An improved moving object tracking algorithm based on CAMSHIFT

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Abstract. There is a problem that Camshift algorithm relies too much on color as a criterion, in order to solve it, this paper presented an improved moving object tracking algorithm which combined Kalman filter predictor with Camshift algorithm. Firstly, the object model was built by Camshift Algorithm, and the centroid coordinates of the moving object were extracted, then the position of the object in the next frame was predicted by using Kalman filter, and finally, the value was used as the centroid coordinates of the object searched by Camshift algorithm in the next frame, proceeding with target match. The simulation results showed that this method can effectively solve the problem of target loss caused by the similar color between the target and the back. The new algorithm can effectively reduce the tracking error accumulation in the tracking process, greatly reduce the template drift, shorten the tracking time, and can have a better practicability and real-time performance.

1. Introduction
CamShift is the abbreviation of continuous adaptive Mean-Shift algorithm, mainly based on color features for tracking, simple calculation, strong anti-interference, stable recognition of target features, when the edge occlusion or target rotation, deformation, the algorithm can be stable tracking, and is not sensitive to background movement. In recent years, Mean Shift algorithm has been widely concerned by scholars, and various optimization algorithms have been proposed [1-4]. Chang-jun wang [5] and others for the Mean shift algorithm can track the target translation rather than tracking rotation problem, put forward the direction with target gray gradient distribution as characteristics, to achieve the goal of rotating movement track, but there was a shade the algorithm in the target, causing the extracted characteristic quantity is not enough, difficult to achieve the follow-up tracking; Hong-peng Yin [6] and others for the Mean shift algorithm is not adaptive to grab the target characteristics of the problem, this paper proposes a fusion algorithm based on adaptive multiple features and real-time update template mechanism, the algorithm is, however, the target and the background difference is bigger when the effect is good, once the target color and background color close cause update template error accumulation.

Camshift algorithm is a non-parametric density estimation algorithm, which tracks mainly based on the color characteristics of the target. There are certain limitations in the tracking process. When there are interference objects with similar colors near the target, the target template will include the...
interference objects, and with the accumulation of errors, the target will eventually be lost. Aiming at this problem, a fast moving target tracking algorithm combining Kalman filter and Camshift algorithm is proposed in this paper. The position of a frame of target is obtained by Kalman filter, which is used as the initial iteration position of Camshift algorithm. This algorithm can effectively solve the failure problem of target tracking when the interference is close to the target color.

2. CamShift algorithm overview
The specific calculation process of CAMSHIFT algorithm is as follows:

First, build the target model. It is defined that the center of the target is at the origin of coordinates, all pixel points in the search window are, and the eigenvalue of the target model is. The mathematical expression of the probability density of the eigenvalue of the color distribution of the target model is as follows:

\[ q_u = C \sum_{i=1}^{n} k(||x_i||^2) \delta[b(x_i) - u] \]  

Then, the candidate target model is established. In the previous frame, it is assumed that the center of the moving target is \( y_j \), which will be used as the initial target iteration position during the calculation of the current frame. The same kernel function bandwidth \( h \) is used to calculate the color probability distribution of the candidate target, and its mathematical expression is as follows:

\[ p_u(y_j) = C \sum_{i=1}^{n} k(||x_i - y_j||) \delta[b(x_i) - u] \]  

The selected feature has a value in the feature bin, then \( p_u(y_0) > 0 \). Mean-shift vector can be calculated by maximizing the similarity function, so that the new target position can be obtained.

\[ y_1 = \frac{\sum_{i=1}^{n} x_i w_i g\left(\left\|\frac{y_0 - x_i}{h}\right\|^2\right)}{\sum_{i=1}^{n} w_i g\left(\left\|\frac{y_0 - x_i}{h}\right\|^2\right)} \]  

Then the candidate target region \( y_0 \) moves to the vector of the real target region \( y \):

\[ m_{h, g}(y) = y_1 - y_0 = \frac{\sum_{i=1}^{n} x_i w_i g\left(\left\|\frac{y_0 - x_i}{h}\right\|^2\right)}{\sum_{i=1}^{n} w_i g\left(\left\|\frac{y_0 - x_i}{h}\right\|^2\right)} - y_0 \]  

In the above formula, \( g(x) = -k'(x) \). By constantly comparing the candidate model with the target model, the position of the moving target in the image is the highest similarity, and then it is marked. The center and size of the search window of the previous frame are taken as the initial value of the search of the next frame, and so on, so as to realize the purpose of moving target tracking.

3. Target tracking based on the improved CamShift algorithm

3.1. Kalman filtering
Kalman filter was proposed by R.E.Kalman in 1960 and has been applied in many fields [23-25]. The main idea is to express the dynamic system in the form of state space, which is a continuous modified linear projection algorithm, including the establishment of the state equation of system input and
output, time update and observation update, so as to predict the position of the target in the system. The specific steps of the algorithm are shown in Figure 1:

![Figure 1. Working diagram of kalman filter.](image)

In the prediction process of Kalman filter trajectory, the first step is to initialize the filter and assign the initial value and velocity of the target. The second step is prediction. Before the input of the next frame, the time interval between the image and the previous frame is recorded, and the initial value and time interval are substituted into the state prediction equation, and then the error covariance correction equation is calculated to make the prediction. The third step is matching, it's centered on \( (\hat{x}_k, \hat{y}) \) of \( \hat{x}_{k-1} \), searching the nearby area to obtain the best matching position; The fourth part is the correction, calculate the Kalman filter gain coefficient, substitute into the state correction equation, and finally calculate the error covariance matrix. Figure 1 shows the entire operation flow of the filter. Repeat these four steps over and over again to complete the prediction of the goal. The specific workflow is.

3.2. Improved CamShift target tracking algorithm

Due to the traditional CamShift algorithm for tracking a moving target, when tracking the target and its color features is large, the background of stability, good tracking effect can be accomplished, but when the target exists in the target color close around distractions, or obscured a moving target, the tracking effect is not so good.

Aiming at the problem that the CamShift algorithm is easy to misjudge and surround the interference into the template frame when the color of the target and the interference are similar, this paper proposes an improved algorithm based on Kalman filter which combines moving target prediction and CamShift tracking.

The specific process of the algorithm is shown in Figure 2:

1. Determine the size of the search window, slightly larger than the moving target, to surround the entire moving target.
2. The target model is established and the centroid coordinates of the moving target are extracted.
3. According to the target's centroid coordinates, the Kalman filter is used to predict the target's position in the next frame of image.
(4) This value is then used as the observed value of Kalman filter to update the state of Kalman filter. Back to the second step, the process of prediction, matching and correction is repeated to complete the tracking of moving targets.

![Flow of improved Camshift moving target tracking algorithm.](image)

**Figure 2.** Flow of improved Camshift moving target tracking algorithm.

### 4. Simulation experiment

In order to verify the effectiveness and feasibility of the algorithm, this paper takes the tennis video recorded in the laboratory as an example, with a video length of 19s and a frame width and height of 620×348 pixels. The simulation results are shown in Figure 3.

Figure 3 shows the tracking effect of a moving target (yellow tennis ball) in a video image using the traditional CamShift algorithm. It can be found that when the color characteristics of the moving target differ greatly from the color characteristics of the surrounding background, the tracking effect is better. But when a similar color was present around the moving target, the search box was slightly deformed to include feet of similar color. After the color interference, when the video goes to the 201th and 250th frames, the traditional CamShift algorithm has been unable to accurately track the moving target (yellow tennis ball), and the moving target area marked by it also includes the feet with a similar color to the moving target, so the moving target to be tracked is lost.

Figure 4 is the tracking chart of the improved target tracking algorithm combined with Camshift and Kalman filtering in this paper, in which the red rectangular box is the current position of the moving target, and the blue rectangular box is the position of the rectangular box of the moving target predicted by Kalman filtering. As shown in Fig. 4, the algorithm proposed in this paper can still track the moving target accurately when there is color interference around the moving target (the feet close to it in the figure).
In order to further verify the real-time performance of the algorithm, the tracking time of the two algorithms for each frame is calculated, and the results are shown in Table 1. It can be clearly found from the data in the table that the algorithm proposed in this paper has stronger real-time performance.

**Table 1.** Comparison results of processing time between the two algorithms.

| Algorithm         | Algorithm processing time |
|-------------------|---------------------------|
|                   | the 80th       | the 91th       | the 121th      | the 150th      | the 201th      | the 205th      |
| Traditional Camshift | 110.12ms     | 108.87ms     | 106.27ms      | 111.99ms      | 108.71ms      | 108.44ms      |
| The new algorithm  | 97.19ms       | 94.56ms      | 95.91ms       | 98.48ms       | 94.77ms       | 96.29ms       |
In order to verify the accuracy of the predicted value of the Kalman filter, the paper also recorded the predicted centroid coordinates, as shown in Table 2. As can be seen from the table, the predicted centroid point of the filter closely follows the motion direction of the moving target and is highly consistent with the actual target position. Assigning the predicted centroid to CamShift as the initial value of iteration can effectively solve the template drift problem caused by the similar color of the target and the interference object.

Table 2. Kalman filter predicts the centroid coordinates of moving targets.

| Frame  | Observations | Estimate |
|--------|--------------|----------|
|        | X coordinate | Y coordinate | X coordinate | Y coordinate |
| the 80th | 335 | 111 | 336 | 111 |
| the 91th | 335 | 111 | 336 | 110 |
| the 121th | 314 | 67 | 314 | 69 |
| the 150th | 252 | 96 | 249 | 95 |
| the 201th | 149 | 104 | 142 | 107 |
| the 205th | 86 | 123 | 89 | 123 |

5. Conclusions
In this paper, a target tracking algorithm combining CamShift and Kalman filter was proposed. The Kalman filter was used to predict the location of the centroid of the moving target in the next frame of video image, and the predicted centroid was assigned to CamShift as the initial value of iteration to reduce the over-dependence on the color characteristics of the target in the tracking process, accurately realize the tracking of the moving target, reduce the search area of CamShift algorithm, and improve the operation speed and real-time performance.

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