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Basic Concepts

> Everything has been said before, but since nobody listens we have to keep going back and beginning all over again.
>
> André Gide

1.1 Introduction

Problems with multiple objectives arise in a natural fashion in most disciplines and their solution has been a challenge to researchers for a long time. Despite the considerable variety of techniques developed in Operations Research (OR) and other disciplines to tackle these problems, the complexities of their solution calls for alternative approaches.

The use of evolutionary algorithms (EAs) to solve problems of this nature has been motivated mainly because of the population-based nature of EAs which allows the generation of several elements of the Pareto optimal set in a single run. Additionally, the complexity of some multiobjective optimization problems[1] (MOPs) (e.g., very large search spaces, uncertainty, noise, disjoint Pareto curves, etc.) may prevent use (or application) of traditional OR MOP-solution techniques.

This book is organized in such a way that its contents provides a general overview of the field now called evolutionary multiobjective optimization (EMO), which refers to the use of evolutionary algorithms of any sort (i.e., genetic algorithms [581], evolution strategies [1460], evolutionary programming [499] or genetic programming [905]) to solve multiobjective optimization problems. In fact, we also cover in this book other metaheuristics that have been used to solve multiobjective optimization problems (e.g., particle swarm optimization [840], artificial immune systems [1161], cultural algorithms [1357],

[1] Note that the terms "multi-objective" and "multiobjective" are used interchangeably throughout this book.

differential evolution [1525, 1294], ant colony [406], tabu search [572], scatter search [938], and memetic algorithms [661], among others).

Multiobjective optimization problems are attacked today using EAs by engineers, computer scientists, biologists, and operations researchers alike. This book should therefore be of interest to the many disciplines that have to deal with multiobjective optimization problems. At the end of each chapter, we include a section called "Future Explorations", which contains class exercises, class software projects, discussion questions, and possible research directions. Such material aims to provide support for teaching a course, and also delineates some possible topics for developing masters and PhD theses.

This chapter presents the basic terminology and nomenclature for use throughout the rest of the book. Furthermore, a historical overview of multiobjective optimization is also provided, together with a short introduction to evolutionary algorithms. Additionally, we also provide a brief description of the most representative mathematical programming techniques that have been proposed to solve multiobjective optimization problems, including a possible classification of them.

Chapter 2 provides an overview of the different multi-objective evolutionary algorithms (MOEAs) currently available. These techniques go from a simple linear aggregating function to the most popular MOEAs based on Pareto ranking (e.g., MOGA [504], NPGA [709], NSGA [1509], PAES [886], NSGA-II [374], SPEA [1782], SPEA2 [1775] and ϵ-MOEA [372, 373]). Other issues such as chromosomal representations, constraint-handling techniques and the use of secondary populations are also addressed.

Chapter 3 discusses both coevolutionary MOEAs and hybridizations of MOEAs with local search procedures (the so-called memetic MOEAs). A variety of MOEA implementations within each of these two types of approaches (i.e., coevolution and hybrids with local search mechanisms) are presented, summarized, categorized and analyzed.

Chapter 4 presents a detailed development of MOP test suites ranging from numerical functions (both unconstrained and with side constraints) and generated functions to discrete NP-Complete problems and real-word applications. Discussions provide understanding of the MOP domain, and an ability to select appropriate MOEA test suites based upon a set of desired characteristics.

MOEA performance comparisons are presented in Chapter 5. Also, an extensive discussion of possible comparison metrics and presentation techniques are presented. This includes a brief treatment of some recent findings regarding the limitations of unary performance metrics. Results are related to the design and analysis of efficient and effective MOEAs.

Chapter 6 summarizes the (still scarce) MOEA theoretical results found in the literature.

Although it is unrealistic to present every MOP application, Chapter 7 attempts to group and classify the wide variety found in the literature. Problem