ISBN 978-952-5726-00-8 (Print), 978-952-5726-01-5 (CD-ROM)
Proceedings of the 2009 International Symposium on Web Information Systems and Applications (WISA'09)
Nanchang, P. R. China, May 22-24, 2009, pp. 449-453

Self-adaptive Detection of Moving Vehicles in Traffic Video

Zhai Hai-tao, Wu Jian, Xia Jie, Cui Zhi-ming
The Institute of Intelligent Information Processing and Application
Soochow University, Suzhou, 215006, China
Email: iamhaitao@hotmail.com

***Abstract*—Aiming at the difficulty of obtaining the initial background, the inaccuracy of real-time background update and the difficulty of controlling the update speed in moving vehicle detection of traffic video, this paper proposes an accurate and effective moving vehicle detection method which can be used in complex traffic environment. This method first constructs initial background image according to the real-time situation of traffic environment, then segmentalizes the current frame into foreground region and background region accurately using the combined method of inter-frame difference and background subtractions, then do the real-time update on background with a adaptive background update speed which is selected according to the background disturbance and illumination changes of road, lastly obtain the moving object and remove the shadow of moving object with the background subtraction method. Experimental results show that this method can detect moving vehicles fast and accurately in complex traffic situation.**

***Index Terms*— Moving detection; Statistical background model; Intelligence traffic system; Background subtraction**

I. INTRODUCTION

In recent years, with the rapid development of China's urban construction, the number of urban motor vehicles is also increasing. Only depending on the manpower to manage the traffic is not enough, so intelligence traffic system (ITS) appears. ITS is an important part of digital city. The information from the ITS will not only help further improve the urban traffic management, but also provide valuable advises for the polices to insure the social order. Fast and accurate vehicles detection from the traffic video is a key step in the process of vehicles tracking and construction of ITS [1]. Because of the influence like complexity and diversity of road conditions, background disturbance and illumination changes of road, traditional moving detection methods such as inter-frame difference, background subtractions and optical flow method can't detect the moving vehicles self-adaptively and timely in the complex traffic situation. After analyzing the traffic video in detail, this paper proposes an accurate and effective moving vehicle detection method which can be used in complex traffic environment.

Ⅱ. FOUNDATION OF INITIAL BACKGROUND IMAGE BASED ON IMPROVED STATISTICAL BACKGROUND MODEL

The accuracy of initial background image plays the important role in the performance of vehicle detection. Many other moving object detection methods have been proposed such as W4 [2], statistic background model [3] and dynamic background model algorithm [4]. However, we can not stop the traffic when we build the initial background image, so the w4 method is not suitable for the traffic detection.

A. Statistical Background Model

The statistical background model proposed by Lin Hongwen in the paper [3] provides a good way to solve the problem in the paper [4]. This method divides Y into several intervals under the YUV color space. To each pixel, we record number of times that brightness value appears in every interval for a period of time, and then find out the interval in which brightness value appears most times, calculate its mean, and then make it as the brightness value of background model at that point. This method has the following two shortcomings.

Firstly, for each pixel, if the pixel's actual intensity Y' scatters uniformly in this period, then the number of Y' is relatively small in each interval. So, the obtained Y can't represent the approximation of Y'. Secondly, this method assumes that once the moving vehicles drive into the video, the vehicles will not stop, so this method is not suitable for the traffic environment such as crossroad in which vehicles often have to stay. Based on this method, this paper gives several improvements.

B. Background Image Initialization Method Based on Improved Statistical Background Model

Firstly, Calculate expectation value and variance of each pixel, define μ_i as gray expectation value of any point *i* in background, σ_i^2 as variance of grey distribution.

$$\mu_i = \frac{1}{n}\sum_{t-1}^{n}\mu_{it} \quad (1)$$

$$\sigma_i^2 = \frac{1}{n}\sum_{t-1}^{n}(\mu_{it} - \mu_i)^2 \quad (2)$$

μ is gray value of point *i* in the *t-th* frame.

Secondly, build the initial background image according to each pixel's variance. Variance can represent the pixels' distribution on N frames. Assuming N is large enough, if $\sigma_i \leqq$ threshold *T*, we believe that the changes of the pixel's value is caused by the subtle changes of the background. This paper uses the shift

AP-PROC-CS-09CN001

method to divide the N pixels into L centers C={{c_i, w_i}|i=1, 2, …s, L}（$0<L\leqq N$）(c_i is the i-th class's center, w_i is the i-th class's weight). This paper selects the class's center whose weight is w=max{ w_i|i=1, 2, …., L } as the pixel's intensity. If σ_i> threshold T, we can know that the pixel distribute dispersedly in this period, so we obtain the pixel's approximation by averaging in the whole period of time.

Ⅲ. SELF-ADAPTIVE BACKGROUND UPDATING

In the process of moving vehicles detection, if we want detect the moving vehicles, we must establish a good background updating model. There are several difficulties.

- Changes caused by the moving object： Such as a man carrying something into or out of the scene, a car driving into or out of the background, a man or something moving after stopping for a moment.
- Disturbance caused by the moving object itself: experimental results show that because the color of the vehicles' windows is familiar with the road, so the real traffic background image is very difficult to be extracted.
- Background disturbance: such as the camera's little jittering, branches' swaying and water wave in the video area. The factor demands a suitable threshold when we get the binary mask by inter-frame difference method which is the key point of background updating.
- Illumination changes: such as the changes between day and night, natural illumination changes and the shadow of moving object.

Taking the above factors into account, this paper proposes a new background update strategy.

A. First Segmentation of The Current Frame

The current frame image minus the pre-image is to be a difference image.

$$D_k(x,y) = F_k(x,y) - F_{k-1}(x,y) \tag{3}$$

Where the *FK(x,y)* is the *k-th* current frame, the current background image is *BK(x,y)*.

Transform the difference image into the binary mask by the threshold T.

$$M(i,j) = \begin{cases} 0 & D(i,j) \geq T \\ 1 & D(i,j) < T \end{cases} \tag{4}$$

Because the background in the traffic video is changing dynamically, we can not choose a fixed value as the threshold. Furthermore, a bad set of thresholds will produce a blurry segmentation when we use binary mask to update the background image which will result in bad vehicle detection [5]. This paper will use the difference image to produce a self-adaptive threshold. Most area of the sequence image belongs to the background, so most pixels in the difference images are low value, while only a few pixels are high value. This histogram of difference image will have high values for low pixel intensities and lower values for the high pixel intensities. We find out the peak of the histogram and use 10% of the peak value as the threshold of the binary mask image. This operation described above can be shown in Fig. 1.

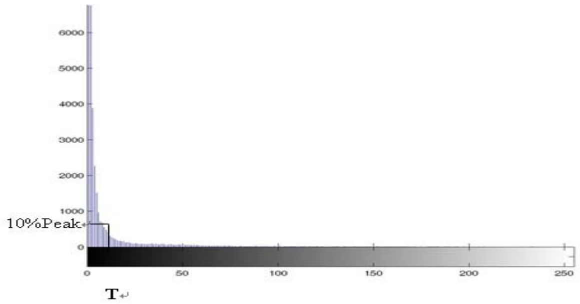


Figure 1. Histogram of difference image

According to the binary mask, we can segmentalize the current frame into foreground region and background region. For each pixel in the binary mask, if the value is 0, we can divide it into the background region; otherwise we divide it into the foreground region. But, this segmentation is not accurate enough. The regions of the red box shown in the Fig. 2 which are considered as the background region, but actually are the windows of the vehicles. Furthermore this will result in many cavities at the last. Because the edge's information of the vehicles produced in the above method will not lost, this paper use the Canny edge detection method [6] which can be used to transform the cavities into connected region to detect the vehicles' edge [7]. At the last of this step, we choose the connected region as the new foreground image.

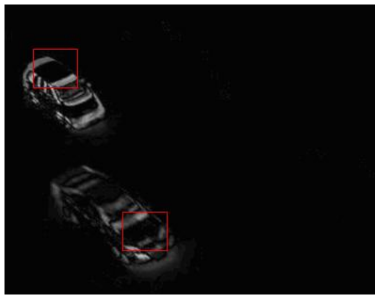


Figure 2. Difference image

B. Fine-grained Segmentation of Current Image

The foreground and background detection result from the Ⅲ（a） is rough. The foreground region will be larger than the actual foreground region and has many cavities. This phenomenon is more serious in the freeway situation because the distance between two frames is further due to vehicles' fast speed. To get more accurate foreground region, this paper use background subtraction method to extract new foreground region from the old foreground extracted by the last step. The foreground region in the *k-th* frame after the first segmentation is *FfK(x,y)*, the foreground region in the current background image is *BfK(x,y)*. The *FfK(x,y)* minus *BfK(x,y)* is difference image.

$$Df_k(x,y) = Ff_k(x,y) - Bf_{k-1}(x,y) \tag{5}$$

According the threshold T, we transform the difference image into a binary mask image.

$$Mf(i,j) = \begin{cases} 0 & Df(i,j) \geq T \\ 1 & Df(i,j) < T \end{cases} \tag{6}$$

We can divide the foreground region obtained from the first step into foreground and background region by equation 6. If the $Mf(i,j)$ is 0, we see the pixel (i,j) as background region, otherwise we see it as new foreground region. The whole segmentation process can be described in the Fig. 3.

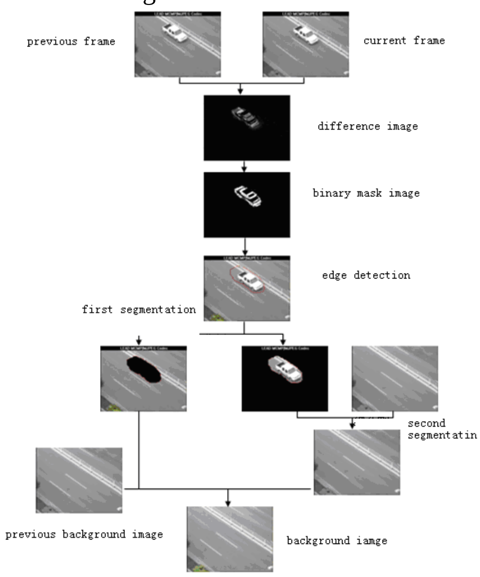


Figure 3. Flowchart of background updating

C. *Self-adaptive Updating of Background Image*

After segmenting the current image into foreground and background region, we should use the current frame image to update the background image.

$$B_k = \begin{cases} (1-\alpha)B_{k-1} + \alpha F_k & D_k = 0 \\ B_{k-1} & D_k = 1 \end{cases} \tag{7}$$

Where α is the background updating speed $\alpha \in [0,1]$. When the traffic scene changes violently, we should increase the α's value to update the background image in time. There are several factors which have impact on the value of α.

1) Background disturbance

The peak region of the difference image's histogram is the dense area of the difference image. We can use the changes of the pixels in the peak area to represent the changes of the background. If the *(k+1)-th* difference image's peak pixel's intensity is f, we count the number of pixels between $f-10$ and $f+10$ as Tk. And this value in the k-th difference image is T_{k-1}.

$$\alpha_1 = \eta\left(1 - \frac{|T_k - T_{k-1}|}{\max(T_k, T_{k-1})}\right) \tag{8}$$

2) Influence by illumination.

Paper [8] proposes an updating method for α based on the influence by illumination. When the scene's illumination changes, the intensity of the background image will change uniformly. We can use the changes between two frames' mean value to represent the background changes caused by the illumination. We make use of this information to adjust the background update rate.

$$\alpha_2 = \eta\left(1 - \frac{|L_k - L_{k-1}|}{\max(L_k, L_{k-1})}\right) \tag{9}$$

3) Considering the impacts of illumination and the background disturbance.

$$\alpha = 0.5 \times \alpha_1 + 0.5 \times \alpha_2 \tag{10}$$

Where $0 \leq \eta \leq 1$. Generally $\alpha \in [0.45, 0.5]$.

Ⅳ. SELF-ADAPTIVE MOVING VEHICLES DETECTION ALGORITHM

Based on the analysis above, this paper proposes an accurate and effective moving vehicle detection method which can be used in complex traffic environment. We list them as follows:

4) Image acquisition

Generally, the traffic videos can be acquired according to the camera which is installed on the road.

5) Initialization of the background image

The initial background image will be constructed by the situation of the traffic.

6) First segmentation of current frame

We will segment the current frame into foreground and background image by the inter-frame difference method.

7) Fine-grained segmentation of current frame

The foreground image acquired by last step will be segmented into foreground and background region furthermore.

8) Updating of the background image

The current frame will be segmented into foreground and background region after step 4. We will use the method described by the chapter Ⅲ(C) to update the background image. The value of α is very important.

9) Moving vehicles detection and shadow removing

At last, the moving vehicles can be detected from the traffic scene by the background subtractions and the shadow of the moving vehicles will be removed in this step. When the background regions are covered by the shadow, the intensity of the pixels belonged to background region will decrease but the hue only changes a little. However, if the background regions are covered by shadow, the hue will change a lot. The shadow of the moving vehicles can be removed by this character.

Ⅴ. EXPERIMENTS

Experiments are conducted to demonstrate the performance of this proposed algorithm and all the experiments are carried out on computers of P(R)4 2.8G CPU and 512M DDR. The videos are captured with the size of 320×240 using the Sony camera.

We choose first 30 frames as the original data to construct the initial background image. The paper [3]'s performance is shown in the Fig. 4 (a), from which we can see the shadow on the right-top corner. This paper's performance is shown in the Fig. 4（b）, which is better than the paper [3]'s.

a) *b)*

a) Background image by the paper[2]' s method

b) Background image by the this paper's method

Figure 4. Experiments results of the background initialing

Fig. 5 (a), Fig. 5 (b), Fig. 5 (c) are the background images at 35th, 105th, 175th frame.

a) *b)*

c)

a）Background image at 35th frame

b）Background image at 105th frame

c）Background image at 175th frame

Figure 5. Background images from this paper

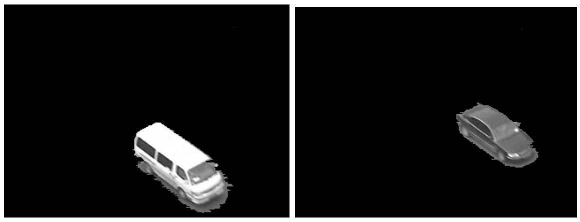
We can see that the background image is more accurately in the process of moving detection.

Fig. 6 shows the moving vehicles which are detected by the method described in this paper.

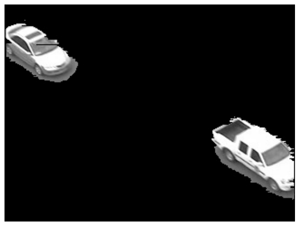
Table 1 and Fig. 7 show the Performance comparison of detection methods.

TABLE I. PERFORMANCE COMPARISON OF DETECTION METHODS

	False detections	Right detection	Lost detection
Inter-frame difference	2.1%	91.7%	6.2%
Background subtractions	1.7%	92.8%	5.5%
This paper's	1.6%	93.1%	5.3%



a) *b)*



c)

a）Moving vehicle at 35th frame

b）Moving vehicle at 105th frame

c）Moving vehicle at 175th frame

Figure 6. Moving vehicles which are detected by the method described in this paper

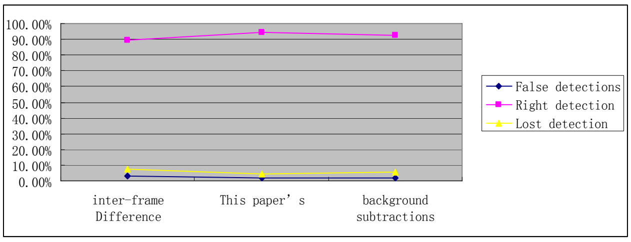


Figure 7. Performance comparisons of detection methods

VI. CONCLUSIONS

In this paper, we have analyzed the traits of the traffic video, put forward an effective method of detecting moving vehicles in the traffic video, by which we can get a very accurate background image. At the same time, we have improved the precision of background image updating by the method which mixes inter-frame difference method and background subtractions method together. Considered the influence caused by the background changes, we have put forward a definite method to adapt the background changes speed self-adaptively. Its advantage is that it can detect the moving vehicles exactly from the traffic video, and has quite robustness according to the background disturbance, illumination changes. Experiments indicate that it can satisfy real-time requirements of vehicles detection. Its disadvantage is that the detection effect is not good enough when the road is very crowded, so the next goal is studying to improve the accuracy of the detection method in all kinds of environment so as to adapt the moving vehicles detection in different traffic situations.

ACKNOWLEDGMENT

This research was partially supported by the National Natural Science Foundation of China (60673092), the Project of Jiangsu Key Laboratory of Computer Information Processing Technology and the Beforehand Research Foundation of Soochow University.

REFERENCES

[1] Xiaobo Li, Zhi-Qiang Liu, Ka-Ming Lenug. Detection of vehicles from scenes using fuzzy integrals. *Pattern Recognition*, 2002, 35(4):967-980.

[2] Haritaoglu I, Davis L S, Harwood D. W4 Who? When? Where? What? A Real Time System for Detecting and Tracking Pepole. *In FGR98*, 1998.

[3] Lin Hongwen, Tu Dan. Moving Objects Detection Method Based on Statistical Background Model [J]. *Computer Engineering*, 2003, 29(16):97-99.

[4] CHEN Tao-tao, Tian Yu-peng. A Real-Time Detection and Tracking algorithm[J]. Journal of Electronic Science and Technology of China, 2007, 36(1):80-85.

[5] Surendra, Osama Masoud, Robert F.K.Martin. Detection and Classification of Vehicles. *IEEE TRANSACTION ON INTELLIGENT TRANSPORTATION SYSTEM*, 2002, 3(1):37-47.

[6] Canny J. A computational app roach to edge detection[J]. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 1986, 8(6):679-698.

[7] MA Hui, LU Guo-dong, TAN Jian-rong. A New Polygon Filling Algorithm Based on Pertinence Between Point and Its Abutting Sides [J]. *Journal of Image and Graphics*, 2004, 9(11) : 1136-1341.

[8] Hu Jianhua, Yang Fan, Xu Jianjian. Motion detection based on blocks frame difference and background substraction[J]. *Electronic Measurement Technology*, 2007, 30(10):49-53.