Optik 125 (2014) 414–418

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Hybrid bio-inspired lateral inhibition and Imperialist Competitive Algorithm for complicated image matching

Linzhi Huang[a], Haibin Duan[a,*], Yin Wang[a,b]

[a] State Key Laboratory of Virtual Reality Technology and Systems, Beihang University, Beijing 100191, PR China
[b] College of Astronautics, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, PR China

ARTICLE INFO

Article history:
Received 19 February 2013
Accepted 30 June 2013

Keywords:
Imperialist Competitive Algorithm (ICA)
Lateral inhibition
Image matching

ABSTRACT

Bio-inspired intelligent algorithms, such as Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO), have been applied to solve image matching problems. However, due to high computational complexity and premature convergence problems associated with these methods, they have limitations in defining the global optimal matcher efficiently and accurately. To address these problems, we proposed a hybrid bio-inspired optimization approach, coupling the lateral inhibition mechanism and Imperialist Competitive Algorithm (ICA), to solve complicated image matching problems. With the adoption of the lateral inhibition mechanism, the global convergence of conventional ICA algorithms has been greatly improved. We demonstrate the efficiency and feasibility of the proposed approach by extensive comparative experiments.

1. Introduction

Image matching is a technique of determining the small regions of an image that match another image (known as template). It can be considered as an optimization process of finding the optimal location of the template image in the original image, where the associated similarity metric (energy) between these two images is maximized. As one of the most important and fundamental problems in the field of computer vision, imaging matching algorithms are widely utilized in digital photogrammetry, object recognition, stereo matching, feature tracking, remote sensing, and other applications [1,2].

In terms of the routine used to form the similarity metric, image matching methods can be generally classified into two folders, namely, the intensity-based approach and the feature-based approach [3]. The intensity-based approaches analyze the attributes of image that reflect the similarity between the template and the original image. On the other hand, feature-based approaches are based on the image features, such as border, unique points, texture, entropy and energy, according to specific applications [4].

Recently, heuristic methods, such as Genetic Algorithm (GA) [5], Ant Colony Optimization (ACO) [6], Particle Swarm Optimization (PSO) [7], have been introduced into the intensity-based matching framework to solve the image matching problems. However, the performance of these original optimization algorithms is not satisfactory in terms of some aspects, such as high computational complexity and non-global maxima convergence.

Imperialist Competitive Algorithm (ICA), inspired by imperialistic competition mechanism, is a novel evolutionary algorithm for solving optimization problems. ICA was firstly proposed by Esmaeil and Lucas [8], who applied such algorithm to solve the continuous optimization problems. However, the conventional ICA method may be trapped in a local minimal solution. It, therefore, cannot be directly used to solve the optimization problem associated in image matching. To address this problem, we propose to combine lateral inhibition mechanism [9] into the basic Imperialist Competitive Algorithm (ICA) framework, which improves the overall performance of the basic ICA method in image matching applications.

The remainder of this paper is organized as follows. Section 2 introduces the essential theoretical foundations of ICA, and the basic principles of lateral inhibition methods are described in Section 3. Section 4 details the implementation procedures of the hybrid bio-inspired lateral inhibition and ICA. This is followed by the presentation and analysis of the results, which demonstrate the performance of the approach in terms of efficiency and accuracy. Finally, concluding remarks are drawn in the final section.

2. Principles of the Imperialist Competitive Algorithm

The optimization problem can be considered as finding an argument $\boldsymbol{x}$ whose relevant cost $f(\boldsymbol{x})$ is optimum, and it is a commonly encountered mathematical problem in many real world applications, such as industrial planning, resource allocation, scheduling,

* Corresponding author. Tel.: +86 10 82317318.
E-mail address: hbduan@buaa.edu.cn (H. Duan).

0030-4026/$ – see front matter
http://dx.doi.org/10.1016/j.ijleo.2013.06.085

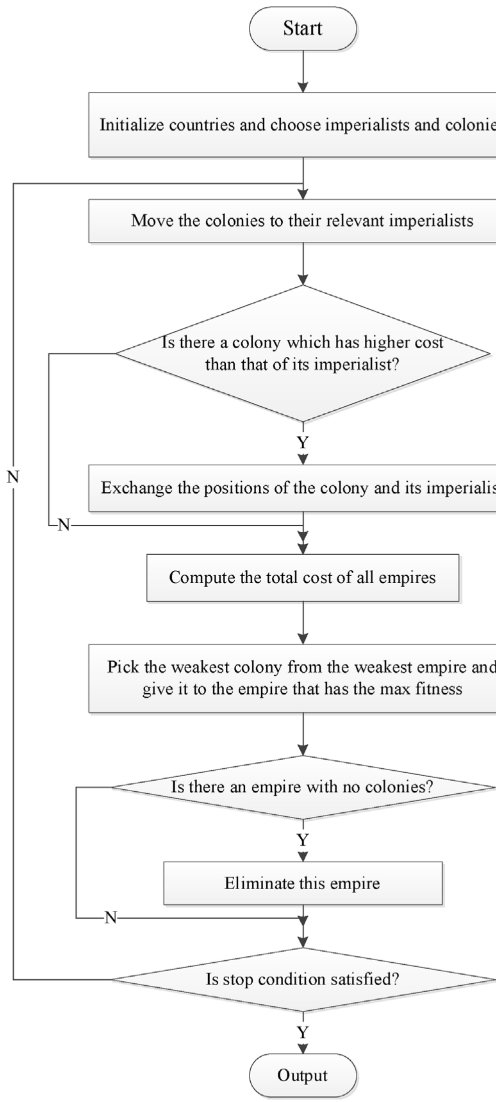

Fig. 1. The flowchart of basic ICA.

and pattern recognition. During the past decade, intensive research effort has been dedicated in design sophisticated methods to solve optimization problems. Particularly, bio-inspired intelligent algorithms have received a great deal of attentions, due to their stochastic nature. GA is a evolutionary algorithm that evolves a population of candidate solutions to a given problem, using operators inspired by natural genetic variation and natural selection [10]. PSO is another example which simulates the social behavior of animals [7]. The first application of ICA algorithm in optimization was reported by Esmaeil and his co-worker, who proposed of solving the optimization problem based on the imperialistic competition mechanism [8]. Fig. 1 depicts the overall workflow of the basic ICA.

Broadly speaking, the basic ICA begins with initial empires, also known as countries. There are two types of countries: namely colony and imperialist states. Imperialistic competitions among these empires form the basis of the ICA. During competition, weak empires collapse and powerful ones take possession of their colonies. Imperialistic competitions will eventually converge to a state, leaving only one empire and its colonies are in the same position and have the same cost as the imperialist, which represents the best solution of the matching problem. The standard procedure of the basic ICA is summarized as follows:

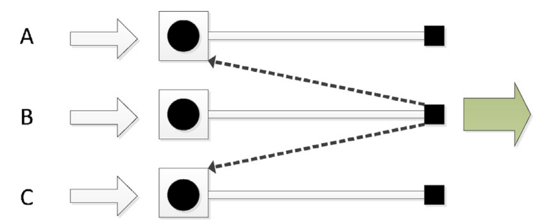

Fig. 2. Lateral inhibition in biology vision.

Step 1: Initialize a number of countries representing possible solutions of the matching problem, and select those with relative high fitness measurements to be the imperialist states, while the rest form the colonies of these imperialists. The strong empires have greater number of colonies while weaker ones have less. The number of colonies that belong to each imperialist state can be computed as

$$P = \frac{NormImperialistCost}{\sum_{i=1}^{m} sum(NormImperialistCost)} \quad (1)$$

Step 2: Selection of some (usually one) of the weakest colonies across the weakest empires, and making a competition among all empires to possess these (this) colonies.

Step 3: When an empire loses all of its colonies, it will be collapsed and become a colony of the strongest imperialist. Eventually, all of the empires except the most powerful one will collapse and all the colonies will be under the control of this unique empire. In this ideal new world all the colonies have the same positions and same costs and they are controlled by an imperialist with the same position and cost as themselves, which means the algorithm converges to the best solution.

Step 4: If the maximum number of steps of the competition has been reached, or the maximum fitness value changes in a small range, the algorithm terminates. The fitness function is chosen to be 1/RMSE, where RMSE is defined as follows:

$$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{1-2}^{n}(d_i - y_i)^2} \quad (2)$$

d_i denotes the output of the realistic system and y_i is the output of the algorithm.

3. Lateral inhibition mechanism

The lateral inhibition mechanism is discovered and demonstrated by Hartline and his research team when they carried out an electrophysiology experiment on the limulus' vision [11]. They found that every microphthalmia of limulus' ommateum is a receptor which is inhibited by its adjacent receptors and the inhibited effect is mutual and spatially summed. It means that when a receptor is inhibited by its adjacent receptors, it will suppress its adjacent receptors at the same time. In general, the nearer the adjacent receptors are from each other, the more strongly they inhibit mutually. Hence, lateral inhibition effect increases the contrast and sharpness in visual responses, and such phenomenon usually takes place in the mammalian retina. For instance, in a dark environment, a small light stimulus will be enhanced by the different photoreceptors (rod cells). The rods in the center of the stimulus will transduce the "light" signal to the brain, whereas different rods on the outside of the stimulus will send a "dark" signal to the brain. The contrast between the light and dark creates a sharp image, thus leading to the Mach band visual effect. As is shown in Fig. 2, a stimulus can affect three adjacent neurons, if such stimulus has the strongest