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Target extraction of blurred infrared image with an immune network template algorithm

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ABSTRACT

To extract targets from blurred infrared images efficiently, this paper presents a coordinated immune network template algorithm based on the coordination mechanism between innate immunity and adaptive immunity. First, the neighbourhood characteristics for every pixel in a blurred infrared image are computed as the template features of each pixel. Next, all of the pixels are divided into three sets according to their grey level values: a target set, a background set and a blurred set. Finally, the pixels in the target set and the background set are used for training the adaptive network, which can divide each blurred pixel into two classes: a target pixel or a background pixel. Experimental results on the hand trace infrared images verified that the proposed algorithm could efficiently extract targets from images and produce better extraction accuracy.

1. Introduction

Current latent handprint and trace evidence collection technologies are usually invasive and can be destructive to the original deposits in crime scene [1]. The temperature of the human hand is generally higher than that of its surroundings. A thermal trace of a hand will be left on surfaces if a human hand has touched its surroundings, and infrared images can describe the hand print trace. If infrared images are used to collect this hand print trace, the original deposits will not be destroyed [2].

If an infrared image of the trace is shot immediately after the hand leaves its surroundings, within one second, the image can reflect the touch contour (the contour of the hand trace) between the hand and its surroundings. However, in crime scenes, infrared images of the traces are generally shot after the hand has been gone for more than a second. In these circumstances, the infrared image will always be blurry because the grey level of its pixels will not accurately reflect the contour of the hand trace. Extracting the hand trace contour from this type of blurred infrared image is a challenging task [3].

The template extraction method, which uses template characteristics to extract targets from an image, has received considerable attention in recent years. Many template image extraction algorithms have been proposed in the literature. In general, template image extraction algorithms can be classified into two categories: boundary-based approaches and region-based approaches.

Boundary-based approaches extract targets from images based on abrupt (local) changes in intensity, but blurring and noise will result in deviations from the ideal shape. The Robert cross-gradient template [4] is one of the earliest attempts to use a 2-D template. The Prewitt template [5] is the simplest digital approximation of the partial derivatives using a template of size 3×3. The Sobel template [6] is developed from the Prewitt template. The Canny template [7] can produce high-quality edge lines with regard to their continuity, thinness and straightness. Deformable templates [8] design templates according to image features based on the results of the Canny template.

Because the boundary-based approaches are more sensitive to blurring and noise, recent template image extraction algorithms have used a region-based approach. Yoon [9] proposed a feature template that extracts various features from an image, such as the shape and texture, to design a template, but the user is asked to label a certain region as the initial foreground. To achieve automatic image extraction, Bhanu [10] proposed a functional template, which encodes templates using a collection of discriminating functions associated with image features; this method is guided by a genetic algorithm (GA) that suffers the defect of a local optimum tendency. To overcome this problem, Hua Bo [11] uses a spatial matrix to describe the spatial characteristics of an image and presents a spatial matrix template based on the mechanism of adaptive immunity. In addition, certain extraction methods based on immunity networks are proposed. Younis [12] proposed an artificial immune-activated neural network (AIANN), which uses neighbouring greyscale intensities of pixels to extract targets from an MRI image. Huang [13] proposed an immune kernel clustering network (IKCN), which uses the mean deviation of a template to

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extract SAR images. However, these immune network methods are all based on the mechanism of adaptive immunity. Medical studies indicate that the biological immune system consists of two components, innate immunity and adaptive immunity. There is a direct signal connection between innate immunity and adaptive immunity [14,15].

To extract a hand trace contour from a blurred infrared image, a coordinated immune network template algorithm (CINTA) is proposed in this paper. Inspired by the coordination mechanism between innate immunity and adaptive immunity, we design an immune network to achieve the extraction. First, the algorithm computes the neighbourhood characteristics for every pixel in a blurred infrared image as region features of each pixel. Next, the pixels are divided into three sets based on their grey level values: the target pixel set, the background pixel set and the blurred pixel set. Finally, the target and background pixel samples are used to train the immune network, which will detect blurred pixels and divide them into target pixel or background pixel categories. Experimental results indicate that the proposed method can improve the target extraction rate and reduce the extraction error rate.

The remainder of the paper is organised as follows: the next section presents our proposed coordinated immune network template algorithm. Section 3 introduces the blurred infrared image of hand trace. Section 4 presents the experimental results, and Section 5 presents the conclusions of this paper.

2. Coordinated immune network template algorithm

Artificial immune networks, derived from immune network theory, are important and effective models of artificial immune systems and have been successfully applied to data analysis [16], multimodal electromagnetic problems [17] and remote sensing [18]. However, these immune network methods are based on the mechanism of adaptive immunity and cannot reflect the overall mechanisms of the biological immune system. The biological immune system consists of innate and adaptive immunity. Innate immunity can recognise pathogens according to their primitive features and change the features of the pathogens. Adaptive immunity can recognise pathogens according to the new features of the pathogens.

Inspired by the coordination mechanism between innate immunity and adaptive immunity, we design a three-layer immune network, which contains an innate feature transformation layer, an innate recognition layer and an adaptive recognition layer, as shown in Fig. 1. The innate feature transformation layer uses a template to obtain the 3×3 neighbourhood characteristics for every image pixel. The innate recognition layer divides image pixels into three sets based on grey level: a target set, a background set and a blurred set. The adaptive recognition layer divides the blurred pixels into target pixel or background pixel based on neighbourhood characteristics.

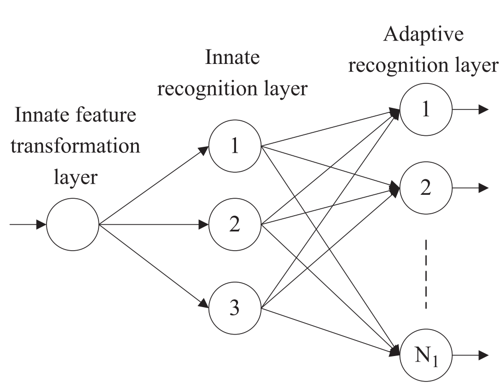

Fig. 1. The three layers immune network.

Fig. 2 shows the entire flow chart of our algorithm.

2.1. Innate feature transformation

For a blurred infrared image that has R rows and C columns, $f(u,v)$ is the grey level at pixel sample point (u,v), $u = 1,2,...R$, $v = 1,2,..C$. Suppose each pixel point (u,v) is a sample $x_i(i = 1,2,\cdots R \times C)$. Next, there are $R \times C$ pixel samples in the blurred infrared image.

The innate feature transformation layer uses a template $g_i(i = 1,2,\cdots R \times C)$ of the size 3×3 (as shown in Fig. 3) to obtain the neighbourhood characteristics of every sample point, and the sample point is the central point of the template. The neighbourhood characteristics of every pixel sample will be the template features of the pixel sample.

The template features include the template mean and the high frequency wavelet coefficient of the template.

The mean g_{i1} of template g_i is given by

$$g_{i1} = \frac{1}{9} \sum_{(s,t) \in g_i} f(s,t) \tag{1}$$

where $f(s,t)$ is the grey value at pixel (s,t).

When the wavelet resolution is 2, the wavelet coefficients of template g_i are given by

$$\begin{cases} d_{q,p}^0 = \sum_{l,k} \phi_{k-2q}\phi_{l-2p} g_i \\ d_{q,p}^1 = \sum_{l,k} \phi_{k-2q}\psi_{l-2p} g_i \\ d_{q,p}^2 = \sum_{l,k} \psi_{k-2q}\phi_{l-2p} g_i \\ d_{q,p}^3 = \sum_{l,k} \psi_{k-2q}\psi_{l-2p} g_i \end{cases} \tag{2}$$

where $d_{q,p}^0$, $d_{q,p}^1$, $d_{q,p}^2$, and $d_{q,p}^3$ are the high frequency coefficient, horizontal high frequency coefficient, vertical high frequency coefficient and diagonal high frequency coefficient, respectively. $\psi(x)$is a one-dimensional scaling function, where $q = 1,\ 2,\ 3$ and $p = 1,\ 2,\ 3$, k is an integer which determines the position of ϕ_{k-2q} along the q-axis, l is an integer which determines the position of

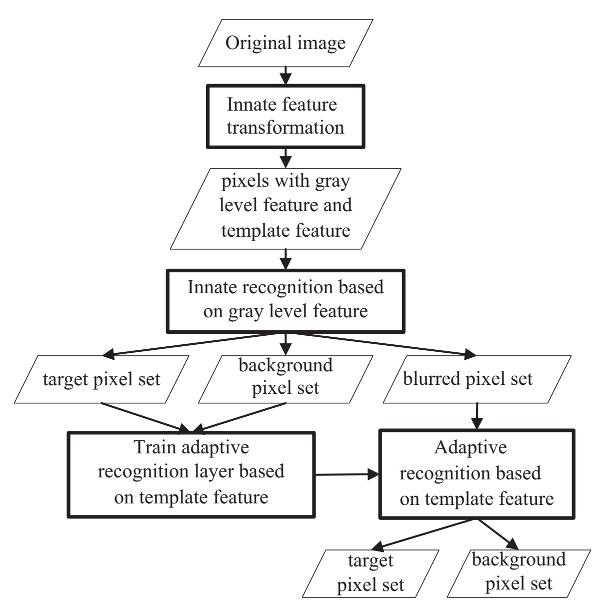

Fig. 2. Coordination immune network template extraction algorithm.