A Robust Object Tracking Algorithm in Complex Environment

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ABSTRACT

In the approaching tracking process, we get infrared images from far to near, and the target in the images varies from small to big. The main problems in the tracking process are the large variety of scale, the change of target's posture and intensity, the collusion of interferences. This paper focuses on the whole tracking and detection process when the target and inferences exist at the same time and block each other. We propose an approach which includes several cues. Firstly, according to the amount of target pixels, the target is divided into small target and shaped target. Then we use the information of the target displacement rate to track and detect the small target which only has several pixels and is unstable. For the shaped target, we can make use of the target's contrast information. Lastly, we validate our method by designing an experiment which simulates the entire tracking and detection process. The test shows that our method improve the performance.

Keywords: Interference, contrast information, displacement rate, tracking and detection

1. INTRODUCTION

Infrared (IR) imaging is an important technology in target tracking and detection, which has been widely used in navigation[1], remote sensing[2], and so on. IR target tracking and detection have been a hot research area and play an important role in automatic target recognition.

It is a challenge to detect and track target which has large variety of scale, the change of target's posture and collusion of interferences, especially for very small targets. To solve the problem of large variety of scale, targets are divided into small target and shaped target. The detection algorithms can be divided into two types for the small target detection: the spatial filtering and the time domain processing. The spatial filter algorithms[3-5] are based on the foundation that background pixels are spatially correlated and target pixels are salient. So we can detect the target by a spatial filter in the complex background. However, the algorithms based on spatial filtering fail to detect the target when inferences appear. In time domain, the algorithms use the multiple frames image to acquire the continuity of target motion trajectory[6] and other information, such as the image entropy difference[7]. But the usual time domain algorithms can't match the real-time requirement. For the shaped target which has dozens of pixels at least, we usually use the shape information and gray value. 3-D Matched Filter[8] which stems from match filter designs multiple 2-D match filter depend on all of the target's possible motions and finds the most matched one. But it cannot achieve real-time. For the change of target posture, the paper[9] introduces a method called Tracking-Modeling-Detection (TMD) that mixes adaptive tracking with online learning of the object-specific detector. It is robust for the change of target posture, but easily confused by the large amount of calculation. And for the collusion of interferences, the paper[10] introduces a method to detect the jet from the flare and the spatially distributed flares by the Intensity Ratio Change IRCCM (IR Counter-Countermeasures) technique and LOS Rate Change IRCCM technique separately. However it cannot handle the tracking process with targets approaching from far to near. The paper[11] proposes an algorithm based on fusion feature matching and mean shift correction for infrared small targets. It overcomes the collusion of the interferences and the bad influence of background. But it is only suitable for small targets.

Based on the three points mentioned above, we propose a novel idea to distinguish the target from the interferences in infrared images by using the information of the intensity feature, the horizontal and vertical direction displacement rate in this paper. It is robust for the variety of scale, the change of the target's shape and the collusion of inferences. By this way, we can distinguish the real target from interferences. Experimental evaluation results show that our method is effective.

This paper is organized as follows. In Section 2, we introduce the target detection algorithm based on continuous stability of target motion, making use of the gray value information, the horizontal and vertical direction displacement

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rate. Section 3 presents the experiments on some IR image sequences to show the effectiveness of the proposed idea. Finally, Section 4 shows the conclusion about the stability and accuracy of our idea.

2. TRACKING AND DETECTION PRINCIPLE

In the tracking process, one of the most difficult tasks is detecting and tracking objects with large variance in scale and texture, the distance between the seeker and the target decreases gradually and the number of the target pixels increases from several to thousands. For the case where the object is extremely small, containing only several pixels and being very unstable, we track and detect the object according to its displacement rate so that we can deal with the noise and interferences. For the case where the object has dozens of pixels, we use the intensity feature to track and detect the object. When the real target's gray values are close to the interferences' gray values, the displacement rate is more reliable than intensity. Combining the motion and the intensity features, our method outperformances other methods. The system framework is shown in Figure 1.

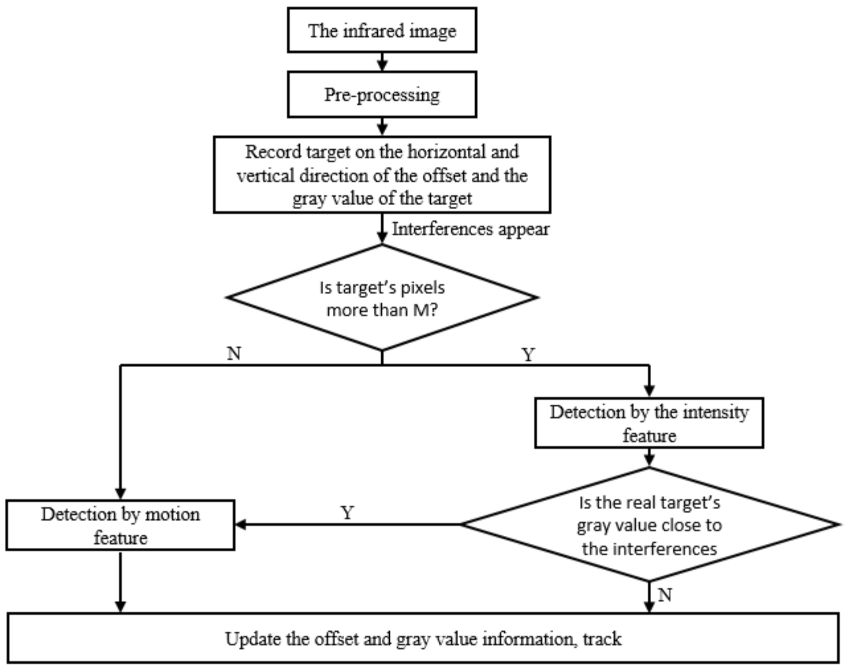

Figure 1. The framework of detection process.

2.1 Detection by the displacement rate information

At the beginning of the whole tracking process, the distance between seeker and target is far, IR small target cannot show the complete shape. The same target may present different shapes in the IR sequence, as shown in Figure 2.

Figure 2. The same small target in each frame. (8*8 pixels).

Because of instability of the small target, it isn't appropriate to track and detect the target using the shape feature. However, the displacement rate is stable in the process, as shown in Figure 3.

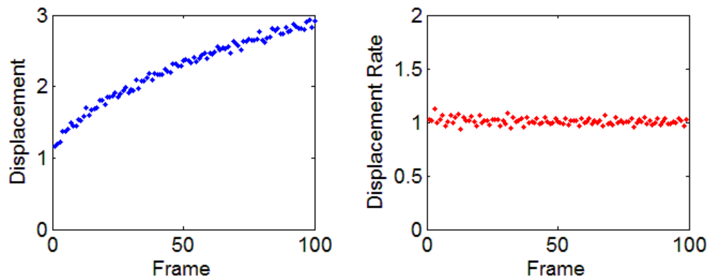

Figure 3. The displacement and displacement rate for small target.

The interferences radiation intensity is high in general. When the interferences appear, there is only one target (the real target is mixed with interferences at first) in the infrared image, and the target's gray values suddenly increase. In this case, we stop update the number of recorded values (denoted by N) until the real target and interferences separate, otherwise the recorded data will be unreliable. After they are separated, the horizontal offsets and vertical offsets can be obtained for each target between frames. Lastly, we compare the horizontal and vertical displacement rate with the original data to get the real target Q using the following measure:

$$Q = \underset{\mathrm{i}}{\operatorname{argmin}} \sqrt{(\Delta x_i - \frac{1}{N}\sum_{j=1}^{N-1}\frac{x_{j+1}}{x_j})^2 + (\Delta y_i - \frac{1}{N}\sum_{j=1}^{N-1}\frac{y_{j+1}}{y_j})^2}, \tag{1}$$

where $\Delta x_i, \Delta y_i$ denote the horizontal and vertical displacement rates for each target, $x_1 \cdots x_N$ the original recorded horizontal offsets, and $y_1 \cdots y_N$ the original recorded vertical offsets. Then we update the recorded data. The minimum value corresponds to the real target.

2.2 Detection by the intensity feature

When the distance between the seeker and the target decreases gradually, the number of the target's pixels in infrared image increases. The target shape is becoming clearer, but because of the exit of interferences, the target shape will change. As shown in Figure 4. We cannot update the recorded target template at this case because the real target is mixed with the interferences. When target is separated with interferences, its posture changes accordingly, therefore the old template is not reliable. So it is not proper to use the shape feature. Instead, the intensity more is robust to target posture.

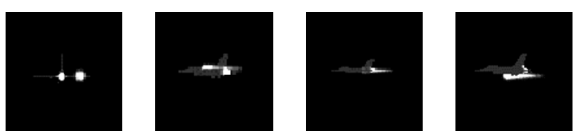

Figure 4. The target shape is interfered by interferences.

Firstly, we calculate the average gray value in the image for each target when the real target separates with interferences. Then we compare each target gray value with the average of the N original data, the target with the minimum value is assumed as the real target Q:

$$Q = \underset{\mathrm{i}}{\operatorname{argmin}} \left| G_i - \frac{1}{N}\sum_{j=1}^{N} G_j \right|, \tag{2}$$

where $G_1 \cdots G_N$ is the gray value we recorded. Lastly, we update the recorded data. However, there may be other objects with gray values close to the minimum value. For such cases, instead of intensity feature, we use the displacement rate information to get real target finally.

3. EXPERIMENTS AND ANALYSIS

To verify our approach, we perform some experiments. Here we describe our experimental scenario and the corresponding results. We evaluate the effectiveness of our method, and compare with some other popular methods, including mean-shift[12] and match filter [13].

3.1 Experimental setup

We design an experiment that the seeker track and detect the target in the 3D environment. The process of tracking is shown in Figure 5.

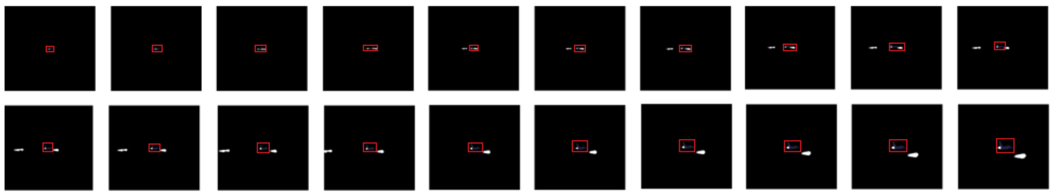

Figure 5. The whole tracking process of our experiment.

In the tracking process, the interferences will appear around the target, and the interferences don't have power, they will gradually separate with the target. The interference has a ball and along with long tail.

Based on the relative positional relationship between the seeker and the target, experiments are divided into two groups. In the first group, the seeker and the target are at the same height, and the seeker tracks by 30 degrees angle stepper. In the second group, the seeker is tracking the target on the ground. Like the first group, the seeker tracks by 30 degrees angle stepper too. The detailed positional relationship is shown in Figure 6.

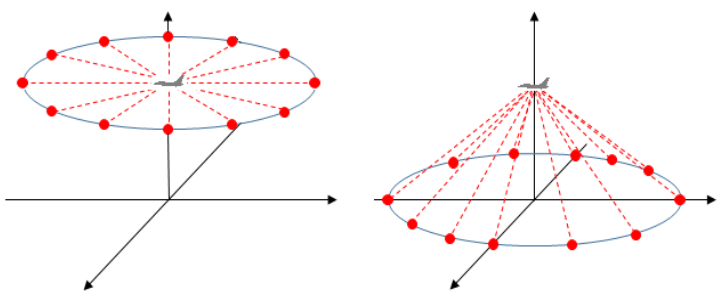

Figure 6. The seeker's initial relative position of the target.

When the simulation starts, the target throws four interferences. They are divided into two groups, each group has two interferences, respectively be threw from the left and right sides of the target. At first, the distance between the target and the seeker is far, therefore the target is small in the imaging screen. With the distance being closer, the target is bigger in the imaging screen. In the process, the target throws the interferences, the interferences and the target separate slowly, the target will try it best to detect and track the target correctly.

3.2 Evaluation of the Effectiveness of our Method

The method based on the displacement rate is suitable for small targets, but bad for shaped targets. On the contrary, the method based on the intensity feature is appropriate for shaped target. The threshold set to 30 pixels in the experiments. The results are shown in Figure 7.

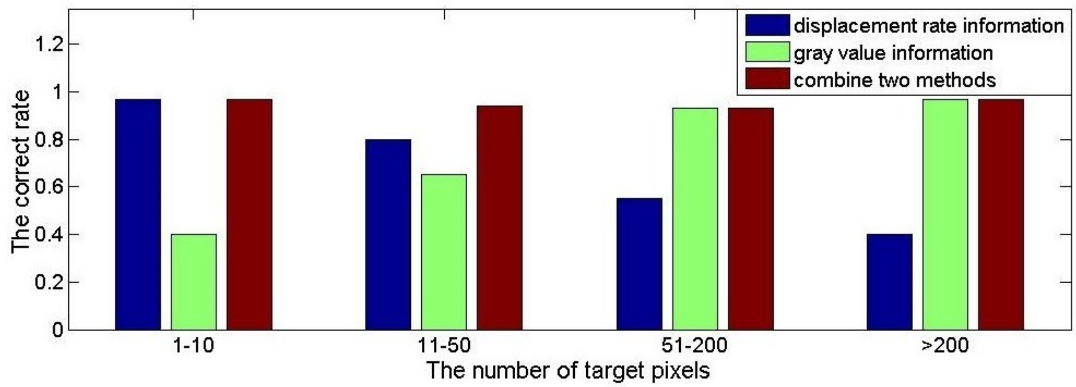

Figure 7. Evaluation of the effectiveness of our method.

From the figure 7, with the pixel numbers of target increasing, the accuracy of the method based on the displacement rate reduces, and the accuracy of the method based on intensity feature increases.

3.3 Comparison with Other Popular Methods

Based on the relative position, we conducted two group experiments – the seeker and target are at the same and different height. By those experiments, we have collected 939 images in which both the target and interferences exist. Mean-shift tracks and detects 853 images correctly. And method of filter match tracks and detects 795 images, the template is shown in Figure 8. Lastly, the method we proposed tracks and detects 924 images correctly. Their performance are shown in Table 1.

Table 1. Experiments Result.

IR experiments	**Methods**		
	Mean-shift (%)	Match filter (%)	Proposed (%)
First group experiments	90.6	82.8	98.1
Second group experiments	90.9	86.0	98.6
All	90.8	84.7	98.4

Mean-shift isn't robust for interferences. When the target throws interferences, the track point will be confused by the interferences. From the results we can see that our approach outperforms it significantly. In addition, our approach achieves a runtime of 50FPS, being suitable for real-time applications. The main reason for the low accuracy of the match filter method is that it's not robust to the change of the target shape, when the target is approaching from far to near.

4. CONCLUSION

In this paper, we have proposed a tracking method based on displacement rate information and the intensity feature. Experiments show that our approach is robust to the change of the target's shape in the approaching tracking process, reducing the influence of the variety of target scale and the collusion of interferences. Our approach can be applied in a real-time system for anti-interferences with a high accuracy.

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