

Methods and Model for Combinatorial Optimization

General info and Programme

Luigi De Giovanni

Contacts

Luigi De Giovanni

Dipartimento di Matematica “Tullio Levi-Civita”, office 423

luigi@math.unipd.it

tel. 049 827 1349, **Zoom meeting**

office hours: Thursday, 10:30 - 12:30 am (or others, email the teacher)

Goals

The course unit introduces advanced modelling and solution techniques for combinatorial optimization problems, where an optimal solution has to be determined among a huge number of alternatives.

The course unit aims at providing mathematical and algorithmic tools to solve optimization problems of practical interest, by the design of algorithms and mathematical programming models, and their implementation with most popular software packages or libraries.

After the course unit, you should be able to search the literature for, find, understand, adapt and implement state-of-the-art approaches to solve real combinatorial optimization problems that may arise in many fields: logistic and transportation networks, production management, complex networks analysis, data-driven decision-making, machine-learning processes, telecommunication network configuration etc.

Prerequisites

Preliminary notions about linear programming and operations research will be thoroughly reviewed during the class units. Programming skills (preferably C++ or Python) are advisable.

Preliminary Programme

Review, advanced topics and application of Linear Programming and Duality

- Linear Programming models, simplex method, basic notions of duality theory
- Column generation technique for large size linear programming models
- Sample applications: production planning optimization, network flows

Advanced methods for Mixed Integer Linear Programming (MILP)

- Branch & Bound and relaxation techniques
- Alternative and strengthened formulations of MILPs
- Cutting plane methods and Branch & Cut techniques
- Sample applications: Travelling Salesman Problem, Facility Location, Set Covering etc.

Meta-heuristics for Combinatorial Optimization

- Neighbourhood search and variants
- Genetic Algorithms
- Introduction to hybrid methods, data-driven optimization and Matheuristics

Sample applications and case study among:

- Modelling optimization problems on graphs as network flows, algorithms for network flows problems (e.g. spanning trees, minimum cost flows, maximum flow)
- Express freight delivery
- Data-driven optimization in Air Traffic Management
- Optimization of Neural Network structure (topology and weights)
- Social Network analysis
- ...

Labs

- On-line optimization servers (e.g., NEOS)
- Optimization software and Algebraic modelling languages (e.g. AMPL, **IBM-OPL**)
- Optimization libraries (e.g. **IBM Cplex**, Coin-OR, Scip, Google OR-Tools, **Python**, Matlab etc.)

Examination method

Lab exercise and Oral examination

Lab exercise [score 0 to 10, minimum 5]: implementation of **(i)** a MILP model (using integer programming libraries or algebraic modelling languages) and **(ii)** a meta-heuristic (using C, C++, python, Matlab or other programming language/library agreed with the teacher) for a combinatorial optimization problem proposed by the teacher. To be delivered about 5 days before the oral examination;

Oral examination on the course unit contents [**score 0 to 20, minimum 10**]

To pass the exam, the total score Lab exercise + Oral examination must be at least 18.

Interested students can also deliver an **Optional short project [score up to 6, depending on size and quality]** consisting in an additional exact and/or heuristic solution method for a combinatorial optimization problem (to be agreed with the teacher).

Practical info

The course unit is delivered in the **First Semester** and includes **48 hours (6 CFU)**: 36 hours lectures + 12 hours labs.

Teaching mode: the teaching units will be delivered in classroom or lab, recordings will be also available on-line. The first teaching unit, devoted to course presentation and organization, will be delivered in dual mode (both face-to-face in classroom and live streaming via Zoom) to facilitate interaction with participants. Further streaming will be discussed with the students.

Moodle: Lecture notes, lab material, virtual classes, teaching unit recordings, notices, interaction with students etc. will be available via the Moodle platform at the link

<https://stem.elearning.unipd.it/course/view.php?id=9937>

Schedule: Thursday and Friday, 2:30 – 4:30 pm

Classes will be in Room 2AB45 or in LabP140 or in LabTA: **please, always check** the official on-line schedule, or the notices from Moodle.

Planned learning activities and teaching methods

Classes, Labs, Discussion about case studies. During labs, some basic optimization algorithms will be implemented, both exact (using modelling languages or optimization libraries) and heuristic.

Textbooks and software

- Lecture notes provided by the teacher + articles from scientific journals.
- Optimization software packages available on line and in labs.