UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

Dipartimento di Scienze e Metodi dell'Ingegneria

Discrete Optimization: Theory and Practical Methods

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This course provides an overview of various techniques and algorithms used to solve discrete optimization problems. The goal of this course is to provide students with a strong foundation in discrete optimization and equip them with the necessary tools and techniques to solve a wide range of discrete optimization problems. By the end of the course, students will have a thorough understanding of the theory, as well as the ability to use both exact and heuristic algorithms to solve discrete optimization problems. They will also be familiar with classical problems and their solutions, and will have hands-on experience using state-of-the-art optimization tools to solve these problems. The course concludes with a focus on recent developments in discrete optimization problems using data science techniques.

Requirements

- Having a good knowledge of Python
- Having successfully passed at least one exam in operations research/optimization

Lectures 2 to 5 will include some programming exercises. Students are encouraged to bring their laptops to those classes. The exercises will be run on Google Colab <https://colab.google/> with Gurobi <https://www.gurobi.com/>. Please ensure that a google account is ready, and a free Academic Web License Service has been registered <https://www.gurobi.com/features/academic-wls-license/>. We will go through the set up together in classes.

Lecture 1: Monday 13 October 2025, 9:00 – 13:00 Reggio Emilia Technopole (room will be confirmed soon)
Review of Linear Programming (LP) and Integer Linear Programming (ILP)

- Standard Form of LP and Geometry
- The Simplex Method
- Duality Theory
- Integer Programming
- Branch-and-Bound
- Cutting Plane Method
- Real-life applications

Lecture 2: Tuesday 14 October 2025, 9:00 – 13:00 Reggio Emilia Technopole (room will be confirmed soon)
Classical Optimization Problems

- Network Optimization
- The Knapsack Problem
- Set Packing, Covering, and Partitioning
- The Traveling Salesman Problem

- Vehicle Routing Problem
- Facility Location
- Problem Complexity
- In-class activity: solving classical problems with Gurobi (in Python)

Lecture 3: Wednesday 15 October 2025, 9:00 – 13:00 Reggio Emilia Technopole (room will be confirmed soon)
Formulation and Polyhedra

- Comparison of Formulations
- Convex hull
- Faces and Facets
- Strong valid inequalities
- In-class activity: adding cuts with Gurobi (in Python) and understanding the solver log files

Lecture 4: Thursday 16 October 2025, 9:00 – 13:00 Reggio Emilia Technopole (room will be confirmed soon)
Heuristics

- Greedy Heuristics
- Tabu Search
- Simulated Annealing
- Genetic Algorithms
- Variable Neighborhood Search
- In-class activity: implementing heuristics with open-source packages and using a heuristic solution as an initial solution for exact methods (in Python)

Lecture 5: Friday 17 October 2025, 9:00 – 13:00 Reggio Emilia Technopole (room will be confirmed soon)
Recent Development for Discrete Optimization Problems with Data Science Techniques

- Stochastic Programming
- Machine Learning
- Reinforcement Learning
- Interplay between Discrete Optimization and Data Science
- In-class activity: implementing a data-driven method for discrete optimization problems (in Python)

Lecture 6: Monday 3 November 2025, 9:00 (deadline)
Final Exam

- Each group will be required to deliver their research project

Bibliography:

- CHVATAL, V, *Linear Programming*, Series of books in the mathematical
- sciences, Bedford books, 2016.CONFORTI, M.; CORNUEJOLS, G.; ZAMBELLI, G. *Integer programming*. Springer International Publishing, 2014.
- NEMHAUSER, G. L.; WOLSEY, L. A. *Integer and Combinatorial Optimization*. John Wiley & Sons, 1988.
- SUTTON, R.S.;BARTO, A.G. *Reinforcement learning: An introduction*. MIT press, 2018.
- VANDERBEI, R.j., *Linear programming: foundations and extensions*. Springer, 2020.
- WOLSEY, L. A. *Integer programming*. John Wiley & Sons, 2020