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MOEA Test Suites

> No amount of experimentation can ever prove me right; a single experiment can prove me wrong.
>
> Albert Einstein

4.1 Introduction

Why test multi-objective evolutionary algorithms (MOEAs)? To evaluate, compare, classify, and improve algorithm performance (effectiveness and efficiency). What is a MOEA test? Should we use a multi-objective optimization problem (MOP) test function, a MOP test suite, pedagogical functions, or a real-world problem? How to find an appropriate MOEA test?

Should we rely on the MOEA literature, on historical use, on test generators, or on well known real-world applications? When to test? Should we adopt and incremental algorithm and test development methodology or should we wait until the final stage of algorithm development to test it?

How should we design a MOEA test? Evidently, several important issues must be taken into consideration. For example: basic assumptions, computational platform selection, statistical tools, performance measures selection, experimental plan, among others. Thus, considerable effort must be spent not only in defining proper MOP tests and in generating the proper design of MOEA experiments, but also in employing the appropriate performance measures and experiment conditions, as well as the proper statistical tools that allow a fair algorithmic comparison. In this chapter, the development of various MOP test suites is discussed in detail.

Many MOEA research efforts select as examples numeric MOP functions to show or judge MOEA performance. In order to appreciate the rational for such selections, a comprehensive discussion of MOP landscape issues and structure is required along with an explanation of why the selected MOPs may be appropriate or inappropriate MOEA test functions. Such MOP characteristics

include objective functions structures, constrained vs. unconstrained genotype and phenotype formulations, and the impact of numerical approximation of continuous forms. This chapter precisely addresses all of these issues. Standard suite(s) of test functions exhibiting *relevant* MOP domain characteristics are presented that can provide the necessary common MOEA comparative basis (see [1630, 1628, 1626, 357, 355, 1790, 375, 375, 721, 1207]).

This chapter on MOP development is organized as follows: Section 4.2 discusses general test suite issues. Relevant MOP domain characteristics are presented in Section 4.3 which also proposes appropriate MOPs for MOEA test function suites given the described MOP domain features. Section 4.4 is devoted to scalable multi-objective test problems, describing several test suites found in the current literature. Combinatorial problems are described in Section 4.5, whereas Section 4.6 is devoted to real-world problems.

4.2 MOEA Test Function Suite Issues

The MOEA community has created various test suites as indicated and referenced previously. Specific functions have however been often employed because other researchers did so in their MOEA research, or perhaps because the MOP appears to exercise certain MOEA components. It is not clear that all these particular test functions are appropriate for inclusion into generic MOEA test suites. Explanation is rarely offered as to the specific MOP's origin or *raison d'etre*, yet several appear to be relatively "easy" (see Section 4.3) in the sense of finding the optimal solution. Poloni et al. [1283] also observed the lack of complex mathematical MOEA performance assessment tests. This situation implies that identification of appropriate test function suites to objectively determine MOEA efficiency and effectiveness is required. Other researchers have also noted the need for comprehensive test suites and have presented some ideas and examples [357, 1284, 1646, 1630, 1773, 721, 1207], which are included in this chapter.

Generic test function suites are both condoned and condemned. Any algorithm successfully "passing" all submitted test functions has no guarantee of continued effectiveness and efficiency when applied to real-world problems, i.e., examples prove nothing except as counter examples. When integrating MOP domains and MOEA domains, new and unforeseen situations may arise resulting in undesirable performance for example. A MOEA test suite is then a valuable tool only if relevant issues are properly considered. To motivate the development of MOP test suites, historical single objective EA test functions are addressed first.

Some single objective EA test suites examine an EA's capability to "handle" various problem domain characteristics. These suites incorporate relevant search space features to be addressed by some particular EA instantiation. Some example single-objective EA test suites are: