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AN ALGORITHM FOR MOVING VEHICLE DETECTION AND TRACKING BASED ON ADAPTIVE BACKGROUND MODELING

[1] FENG YOU, [2]RONGHUI ZHANG, [1]HUIYING WEN , [1]JIANMIN XU
[1]School of Civil Engineering and Transportation, South China University of Technology, 510640
Guangdong, China
[2]Xinjiang Technical Institute of Physics & Chemistry, Chinese Academy of Sciences, Urumqi 830011, China

ABSTRACT

In modern traffic surveillance, computer vision methods have commonly been utiliezed to detect vehicles because of the rich information content contained in an image. And detection and tracking of moving vehicle in traffic environment is one of the most important components in intelligent transportation system (ITS). The adaptive background modeling method was used to eliminate the negative effects from moving vehicle and rebuild the background images. The moving vehicles were segmented with difference images between background and current images. To suppress noise caused by segmentation and improve robust performance of vehicle detection, a template with 3-by-3 window was utilized to decrease isolated noise points around vehicle contours. Then, the morphological filtering, including erosion and dilation operation, was also applied, which minimizes the influence of the discontinuous block noise. Finally, to reduce the searching scope of vehicle detected and improve the calculation speed, Kalman filter model was performed to track motive vehicles. The experimental results verifid the effectiveness and real-time of algorithm.

Keywords: *Vehicle Detection, Mixture Gaussian Distribution, Computer Vision, Morphological Filtering, Extended Kalman Filtering, Intelligent Transportation System*

1 INTRODUCTION

Real time detection and tracking of moving vehicle are one of the most significant components in consumer video analysis applications, such as intelligent transportation system (ITS), surveillance systems and advanced safety systems for vehicles[1-3]. Sufficient information related to traffic flow such as traffic flow, vehicle velocity, vehicle density and etc., can be acquired using detection and tracking of moving vehicle. Consequently, the technology of detection and tracking of moving vehicle is widely used on freeway and urban road.

Recently, technology of moving vehicle detection is mainly divided into three categories- detection based on wave frequency, magnetic frequency and video[3]. The technology of detection based on video has some advantages compared with the other two, for instance, non-touching detection, easy installation and maintenance, wide searching region and etc. In addition, with the development of hardware and software of computer, image process, artificial intelligence and pattern recognition, the detection based on video has higher detection accuracy rate, which is considered to be the most promising detection technology. Therefore, vehicle detection based on video has higher practical value and broad application in the future.

Vehicle detection methods commonly used are classified into the following types - background subtraction[4], adjacent frame difference[5] and optical flow field[6, 7]. Wherein, background subtraction method whose advantages lie in simple calculation, good real-time performance and accurate location of vehicle, is easily influenced by illumination changes. Technology of adjacent frame difference is capable of detecting moving vehicle effectively, but vehicle location in image is accurate. The optical flow field can detect moving vehicle without much scene information in advance. However, it is at lower process speed and sensitive to influence of noise.

Therefore, this paper put forward a real-time algorithm with adaptive extraction background. The main content of the article contains background reconstruction and updating, motive vehicle extraction, noise suppression and vehicle tracking. Firstly, the method of adaptive background extraction that eliminates the impact of motive vehicle is used to rebuild background images. Secondly, the moving vehicle is segmented with

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differential image between current and background images. A 3 by 3 window template was introduced to eliminate the isolated noise around vehicle contour to improve the robustness of vehicle detection. Then a morphological filter with 3 by 3 structural operator was utilized to acquire erosion and dilation set of vehicle image to re-construct edge feature of motive vehicle as much as possible. Finally, to narrow the searching scope of target, Kalman filtering was performed to track the vehicle detected. Experimental results indicated the algorithm has good real-time and reliable performance.

2 DETECTION OF MOTIVE VEHICLE

Vehicle detection is designed to extract the moving vehicles from video image sequences., how to effectively detect and extract the moving vehicle from background is essential in surveillance system for traffic since tracking, recognition and behavior analysis of motive vehicle is on the basis of vehicle detection. A robust background model which adapt itself to change of external environment should be selected because the extraction of moving vehicle is sensitive to vehicle velocity, shadow, background and illumination that change slowly.

In this paper, we used adaptive background model to acquire background image and update in real-time. And then two method of noise suppression were performed to improve the robustness of algorithm. Finally, we accurately located the vehicle region in image taken by CCD by comparison between current and background image.

2.1 Traffic Background Extraction And Update

In target detection algorithm based on video, re-construction and updating of background image are crucial in accurate localization of vehicles using background image difference. Actually, it is difficult to obtain background image without any motive target. In addition, the background should be updated due to changes of illumination and weather. At present, background models commonly used are statistical model[8], mixed Gaussian distribution model[9], model based on Kalman filtering[10] and adaptive updating model [9]. Statistical model will fail when there are many vehicles that move slowly in images acquired by CCD. The Gaussian mixture distribution model can not meet demand of practical application due to huge computation cost and complex algorithm. Algorithm based on Kalman filtering is carried out easily and real-time. However, the background need initializing with a image without any motive target, which is more difficult in surveillance system based on video. Adaptive updating model initializes the background with the first image frame taken by CCD. However, the localization of vehicles will be influenced if vehicles exist in the first image frame. For these reasons, improved adaptive background modeling method was put forward to separate foreground targets from background. The proposed framework of adaptive method is shown in Figure1.

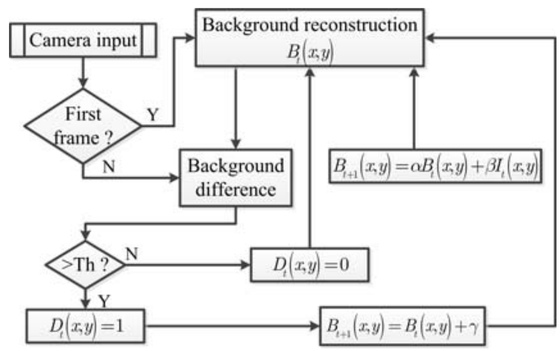

Figure1 .Adaptive Background Model For Vehicles Detection

Actually, the adaptive updating method improves current background image $B_t(x,y)$ using current image frame acquired by camera. Specifically, the next background image $B_{t+1}(x,y)$ is composed of current background image $B_t(x,y)$ and current image $I_t(x,y)$.

$$B_{t+1}(x,y) = \begin{cases} aB_t(x,y) + bI_t(x,y) & \text{if } D_t(x,y) = 0 \\ B_t(x,y) + g & \text{otherwise} \end{cases} \qquad (1)$$

$$a + b = 1 \qquad (2)$$

$$D_t(x,y) = \begin{cases} 0 & \left|I_t(x,y) - B_t(x,y)\right| < Th \\ 1 & \text{otherwise} \end{cases} \qquad (3)$$

Where, $I_t(x,y)$, $B_t(x,y)$ and $D_t(x,y)$ are current image, background image and difference image, respectively. The coefficient, a , whose initial value is selected to 0.1 by experiments, stands for the background update speed. The coefficient, g , depends on $I_n(x,y) - B_n(x,y)$.

Figure2 shows the background image established by the improved method of adaptive updating background, from which, the background image reconstructed basically eliminated the influence of motive vehicles.

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Figure2 .Background Image Processed By Adaptive Background Model

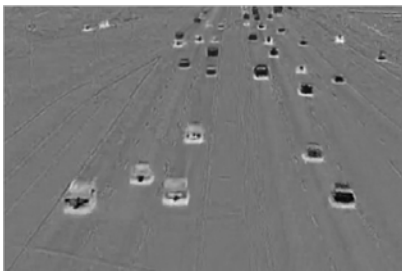

Figure3. Difference Image Between Background And Current Image

The updating speed of background relies on the coefficient, α , in Equ. (1) . The adapting time increases notablely, especially on conditions that illumination changes abruptly, when α is set to a some smaller value. Nevertheless, the moving vehicle in current image had great influence on the background image re-constructed. Accordingly, the updating speed and effect of background image can be automatically regulated by the coefficient α .

$$\alpha^{*} = \frac{\alpha'}{\alpha''} \qquad (4)$$

$$\alpha' = \sum_{(x,y)} 1 - V_m(x,y) \qquad (5)$$

$$\alpha'' = \sum_{(x,y)} \frac{\left| I_t(x,y) - I_{t-1}(x,y) \right|}{256} \qquad (6)$$

Where α^{*} represents variation of illumination between image $I_t(x,y)$ at time t and image $I_{t-1}(x,y)$ at time $t-1$. α' stands for the quantities of pixels from non-motive region in the image $f_t(x,y)$ at time t . $V_m(x,y)$ is the variation of illumination normalization between image $B_t(x,y)$ and image $I_t(x,y)$. To obtain the even variable background image, we associated the coefficient , α_t , with history data using Equ. (7) . Where α_t is the weight of updating for background at time t .

$$\alpha_t = 0.85\alpha_{t-1} + 0.15\alpha^{*} \qquad (7)$$

2.2 MOTION VEHICLE SEGMENTATION

Background difference method [11] that segments motive pixels from images is utilized to compute the difference image between background image and current image. Pixels of moving vehicle can be detected according to Figure4. Experiments show most of pixels value in image $V = \left| I_t(x,y) - B_t(x,y) \right|$ remain lower, yet the pixels value in moving vehicle region are high. Accordingly, the threshold Th can be determined with the following equations.

$$C_0 = median\left(V(x,y)\right) \qquad (8)$$

$$C_1 = median\left(V(x,y) - C_0\right) \qquad (9)$$

$$Th = C_0 + 3\mu C_1 \qquad (10)$$

$$\left| I_t(x,y) - Th \right| > 0 \qquad (11)$$

With the advancement in networking and multimedia technologies enables the distribution and sharing of multimedia content widely.

Where $\mu = 1.482$ is normalized parameter of Gaussian distribution. The regions of motive vehicle in images are marked by using Equ.xxxxx. In the experiment we observed the noise pixels do not appear at the same position 3 times or more. Therefore, we select a buffer $bf(x,y,t+i)$, $i \in 1,2,3,4$. If it meets the condition of Equ. (11) and (12) , $bf(x,y,t+1)$ is set to 1, otherwise 0. Read in images at time $t+2$, $t+3$, $t+4$. If the results meet the equ.xxx, the pixel is consider to be a noise point. Figure5 is the image detected of moving vehicle.

$$bf(x,y,t+1) + bf(x,y,t+2) + bf(x,y,t+3) + bf(x,y,t+4) < 3 \qquad (12)$$

With the advancement in networking and multimedia technologies enables the distribution and sharing of multimedia content widely.

3 NOISE POINT SUPPRESSION

3.1 Image Processing For Isolated Noise Point

From Figure4, there exist many noise points isolated around contour of vehicles. And we used a template with a 3 by 3 window to eliminate the noise. The center element of the window template aims at a arbitrary pixel in the images segmented above and counts the num, , of moving vehicle (pixels marked by 1). To select a threshold T_{sum} , we consider the pixel corresponding to central point of template as isolated noise under the condition,

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$sum < T_{sum}$. The image processed was obtained after traversing each pixel in a image. Most of noise isolated was eliminated as shown in Figure5.

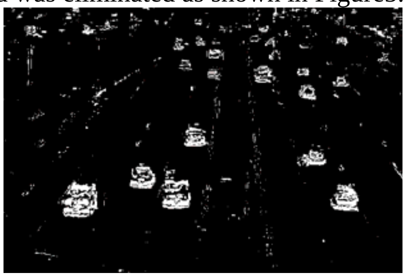

Figure4. Motive Vehicles Extraction From Background Image

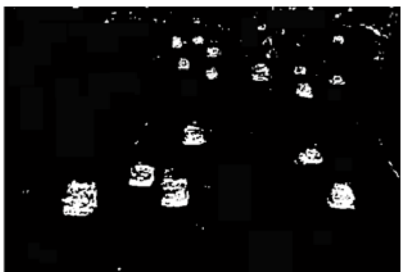

Figure5. Vehicle Images Processed By Elimination Of Isolated Pixels

3.2 Morphology filtering algorithm of noise processing

After the image processing discussed above, the intensity between moving vehicles and background is so similar that there are many discontinuous blocks in the image processed, which notably influences the location accuracy of target vehicle. Consequently, the morphological filtering method is utilized to fill the region of motive vehicle segmented. The computation is described as followings. The process of noise suppression not only minimize the effects of noise in vehicle detection, but keep the details of contour of moving vehicle as much as possible. Figure6 shows the result of morphology filtering.

(1) To acquire the erosion set image. The erosion process with a 3 by 3 structural operator is performed to eliminate the noise of moving vehicle.

(2) To acquire the dilation set image. The dilation process with a 3 by 3 structural operator is used to fill the hole in the region of moving vehicle in image processed.

(3) Traversing the pixel of moving vehicles in dilation image, we search the moving vehicle region in erosion image and mark them with 0 or 1 (0, 1 stand for background and vehicle pixel, respectively)

Figure6. Vehicle Images Filtered By Morphology Algorithm

3.3 Neighborhood Analysis

Neighborhood analysis algorithm, which is to find out a path between two pixels in a certain region, aims to calculate the position of moving vehicle in each image acquired by CCD. There are two kinds of neighborhood path: 4- neighbor and 8-neighbor. We analyzed the connectivity region using 8-neighbor method to detect the size of vehicle. To eliminate noise effects, we discarded the region whose size is too smaller than 20 (the threshold depends on experiment). Thus, we obtained the Minimum Enclosing Rectangle (MER) for moving vehicle, which is critical for searching range of vehicle tracking. Every vehicle in image were marked with MER and the analysis results are shown in Figure7.

4 BASED ON EXTENDED KALMAN FILTER TO TRACK EACH MOVING VEHICLE MOVEMENT

In the calculation process, there is a large amount of redundant data that need to be processed and the searching time is about 100ms. So real-time still cannot meet the practical demand. For efficiency for algorithm, we developed a motion model based on extended Kalman filter[12] for vehicle tracking to predict the position of current vehicles in images, which narrow the searching scope of target vehicles and improve the performance of reliability and robustness of algorithm. Because of high frequency sampling for image, obviously, the contents of adjacent frames should have similarity, so do the motion trajectory. And we presume that vehicles travel with uniform motion. Accordingly, we established the state equation and measure equation as follows.

$$X(k) = F(X_{k-1}, W_{k-1}) \quad (13)$$

$$Z(k) = H(X_k, V_k) \quad (14)$$

$$X(k) = (x_k, \dot{x}_k, y_k, \dot{y}_k)^T \quad (15)$$

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Where, x_k and y_k are the centroid coordinates of vehicles detected, respectively. And $\dot{x}_k$ and $\dot{y}_k$ are displacement of centroid coordinates in the direction of x and y, respectively.

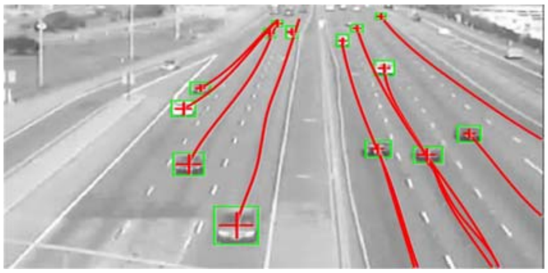

Figure7. Vehicles Tracking Based On Kalman Filtering

$$\begin{bmatrix} x_k \\ \dot{x}_k \\ y_k \\ \dot{y}_k \end{bmatrix} = \begin{bmatrix} 1 & \Delta_k & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & \Delta_k \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_{k-1} \\ \dot{x}_{k-1} \\ y_{k-1} \\ \dot{y}_{k-1} \end{bmatrix} + \begin{bmatrix} \Delta_k^2/2 & 0 \\ \Delta_k & 0 \\ 0 & \Delta_k^2/2 \\ 0 & \Delta_k \end{bmatrix} \begin{bmatrix} w_{k-1,1} \\ w_{k-1,2} \end{bmatrix} \quad (16)$$

$$\begin{bmatrix} \dot{x}_k \\ \dot{y}_k \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \dot{x}_{k-1} \\ \dot{y}_{k-1} \end{bmatrix} + V_k \quad (17)$$

Where Δ_k is time interval. Given that the state error and observation error are Gaussian noise in experiment. The tracing results applied Kalman filter is shown in Figure7.

5 EXPERIMENTAL ANALYSIS

The video format is PAL form and frame rate is 25 frame/s in experiment. The size of image processed is 640 by 480. The software platform used is Visual Studio2005. And hardware platform is Pentium4 2.8G/ 2G memory.

We carried out a large number of test with the algorithm described above, whose updating time is 3 ~ 5 ms. The test site is a 10-lane highway in both directions in Western Shenzhen expressway. We performed 9 statistical experiments, each of which takes 60 minutes. Experimental conditions include a variety of weather conditions, such as shadow, thunderstorm and lightning and so on. Statistical results are shown in table 1. According to the table, the whole accuracy of vehicles detection and vehicles tracking in outdoors environments is above 95%, 97%, respectively. The experimental results indicate that the algorithm has higher reliability and robustness. However, accuracy of vehicle detection and tracking go down under condition of bad weather, such as thunderstorms and lighting. This is mainly due to the strong influence of reflect light and flash. Therefore, how to identify, suppress and eliminate the interference is the research contents in the future.

Table1 Statistical Result Of Detection And Tracking For Vehicles

No.	Experimental environment	vehicles count	detected vehicles count	count of Tracking vehicles	Accuracy of vehicle detection	Accuracy of vehicle tracking
1.	Cloudy day without shadow	1017	1001	983	98.4%	98.2%
2.	Sunny day without shadow	985	968	954	98.3%	98.6%
3.	Cloudy day with shadow	948	921	908	97.2%	98.6%
4.	Sunny day with shadow	855	835	813	97.7%	97.4%
5.	Cloudy and rainy day without ground water	827	796	783	96.3%	98.4%
6.	Cloudy and rainy with ground water	749	716	691	95.6%	96.5%
7.	Small fog	735	689	676	93.7%	98.1%
8.	Thunderstorm with lightning	651	587	570	90.2%	97.1%
	summation	6767	6513	6378	95.9%	97.9%

6 CONCLUSION

A algorithm based on adaptive background method was put forward to eliminate influence of motive vehicle and established the model of background for vehicle detection. And the segmentation and updating of background images was performed by the adaptive coefficient method. The pixels of motive vehicles were extracted from background image using background difference that compute the difference between background and current images. To improve the robustness of vehicle detection, a 3 by 3 window template was introduced to eliminate the isolated noise around vehicle contour. Then a morphological filter with 3 by 3 structural operator was utilized to acquire erosion and dilation set of vehicle image to re-construct edge

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feature of motive vehicle as much as possible. Finally, we applied the Kalman filter to narrow the searching scope of vehicles and enhance the computational speed and accuracy of algorithm. Experimental data shows that the algorithm has good real-time and reliability and collect traffic parameters that meet requirement of piratical application.

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REFRENCES:

[1] K. Jong Sun, Y. Dong Hae, and J. Young Hoon, "Fast and robust algorithm of tracking multiple moving objects for intelligent video surveillance systems," Consumer Electronics, IEEE Transactions on, vol. 57, pp. 1165-1170, 2011.

[2] T. Wang and Z. Zhu, "Real time moving vehicle detection and reconstruction for improving classification," in 2012 IEEE Workshop on the Applications of Computer Vision, WACV 2012, January 9, 2012 - January 11, 2012, Breckenridge, CO, United states, 2012, pp. 497-502.

[3] S. Lefebvre and S. Ambellouis, "Vehicle detection and tracking using mean shift segmentation on semi-dense disparity maps," in 2012 IEEE Intelligent Vehicles Symposium, IV 2012, June 3, 2012 - June 7, 2012, Alcal de Henares, Madrid, Spain, 2012, pp. 855-860.

[4] Y.-T. Wu, J.-H. Kao, and M.-Y. Shih, "A vehicle color classification method for video surveillance system concerning model-based background subtraction," in 11th Pacific Rim Conference on Multimedia, PCM 2010, September 21, 2010 - September 24, 2010, Shanghai, China, 2010, pp. 369-380.

[5] Z. Yun, P. Berkowitz, A. Miller, K. Shafique, A. Vartak, B. White, et al., "Multiple vehicle tracking in surveillance videos," in 1st International Evaluation Workshop on Classification of Events, Activities and Relationships, CLEAR 2006, April 6, 2006, April 7, 2006, Southhampton, United kingdom, 2007, pp. 200-208.

[6] P. H. Batavia, D. Pomerleau, and C. E. Thorpe, "Overtaking vehicle detection using implicit optical flow," in Intelligent Transportation System, 1997. ITSC'97., IEEE Conference on, 1997, pp. 729-734.

[7] W. Kruger, W. Enkelmann, and S. Rossle, "Real-time estimation and tracking of optical flow vectors for obstacle detection," in Intelligent Vehicles' 95 Symposium., Proceedings of the, 1995, pp. 304-309.

[8] P. M. Daigavane, P. R. Bajaj, and M. B. Daigavane, "Vehicle detection and neural network application for vehicle classification," in 2011 International Conference on Computational Intelligence and Communication Systems, CICN 2011, October 7, 2011 - October 9, 2011, Gwalior, India, 2011, pp. 758-762.

[9] M. Lei, D. Lefloch, P. Gouton, and K. Madani, "A video-based real-time vehicle counting system using adaptive background method," in 4th International Conference on Signal Image Technology and Internet Based Systems, SITIS 2008, November 30, 2008 - December 3, 2008, Bali, Indonesia, 2008, pp. 523-528.

[10] Z. Qu, J. Hu, H. Hu, S. Jiang, and D. Wang, "Nighttime vehicle detection based on illumination visibility recognition," in 11th International Conference of Chinese Transportation Professionals: Towards Sustainable Transportation Systems, ICCTP 2011, August 14, 2011 - August 17, 2011, Nanjing, China, 2011, pp. 1401-1409.

[11] C. Chen and X. Zhang, "Moving vehicle detection based on union of three-frame difference," in 2011 International Conference on Electronic Engineering, Communication and Management, EECM 2011, December 24, 2011 - December 25, 2011, Beijing, China, 2012, pp. 459-464.

[12] P.-H. Lee, T.-H. Chiu, Y.-L. Lin, and Y.-P. Hung, "Real-time pedestrian and vehicle detection in video using 3D cues," in 2009 IEEE International Conference on Multimedia and Expo, ICME 2009, June 28, 2009 - July 3, 2009, New York, NY, United states, 2009, pp. 614-617.