Adequacy of Empirical Performance Assessment for Multiobjective Evolutionary Optimizer

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Abstract. Recent studies show that evolutionary optimizers are effective tools in solving real-world problem with complex and competing specifications. As more advanced multiobjective evolutionary optimizers (MOEO) are being designed and proposed, the issue of performance assessment has become increasingly important. While performance assessment could be done via theoretical and empirical approach, the latter is more practical and effective and has been adopted as the de facto approach in the evolutionary multiobjective optimization community. However, researches pertinent to empirical study have focused mainly on its individual components like test metrics and functions, there are limited discussions on the overall adequacy of empirical test in substantiating their statements made on the performance and behavior of the evaluated algorithm. As such, this paper aims to provide a holistic perspective towards the empirical investigation of MOEO and present a conceptual framework, which researchers could consider in the design and implementation of MOEO experimental study. This framework comprises of a structural algorithmic development plan and a general theory of adequacy in the context of evolutionary multiobjective optimization.

Keywords: Multiobjective Optimization, Evolutionary Computation, Adequacy, Performance assessment.

1 Introduction

Many real-world applications involve complex optimization problem with various competing specifications and constraints that are often difficult, if not impossible, to be solved without the aid of powerful and efficient optimization algorithms. Over the years, many multi-objective evolutionary optimizers (MOEO), a class of stochastic search technique, have been developed for this purpose, ranging from evolutionary algorithm, evolutionary strategy, genetic programming, to newly proposed algorithmic models, like ant colony optimization, particle swarm optimization, estimation of distribution algorithm and etc. and they have been demonstrated to be very powerful and applicable for solving such problems.

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The algorithmic development of MOEO involves an iterative process of designer intuition and validation, where performance assessment is carried out continuously to examine and improve algorithmic design. In addition, performance assessment plays a crucial role in improving our understanding of MOEO and the interplay between its different components. The knowledge gained will greatly aid in the future development of better MOEO. Therefore, as more advanced MOEO are being designed and proposed, the issue of performance assessment has become increasingly important. However, the assessment of MOEO capability is not a trivial task. Due to its stochastic nature, the capability of MOEO cannot be precisely determined before its actual application. Furthermore, performance assessment is complicated in the context of evolutionary multiobjective optimization (EMOO), where the various conflicting goals of EMOO have a profound impact on the performance assessment of MOEO. Interestingly, Bosman and Thierens [1] noted that state-of-the-art MOEO have similar or incomparable performances due to these conflicting optimization goals.

The most practical and effective means for assessing the performance of MOEO is via an empirical study, where the evaluated algorithm will be applied to a set of test functions and the evolved solutions will be taken as an indication of the algorithmic performance. Although performance assessment can also be done via theoretical study [2], this approach often lacks the flexibility and practicality of empirical investigation. Furthermore, due to the stochastic nature of MOEO and its complex relationship with the optimization problem, it is difficult, if not impossible, to establish any formal mathematical treatment of algorithmic performance. Consequently, researchers will either get lost in the mire of complexity or resort to substantial simplifications before any analysis can be done. Due to the limitations of theoretical studies, performance assessment via the empirical approach has been adopted as the *de facto* approach in the EMOO community.

Research pertinent to empirical study has been focused on the development of test functions and performance metrics, resulting in great strides in these areas. Initial empirical studies are usually based on simple extension of single objective optimization problems, which reveals little or no characteristics of the algorithm under investigation. To this end, benchmark test suites have been formalized [3], [4] to challenge the MOEO in various aspects of problem difficulty [5]. In order to quantify the evolved tradeoffs, different metrics have been proposed over the years to measure the various goals in EMOO i.e. proximity, diversity and distribution. The fact that the interpretation of experimental results is largely dependent on the accuracy of performance indicators has initiated much research in this aspect also [6], [7], [8].

Although much work has been done to improve the reliability of empirical studies, there are little or no discussions at all on how it should be conducted with adequate substantiality on their statements made on the performance and behavior of the evaluated algorithm. As such, in contrast to existing works, this paper provides a holistic perspective towards the empirical investigation of MOEO and presents a conceptual framework for the design and implementation of MOEO empirical study and its definition of adequacy in the context of EMOO. For this purpose, the various aspects of MOEO empirical study will be considered, which includes the delineation of its essential components and the description and discussion of related design and implementation issues.