1 Lectures

Class sessions:

- Lecturer: Fernando Dias (fernando.dias@aalto.fi);
- Session info: Thu, 14:15h - 16:00h - 213a - 213a (Starting Sept 7th);

Exercise sessions:

- Teaching Assistant: Topias Terho (topias.terho@aalto.fi);
- Session info: Thu, 16:15 - 18:00h - E-sali - Y124 (Staring Sept 7th);

2 Course description

Mathematical optimisation (nonlinear optimisation, in its most general form) is a powerful framework in which one seeks to **find** variable values within a **domain** that maximise (or minimise) the value of a given **function**. Using the analogy that variables represent **decisions** or parameters to be defined and the function is a **performance** measure, one can use that framework to support decision-making in a wide range of applications (even beyond mathematics and engineering), from planning industrial chemical plants to training models that learn from data and bioinformatic tools.

In this course, the student will learn the basic optimisation theory behind the main numerical algorithms available and how they can be applied to optimisation problems. At the end of the course, it is expected that the student will be capable of **analysing** the main characteristics of an optimisation problem and **deciding** the most suitable method for its solution.

3 Learning outcomes

Upon completing this course, the student should be able to

- **understand** how several important problems arising from diverse fields can be cast and solved as nonlinear optimisation problems;
- **familiarise** themselves with classical non-linear problems;
- **know** the main techniques for **modelling** and **solving** nonlinear optimisation problems and how to apply them in practice;
- **know** how to use optimisation software for **implementing** and **solving** nonlinear optimisation problems.

4 Teaching methods

The course will be taught by a composition of the following methods:

- lectures;
- theoretical and computational exercises;
- project assignment and feedback.

The lectures will be in person. For the exercise sessions and to address general questions about the course content or administration, we will use **Zulip**. **Zulip** is the standard chat platform in the Department of Mathematics and Systems Analysis and offers the possibility for calls and using Latex on messages.

Remark: Zulip link: `https://ms-e2122.zulip.aalto.fi/join/3mvt6c55kaflno6zn5ujkco2/`

As preparation for the lectures (Thursdays at 14.15h-16.00h), the students will be encouraged to study and familiarise themselves with the **lecture notes** (about 10 pages per lecture) beforehand and formulate questions to be submitted before (via Zulip) or during the lectures. Lecture notes for each week will be available every Monday (prior to the weekly lecture).

The exercise sessions (Thursday at 16:15-18:00h) will happen as self-study sessions, in which the students are expected to study the exercises and by the end, the teaching assistant will help and provide solution to such exercises. In addition, whenever possible due to time constraints, addition support on additional assignment and homework will be also provided.

The time slot of the exercise sessions will work as office hours for the students to clarify questions related to content, homework and assignments. Whenever possible, we will monitor the course's Zulip chat to answer any questions. However, for timely support, we recommend that the students join the exercise sessions on Zulip and ask questions there.

Remark: Reception hour: Lecturer: Fridays at 13:00 - 14:00 in room Y214 (Otakaari 1). Please confirm the appointment by contacting via email first.

5 Assessment

The final grade of the course is composed of three components:

H: 4 homework assignments;
$P1$: Project assignment 1;
$P2$: Project assignment 2;

Each component will be graded individually in a scale of 0-100. The final grade FG will be calculated as

$$FG = 0.5 \times H + 0.25 \times P1 + 0.25 \times P2.$$

The conversion scale for to the 1-5 scale is as follows.

1-5	0-100
Fail	0-50
1	51-60
2	61-70
3	71-80
4	81-90
5	91-100

Table 1: Conversion from 0-100 to 1-5 scale

5.1 Homework assignments

A total of 4 homework assignments will be handed out. Each homework is worth 25 points, adding to 100 points. The homework will be available on specific Mondays (see schedule below) from MyCourses and will have a deadline of the Monday evening of the following fortnight (two weeks). The submission of the solutions must be made through MyCourses. Homework submissions after the deadlines will have a 5-point discount plus extra 5 points per each day (24h) after the deadline.

The homework will be composed of theoretical and computational exercises. The computational skills required to solve the exercises will be introduced in the exercise tutorials, but the student is expected to learn and practise the language independently. Supporting material for that will be provided. The programming language) will be used in this course is Julia (julialang.org).

5.2 Project assignments

The students will be requested to develop guided projects on two distinct topics to be provided. The objective of the projects is to use the acquired knowledge in nonlinear optimisation in practice and discuss related technical aspects.

The projects can be conducted individually or in pairs. Each project will comprise an implementation using Julia that addresses the requirements of the projects and a 3000-4000 word (approximately 5-7 pages) report. The course lecture will grade each report.

6 Course material

Main study material: lecture notes, lecture slides, exercise tutorials, homework assignments, course book.

The lecture material is mostly based on the main course book *M. Bazaraa et al., Nonlinear Programming, Wiley-Interscience, 2006.*

7 Course schedule

A tentative schedule for the course is given. Content of each class may be adapted according to the pace of the classes.

Week	Lecture	Content
35	I	Admin. and introduction
36	II	Topology - Convex sets
37	III	Analysis - Convex functions (Homework I - Published)
38	IV	Optimality conditions I (Homework II - Published)
39	V	Unconstrained optimisation methods I (Project I - Published
40	VI	Unconstrained optimisation methods II
41	–	*Break between Periods I and II*
42	VII	Optimality conditions II
43	VIII	Lagrangian duality (Homework III - Published)
44	IX	Constrained optimisation methods I
45	X	Constrained optimisation methods II (Homework IV and Project II - Published)
46	XI	Constrained optimisation methods III
47	XII	Computational and practical points

Table 2: Schedule of classes

8 Workload estimate

The table below shows an estimate of the total workload of the course. Recall that each ECT credit is equivalent to 28h of work, and thus, 5 ECTs are equivalent to 140h in total.

Activity	Hours	# Events	Total hours
Self study (exercise videos, notes)	3	12	36
Contact session	2	12	24
Homework	10	4	40
Project assignments	20	2	40
		Total workload:	**140**