RESEARCH OF VEHICLE SPEED DETECTION ALGORITHM IN VIDEO SURVEILLANCE

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ABSTRACT

The paper presented a vehicle speed estimation algorithm based on moving target detection in video surveillance. Firstly, the features of moving vehicles were extracted by using the three frame difference method and the background difference method; secondly, tracked and positioned the moving target according to moving vehicle centroid feature extraction method; finally, the vehicle speed was estimated based on mapping relationship between the pixel distance with the actual distance.

***Index Terms*—**center of mass, feature extraction, velocity estimation, motion detection

1. INTRODUCTION

Vehicle detection is the most basic and the most important part of the intelligent transportation. Traditional detection technologies included in this study are infrared detection [1], the induction line detection [2], ultrasonic detection [3], acoustic array detection [4], radar [5], video image detection systems [6] and so on. During the last decades, there are various new vehicle detection techniques in video surveillance are discovered [7-10]. Vehicle detection technology based on video can obtain abundant information such as the vehicle speed, vehicle flow, vehicle type and so on from video image sequences, which has low cost and high efficiency.

Vehicle motion analysis is a hot research field of computer vision. At present, the research of vehicle detection is mainly based on moving objects detection in video. Moving target detection is to extract the change area from the image sequence. The main methods for moving target detection are background difference method, frame difference method and optical flow method.

The paper studied the vehicle speed detection algorithm based on moving target detection in video. The main work includes the following aspects: motion detection, vehicle tracking and vehicle speed estimation.

2. THE BASIC THEORY OF MOTION DETECTION

Frame difference method is based on the strong correlation of the adjacent frames in motion image sequences. In the experiments, the camera is always fixed, using pixel-based time difference on two adjacent frame images or three frame images of successive images sequence, and then by means of thresholding to remove static objects and extract moving regions in the image.

The sign $f_k(x, y)$ represents the k th frame in the video sequence image, and the sign $f_{k-1}(x, y)$ represents the k-1 *th* frame image, the difference image is represented as $D_{k-1}(x, y)$. the numerical relationship can be expressed as:

$$D_{k-1}(x,y) = \left| f_k(x,y) - f_{k-1}(x,y) \right| \quad (1)$$

Using thresholding T to segment image into binary image $R_{k-1}(x, y)$:

$$R_{k-1}(x,y) = \begin{cases} 1, & D_{k-1}(x,y) \geq T \\ 0, & D_{k-1}(x,y) < T \end{cases} \quad (2)$$

Frame difference method has a strong adaptability for changes of light. It is easy to implement and suitable for moving target detection in real-time system. But its disadvantage is often unable to get complete boundary information of moving object.

Background difference method subtracts the current real-time image frame to be detected and the original background image. The changed region will be determined as moving target area. At present, common background image estimation methods are statistical average method, median method and Surendra background updating algorithm and so on. The background difference method can obtain complete and accurate information of the moving target region. The deficiencies of the algorithm is that it is sensitive to changes of the light, weather and other environmental conditions.

Optical flow method is based on constraint conditions of gray gradient unchanged and brightness preservation to detect moving target. Optical flow method can detect independently moving target without knowing any scene information in advance. But its calculation is too complex and time-consuming to achieve real-time detection.

3. THE VEHICLE SPEED DETECTION BASED ON VIDEO

The main process of vehicle speed detection includes the following parts: the establishment and updating of background model, moving target detection, vehicle centroid localization and motion speed calculation. The flow-chart is shown in Figure .1:

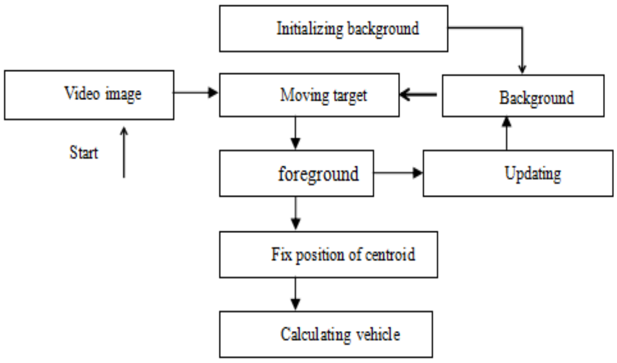


Figure 1. The flow-chart of the estimation of vehicle speed

3.1. Background Reconstruction and Update Strategy

It is found that only when the target motion through the pixel would the RGB value of a pixel take place great changes. So background reconstruction is based on median method in RGB space in the paper. The RGB components were treated respectively.

The changed light or lingering moving object will cause background to take place changes, therefore the background should be updated. Based on the complete moving object image I_k, replace the regions having the moving object with the previous background figure B_{k-1} in corresponding areas, other regions don not need change, thus complete the background updating. The mathematical expression is as:

$$B_k(x,y)=\begin{cases} B_{k-1}(x,y) & if\ I_k(x,y)=1 \\ w*I_k(x,y)+(1-w)*B_{k-1}(x,y) & if\ I_k(x,y)=0 \end{cases} \quad (3)$$

Where $B_k(x,y)$ represents the pixels of the background in current moment, while $B_{k-1}(x,y)$ represents the pixels of background in the previous moment. The sign w is weighted coefficient which value is obtained by experience, in this paper, w is set 0.03.

3.2. Extract Moving Object

In order to get the accurate moving object which has complete boundary from video image sequences, considering the advantages of the background difference method and frame difference method, the three frame difference method and background difference method are combined used to extract the moving vehicle area. In order to shorten the experiments time, the extraction is operated in gray space.

3.3. Position Vehicle Centroid

Centroid as the moving target location parameters has small error and good stability. After extracting the complete motion object, extract centroid of the object in gray space to position the moving target. The centroid is calculated by formula as follows:

Among them, G(x,y) represents the gray value of pixel in coordinates (x,y). X is the x-coordinate of centroid, Y is the y-coordinate of centroid.

$$\begin{cases} X=\dfrac{\sum_{x=1}^{m}\sum_{y=1}^{n} xG(x,y)}{\sum_{x=1}^{m}\sum_{y=1}^{n} G(x,y)} \\ Y=\dfrac{\sum_{x=1}^{m}\sum_{y=1}^{n} yG(x,y)}{\sum_{x=1}^{m}\sum_{y=1}^{n} G(x,y)} \end{cases} \quad (4)$$

3.4. Calculate Vehicle Speed

Suppose that the video frame rate is *fps,* ($x1$, $y1$) is the centroid position of moving target in the t frame in video, ($x2$, $y2$) is the centroid position of moving target in the $t1$ frame. So the speed of moving object in video can be calculated by formula (5), the unit for it is /s.

$$v=\sqrt{(x1-x2)^2+(y1-y2)^2}\times fps \quad (5)$$

The speed calculated based on the formula (3-13) is the speed of the moving object in the image, so the calculation of the actual vehicle movement speed need through the mapping of the pixel distance with the actual distance. Camera calibration technology which uses the image captured by camera to restore the objects in space is a commonly and good method to solve the mapping relationship.

In complex situations, the mapping of pixel with space distance does not always show a linear relationship. So we can use a variety of learning methods by repeatedly measuring to obtain the coefficient of relationship for different scenarios.

4. EXPERIMENTAL RESULTS AND ANALYSIS

Experiments are operated on groups of videos captured outdoor, the size of video image is 640 × 480, the frame rate is18 *fps*, the camera is static monocular camera. Firstly, using the moving object extraction method mention above to extract the vehicles in the video, and then analyzing the trajectory of the centroid, finally according to the mapping relationship to estimate the vehicle speed.

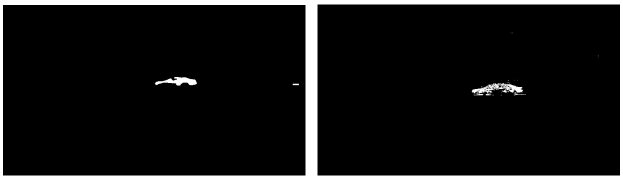
4.1. Moving Object Extraction

For example, the detection process of video lips is shown in Figure 2.

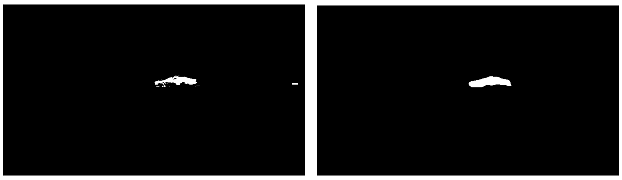
The Figure 2(d) shown that based on the median method in RGB color space the background can be effectively reconstructed; comparing the Figure 2(g) and Figure 2(h), after noise reduction, the empty area made by the similarity of background and foreground is filled, and the shadow regions has also been greatly eliminate. Experimental results show that the proposed method which combined the three frame difference method and background difference method has better robustness, can

(a) The 49th frame (b) The 50th frame

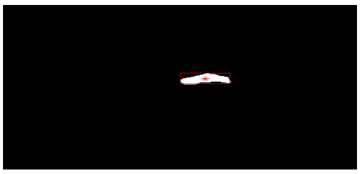
(c) The 51th frame (d) The reconstruction background



(e) Moving object extracted by background difference
(f) The moving object extracted by frame difference



(g) The moving object extracted by proposed method
(h) The moving object after noise reduction



(i) Mark the target area and its centroid

Figure 2. Moving object extraction

well remove the noise and extract the complete boundary of vehicle.

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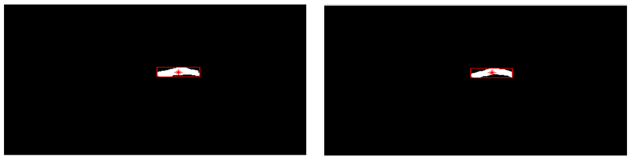
4.2. Vehicle Speed Detection

Experiments on vehicle speed detection are mainly operated in two aspects: first, verifying the rationality of the mapping relationship coefficient value, then using the formula (5) to calculate the vehicle speed. Supposing using the measured mapping relationship coefficient, the conclusion from ten groups of measured data is that the average error is 0.097. And when pixel distance becomes larger, the error becomes smaller. Due to not taking into account the actual image-forming principle of camera, so the results always exist a amount of error.

In this paper, we using two arbitrary selected frames of video segment for experiments, according to the formula (5) to calculate vehicle speed.



(a) The centroid position of 87th frame
(b) The centroid position of 88th frame

Figure 3. The centroid position

The centroid position of 87*th* frame shown in Figure 2(a) is signed (366.31, 217.03), while centroid position of 87th frame shown in figure 4.2(b) is signed (354.86, 215.93). According to formula and mapping relationship coefficient, we can calculate the instantaneous velocity of motion vehicle, the speed. The velocity can be used for vehicle overspeed detection.

Experimental results show that the speed has great relationship with the completeness and accuracy of the vehicle target detection. Therefore, the vehicle speed is only a preliminary for follow-up operation. Because of not considering malformations in the camera, the calculation error is unavoidable, but the accuracy of calculation can be further enhanced if joins the camera imaging mechanism in the experiment.

5. CONCLUSIONS

In this paper, the three frame difference method and background difference are used for extracting moving targets. The approximation velocity of vehicle is estimated by analyzing the centroid position of moving target and mapping relationship. The method has good robustness and strong practicability, but it exists certain error. The next work is to combine with more detail information of visual motion for speed calculation.

6. REFERENCES

[1] T.M. Hussain, A.M. Baig, T.N. Saadawi, S.A. Ahmed, "Infrared pyroelectric sensor for detection of vehicular traffic using digital signal processing techniques",IEEE Transactions on Vehicular Technology, 44(3),pp. 683-689, 1995.

[2] J. Gajda, R. Sroka, M. Stencel, A. Wajda, "A vehicle classification based on inductive loop detectors", Instrumentation and Measurement Technology Conference, 2001. IMTC 2001. Proceedings of the 18th IEEE (Volume:1).pp. 460-464, 2001.

[3] K.T. Song, C.H. Chen, C.H. C. Huang, "Design and experimental study of an ultrasonic sensor system for lateral

collision avoidance at low speeds", Intelligent Vehicles Symposium, pp. 647-652, 2004

[4] Fazenda, BM, Atmoko, H, Gu, F, Guan, L and Ball, A 2009, Acoustic based safety emergency vehicle detection for intelligent transport systems , in: ICROS-SICE International Joint Conference 2009, 18th - 21st August 2009, Fukuoka, Japan.

[5] S. P. Lohmeier, R. Rajaraman,V. C. Ramasami.Development of an ultra-wideband radar system for vehicle detection at railway crossings. IEEE Conference on Ultra Wideband Systems and Technologies.207 - 211.2002

[6] J.F. Alves, G.R. Cacnio, D.R. Stevens, "Video image processor and method for detecting vehicles", US5535314 A, 1996.

[7] Z.W. He, J.L. Liu, P.H. Li, "New method of background update for video-based vehicle detection", The 7th International IEEE Conference on Intelligent Transportation Systems, pp. 580-584, 2004

[8] E. Mosabbeb, M. Sadeghi and M. Fathy, "A new approach for vehicle Detection in Congested Traffic Scenes Based on Strong Shadow Segmentation", Springer, part II, LNCS 4842, pp. 427-436, 2007

[9] J. Hsieh, L. Chen and D. Chen, "Symmetrical Surf and its Applications to Vehicle Detection and Vehicle Make and Model Recognition", IEEE Trans, Intell. Transp. Syst., 15(1), pp. 6-20, 2014

[10] Y.B. Rao, "Automatic vehicle recognition in multiple cameras for video surveillance", The Visual Computer, 31(3): pp. 271-280,2015