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Local dominance and local recombination in MOEAs on 0/1 multiobjective knapsack problems

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Abstract

This work studies and compares the effects on performance of local dominance and local recombination applied with different locality in multiobjective evolutionary algorithms on combinatorial 0/1 multiobjective knapsack problems. For this purpose, we introduce a method that creates a neighborhood around each individual and assigns a local dominance rank after alignment of the principle search direction of the neighborhood by using polar coordinates in objective space. For recombination a different neighborhood determined around a random principle search direction is created. The neighborhood sizes for dominance and recombination are separately controlled by two different parameters. Experimental results show that the optimum locality of dominance is different from the optimum locality of recombination. Additionally, it is shown that the performance of the algorithm that applies local dominance and local recombination with different locality is significantly better than the performance of algorithms applying local dominance alone, local recombination alone, or dominance and recombination globally as conventional approaches do.

Keywords: Evolutionary computations; Multiobjective combinatorial optimization; 0/1 multiobjective knapsack problems; Local dominance; Local recombination; Alignment of the principle search direction; Polar coordinates; Optimum locality

1. Introduction

Multiobjective evolutionary algorithms (MOEAs) (Fonseca and Fleming, 1995; Zitzler and Thiele, 1999; Van Veldhuizen and Lamont, 2000; Deb, 2001; Coello et al., 2002) are being increasingly investigated for solving multiobjective optimization problems. MOEAs are particularly suitable for this task because they evolve simultaneously a population of potential solutions to the problem in hand, which allows us to search a set of Pareto optimal solutions in a single run of the algorithm. Main features of state of the art MOEAs approaches (Deb, 2001; Coello et al., 2002) are that selection incorporates elitism and it is biased by Pareto dominance and a diversity preserving strategy in objective space. Also, in discrete binary search spaces like knapsack problems, recombination is usually implemented as one-point or two-point crossover and mutation as the standard bit flipping method. Some approaches also include specialized mutation operators to

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perform local search. In this work, we focus on the locality of dominance and recombination.

The conventional approach to calculate dominance has been using the whole population, i.e. *global dominance*. Global dominance has been shown to offer important advantages to MOEAs. It helps to push the search towards higher fronts and is thought to be effective for problems with convex and non-convex fronts. A potential problem with this conventional approach is that some global non-dominated solutions may have a too strong influence and may undermine the contribution of other solutions that, although globally dominated, have the potential to make the entire population diverse in objective space. In other words, a solution may globally dominate a broad region but may not be the best point from which to reach other not yet found non-dominated solutions.

The conventional approach to recombination has also been using the whole population for mating, i.e. *global recombination*, although there are several reports in the literature in which the benefits of mating restrictions have been studied (see Section 2 for related works). Mating restrictions, particularly in objective space, could be especially important in some combinatorial discrete problems where there is not a clear correlation between objective and decision space.

The motivation of this work is to determine the benefits of assigning non-domination rank based on the locality of solutions in objective space in order to develop efficient and effective MOEAs. In this work, we study and compare the effects on performance of applying simultaneously dominance and recombination using different locality in MOEAs on multiobjective combinatorial problems. To accomplish this purpose we introduce a method that creates a neighborhood around each individual and assigns a local dominance rank after alignment of the principle search direction of the neighborhood by using polar coordinates in objective space. For recombination a different neighborhood determined around a random principle search direction is created. The neighborhood sizes for dominance and recombination are separately controlled by two different parameters. Note that in this paper we focus on observing the effects of locality on performance without concerning about the computational cost. As benchmark problems 0/1 multiobjective knapsack problems with two, three, and four objectives ($m = \{2, 3, 4\}$) are used in our study.

2. Related works

Related works to the way we perform local recombination include methods that bias mating to recombine similar parents and methods that group individuals by similar search direction in the objective space.

Recombination of similar parents in MOEAs was initially implemented following the mating restriction suggested by Goldberg (1989) for single objective genetic algorithms, see for example (Hajela and Lin, 1992 and Fonseca and Fleming, 1993). In these approaches, individuals whose distance is farther apart than a value σ_{mating} are banned from recombination. The importance of mating restrictions was also emphasized in Watanabe et al. (2002) and Kim et al. (2004), where recombination was performed only between individuals next to each other in one of the objectives. Recently, a simple yet effective similarity based-mating scheme to recombine similar parents has been proposed in Ishibuchi and Shibata (2003a). In this approach the first parent is selected using tournament selection. Then, other β individuals are selected using tournament selection and the individual closer to the first parent is selected as its mate. This approach has been extended successfully to recombine extreme and similar parents (Ishibuchi and Shibata, 2003b, 2004). All these methods that restrict mating have been incorporated in algorithms that bias selection by calculating dominance in the whole population. The approach we propose, in addition to local recombination, is used together with local dominance.

Other way to induce local recombination is achieved by temporarily grouping the population around a search direction (Ishibuchi and Murata, 1998; Murata et al., 2000, 2001; Jin et al., 2001; Jaszkiewicz, 2002a,b). Besides local recombination, an additional and important aim of these methods is to assign uniformly the search effort towards all search directions trying to avoid that the algorithm focuses only in a narrow region of the objective space. However, the methods proposed so far have been based on aggregation approaches, which use the weighted sum of m objectives as a fitness function and specify weighting coefficients randomly whenever a pair of parent individuals are selected. These methods have shown good performance in several applications but are expected to face difficulties on problems with non-convex Pareto fronts. In contrast, the method we propose is based on dominance