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A novel infrared small moving target detection method based on tracking interest points under complicated background

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HIGHLIGHTS

- A moving target detection method based on tracking interest points is proposed.
- A novel clustering method named as *R*-means is proposed.
- These interest points are divided into target points and background points.

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ABSTRACT

Infrared moving target detection is an important part of infrared technology. We introduce a novel infrared small moving target detection method based on tracking interest points under complicated background. Firstly, Difference of Gaussians (DOG) filters are used to detect a group of interest points (including the moving targets). Secondly, a sort of small targets tracking method inspired by Human Visual System (HVS) is used to track these interest points for several frames, and then the correlations between interest points in the first frame and the last frame are obtained. Last, a new clustering method named as *R*-means is proposed to divide these interest points into two groups according to the correlations, one is target points and another is background points. In experimental results, the target-to-clutter ratio (*TCR*) and the receiver operating characteristics (ROC) curves are computed experimentally to compare the performances of the proposed method and other five sophisticated methods. From the results, the proposed method shows a better discrimination of targets and clutters and has a lower false alarm rate than the existing moving target detection methods.

1. Introduce

Infrared (IR) technology has a wide application in the areas of pre-warning, precision-guide and so on, because it can be used in all kinds of weather. The ability to detect targets in infrared images or videos has a major impact on these applications. In these applications targets are always far away from imaging equipment, as a result, targets in the sensed IR images or videos are usually very dim, small and shapeless. Besides, IR images have a low Signal-to-Noise Ratio (SNR) and the backgrounds of targets are complicated and chaotic. All these factors make this problem far from being solved. According to the state of imaging equipment, the background of infrared image is mainly divided into static background and dynamic background. Static background is the background of the image captured by fixed imaging equipment. And the image with dynamic background is obtained by non-fixed imaging equipment. According to the complexity of background, the background of infrared image can be divided into homogeneous background and complicated background.

Recently, there has been a surge of interest in infrared dim and small targets detecting. The leading approaches for this problem can be divided into two classes: one is to detect targets using only a single frame of image and this kind of algorithms is simple and only suitable for target detection in images with homogeneous background, such as algorithms based on high-pass filter, morphological operators [1,2] and template matching [3]. These algorithms either use the characters of small target to detect the target directly or to estimate the clutter background for target enhancement, and work well under homogeneous background. The more complicated the background is, the higher the detection false alarm becomes.

Another class uses video sequences to detect moving targets. Because of the continuity and regularity of moving targets, this

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kind of algorithms can deal with images with more complicated background. Elgammal et al. [4] proposed a background subtraction approach based on a non-parametric background model which can handle situations where the background of the scene is cluttered and not completely static but contains small motions such as tree branches and bushes. This model estimates the probability of observing pixel intensity values based on a sample of intensity values for each pixel, so it can adapt quickly to changes in the scene which enables very sensitive detection of moving targets. Zhang et al. [5] developed a three-dimensional wide-to-exact search directional filtering (3DWESDF) algorithm for detecting and tracking a weak moving dim target against a cluttered background in real infrared (IR) image sequence. In this paper, a newly preprocessing method termed three-dimensional spatial–temporal adaptive prediction filter (3DSTAPF) is used here to suppress complex cluttered background. Then a novel 3DWESDF which is composed by three-dimensional wide search directional filter (3DWSDF) and three-dimensional exact search directional filter (3DESDF) is proposed to increase the target energy. This algorithm is so complicated and has a high computational cost. Ji et al. [6] proposed an algorithm based on wavelet transform to detect the small moving target in infrared image sequences with the dynamic background. Based on the registration of four continuous frame images, these images are processed by the 1-D wavelet transform to separate the target from background. The target is enhanced by multiplying the images contain the moving target by pixel. Then the moving small target is detected after segmentation. Deshpande et al. [7] proposed a moving target detection method based on Max-mean and Max-median filters. This paper investigates the usefulness of Max-mean and Max-median filters in preserving the edges of clouds and structural backgrounds, which helps in detecting small-targets. Many background clutters can be removed from the image by subtracting the Max-median/Max-mean filtered image from the original image. A threshold step is incorporated in order to limit the number of potential target pixels. The threshold is based on the sum of means and standard-deviations computed over a small window in the subtracted images. The proportionality constant of the standard-deviations depends on the false alarm rate. Finally, the processed images of different frames are accumulated so that the moving target forms a continuous trajectory and can be detected by using the post-processing algorithm. But this method is not effective for dim target detection in IR sequences with low contrast. Yang et al. [8] proposed a temporal–spatial high-pass filter using adaptive Butterworth high-pass filter to detect a small moving target under a sea–sky complex background. This method uses the weighted information entropy (WIE) of IR images to adaptively decide the cutoff frequency of Butterworth high-pass filter which is used to discriminate target and clutters in frequency domain. The pixels' WIE can be obtained from its gray value, its probability, and its weight coefficient. Zhang et al. [9] presented an algorithm for detecting and tracking dim moving point target in IR image sequence with low Signal-to-Noise Ratio (SNR). Original images are preprocessed using temperature nonlinear elimination and Top-hat operator, and then a composite frame is obtained by accumulating the processed images of several continuous frames. Finally the target trajectory is tracked under the condition of constant false-alarm probability (CFAR). Nie et al. [10] proposed a wiener filter based infrared small moving target detecting and tracking method. This paper models the background in infrared image after analyzing the background properties, and then investigates an adaptive background suppression algorithm based on Wiener method. The false targets are eliminated after target segmentation. The accumulative times statistics (ATS) of target appearance and path statistics (PS) are constructed based on the continuity and regularity of the target motion. Then the moving targets can be detected successfully with multi-level hypothesis testing (MHT). Bae [11] introduced a spatial and temporal moving target detection method using spatial bilateral filter (BF) and temporal cross product (TCP) of temporal pixels in infrared image sequences. In order to exactly predict the background without targets, the proposed BF adjusts its standard deviation by using the TCP value of the pixel processed spatially. The spatial target image (STI) is obtained by subtracting the predicted image from the original image. Thus, the spatial and temporal target image (STTI) is achieved by multiplying the STI and the temporal target image (TTI) which is the summation of TCP values of temporal pixels in spatial coordinates, and then targets are finally detected in STTI.

But one common restriction of these algorithms mentioned above is that the static background is needed. This narrows the application of these algorithms down. Especially in the application of precision-guide, the imaging equipment is fixed in the missile and dose a rapid motion with the missile. So at present, a group of infrared dim and small target detection methods under variational and complicated background are needed urgently. We propose a novel infrared small moving target detection method based on tracking interest points under complicated background. Firstly, DOG filters are used to detect a group of interest points (including the moving targets). Secondly, a sort of small targets tracking method, inspired by Human Visual System (HVS), is used to track these interest points for several frames. Then the relations between interest points in the first frame and interest points in the last frame are obtained. Last, according to the relations, a new clustering method named as *R*-means is proposed to divide these interest points into two groups, one is target points and another is background points.

The outline of this paper is organized as follows. Section 2 gives a detailed description of the proposed method. The parameters analysis of the proposed method and the experimental results which include the comparisons between the proposed method and the other five sophisticated methods are given in Section 3. Section 4 makes a conclusion to this work.

2. The proposed methods

In this section, a novel detection algorithm of infrared small moving targets is proposed. The process of this algorithm includes three steps. Fig. 1 gives the framework of this method. The following subsections give a detailed description of each part of the algorithm respectively.

Step 1: Extracting interest points with the means of DOG filters in the first frame. The moving targets should be included in these interest points.
Step 2: Tracking these interest points for several frames in order to obtain the relations of these interest points in the first frame and the last frame. The relations are marked by bidirectional arrows.
Step 3: Clustering these interest points into two groups, one is the target points and another is the background points, according to the relations.

2.1. Interest points detection

Interest points mentioned in this paper are defined as small bright dots, so they can be detected by DOG filters. The 2-D Gaussian function is defined as Eq. (1),

$$G(x,y,\sigma) = (1/2\pi\sigma^2)\cdot\exp(-(x^2+y^2)/2\sigma^2) \quad (1)$$

where σ is the standard deviation of the Gaussian. The difference of two Gaussians with different standard deviations forms a DOG filter as depicted in Eq. (2),