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Multi-operator based biogeography based optimization with mutation for global numerical optimization☆

Xiangtao Li, Minghao Yin*

College of Computer Science, Northeast Normal University, Changchun, 130117, PR China

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ABSTRACT

Biogeography based optimization (BBO) is a new evolutionary optimization based on the science of biogeography for global optimization. We propose two extensions to BBO. First, we propose a new migration operation based multi-parent crossover called multi-parent migration model, which is a generalization of the standard BBO migration operator. The new migration model can satisfy a balance of exploration and exploitation. Second, the Gaussian mutation operator is integrated into multi-operator biogeography based optimization (MOBBO) to enhance its exploration ability and to improve the diversity of population. Experiments have been conducted on 23 benchmark problems of a wide range of dimensions and diverse complexities. Simulation results and comparisons demonstrate the proposed MOBBO algorithm based multi-parent crossover model is better, or at least comparable to, the BBO, PBBO and evolutionary algorithms from literature when considering the quality of the solutions obtained.

1. Introduction

Optimization problems play an important role in both industrial application fields and the scientific research world. During the past decade, we have viewed significant progress on tackling optimization problems. Different kinds of classical techniques have been advanced to handle optimization problems [1–4]. Among them, Meta-heuristic based methods, such as the simulated annealing algorithm (SA) [5], the genetic algorithm (GA) [6,7], the Artificial Immune system Algorithm (AIS) [8], the particle swarm optimization algorithm (PSO) [9–12], the ant colony algorithm (ACO) [13,14], the differential evolution algorithm (DE) [15–17], Biogeography based optimization [18,19], and the estimation of distribution algorithm (EDA) [20,21], which may be one of the most popular methods.

Particularly, Biogeography based optimization (BBO) is a novel meta-heuristic algorithm for global optimization that was introduced in 2008. The basic idea of BBO is based on the biogeography theory, which is the study of the geographical distribution of biological organisms. Different from other population based algorithms, in BBO, poor solutions can improve the qualities by accepting new features from good ones. Several variations of BBO have been proposed to enhance the performance of the standard BBO recently. Du and Simon [22] proposed a new biogeography based optimization based on evolution strategy, where a new immigration refusal approach is added to BBO. In this literature, F-tests and T-tests are also used to demonstrate the differences among different implementations of BBOs. Ergezer and Simon [23] proposed an oppositional biogeography based optimization (OBBO). The algorithm employs the opposition-based learning (OBL) alongside BBO's migration rates to create oppositional BBO. The results demonstrate that with the assistance of quasi-reflection, OBBO significantly outperforms BBO. Boussaïd and Chatterjee [24] proposed an algorithm combining the

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* Corresponding author. Tel.: +86 0431 84536338; fax: +86 0431 84536338.
E-mail addresses: lixt314@nenu.edu.cn, ymh@nenu.edu.cn (M. Yin).

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biogeography based optimization with the differential evolution algorithm. The populations of this algorithm are updated by applying the BBO and DE updating methods alternatively. The paper also proposed an additional selection procedure for BBO, which preserves fitter habitats or subsequent generations. Gong et al. [25] proposed a real-code BBO approach, called RCBBO, for the global optimization problems in the continuous domain. What is more, in order to enhance the diversity of the population and to improve the exploration of RCBBO, the mutation operation is incorporated into RCBBO. Simon [26] proposed a simplified version of BBO and performed an approximate analysis of the BBO population by using probability theory to find three quantities: the probability per generation that its population optimum improves, the state transition matrix of the algorithm, and the excepted amount of improvement in the population optimum. However, this field of study is still in its early days, a large number of future researches are necessary in order to develop new improved BBO based algorithms for solving real world problems other than only for those areas the inventors originally focused on.

BBO has a structure similar to PSO. In these two approaches, solutions are maintained from one iteration to the next, but each solution can learn from its neighbors and adapt itself as long as the algorithm progresses. PSO represents the change over time of each solution as a velocity vector. However, PSO solutions do not change directly; it changes according to their velocities, and this indirectly results in solution changes. Compared with PSO, the solutions of BBO are changed directly via migration from other solutions. In a word, BBO solutions directly share their attributes with other solutions. It is these differences between BBO and PSO methods that may prove to be its strength.

In this paper, we propose a multi-operator biogeography based optimization (MOBBO) method, integrating multi-parent crossover into biogeography based optimization, which we call MOBBO. First, we propose a new migration operation based multi-parent crossover called multi migration, which is a generalization of the standard BBO migration operator. The proposed multi-parent migration was used to generate new offspring to find the global optimal solution. In the proposed migration model, three individuals are able to generate three offspring. Second, we add the Gaussian mutation operator to MOBBO to improve the diversity of population. Simulation results and comparisons demonstrate the effectiveness of the proposed algorithm.

The rest of this paper is organized as follows: in Section 2 we will review basic Biogeography based optimization. Section 3 describes the proposed MOBBO algorithm. Benchmark problems and corresponding experimental results are given in Section 4. In the last section we conclude this paper and point out some future research directions.

2. Biogeography based optimization

Biogeography based optimization Simon [18] is a new evolution algorithm developed for the global optimization. It is inspired by the immigration and emigration of species between islands in search of more friendly habitats. Each solution is called a "habitat" with a habitat suitability index (HSI) and represented by an *n*-dimension real vector. The variables of the individual that characterize habitability are called suitability index variables (SIVs). An initial individual of the habitat vectors is randomly generated. Those solutions that are good are considered to be habitats with a high HSI. Those that are poor are considered to be habitats with a low HSI. The high HSI tends to share their features with low HSI. Low HSI solutions accept a lot of new features from high HSI solutions. In BBO, a habitat H is a vector (SIVs) which follows migration and mutation step to reach the optimal solution. The new candidate habitat is generated from all of the salutation in the opulation by using the migration and mutation operators.

In BBO, the migration strategy is similar to the evolutionary strategy in which many parents can contribute to a single offspring. BBO migration is used to change existing solution and modify existing island. Migration is a probabilistic operator that adjusts a habitat H_i. The probability H_i is modified is proportional to its immigration rate λ_i, and the source of the modified probability comes from H_j is proportional to the emigration rate μ_j. Migration can be described as follows:

procedure *Habitat migration*

Begin
  for $i = 1$ *to NP*
    Select X_i *with probability based on* λ_i
    if $rand(0, 1) < \lambda_i$ ***then***
      for $j = 1$ *to D*
        Select H_j *with probability based on* μ_j
        if $rand(0, 1) < \lambda_j$ ***then***
          $H_i(SIV) \leftarrow H_j(SIV)$
        end if
      end for
    end if
  end for
End.