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Artificial algae algorithm with multi-light source for numerical optimization and applications

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ABSTRACT

Artificial algae algorithm (AAA), which is one of the recently developed bio-inspired optimization algorithms, has been introduced by inspiration from living behaviors of microalgae. In AAA, the modification of the algal colonies, i.e. exploration and exploitation is provided with a helical movement. In this study, AAA was modified by implementing multi-light source movement and artificial algae algorithm with multi-light source (AAA_{ML}) version was established. In this new version, we propose the selection of a different light source for each dimension that is modified with the helical movement for stronger balance between exploration and exploitation. These light sources have been selected by tournament method and each light source are different from each other. This gives different solutions in the search space. The best of these three light sources provides orientation to the better region of search space. Furthermore, the diversity in the source space is obtained with the worst light source. In addition, the other light source improves the balance. To indicate the performance of AAA with new proposed operators (AAA_{ML}), experiments were performed on two different sets. Firstly, the performance of AAA and AAA_{ML} was evaluated on the IEEE-CEC'13 benchmark set. The second set was real-world optimization problems used in the IEEE-CEC'11. To verify the effectiveness and efficiency of the proposed algorithm, the results were compared with other state-of-the-art hybrid and modified algorithms. Experimental results showed that the multi-light source movement (MLS) increases the success of the AAA.

1. Introduction

In the last 30 years, both a large number of bio-inspired algorithms have been proposed such as ant colony optimization (ACO; Dorigo, 1992), particle swarm optimization (PSO; Kennedy and Eberhart, 1995), bacterial foraging optimization algorithm (BFOA; Passino, 2002), artificial bee colony algorithm (ABC; Karaboga, 2005), firefly algorithm (FA; Yang, 2009), and also, improvement studies have been made on some of these algorithms in the literature (Dorigo et al., 1996; Zhao et al., 2010; Zhang et al., 2003; Clerc, 2015; Chen et al., 2014; Dasgupta et al., 2009; Zhang et al., 2015; Cui and Gu, 2015; Wang et al., 2012; Baykasoğlu and Ozsoydan, 2014; Wang et al., 2014a). Later, hybrid structures have also been developed using pure or modified versions of optimization methods and other methods together (Farahani et al., 2012; Yan et al., 2012; Samuel and Rajan, 2015; Abd-Elazim and Ali, 2013; Kıran et al., 2012; Wang et al., 2014b). Due to an increasing need for optimization in the field of technology and engineering, in addition to the well-studied optimization algorithm, many new algorithms have been proposed such as krill herd optimization (KHO; Gandomi and Alavi, 2012), migration bird optimization (MBO; Duman et al., 2012), fruit fly optimization algorithm (FFO; Pan, 2011), social spider algorithm (SSA; Yu and Li, 2015), monarch butterfly optimization (Wang et al., 2015) and artificial algae algorithm (AAA; Uymaz et al., 2015).

AAA had been introduced by inspiration from living behaviors of microalgae. It has been modeled on the basic features of microalgae such as the algal tendency to be close to the light, algal helical movement, reproduction by mitotic division and adaptation to the environment. Basically it has three main processes; these are helical movement, evolutionary and adaptation process. Algal colonies forming the population in AAA, perform helical motion to find the global optimum value in the search space. According to AAA, the cells of colonies, which are close to the light, grow and reproduce with mitotic division in the population. Algal colonies, which cannot grow sufficiently in an environment, try to adapt themselves

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to the environment and as a result the dominant species change (Uymaz et al., 2015).

According to AAA, algal colonies draw near to a unique light source through a helical movement in three different dimensions. Thus, the selection of the light source is important to find the global optimum. In AAA, with tournament method, each algal colony determines the location of one of the other algal colonies in the population as a light source. The location of selected algal colony may be near to local optimum or far to the global optimum. This situation may lead colonies to get stuck in a local minimum or slow down the rate of convergence of the algorithm.

In order to prevent such a situation, this study focused on the multi-light movement approach by adopting the multi-parent recombination approach used in evolutionary algorithms (EAs). A recombination operation with two parents is commonly used to generate new individuals in many EAs (Tsutsui et al., 1999). There are studies that use more than two parents for recombination such as multi-parent recombination with simplex crossover (SPX; Tsutsui et al., 1999), triangular crossover (TC) with selection of three individuals as parent (Elfeky et al., 2008), uni-modal distribution crossover (UNDX; Kita et al., 1999) and multi-parent crossover (MPC; Elsayed et al., 2011).

In this paper, multi-light source movement (MLS) for AAA is proposed, namely AAA_{ML}. For each dimension selected in the helical movement, a different light source is used in the MLS. This method both provides diversity in the search space and also increases the speed of convergence to the global optimum owing to the selection of three different light sources. Hence, the MLS provides a balance between exploration and exploitation. The rest of the paper was organized as follows. Section 2 describes the basic AAA and the proposed AAA_{ML} approach. Subsequently, benchmark problem sets used in experimental studies and other optimization algorithms used in the comparison are explained in Section 3. In addition, experimental simulations compared with other optimization methods, results, and analyses are presented in Section 4. Finally, the study is concluded in Section 5.

2. Basic artificial algae algorithm and proposed strategies

2.1. Artificial algae algorithm

AAA has been proposed by Uymaz et al. (2015). This algorithm is inspired by the living behaviors of microalgae. In the algorithm, population is composed of algal colonies. An algal colony is a group of algal cells living together. AAA is based on 3 basic parts called “evolutionary process”, “adaptation” and “helical movement”. In evolutionary process, if the algal colony receives enough light, algal cells in algal colonies grows and reproduces itself to generate two new algal cells similar to the real mitotic division. In adaptation process, Algal colonies, which cannot grow sufficiently in an environment, try to adapt itself to the environment. Helical movement is a process which update of algal colonies. In this process, only three algal cells of each algal colony are modified. The steps of AAA can be described as follows.

Step 1. Initialization.

1.1 Parameters of problems (number of dimension (D), maximum and minimum values for each dimension (UB, LB)).
1.2 Parameters of algorithm (Shear force (Δ), energy loss (e), adaptation (A_p)), population number (N) and maximum fitness evaluations number (MaxFES) are initialized.
1.3 Initialize algal colonies with random solutions. Define the size of each algal colony as (1).

$$x_{ij} = LB_j + (UB_j - LB_j) \times \text{Rand} \quad i = 1, \ldots, N; \quad j = 1, \ldots, D \tag{1}$$

1.4 Evaluate fitness of each algal colony.
1.5 Evaluate size (G) of algal colonies.

$$\mu_i = \frac{S}{K_i + S} \tag{2}$$

where K is the substrate half saturation constant of the algal colony and at time t K_i will be equal to the half of G_i.

$$G_i^{t+1} = G_i^t + (G_i^t \times \mu_i) \tag{3}$$

1.6 Evaluate friction surface (τ) of algal colonies

$$\tau(x_i) = 2\pi \left(\sqrt[3]{\frac{3G_i}{4\pi}} \right)^2 \tag{4}$$

1.7 Evaluate energy (E) of algal colonies from normalized G $E^{t+1} = \text{norm}((\text{rank}(G^t))^2)$

Step 2. Main section. This section is iterated until reach MaxFES.

2.1 Helical movement phase for every algal colonies.
2.1.1. Select another colony with tournament selection.
2.1.2. Select three algal cells (k, l and m) in the colony randomly.
2.1.3. Modification the colony.

$$x_{im}^{t+1} = x_{im}^t + (x_{jm}^t - x_{im}^t)(\Delta - \tau^t(x_i))p \tag{5}$$

$$x_{ik}^{t+1} = x_{ik}^t + (x_{jk}^t - x_{ik}^t)(\Delta - \tau^t(x_i))cos \quad \alpha \tag{6}$$

$$x_{il}^{t+1} = x_{il}^t + (x_{jl}^t - x_{il}^t)(\Delta - \tau^t(x_i)) \sin \quad \beta \tag{7}$$

2.1.4. Decrease energy caused by movement.
2.1.5. If new solution is better, move new position else decrease energy by metabolism.
2.1.6. If energy of the colony did not finish go to 2.1.1.
2.1.7. If colony did not find better solution increase starvation of colony.
2.2 Reproduction phase.
2.2.1 Select smallest and biggest colonies.

$$\text{biggest}^t = \max G_i^t \quad i = 1, 2, \ldots, N \tag{8}$$

$$\text{smallest}^t = \min G_i^t \quad i = 1, 2, \ldots, N \tag{9}$$

2.2.2 Select randomly algal cell (m).
2.2.3 Algal cell is replicated from biggest to smallest.

$$\text{smallest}_m^t = \text{biggest}_m^t \quad m = 1, 2, \ldots, D \tag{10}$$

2.3 Adaptation phase.
2.3.1 Select most hungry colony.

$$\text{starving}^t = \max A_i^t \quad i = 1, 2, \ldots, N \tag{11}$$

2.3.2 Modification the colony.

$$\text{starving}^{t+1} = \text{starving}^t + (\text{biggest}^t - \text{starving}^t) \times \text{rand} \tag{12}$$

Step 3. Finally, report best solution.

2.2. Modified artificial algae algorithm

2.2.1. Artificial algae algorithm with multi-light source movement (AAA_{ML})

In AAA, exploration and exploitation is provided with a helical movement, in other words, with the modification of the algal colonies. The evolutionary process and adaptation process help exploitation. Balance of local and global search ability is important in the solution of optimization problems. If the distribution of