UNIVERSITÀ DI PISA
DOTTORATO DI RICERCA IN INGEGNERIA INDUSTRIALE

Doctoral Course

Fundamentals of multi-objective optimization

Alessio Artoni (DICI[1]), **Francesco Pistolesi** (DII[2])

Dipartimento di Ingegneria Civile e Industriale – Università di Pisa

Contents

PART 1
Multi-objective optimization: fundamentals and classical algorithms (A. Artoni, 10 hrs)

- Introduction to multi-objective optimization
- Basic solution methods
- Advanced solution methods
- Simulation- and experiment-based multi-objective optimization
- Practical solution of real multi-objective optimization problems

PART 2
Multi-objective optimization: genetic algorithms (F. Pistolesi, 10 hrs)

- Background on multi-objective genetic algorithms
- The Non-dominated Sorting Genetic Algorithm II (NSGA-II)
- Handling constraints
- Performance evaluation
- Multi-criteria decision making

Schedule

The course is made up of ten two-hour lectures, which will be held once or twice a week. More details on the topics of each lecture can be found here below.

[1] Dipartimento di Ingegneria Civile e Industriale – Department of Civil and Industrial Engineering
[2] Dipartimento di Ingegneria dell'Informazione – Department of Information Engineering

1. **Introduction to multi-objective optimization**. Motivation for multi-objective optimization. Vector objective functions. Decision space and objective space. Pareto optimality, Pareto front and Pareto set. Ideal and nadir objective vectors. Normalization of objective functions. Examples of Pareto fronts (Alessio Artoni, 2 hrs)

2. **Basic solution methods**. Solving a multi-objective optimization problem: what does it mean? The Decision Maker. Scalarization. Weighting method. Method of weighted metrics. ε-constraint method (Alessio Artoni, 2 hrs)

3. **Advanced solution methods**. Goal programming. Normal Boundary Intersection method. Reference points. Achievement scalarizing function. Reference point method (Alessio Artoni, 2 hrs)

4. **Simulation- and experiment-based multi-objective optimization**. Computational challenges. Handling computational cost. Derivative-free optimization. Global optimization. The DIRECT algorithm and alternatives (Alessio Artoni, 2 hrs)

5. **Practical solution of real multi-objective optimization problems**. Problem formulation and solution process. Gear design optimization for automotive and aeronautical applications. Software for multi-objective optimization (Alessio Artoni, 2 hrs)

6. **Background on multi-objective genetic algorithms.** Background and preliminaries on multi-objective genetic algorithms. Encoding solutions. Genetic operators: selection, crossover, mutation. Pareto-based approaches vs. scalarized approaches: pros and cons. Typical main loop. (Francesco Pistolesi, 2 hrs)

7. **The Non-dominated Sorting Genetic Algorithm II (NSGA-II).** Pareto dominance and non-domination sorting. Diversity. The crowding distance. Main loop. The NSGA-II algorithm in MATLAB. Tutorial on the Global Optimization Toolbox. (Francesco Pistolesi, 2 hrs)

8. **Handling constraints.** Constrained problems. Measuring the constraint violation. Selection techniques that handle constraints. The NSGA-II example. Repairing techniques. How to modify crossover and mutation to fix or avoid constraint violation. Examples in combinatorial optimization (the disassembly line balancing problem). Penalty techniques. (Francesco Pistolesi, 2 hrs)

9. **Performance evaluation.** Setting the values of the parameters: crossover rate, mutation probability, population size and termination criteria. How to evaluate the performance of a multi-objective genetic algorithm. The Lebesgue measure. Statistical validation. (Francesco Pistolesi, 2 hrs)

10. **Multi-criteria decision making.** How to select the best solution from the Pareto front. Preference elicitation. Objectives and criteria. The Analytic Hierarchy Process (AHP). The Technique for Order of Preference by Similarity to Ideal Solution. (Francesco Pistolesi, 2 hrs)

Timetable

All lectures will be held in room “DIA”, Dipartimento di Ingegneria Civile e Industriale – sede di Ingegneria Aerospaziale, via G. Caruso 8, Pisa, and will be scheduled as follows.

Lecture number	Date	Time	Lecturer
1	8/10/2018 (Monday)	14:30–16:30	Alessio Artoni
2	10/10/2018 (Wednesday)	14:30–16:30	Alessio Artoni
3	15/10/2018 (Monday)	14:30–16:30	Alessio Artoni
4	17/10/2018 (Wednesday)	14:30–16:30	Alessio Artoni
5	22/10/2018 (Monday)	14:30–16:30	Alessio Artoni
6	29/10/2018 (Monday)	15:00–17:00	Francesco Pistolesi
7	5/11/2018 (Monday)	15:00–17:00	Francesco Pistolesi
8	12/11/2018 (Monday)	15:00–17:00	Francesco Pistolesi
9	19/11/2018 (Monday)	15:00–17:00	Francesco Pistolesi
10	26/11/2018 (Monday)	15:00–17:00	Francesco Pistolesi

About the lecturers

Alessio Artoni is Assistant Professor of Applied Mechanics at the Department of Civil and Industrial Engineering, University of Pisa. His research interests include geometric modeling, analysis and design optimization of gear drives, robotic motion planning and numerical optimal control, simulation-based multi-objective/robust design optimization, and biomechanics.
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Francesco Pistolesi is a Postdoctoral Researcher with the Department of Information Engineering, University of Pisa. His research interests are in computational intelligence and data mining, with applications to decision support and multi-objective optimization. He is currently working toward innovative solutions for the smart industry, ranging from industrial processes to the workers' safety, health and wellbeing.
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