Controlling Dominance Area of Solutions and Its Impact on the Performance of MOEAs

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Abstract. This work proposes a method to control the dominance area of solutions in order to induce appropriate ranking of solutions for the problem at hand, enhance selection, and improve the performance of MOEAs on combinatorial optimization problems. The proposed method can control the degree of expansion or contraction of the dominance area of solutions using a user-defined parameter S. Modifying the dominance area of solutions changes their dominance relation inducing a ranking of solutions that is different to conventional dominance. In this work we use 0/1 multiobjective knapsack problems to analyze the effects on solutions ranking caused by contracting and expanding the dominance area of solutions and its impact on the search performance of a multi-objective optimizer when the number of objectives, the size of the search space, and the complexity of the problems vary. We show that either convergence or diversity can be emphasized by contracting or expanding the dominance area. Also, we show that the optimal value of the area of dominance depends strongly on all factors analyzed here: number of objectives, size of the search space, and complexity of the problems.

1 Introduction

Multiobjective evolutionary algorithms (MOEAs) [1,2] 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 non-dominated solutions in a single run of the algorithm.

Some important features of the latest generation MOEAs are that selection incorporates elitism and it is biased by Pareto dominance and a diversity preserving strategy in objective space. Pareto dominance based selection is thought to be effective for problems with convex and non-convex fronts and has been successfully applied, especially in two and three objective problems. However, some current research reveals that ranking by Pareto dominance on problems with an increased number of objectives might not longer be effective [3,4,5]. It has been shown that the characteristics of multiobjective landscapes viewed in terms of non-dominated fronts (that are found in the process of non-domination sorting) can change drastically as the number of objectives increases, i.e. the

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number of fronts reduces substantially and become denser (more solutions per front) just by increasing the number of objectives [5]. In this case, most sampled solutions at a given time turn to be non-dominated. That is, most solutions are assigned the same rank of non-dominance and Pareto selection weakens since it has to discriminate mostly based on diversity of solutions. Another factor that affects the density of the fronts is the complexity of the individual single objective landscapes. It has been shown that the top non-dominated fronts become denser as the complexity of the landscapes reduces, and vice-versa [5]. This has been observed for multiple and many objectives landscapes and affects the behavior and effectiveness of Pareto selection in two ways. First, although the effect of the landscapes complexity on front density is not as strong as the effect of increasing the number of objectives, in practice the increased density of the top non-dominated fronts combined with elitism could make the instantaneous elite-population to be mostly composed of individuals with the same non-domination rank since early generations. In this case, again, selection has to rely mostly on diversity rather than on Pareto dominance ranking. Second, on problems of increased complexity could happen that there are too many but sparse fronts, in which case Pareto selection could become too strong increasing the likelihood that the algorithm gets trapped in local fronts. These studies suggest that for selection to be effective a more careful analysis of Pareto dominance relation is required when dealing with problems that have more than three objectives. In addition, for any number of objectives, the dominance relation should be appropriately revised according to the characteristics of the multi-objective landscape.

There are a few works on relaxed forms of Pareto dominance, such as ϵ-dominance [6] and α-domination [7]. ϵ-dominance acts as an archiving strategy and was proposed as a way of regulating convergence of a MOEA. The algorithm maintains a finite-size archive of non-dominated solutions, in which new points are only accepted if they are not ϵ-dominated by any other point of the current archive. ϵ-dominance strengthens selection during the archiving process. On the other hand, α-domination permits a solution $\boldsymbol{x}$ to dominate a solution $\boldsymbol{y}$ if $\boldsymbol{x}$ is slightly inferior to $\boldsymbol{y}$ in an objective but largely superior to $\boldsymbol{y}$ in some other objectives. α-domination was tried on an ad hoc continuous problem created specifically to illustrate a potential problem that Pareto selection could face. In addition, α-domination only introduces a method to strengthen selection and its effects have not been explained nor tested on standard test suit problems.

In this work, we propose a method to control the dominance area of solutions in order to induce appropriate ranking of solutions for the problem at hand, enhance selection, and improve the performance of MOEAs on combinatorial optimization problems. The proposed method can control the degree of expansion or contraction of the dominance area of solutions using a user-defined parameter S. Modifying the dominance area of solutions changes their dominance relation inducing a ranking of solutions that is different to conventional dominance. Contrary to ϵ-dominance and α-domination, the proposed method can strengthen or weaken selection by expanding or contracting the area of dominance and conceptually can be considered as a generalization of Pareto dominance. In