Infrared Physics & Technology 76 (2016) 474–481

Contents lists available at ScienceDirect

Infrared Physics & Technology

journal homepage: www.elsevier.com/locate/infrared

An infrared small target detection algorithm based on high-speed local contrast method

Zheng Cui, Jingli Yang *, Shouda Jiang, Junbao Li

Department of Automatic Testing and Control, Harbin Institute of Technology, Harbin 150080, China

HIGHLIGHTS

- A novel framework inspired by Human Visual System is presented.
- Improve local contrast method to high speed local contrast method.
- The accuracy of HSLCM are analyzed.

ARTICLE INFO

Article history:
Received 29 October 2015
Revised 30 March 2016
Accepted 30 March 2016
Available online 4 April 2016

Keywords:
Small target detection
Human Visual System
High speed local contrast method
Machine learning

ABSTRACT

Small-target detection in infrared imagery with a complex background is always an important task in remote sensing fields. It is important to improve the detection capabilities such as detection rate, false alarm rate, and speed. However, current algorithms usually improve one or two of the detection capabilities while sacrificing the other. In this letter, an Infrared (IR) small target detection algorithm with two layers inspired by Human Visual System (HVS) is proposed to balance those detection capabilities. The first layer uses high speed simplified local contrast method to select significant information. And the second layer uses machine learning classifier to separate targets from background clutters. Experimental results show the proposed algorithm pursue good performance in detection rate, false alarm rate and speed simultaneously.

1. Introduction

Infrared (IR) small-target detection plays a critical role in large amounts of practical projects such as infrared warning and defense alertness, in which not only accuracy is needed but also robustness is required [1].

Various algorithms have been developed in the past few decades [2–4]. Conventional small target detection methods such as top-hat filter [2], max-mean/max-median filter [3], highpass filters based on LS-SVM [4], nonparametric regression method [5], Bayesian estimation [6] and two-dimension minimum mean square error (TDLMS) method [7] are widely used to reduce the background clutters. Guo et al. [8] proposed a model multi-channel adaptive mixture background model to detect the target. Beyond that, a series of simple and fast algorithm based on Fourier Transform was proposed, such as spectral residual (SR) [9], phase spectrum of quaternion fourier transform (PFT) [10], hypercomplex fourier transform (HFT) [11]. With regards to small target detection, frequency domain methods are quite different from other methods. They transform the airspace information to the frequency domain, and testing in the frequency domain. Some researchers use a variety of tracking algorithms to find the target, such as Kalman filtering [12]. In recent years, methods based on the Human Visual System have been proposed. HVS is a kind of layered image processing system consisting of optical system, retina and visual pathways, which is nonuniform and nonlinear. Researchers found that using HVS to detect target could get favorable results. That is because human vision has selective attention property which can help people search the salient target from complex unknown scene quickly and precisely without being influenced by complex background. For instance, Kim et al. [13] proposed a novel HVS contrast mechanism based detecting algorithm, which is capable of increasing target intensity as well as suppressing background clutter and noise.

Although numerous methods have been proposed, many of them may fail in certain circumstances [14]. When they were used in surveilling the ground by a helicopter or an unmanned aerial vehicle (uav), the targets have a recognizable shape [15] but a size of small target and easily overlapped by vegetation, roads, rivers, bridges. In view of the above reasons traditional algorithm produce huge false alarm rate in result. Algorithms based on machine

* Corresponding author.
E-mail address: jinglidg@hit.edu.cn (J. Yang).

http://dx.doi.org/10.1016/j.infrared.2016.03.023
1350-4495/

learning and neural networks are very effective for this kind of problems, but their computation speed cannot get guaranty. In order to design an appropriate method, a small target detection method inspired by the Human Visual System (HVS) has been designed in this paper.

2. Algorithm Inspired by HVS

2.1. Two layers framework

Here is the proposed framework inspired by HVS with two layers (see Fig. 1). The basic idea of Hierarchical framework is to ensure that the target is detected by the first layer, even if the background clutters were also included. Then, screen out the background clutters from the detection results of the first layer in the second layer. On the other hand, as a component of low-level artificial vision processing, it facilitates subsequent processing by reducing computational cost, which is a key consideration in real-time applications.

Small infrared target has no texture information or direction information but a higher brightness comparing with the background. That means contrast is the most important quantity encoded in the streams of visual system. With these considerations in mind, we select the contrast of brightness as a standard to decide whether pay attention to the areas or not. There are many methods based on brightness contrast. LCM algorithm is popular because of its high detection rate and lower false detection rate.

After that, some complex processing is performed to extract targets from candidate targets in the second layer.

In view of background clutters are similar to the infrared targets in the size and shape, it is very difficult for traditional algorithms to distinguish them [16]. The machine learning method, such as support vector machines (SVM) [17] classifier, making use of the statistical features of targets, which will be very effective for this kind of classification problem. Details will be described in Section 2.3.

We believe that these two stages would get a better balance algorithm [5].

2.2. First layer processing method

The details of HSLCM will be introduced in this section. Here are some basic definitions.

As shown in Fig. 2, u denotes the local region, and the area between u and v is the local background region. Moreover, the whole image (frame) is denoted by w. In this case, the windows v can move on the w.

Based on the aforementioned preparation, we can find that different image patches of size v can be obtained by moving the window v on the whole image. Furthermore, u can move on v. Consequently, the obtained image patches can be given by nine cells (see Fig. 3).

Through the analysis of LCM algorithm, we find out that several average operations and calculated pixel by pixel are both time consuming. The saliency c of LCM is defined as follows.

$$c_{LCM} = \frac{g_{max}^2}{m_{max}} \tag{1}$$

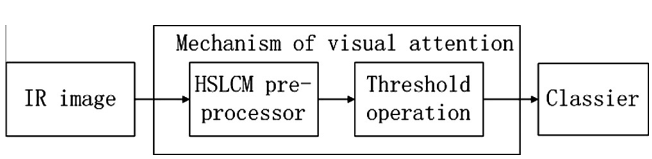

Fig. 1. The proposed framework inspired by HVS.

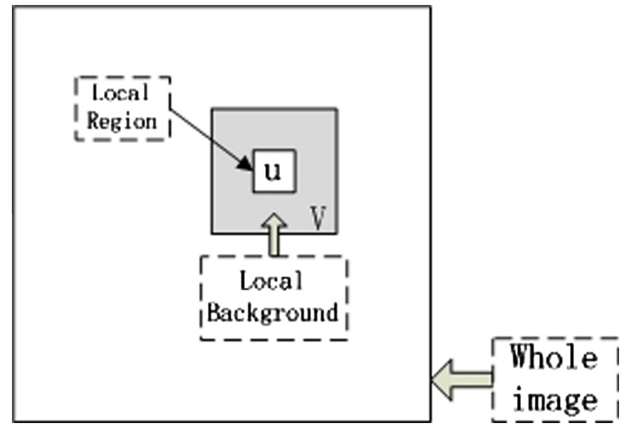

Fig. 2. Multiple windows.

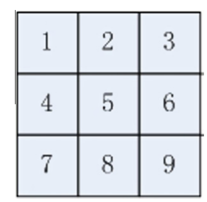

Fig. 3. Image patch obtained by sliding window.

g_{max} expresses the maximum of the gray value of the central cell and m_{max} express the maximum gray mean of the cells in the local background. In order to increase computation speed of LCM, we try to simplify the model. Like LCM, HSLCM describes a pixel (position) by generating a signal value.

Instead of the maximum gray mean, we use the average of all neighboring cells gray values to be the comparison, which makes the saliency c as follows.

$$c_{HSLCM} = \frac{g_{max}^2}{m_{all}} \tag{2}$$

m_{all} can be defined as follows.

$$m_{all} = \frac{1}{N} \sum_{i=1, i\neq 5}^{9} \sum_{j=1}^{N} g_{ij} \tag{3}$$

where N is the number of the pixels in the i_{th} cell and g_{ij} is the gray level of the j_{th} pixel in the i_{th} cell. Cell 5 is the central cell, so i is not equal to 5.

Obviously the new method could be much faster than the original method. Then we analyze amount of calculation of the two algorithms.

Assuming the size of the cell to $a \times a$ and image pixels to N. Each pixel has $a * a * 8$ times of add operation, 8 times of division operation and $a * a + 7$ times of comparison operations needs to be done for traditional LCM algorithm. But for HSLCM algorithm, only $a * a * 8$ times of add operation, 1 time of division operation and $a * a$ times of comparison operations needs to be done. Due to the 7 times of division operation and 7 times of comparison operations reduced for each pixel, the new method could be much faster than the original method. Therefore, the amount of calculation for a picture will reduced by $7 * N$ times of division operation and $7 * N$ times of comparison operations.

HSLCM algorithm also brings some influence to calculation accuracy which will be analyzed from the configuration of the target. Due to the optics point spread function (PSF) of the thermal imaging system at a long distance, there are often two kinds of