esade

Syllabus

Optimization and Computational Modeling

Barcelona, February 2026

Do Good. Do Better

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1. Course description

This course aims to develop a comprehensive understanding of optimization and modeling approaches to effectively tackle complex economic, social, and environmental challenges. By integrating optimization methods and simulations, the course bridges the gap between theory and practice, empowering students with computational problem-solving skills. Optimization methods play a crucial role in enhancing decision-making processes and maximizing outcomes. By exploring various techniques such as heuristic search, hill-climbing search, simulated annealing, and tabu search. Heuristics are a way to define KPIs using a mathematical formula to optimize. The hill-climbing search involves iteratively improving a solution by making small changes, while simulated annealing mimics the process of annealing to find global optima. Tabu search utilizes a memory mechanism to avoid revisiting previously explored solutions. Combined, these methods will equip students with tools to identify the most optimal solution, leading to increased efficiency, cost savings, and competitive advantage.

Besides the course will introduce students into simulations methods, starting with Monte Carlo simulations that utilize random sampling to estimate outcomes. We will then introduce evolutionary algorithms that involve iterative selection, recombination, and mutation to find optimal solutions. Finally, we describe ant algorithms, a kind of algorithm that is inspired by the behavior of ants and their pheromone trails to solve complex problems.

In the context of business and artificial intelligence, these techniques are highly relevant and applicable across various domains, including operations management, finance, marketing, and strategic planning. Students will be well-equipped to analyze data, optimize processes, and devise innovative solutions, which are essential competencies in the evolving landscape of business and technology.

2. Learning objectives and competencies

At the end of the course, students should:

1. Understand the difference between search and optimization
2. Have the computational mindset to solve tasks such as optimization.
3. Learn how to use different types of simulations to solve computational problems.
4. Be familiar with the main ideas behind optimization algorithms.
5. Revisit programming skills. Throughout the course, participants will develop abilities to write and execute Python programs to solve several business-oriented problems using algorithms.

Upon the course completion, students will possess a comprehensive toolkit for tackling optimization tasks, empowering them to address several business challenges.

3. Course format and methodological approach

To achieve the course objectives, a blend of lectures, class discussions, and practical exercises will be employed. The course structure is designed in a way that lectures and in-class activities constitute 50% of student's engagement. The remaining 50% is dedicated to assignments and preparation for the mid-term and final exams.
Lecture/Discussion. During theoretical lessons, we will introduce the basic concepts for each topic. These sessions will be devoted to the presentation and discussion of frameworks, concepts, and theories.

Practice. In Practice sessions, students will work with different practical exercises. In-class exercises will help to interiorize and reflect the concepts discussed in theory lessons. Exercises can be on paper or with Python.

What do we expect from you in class?

In lectures, we expect students to participate in questions and discussions.

In practical sessions, we expect students to solve the exercises included in the notebooks. Some of the work will be handed in as homework for the students to complete individually.

A learning area will be available on the Moodle webpage, where you will find instructions for the sessions, communications, bibliography, etc. Slides for the different sessions will also be posted here every week.

Solving optimization and mathematical problems is an activity that is usually done in teams. Your classmates can help solve your doubts, find errors in your solution, and suggest different ideas and solutions. To facilitate this exchange, a dedicated Forum will be opened in Moodle for students to share their doubts. Participation in this Forum is highly encouraged and will be considered for the final grade.

4. Course Contents

Topic 1: Algorithmic recap

Content:

- Introduction to the course
- The Big O Notation
- Graph recap
- Dynamic Programming
- Introduction to NumPy (Practice I)

Preparation:

- Read this syllabus!
- Moodle's Video

Topic 2: Heuristic Search

Content:

- Heuristic functions
- A* Algorithm
- Dijkstra's algorithm
- Heuristic properties
- Implementing linear models with NumPy (Assignment I)

Preparation:

- Complete some exercises
- Moodle's Video

Topic 3: Monte Carlo Method

Content:

- Gambler's fallacy
- Gibbs Sampling
- Monte Carlo Simulation
- Markov Chain Models
- Propagation models using Monte Carlo Simulations (Assignment II)

Preparation:

- Complete some exercises
- Moodle's Video

Topic 4: Hill-climbing

Content:

- Introduction to optimization methods
- Recap on greedy approaches
- Hill-climbing algorithm
- Iterative hill-climbing
- Stochastic hill-climbing

Preparation:

- Complete some exercises
- Moodle's Video

Topic 5: Simulated Annealing

Content:

- Metaheuristic definition
- Introduction of the Gibbs Energy idea
- The annealing schedule

Preparation:

- Complete some exercises

- Moodle's Video

Topic 6: Tabu search

Content:

- Definition
- Tabu memory
- Memory management
- Algorithm
- Optimizing portfolio management (Assignment III)

Preparation:

- Complete some exercises
- Moodle's Video

Topic 7: Swarm intelligence

Content:

- Distributed AI introduction
- Particle swarm optimization (PSO)
- Ant colony optimization (ACO)

Preparation:

- Complete some exercises
- Moodle's Video

Topic 8: Genetic algorithms

Content:

- Framework
- Crossover definition
- Mutation
- Algorithm

Preparation:

- Complete some exercises
- Moodle's Video

5. Assessment

30%	Assignments (10% each)
30%	Mid-term Exam
40%	Final Exam

Assignments:

Three different group assignments will be delivered throughout the course. Submission of all assignments is mandatory to pass the course.

Assignments will cover the contents of the practice sessions. A text file with instructions will be made available for students to download from Moodle and submit back with their answers. The only accepted submission format is a Python file. Students will be expected to check that their code runs and that it fulfills all the requirements.

Assignments will be graded in terms of the level of completion of the different exercises. Some practice sessions will include a quiz at the end of the session. These quizzes form part of the assignment grade and are used to evaluate individual practical knowledge. Quizzes missed due to absence cannot be recovered or compensated.

IMPORTANT: Assignments should be delivered on time to be evaluated. Check the calendar for due dates. Late assignments will be marked with a 0.

This course follows strictly ESADE's code of Honor. If you read or use assignment solutions from previous years, it would not only harm your learning process but would be considered as a serious violation of the Honor Code and will carry the corresponding disciplinary measures (among them: course failure). The same would happen if you know that someone has done it and you don't inform us. All submissions go through a process of plagiarism detection.

Class participation:

Students will be expected to actively participate in class. Given that many of the lessons will be delivered with the entire group it may be difficult for many of you to take active part in class. Hence, participation grade is included in the assignments' grades.

Mid-term exam:

The mid-term exam will consist of four exercises covering both the theoretical material and the practice learnings of the course. More information about the mid-term exam will be made available as the course progresses. It's an incremental subject; the mid-term exam does not exonerate any content for the final exam.

Final Exam:

The final exam will consist of four exercises covering both the theoretical material and the practice learnings of the course. A minimum grade of 4 is required to pass the course. More information about the final exam will be made available as the course progresses.

Retake Exam:

The retake exam will consist of four exercises covering both the theoretical material and the practice learnings of the course. A minimum grade of 4 is required to pass the course. The first retake exam grade only substitutes the mid-term and final exam grades. The rest of the evaluation will remain unchanged. In subsequent retake exams, only the retake exam grade will be taken into consideration, necessitating a minimum score of 5.0.

Attendance:

Students will be expected to be present in class at the scheduled start time. It is recommended that they arrive a few minutes early to ensure sufficient time for settling in and registering attendance. They will be marked **Late** if they miss

between 5 and 15 minutes of total class time, and **Absent** if they miss 15 minutes or more of the class session. Four **Late** designations will be counted as an absence.

Occasional absences will not be justified. For prolonged absences (a minimum of one week), students must provide a valid justification to their program manager. According to BBA&BAIB rules and regulations, students are obligated to submit these documents within one week of their initial absence. Under no circumstances should such justifications be sent directly to the professor. Fully justified absences will be excused by the end of the course.

In adherence to ESADE regulations, **attendance is mandatory** for this course. Students will be allowed to miss up to 20% of class hours, which corresponds to **4 sessions**. This includes absences accumulated, even partially, due to the tardiness/lateness policy. Students who exceed the absence limit will not be allowed to pass the course in the first attempt and will be required to sit the retake.

6. Materials

PDF Slides (available through Moodle) Python
Problems, notebooks, and additional files (Moodle)

Reference book (additional material, not a requirement for the course):

1. Edelkamp, Stefan, and Stefan Schrodl. Heuristic search: theory and applications. Elsevier, 2011.
2. Stuart Russell and Peter Norvig, Artificial Intelligence: A Modern Approach, 4th edition, Pearson, 2021.

Additionally, specific literature (both articles and/or books) could be recommended for other topics if required.

7. Faculty leading the course

Jordi Nin obtained a computer science degree from the Universitat Autònoma de Barcelona (UAB) in 2004. Then he joined the Artificial Intelligence Research Institute of the Spanish National Research Council (IIIA-CSIC). In 2008, he received the Ph.D. in Computer Science obtaining the Outstanding Ph.D. Award from the UAB computer science department. Later he joined as a post-doctoral researcher at the French National Center for Scientific Research (CNRS). In 2010, he joined the Computer Architecture Dept. of the Universitat Politècnica de Catalunya (UPC) as a tenure-track lecturer. Lastly, from 2015 to 2019 he worked as a senior data scientist at BBVA Data & Analytics. Since 2020, he has worked as an associate professor at Esade. Jordi's research interests are machine learning, complex networks, and trustworthy AI.

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Davide Careglio received the M.Sc. double degree in telecommunications engineering and electrical engineering from the Technical University of Catalonia (UPC) (2000) and Politecnico di Torino (2001), respectively, and his PhD from UPC in 2005. His research interests are focused on algorithms and protocols for computer networks with special interests in interoperability, control, management, planning, and routing. He has been involved in several EU and industrial research projects.

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8. Timetable and sections (Information obtained from the Registrars' Office)