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Target extraction of banded blurred infrared images by immune dynamical algorithm with two-dimensional minimum distance immune field

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HIGHLIGHTS

- An immune dynamical algorithm with two-dimensional minimum distance immune field is proposed.
- The minimum distance immune field is presented and proved in two-dimensional space.
- An immune dynamical network is proposed by investigating the connection between nodes in the same immune layer.

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ABSTRACT

Banded blurred Infrared image segmentation is a challenging topic since banded blurred infrared images are characterized by high noise, low contrast, and weak edges. Based on the interconnected and networked collaborative mechanism between innate immune factors and adaptive immune factors, this paper presents an immune dynamical algorithm with two-dimensional minimum distance immune field to solve this puzzle. Firstly, using the original characteristics as antigen surface molecular patterns, innate immune factors in the first layer of immune dynamical network extract banded blurred regions from the whole banded blurred infrared image region. Secondly, innate immune factors in the second layer of immune dynamical network extract new characteristics to design the complex of major histocompatibility complex (MHC) and antigen peptide. Lastly, adaptive immune factors in the last layer will extract object and background antigens from all the banded blurred image antigens, and design the optimal immune field of every adaptive immune factors. Experimental results on hand trace infrared images verified that the proposed algorithm could efficiently extract targets from images, and produce better extraction accuracy.

1. Introduction

Current latent hand print and trace evidence collecting technologies are usually invasive and can be destructive to the original deposits in crime scene [1]. The temperature of human hand is always higher than the temperature of its surroundings. Thermal trace of hand will be left on the surface of its surroundings if 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, original deposits will not be destroyed [2].

If an infrared image of the trace is shot when the hand leaves its surroundings within 1 s, it can reflect the touching contour (the contour of the hand trace) between the hand and its surroundings. But in crime scene, the infrared image of the trace is always shot when the hand leaves for longer than 1 s, then it will be a blurred infrared image because the gray level of its pixels can not reflect the accurate touching contour. Extracting the hand trace contour from this kind of banded blurred Infrared images is a challenging topic since banded blurred infrared images are characterized by high noise, low contrast, and weak edges [3].

Many image target extraction algorithms for infrared images have been proposed in the literature. EtehadTavakol modeled and compared two color segmentation techniques for color segmentation of infrared (IR) breast images, K-means and fuzzy c-means [4]. Wang proposed an adaptive segmentation algorithm with automatic estimation of gradient histogram threshold according to the statistical characteristics and the least classified

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probability [5]. Song proposed a new algorithm for infrared image segmentation based on clustering combined with sparse coding and spatial constraints, the clustering algorithm is fused on the basis of sparse coding [6]. Liu proposed infrared segmentation method based on 2D histogram shape modification, which is realized by target information prior restraint after enhancing target information using plateau histogram equalization [7]. Kim present a region of interest (ROI) generation method specialized for nighttime pedestrian detection using far-infrared (FIR) images [8]. Kim propose an efficient method of extracting targets within a region of interest in non-homogeneous infrared images by using a principal component analysis (PCA) plane and adaptive Gaussian kernel [9]. Vlachos presented an algorithm for robust finger vessel pattern extraction from infrared images based on image processing, edge suppression, fuzzy enhancement, and fuzzy clustering [10]. In addition, there are also template image extraction algorithms, watershed algorithm, and Co-occurrence matrix clustering.

In recent years, In order to overcome the sensitivity of the traditional methods, neural network and other kinds of network model are applied to image target extraction. Kong presented a new image segmentation algorithm based on the pulse coupled neural network (PCNN) and histogram method by considering the features of targets in infrared images [11]. Han proposes a novel image segmentation method based on BP neural network, which is optimized by an enhanced Gravitational Search Algorithm (GSA) [12]. Pang introduce a novel parametric image model using the level set framework and an associated variational approach which simultaneously restores and segments images [13]. Proposed a canny operator-based method using PCNN (Pulse-Coupled Neural Network) for color image segmentation [14]. Present an automated segmentation method to segment nuclei in reflectance confocal images using a pulse coupled neural network algorithm [15]. Proposed a robust fuzzy radial basis function network (RFRBFN) technique, the proposed technique modified fuzzy RBF algorithm by incorporating spatial information and a smoothing parameter into its objective function, consequently, the proposed technique is able to cope with noise related variations [16]. In addition, there are also artificial immune activated neural network (AIANN) [17] and immune kernel clustering network (IKCN) [18]. However, the treatment objects of these methods are sharp images, and the fault tolerant fields of these methods are not been considered. In our previous study, we have given a preliminary algorithm, but we have not design the immune fields of the algorithm [19].

State-of-the-art segmentation algorithms exhibit poor performance for banded blurred infrared image, which is mainly because of the noise such as low contrast, non-uniform illumination, reflections, and among others. To address this issue, this paper draws lessons from interconnection and network synergy between innate immune factors and adaptive immune factors, proposes a new immune factor network with optimal immune field, including topological structure, node operational rule, and working algorithm of the network model. The design processes of these constituent parts of network model are closely related to characteristics of banded blurred infrared images.

2. Immune dynamical algorithm with optimal immune field

The global dynamics of the immune model is completely determined by two kinds of immune network, innate immune network and adaptive immune network. Although empirical applications of combinational immune boost such as dendritic boost of T cells or NKT cells are known, dynamical behaviors of immune response and immune network at the population level remain largely unknown. In our previous study, we have given a preliminary algorithm, but we have not describe the network relationship of innate immune, adaptive immune and immune system. In the present paper, we construct a mathematical model representing dynamical network behaviors of innate immune and adaptive immune (see Fig. 1).

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

2.1. Innate immune network

The innate immune network plays many different roles in the central nervous system during development and disease. The primary component of innate immunity network is the complement system, and its involvement in the central nervous system disorders is well documented. Innate immune network responses have been well studied in the holometabolous insect species, especially in dipteran (fruit fly, mosquito), and lepidopteron insects (moth species), as they are important to human health and agricultural production. By contrast, little is known about the immune network responses in hemimetabolous insects, despite the fact that their destruction of agricultural crops has become increasingly serious in recent years.

Banded blurred infrared images always have three parts of pixel areas with different pixel gray values, area contains high gray value pixels, area contains low gray value pixels, and area contains both high gray value pixels and low gray value pixels. A great portion factors in innate immune network can give fast reaction for many pixels, they can classify pixels according to the pixel gray value. Usually, f is used to represent a banded blurred infrared image, $f(u, v)$ represent the pixel gray value of pixel (u, v), $u = 1, 2, \ldots, R$ is the row of the infrared image, $v = 1, 2, \ldots, C$ is the column of the infrared image. As the first line of defense, the classify factors of innate immune network must classifying pixels quickly. j_i is the class label for the ith pixel in banded infrared image; θ_{k1} is the first threshold of the factors in innate immune network, which can divide the kth area in infrared image, and θ_{k1} is the second threshold.

$$\begin{cases} j_i = j_m(m=1) & \text{if } f_i \in [\theta_{11}, \theta_{12}] \\ j_i = j_m(m=2) & \text{if } f_i \in [\theta_{21}, \theta_{22}] \\ j_i = j_m(m=3) & \text{if } f_i \in [\theta_{31}, \theta_{32}] \end{cases}$$

At the same time, the classification result of factors should be accurate, because the wrong classification result cannot be corrected by other factors in innate immune network.

In the ideal situation, the three areas in banded blurred infrared images can be classified by the classify factors of innate immune network. In practice, however, pixels in the banded area cannot

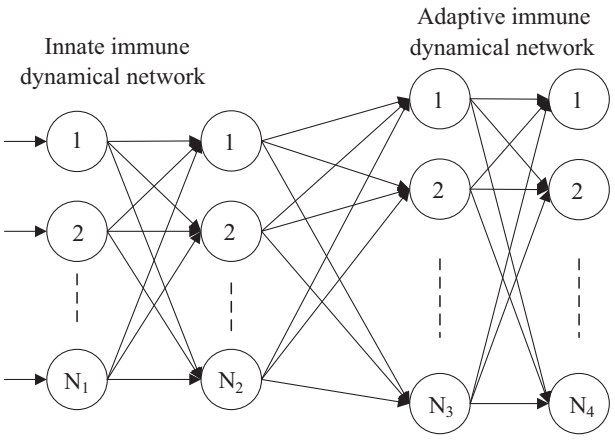

Fig. 1. The dynamical network behaviors of innate immune and adaptive immune.