esade

TEACHING GUIDE - 2024-2025

Computational Problem Solving

UGRA_015726

Departments	Dept. of Operations, Innovation & Data Sciences
Teaching Languages	English
ECTS	6
Teacher responsible	Nin Guerrero Jordi - jordi.nin@esade.edu

Course Goals

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 hill-climbing search, simulated annealing, and tabu search. 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.

The second part of the course will delve into simulations, 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. The course will end by explaining the basis of Bayesian optimization, which allows students to explore emergent properties and simulate the behavior of the complex interactions within a system, providing insights into the dynamics of environmental, and economic phenomena.

Previous knowledge

This is an introductory course to numerical optimization and simulations with Python. To follow this course, a solid understanding of basic mathematical operations and functions is recommended. It includes familiarity with derivatives, gradients, and general algebraic expressions. In addition to the mathematical prerequisites, this course assumes a certain level of proficiency in Python. Specifically, you should be comfortable with the following aspects of Python:

· Basic Python Syntax: Understanding of basic Python syntax, including variable assignments, control structures (like loops and conditionals), and data structures (like lists, tuples, and dictionaries).
· Functions: Ability to define and call functions, understanding of the concept of function arguments, and return values.
· Classes and Object-Oriented Programming (OOP): Knowledge of how to create classes using the object-oriented programming framework in Python is crucial. You should be familiar with concepts like classes, objects, methods, and attributes.
· Python Libraries: Familiarity with Python's scientific libraries like NumPy, Pandas, and Matplotlib will be beneficial.

- Despite these prerequisites, the course is designed to be as self-contained as possible.

Prerequisits

- Computing Foundations
- Programming with data
- Data Structures and Algorithm Design

Recomended courses

- Computing Foundations
- Programming with data
- Data Structures and Algorithm Design

Teaching methodology

To achieve the objectives, this course will be based on lectures, class discussions, and practice. Lectures and in-class exercises will represent 50% of the workload. The assignments and the preparation for the mid-term and final exams will represent the other 50% of the workload.

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, and discussed in theory class. 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 that students solve the different 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 AI/ML problems is an activity that is usually done in teams. Your classmates can help to 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.

Description

Course contribution to program

In the context of business administration and artificial intelligence, optimization and simulation 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.

Short description

This course is designed to equip students with the fundamental concepts and tools of optimization and simulation, which are integral to decision-making in the business world.

The **optimization** component of the course focuses on techniques for finding the best solutions to complex business problems, such as resource allocation, scheduling, and strategic planning. Students will learn various optimization methods, including linear programming, integer programming, and nonlinear programming.

The **simulation** component introduces students to the process of creating computer models to imitate real-world business scenarios. This allows students to analyze complex systems, test hypotheses, and predict future outcomes. Topics covered include Monte Carlo simulation, discrete-event simulation, and risk analysis.

By the end of the course, students will be able to apply these techniques to solve real-world business problems, making them valuable assets in any organization. This course is ideal for students who are interested in enhancing their analytical skills and learning how to make data-driven decisions.

Bibliography

Stuart Russell and Peter Norvig, Artificial Intelligence: A Modern Approach (4th edition), Pearson, 978-1-292-40113-3 (Book)

Stefan Edelkamp, and Stefan Schrodl., Heuristic search: theory and applications, Elsevier, 978-0-12-372512-7 (Book)

Content

#	Topic
1	Monte Carlo Method. The topic includes the Gambler's Fallacy, a common misconception in probability theory, explores Gibbs Sampling as an iterative technique in statistical mechanics, and examines the Monte Carlo Simulation method used for approximating numerical solutions
2	Hill-climbing. This topic provides an introduction to optimization methods, offers a recap on greedy approaches, and delves into the specifics of the Hill-Climbing algorithm, including its iterative and stochastic variants.
3	Simulated Annealing. This topic introduces the concept of Metaheuristics, describes the idea of Gibbs Energy in statistical mechanics, and explains the Annealing Schedule used in optimization algorithms.
4	Tabu search. This topic delves into the definition of Tabu Search, an optimization algorithm, explores the concept of Tabu Memory used in the search process, and discusses strategies for effective memory management in tabu search algorithms.
5	Swarm intelligence. This topic introduces the concept of Distributed AI, delves into the Particle Swarm Optimization (PSO) technique, and explores the Ant Colony Optimization (ACO) algorithm, both inspired by nature's collective behaviors.
6	Genetic algorithms. This topic introduces the idea behind Genetic Algorithms, explains the concept of Crossover in genetic reproduction, discusses the role of Mutation in genetic variation, and delves into the structure and functioning of these algorithms.
7	Bayesian optimization. This topic delves into the Bayes' Theorem and its evaluation in probabilistic models, and introduces the definition of Gaussian Processes.

Assessment

Tool	Assessment tool	Category	Weight %
Individual or team exercises	Assignment 1 - Monte Carlo Simulation	Ordinary round	10.00%
Individual or team exercises	Assignment 2 - Numerical optimization	Ordinary round	10.00%
Individual or team exercises	Assignment 3 - Distributed numerical optimization	Ordinary round	10.00%
Individual or team exercises	Assignment 4 - Bayesian optimization	Ordinary round	10.00%
Written and/or oral exams	Mid-term exam	Ordinary round	30.00%
Written and/or oral exams	Final exam	Ordinary round	30.00%

Tool	Assessment tool	Category	Weight %
Written and/or oral exams	First retake exam	Retake	60.00%
Written and/or oral exams	Second and subsequent retake exams	Retake	100.00%
Attendance and punctuality	Attendance. In accordance with ESADE regulations, attendance is mandatory for this course. Students who fail to attend 80% of the course will not be allowed to pass and will be required to sit the retake exam.	Ordinary round	0.00%

PROGRAMS

DBAI21-Double Degree in Business Administration and Artificial Intelligence for Business (Undergraduates: Business)
- DBAI21 Year 2 (Mandatory)

DBAI23-Double Degree in Business Administration and Artificial Intelligence for Business (Undergraduates: Business)
- DBAI23 Year 2 (Mandatory)