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A novel hybrid multi-objective immune algorithm with adaptive differential evolution

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ABSTRACT

In this paper, we propose a novel hybrid multi-objective immune algorithm with adaptive differential evolution, named ADE-MOIA, in which the introduction of differential evolution (DE) into multi-objective immune algorithm (MOIA) combines their respective advantages and thus enhances the robustness to solve various kinds of MOPs. In ADE-MOIA, in order to effectively cooperate DE with MOIA, we present a novel adaptive DE operator, which includes a suitable parent selection strategy and a novel adaptive parameter control approach. When performing DE operation, two parents are respectively picked from the current evolved and dominated population in order to provide a correct evolutionary direction. Moreover, based on the evolutionary progress and the success rate of offspring, the crossover rate and scaling factor in DE operator are adaptively varied for each individual. The proposed adaptive DE operator is able to improve both of the convergence speed and population diversity, which are validated by the experimental studies. When comparing ADE-MOIA with several nature-inspired heuristic algorithms, such as NSGA-II, SPEA2, AbYSS, MOEA/D-DE, MIMO and D^2MOPSO, simulations show that ADE-MOIA performs better on most of 21 well-known benchmark problems.

1. Introduction

Optimization problems widely exist in many domains of scientific research and engineering application [1–4]. Based on the number of objectives needed to be optimized, they are generally classified into two categories, such as single-objective optimization problems (SOPs) and multi-objective optimization problems (MOPs). Generally, MOPs bring more challenges as they are aimed at optimizing several conflicting objectives simultaneously, while SOPs only locate a global optimal value. Due to the complex landscape in decision and objective spaces of MOPs, it is practically impossible for traditional deterministic approaches to travel the entire solution space and find a satisfactory result within a limited time. As a result, evolutionary algorithms (EAs) are presented for solving MOPs, which demonstrate the excellent global search capability in finding optimal solution set [5,6]. The ability to handle complex MOPs that are characterized with discontinuities, multimodality, disjoint feasible spaces and noisy function evaluations, reinforces the potential effectiveness of multi-objective EAs (MOEAs) [7,8].

The first reported literature of MOEAs may be the vector evaluated genetic algorithm (VEGA) in mid-1980s [9]. After that, MOEAs attract more and more interests of researchers and numbers of various MOEAs are presented. The first generation of MOEAs published around 1990s mostly adopted the Pareto-rank based selection and fitness sharing, the representatives of which include multi-objective genetic algorithm (MOGA) [10], niched Pareto genetic algorithm (NPGA) [11] and non-dominated sorting genetic algorithm (NSGA) [12]. In 2000s, the second generation of MOEAs was designed based on the elitist selection strategy, such as strength Pareto evolutionary algorithm (SPEA) [13] and its improved version (SPEA2) [14], Pareto envelop-based selection algorithm (PESA) [15], and a fast non-dominated sorting genetic algorithm (NSGA-II) [16]. Recently, as more and more heuristic algorithms including scatter search [17], simulated annealing [18], particle swarm optimization [19], ant colony optimization [20], differential evolution [21] and immune algorithm [22], are presented, it is found that multiple heuristic algorithms can be hybridized to achieve stronger search capabilities [23–25]. This is realized by combining the advantages of various heuristic algorithms to overcome the natural weakness of each algorithm. For example, an archive-based hybrid scatter search algorithm (AbYSS) is proposed [23], which embeds the mutation and crossover operators of EAs into the framework of scatter search. The experimental studies show that this hybrid approach obviously outperforms the state-of-the-art algorithms, such as SPEA2 and NSGA-II. A novel hybrid multi-objective evolutionary algorithm [24] is designed for real-valued MOPs by combining the concepts of personal best and global best in particle swarm optimization into MOEAs. Multiple crossover operators are also adopted here to

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