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A hybrid Particle Chemical Reaction Optimization for biological image matching based on lateral inhibition

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ABSTRACT

In this paper, a hybrid Particle Chemical Reaction Optimization (PCRO) algorithm and lateral inhibition is proposed to solve the image matching problem. Lateral inhibition has the ability to enhance the characters of image, which can help to improve the accuracy of image matching. In order to overcome the shortcomings of basic Chemical Reaction Optimization (CRO) algorithm, we improve CRO by proposing PCRO which inspired from the thought of Particle Swarm Optimization (PSO). Comparative experimental results in image matching show that our proposed hybrid method performs much better than other bio-inspired algorithms.

1. Introduction

Image matching is a hot issue in the area of image navigation, image analysis, pattern recognition and computer vision [1]. The algorithms of image matching are variable which can be classified into two types. One is image statics based algorithm and the other is image properties based algorithm. Image statics based algorithm has an analysis of the similar properties of the original image and the template image. Image properties based algorithm depends on the quality and stability of the selected dynamic features [2–4].

Template matching is the process of searching for the right sub-image in the original image according to the template image. The cost of computing time in image matching is rather tremendous. So many optimization algorithms are proposed to solve this problem, such as Genetic Algorithm (GA) [5], Ant Colony Optimization (ACO) [6], Artificial Bee Colony (ABC) [7], Particle Swarm Optimization (PSO) [8], and Biogeography-Based optimization (BBO) [9]. In this paper Chemical Reaction Optimization is introduced to solve the image matching problem.

CRO is an optimization algorithm proposed by Lam and Li [10]. It mimics the interactions of molecules driving toward the minimum state. The manipulate agents are molecules. Each molecule contains a profile of several properties of molecule, which represents a solution of the optimization problem. PE is an objective function value of the optimization problem. KE is associated with solution's ability of jumping out of local optima. Molecules in the container interact with each other. There are four element reactions (on-wall ineffective collision, decomposition, decomposition and synthesis). With the conservation of energy, all molecules tend to have less PE. In the end, we can find the best solution.

CRO has its shortcomings. The speed of convergence in CRO cannot meet our demand. In order to overcome this disadvantage, we have a reference to the thought of Particle Swarm Optimization (PSO) algorithm [11]. We improve the algorithm by proposing PCRO which can improve our method a lot. So we can ensure that we can improve the ability to searching a better result.

In this paper, lateral inhibition is introduced into PCRO. The hybrid model is named as LI-PCRO. The electrophysiological research of lateral inhibition network was first introduced and verified by Hartline and his colleagues of Rockefeller University [12]. The lateral inhibition theory has been used in image edge extraction, image enhancement, etc. When the lateral inhibition is applied into the template matching, the characters of the original image and the template image are both enhanced. Even if the RGB image is changed into grayscale, we still can extract the edges with the lateral inhibition. The comparative experiment results show that our proposed LI-PCRO method has a better performance compared to other bio-inspired algorithms.

The rest of this paper is organized as follows: in Section 2, we describe CRO and our improving PCRO. In Section 3, we introduce

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the principle of lateral inhibition. In Section 4, we describe our proposed LI-PCRO and its process. Section 5 is the comparative experiments and the analysis. Section 6 concludes the paper by summarizing our result.

2. Chemical Reaction Optimization

CRO, an optimization algorithm for multimodal optimization problem proposed by Albert T.S. Lam and Victor O.K. Li, is inspired by the nature of chemical reactions [10,13]. In the process of CRO, molecules interact with each other intending to reach the minimum state of free energy. CRO captures this phenomenon of driving the resultant molecules to stable states with the lowest free energy through a sequence of elementary reactions

2.1. Molecules

CRO is designed to occur in a container including various types of molecules [14–16]. The manipulated agents of CRO are molecules. And each molecule contains a profile of several properties of molecule, which represents a solution of the optimization problem. The attributes of molecules are the molecular structure, potential energy (PE), kinetic energy (KE), the number of hits, the minimum hit number, and the minimum value [14]. PE is an objective function value of the optimization problem. KE is associated with solution's ability of jumping out of local optima. It can be the current tolerance for the molecule to hold a worse molecule structure with more PE than the existing one. Minimum hit number is the index of the molecule which has the best solution. It is also the criterion for decomposition reaction.

2.2. Elementary reaction operators

CRO has four types of elementary reaction, including on-wall ineffective collision, decomposition, intermolecular ineffective collision, and synthesis [15]. Only one molecule is involved in the reaction of on-wall ineffective collision and decomposition. However, two molecules are selected to interact with each other. Only one molecule reaction is related to the buffer energy. Of the four reactions, on-wall ineffective collision and inter-molecular ineffective collision are also called ineffective collisions. The two ineffective collisions explored its neighborhoods and contain solutions closed to the original ones. The other reaction (decomposition and synthesis) can generate the solutions further apart.

2.2.1. On-wall ineffective collision

An on-wall ineffective collision happens when a molecule hits on the wall of the container and bounces back. This reaction is not vigorous and the new molecule is quite similar to the original one. Thus, a small change to the solution can be adopted. And the change is allowed only if

$$PE_x + KE_x > PE_{x'_1} + PE_{x'_2}, \tag{1}$$

where PE_x and KE_x is the structure of the original one, and $PE_{x'_i}$ is the structure of the new molecule. If it happens, $KE_{x'}$ is calculated as following:

$$KE_{x'} = (PE_x + KE_x - PE_{x'}) \times q \tag{2}$$

where

$$q \in [KELossRate, 1], \tag{3}$$

$1 - q$ is the fraction of KE lost to buffer. In fact $PE_{x'_i}$ may be larger than PE_x, which means the new solution is no better than the original one. However, KE of the new molecule must be less than the original one. It represent that the ability of the molecules of going far away is less as the reaction happens again and again. So the possibility of get a molecule with more PE is less. The energy that KE loses to buffer can be used to support decomposition.

2.2.2. Decomposition

Decomposition occurs when one molecule decomposes into two molecules or more. We assume that the molecule break into two molecules. The decomposition reaction is quite vigorous and the structures of the two new molecules are quite different from the original one. This can help us jump out of local minima when we finish the local search and cannot find a better solution for a long time. Decomposition is happen when the molecule has sufficient energy to satisfy

$$PE_x + KE_x > PE_{x'} + KE_{x'}, \tag{4}$$

when (4) is not satisfied, we can use the energy in buffer to support the reaction. So the condition becomes

$$PE_x + KE_x + buffer > PE_{x'_1} + PE_{x'_2}. \tag{5}$$

If (4) is satisfied, the decomposition occurs. We contains the new KE by

$$KE_{x'_1} = (PE_x + KE_x - PE_{x'_1} - PE_{x'_2}) \times \eta, \tag{6}$$

$$KE_{x'_2} = (PE_x + KE_x - PE_{x'_1} - PE_{x'_2}) \times (1 - \eta). \tag{7}$$

If (5) satisfied then we can get the new KE by

$$KE_{x'_1} = (PE_x + KE_x - PE_{x'_1} - PE_{x'_2} + buffer) \times \eta_1 \times \eta_2, \tag{8}$$

$$KE_{x'_2} = (PE_x + KE_x - PE_{x'_1} - PE_{x'_2} + buffer - KE_{x'_1}) \times \eta_3 \times \eta_4 \tag{9}$$

where $\eta_1, \eta_2, \eta_3, \eta_4$ are randomly generated from the interval [0,1].

2.2.3. Inter-molecular ineffective collision

The inter-molecular ineffective collision occurs when two or more molecules involved in this collision and then separate (assume two molecules involved). Similar to the on-wall ineffective collision, the inter-molecular ineffective collision is not vigorous and the new molecular structure is generated from the neighborhood of the original two molecules. The change is allowed only if

$$PE_{x_1} + PE_{x_2} + KE_{x_1} + KE_{x_2} > PE_{x'_1} + PE_{x'_2}, \tag{10}$$

where the corresponding KE are determined by

$$KE_{x'_1} = (PE_{x_1} + KE_{x_1} + PE_{x_2} + KE_{x_2} - PE_{x'_1} - PE_{x'_2}) \times \eta, \tag{11}$$

$$KE_{x'_2} = (PE_{x_1} + KE_{x_1} + PE_{x_2} + KE_{x_2} - PE_{x'_1} - PE_{x'_2}) \times (1 - \eta), \tag{12}$$

where η is randomly generated from the interval [0,1].

2.2.4. Synthesis

The synthesis refers to an occasion when two molecules collision and combine into one molecule. The change is vigorous and the structure of the new molecule is quite different from the original two. This is to say that we give up the search region and start to search another one. The change will be accepted only if

$$PE_{x_1} + KE_{x_1} + PE_{x_2} + KE_{x_2} > PE_{x'}. \tag{13}$$

If (13) hold, we can get KE by

$$KE_{x'} = PE_{x_1} + KE_{x_1} + PE_{x_2} + KE_{x_2} - PE_{x'}. \tag{14}$$

The new molecule is usually larger than the original ones. It means it will have a greater ability to escape from a local minimum in subsequent. So we usually set a synthesis criterion β. When both original KE is lower than β, synthesis will happen.