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Multiscale patch-based contrast measure for small infrared target detection

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ABSTRACT

Infrared (IR) small target detection plays an important role in IR guidance systems. In this paper, a biologically inspired method called multiscale patch-based contrast measure (MPCM) is proposed for small IR target detection. MPCM can increase the contrast between target and background, which makes it easy to segment small target by simple adaptive thresholding method. Experimental results on three sequences demonstrate that the proposed small target detection method can not only suppress background clutter effectively even if with strong noise interference, but also detect targets accurately with low false alarm rate and high speed.

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1. Introduction

Small infrared (IR) target detection is one of the most important techniques in passive defense systems [1–5]. On the one hand, small targets are usually submerged in background clutter and heavy noise. On the other hand, the small targets do not have concrete shapes and textures, so there is no obvious feature and useful texture information can be used. Hence the small IR target detection is an extremely challenging task [6,7].

A lot of small IR target detection methods have been designed over the last two decades [8–11]. Existing methods focus mostly on how to "pop out" (enhance) the target and "neglect" (suppress) background regions as much as possible [12,8]. Existing techniques could be divided into two categories: detection based on single frame [13] and sequential frames, respectively [14]. The sequential detection methods need more prior information and usually based on the single frame detection. Consequently, sequential detection methods have limitation in military applications [14]. The detection based on single frame is of great importance due to the nature of early-warning [15]. A lot of conventional methods have been used in single frame detection [15], such as Top-hat filter [16], max-mean/max-median filter[17], high-pass filter, matched filter, and wavelet transformation [18,19]. However, these methods would result in serious false alarms and degraded detection performance when the signal-clutter ratio (SCR) is low. In the small target detection, the edges of the targets can be used [20–22]. For instance, Laplacian of Gaussian (LoG) filters [23], an edge detector, has been used to detect small targets [24,20]. Targets can be enhanced and clutters can be suppressed significantly by LoG. However, the edge around cloud clutter can generate false detections, and the horizontal edge line due to a heterogeneous background produces false detections [25]. Recently, sparse representation [26] has been used for small target detection. Zhao et al. proposed sparse representation-based method for small target detection [27]. But it cannot describe the background very well. Zhao et al. then proposed the principal curvature-based method for small target detection [28]. However, this approach is not suitable for very dim and small targets.

Recently, a new trend towards imitating robust human visual system (HVS) for promoting the performance of small IR target detection has been emerging [20,1,29]. HVS-based methods have shown great potential in various target detection tasks, however, they still need to be improved. For example, Wang et al. developed an efficient method called average gray absolute difference maximum map (AGADMM) for multiscale small target detection [30]. But it roughly characterizes the background. Kim et al. proposed a HVS contrast mechanism-based detection algorithm, which is capable of increasing target intensity as well as suppressing background clutter and noise [20]. However, this method need to detect sea-sky line. In order to deal with this problem, we proposed a small IR target detection method called local contrast measure (LCM) [1]. However it assumes that the targets are brighter than the background. Subsequently, Han et al. proposed the improved

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LCM (ILCM) to improve detection rate and reduce false alarm rate, where the HVS size-adaptation process and attention shift mechanism are adopted [31]. But it smooths the targets. Shao et al. proposed an improved algorithm based on the contrast mechanism of HVS, which exploits LoG filter to deal with input image and processes the filtered image with morphological method in all directions [15]. A novel method called accumulated center-surround difference measure (ACSDM) was also proposed to detect small IR targets in heavy clutter [32]. But this method is very time-consuming.

The current research shows that defining the contrast between the target and background is one of the most important tasks in small IR target detection [33]. Consequently, a new local contrast measure method is defined in this paper from the perspective of image patch difference. Experimental results demonstrate that the proposed method has better detection performance comparing with several widely used methods. The contributions of this paper can be summarized as follows.

- An effective local contrast measure method called multiscale patch-based contrast measure (MPCM) is presented. The roles of the MPCM are twofold: the target of interest is enhanced, while complicated clutter and noise is adaptively suppressed. It can enhance the dark and bright targets simultaneously.
- Based on MPCM, a small IR target detection algorithm is designed. Experimental results show that the proposed method is effective with respect to detection accuracy, and faster than other methods.

This paper is organized as follows. Related work is given in Section 2. Section 3 provides a detailed description of the proposed MPCM. Based on MPCM, a new small IR target detection method is presented in Section 4. Although the proposed detection method is simple, it can achieve better performance. Section 5 presents the experimental results on three IR image sequences to demonstrate the effectiveness of the proposed target detection method. Finally, the conclusions and future works are provided in Section 6.

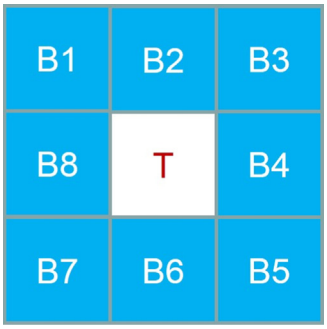

Fig. 1. The nested structure.

2. Related work

The concept of local contrast has been widely used in pattern recognition community [34,35]. Chen et al. proposed an effective measure called LCM for small target detection [1]. In LCM, a sliding window moves on the IR image from up to down and left to right pixel by pixel. Then the sliding window can be divided into 9 (3×3) subwindows. Note that the central subwindow denoted by "0" is a region where the target could appear. The gray mean of the ith subwindow is denoted by m_i ($i = 1, 2, \ldots, 8$), that is,

$$m_i = \frac{1}{N_u} \sum_{j=1}^{N_u} I_j^i, \tag{1}$$

where N_u is the number of the pixels in the ith subwindow, and I_j^i is the gray level of the jth pixel in the ith subwindow. Hence, the contrast between central subwindow and the ith surrounding subwindow is defined by

$$c_i = \frac{L_0}{m_i}, \tag{2}$$

where L_0 represents the maximum of the gray value of the central subwindow.

In IR image, target is usually brighter than that of their neighborhoods. So the LCM is defined as follows:

$$C = \min_i L_0 \times c_i = \min_i L_0 \times \frac{L_0}{m_i} = \min_i \frac{L_0^2}{m_i}. \tag{3}$$

This definition means that the larger the C is, the more likely a target appears. If $(L_0/m_i) = (L_{0'}/m_{i'})$, then the larger of L_0 and $L_{0'}$ is more likely to correspond to a target.

In fact, the sizes of small targets are changing. In the ideal case, the size of subwindow should be the same as the target size. In order to deal with this problem, multiscale LCM has been defined. Sequently the ILCM is proposed to pursuit a good performance in the detection rate, false alarm rate, and speed simultaneously [36]. The proposed MPCM is an improved version of the LCM too.

3. Multiscale patch-based contrast measure

In human visual streams, contrast is one of the most important quantities [20]. Using this mechanism, we can perceive the world similarly regardless of the huge changes in illumination over the day or from place to place. On the other hand, IR target has the signature of discontinuity comparing with its neighborhood but no obvious structural information [1,31]. For these reasons, designing effective target enhancement method based on contrast mechanism is a possible way to promote the performance of the small target detection system. In this paper, a small IR target enhancement method inspired by the contrast mechanism of HSV is proposed. Firstly, local contrast of each pixel is computed by the defined patch difference on each scale, then the final contrast map consisting of each pixel's MPCM is obtained by taking the

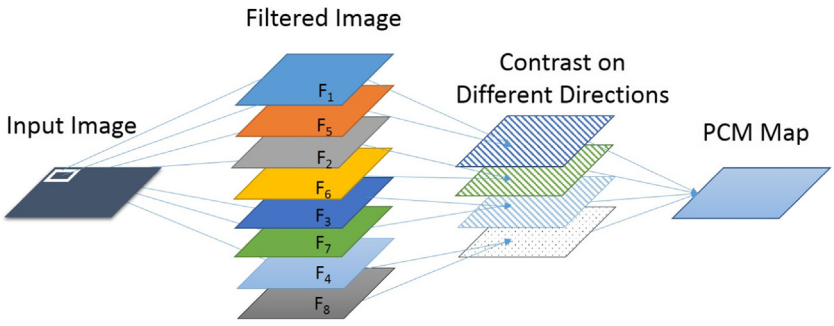

Fig. 2. The flowchart of PCM.

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