Initial Population Construction for Convergence Improvement of MOEAs

Christian Haubelt, Jürgen Gamenik, and Jürgen Teich

Hardware-Software-Co-Design
Department of Computer Science 12
University of Erlangen-Nuremberg, Germany
{haubelt, teich}@cs.fau.de

Abstract. Nearly all Multi-Objective Evolutionary Algorithms (MOEA) rely on random generation of initial population. In large and complex search spaces, this random method often leads to an initial population composed of infeasible solutions only. Hence, the task of a MOEA is not only to converge towards the Pareto-optimal front but also to guide the search towards the feasible region. This paper proposes the incorporation of a novel method for constructing initial populations into existing MOEAs based on so-called Pareto-Front-Arithmetics (PFA). We will provide experimental results from the field of embedded system synthesis that show the effectiveness of our proposed methodology.

1 Introduction and Related Work

Many optimization techniques have been proposed in the literature to solve global optimization problems [1]. A special class of stochastic optimization methods that can be applied to Multi-objective Optimization (MOP) problems is called *Multi-Objective Evolutionary Algorithms* (*MOEA*) [2]. MOEAs are *iteratively improving* optimization techniques, i.e., starting from a set of initial solutions, the so-called *initial population*, a MOEA tries to improve this set of solutions. Due to complexity reasons, nearly all MOEAs use a simple random sampling from search space to construct the initial population. In the presence of search spaces containing only a few feasible solutions, these random sampling methods are expected to produce only infeasible solutions. Hence, it is the task of the MOEA to guide the search not only towards the *Pareto-optimal front* but also towards the *feasible region*. To find the feasible region can be as complicated as improving a feasible solution to find the Pareto-optimal front.

This paper proposes the incorporation of constructive methods into existing MOEAs to create the initial set of solutions. Therefore, a novel approach called *Pareto-Front-Arithmetics* (*PFA*) is proposed which allows a fast approximation of the Pareto-optimal front [3]. Although this method is expected to generate infeasible and suboptimal solutions, we will show by experiment that this approach is indeed useful when applied to the task of initial population construction. The key idea is as follows: First the MOP is separated into several

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subproblems, these subproblems are optimized independently using any standard optimization strategy. Afterwards, the results of the suboptimizations are combined in the fast PFA step. The obtained non-dominated solutions are used as initial solutions to the overall optimization problem. An advantage of the proposed methodology is that this technique can be integrated into any existing MOEA.

In [4], Gandibleux et al. compare population-based optimization runs which use different seeding solutions. Their basic idea is, that some solutions can be computed efficiently by constructive of heuristic methods. Their idea is is based on the fact that solutions of each combinatorial optimization problem are composed of so-called *supported efficient solutions*, i.e., solutions which can be computed by a weighted sum approach suggesting a convex Pareto front, and so-called *non-supported efficient solutions*. In their test cases, Gandibleux et al. use either constructed single-objective solutions, the supported efficient solutions, or an approximation of the supported efficient solutions for seeding the population-based optimization strategy. The same authors present in [5] a multi-objective optimization approach that incorporates knowledge of supported efficient solutions in the crossover operator. In their experiments it can be seen that using this information during crossover improves the convergence of the optimization of their particular problem enormously. Hence, the motivation is very similar to the one presented in this paper.

However, the proposed PFA methodology is more comparable to subdivision techniques. In subdivision approaches, the optimization complexity is reduced by separating the MOP into several subproblems. By solving these subproblems, the solutions to the original problem may be found. These techniques have some limitations regarding the optimization problem [6, 7, 8]. This will be discussed in detail in Section 3. However, these methods are proposed as stand alone approaches, whereas our idea is the use of subdivision techniques for the initialization.

The rest of the paper is organized as follows: Section 2 provides the necessary mathematical background and the problem formulation to this paper. In Section 3, a method called *Pareto-Front-Arithmetics*, for initial population construction is discussed in detail. Experimental results showing the effectiveness of our approach are presented in Section 4. In all test cases, the method using Pareto-Front-Arithmetics on average outperforms the random-based traditional method. Finally, Section 5 concludes the paper.

2 MOPs and MOEAs

This section will provide the formal background and the problem description this paper is dedicated to. We will start with a formal notation of multi-objective optimization problems.

Definition 1 (Multi-objective Optimization Problem). *A* multi-objective optimization problem *(*MOP*) is given by:*