Research and application of volleyball target tracking algorithm based on surf corner detection

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Abstract. Real-time target tracking is a popular application in the field of computer vision, and it is also a topic of practical significance. As the requirements of tracking speed and precision in modern society are more and more high, corner point has the advantage in improving tracking precision as the key feature of image. SURF corner detection algorithm is extensible, suitable for combination with other target tracking algorithms, and it can be combined with motion detection and other tracking algorithms to improve the speed. In this paper, the SURF corners detection algorithm and target tracking algorithm are studied, and an improved method of combining the SURF corner detection with the Kalman filter is proposed. The Kalman filter prediction and updating algorithm is used to rapidly update the region of interest.

Key words. Target tracking, SURF corner detection, Kalman filter, tracking speed.

1. Introduction

In recent years, with the rapid development of surveillance system, the application of real-time position tracking of monitoring image gets more and more widely used in many areas, quantity demand also gets bigger and bigger, and the accuracy of the tracking system is getting higher and higher. However, due to the real-time tracking requirements, many tracking algorithms have to reduce the accuracy requirements, it can easily lead to tracking failure [1]. The tracking will be seriously disturbed when the tracking target is close to the target environment [2]. The corner is an important local feature of the image, also known as the feature points, the video sequences can be detected and matched. Although there is no definite mathematical definition of corners so far, corner points are usually defined as points that can contain enough information of the image, which focuses on the important shape and edge information [3]. By using the rotation invariant feature of corner point and the insensitive to light and the advantages of very few pixels, this method is applied to

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target tracking by optimizing the speed of corner detection.

In this study, the tracking algorithm based on corner detection is applied to the volleyball test in order to track the movement of volleyball and calculate the distance. Through this study, the human error in the process of volleyball testing is solved, and the test results are more reliable.

2. SURF algorithm

2.1. SURF corner detection algorithm

There are different sizes of objects in the image. If an attempt is made to use fixed dimensions to match the same corner feature in different frames, such as the Harris operator, the strength response template will not match due to the scale change. The principle and process of SURF corner detection algorithm are described in the following.

Firstly, according to the definition of SURF corner, the algorithm uses the Hessian matrix [4] to describe the corner of the image, which is used to represent the local curvature of a pixel, that is, to find the corresponding pixel level and the vertical direction of the second-order partial derivative. It is shown in equation

$$H\left(I\left(x,y\right)\right)=\begin{bmatrix} \frac{\partial^2 I}{\partial x^2} & \frac{\partial^2 I}{\partial x \partial y} \\ \frac{\partial^2 I}{\partial x \partial y} & \frac{\partial^2 I}{\partial y^2} \end{bmatrix}. \tag{1}$$

In the equation, $I(x, y)$ is the pixel point in the image whose coordinates are (x, y).

According to the specificity of SURF angular scale independence, Hessian matrix needs to introduce scale variable. The so-called scale is the definition of clarity, the larger the scale, the more blurred the image, on the contrary, the smaller the scale, the clearer the image. In the field of image processing, Gaussian filtering can be used to simulate the scale. Let σ be the standard deviation of the Gaussian function, which implicitly defines the scale of the image. The filter with larger σ value smooths the details of the image. The larger the image scale, the more blurred the image. The Gaussian filtering equation is shown in (2).

$$G\left(x,y\right)=\frac{1}{2\pi\sigma^2}\mathrm{e}^{-\frac{\left(x-\frac{m}{2}\right)^2+\left(y-\frac{n}{2}\right)^2}{2\sigma^2}}. \tag{2}$$

In the equation, x, y are the coordinates of the corresponding position on the template and m, n define the Gaussian template size that is expressed as $m \cdot n$.

2.2. Optimization of SURF corner description

According to the study of corner detection algorithm in this study, the following description of SURF corner points is studied and optimized [5]. Firstly, the process of SURF corner description is described briefly. At last, the optimization scheme is given.

(1) Determine the corner orientation:

Using the detected corner features, the principal directions of these corner points are determined, that is, the direction of the region with the largest gray-scale variation is described.

The method can be simply described as the center of the corner to calculate the radius of 6σ (σ being the corresponding scale value of the corner) within the neighborhood of pixels in the x, y directions of the Hall wavelet response. The so-called Hall wavelet response reflects the gray-scale image changes, here used Hall wavelet template side length is 4, respectively, 4×4 neighborhoods in x, y direction of gray-scale changes. Then, in the range of 360 degrees, every 60 degrees to do a Harvard wavelet response vector addition operation. And finally, select the direction of the longest vector as the main direction of the corner. That is, the main direction describes the direction of the most dramatic changes in gray, as shown in Fig. 1.

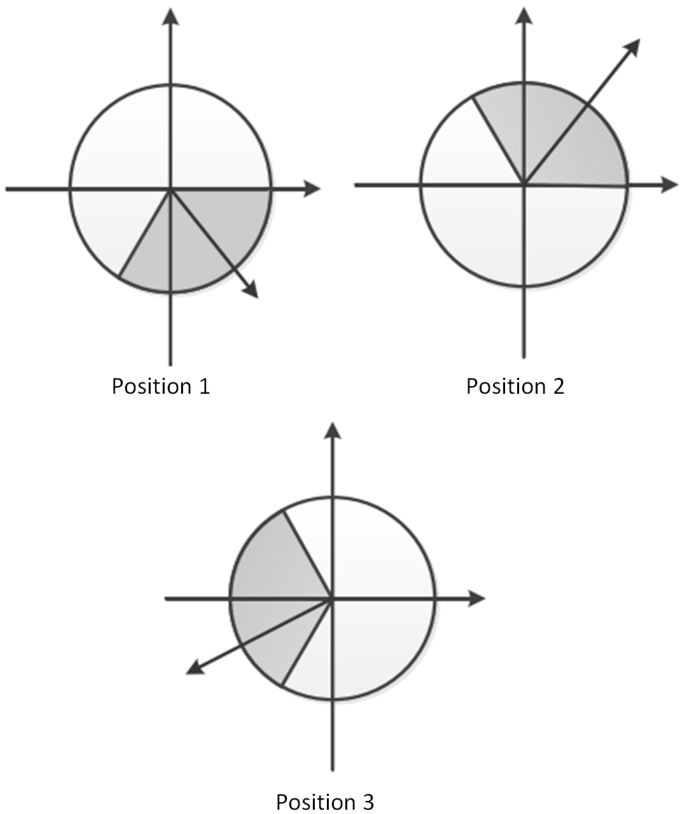

Fig. 1. Schematic diagram of main direction determination method

(2) Rotation corner neighborhood

After determining the main direction, we need to construct the descriptor of the main direction of the corner point. The method is to center the corner point, take the square with a side length of 20σ as the neighborhood, and rotate with its main direction as the rotation angle.

2.3. Target tracking algorithm

(1) Kalman filter

Kalman filter is the most typical representative of the predictor, the so-called predictor refers to the completion of the target motion prediction method, which can accurately predict the next frame of the target state of motion. Kalman filter test phase to consider three kinds of movement [6].

(2) Optimized tracking algorithm

Based on the optimization of the SURF corner detection algorithm and the motion prediction function of the Kalman filter, a tracking algorithm combining the improved SURF corner detection and the Kalman filter is proposed. The Kalman filter is used to predict the center position and velocity of the target, and return to the possible region of interest, that is, the region of interest. The SURF corner detection is performed in the reduced area and the matching tracking is completed.

- The x_k Kalman prediction system with target state vector $\boldsymbol{A}$ is established, and the predicted position of the target can be predicted by Kalman filter. it is given by the equation (3).

$$x_k = \begin{bmatrix} x \\ y \\ v_x \\ v_y \end{bmatrix} . \tag{3}$$

  where x is the pixel abscissa of the target center in the image and y is the pixel ordinate of the center of the target in the image. Symbol v_x denotes the moving speed of the target center point in the x-axis direction of the image coordinates and v_y stsnds for the movement speed of the target center point in the y-axis direction of the image coordinates.

- The observation vector z_k of the moving object is determined, as shown in the equation (4).

$$z_k = \begin{bmatrix} z_x \\ z_y \end{bmatrix} . \tag{4}$$

  In this equation, $(z_x z_y)$ is the observed center of coordinates of the moving object.

3. Design of target tracking

3.1. Target detection design

(1) SURF corner detection

According to the study and analysis of SURF corner detection algorithm, the general steps of its implementation are shown in Fig. 2.

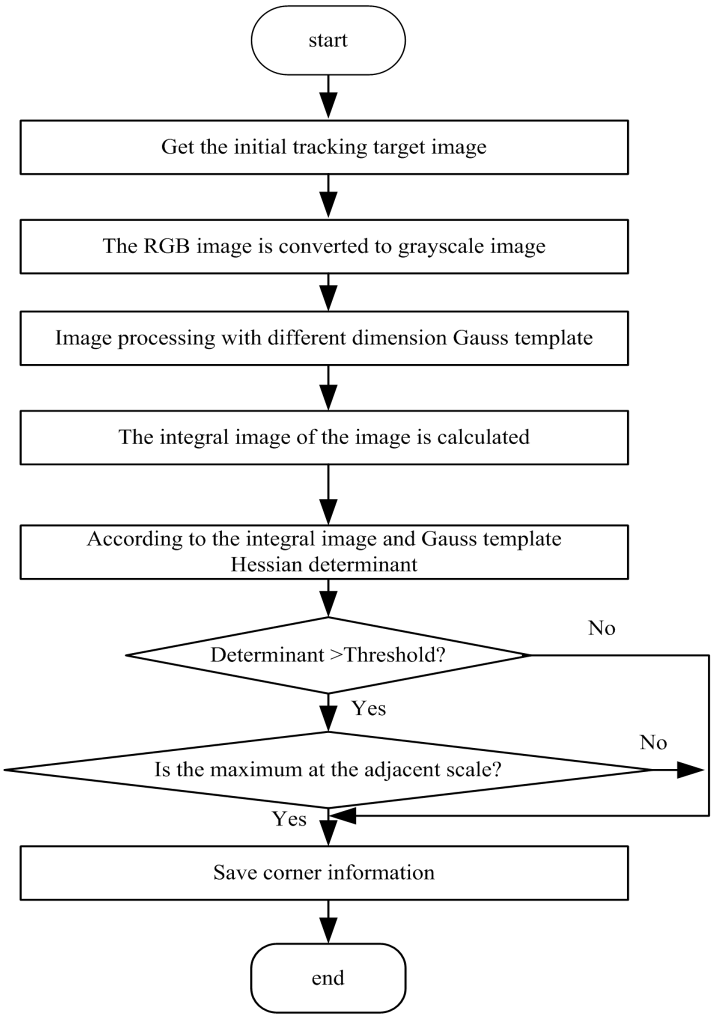

Fig. 2. SURF corner detection algorithm flow chart

(2) SURF corner description

Although the corner description process is encapsulated in the same function as corner detection, however, due to the complexity of the implementation of the corner description, the flow is described separately here. It is shown in Fig. 3.

3.2. Target prediction tracking design

(1) Target prediction

According to the optimized tracking algorithm, the realization of motion prediction is the realization of Kalman filter. The realization of the specific process is shown in Fig. 4. The implementation of the prediction update of the region of interest is described in detail below.

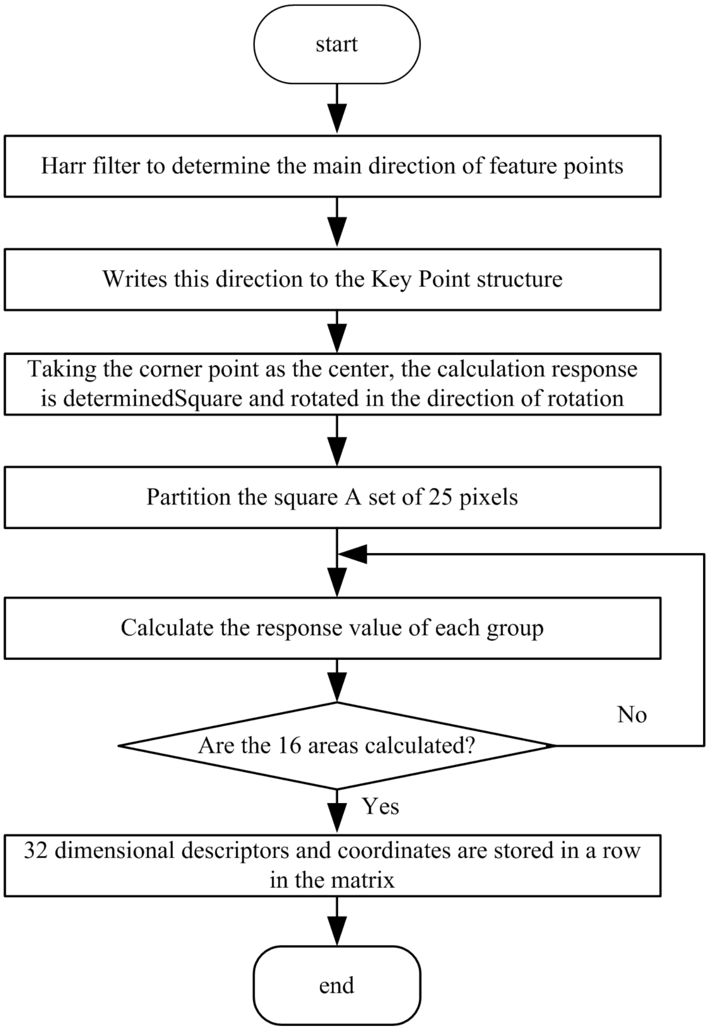

Fig. 3. Corner description implementation flow diagram

- When the tracking is started, the region of interest of the initial two consecutive frames is set to the whole tracking window. After detecting the matching to the target, the Kalman filter is initialized with its center position and velocity and the region of interest is updated.
- When there is no match to the corresponding target, the entire tracking window is set again as the region of interest and the variable representing the number

of frames is reset to zero. According to the analysis of the Kalman filter, it is necessary to set the transfer matrix F and gain matrix H, and transfer the process noise covariance matrix Q and observation process noise covariance matrix R. Matrices F and H are set as shown in equation (5).

$$Q = \begin{bmatrix} 0.01 & 0 & 0 & 0 \\ 0 & 0.01 & 0 & 0 \\ 0 & 0 & 0.01 & 0 \\ 0 & 0 & 0 & 0.01 \end{bmatrix}, \quad R = \begin{bmatrix} 0.0001 & 0 \\ 0 & 0.0001 \end{bmatrix}. \tag{5}$$

(2) Target measurement output

In the output part of the results, the system must ensure that tracking and output results are provided at the same time, that is, real-time output, which requires a refresh function, refresh once per second.

4. Results and discussion

After the optimization, the speed of 512×512 Lena RGB image is described, and the test result is shown in Fig. 4.

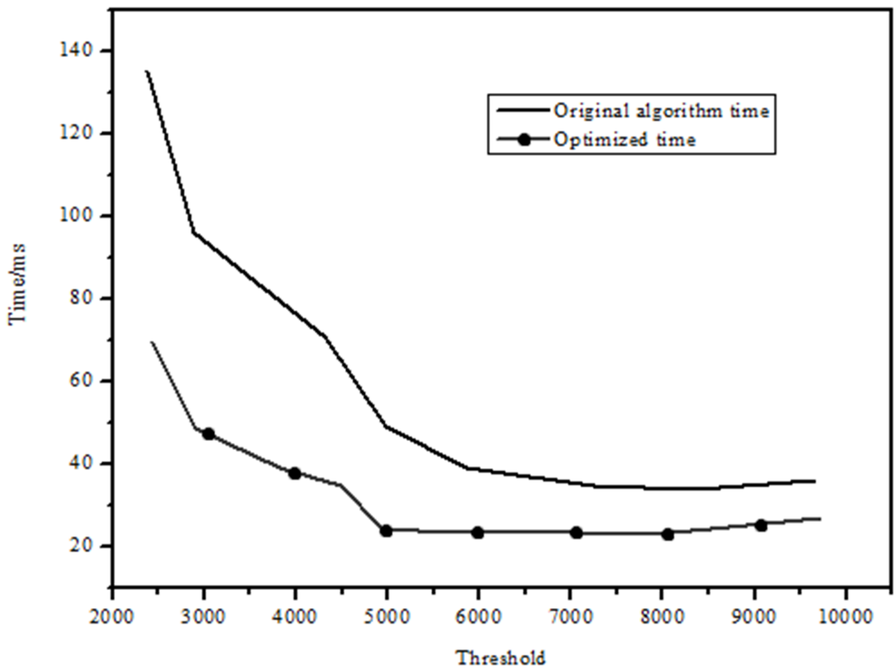

Fig. 4. Comparison of line charts of the corner description time after the optimization

It can be seen from Fig. 5 that the optimized algorithm consumes only 50 % of the time described in the original algorithm. The speed has been significantly improved. Since the dimension of the corner vector is smaller after optimization, it will also improve the speed in tracking and matching process. In this paper, two identical 512×512 Lena RGB images are tested for matching speed. The matching method is based on the widely used Euclidean distance matching method.

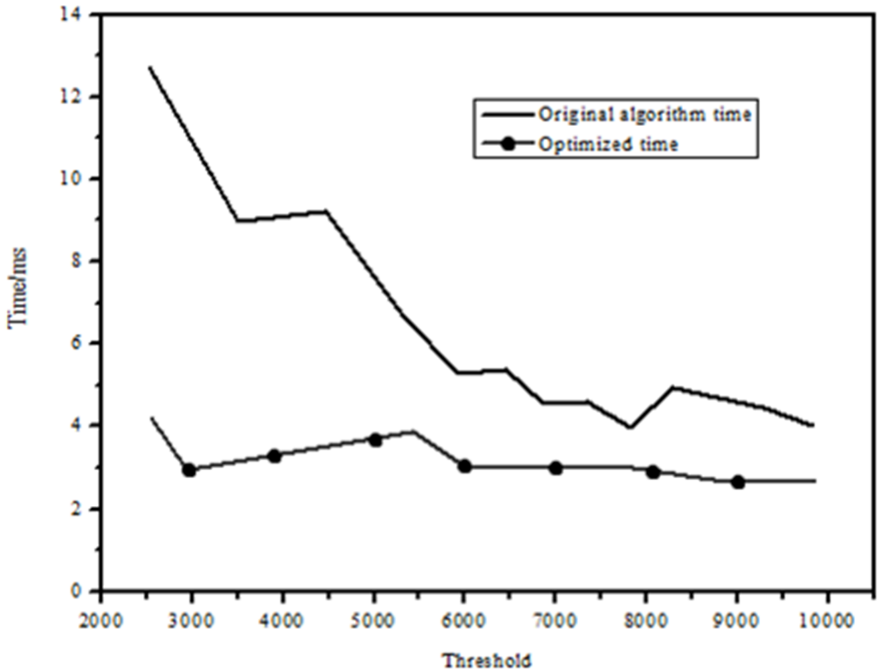

Fig. 5. Comparison of line charts of corner optimization

It can be seen from Fig. 5 that the optimized description algorithm significantly improves the speed of operations. The time in the Fig. 5 means the time required for the corner point to complete the description. It is the time taken to describe the corner points of the volleyball image shown in Fig. 5 after setting the different thresholds for corner detection. The time used is only 33 % of the original algorithm.

5. Conclusion

In this paper, based on the research of SURF corner detection algorithm, we proposed a real-time target tracking method which combines the optimized SURF corner detection algorithm and Kalman filter. The improved corner detection algorithm is applied to the volleyball test and tracking system, and the tracking effect of the system is tested by using the volleyball. It is verified that the algorithm can track the real-time moving object accurately.

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