An Introduction to Evolutionary Multiobjective Optimization

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Objectives

In this course, we will study the basic concepts related to multiobjective optimization and the use of evolutionary algorithms within this area. We will start with the historical origins of multiobjective optimization (in economics and planning) and the initial attempts to use evolutionary algorithms for solving multiobjective problems. Then, we will provide a historical review of the different algorithms, metrics, test functions, applications and theory developed to date. The incorporation of user's preferences as to bias the search of a multiobjective evolutionary algorithm will also be studied together with the use of parallel algorithms in this context. In the final part of the course, we will study other metaheuristics that have (or can be) extended to deal with multiple objectives (e.g., the ant system, cultural algorithms, particle swarm optimization, the artificial immune system, etc.). In each case, we will analyze the main advantages and disadvantages of using such approaches. Finally, some of the most promising paths of future research in the area will be discussed.

Topics Covered

- **Basic Concepts**
  - Attributes, goals, criteria and objectives.
  - Defining a multiobjective optimization problem.
  - Types of multiobjective optimization problems.

  - Ideal vector.
  - Convexity and concavity.
  - Pareto optimality.
  - Pareto dominance and Pareto optimal set.
  - Pareto front

- **Historical Background**

  - Origins of multiobjective optimization.
  - Classifying classical multiobjective optimization techniques.
  - A quick review of classical multiobjective optimization techniques.

- **Evolutionary Algorithms**

  - Motivation.
  - Aggregating functions (linear and nonlinear).
  - Population-based approaches.
  - Pareto ranking.
  - Other approaches.

- **Test Functions**

  - How to design appropriate test functions?
  - Examples of unconstrained test functions.
  - Examples of constrained test functions.
  - Multiobjective combinatorial optimization.
  - Real-world problems.

- **Metrics**

  - How to compare two or more multiobjective evolutionary algorithms?
  - Number of elements of the Pareto optimal set.
  - Spread.
  - Closeness to the true Pareto front.
  - Statistical Methods.
  - Are metrics doomed to fail?

- **Applications**

  - Engineering (environmental, naval & hydraulic, telecommunications and network optimization, structural & mechanical, aeronautical, electrical and electronics, robotics and control, civil and construction, and transport).

  - Scientific (geography, chemistry, physics, medicine, ecology and computer science & computer engineering).
  - Industrial (design and manufacture, scheduling, management and grouping & packing).
  - Miscellaneous (finance and classification & prediction).

- **Theory**
  - Partially ordered sets.
  - Convergence of multiobjective evolutionary algorithms.
  - Niches and other techniques used to maintain diversity.
  - Mating restrictions.
  - Complexity analysis of the main multiobjective evolutionary algorithms.
  - Computational cost.

- **Parallel Multiobjective Evolutionary Algorithms**
  - Philosophy.
  - Paradigms.
  - Examples.

- **Multi-Criteria Decision Making**
  - Attitude of the decision maker.
  - Incorporation of user's preferences into multiobjective evolutionary algorithms.
  - Issues that deserve attention.

- **Alternative Metaheuristics for Multiobjective Optimization**
  - Simulated annealing.
  - Tabu search.
  - The ant system.
  - Reinforcement learning.
  - Memetic algorithms.
  - Miscellaneous approaches (cultural algorithms, artificial immune system, cooperative search, particle swarm optimization).

- **Some Promising Paths of Future Research**
  - Multicriteria decision making and evolutionary algorithms.
  - New algorithms.

- Theoretical foundations of evolutionary multiobjective optimization.
- New heuristics.
- New metrics and limitations of the current ones.
- Local search.
- Efficiency issues.
- Unexplored ideas.

Textbook

Coello Coello, Carlos A.; Van Veldhuizen, David A. & Lamont, Gary B., *Evolutionary Algorithms for Solving Multi-Objective Problems*, Kluwer Academic Publishers, Boston, 2002 (en prensa).