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Research of CamShift Algorithm to Track Motion Objects

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Abstract

At present, objects detection, identification and tracking are the very popular research areas in computing vision. A real-time objects tracking system was proposed in this paper. This paper focuses on improve CamShift algorithm, which can track the motion objects with high a accuracy. An Adaptive Gaussian Background Model is proposed in the system, which was established in order to automatically update the background and detect the outline of moving objects. By analyzing different algorithms, this paper brings out approaches to promote the performance. The CamShift algorithm to complete motion detection and objects tracking, which applied for static background video sequences. And the experimental results show that this algorithm can detect all motion objects and track almost motion objects.

Keywords*: motion detection, object tracking, CamShift, adaptive gaussian background model*

1. Introduction

Detection and tracking of moving objects refers to a widely used technology used for automatically recognizing, extracting and tracking objects from a sequence of video image information which combines with image processing, automatic control, information science and other disciplines [1]. Detection and tracking of moving objects technology is one of the technologies which are important to realize the so-called ubiquitous society, which can be applied to various industries such as transportation, astronomical observation, scientific research, national defense, and medicine, to achieve advances of productivity and safety, and improve the quality of human life [2].

The purpose of object detection is to detect if there are the objects moving occurred in the surveillance area. If that, then determine the information of location and size of the objects. Object tracking is also an important application branch of Computer Vision [4]. The goal of tracking is to recognize target objects from the background and extract features, then to depict the moving locus of them. How to track the objects precisely and fast is the key problem of objects tracking system.

In this paper, the main objective is to design a real-time monitoring system for the object interested. After the image pretreatment, the system firstly recognizes the moving targets in video sequences by background difference method and updates the background image using Adaptive Gaussian Background Model. According to the outline and color of the moving targets, the system completes the tracking of the objects via CamShift algorithm.

2. Research Method

2.1. Mathematical Morphological Filtering

The principle of mathematical morphology refers to measure and extract the shape of objects in images and it has an excellent mathematical foundation which is set theory. There are four basic operators of mathematical morphology, including dilation, erosion, opening, closing, which are usually defined via set theory names [3, 6]. With the parallel implementation structure, mathematical morphology filtering can easily achieve morphological analysis and parallel processing, thus it greatly improves the speed of image analysis and processing. When it is used in image pre-processing, mathematical morphology filtering, with smooth contours, filling

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holes, connected fracture zone characteristics, can simplify image data to maintain objects' basic shape characteristics and remove extraneous structures.

2.2. Foreground-background Subtraction Method

In this paper, foreground-backgroud subtraction method is adopted for target detection and extraction based on the difference between the current frame in the video sequence image and the backgroud. The flowchart is shown in Figure 1. According to the method, the background image adopted is first stored in the system. Because there are differences between moving objects and background in grayscale or color, the target can be distinguished from the background image by doing substraction. Each pixel value in the result will be compared with a pre-set threshold value. If the value of the pixed is greater than the threshold, this point belongs to the foreground, otherwise it belongs to background.

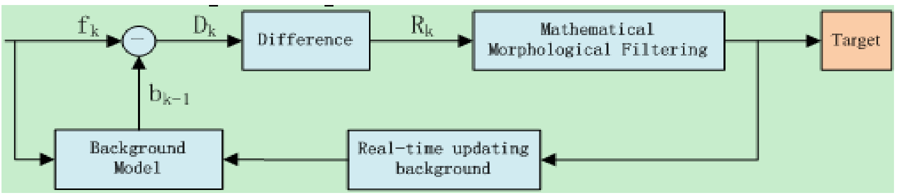


Figure 1. The Flow of Foreground-background Subtraction Method

2.3. Adaptive Gaussian Background Model

However, the background is relatively sensitive to external conditions such as illumition. There are many false target point which will reduce the correct rate. So, we adopted the Adaptive Gaussian Background Model to adapt to changes in the background. Adaptive Gaussian Background Model applies to the case of the camera stationary. It firstly established a background model for a stationary background, and then automatic updates the background model according to the change of the environment.

The model establishes the origin background model B_0 via Equation 1. The μ_0 refers to the pixel average value and σ_0^2 refers to pixel variance.

$$B_0 = [\mu_0, \quad \sigma_0^2] \cdot \tag{1}$$

It defines a parameter ρ to present the update rate using Equation 2. In the formula, K is a const belongs to [0,1] and the character t presents the frame t. The $\eta(f_t \mid \mu_{t-1}, \sigma_{t-1})$ means the Gaussian Probability Density Function in which μ_{t-1} refers to the average value and σ_{t-1} refers to the variance.

$$\rho = K\eta(f_t \mid \mu_{t-1}, \sigma_{t-1}) \tag{2}$$

The Equation 3 shows the method to caculate the pixel average value of the frame t.

$$\mu_t = (1-\rho)\mu_{t-1} + \rho f_t \tag{3}$$

The variance of the frame t is caculated using Equation 4.

$$\sigma_t^2 = (1-\rho)\sigma_{t-1}^2 + \rho(f_t - \mu_t)^T(f_t - \mu_t) \tag{4}$$

The equation 5 discribes how to establishes the background model of frame t.

$$B_t = [\mu_t, \quad \sigma_t^2] \tag{5}$$

3. Key Algorithm

3.1. MeanShift Algorithm

MeanShift is non-parametric method based on density function estimation. On basis of the probability distribution gradient, MeanShift finds the nearest extremum and implements efficiently tracking through color probability distribution of objects [5].

3.2. CamShift Algorithm

On basis of MeanShift algorithm, CamShift Algorithm achieves objects tracking through iterative calculation, which means CamShift defines the initial value of search window for MeanShift algorithm using the results gotten in the previous frame [7]. The formula of the algorithm is as follows.

Caculate the second-monment of the match window. The Equation 6 discribes the second-moment of X direction. The equation 7 discribes the second-moment of Y direction and the Equation 8 discribes the second-moment of XY direction.

$$M_{20} = \sum_x \sum_y x^2 I(x,y) \tag{6}$$

$$M_{02} = \sum_x \sum_y y^2 I(x,y) \tag{7}$$

$$M_{11} = \sum_x \sum_y xyI(x,y) \tag{8}$$

Caculate three operational parameters using Equation 9.

$$a = \frac{M_{20}}{M_{00}} - x_c^2 \tag{9-a}$$

$$b = 2\left(\frac{M_{11}}{M_{00}} - x_c y_c\right) \tag{9-b}$$

$$c = \frac{M_{02}}{M_{00}} - y_c \tag{9-c}$$

Caculate the length and width of the match window using Equation 10.

$$length = \sqrt{\frac{(a+c)+\sqrt{b^2+(a-c)^2}}{2}} \tag{10-a}$$

$$width = \sqrt{\frac{(a+c)-\sqrt{b^2+(a-c)^2}}{2}} \tag{10-b}$$

3.2. Comparison

MeanShift algorithm can match the tracking range, but the initial value of the search window can not be adjusted. When the tracking targets move towards or away from the aquisiton devices, the target's area will enlarge or reduce in various degrees. If the search window remains the same size, the target's area will essily exceed the search window or be within a narrow range. However, CamShift Algorithm completes the real-time and accuracy tracking though the adaptive adjustment of the search window.

CamShift algorithm search the objects along the aradient direction, considering only the color distribution rather than object contours. Therefore, CamShift can well adapt to the external environment. The time complexity of CamShift is O(N2), which is a fast, real-time tracking algorithm and can reduce the tracking cycle. Beacause CamShift shows good anti-jamming ability, a considerable degree of noise, partial occlusion of disruptors and the light changes can be ignored. CamShift shows excellent efficiency, accuracy and robustness, therefore, it has been used in the system to improve tracking accuracy.

4.System Design and Implementation

4.1. System Structure

The proposed system is composed of two parts that are moving objects detecting and moving objects tracking. In the part of moving objects detecting, the automatically updating background method was used in order to reduce the external interference and improve the success rate. In the other part of the system, CamShift applied to tracking the centroid of the moving objects rather than the whole one. The flow of the processes is shown in Figure 2.

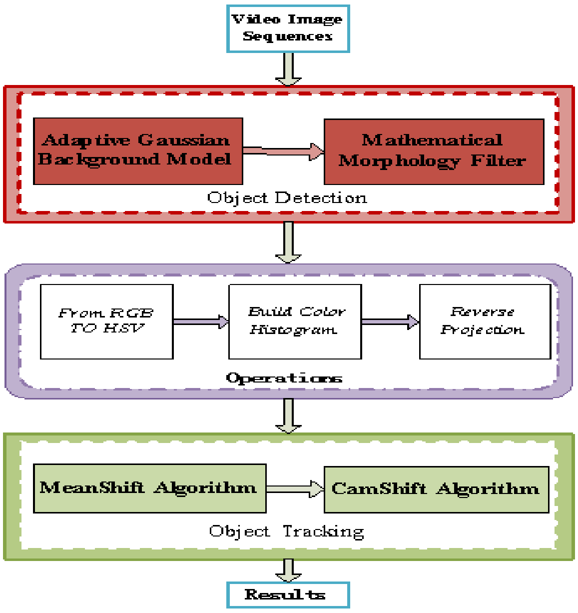


Figure 2. System Process Flow

Firstly, the system establishes the Adaptive Gaussian Background Model after inputting the video images to separate the background and foreground and reduce the external influences such as illumination. After that, in order to obtain the contour more effectively, mathematical morphology filter is used to eliminate the noise, simplify the shape of objects and enhance the structure.

RGB color space is converted into HSV color space so that human eye can judge the color similarity easily. Then, build a color histogram through detaching H parameter from the HSV color space. After that, according to the color histogram, the system converts the origin images into color probability distributions images, which means reverse projection. At last, through MeanShift algorithm and CamShift algorithm, the system completes the real-time and accuracy tracking.

4.2. Implementation and Experiments

A camera was set in a stationary place to monitor a scene. In this paper, the hardware platforms are composed of a computer and a webcam. And the software platforms conclude Windows XP, VS2010, OpenCV2.3 and video parser xvid and VirturalDub 1.10.1. According to the different experimental environment, three groups of experimental results are shown as follows.

1. Single moving object detection and tracking

The experimental results are shown in Figure 3, which prove that the system has realized moving objects detection and tracking with Adaptive Gaussian Background Model.

A:Single moving object detection and tracking when sunning

B:Single moving object detection and tracking when raining

Figure 3. Single Moving Object Detection and Tracking in Different Weather Condition

In different test scenarios, we can get the experimental results shown in Table 1.

Table 1. Experimental Results in Different Weather Condition

scene	Object detection	Object tracking
sunny	√	√
raining	√	√

2. Two moving objects detection and tracking

When the moving targets increase to two and the two targets are close, we find that the search window will automatically expand and the contour of two targets detected will be joined together. The reason for this is that mathematical morphology filter can fill some small holes through closing operator. In Figure 4, if the distance between the targets is not close, the system has detected two objects; however, it has tracked only one target according to the order scanning from top down.

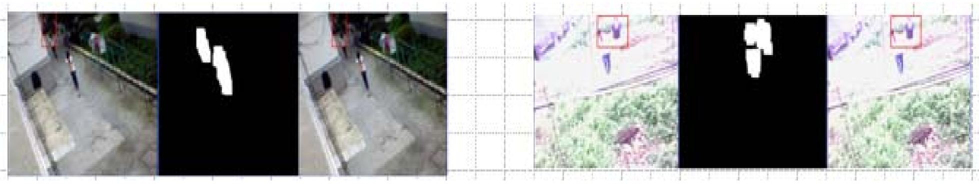


Figure 4. Two Moving Objects Detecting and Tracking Results

3. Multiple moving objects detection and tracking

When all the targets are close, the search window will automatically expand and the contour of the targets detected will be joined together. In addition, the system has detected two objects; however, it has tracked only one target according to the order scanning from top down. Figure 5 shows that the result of moving objects detection and tracking based on CamShift algorithm.

A:Many people gathered B:Many people spread out 1 C:Many people spread out 2

Figure 5. Multiple Moving Objects Detction and Tracking Results

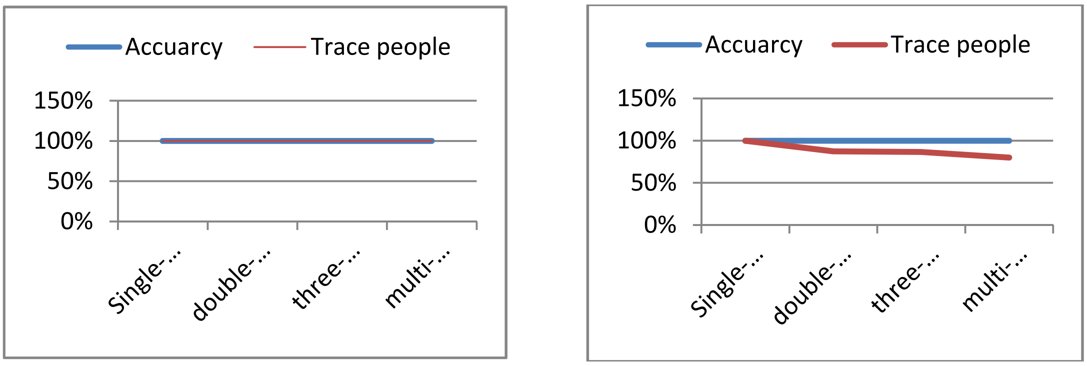
The result for different number of moving targets is shown in Table 2.

Table 2. Experimental Results for Different Number of Targets

The number of targets	Object detection	Object tracking
single	√	√
two	√	Distant objects
multiple	√	Distant objects

4. Accuracy rate analysis

In order to detect the accuracy of the algorithm, we used 50 sets of video scene which are respectively composed by a different number of moving objects. The result is shown in Figure 6.



A: Target detected and tracked in the same area

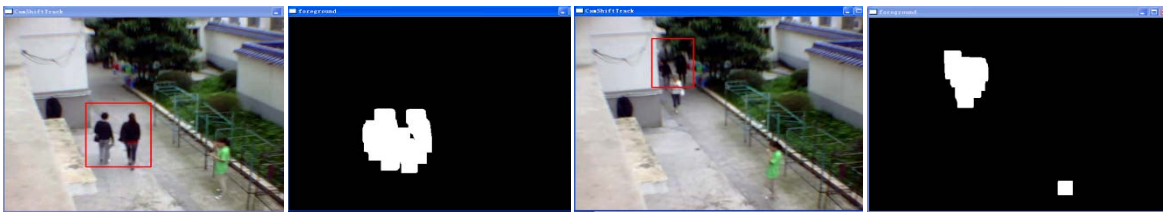
B:Target detected and tracked in the different areas

Figure 6. Accuracy Rate Analysis

From the above results, we can speculate that the algorithm is able to detect the moving objects in the monitored area. But the accuracy rate of the algorithm decreases linearly with the increase in the number of moving objects.

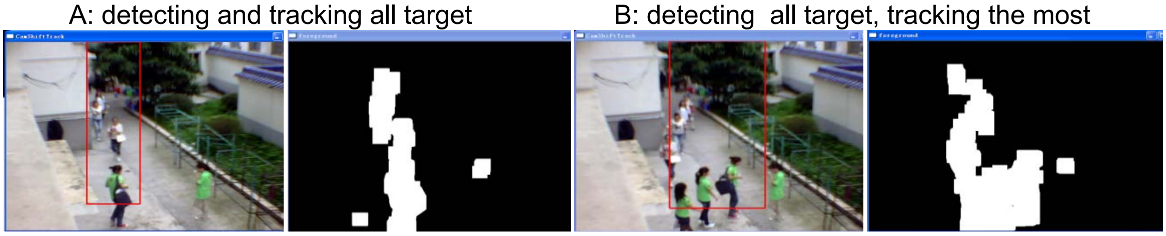
5. Detection and tracking under continuous video scene

For further analyzing the accuracy rate of the algorithm, we have completed the test under some sets of comtinuous video scene. The results are shown in Figure 7.



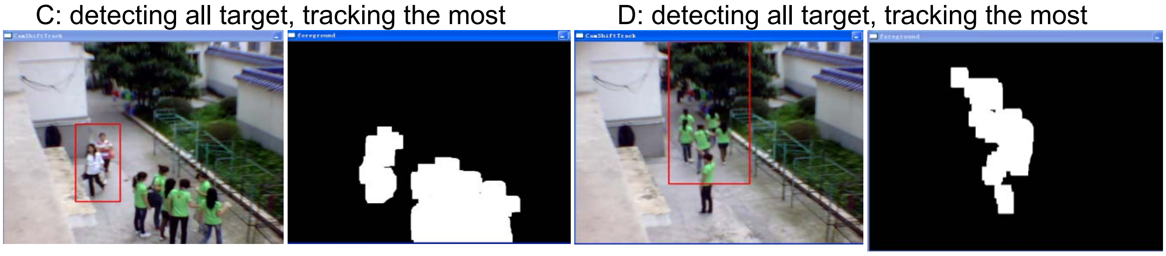
A: detecting and tracking all target

B: detecting all target, tracking the most



C: detecting all target, tracking the most

D: detecting all target, tracking the most



E: detecting all, tracking the remote target

F: detecting and tracking all target

Figure 7. Analysis of Multiple Moving Objects Teacking

From the above results, we can speculate that the algorithm is able to detect the moving objects under comtinuous video scene, however, the accuracy rate of the algorithm decreases with the increase in the complexity of the changes in the monitered area. Though the algorithm can track the remote target well, it is not effective to track the close-range moving target, which is one of the follow-up work in the project.

5. Conclusion

In this paper, we have proposed a monitoring system for the static background video sequences. This surveillance system mainly combines two sub-systems, motion detection and object tracking. How to detect and track the objects precisely and fast is the key problem of objects detection and tracking system. By analyzing the detecting and tracking algorithm, this paper brings out methods to promote the performance. Experiments show our method can achieve the pre-determined targets. Further improvement of the system is our current work to deal with portrait and shadow overlap.

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