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Blurred trace infrared image segmentation based on template approach and immune factor

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HIGHLIGHTS

- An immune factor algorithm for segmenting blurred trace infrared images is proposed.
- I use innate immune factors to present the template characteristics of infrared images.
- Adaptive immune factors are used to segment blurred pixels with immune mechanism.

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ABSTRACT

This paper proposes an image segmentation method for blurred trace infrared images, exploring statistical properties of blurred infrared data to segment target regions. I consider the function of immune factors for blurred infrared image segmentation, combined to the template algorithm framework. First, all of the pixel antigens are divided into three classes by innate recognition factors: target antigens, background antigens and blurred antigens. Next, the innate presentation factors present template characteristics as new features for each antigen. Finally, target and background antigens are used for generating mature adaptive immune factors, and these mature factors will recognise each blurred antigen into two classes: a target pixel or a background pixel. Experimental results indicate that the superstring galaxy template algorithm can improve the target segmentation rate and reduce the segmentation error rate.

1. Introduction

Current latent handprint and trace evidence collection technologies are usually invasive and can be destructive to the original deposits in crime scene [1,2]. If infrared images are used to collect hand print traces of the criminal, the original deposits will not be destroyed [3]. However, in crime scenes, infrared images of the traces are generally shot after the criminal 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. Segmenting the hand trace contour from this type of blurred infrared image is a challenging task [4].

Template segmentation methods have been widely applied to extract targets from images in recent years. These existing template image segmentation algorithms proposed in the literature can be classified into two categories: gradient-based approaches and statistics-based approaches.

Gradient-based approaches extract pixel gradient features from images based on abrupt changes in pixel intensity. Such as the Robert cross-gradient template [5], the Prewitt operators [6], the Sobel operators [7], the Marr-Hildreth edge detector [8], the Canny edge detector [9] and the Deformable templates [10].

As the pixel gradient features extracted by the gradient-based approaches are more sensitive to blurring, statistics-based template algorithms have used templates to extract region statistical characteristics, including Feature template method [11] and Functional template method [12]. However, the regional features extracted by these statistics-based template algorithms cannot describe the differences between targets and background of a blurred infrared image. What's more, the classifier trained by these template algorithms cannot divide blurred pixels into a target pixel or a background pixel effectively.

In view of the problems mentioned above, plenty of template approaches and their corresponding improvements have been proposed to ensure the accuracy and rapidity of image segmentation. But there is still much work to be done to overcome their drawbacks and attempts at utilising knowledge on other domains,

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especially artificial intelligence, should be highly appreciated. Image segmentation can also be viewed as a classification problem based on features. More recently, intelligent template approaches, such as support vector machine (SVM) and artificial immune system have already been utilised successfully in image segmentation. The main advantage of the SVM-based image template segmentation comes from the fact that the segmentation of characteristic pixels is performed not in the original but in the higher dimensional feature space [13]. But, the technique is very complex and some undesired results occur frequently, and it must be trained using the sample features of target and background obtained from ground truth images [14]. Artificial immune template methods come from the immune mechanism of creatures and does not need the ground truth image to obtain sample features. However, this technique such as local entropy template [15], artificial immune-activated neural network method [16] and co-occurrence matrix clustering method [17], is inspired only by the adaptive immune mechanism. Medical studies indicate that the biological immune system consists of two components, innate immunity and adaptive immunity, and there is a direct signal connection between innate immunity and adaptive immunity [18,19].

To overcome these problems and segment hand trace blurred infrared images, a template algorithm based on immune factors is proposed in this paper, which inspired by the coordination mechanism between innate immune factors and adaptive immune factors. First, pixel antigens are divided by innate immune recognition factors into target, background and blurred ones, then, the antigens are presented by innate immune presentation factors based on the neighbourhood characteristics for every antigen pixel. Next, target and background antigens with neighbourhood characteristics are used to train semi-mature and mature adaptive immune factors. Finally, the blurred antigens are recognised by mature adaptive immune factors and divided into target antigen or background antigen categories. Experimental results indicate that the proposed method can improve the target segmentation rate and reduce the segmentation error rate.

The remainder of the paper is organised as follows: the next section presents my proposed immune factor template algorithm. Section 3 presents the simulation experiments, and Section 4 presents the conclusions of this paper.

2. Immune factor template algorithm

The biological immune system consists of innate immune factors and adaptive immune factors. Innate immune recognition factors can recognise pathogens according to their primitive features, and innate immune presentation factors can change the features of the pathogens. Adaptive immune mature factors can recognise pathogens according to the new features of the pathogens.

Inspired by functions of innate immune factors and adaptive immune factors, I design a template segmentation algorithm. Pixel antigens divided and presented by innate immune recognition factors and presentation factors, respectively. Presented target pixel antigens and background pixel antigens are used to train the adaptive immune factors based on neighbourhood characteristics, which will divide blurred pixel antigens into target or background ones. Fig. 1 shows the entire flow chart of my algorithm.

2.1. Function of innate immune recognition factors

Considering the temperature of human hand is always higher than the temperature of its surroundings, the grey level of trace pixels is always larger than the grey level of background pixels in trace blurred infrared images.

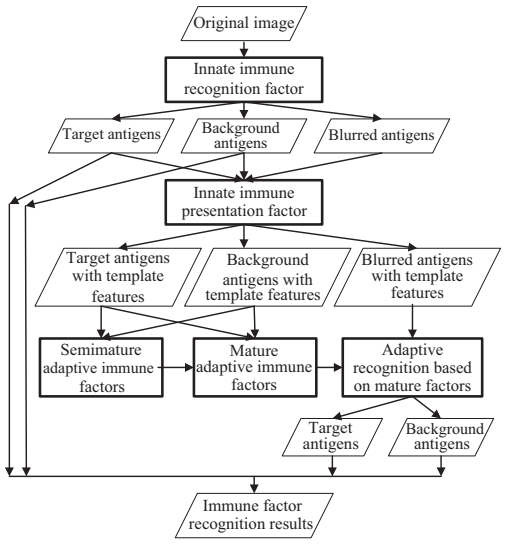

Fig. 1. The flow chart of immune factor template algorithm.

I design three innate immune recognition factors and compute their recognition thresholds. For a blurred trace infrared image that has R rows and C columns, $f(u, v)$ is the grey level at pixel antigen point (u, v), $u = 1, 2, \cdots R$, $v = 1, 2, \cdots C$. First, I classify blurred infrared image pixels by using maximal between-class variance method [20] to get a grey threshold k_1^* and two pixel sets, C_1' (with grey range $[0, k_1^*]$) and C_2' (with grey range $[k_1^* + 1, L - 1]$). Then, classify pixel set C_1' by using maximal between-class variance method to get a grey threshold k_2^* and two pixel sets, background pixel set C_4 (with grey range $[0, k_2^*]$) and blurred pixel set C_3 (with grey range $[k_2^* + 1, k_1^*]$); and classify pixel set C_2' by using maximal between-class variance method to get a grey threshold k_3^* and two pixel sets, blurred pixel set C_2 (with grey range $[k_1^* + 1, k_3^*]$) and target pixel set C_1 (with grey range $[k_3^* + 1, 255]$). Finally, thresholds of three innate immune recognition factors are set as k_1^*, k_2^*, k_3^*, and these factors divide pixel antigens into three antigen classes, target antigens, background antigens and blurred antigens. The class label of target antigen is 1, whose grey value ranges are $[k_3^* + 1, 255]$. The class label of background antigen is -1, whose grey value ranges are $[0, k_2^*]$. The class label of blurred antigen is 0, whose grey value ranges are $[k_2^* + 1, k_1^*]$ and $[k_1^* + 1, k_3^*]$.

2.2. Function of innate immune presentation factors

Suppose each pixel antigen (u, v) is a antigen sample x_i. Then, there are $R \times C$ antigen samples in the blurred trace infrared image. I design innate immune presentation factors to extract neighbourhood region features of each antigen sample.

Templates g_i ($i = 1, 2, \cdots R \times C$) of the size 5×5 are designed as innate immune presentation factors to obtain the neighbourhood characteristics of every antigen sample, these neighbourhood characteristics will be the presented template features of antigen samples. The presented template features of antigen samples include the extended spatial information g_{i1} and the low frequency coefficients of wavelet transform g_{i2}.

The extended spatial information g_{i1} of each presentation factor template g_i is given by

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

where $f(s, t)$ is the grey value of the antigen (s, t), $(s, t) \in g_i$. w_{st} is the weight, which depends on the similarity between antigen (s, t) and the centre antigen point (u, v) of the presentation factor template g_i. w_{st} is defined as