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Review

Infrared small target tracking based on target and interference behaviors model

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HIGHLIGHTS

- A novel approach for tracking infrared small target with the existence of interference is proposed.
- The complicated small target and interference behaviors are modeled based on random finite sets.
- An interference occurrence decision algorithm is proposed to recognize interference.
- A behaviors model based target and interference tracking method is proposed.

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ABSTRACT

A new infrared small target tracking method is proposed to track small target with existence of interference. First, interference occurrence decision algorithm is presented to decide whether the tracking method is interfered by multi-targets or infrared decoys. Second, target and interference behaviors are modeled using random finite sets (RFS). Then behaviors model based target and interference tracking method is formulated using maximum a posteriori probability which is propagated through Gaussian mixture probability hypothesis density filter (GMPHD filter). Experimental results show that the proposed tracking method can track small target and interference accurately and efficiently.

Contents

1. Introduction

Infrared target detection and tracking method has been widely used in many military and civilian fields, such as infrared guidance, infrared warning system and video surveillance. But the existence of interference caused by infrared decoy and multi-targets will have a serious impact on target tracking result.

In past few decades, lots of researches have been done in tracking of small targets [1–8]. These methods pay their attentions on target evolution and template updating during target tracking. And in [5] Intensity Variation Function is used to avoid tracking of wrong targets. Some target tracking methods with existence of

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interference also have been proposed in literature. But these algorithms deal with the target whose size is big enough. In [9], many features including intensity, size, and shape factor of candidate targets are extracted to distinguish target and interference. And edge feature is used in [10] to detect and track target in clutter. Su et al. [11] proposed a tracking algorithm which uses the edge of target and Camshift method to track partly occluded target in forward looking infrared imagery.

However, when target is small, edges, local texture and shape features are unavailable to distinguish target from interference, so the above tracking methods are no longer valid. In this paper we proposed a novel method to track the small target with existence of various interference.

Interference caused by multi-targets and decoy have different and complicated behaviors, behaviors of interference will lead to break-down of small target tracking. And to deal with these complicated behaviors in our tracking method, we have to know whether interference event happens and what kind of interference first, so the interference occurrence decision algorithm is proposed in this paper first. Then with result of interference occurrence decision algorithm, target and interference behaviors are all modeled using RFS. As we have mentioned above, the features we usually used have no ability to distinguish small target from interference. So we adopted motion features in our tracking method, it is because that target and interference usually have different motion models which has been proofed in [12]. At last, the tracking method is formulated to tracking the target and interference using behaviors model and adopted tracking features.

The remainder of this paper is organized as following: interference occurrence decision algorithm will be described in Section 2. In Section 3, target and interference behaviors model is modeled using random finite sets, then the behaviors model based tracking method is formulated using MAP which is propagated through GMPHD filter. The experiment results and discussion are presented in Section 4. Finally we will reach the conclusions in last section.

2. Interference occurrence decision algorithm

Interference occurrence decision algorithm is designed to decide the occurrence and the kind of interference in this section. First, we analyse behavior of target and decoy when decoy interference is spawning from real target, and decoy interference occurrence decision algorithm is proposed based on this behavior. Then the behavior of multi-targets and target is considered. Interference occurrence decision algorithm will be proposed at last.

We perhaps have already known that decoy intensity is usually higher than real target, and target intensity is also used to decide whether decoy interference occurs in [9]. But if decoy intensity is adjusted to a lower level, this feature is easily messed up. Thus, we will add a more robust feature in this paper. When decoy is released from target, it overlaps with target, the small target detection method will regard them as one "target", the size of "target" changes dramatically, and this behavior is illustrated in Fig. 1. And this is also correspondingly matched with image (a) and (b) in Fig. 2. So we include this robust feature in our interference occurrence decision algorithm.

And Neyman–Pearson criterion is used to decide whether decoy interference happens. Given target intensity I and target size S, and decision will be made between following two hypotheses:

$$\begin{cases} H_0 & \text{no decoy} \\ H_1 & \text{have decoy} \end{cases}$$

Set $\xi = (I, S)$, we suppose that likelihood probability $p(\xi|H_0)$ and $p(\xi|H_1)$ satisfy Gaussian distribution, which are shown in Eq. (1).

$$\begin{aligned} p(\xi|H_0) &= \frac{1}{2\pi\sigma_I\sigma_S}\exp\left\{-\left(\frac{(I-I_0)^2}{\sigma_I^2}+\frac{(S-S_0)^2}{\sigma_S^2}\right)\right\} \\ p(\xi|H_1) &= \frac{1}{2\pi\sigma_I\sigma_S}\exp\left\{-\left(\frac{(I-I_1)^2}{\sigma_I^2}+\frac{(S-S_1)^2}{\sigma_S^2}\right)\right\} \end{aligned} \tag{1}$$

Here, I_0 and S_0 are means of I and S when there is no decoy, I_1 and S_1 are means of I and S when decoy interference happens, σ_I and σ_S are standard deviations of target intensity and size.

So decision $d(\xi)$ can be made using Eq. (2):

$$d(\vec{x}) = \begin{cases} H_0 & \text{if } l(\xi) = \frac{p(\xi|H_0)}{p(\xi|H_1)} \geqslant \lambda \\ H_1 & \text{otherwise} \end{cases} \tag{2}$$

Here, $l(\xi)$ is likelihood ratio function, and λ is corresponding threshold which can derived from given P_{fa}. P_{fa} represents the probability of the decoy interference happens when the decision H_0 has been made.

We have designed decoy interference occurrence decision algorithm. Here, we will analyse behavior of multi-targets when multi-targets interference occurs in image. When multi-target interference occurs in the image, the new target will spontaneously appear in image, as shown in Fig. 3(a) and (b). In this situation, target number in image will change first, the size and intensity real target have no change. So we can easily use target size, target intensity and target number to decide the kind of interference.

The flowchart of interference occurrence decision algorithm is illustrated in Fig. 4. At each frame, we will first detect small target in image. If interference have not happened yet, target number of detection result will be checked with the tracked target number to decide whether the multi-targets interference happens. If the number is unchanging, the Neyman–Pearson criterion is used to decide whether decoy interference happens. If the interference has happened already, the interference occurrence decision is able to decide whether interference happens and what kind of the interference is in following frames.

3. Tracking algorithm based on target and interference behaviors model

In this section target and interference behaviors will be modeled using random field sets. Then behaviors model based tracking

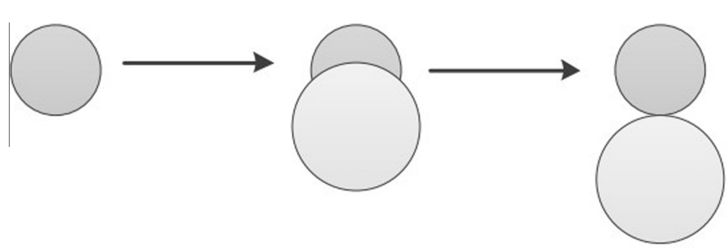

Fig. 1. Targets behaviors when decoys is released.