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Temporal noise suppression for small target detection in infrared image sequences

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ABSTRACT

Target detection algorithms based on temporal profiles have been showing excellent performance in detecting moving small targets in infrared image sequences. However, the temporal noise presented in infrared image sequences may change the form of temporal profiles, causing a degradation of detection performance of target detection algorithms that are performed on temporal profiles. To address the issue, a temporal noise suppression approach is proposed. First, we will show the effect of temporal noise on target detection algorithms based on temporal profiles. Then, a temporal noise suppression approach is proposed and its impact on temporal profiles is analyzed. Next, the execution procedure of the proposed approach is given. Finally, the proposed approach is evaluated and compared with several conventional target detection algorithms based on temporal profiles. The results show that our approach can significantly improve the detection performance of target detection algorithms based on temporal profiles.

1. Introduction

Detecting small targets from infrared image sequences is of great importance both in civil and military fields [1–3]. Since the detected target is far away from the infrared detector, it only occupies several pixels in infrared image sequences and has no shape or texture features, making target detection algorithms complicated and vulnerable [4–6].

During last two decades, many target detection algorithms have been designed to deal with the issues [7–9]. In general, the target detection algorithms can be divided into two categories, the detect before track (DBT) algorithms and the track before detect (TBD) algorithms. DBT algorithms focus on detecting targets in single frame, and then track them using temporal associations [10,11]. While TBD algorithms focus on tracking all pixels in a short period of time, and then detect targets based on the temporal differences of targets and background [12,13]. TBD algorithms are proposed to encounter situations where targets are too dim to detect in one single frame. Many fundamental works of TBD algorithms are done by Silverman *el al*, coming from Rome laboratory [14,15]. Their works indicate that damped sinusoid filters [16,17], continuous wavelet transform [18], and hypothesis testing [19,20] are effective in detecting dim point targets from evolving clutter in infrared image sequences. Subsequently, Lim *el al* developed a simple and high efficient detector by using the means and variances of temporal profiles to distinguish target and background pixels [21]. Unfortunately, temporal profiles of background, especially the cloud edge, have similar means and variances to those of target temporal profiles. This is commonly caused by the large fluctuations on background temporal profiles. In Ref. [22], we found that the large fluctuations on cloud edge temporal profiles can be removed by using connection line of the stagnation points (CLSP). Lately, the CLSP algorithm are examined and improved in Ref. [23–25]. Recently, many new methods are proposed for small target detection based on temporal profiles [26,27].

Intrinsically, target detection algorithms based on temporal profiles detecting point-like targets mainly depend on the form of temporal profiles. While, the presence of temporal noise may change the form of temporal profiles, which will reduce the detection performance of some target detection algorithms. In this paper, we propose a temporal noise suppression approach to promote the detection performance of target detection algorithms based on temporal profiles. We first analyze the effect of temporal noise. And then propose a Gaussian filter for temporal noise suppression. The proposed approach is tested via two infrared image sequences. The experimental results show that the suppression of temporal noise in infrared images can significantly improve the detection performance of the target detection algorithms based on temporal profiles.

This paper is organized as follows. Section 2 discusses temporal profiles of targets and background in infrared image sequences. Section 3 analyzes the effect of temporal noise on target detection

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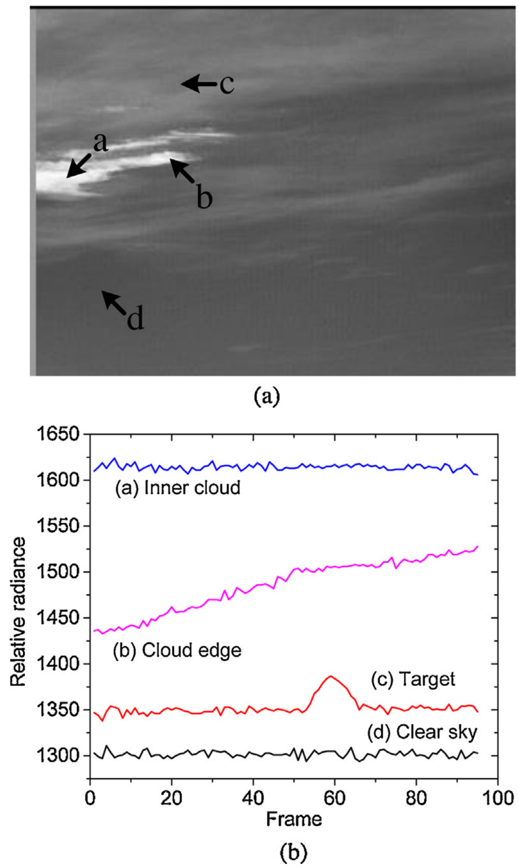

Fig. 1. Temporal profiles of a target, clear sky, inner cloud, and cloud edge pixel. (a) One frame of an IR image sequence. (b) Temporal profiles.

algorithms based on temporal profiles. Section 4 illustrates the proposed approach. The execution of the proposed approach is given in Section 5. In Section 6, the proposed approach are evaluated and discussed. Finally, we conclude in Section 7.

2. Temporal profiles of infrared image sequence

By using a focal plane array (FPA) constantly monitoring a scene, one can get a temporal profile from each pixel in a short period of time. The temporal profile indicates variation of the pixel values in this period of time. When a target moves across a pixel, a pulse-like signal is created on the temporal profile of the pixel. The width of the pulse will be inversely proportional to the target velocity. Its height above (or depth below) background depends on its differential radiance with respect to the background. This model is based on the assumption that the target is very small (in the order of one pixel) and moving across a scene.

For clear sky background, the temporal profiles affected by targets can easily be discriminated. However, in practice there are also drifting and evolving cloud clutters in background. Temporal profiles produced by this drifting and evolving clutters may have similar temporal behaviors to those of targets, which will cause false alarms. Fig. 1 shows temporal profiles of a target, clear sky, inner cloud, and cloud edge pixels.

As shown in Fig. 1, pixels affected by clear sky or inner cloud background have temporal profiles that behave like a constant mean value plus white noise. Pixels affected by cloud edges will have less regular temporal behaviors. Pixels affected by small moving targets will have pulse-like shape on their temporal profiles, which are distinct from those of the cloud clutters and clear sky.

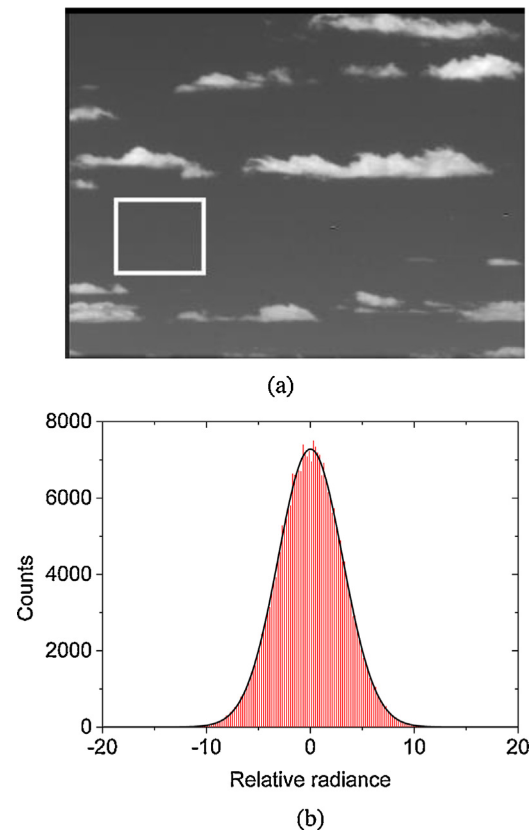

Fig. 2. Temporal noise in an infrared image sequence. (a) An infrared scene. (b) Temporal noise distribution.

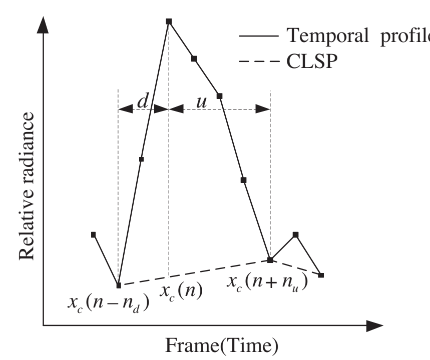

Fig. 3. Calculation of CLSP.

The principle of target detection algorithms based on temporal profiles is to extract temporal profiles with pulse-like signal from infrared image sequences. However, the target pulse signal on temporal profiles many have variational signature and can be easily contaminated by noise, making target detection algorithms complicated and venerable.

3. Temporal noise and its effect for target detection algorithms

3.1. Temporal noise in infrared image sequences

Temporal noise, coupled with useful signals, is an intrinsic composition of small target signals in infrared image sequences. Generally, temporal noise in infrared image sequences are mainly composed of thermal noise (sometimes Johnson or Nyquist noise), $1/f$ noise and others noise [28,29]. Thermal noise is generated by