

STUDY GUIDE

Heuristics and Metaheuristics for Optimization and Learning

Organised by

Department of Mathematics and Computer Science,
University of Catania

1. IDENTIFYING DATA.	
· Course Name.	Heuristics and Metaheuristics for Optimization and Learning
· Coordinating University.	University of Catania
· Partner Universities Involved.	-

· Course Field(s).	Computer Science; Engineering Computer Science; Mathematics; Operational Research; Complex Systems; Network Science	
· Related Study Programme.	Master degree in Computer Science	
· ISCED Code.		
· SDG.	4 – Quality Education 9 – Industry, innovation and infrastructure	
· Study Level.	Bachelor, Master and/or Doctorate	
· EUNICE Key Competencies	<ul style="list-style-type: none"> • Green – strongly • Orange - moderately • Red – partially • Blank cell - not at all 	
	Problem solving	Green
	Teamworking	Orange
	Communication	Blank
	Self-management	Red
	Cognitive flexibility	Red
	Digital competence	Blank
	Technical competence	Green
	Global intercultural competence	Blank

· Number of ECTS credits allocated.	6 ECTS
· Mode of Delivery.	Online live and onsite
· Language of Instruction.	The course is taught in both domestic and english language, since it often hosts lectures/seminars by international guest lecturers.
· Course Dates.	The course takes place in the second semester: from March to mid-June.
· Precise Schedule of the Lectures.	The course consists of two lessons (2h each) per week. Occasionally, there could be additional lessons, such as seminars, focusing on more practical aspects.
· Key Words.	Heuristics; metaheuristics; optimization; complex problem solving; autoML
· Catchy Phrase.	Stop and listen... Nature is a great teacher!

· Prerequisites and co-requisites.	The course requires a good knowledge of mathematical tools (discrete and continuous); algorithms and data structures; as well as excellent knowledge of at least one of the following programming languages: C, C ++, and Python.
· Number of EUNICE students that can attend the Course.	No limit
· Number of EUNICE students that can attend the course per institution	No limit
· Course inscription procedure(s).	Via EUNICE Platform

2. CONTACT DETAILS.

· Department.	Department of Mathematics and Computer Science
· Name of Lecturer.	Mario Pavone
· E-mail.	mario.pavone@unict.it
· Other Lecturers.	

3. COURSE CONTENT.

- An introduction to Computational Theory and NP-complete problems
- An introduction to the base concepts in Machine Learning and Computational Learning Theory
- Landscape, Search Space and Optimization models
- Unconstrained optimization; constrained optimization; multiobjective optimization
- Optimization methods:

- Algoritmi Greedy
- Metodi Esatti: dynamic programming; A*; branch & bound algorithm; constraint programming
- Meta-euristiche a singola soluzione: local search; tabu search; iterated local search; simulated annealing; guided local search; and GRASP
- Meta-euristiche basate su popolazione: concetti base
- Metaheuristics population based:
 - Genetic Algorithms and Genetic Programming;
 - Artificial Immune Systems;
 - Swarm Intelligence: Ant Colony Optimization; Particle Swarm Optimization; Artificial Bee Colony;
 - Differential Evolution
- Hybrid metaheuristics
- Multiobjective optimization evolutionary algorithms (MOEA)
- Metaheuristics in Decision Making
- Machine learning & Metaheuristics
- Examples of metaheuristics application in: Network Sciences; Games; Internet of Things; Computer Security; Robotics; Art and Design.

4. LEARNING OUTCOMES.

The aims of the course are focused on the design and develop of algorithms, included also the ones that take inspiration from nature and biology, as well as the key features required for developing a successful algorithm. All investigated algorithms will be analysed and applied in the following application fields: optimization; anomaly detection; decision theory; network science and game theory.

5. OBJECTIVES.

The goal of the course is to provide to each student:

- 1) good knowledge on the basic concepts;
- 2) good knowledge on the "intelligent systems" and their designing;
- 3) excellent ability in developing an efficient bio-, or nature-inspired algorithm;
- 4) problem-solving.

6. COURSE ORGANISATION.

UNITS

1.	Complexity Theory Summary & Basic Concepts
2.	Heuristics and Metaheuristics

3.	Automated Machine Learning
4.	Practical works
LEARNING RESOURCES AND TOOLS.	
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PLANNED LEARNING ACTIVITIES AND TEACHING METHODS.	
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7. ASSESSMENT METHODS, CRITERIA AND PERIOD.

The evaluation is based on three tests:

- 1) *THEORY TEST*: it consists of a written test relating to the topics covered in class;
- 2) *PROJECT AND REPORT*: it consists on the development of an investigated algorithm to be applied and tested on a given complex problem. The following information will be provided: (i) problem to be solved; (ii) set of problem instances on which to test the efficiency of the developed algorithm; (iii) list of some heuristics and/or meta-heuristics, from which the student must choose the algorithm to be implemented; (iv) objective function (if needed); (v) experimental protocol to follow for evaluating the efficiency of the algorithm. The project must be delivered within 15-20 days of its assignment. Expired the assigned time, the student must submit (by email) for the evaluation: (a) source code of the developed algorithm; and (b) report written in Latex. The algorithm must be developed using one of the following programming languages: C, C ++, or Python.
- 3) *ORAL INTERVIEW*: oral discussion on the project, via PowerPoint or PDF presentation made by the student. The student will have 10 minutes as maximum time, during which discuss on the algorithm carried out, the relative key points and the originalities introduced.

OBSERVATIONS.

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8. BIBLIOGRAPHY AND TEACHING MATERIALS.

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