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ORIGINAL ARTICLE

Artificial root foraging optimizer algorithm with hybrid strategies

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Abstract In this work, a new plant-inspired optimization algorithm namely the hybrid artificial root foraging optimizion (HARFO) is proposed, which mimics the iterative root foraging behaviors for complex optimization. In HARFO model, two innovative strategies were developed: one is the root-to-root communication strategy, which enables the individual exchange information with each other in different efficient topologies that can essentially improve the exploration ability; the other is co-evolution strategy, which can structure the hierarchical spatial population driven by evolutionary pressure of multiple sub-populations that ensure the diversity of root population to be well maintained. The proposed algorithm is benchmarked against four classical evolutionary algorithms on well-designed test function suites including both classical and composition test functions. Through the rigorous performance analysis that of all these tests highlight the significant performance improvement, and the comparative results show the superiority of the proposed algorithm.

1. Introduction

Nature-inspired methods which mimic the intelligent behaviors of certain creatures have the excellent abilities of tackling complex NP-hard problems. For examples, the particle swarm optimization (PSO) (Gao et al., 2013), the ant colony optimization (ACO) (Huang et al., 2008), the artificial bee colony (ABC) (Bhandari et al., 2015), and the bacterial foraging algorithm (BFA) (Bouaziz et al., 2015) have been found to perform better than the classical heuristic methods and already come to be widely used in many areas.

Recently, many top researchers are paying more interest investigation how to improve the accurate of the result and greatly reduce the computation time. The computational models of artificial root foraging behavior have attracted more and more attention, due to their remarkable adaptive growth processes can provide novel insights into new computing paradigm for global optimization (Karaboga and Basturk, 2008; McNickle et al., 2009). In this paper, we implement a novel hybrid artificial root foraging optimizion (HARFO) by incorporating a set of hybrid strategies in the following aspects:

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- The proposed HARFO adopts the root-to-root communication. The individual roots share more information from the elite roots through different effective topologies in the early exploration stage of the algorithm.
- By introducing a multi-population co-evolution mechanism. The hierarchical population of roots can be structured with enhanced interactions of individual behaviors from different sub-populations.

The rest of this paper is organized as follows: in Section 2, we outline the classical Artificial Root Foraging Model in sufficient details. Section 3 gives a brief overview of the model and algorithm of the proposed HARFO. In Section 4, the experiment studies of the proposed HARFO and the other algorithms are presented with descriptions of a set of benchmark functions. In Section 5, the conclusions are drawn, the results show that the proposed HARFO is feasible and have a powerful search ability.

2. Classical Artificial Root Foraging Model (ARFO)

2.1. Biological basis of plant root growth optimization

Plant roots are generally composed of the main root and lateral roots. The main root is developed by radicle, main root growth model mainly shows geotropism, means vertical growth down to the ground. Lateral roots are many branches which are grown from the main root edges. The lateral roots can grow another lateral root, these lateral roots can be graded to be first degree, second degree, third degree and so on. Lateral root growth direction has an angle from the main root. The lateral root growth pattern is mainly reflected in hydrotropism. Based on the plant growth mechanisms and biological model, and Optimal foraging theory and adaptive optimization model of plant growth, the classical Artificial Root Foraging Model (ARFO) is presented, The optimization process of ARFO is shown in Fig. 1.

2.2. Basic concepts

We regard the soil environments for plant root growth as a minimization problem and the root population as a homogeneous biomass, so each root apex represents a feasible solution of the specific problem, and each of its search for the optimal area through adjusting the directions, elongation length and

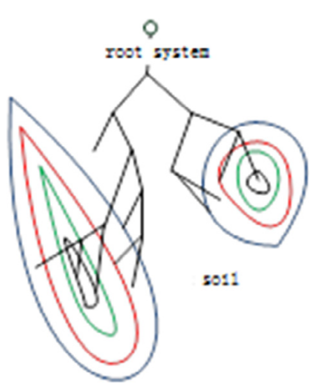

Figure 1 The optimization process of ARFO.

the propagation strategies. Some criteria should be obeyed to obtain the ideal plant root growth behaviors, which is shown as follows:

a. *Criterion-1:* The auxin concentration regulating the roots' spatial structure reallocated dynamically instead of static.
b. *Criterion-2:* One root apex elongates forward in the substrate and produces daughter root apices.
c. *Criterion-3:* According to the size of auxin concentration, there are three categories in the whole root system, main roots, the lateral-roots and the dead-roots.
d. *Criterion-4:* The hydrotropism influences the growth trajectory of plant roots, and makes the growing direction of the root tips toward the optimal individual position.

2.3. Auxin regulation

Various growth operations and the branching number should be controlled by the auxin. In artificial soil environment, the nutrient distribution should be formulated as the following expression (He, 2015; Wang et al., 2006):

$$f_i = \frac{fitness_i - f_{min}}{f_{max} - f_{min}} \quad (1)$$

Then the auxin concentration can be stated mathematically as below:

$$A_i = \frac{f_i}{\sum_{j=1}^{S} f_i} \quad (2)$$

where $fitness_i$ is the functional fitness value, f_i is the normalization fitness value of the root i, f_{min} and f_{max} are the maximum and minimum of the current population, respectively, S is the size of current population.

2.4. The growth strategy of main root

According to the criteria, a main root regrows including regrowing operator and branching operator (He, 2015; Ma et al., 2015a,b).

2.4.1. Regrowing operator

A main root makes the growing direction toward the best individual of current population, the operator is formulated as the following expression (He, 2015; Ma et al., 2015a,b).

$$x_i^t = x_i^{t-1} + l \cdot rand \cdot (x_{lbest} - x_i^{t-1}) \quad (3)$$

where x_i^t is the new position, x_i^{t-1} is the original position of root i, l is a local learning inertia, $rand$ is a random coefficient varying within [0, 1], x_{lbest} is the local best individual in current population.

2.4.2. Branching operator

Once some specific conditions are met, branching operator means a root apex generates new individuals. When auxin concentration value is more than a branching threshold T_Branch, it will start generating a certain number of new individuals as follows.