameras installed in the highway satisfy this assumption. Under this camera configuration, the view of the vehicle looks like that of the passing vehicle described in [5]. Therefore, the proposed method determines whether a plane is vertical or horizontal by examining motion of two horizontal line segments existing on the plane.

The outline of the method proposed in [5] is explained briefly. Let $y_i(t_1)$ and $y_j(t_1)$ denote the positions of two horizontal line segments observed at time t_1, and $y_i(t_2)$ and $y_j(t_2)$ denote the positions of two horizontal line segments observed at time t_2. If these line segments exist on the same vertical plane, the motion constraint of the vertical plane is obtained as follows:

$$\frac{y_j(t_2)}{y_j(t_1)} = \frac{y_i(t_2)}{y_i(t_1)}. \tag{1}$$

Therefore, if two horizontal line segments exist on the same vertical plane, the position of $y_j(t_2)$ is predicted as follows:

$$y_j^v(t_2) = \frac{y_i(t_2)}{y_i(t_1)} y_j(t_1), \tag{2}$$

where $y_j^v(t_2)$ denotes the predicted position of $y_j(t_2)$.

Similarly, if two horizontal line segments exist on a horizontal plane, the motion constraint of the horizontal plane is obtained as folows:

$$\frac{1}{y_j(t_2)} - \frac{1}{y_j(t_1)} = \frac{1}{y_i(t_2)} - \frac{1}{y_i(t_1)}. \tag{3}$$

Therefore, if two horizontal line segments exist on the same horizontal plane, the position of $y_j(t_2)$ is predicted as folows:

$$y_j^h(t_2) = \frac{1}{\frac{1}{y_i(t_2)} - \frac{1}{y_i(t_1)} + \frac{1}{y_j(t_1)}}, \tag{4}$$

where $y_j^h(t_2)$ denotes the predicted position of $y_j(t_2)$.

Two horizontal line segments exist on the same vertical plane if the observation $y_j(t_2)$ is close to the predicted position $y_j^v(t_2)$ and it is far from $y_j^h(t_2)$. Thus, if $d^v = \mid y_j^v(t_2) - y_j(t_2) \mid$ is small and $d^h = \mid y_j^h(t_2) - y_j(t_2) \mid$ is large, it can be determined that the region between two horizontal line segments is vertical to the ground plane.

3 Vehicle Detection Method

At first, the proposed method extracts horizontal line segments and corresponds them between frames. Then, it selects two horizontal line segments adjacent vertically and determines whether or not a plane containing these line segments is vertical by applying the method mentioned in Sec. 2. A Rectangle circumscribed on each region existing on vertical planes is obtained by the labeling and adjacent circumscribed rectangles located vertically or horizontally are merged if the motion of horizontal line segments contained in rectangles adjacent to each other satisfies the motion constraint of the vertical plane. These merged areas are detected as vehicles respectively because there's good possibility vertical planes exist on the back of the vehicle.

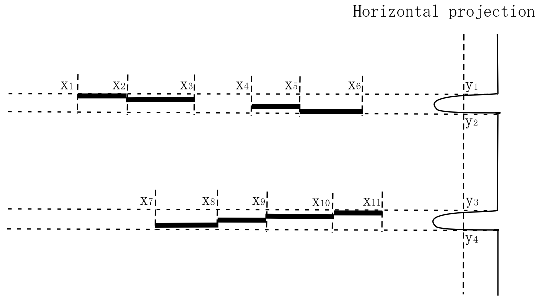


Figure 1. Horizontal line detection

3.1 Horizontal Line Detection

A horizontal edge image E_h and a vertical edge image E_v are obtained by applying the 3×3 Sobel operator, thresholding, thinning and elimination of small edges. Then, a horizontal edge image E_h is projected horizontally as shown in Fig. 1. In order to detect a little slant lines, projected values in up and down scanning lines are accumulated. A horizontal line exists in a vertical position y_i whose accumulated value is large. In the example shown in Fig.1, vertical positions y_i both in a range from y_1 to y_2 and in a range from y_3 to y_4 are selected as vertical positions where horizontal lines exist. Endpoints of a horizontal line segment are detected by searching on a horizontal line whose vertical position is y_i. In Fig. 1, segments whose endpoints are x_1 and x_2, x_3 and x_4,..., x_{10} and x_{11} are detected. These segments are often connected to other segments on a upper or lower scanning line. In order to merge these segments, the proposed method detects rectangles circumscribed on connected segments. Let (x_s, y_s) denote the left upper corner of the circumscribed rectangle, (x_e, y_e) denote the right lower corner of it and (x_c, y_c) denote the center of it. The line between (x_s, y_c) and (x_e, y_c) is detected as the final horizontal line. Figures 4(b) and 5(b) show horizontal lines obtained by this procedure.

3.2 Tracking Horizontal Lines

The proposed method corresponds horizontal line segments between frames by the cross correlation. Let W_i^t denote the rectangular area surrounding each horizontal line segment S_i^t in the present frame I_t. Vehicles move upward in images because we assume that a traffic monitoring camera takes a vehicle's image from behind. Therefore, in the previous frame $I_{t-\Delta t}$, the area corresponding to W_i^t is searched below W_i^t.

3.3 Detecting Vertical Planes

In the present frame I_t, two horizontal line segments, S_i^t and S_j^t, which are adjacent vertically are selected in order from the top of an image. A pair of segments whose horizontal overlap is small are excluded. And then, the method described in Sec. 2 is applied to determine whether or not S_i^t and S_j^t exist on the same vertical plane. The degree of overlap T between S_i^t and S_j^t is given by

$$T = \begin{cases} \frac{L_{ij}^t}{L_i^t} & (L_i^t < L_j^t) \\ \frac{L_{ij}^t}{L_j^t} & (L_i^t \geq L_j^t) \end{cases} \tag{5}$$

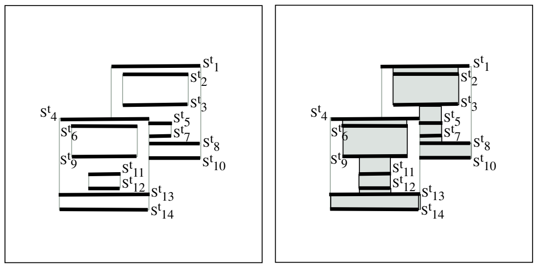
where L_i^t is the length of S_i^t, L_j^t is the length of S_j^t and L_{ij}^t is the overlap length between S_i^t and S_j^t.

In Fig. 2(a), a pair of segments are selected in order of (S_1^t, S_2^t), (S_2^t, S_3^t), (S_3^t, S_4^t), (S_4^t, S_6^t), (S_5^t, S_7^t), (S_6^t, S_9^t), (S_7^t, S_8^t), (S_8^t, S_{10}^t), (S_9^t, S_{11}^t), (S_{11}^t, S_{12}^t), (S_{12}^t, S_{13}^t) and (S_{13}^t, S_{14}^t). When the overlap between two segments is small, such as (S_3^t, S_4^t), there is a strong possibility that each segment belongs to a different vehicle respectively. In this case, there might be another segment S_5^t overlapping S_3^t sufficiently. Therefore, if the degree of overlap T between S_i^t and S_j^t is small, the proposed method examines whether or not another segment S_k^t whose degree of overlap T is large exists below S_i^t. If a segment S_k^t overlapping S_i^t sufficiently is found, a pair of segments (S_i^t, S_k^t) are also examined whether or not they exist on the same vertical plane. The overlap region between two segments existing on the same vertical plane is detected as a part of vertical surfaces on a vehicle. Gray areas in Fig. 2(b) show detected vertical surfaces.

In order to detect vertical surfaces more stably, vertical surfaces obtained in past several frames are accumulated. Because this processing may connect different vertical surfaces, accumulated vertical surfaces are divided by horizontal line segments S_i^t detected in the present frame I_t and vertical edges in E_v. Figures 4(c) and 5(c) show the results after accumulated vertical surfaces were divided.

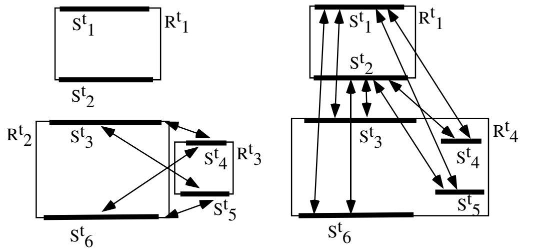
3.4 Merging Vertical Planes

Some of vertical planes detected in Sec. 3.3 may exist on the same vertical plane. Therefore, vertical planes adjacent to each other are merged if they exist



(a)Horizontal line sements (b)Vertical surfaces

Figure 2. A combination of horizontal lines



(a) Initial rectangles (b) R^t_2 and R^t_3 are merged into R^t_4

Figure 3. Merging vertical surfaces

on the same vertical plane. At first, the rectangle R_i^t circumscribed on each vertical region is detected by the labeling. Next, adjacent circumscribed rectangles, R_i^t and R_j^t, located vertically or horizontally are merged if the motion of horizontal line segments, S_i^t and S_j^t, contained in these rectangles respectively satisfies the motion constraint of the vertical plane. If R_i^t and R_j^t exist on the same vertical plane, a new rectangle circumscribed on both R_i^t and R_j^t is obtained as the merged rectangle. As shown in Fig. 3, several horizontal line segments exit in a circumscribed rectangle. Therefore, d^v and d^h defined in Sec. 2 are estimated for all combinations of segments in R_i^t and segments in R_j^t. Then, the coplanarity of R_i^t and R_j^t is determined by examining the average of them. In Fig. 3(a), an average of d^v and that of d^h estimated for four combinations of segments, (S_3^t,S_4^t), (S_3^t,S_5^t), (S_6^t,S_4^t) and (S_6^t,S_5^t) decide whether or not R_2^t and R_3^t exist on the same vertical plane. If R_2^t and R_3^t exist on the same plane, a rectangle R_4^t circumscribed on both R_2^t and R_3^t is obtained as a merged rectangle as shown in 3(b). In the same way, four segments, $S_3^t, \ldots, S_6^t$ in R_4^t and two segments, S_3^t, S_4^t in R_1^t are used to check whether or not R_1^t and R_4^t exist on the same plane. Merged rectangles whose size are not small are detected as vehicle's area.

4 Experiments

Figures 4 and 5 show vehicle detection results. In each scene, vehicles in the left lane have been detected.

Most of vehicles have already overlapped with each other when they entered the field of view. The rectangle circumscribed on the whole vehicle is not detected because the proposed method detects only an overlap area between two horizontal line segments as a vertical region. However, vehicles overlapping each other are detected as separate rectangles. Fig. 6 shows the result in a scene where vehicles entered the field of view at almost same speed. Each vehicle is detected separately. This result shows the proposed method is effective for dividing overlap vehicles. Sometimes there are vertical surfaces leaning a little in a vehicle, such as the back of the tank truck in Fig.4 or the rear window of the sedan in Fig.6. In order to deal with these surfaces, threshold values for d^v and d^h were adjusted so that these vertical surfaces can be detected.

5 Conclusion

This paper proposed the method to divide vehicles which have already overlapped with each other when they entered the field of view. Experimental results for real road scenes under a traffic jam show the effectiveness of the proposed method. The performance of the vehicle detection can be improved by corresponding detected rectangles in several frames. This is a subject for future work.

References

[1] H. Kuboyama and S. Ozawa, "Measurement of heavy traffic in a tunnel from image sequences," Systems and Computers in Japan, vol 35, Issue 13, pp.52-62, 2004.

[2] M. Anbai and S. Ozawa, "Traffic Monitoring System for Measuring Number of Vehicles in Various Environments," Proceedings of ITS2005, 2005.

[3] S. Kamijo, Y. Matsushita, K. Ikeuchi and M. Sakauchi, "Occlusion Robust Tracking Utilizing Spatio-Temporal Markov Random Field Model, Proc. of ICPR'00, pp.1140-1144, 2000.

[4] R. Okada, Y. Taniguchi, K. Furukawa and K. Onoguchi, "Obstacle Detection Using Projective Invariant and Vanishing Lines," Proc. of ICCV'03, pp.330-337, 2003.

[5] K. Furukawa, R. Okada, Y. Taniguchi and K. Onoguchi, "Onboard Surveillance System for Automobiles Using Image Processing LSI," Proc. of IV'04, pp.555-559, 2004.

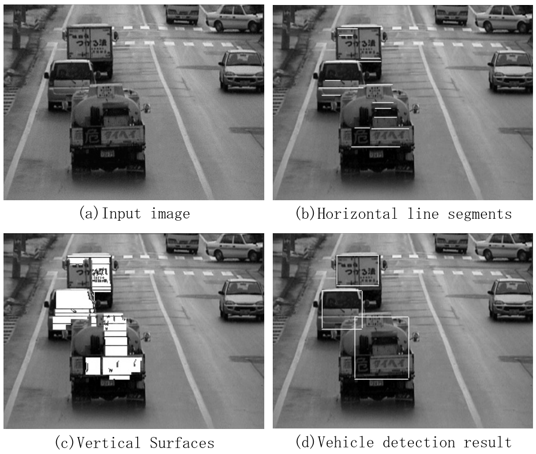


Figure 4. Result for the scene1

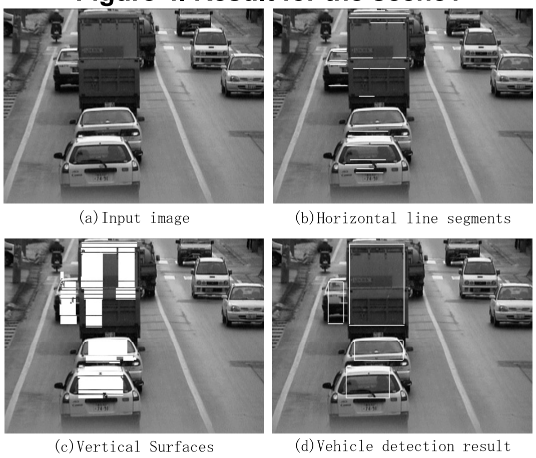


Figure 5. Result for the scene2

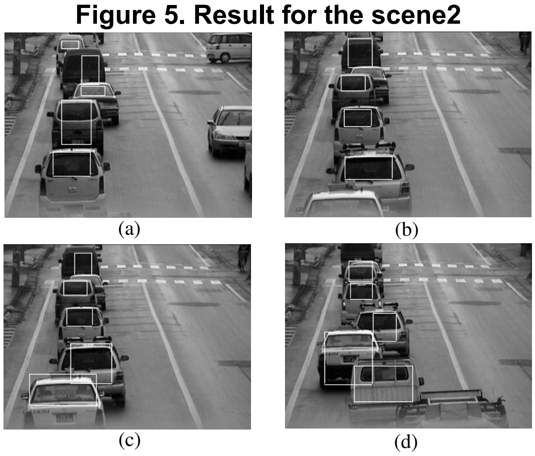


Figure 6. Results for continuous frames