Target Tracking Based on Camshift Algorithm and Multi-feature Fusion

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Abstract. This paper proposes a new algorithm on the basics of Camshift algorithm and multi-feature fusion. First, the target area is weighted by the Gaussian function. Then LBP is used to extract local texture features, next fuse the texture features with the color features to obtain the color and texture histogram. Finally, for the purpose of tracking the target accurately and preventing occlusion, the Kalman filter is used to forecast the position of the moving target. From the comparison of the experimental results, the conclusion can be drawn that the new algorithm can effectively overcome the interference of objects and track the target accurately in a more complex environment.

1. Introduction
Target tracking is currently an important research topic in the domain of computer vision, it has been applied to many fields, such as public safety, virtual reality, medical image analysis, robot navigation, etc, but tracking the target accurately under complex conditions is still a challenge, such as scale scaling, rotation, occlusion, illumination changes, etc, which will cause the target tracking process becoming more complex and unstable. Han [1] improved the tracking accuracy of Camshift algorithm by combining Kalman prediction and inter-frame difference, and the algorithm had certain anti-interference for similar colors. C. Xiu [2] proposed a new target tracking method which determines a target area by the Gauss weight function. It could be used to track objects in complex backgrounds, but the effect could be affected when occlusion occurs or light changes. In order to overcome the shortcomings of Camshift and enhance robustness, the paper proposes a new tracking algorithm.

2. The traditional Camshift algorithm
2.1. The principle of traditional Camshift algorithm
The Camshift algorithm is an adaptive Meanshift algorithm, that is to say it extends the MeanShift algorithm to a sequence of continuous images. Besides, the tracking window can be adaptively resized according to the scale of the target. The Camshift algorithm generally obtains the tracking target area by target detection or manual selection. Next, on the basis of the tracking target color probability model, convert the video image into a probability distribution image. For each frame of probability distribution image, the Meanshift algorithm is used to search the optimal region of target matching. Then calculate the size and position of the tracking target according to the invariant moment of the
search area, save, then output, and the current frame search result is used as the initial value of the next frame of the search window. The process of the Camshift algorithm is as follows:

Step 1. Read the video frame, initialize the tracking target area.

Step 2. Convert the input image to the HSV color space, separate the tonal H component and calculate the tonal histogram of the region. Then according to the color histogram of H component, convert the original input image to the color probability distribution image.

Step 3. Suppose the pixel point \( I(i, j) \) is located in the search window, and \( I(i, j) \) is the pixel value of the coordinate \((i, j)\) in the probability distribution map. The zero-order moment \( M_{00} \) and first-order moment \( M_{10}, M_{01} \) can be computed as follows:

\[
M_{00} = \sum_i \sum_j I(i, j) \\
M_{10} = \sum_i \sum_j i \cdot I(i, j) \\
M_{01} = \sum_i \sum_j j \cdot I(i, j)
\]

Then the location of the center of mass of the search window is as follows:

\[
x_c = \frac{M_{10}}{M_{00}} \\
y_c = \frac{M_{01}}{M_{00}}
\]

Step 4. Move the center of the search window to the center of mass, and judge if the center position converges or not. If not, return to step 3, and continue to calculate the center of mass position according to the new center position until it converges.

Step 5. Calculate the second moment of the final search window.

\[
M_{20} = \sum_i \sum_j i^2 \cdot I(i, j) \\
M_{02} = \sum_i \sum_j j^2 \cdot I(i, j) \\
M_{11} = \sum_i \sum_j ij \cdot I(i, j)
\]

The new search window can be calculated:

\[
L = \sqrt{\frac{(2 \cdot \frac{M_{20}}{M_{00}} \cdot x_c^2 - y_c^2 + \frac{4 \cdot (\frac{M_{11}}{M_{00}} - x_c \cdot y_c)^2 + (-x_c^2 + y_c^2)^2}{2}}{2}}}
\]

\[
W = \sqrt{\frac{(2 \cdot \frac{M_{20}}{M_{00}} \cdot x_c^2 - y_c^2) - \frac{4 \cdot (\frac{M_{11}}{M_{00}} - x_c \cdot y_c)^2 + (-x_c^2 + y_c^2)^2}{2}}{2}}
\]

\[
\theta = \frac{1}{2} \arctan\left(\frac{2 \cdot \frac{M_{11}}{M_{00}} - x_c \cdot y_c}{-x_c^2 + y_c^2}\right)
\]

Step 6. Obtain the next frame of image to continue tracking.

### 2.2. Shortcomings of basic Camshift algorithm

The tracking effect of basic Camshift algorithm is better when there is simple background, but there are limitations in the following cases: For example, the tracking effect is poor in the case of obvious
illumination changes or there is interference of similar background color. And if part of the target area is blocked or the target is scaled and rotated, it is too hard to achieve effective tracking. In addition, the basic Camshift algorithm fails to track the target moving in a high speed.

3. Improved Camshift tracking algorithm

3.1. Introducing Gaussian Weighted Function
In this paper, Gaussian function weighting is applied to the target region that selected at the first before generate back-projection image. In this way, the weight of target position is different from that of other regions, and interference from other locations can be prevented to some extent.

3.2. Feature extraction and fusion
Color features can reflect the overall characteristics of an object. Different colors can distinguish different positions. In this paper, HSV color space which is less affected by the change of illumination is adopted, and only H components are extracted to establish the color space histogram model. Texture features are less affected by the change of light and color, and they are not easily affected by image gray scale changes or noise. In this paper, LBP is mainly used to describe texture features. And then the two features are fused adaptively to generate the probability density distribution map by projection.

3.3. Introducing Kalman filter to predict the position
Kalman filter is an autoregressive linear estimation algorithm based on the minimum error variance criterion. This paper uses Kalman filter to store the motion information of the tracking object, establish the object's motion equation, and predict the position of the object. By comparing the histogram of the tracking area with the histogram of the target template area, the Bhattacharyya coefficient can be obtained by the following formula,

\[
d(H_1, H_2) = \sqrt{1 - \frac{1}{\sqrt{H_1H_2N^2}} \sum_i |H_1(I) - H_2(I)|}
\]

When the Bhattacharyya coefficient is larger than the threshold, occlusion happens. And then Kalman filter is used to predict target tracking results. If there is no occlusion, the observed value is the target candidate area tracking by the Camshift algorithm.

3.4. Improved algorithm
Figure 1 shows the improved algorithm flow.

Figure 1. Overall algorithm flow chart.
Step 1. Initialize the search window and Kalman filter.
Step 2. Gaussian weighted target region.
Step 3. Extract the color and texture features of the target area and then fuse adaptively to obtain a new back projection.
Step 4. The Camshift algorithm is used to track the target and obtain the target candidate region.
Step 5. Compare the histogram of the target candidate region with that of the target model, obtain the Bhattacharyya Coefficient and then compared with the threshold. If it is greater than the threshold, occlusion happens. Then use the Kalman predictor to predict the position of the target, and use the tracking results predicted by Kalman as the observation value. If there is no occlusion, the observed value is the target candidate area tracking by the Camshift algorithm.
Step 6. Update the search window and the Kalman filter.
Step 7. Acquire the next frame image and continue execution.

4. Experiment results and discussion
This algorithm is implemented with VS2010 installed OpenCV2.4.8, and test in Windows 7 with a 3.20GHz CPU with a memory of 8 GB. For different scene, three algorithms are used for target tracking. The three algorithms are Camshift algorithm, Camshift and Kalman combination algorithm and the algorithm this paper proposed, and the experiment results are shown in following images. Among them, (a) presents the experiment results tracking by the basic Camshift algorithm. (b) presents the experiment results tracking by Camshift and Kalman combination algorithm. (c) presents the experiment results tracking by the proposed algorithm.

Figure 2 compares the tracking results when interference occurs. Figure 3 compares the tracking results of the when the light changes. Figure 4 presents the tracking results when the target moves in a high speed and occlusion happens. On the basis of the tracking results, it can be seen that the tracking effect of the proposed algorithm is better compared with the other two algorithms. It can track the target accurately when the target is interfered or occluded or the target is moving in a high speed. And the new algorithm is insensitive to light. Figure 5 shows the center location error(CLE) various algorithms. Experimental results present that the center location error of the new algorithm is smaller.
Figure 3. Tracking results when light changes.

Figure 4. Tracking results when the target moves in a high speed and occlusion occurs.
5. Conclusion

This paper proposes a new tracking method based on Camshift and multi-feature fusion. Firstly, the Gaussian weight function is used to weight the target region. Then extract color features and combine with the texture features. Finally, the Kalman filtering algorithm is used to predict the position of the target to prevent occlusion. And the results present that the method can effectively overcome the interference of objects and improve the stability and reliability of tracking. When the interference happens or the light changes, it can still track the target effectively, avoid the problem of target loss, which indicates that the new algorithm has better robustness and anti-interference. However, due to the high complexity of the algorithm, the real-time performance needs further optimization.

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