Moving Target Detection and Tracking Based on Pyramid Lucas-Kanade Optical Flow

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Abstract—**In order to enable the optical flow to track larger and faster moving targets, pyramid Lucas-Kanade optical flow method is used to detect and track moving targets. First, detecting the corners which is easy to track, in order to improve the tracking accuracy, detected corners and then calculate the sub-pixel corner, and then the video in each frame of the image layered in the image pyramid to calculate the optical flow at the top corner, use the next pyramid as the starting point of the pyramid and repeat this process until the bottom pyramid image, which can overcome the Lucas-Kanade optical flow method cannot track faster and larger movements the shortcomings, to achieve the tracking of moving goals.**

Keywords-corner detection; sub-pixel corner; pyramid Lucas-Kanade optical flow; target tracking

I. INTRODUCTION

There are many methods of target detection and tracking, which are divided into two parts: target detection and target tracking. The target detection mainly includes the frame difference method and the background subtraction method. The frame difference method uses the pixel difference between two adjacent frames to determine whether there are moving objects in the video. It requires constant illumination and less noise. Background subtraction method can model the background illumination, noise and periodic motion. It can detect moving objects accurately under various conditions. It is suitable for a scene with a fixed camera.

The main methods of moving target tracking are region matching, feature point tracking, contour tracking, optical flow and so on. The region matching method needs to know the object which is tracked, and then matches the video frames with some feature points of the object. The method is simple, but the computation speed is slow. The feature point tracking method mainly finds some feature points on the tracking object, and then tracks the feature points on the target to achieve the target tracking. This method relies on the detection of the feature points and has high computation. Contour tracking method can track the contour of the target accurately. It can track better combined with Kalam filter. It is suitable for single target tracking. The optical flow method is divided into many kinds. The traditional optical flow method is unstable, so the later Horn-Schunck dense optical flow method and the Lucas-Kanade sparse light flow method are used. Because of the computational complexity of the Horn-Schunck dense optical flow method is huge, the commonly used optical flow method is the Lucas-Kanade sparse optical flow method to track the moving target [1].

Optical flow is a background description of image brightness information. Using the optical flow to detect moving targets and the tracking of targets are first proposed by Horn and Schunck. The optical flow method connects the speed with the gray level of the image, and the change of the pixel's speed can be calculated by the gray relation between two adjacent pixels[1]. The Lucas-Kanade algorithm, proposed by Lucas.B and Kanade.T in 1981, is easy to apply to a set of points in the input image and is later used in methods for finding sparse optical flows. Lucas-Kanade is a widely used differential method of optical flow estimation. It assumes that the neighborhood of the optical flow is a constant in the neighborhood of pixels, and then uses the least square method to solve the basic optical flow equation for all the pixels in the neighborhood. By combining the information of several neighboring pixels, the Lucas-Kanade method usually eliminates the ambiguity in the optical flow equation. Moreover, compared with the point by point method, the Lucas-Kanade method is insensitive to image noise. The Lucas-Kanade algorithm has three assumptions: (1) Brightness is constant, that is, the target pixel in the image scene remains unchanged in appearance when moving between frames. (2) The time is continuous, that is, the movement of the image changes slowly. (3) Space uniform, that is, adjacent points which are on the same surface in a scene have similar movements[2].

II. EXPERMENT

A. Corner Detection

We will detect the corner as the target of optical flow tracking in this paper. Intuitively, a corner is a type of feature point that contains enough information to be extracted from both the current frame image and the next frame image. The local neighborhood of the corner points should have two different directions in different regions. In practical applications, most so-called corner detection methods detect image points with specific features, not just corner points.

These feature points have specific coordinates in the image and have some mathematical characteristics, such aslocal maximum or minimum grayscale and some gradient features.The corners are insensitive to changes in brightness and contrast, invariance in rotation and other properties and are therefore suitable for tracking [3].

The Moravec corner detection algorithm is one of the earliest corner detection algorithms. The algorithm defines the corner as a point with low "autocorrelation". The algorithm detects every pixel of the image, uses a neighborhood of the pixel as a patch, and detects the correlation between the patch and the surrounding other patch. This correlation passes through two patches. The smaller the sum of squares (SSD) is to measure the smaller the SSD value, the higher the similarity is. If the pixel is in the smooth image area, the surrounding patch will be very similar. If the pixel is on the edge, the surrounding patch is very different in the direction perpendicular to the edge, and in the direction of the edge is more similar. If the pixels are different, the patches are different. There is a change in the direction, then all the surrounding patch will not be very similar.The Moravec algorithm will calculate the SSD minimum value of each pixel patch and the surrounding patch as the strength value, and take the maximum local intensity point as the feature point. FAST corner detection algorithm is a completely different corner extraction method proposed by Smith and Brady in 1997. The basic principle of the "SUSAN (Smallest UnivalueSegment AssimilatingNucleus)" extraction operator.SUSAN extraction operator is that the local area related to each image point has the same brightness. If each pixel brightness value in a window area is the same or similar as the pixel brightness value of the window center, the window area will be used. Image can be called to detect the existence of the edges. The pixels on the edges are smaller and the pixels at the corners are smaller. Therefore, the corner points can be determined only by finding the smallest USAN.

In this paper, the corner detection method is the Harris, which defines the corner where the autocorrelation matrix of the second derivative of the image has two maximum eigenvalues.

The steps of the algorithm are as follows:

a) Firstly, we calculate the x and y direction of the derivative of the image by using the operators [-1,0,1; -1,0,1; -1,0, -1] and [-1, -1, -1; 0,0,0; 1,1], respectively, I_X and I_Y;

b) Calculate the matrix $M = [I_X^2\ I_X{*}I_Y;\ I_X{*}I_Y\ I_Y^2]$ by using the result I_X and I_Y, and perform Gaussian filtering on the M matrix corresponding to each pixel to filter out the lone points;

c). $R = \det(M) - k(\mathrm{trace}(M))^2$ is calculated from matrix M, where $\det(M) = \lambda 1 * \lambda 2$, $\mathrm{trace}(M) = \lambda 1 + \lambda 2$;

d). Local maximum suppression, while selecting the local maximum. The selected local maxima are compared with the set threshold, and if the local maxima are greater than the set threshold, the pixel is regarded as the corner point.

Figure 1 shows the corners calculated by using the Harris corner detection algorithm. It can be seen that all the found corners are on the target to be tracked.

B. Sub-pixel Corner Detection

In order to improve the tracking accuracy, this paper adopts the method of tracking sub-pixel corner. The realization of sub-pixel corner localization is based on the observation of the orthogonal of vectors. There are three common sub-pixel level precise positioning methods, interpolation method; geometric moments; fitting method. There are third methods used in this paper.

First calculate the corner of the image, and then calculate the sub-pixel corners. Sub-pixel corner is always used in the camera calibration, 3D reconstruction and other techniques [4]. Sub-pixel corner points in this article will make the tracking of higher accuracy, the result is more accurate. The sub-pixel location of the corner is based on the orthogonal of the vector. By using the orthogonal of the vector, the position of the sub-pixel corner is calculated according to the calculated position of the corner and the size of the controllable parameter in the process is calculated Control sub-pixel corner accuracy [5]. Figure 2 is sub-pixel corners calculated based on Harris corner.

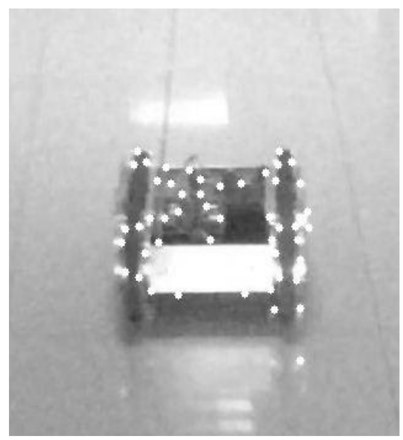


Figure 1. Corners

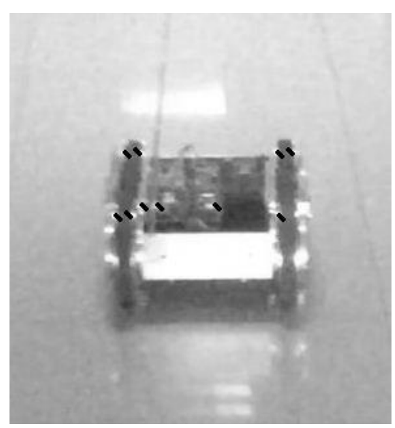


Figure 2. Sub-pixel corners

It can be seen that although the number of sub-pixel corners does not have a large number of corner points, the sub-pixel corners are all on the tracked object with higher accuracy[6].

III. Pyramid Lucas-Kanade Optical Flow Target Tracking

The concept of optical flow was first proposed by Gibson in 1950. It is the instantaneous velocity of the motion of the space moving object on the imaging plane. It is a method to calculate the motion information of the object between the adjacent frames by using the changes of the pixels in the time domain and the correlation between the adjacent frames to find the corresponding relationship between the last frame and the current frame. Generally speaking, the optical flow is caused by the movement of the foreground target in the scene, the movement of the camera, or the common movement of the two. The computational methods of the optical flow method can be divided into three categories: (1) a region based or feature based matching method; (2) a method based on frequency domain; (3) a gradient based method.

The principle of optical flow for target detection is to assign a velocity vector to each pixel in the image, thus forming a motion vector field. At a specific time, the points on the image correspond to the points on the three-dimensional object, and the corresponding relations can be calculated by projection. According to the velocity vector characteristics of each pixel, the image can be dynamically analyzed. If there is no moving target in the image, the optical flow vector is continuous in the whole image area. When there are moving objects in the image, there is relative motion between the target and the background. The velocity vector formed by a moving object must be different from the velocity vector of the background, so that the position of the moving object can be calculated. After detecting the location of the target, the target can be tracked iteratively according to the relationship between the corners of the adjacent frames.

The small velocity, brightness invariance and regional consistency in Lucas-Kanade optical flow method are strong assumptions and are not easily satisfied. If the motion speed of the object is faster, the hypothesis is not set up, then the subsequent hypothesis will have a larger deviation, making the final value of the optical flow has a greater error. When the velocity of the object is large, the algorithm will have large errors. Then we hope to reduce the motion speed of objects in images. An intuitive way is to narrow the size of the image. It is assumed that when the image is 400 * 400, the speed of the object is [16 16], and when the image is reduced to 200 * 200, the speed will change to [8,8]. When it is reduced to 100*100, the speed is reduced to [4,4]. So after scaling the source image a lot, the original algorithm becomes applicable. Therefore, the optical flow can be solved by creating the Pyramid image of the original image, so as to improve the accuracy and make the use range wider.

Pyramid Lucas-Kanade optical flow method is an improvement on the traditional Lucas-Kanade optical flow method[7]. As the traditional Lucas-Kanade optical flow method be used to track a specified pixel, if the pixel moving faster, it will be more difficult to track and result in the loss of tracking point. The pyramid Lucas-Kanade optical flow method can solve this problem, to achieve faster tracking. Pyramid Lucas-Kanade optical flow method is to layer the image, and then calculate the optical flow at the highest level of the image pyramid, the resulting motion estimation results as the starting point of the pyramid image of the next level, repeat the entire process to know the pyramid image of the most the bottom layer, so you can track faster movement[8].

The Pyramid feature tracking algorithm is described as follows: first, the optical flow and the affine transform matrix are calculated on the highest level of the image; the calculated results of the upper layer are passed to the next image as the initial value. The image of this layer is based on this initial value to calculate the light flow and the affine change matrix of this layer; then this one will be the same. The optical flow and affine matrix of the layer are transferred to the next layer of image as the initial value until the last layer, the original image layer, the calculated optical flow and the affine transformation matrix are the result of the final optical flow and the affine transformation matrix.

A. *Optical Flow Vector*

In the experiment, a moving car is used as the object to be tracked. Figure 3 is the optical flow vector obtained after matching the corners in two adjacent video frames.

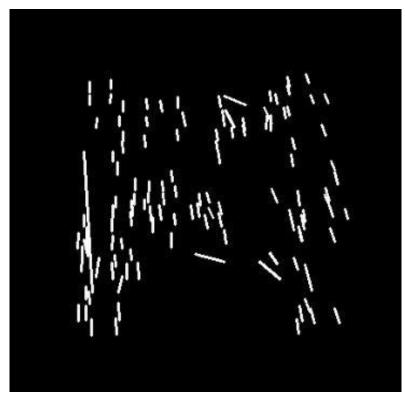


Figure 3. Optical flow vector

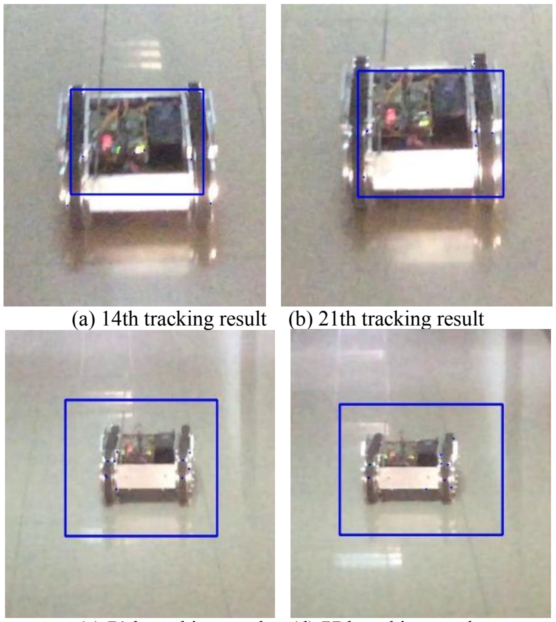
The optical flow vector obtained from the corner matching can judge the movement trend of the car.

B. *The Main Steps of Pyramid Lucas-Kanade Optical Flow Method to Track the Moving Goal*

- Firstly, preprocess a frame of input video, then detect Harris corner;
- Next, detect sub-pixel corner based on the detected corner;
- Then, load the next frame of video image, and use the pyramid Lucas-Kanade optical flow method to match the corners and find the position of the corners in this frame image which are in the previous frame image;
- Finally, estimate the location of the tracked target based on the matching result..

C. *The Result of Tracking the Moving Car at Different Times*

Figure 4 shows the result of tracking the moving car at different times.



(a) 14th tracking result (b) 21th tracking result

(c) 71th tracking result (d) 77thtracking result

Figure 4. The result of the tracking the moving car

It can be seen from the above experimental results that this method can track the moving car very well. Although the background of the car running environment changes, and the optical flow method does not match the assumptions, we can see the use of sub-pixel corner can still achieve good tracking from the above results.

IV. CONCLUSION

In this paper, we use the method of Lucas-Kanade optical pyramid combining with corner to track moving target. Sub-pixel corners matching improves the tracking accuracy. The pyramid Lucas-Kanade optical flow method can track a target with a higher speed and overcomes the shortcomings that the traditional optical flow method can only effectively track a target with a small moving speed. However, this algorithm needs to compute the sub-pixel corner and calculate the pyramid level one more times, so the computation is relatively large. This article is implemented on the VS2013 software platform, and based on the OPENCV library to achieve the whole process of the algorithm.

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