Moving Vehicle Detection Based on Optical Flow Method and Shadow Removal

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Abstract. Video-based moving vehicle detection is an important prerequisite for vehicle tracking and vehicle counting. However, in the natural scene, the conventional optical flow method cannot accurately detect the boundary of the moving vehicle due to the generation of the shadow. In order to solve this problem, this paper proposes an improved moving vehicle detection algorithm based on optical flow method and shadow removal. The proposed method firstly uses the optical flow method to roughly detect the moving vehicle, and then uses the shadow detection algorithm based on the HSV color space to mark the shadow position after threshold segmentation, and further combines the region-labeling algorithm to realize the shadow removal and accurately detect the moving vehicle. Experiments are carried out in complex traffic scenes with shadow interference. The experimental results show that the proposed method can well solve the impact of shadow interference on moving vehicle detection and realize real-time and accurate detection of moving vehicles.

Keywords: Moving vehicle detection · Shadow removal · Optical flow method · HSV color space

1 Introduction

In recent years, the popularization of vehicles has caused severe traffic accidents and traffic congestion, and it has become necessary to relieve traffic pressure during peak period. Therefore, in the intelligent transportation system, detecting the moving vehicles and counting them can be used to reasonably regulate the traffic flow of a certain section of the road or quickly arrange traffic policemen to deal with the traffic problems.

In general, there are mainly three kinds of methods to detect moving vehicles, i.e., inter-frame difference method, background subtraction method and optical flow method [1].

The optical flow method has high detection accuracy and can accurately analyze moving targets [2, 3]. At the same time, the optical flow method can also detect moving

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targets in the case of background motion. Compared with the inter-frame difference method and the background subtraction method, the optical flow method can obtain more information about moving targets. However, although the optical flow method has high detection accuracy, it cannot obtain an accurate contour of a moving target due to the generation of a shadow.

In this paper, based on traditional optical flow method, the moving vehicle detection algorithm based on optical flow method and shadow removal is proposed. Firstly, the moving vehicle is roughly detected by the optical flow method, and then the shadow detection algorithm based on HSV color space is used to detect the shadow position by threshold segmentation. Then, according to the detected shadow area, accurate moving vehicle detection is realized by removing shadow area. The total detection flow chart is shown in Fig. 1.

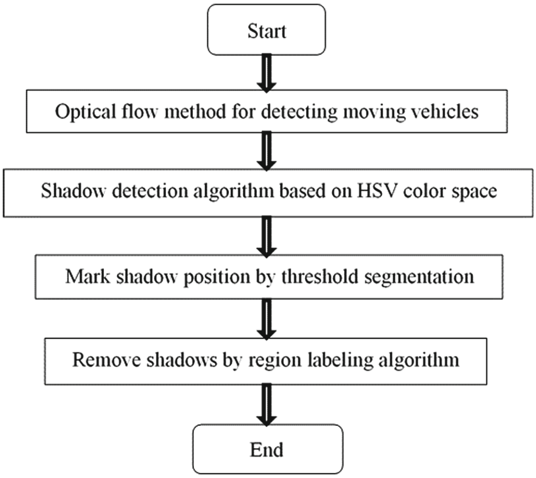


Fig. 1. Total detection flow chart of moving vehicles

2 Moving Vehicle Detection Based on Optical Flow Method

The proposed algorithm is based on the classical Horn-Schunck (HS) algorithm. Based on the four hypotheses of the classic HS algorithm, the optical flow constraint equation can be obtained as follows:

$$f_x u + f_y v + f_t = 0 \tag{1}$$

Then, using the variational calculation [4], the gradient values, f_x, f_y and f_t can be calculated as follows:

$$f_x = \frac{1}{4}(f_{i,j+1,k} - f_{i,j,k} + f_{i+1,j+1,k} - f_{i+1,j,k} + f_{i,j+1,k+1} - f_{i,j,k+1} + f_{i+1,j+1,k+1} - f_{i+1,j,k+1}),$$

$$f_y = \frac{1}{4}(f_{i+1,j,k} - f_{i,j,k} + f_{i+1,j+1,k} - f_{i,j+1,k} + f_{i+1,j,k+1} - f_{i,j,k+1} + f_{i+1,j+1,k+1} - f_{i,j+1,k+1}),$$

$$f_t = \frac{1}{4}(f_{i,j,k+1} - f_{i,j,k} + f_{i,j+1,k+1} - f_{i,j+1,k} + f_{i+1,j,k+1} - f_{i+1,j,k} + f_{i+1,j+1,k+1} - f_{i+1,j+1,k})$$

Thus, we can use the iterative method to solve the optical flow Eq. (1), where n represents the number of iterations.

$$u^{(n+1)} = \bar{u}^{(n)} - \frac{f_x(f_x\bar{u}^{(n)} + f_t + f_y\bar{v}^{(n)})}{\lambda + (f_x^2 + f_y^2)} \tag{2}$$

$$v^{(n+1)} = \bar{v}^{(n)} - \frac{f_y(f_x\bar{u}^{(n)} + f_t + f_y\bar{v}^{(n)})}{\lambda + (f_x^2 + f_y^2)} \tag{3}$$

But before solving the Eq. (1), we need to determine two parameters, $\bar{\mu}$ and $\bar{\nu}$. The two parameters can be calculated by the nine-point difference algorithm [5].

After determining all the parameters, we can solve the velocity field based on the current-frame and previous-frame grayscale images.

3 Moving Vehicle Detection Based on Shadow Removal

The changes of external environments can affect the detection of moving vehicles. How to effectively remove the shadow is an important factor for optical flow detection. A large number of experiments have shown that shadows can be well detected in the HSV color space [6]. Therefore, this paper combines the shadow removal with the optical flow method to eliminate the interference of shadows and make the moving vehicle detection more accurate. The detailed steps are as follows:

i) Read the video of moving vehicle, determine the shadow areas after converting each frame image in the video two times in the HSV color space, and then convert the obtained image into a grayscale image.
ii) Calculate the optical flow field vector, and add the optical flow field vector to the video frame.
iii) Calculate the average amplitude value of the optical flow vector to obtain the speed threshold; then, extract the moving object according to the speed threshold; finally, remove the noise by the median filter.
iv) Remove the shadow areas on the moving vehicle according to the shadow areas detected by the shadow detection algorithm.
v) Remove the road area by morphological erosion algorithm, and then fill the “cavity” areas of the vehicle by morphological close operation.

3.1 Shadow Detection Based on HSV Color Space

The pipeline of shadow detection in the HSV color space is: first, input an frame of image and convert the RGB image into a gray image by color space transformation; second, use the Otsu threshold detection method to obtain the threshold of image and binarize the image; third, remove noise by filter; fourth, the shadow area is detected.

HSV Color Model. The HSV color model is similar to an inverted hexagonal pyramid model [7], where V, H and S represent the brightness, color, and saturation, respectively. The transformation from RGB to HSV is shown in Eqs. (4), (5) and (6):

$$S = \begin{cases} \frac{V - \min(R,G,B)}{V}, V \neq 0 \\ 0, \text{others} \end{cases} \tag{4}$$

$$V = \max(R, G, B) \tag{5}$$

$$H = \begin{cases} \dfrac{60(G - B)}{V - \min(R, G, B)}, V = R \\ \dfrac{120 + 60(B - R)}{V - \min(R, G, B)}, V = G \\ \dfrac{240 + 60(R - G)}{V - \min(R, G, B)}, V = B \end{cases} \tag{6}$$

Shadow Detection. The HSV color space is closer to human vision and can accurately reflect the information of the target. The shadow of the moving vehicle is detected by the nature of the various parameters on the background by the shadow in the HSV color space. In the detection area, the V component will become smaller and change a lot relative to the background area, and it will be an important parameter for discriminating the shadow. For the S component, the shadow has a lower value and the difference from the background is negative. The H component usually does not change [8]. Based on this feature, the shadow can be detected. The specific algorithm is as follows:

$$SP(i, j) \begin{cases} \text{shadow points,} & \text{if } \alpha \leq T_{i,j}^{v} / B_{i,j}^{v} \leq \beta, (I_{i,j}^{S} - B_{i,j}^{S}) \leq T^{S} \\ & \text{and abs}\left(I_{i,j}^{H} - B_{i,j}^{H}\right) \leq T^{H} \\ \text{non-shadow points otherwise} & \end{cases} \tag{7}$$

where, α and β represent the threshold values of luminance; T^S and T^H represent the threshold values of saturation and color, respectively, and $0 < \alpha < 1, 0 < \beta \leq 1$.

Automatical Threshold Determination Based on Otsu. The Otsu algorithm [8] is used in the HSV color space for shadow detection [8], which is a self-adaptive threshold determination method. The larger the variance between the foreground and the background is, the greater the difference between them is. Assuming t is the set threshold, the gray level of the image is L, then traverse t from 0 to L, if when t is a certain value, for which the variance of foreground and background is the largest, then the t is the required threshold. The variance is calculated as follows:

$$\sigma^2 = A_0 \times (B_0 - B)^2 + A_1 \times (B_1 - B)^2 \tag{8}$$

where, $B = A_0 \times B_0 + A_1 \times B_1$, A_0 is the proportion of the moving target pixels to the total image pixels, B_0 is the average grayscale value of the moving target pixels, A_1 is the proportion of the background pixels to the total image pixels, B_1 is the average grayscale value of the background pixels, and B is the total average grayscale value of the total image.

3.2 Shadow Removal

Remove the shadow of the moving vehicle based on the detected shadows area and obtain accurate vehicle detection. Then use morphology operation [9] to remove the road area. Finally, obtain complete and accurate detection area of the moving vehicle by filling the “cavity” via close operation [9].

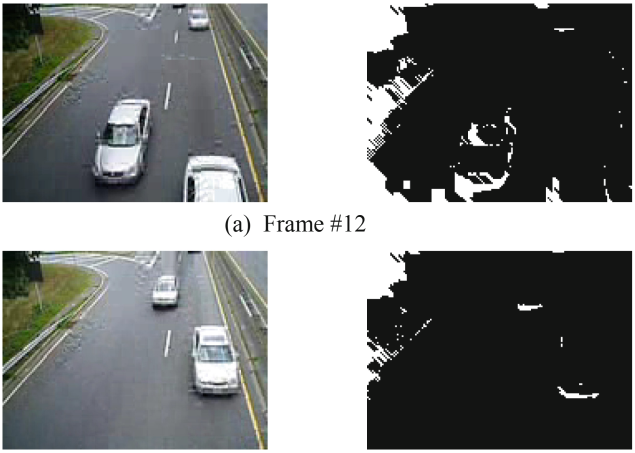
4 Experiment

Experiments are implemented on the computer with Intel(R) Core (TM) i5-2410 M CPU 2.30 GHz and 4.00G memory. The image size is 320 $\times$ 240 pixels, and the software is programmed by Matlab 2013. The experimental results are as follows.

4.1 Shadow Detection Results

The video of moving vehicles is captured by a camera fixed on an overpass. The video is AVI format with a frame rate of 15 frames/s. The number of moving vehicles is sufficient for the experiments. The following is the experimental results of shadow detection, shown in Fig. 2, where the left column is the original images, and the right column is the detection results of shadow area.

On the right column, the white area indicates the shadow area detected by the shadow detection algorithm based on HSV color space. In order to obtain complete shadow area, the morphological close operation is performed after the image binary based on the threshold segmentation.



(a) Frame #12

(b) Frame #23

Fig. 2. Shadow detection results based on HSV color space

4.2 Comparison of the Proposed Method and Other Methods

Table 1 shows the performance comparison of the proposed method, background subtraction method, inter-frame difference method, and traditional optical flow method in terms of average computational time and accuracy. Seen from Table 1, although the background subtraction method, inter-frame difference method, and traditional optical flow method have fast detection speed, they have lower accuracy than the proposed method.

Table 1. Performance comparison of the proposed method and other methods

Methods	Average computational time (millisecond)	Accuracy
Background subtraction method	56	87%
Inter-frame difference method	49	89%
Traditional optical flow method	103	92%
The proposed method	119	95%

5 Conclusion

This paper proposed a moving vehicle detection method based on optical flow method and shadow removal. The proposed method firstly uses the optical flow method to roughly detect the moving vehicle, and then uses the shadow detection algorithm based on the HSV color space to realize the shadow removal, finally accurately detect the moving vehicle. The experiments in complex traffic scenes with shadow interference demonstrate that the proposed method can well solve the impact of shadow interference on moving vehicle detection and realize real-time and accurate detection of moving vehicles.

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