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Infrared small target tracking based on sample constrained particle filtering and sparse representation

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HIGHLIGHTS

- A target dictionary combined with a binary support vector is developed.
- The reconstruction of target is converted to a non-convex optimization problem.
- Using Bayesian state inference under particle filtering framework to track target.
- Update target state by sparse representation coefficient & reconstruction residual.

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ABSTRACT

Infrared search and track technology for small target plays an important role in infrared warning and guidance. In view of the tacking randomness and uncertainty caused by background clutter and noise interference, a robust tracking method for infrared small target based on sample constrained particle filtering and sparse representation is proposed in this paper. Firstly, to distinguish the normal region and interference region in target sub-blocks, we introduce a binary support vector, and combine it with the target sparse representation model, after which a particle filtering observation model based on sparse reconstruction error differences between sample targets is developed. Secondly, we utilize saliency extraction to obtain the high frequency area in infrared image, and make it as a priori knowledge of the transition probability model to limit the particle filtering sampling process. Lastly, the tracking result is brought about via target state estimation and the Bayesian posteriori probability calculation. Theoretical analyses and experimental results show that our method can enhance the state estimation ability of stochastic particles, improve the sparse representation adaptabilities for infrared small targets, and optimize the tracking accuracy for infrared small moving targets.

1. Introduction

Capturing and tracking for infrared small target have been extensive applied in infrared precise guidance, remote sensing, space exploration and air navigation. As a significant symbol of national defense capability, infrared search and track has always been a hot research topic during the past decades. However, sometimes the application environment forces us to keep the imaging system away from the target, which leads to a small target appearance in the view of camera. For the influences of energy attenuation and sensor noise, dim targets in infrared image are fairly small and lack of texture information, with weak brightness and very few pixels. In addition, in case of complex backgrounds, small targets are easily to be immersed in heavy noises and clutters. And the low signal-to-clutter ratio (SCR) results in considerable difficulties and challenges of tracking process. Therefore, it is of great significance and value for us to design a robust infrared small target tracking algorithm.

For infrared small target tracking, the methods available now are mainly divided into the following three categories: methods based on target modeling and orientation theories, methods based on filtering and data correlation theories, and methods based on sparse and low-rank matrix representation. Comaniciu et al. proposed a Mean-Shift [1] algorithm which realized rapid tracking in current frames. As a typical method of the first branch, it utilizes an isotropic kernel function weighing the histograms of the target region and the candidate target region, and measures the similarities between them. And then, the target is located by gradient descent. Researchers have carried on many studies in this framework, such as the method constructing a cascade gray space in the x, y directions and using the gray weighted histogram to model the

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infrared small target [2], the method introducing adaptive nonlinear improvements with gradient information fusion [3], etc. While common methods are mostly based on the image gray space and use the histogram characteristic to model the object, the result of this branch is not always satisfactory due to the small size and few pixels of the infrared small target. The second branch based on filtering theory and data correlation transfers the problem of target tracking to state estimation, the most representative ones of which are tracking framework of Kalman filtering and particle filtering, which are more applicable to nonlinear and non-Gaussian conditions. The basic idea of this method is to express the posterior probability density of dynamic samples according to the estimation of a group of random samples with correlation weights. Among them, the incremental learning model [4] and the Probability Continuous Outlier Model [5] are two widely used methods.

For target appearance models, the frequent use of statistical features, such as gray scale histograms and gray mean values, usually leads to instability information for target recognition. Since the model is quite sensitive to noise, it may result in the failure of tracking in some cases. To deal with these circumstances, researchers proposed an infrared small target tracking method based on sparse and low-rank matrix representation. For example, the particle discriminative sparse representation tracking algorithm [6] proposed by Li et al., the accelerated proximal gradient L1 tracking algorithm [7] proposed by Bao et al., and the robust low-rank sparse learning tracking algorithm [8] proposed by He et al. Former researches have proved that sparse representation not only has strong anti-noise ability and insensitivity to the occlusions in the process of infrared small target detection and tracking, but also has good associativity and compatibility with the framework of particle filtering.

This paper proposed an infrared small target tracking method based on sample constrained particle filtering and sparse representation. First of all, for the target subspace, a binary support vector is introduced to distinguish the normal region and interference region in target sub-blocks. Then, under the framework of Bayesian inference, a particle filtering observation model based on sparse reconstruction error differences between sample particles is constructed. Next, we utilize saliency extraction to obtain the high frequency area in infrared image, and take it as a priori knowledge of the transition probability model. After that, a constraint condition is added to the particle filtering sampling process according to the classic Monte Carlo method. Besides, by means of taking target particle samples reconstruction residual as the similarity measure standard, the tracking results are brought about via posterior probability estimation of target states. As a result, the target appearance model based on sparse representation improves the robustness of target description; the saliency extraction increases the ratio of effective particles in the sampling process and decreases the computational burden of the whole algorithm. Finally, for further adjustment of the changes caused by factors such as background clutters and noises, we update the target subspace online, which enhances the algorithm's effectiveness and robustness to a great extent.

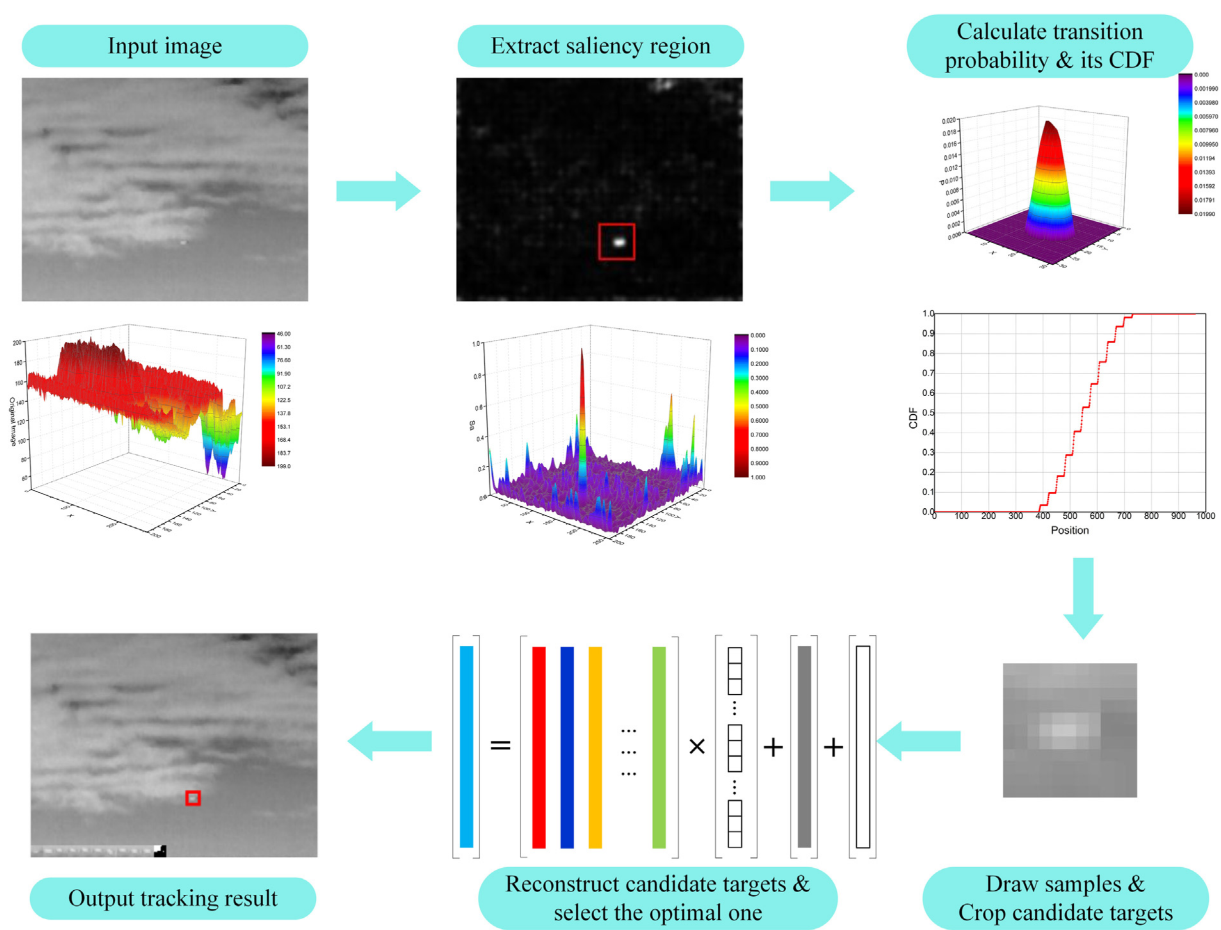

Fig. 1. Flow chart of the presented method.