A Comparative Study of Moving Target Detection Algorithms

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Abstract. This paper wants to analyze and compare the mainstream algorithms for moving target detection and lay a foundation for algorithm improvements as well as for such research directions as intelligent transportation system and traffic calculation, this paper selects three target detection algorithms for comparative study: methods of interframe difference, background difference and optical flow. It conducts simulation experiment on traffic surveillance videos with MATLAB programming, selects the threshold for frame difference method suitable for the current video and improves detection accuracy by binaryzation, expansion, corrosion and other processing methods. Interframe difference method compares the effects between the original difference image and grayscale difference image and considers bad difference caused by excessive moving distance. Background difference method compares the effect images after morphological processing, and reduces the impact of noises. The advantages are shown by comparing the original image with the labeled optical flow diagram using the optical flow method. By comparing the recognition effect images and processing time of these three algorithms, it analyzes and concludes the strengths and weaknesses as well as the ranges of application in intelligent transportation system.

Keywords: Target detection; Interframe difference; Background difference; Optical flow method; Comparative study; Threshold segmentation.

1. Introduction

Due to the rise of computer vision, it has been widely used in the field of intelligent transportation\cite{1}. The detection and recognition of moving targets in video sequence, especially the extraction and tracking of moving vehicle information\cite{2} has already been a hot research topic in intelligent transportation control. The recognition and tracking of moving target is the core issue in the research of computer vision\cite{3} and the foundation for target detection in video sequence is image processing technology\cite{4,5}. To extract and analyze the information of moving vehicle in the surveillance video\cite{6} can help effectively monitor the vehicle movement status, and make intelligent analysis of moving path\cite{7}, which plays an important role in driverless technology. It can accurately identify the number of vehicles, effectively monitor traffic flow, and prevent road congestion in advance. While tracking the moving objects in surveillance video sequence\cite{8}, it may be restricted by many factors like object blockage, deformation, different illumination, extra-rapid velocity, and actual-time demands; So, accurate detection and recognition of moving object has become a research priority.

Object detection in motion in the video sequence is divided into object recognition of each frame, and interframe difference method\cite{9,10}, background difference method\cite{11} and optical flow method\cite{12,13} are compared. Conventional interframe difference method is simple and fast in calculation, but the difference region of two adjacent frames will have holes, ghosts and streaking so that it cannot completely and accurately extract the moving target region and it is greatly affected by shadow and
noises. Background difference method mainly depends on the effect of background image built upon model. The misjudgment as a result of the waggling actual background objects and weather influence will affect the detection effect and background update is also a problem to be considered in the background model, but the stability of model building is its advantage. Optical flow method recognizes and tracks moving object by calculating the changes of optical flow vector features of moving object. It involves a great amount of calculation; it cannot ensure the actual-time requirements of surveillance video and it suffers huge impact from noises. At present, many scholars have done plenty of work on and made excellent achievements in the research of moving target detection in video sequence through the above three mainstream methods. Literature\cite{14} proposes the adaptive interframe difference adaptive moving target detection algorithm where the maximum probability grayscale is calculated via histogram statistics. This method has good adaptivity, but it involves much calculation when extracting the background with histogram statistics and holes may occur when the threshold is too close. Literature\cite{15} proposes the moving object detection algorithm which combines background difference method and three-frame difference method. It can get adapted to sudden changes in illumination for quick detection and it has strong robustness. Literature\cite{16} combines five-frame difference with background difference. It extracts the moving region with dynamic thresholds, and it has strong adaptivity to background and excellent actual-time, but it has no good effect under complex and dynamic backgrounds. Literature\cite{17} introduces three-frame difference method to reduce the computation of optical flow method. It selects Harris corner features and it only calculates the optical flow information of some points so that it effectively reduces complexity and meet the actual-time requirement, but the effect is related to the velocity of moving target and the effect is bad when it comes to slow velocity. Literature\cite{18} obtains binary image with the gradient threshold of frame difference method, extracts feature points and make markers in vector segment, ROI region is set. It has real-time and robustness and it can calculate vehicle flow, but the optical flow is slight sparse and it also has difficulties in feature extraction and accurate matching.

This paper makes a comparative study of the algorithms in transportation field, detects and recognizes the moving vehicles in road surveillance video sequence. It selects vehicle surveillance video for simulation experiment with MATLAB, conducts comparative analysis of the detection results by three algorithms, and obtains their respective strengths and weaknesses as well as ranges of application, thus providing a foundation and development direction for the application of computer vision in intelligent transportation system. The comparative study of these three algorithms in moving target detection is as follows: interframe difference method has simple calculation and a wide application scope, but it is not good in moving objects; background difference method has good stability and the key is the building of background, but the update problem will slow down the operation; and optical flow method involves large calculation in early stage. It is suitable for the objects with a fast velocity and it can recognize multiple objects, but it is greatly affected by noises. In this paper, Section 1 introduces the research background, the research basis of related work and the main procedures of the comparative analysis; Section 2 introduces the theoretical foundations of the above three algorithms and their applications in vehicle monitoring videos in the field of intelligent transportation system; Section 3 and 4 introduces the simulation experiment by applying MATLAB programming in vehicle monitoring video sequence and the comparative analysis of the results of three algorithms; and Section 5 concludes the research results.

2. Theoretical Foundation
This paper selects three mainstream moving object detection algorithms for simulation experiment and comparative study and the study is mainly applied in traffic calculation and intelligent transportation system.

2.1. Interframe Difference Method
Interframe difference method is the simplest method to extract moving objects and it extracts the information of moving target according to the difference of two adjacent frames. Select the \(t^\text{th}\) frame and \(t+1^\text{th}\) frame to make a difference, extract the general contour of moving target and see its effect in Fig. 1.
Convert the RGB image in the video sequence into grayscale image and what affect the difference result is illumination change. Grayscale image changes significantly. Compare the grayscale difference image with the original difference image (as shown in Fig. 2 below) and it is clear that grayscale image has a better effect; so grayscale image is selected for difference calculation.

The main principles of interframe difference algorithm are as follows: Let \( I_t \) indicate the input video image sequences and take two adjacent frames \( G_t \) and \( G_{t+1} \) and the pixel values of pixel \( O(i,j) \) at \( t \) are \( G(i,j,t) \) and \( G(i,j,t+1) \) respectively. \( t \geq 1 \).

\[
M(i,j) = \|G(i,j,t) - G(i,j,t+1)\|
\]  
(1)

In order to improve the difference effect and cut the calculation amount, binarize the difference result. Gray RGB image in the video sequence. Take two adjacent grayscale images: \( G_t \) and \( G_{t+1} \) and the grayscale value of pixel \((i,j)\) at \( t \) is \( \delta(i,j,t) \). \( M(i,j) \) is difference image and \( t \geq 1 \).

\[
M(i,j) = \begin{cases} 
255 & \text{if } \|\delta(i,j,t) - \delta(i,j,t+1)\| \geq Th \\
0 & \text{otherwise}
\end{cases}
\]  
(2)

\( Th \) indicates the threshold and it is determined mainly by the experience of predecessors, but it can also be properly adjusted according to different video effects. When the difference result of the pixels in two adjacent frames is bigger than the threshold \( Th \), it is the moving target (i.e. the white region in Fig.2); otherwise, i.e. the black area in Fig.2 is the background.

Select the proper threshold based on current video, compare the difference results of different \( Th \) s, as shown in Fig.3.

As shown in Fig.3, the threshold is too small and it will consider the object in the background region as the moving object and increase the threshold. It is clear that has a better effect, when it is too big and
part of the moving object is recognized as the background, resulting in a reduced recognition effect. So, is the threshold limit value for the current difference method.

The premise of good interframe difference effect is small changes in two adjacent frames. If the moving distance of the object is too big, the difference effect is seen Fig.4. The recognized moving target region is far bigger than the right region, thus greatly lowering the target recognition accuracy. Therefore, interframe difference effect is more suitable for the moving objects with small interframe changes.

Figure 4. Interframe difference image.

2.2. Background Difference Algorithm

Background difference algorithm builds its background model according to the current video sequence, selects the background and the current frame to make the interframe difference, extracts the moving target region, and conducts recognition and tracking. If the pixel in the difference image is bigger than the threshold, it is in the moving region and it does not need to be counted in the background; otherwise, it needs to be updated into the background. It is important to build and update background model for background difference algorithm. See Fig.5 below for the moving target detection flow chart:

Figure 5. Flow chart of moving target detection

Here are the main steps to building a background model:

(1) As the premise, convert the RGB image in the video sequence into grayscale image. It is the illumination change that affects the difference result. Grayscale image changes greatly. It needs little calculation to build the background model and it has a fast velocity and excellent effect. So, grayscale image is chosen for the subsequent processing.

(2) Make a difference on adjacent frames. Let $\delta(i,j,t)$ denote the grayscale value of pixel $O(i,j)$ at $t$, $M(i,j)$ be the difference image and $t \geq 1$.

$$
M(i,j,t) = |\delta(i,j,t) - \delta(i,j,t+1)|
$$

(3) Binarize the difference image.

$$
L(i,j) = \begin{cases} 
1 & M(i,j) \geq Th \\
0 & \text{others}
\end{cases}
$$

$L(i,j,t)$ is the binarized image after difference, the binarized threshold is $Th$. When $L(i,j,t) = 1$, it means that this pixel point is moving; otherwise, it is static and it needs to be updated into the background.
In the background building process, it needs to calculate the model according to different circumstances and the update calculation formula is as follows:

\[ B(i, j, t) = (1 - \lambda) L(i, j, t) + \lambda B(i, j, t-1) \]  

(5)

\( B(i, j, t) \) is current background image and \( \lambda \) is the update factor.

The background building process is mainly divided into the following four situations:

When \( L(i, j, t) = 0 \) and \( t = 1 \), initialize and set the first frame of image as the initial background image.

\[ B(i, j, t) = L(i, j, t) \]  

(6)

When \( L(i, j, t) = 1 \) and \( t = 1 \), initialize and take the all-black image as the initial background image.

\[ B(i, j, t) = 0 \]  

(7)

When \( L(i, j, t) = 0 \) and \( t > 1 \), according to the result of the comparison between the moving target and the background, the update factor is introduced to update the current background image in real time.

\[ B(i, j, t) = (1 - \lambda) L(i, j, t) + \lambda B(i, j, t-1) \]  

(8)

When \( L(i, j, t) = 1 \) and \( t > 1 \), the background at the time of \( t \) is the same as that at the time of \( t-1 \) and keep it unchanged.

\[ B(i, j, t) = B(i, j, t-1) \]  

(9)

When \( \lambda \) is close to 1, the background image at this moment is highly similar to that at the previous moment, which is mainly a result of illumination impact. The smaller the illumination change, the higher level of similarity. When its value approaches 0, it will suffer less illumination impact and the relationship between the updated background image and the sequence image is becoming more and more irrelevant. To change the update factor can make the model adapted to the impact of illumination change on detection result and build a relatively stable background model, but the background model has poor real-time and it needs to obtain the video and build the model in advance.

Apply MATLAB programming to build the model, select moving vehicle surveillance video for simulation experiment and use part of video sequence to build the background model. The experiment result is seen in Fig.6.

![Figure 6. Interframe difference background model renderings.](image)

Fig.6 shows the 105th foreground image, the 105th background image and the 105th processed image after difference and morphological expansion and corrosion. It can be seen that the background built may be a little blur, but the background is basically stable and the foreground target can be extracted.

2.3. Optical Flow Method

The optical flow field\(^{[19,20]}\) is the apparent motion of grayscale and the pixel-level movement. Optical flow method through to the change of the velocity vector of the image of each pixel motion object detection recognition, No movement object in video image sequence, the change of the optical flow vector is continuous. When a moving object appears, the moving object will move relative to the
background, and the velocity vector will change to form a difference with the velocity vector of the field background, so as to detect and identify the moving object and its position. According to the difference, the moving target and its position can be detected and recognized.

The optical flow marker effect by optical flow field on the moving target is seen in Fig.7 below.

![Optical Flow Marker Rendering](image)

**Figure 7.** Optical flow marker rendering.

The calculation method of optical flow field is mainly gradient-based methods, which use the gradient of image grayscale. The premise of gradient-based methods is to maintain the grayscale unchanged before and after the movement and obtain the optical flow constraint equation. The determination of optical flow needs not only the restrictions of constraint equation, but also other constraints.

Let the grayscale value of pixel \( O(i,j) \) at \( t \) be \( \delta(i,j,t) \). And at the time of \( t + dt \), the new position of this pixel is \( (i + di, j + dj) \) and the grayscale value of the current pixel is \( \delta(i + di, j + dj, t + dt) \). According to the premise constraints, pixel moves along the track, but the brightness does not change,

\[
\delta(i, j, t) = \delta(i + di, j + dj, t + dt)
\]  

(10)

If the grayscale value changes slowly with pixel \( O(i,j) \), the above formula will be the following according to Taylor series expansion.

\[
\delta(i + di, j + dj, t + dt) \approx \delta(i, j, t) + \frac{\partial \delta}{\partial i} di + \frac{\partial \delta}{\partial j} dj + \frac{\partial \delta}{\partial t} dt
\]  

(11)

\[
\frac{\partial \delta}{\partial i} di + \frac{\partial \delta}{\partial j} dj + \frac{\partial \delta}{\partial t} dt = \delta u + \delta v + \delta t = 0
\]  

(12)

where \( \delta_i = \frac{\partial \delta}{\partial i} \), \( \delta_j = \frac{\partial \delta}{\partial j} \) and \( \delta_t = \frac{d \delta}{dt} \) are the rates of change of the grayscale value of pixel \( O \) over \( i,j,t \); \( u = \frac{di}{dt} \) and \( v = \frac{dj}{dt} \) are the velocities of pixel \( O \) changing along the directions of \( i,j \).

Present the following equation with vectors:

\[
\nabla \delta \cdot U + \delta_t = 0
\]  

(13)

where \( \nabla \delta = [\delta_i, \delta_j] \) is the gradient direction and \( U = [u, v]^T \) is optical flow constraint equation. Directions \( u,v \) constitute a 2D plane space and all the optical flows \( U = [u, v]^T \) that meet the constraint equation of \( \delta u + \delta v + \delta t = 0 \) are in this straight line and this line is vertical to the gradient \( \nabla \delta = [\delta_i, \delta_j] \). As there are two unknowns \( u,v \) in the optical flow equation, one constraint equation
cannot be solved. As shown in Fig.8. In order to identify the optical flow, it needs to introduce new constraints according to different algorithms and actual demands. As for the moving vehicle surveillance video selected in this paper, the flow chart of detecting moving target with optical flow field is shown in Fig.9 below:

\[
\delta \mu + \delta \nu + \delta t = 0
\]

\[
\nabla \delta = [\delta_x, \delta_y]
\]

**Figure 8.** Optical flow basic equation constraint line image.

**Figure 9.** Flow chart of optical flow field detecting moving target.

### 3. Experimental Simulation

This paper selects the above vehicle surveillance video and conducts simulation experiment through MATLAB programming with interframe difference method, background difference method and optical flow method. As for the moving object detection results by interframe difference method, Fig.10 (a) show part of the images with good recognition effect and Fig.10 (b) are some unrecognized images.
Figure 10. (a) Interframe difference recognition effect image (b) Interframe difference unrecognized image.
For the background difference method, the images with good recognition effect, the unrecognized images and the images in special case can be seen in Fig.11(a), Fig.11(b) and Fig.11(c).

Figure 11. (a) Background difference recognition effect image (b)Background difference unrecognized image (c) Special case recognition image.
As for the optical flow method, see Fig.12(a) for the images with excellent recognition effect, Fig.12 (b) for the unrecognized images and Fig.12 (c) for the images in special case.
4. Analysis of Comparative Results

In order to demonstrate the strengths and weaknesses as well as the applicable scopes of these three algorithms more accurately, it segments the video into 120 frames of images as samples. Then it adopts these algorithms for target detection, and calculates the operation time needed to process every frame of image. The result can be seen in Fig.13.

From what has been discussed above, It concludes that interframe difference algorithm needs more or less the same operation time, which is basically in the scope of 0.11 and that it is fast in calculation. The calculation time of background model changes greatly with background fluctuation and the operation time also gradually increases. Due to the background update problem, operation time also increases over update. The running time of the optical flow method is stable in the range of 0.01-0.03s. It is the fastest among these algorithms. Optical method consumes a longer time when calculating optical flow in the early stage, and then its velocity accelerates after that.

For this traffic surveillance video, the simulation results show that the optical flow method has the best effect and meets the real-time requirement; however, it is more suitable for fast surveillance videos with...
little noise impact; moreover, the calculation at early stage is huge. Though interframe difference method fast, simple and stable, it needs to make sure that between the adjacent frames, the object moves slightly; otherwise, the recognized region will go beyond the accurate region and cause a rising error rate. Background difference method has the slowest calculation speed. The reason is that background update problem gradually increase the calculation time and the time fluctuates greatly; additionally, the more similar the adjacent background, the better the result. This method has high stability.

5. Conclusion
This paper has made simulation experiment and careful comparison among interframe difference method, background difference method and optical flow method in their applications of traffic monitoring videos and analyzed their potential strengths and weaknesses as well as ranges of application. Interframe difference method has simple calculation and a fast velocity, but it needs to ensure that the distance of the moving objects between adjacent frames is not extra-big. Background difference method is slow in calculation though, its model is stable and the key to the effect is the effect of background building and updating. But it has its own advantages. Optical flow method has a huge amount of calculation in early stage and it needs some time, but it is suitable for the videos with fast moving velocity and small noise impact. The comparative study of these three algorithms has provided a direction for their improvements as well as applications and development in intelligent transportation system.

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References
[1] Ahmad Ali, Abdul Jalil, Jianwei Niu, Xiaoke Zhao, Saima Rathore, Javed Ahmed, Muhammad Aksam Iftikhar. Visual object tracking classical and contemporary approaches[J]. Frontiers of Computer Science,2016,10(1).
[2] Su Zhang, Jin Duan, Qiang Fu, Wen-sheng Wang. Infrared zoom lens design based on target correlation recognition and tracking[P]. Applied Optics and Photonics China,2015.
[3] Jiang Qin. Research of multiple-instance learning for target recognition and tracking[J]. EURASIP Journal on Embedded Systems,2016,2016(1).
[4] Mayank Tiwari, Subir Singh Lamba, Bhupendra Gupta. An image processing and computer vision framework for efficient robotic sketching[J]. Procedia Computer Science,2018,133.
[5] Tudor Barbu, Gabriela Marinoschi, Costică Moroșanu, Ionuţ Munteanu. Advances in Variational and Partial Differential Equation-Based Models for Image Processing and Computer Vision[J]. Mathematical Problems in Engineering,2018,2018.
[6] Wei Lei, Dongjun Huang, Xiwen Cui. Moving object tracking in video surveillance using YOLOv3 and MeanShift[P]. International Conference on Graphic and Image Processing,2019.
[7] Yuhao Luo, Dong Yin, An Wang, Wentao Wu. Pedestrian tracking in surveillance video based on modified CNN[J]. Multimedia Tools and Applications,2018,77(18).
[8] Seungwon Jung, Yongsoon Kim, Eunjun Hwang. Real-time car tracking system based on surveillance videos[J]. EURASIP Journal on Image and Video Processing,2018,2018(1).
[9] Muyun Weng, Guoce Huang, Xinyu Da. A new interframe difference algorithm for moving target detection[P]. Image and Signal Processing (CISP), 2010 3rd International Congress on,2010.
[10] Pan Qing, Tian Nili, Xu Ruyi. A motion estimation algorithm based on interframe differences detection model for virtual edges detection[P]. Natural Computation (ICNC), 2011 Seventh International Conference on,2011.
[11] Arun Varghese, Sreeleekha G. Sample-based integrated background subtraction and shadow detection[J]. IPSJ Transactions on Computer Vision and Applications,2017,9(1).
[12] Photonics; Investigators at South China University of Technology Describe Findings in Photonics (High-speed Robust Dynamic Positioning and Tracking Method Based On Visual Visible Light Communication Using Optical Flow Detection and Bayesian Forecast)[J]. Science Letter,2019.
[13] Kanagamalliga S., Vasuki S.. Contour-based object tracking in video scenes through optical flow and gabor features [J]. Optik, 2018, 157.

[14] XUE Li-xia; LUO Yan-li; WANG Zuo-cheng. Detection algorithm of adaptive moving objects based on frame difference method [J]. Application Research of Computer, 2011, 28(04):1551-1552+1559.

[15] LU Zhang-ping; KONG De-fei; LI Xiao-lei; WANG Jun-wei. A method for Moving Object Detection Based on Background Subtraction and Three-Frame Differencing [J]. Computer Measurement & Control, 2013, 21(12):3315-3318.

[16] HAO Hao-gang, CHEN Jia-qi. Moving Object Detection Algorithm Based on Five Frame Difference and Background Difference [J]. Computer Engineering, 2012, 38(04):146-148.

[17] YUAN Guo-wu; CHEN Zhi-qiang; GONG Jian; XU Dan; LIAO Ren-jian; HE Jun-yuan. A Moving Object Detection Algorithm Based on a Combination of Optical Flow and Three-Frame Difference [J]. Journal of Chinese Computer Systems, 2013, 34(03):668-671.

[18] HU Jue-hui; LI Yi-min; PAN Xiao-lu. An Improved Optical Flow Algorithm in Vehicle Identification and Tracking [J]. Science Technology and Engineering, 2010, 10(23):5814-5817.

[19] DONG Ying. Video Motion Detection Based on Optical Flow Field [D]. Shandong University, 2008.

[20] XU Jun-hong. Video Motion Estimation Based on Optical Flow Field [D]. Harbin Engineering University, 2005.