Moving Target Detection and Tracking in Complex Background

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Abstract

The influence of environment changing, e.g. background beam change, trees waggle, and rain or snow day brings More difficult for moving target detecting. A background dynamic generation algorithm is presented in the paper, and the background dynamic generation algorithm is used to dynamically construct background image, the impact of the environment change is reduced in a certain extent for the moving target detection. Secondly, the background difference method is used to detect the moving target, when the moving target exists, the direction and the coordinate of the moving target is determined according to the result of continuous 2 frame images subtract the background. Finally, an algorithm for calculating the rotation angle of the pan/tilt/zoom is presented, the horizontal rotation angle and the vertical rotation angle of the pan/tilt/zoom is calculated according to the pan/tilt/zoom rotation angle algorithm, and the moving target detection and automatic tracking function is realized.

Keywords: moving target, dynamic background generation, background difference method, Inter-frame difference method, pan/tilt/zoom control

1. Introduction

With the development of science and technology and social economy, computer vision technology has been widely used in the financial, transportation, security and other fields, so how to detect moving targets from the video information, and to realize real-time automatic tracking of the moving target is a hot spot in the current research of the computer vision.

Scholars from various countries have done a lot of research in intelligent detection and tracking technology of the moving target, they have achieved good results. G. Baldini *et al*. [1] propose an improved background difference method and this method is used to examine the unknown category motion target detection in the video information, and this method's good practicability has been verified by experiment. M. Gupta et al. [2] study the detection and tracking of the moving target in the video information by application of the kernel function, and they achieve good experimental results in laboratory. Z. Lei et al. [3] study the phenomenon such as empty, ghosting, elongated etc. that the Inter-frame difference method can easily lead to, and they propose related solutions. L. Z. Yong et al. [4-5] use the Inter-frame difference method in warehouse monitoring intelligent tracking system and this realize unattended the automatic monitoring system. T. Horprasert et al. [6] model the luminance and the color information in the image separately, in order to eliminate the effect of the target shadow and the environmental illumination change on the moving target detection. The authors above have studied detection and tracking of the moving target under complex background, and achieved some research results. Because of the complexity of the moving target detection in complex background, a large number of unresolved problems still exist in the moving target detection under complex background.

For the current difficulties in the moving targets detection and tracking under complex background, a dynamic background generation algorithm is proposed in the paper. The background image is generated according to the continuous multi frame images by the algorithm, when the environmental information changes, the generated background images are changed. Secondly, the background difference method is used to detect whether there is a moving target in real time, when the moving target exists, the direction and the coordinate of the moving target is determined according to the result of continuous 2 frame images subtract background image. Finally, an algorithm for calculating the rotation angle of the pan/tilt/zoom is presented, the horizontal rotation angle and the vertical rotation angle of the pan/tilt/zoom is calculated according to the pan/tilt/zoom rotation angle algorithm, and the moving target detection and automatic tracking function is realized. Through the analysis of examples, the moving objects detection and tracking technology under the complex background described in this paper is verified effectively.

2. Background Difference Method and Inter-Frame Difference Method

The background difference method, and the inter-frame difference method and the optical flow method are common moving target detection algorithm. The optical flow method is a kind of complete theoretical algorithm for the moving target detection. The calculation principle of the optical flow method is to determine the direction and the position of the moving target according to the principle that there is a certain relative motion between light and the target. But the theory of the optical flow method is complex, the computing workload is large, so it is less used in actual production. The principle of background difference method and inter-frame difference method are mainly introduced in the following parts.

2.1. Background Difference Method

Background difference method is to achieve the average of a frame image or a few frames images as the background frame image, and use the behind frame image subtract the background frame image, to achieve the purpose of eliminating the background and detecting moving targets [7-8]. The calculation method can be expressed by equation (1).

$$P_i(x, y) = |C_i(x, y) - B(x, y)|$$
$$SUB_i(x, y) = \begin{cases} 1, P_i(x, y) > T \\ 0, P_i(x, y) < T \end{cases} \tag{1}$$

Where i is the i-th frame image of the image series, $C_i(x,y)$ is the gray-scale value whose coordinates is (x, y) in the i-th frame image, $B(x,y)$ is the gray-scale value whose coordinates is (x, y) in the background image, $P_i(x,y)$ is the pixel value which is obtained according to the result of the i-th frame image subtract the background image, T is the threshold, $SUB_i(x,y)$ is the binary image after threshold operation.

The background difference method is a fast speed and simple algorithm, so it is widely applied. However, the background difference method also has its own shortcomings, such as it is easily influenced by the change of background light, the change of weather and trees shaking etc., small rotation of pan-tilt-zoom will bring disastrous consequences to the background difference method. In general, background difference method is mainly used in the condition that the background remains the same.

2.2. Inter-Frame Difference Method

Adjacent two frame images subtraction or two frame images with a certain interval subtraction is the inter-frame difference method [9]. When there is a moving object in the image information, the two frame images will have very obvious changes. Then differential operation is performed on two frame images, and the absolute value of the operation results is taken, then the binary image of the moving target can be obtained. The operation process can express by equation (2).

$$P_i(x,y) = |C_i(x,y) - C_{i-k}(x,y)|$$
$$SUB_i(x,y) = \begin{cases} 1, P_i(x,y) > T \\ 0, P_i(x,y) < T \end{cases} \tag{2}$$

Where i is the i-th frame image in the image series, $C_i(x,y)$ is the gray-scale value whose coordinates is (x,y) in the i-th frame image, $C_{i-k}(x,y)$ is the gray-scale value whose coordinates is (x,y) in the $i-k$-th frame image, $P_i(x,y)$ is the pixel value which is obtained according to the result of the i-th frame image subtract the $i-k$-th frame image, T is the threshold, $SUB_i(x,y)$ is the binary image after threshold operation.

The inter-frame difference method is a simple algorithm, and the calculation speed is fast. However, the inter-frame difference method also has the following shortcomings:

(1) The inter-frame difference method can not accurately determine the area of the moving target. It can only be able to determine the boundary of the moving target;

(2) When the object moves faster, two moving targets would be got; When the object moves slower, no moving target could be detected;

(3) When there are trees shaking, or the complex weather conditions such as rain, snow etc., the moving target detection effect is poorer.

3. Dynamic Background Image Generation in Complex Background

Since the background difference method and the inter-frame difference method cannot detect the moving targets accurately in complex environment, a background dynamic generation algorithm in complex environment is presented in the paper to construct real-time background image. Then the background difference method is used to detect the moving target, determine the direction and the position coordinates of the moving target.

At the beginning of system operation, collect K frame images firstly, and then take the average value of the K frame images as the background image. The value of K is determined by the hardware capability of the system and the complexity of the environment. It requires higher hardware memory if the K value is too large, and the computational time-consuming is large. If the K value is too small, it is not able to solve the effect of light changes, weather changes and trees waggle etc. General K is about 50 frame images. The algorithm specific procedure is as follows.

(1) Calculate the average value of the K frame images, take the average value as the background image, the calculation formula can be expressed by equation (3).

$$B(x,y) = \frac{1}{K} \sum_{i=1}^{K} F_i(x,y) \tag{3}$$

Where $i = 1, 2, \cdots, K$, $F_i(x,y)$ is the pixel value of the i-th frame image.

(2) After getting the background image, capture current frame image $C1(x,y)$, get the binary image $SUB1(x,y)$ by using differentiate operation between $C1(x,y)$ and $B(x,y)$ and making threshold segmentation, then do morphology calculation such as expansion, corrosion to the binary image $SUB1(x,y)$, in order to eliminate the influence of the noise on the detection of the moving target. Determine whether there is the moving target in $SUB1(x,y)$. If there is no the moving target, make the K frame images in the memory to move forward one frame image storage space. It means that the content of the $F_{i-1}(x,y)$ is covered with the $F_i(x,y)$. After the all K frame images move tasks are completed, store the current frame image $C1(x,y)$ in the $F_K(x,y)$ position, and continue the task (1). If there is a moving target, then go to the task (3).

(3) Capture the current frame $C2(x,y)$, get the binary image $SUB2(x,y)$ by using differentiate operation between $C2(x,y)$ and $B(x,y)$ and making threshold segmentation. Determine whether there is a moving target in $SUB2(x,y)$. If there is no moving target, then the moving target that obtained by $C1(x,y)$ subtract background $B(x,y)$ is the false target. Make the K frame images in the memory to move forward two frame image storage space. Then store the image $C1(x,y)$ and $C2(x,y)$ in the location of $F_{K-1}(x,y)$ and $F_K(x,y)$ respectively, and turn to task (1) to continue running. If there is a moving target, calculate the centroid point $P11(x,y)$ of the moving target in $SUB1(x,y)$ and the centroid point $P21(x,y)$ of the moving target in $SUB2(x,y)$, and turn to task (4).

(4) According to the obtained centroid points $P11(x,y)$ and $P21(x,y)$, the direction of the moving target can be determined. Take the center point of the image as the origin of the axes. When the x-coordinate of $P11(x,y)$ is greater than $P21(x,y)$, the moving target move from right to left. When the x-coordinate of $P11(x,y)$ is smaller than $P21(x,y)$, the moving target move from left to right. The judgment of the moving target along the y direction is the same as the x direction.

According to the current coordinates of the moving objects, the angle that the pan/tilt/zoom needs to rotate in the horizontal direction and the vertical direction can be calculated. Control the pan/tilt/zoom rotation, then go to the task (1), and restarted the loop execution. The calculation process of the algorithm is shown in Figure 1.
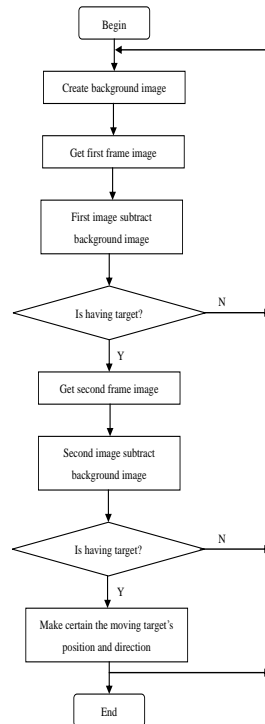
Figure 1. Moving Target Detection and Motion Direction Determination

4. Pan/Tilt/Zoom Rotation Angle Calculations

After make sure the movement direction of the moving target, the horizontal rotation and the vertical rotation angle of the pan/tilt/zoom can be calculated according to the current position coordinates of the moving targets [10-11]. Under the principle of optical imaging, a calculation method of pan/tilt/zoom rotation angle is proposed in order to rotate the camera center point to the moving target location accurately.

The camera imaging principle could be showed in Figure 2, according to the Figure 2, the angle β between the camera center line (dashed line) and the actual object is equal to the angle β' between the image points and the camera center line. Therefore we could obtain the pan/tilt/zoom's rotation degree by calculating the angle β' between the image points and the camera center line.
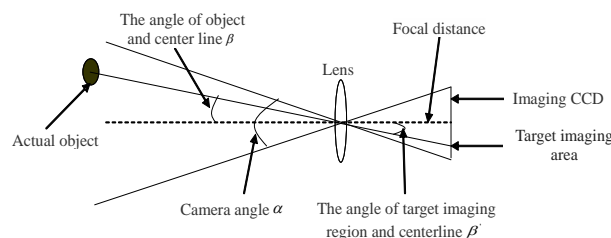

Figure 2. The Camera Imaging Principle

For a certain type camera, the camera focal distance value in anytime can be obtained by reading the real-time parameters in the camera. Here assume the camera focal distance obtained is l, and the width and the height of the camera CCD are w and h respectively. The location of the moving target can be indicated by P. The angle between point P and the camera focal distance can be respectively shown in

α and β at the horizontal direction and the vertical direction. The width and the height of the point P to the centre point o of CCD can be respectively indicated by w' and h', o_1 is the center point of camera lens. The relationship of each parameter is shown in Figure 3. In figure 3, the distance between o_1 and o is the camera focal distance value l.
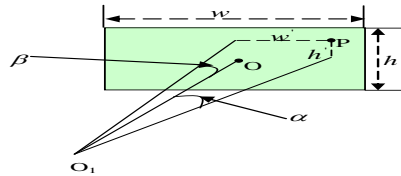

Figure 3. The Relationship of Each Parameter in the CCD

It is known from the figure 3.

$$tg\,\alpha = \frac{w'}{l} \tag{4}$$

$$tg\,\beta = \frac{h'}{l} \tag{5}$$

α And β can be obtained by calculating the arctangent function of the equation (4) and (5) respectively.

$$\alpha = arctg\,\frac{w'}{l} \tag{6}$$

$$\beta = arctg\,\frac{h'}{l} \tag{7}$$

α And β are the rotation angle in the horizontal direction and the vertical direction.

5. Example Study

The moving target detection and tracking system under complex background is designed according to the above algorithm, and the system is tested and analyzed.

The system uses continuous 50 frame images to generate the background image. During the acquisition process of the image series, the local wind speed was 3 ~6 m/s, the surrounding trees keep shaking. The image information collected by the system is shown in Figure 4(a).

(1) In figure 4 (a), the front 5 frame images correspond separately to the 21-th frame image, the 31-th frame image, the 41-th frame image, the 51-th frame image, and the 61-th frame image. The 6-th frame image is a background image frame that generated by the continuous 50 frame images.

(2) The six frame images in Figure 4(b) are the operation result of the inter-frame difference method. They are obtained separately by subtracting the 11-th frame image from the 21-th frame image, subtracting the 21-th frame image from the 31-th frame image, subtracting the 31-th frame image from the 41-th frame image, subtracting the 41-th frame image from the 51-th frame image, subtracting the 51-th frame image from the 61-th frame image, subtracting the 61-th frame image from the 71-th frame image. It is could be known from the figure 4(b), the direct Inter-frame difference method has more noise, and it is easy to generate the false moving target.

(3) The six frame images in figure 4 (c) are obtained separately by the difference operation of the 21-th frame image, the 31-th frame image, the 41-th frame image,

the 51-th frame image, the 61-th frame image and the 71-th frame image with the background image which is generated dynamically. Compare figure 4(b) with figure 4(c), it could be seen that the background dynamic generation algorithm reduces the background noise and eliminates the false moving target.

(4) Figure 4 (d) is obtained after filtering out the noise of figure 4 (c). Figure 4(e) is the result of the moving object detection.
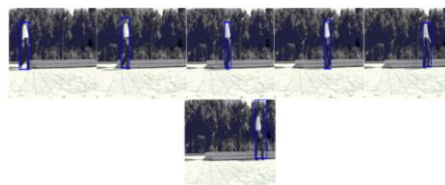

(A) Real Time Image Data

(B) The Operation Results Of Inter-Frame Difference Method

(C) Background Subtraction Operation Result

(D) After Image Noise Filtering

(E) The Results of Moving Object Detection

Figure 4. The Running Process of the System

6. Conclusions

Focus on the problem that the moving target detection and tracking in complex background is difficult, a background dynamic generation algorithm is presented in

the paper, and the background dynamic generation algorithm is used to dynamically construct the background image, the impact of the environment changing is reduced in a certain extent for the moving target detection.

In addition, the background difference method is used to detect whether there is a moving target in real time, when the moving target exists, the direction and the coordinate of the moving target is determined according to the result of continuous 2 frame images subtract the background. And an algorithm for calculating the rotation angle of the pan/tilt/zoom is presented, the horizontal rotation angle and the vertical rotation angle of the pan/tilt/zoom is calculated according to the pan/tilt/zoom rotation angle algorithm, and the moving target detection and automatic tracking function is realized.

The moving target detection and tracking detection system under complex background is designed according to the algorithm that is presented in the paper, and this system is tested and analyzed. The results show that the proposed dynamic background generation algorithm to some extent reduces the background noise and eliminates the false moving target.

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