Program	Type of studies (cycle)	Third cycle
	Name of the program	Doctoral Studies in Mathematical and Computer Science

COURSE

Course title	**Metaheuristic optimization and intelligent search**

Course code	Semester	Course status	ECTS credits	Contact hours
CS 602	II	elective	10	30

Aims and intended learning outcomes	The aim of the course is to deepen advanced knowledge of metaheuristic optimization and intelligent search, with an emphasis on evolutionary algorithms, swarm intelligence, gradient-free algorithms, and hybrid approaches to solving complex optimization problems. The course enables the student to understand local and global optimization, constrained and unconstrained optimization, multi-objective optimization, constraint handling, objective-function definition, selection of a solution representation, and the analysis of convergence, robustness, and computational complexity of metaheuristic methods. Upon completion of the course, the student is able to independently formulate an optimization problem, select or design an appropriate metaheuristic method and implement it, and experimentally evaluate it and statistically compare it with methods from the literature. The student should also be able to present research results in the form of a seminar paper or scientific article.

Course content/topics

- Introduction to optimization and intelligent search: problem formulation, solution space, objective function, constraints, local and global optima, deterministic and stochastic approaches.
- Fundamentals of metaheuristic methods: solution representation, initialization, search operators, stopping criteria, exploration and exploitation, robustness, and computational complexity.
- Classical optimization methods: gradient-based methods, gradient-free methods, line search, conjugate gradient, Quasi-Newton methods, and their relationship to modern metaheuristics.
- Evolutionary algorithms: genetic algorithms, differential evolution, evolution strategies, selection, crossover, mutation, parameter adaptation, and performance analysis.
- Swarm intelligence and nature-inspired algorithms: PSO, ACO, ABC, Bat Algorithm, Cuckoo Search, Flower Pollination Algorithm, Harris Hawks Optimization, and related approaches.
- Constrained and multi-objective optimization: penalty methods, repair operators, Pareto optimality, compromise solutions, and algorithm evaluation.
- Hybrid and memetic metaheuristics: combining global and local search, hybridization with K-means, problem-specific heuristics, and machine learning.
- Applications in machine learning and intelligent systems: hyperparameter optimization, feature selection, and tuning of classification, regression, and deep learning models.
- Applications in image processing, computational geometry, and engineering problems: image segmentation and compression, image reconstruction, path planning, sensor and camera placement, triangulations, and coverage problems.
- Experimental design and reproducibility: benchmark problems, quality measures, execution time, algorithm stability, statistical tests, comparison with the literature, visualization of results, and preparation of a scientific paper.
- Research project: formulation of a specific optimization problem, implementation of one or more metaheuristics, experimental analysis, and presentation of results in the form of a paper appropriate for doctoral studies.

LITERATURE

[1] Bastien Chopard, Marco Tomassini: An Introduction to Metaheuristics for Optimization, Springer Nature Singapore, 2026.

[2] Abualigah, L., Metaheuristic Optimization Algorithms: Optimizers, Analysis, and Applications. Elsevier, 2024.

[3] Yang, X.-S., Nature-Inspired Optimization Algorithms, Academic Press, 2021; 2nd ed., 2021.

[4] Michel Gendreau and Jean-Yves Potvin (eds.), Handbook of Metaheuristics, 3rd ed., Springer, 2019.

[5] Yang, X.-S., Introduction to Algorithms for Data Mining and Machine Learning, Academic Press, 2019.

[6] Selected recent research papers from IEEE, ACM, Springer and Elsevier databases, in accordance with the selected doctoral research topic.

Grading

	Criterion	Points	Cut-off points
1.	Assignments	20	11
2.	Project	40	22
3	Final exam	40	22
	T o t a l	100	55