Designing Multi-objective Variation Operators Using a Predator-Prey Approach

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Abstract. In this paper, we propose a new conceptual method for the design, investigation, and evaluation of multi-objective variation operators for evolutionary multi-objective algorithms. To this end, we apply a modified predator-prey model that allows an independent analysis of different operators. Using this model problem specific operators can be combined to more complex operators. Additionally, we review the simplex recombination, a new rotation-independent recombination scheme, and examine its impact concerning our design method. We show exemplarily as a first attempt the advantageous combination of several standard variation operators that lead to better results for selected test functions.

Keywords: Predator-Prey Model, Multi-Objective Operators, Evolutionary Multi-Objective Algorithm, Operator Design.

1 Introduction

In the last years of research several multi-objective evolutionary algorithms have been proposed for the simultaneous optimization of multiple and competing objectives. The manifold experiences with different algorithms and multi-objective optimization problems reveal that only an adroit combination and problem specific adjustment of the different evolutionary operators decide on the system's success or failure. All the more, this insight is ubiquitous in the case of single-objective optimization.

It is therefore even more astonishing that within the multi-objective optimization, the conceptual approaches are still mainly concerned with the selection operator. Instead of adapting all evolutionary operators, like in the single-objective algorithms, external or internal archives [18], metrics as new selection criteria [11] or other even more complicated and time consuming procedures are developed. Consequently, the selection operators are in most cases not well concerted with the rest of the applied operators. Büche [3] shows for some state-of-the-art evolutionary multi-objective algorithms that the approximation of the set of efficient solutions cannot be done with an arbitrary precision. The distance between the true Pareto front and the approximated set can be reduced only by a noticeable rise of the size of the archives - otherwise stagnation occurs.

S. Obayashi et al. (Eds.): EMO 2007, LNCS 4403, pp. 21–35, 2007.

However, research focusing on the field of variation operators or representations remains rare, so only a few approaches can be found in literature: Kursawe [8] examined for example the use of diploid representations for two objective test functions while Rudolph [13] and Hanne [7] are concerned with the problem of finding an appropriate controlling mechanism for the mutation strength in the multi-objective case. Only Rudenko and Schoenauer [12] design a special recombination operator for real value coded multi-objective problems.

One fact that is emerging from those studies is that traditional single objective operators are not suitable for the multi-objective case. It is therefore quite conceivable that interaction between the evolutionary operators cannot be taken over from the single-objective case and the exclusive change of the selection operator is not sufficient to meet the requirements of multi-objective optimization. Those requirements can be formulated as the simultaneous ability of diversity preservation and a good convergence to the optimum. In contrast to existing selection schemes we try to avoid complex and time consuming computations for the variation operators.

The scope of this paper is the analysis and development of variation operators for multi-objective optimization. To this end, we provide a model for the analysis of single-objective operators in a multi-objective problem context. Our model is based on the predator-prey model of Laumanns et al. [9] but includes many modifications. With this analysis environment it is possible to identify potential advantageous properties of single-objective operators for multi-objective problems. Therefore, this model can be applied for the design of a multi-objective variation operator by the tunable combination of several operators.

The remainder of the paper is organized as follows. First we describe our predator-prey model that consists of many modifications compared to Laumans' original model. Those changes are described and explained in Section 3. Further, in Section 4 we motivate and sketch a recombination scheme that has already been proposed by Grimme and Schmitt [6]. Afterwards, in Section 5 we show how existing variation operators can be combined to a problem specific adapted multi-objective operator. The paper ends with a brief conclusion and a motivation for future work.

2 Background

This section provides a relatively short introduction into the predator-prey model of Laumanns et al. [9]. Additionally, some existing extensions are reviewed and problems of this model are outlined which motivate modifications done to the model later on.

2.1 Laumanns' Predator-Prey Model

The idea that individuals interact in *time* and *space* within their own species as well as with other species forms the basis of Laumanns' asynchronous spatial structured predator-prey model, as shown in Figure 1 (a). The "prey" are the