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# In-frame and inter-frame information based infrared moving small target detection under complex cloud backgrounds

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## HIGHLIGHTS

- Presented method is based on both in-frame and inter-frame information of infrared moving small target.
- Several novel filters are designed to suppress background in spatial domain.
- Two saliency detections are proposed to highlight target in frequency domain.
- Intensity and spatial distance criteria are used to eliminate false alarms for the single frame.
- Differences of motion features are selected to conduct false alarm suppression for consecutive frames.

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## ABSTRACT

Infrared moving small target detection under complex cloud backgrounds is one of the key techniques of infrared search and track (IRST) systems. This paper proposes a novel method based on in-frame inter-frame information to detect infrared moving small targets accurately. For a single frame, in the spatial domain, a directional max-median filter is developed to make a pre-processing and a background suppression filtering template is utilized on the denoised image to highlight target. Then, targets in cloud regions and non-cloud regions are extracted by different thresholds according to a cloud discrimination method so that a spatial domain map (SDM) is acquired. In the frequency domain, we design an $\alpha$-DoB band-pass filter to conduct coarse saliency detection and make an amplitude transformation with smoothing processing which is the so-called elaborate saliency detection. Furthermore, a frequency domain map (FDM) is acquired by an adaptive binary segmentation method. Lastly, candidate targets in single frame are extracted by a discrimination based on intensity and spatial distance criteria. For consecutive frames, a false alarm suppression is conducted on account of differences of motion features between moving target and false alarms to improve detection accuracy again. Large numbers of experiments demonstrate that the proposed method has satisfying detection effectiveness and robustness for infrared moving small target detection under complex cloud backgrounds.



## 1. Introduction

Infrared small target detection is one of the key techniques in IRST systems, infrared early warning systems, accurate guiding systems, satellite remote sensing systems and so on. Performance of the whole system usually depends on the accuracy of target detection results to a great extent. Because of the special imaging mechanism, infrared small targets show many inherent attributes which also make detection techniques very hard. For example, target sizes are usually small (vary from $2 \times 2$ to more than $10 \times 10$ pixels) due to the long imaging distance; small targets have little texture information and commonly have an irregularity of shapes; contrast between target and background has a large variety on account of differences of target types and imaging distances. Furthermore, real targets may be immersed in the background when large quantities of noise and complex cloud cluttering exist, which generates a big technical problem of detection. Hence, it is always a challenge for us to detect infrared moving small targets accurately, especially in complex cloud backgrounds. Although large numbers of experiments have been conducted in the past decades of years, it is still a research project to be developed further.

So far, many kinds of algorithms have been applied to infrared small target detection under various complex backgrounds. They

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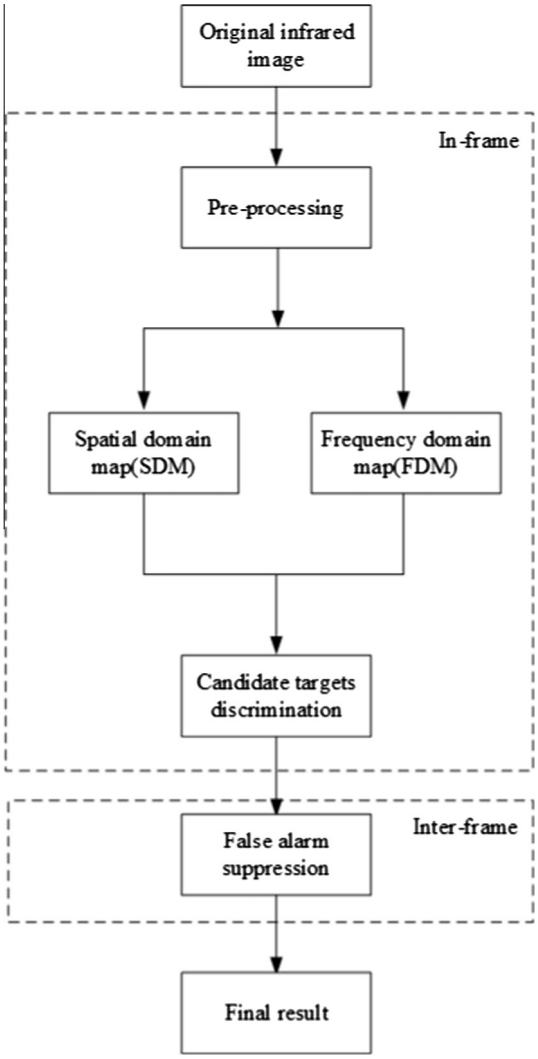


**Fig. 1.** Schematic of the presented method.

can be roughly classified into the following categories: methods based on filtering, wavelet, mathematical morphology, artificial intelligence and so on. Filtering is the most widely used detection method. For example, Peng and Zhou [1] proposed a real-time target detection method using a high-pass filtering template; Gu et al. [2] developed a kernel-based non-parametric regression method; Cao et al. [3] introduced two-dimensional least mean square (TDLMS) filter into small target detection. These algorithms are aimed to remove the background according to intensity differences. They usually have specific filtering templates and do well in real-time processing in hardware, but the result is usually not accurate. Wavelet is also widely applied in small target detections. Ye et al. [4] proposed a maximal coefficient based wavelet. In addition, directional wavelet [5], morphological wavelet [6], and so on, were all developed and studied by researchers. Mathematical morphology theory is another important bunch in small target detection domain. These operations, like all kinds of top-hat transformations [7], can enhance regions of interest in infrared images efficiently, but are sensitive to dim target and clutter background. Training based methods in the pattern recognition domain, like a support vector machine based supervised learning method presented by El-Naqa et al. [8], need passive and negative samples marked artificially to calculate the optimal separating hyper-plane. This kind of methods not only have complex operations, but also have a poor robustness on different testing sequences.

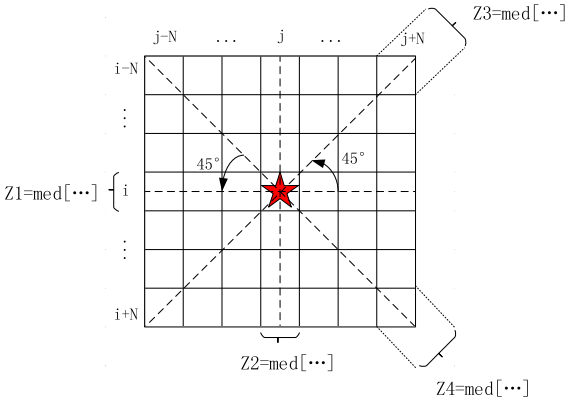


**Fig. 2.** Template structure of directional max-median filtering.

Controlling false alarm rate is the most troublesome problem because motion features are seldom taken into consideration. This paper presents a novel method of infrared moving small target detection under complex cloud backgrounds which is based on in-frame and inter-frame information. This method stems from the following reasons: firstly, intensity of a real target is higher or lower than that of pixels in the neighborhood, which can be seen as an intensity outlier; secondly, contrast between target and neighboring pixels in cloud regions is comparatively lower than that in non-cloud regions; thirdly, infrared small target has visual saliency, based on which target detection can be transformed into saliency detection in the frequency domain; fourthly, sources of false alarms in spatial domain and frequency domain are quite different, which results in different intensity information and spatial position information; finally, motions of random noise in consecutive frames satisfy the Gaussian distribution while those of target may form a regular trajectory, which can be the basis of inter-frame false alarm suppression.

The rest of this paper is organized as follows: in Section 2, procedures of this method will be introduced. Theories of our work are described in detail in Section 3. Performances of our method and other baseline methods are analyzed in Section 4. Then, in Section 5, a conclusion of this work is made.

## 2. Framework

Our method includes five main steps and the flow chart is shown in Fig. 1.

Step 1: Develop a directional max-median filter to remove the outstanding noise and preserve the target as much as possible.
Step 2: Acquire SDM which contains candidate targets of the spatial domain by making several kinds of spatial filtering.
Step 3: Extract FDM which contains candidate targets of the frequency domain by two saliency detections.
Step 4: Pick up targets of the single frame from candidate ones in SDM and FDM according to the correlation of intensity and spatial position.
Step 5: False alarm suppression is conducted in consecutive frames and export final detection results.

## 3. Theory

In this section, we discuss the proposed method in detail. The whole detection process can be divided into five main parts: preprocessing, SDM calculation, FDM calculation, candidate targets discrimination and false alarm suppression.