MVE165/MMG630 Applied Optimization, 7.5 hec

AIM: A main purpose with the course is to give the students an overview of important areas where optimization problems often are considered in applications, and an overview of some important practical techniques for their solution. Another purpose of the course is to provide insights into such problem areas from both an applications and a theoretical perspective, including the the analysis of an optimization model and suitable choices of solution approaches. The work with concrete problems during the course enables the establishment of these insights.

After completion of this course, the student should be able to understand the main principles behind the modelling of optimization problems and have a clear overview of the most important classes of optimization problems. Within each class the student shall have reached insights about at least one basic solution technique and be able to complete an entire optimization project within this class, including all links of the chain *modelling → model analysis → implementation in suitable algorithm/software → (sensitivity) analysis of an optimal solution.*

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- Mehdi Sharif Yazdi, PhD, Department of Mathematical Sciences
- Emil Gustafsson, MSc, Department of Mathematical Sciences.

CONTENTS: This course describes with the aid of practical cases how optimization problems are modelled and solved in practice. In addition to a lecture series given by staff at Mathematical Sciences there is a series of guest lectures mainly by staff at other departments of Chalmers and University of Gothenburg. The contents of the course may therefore vary in terms of topics between the years, but a common thread is the practical solution of optimization problems. The lectures and guest lectures are connected to computer exercises and project assignments, which constitute the main basis for examination.

The variety of problems covered over the years includes investment, blending, models of energy systems, production and maintenance planning, network models, routing and transport, multi-objective optimization, and inventory planning. Among the algorithm techniques discussed are simplex and interior points methods for linear programming, gradient based methods for non-linear optimization, branch–and–bound and heuristic methods for integer linear programming, simulation, and dynamic programming. The software used to solved practical problems include AMPL, Cplex, Matlab, and Tomlab.

PREREQUISITES: Passed courses in analysis (in one and several variables) and linear algebra; familiarity with matrix/vector notation and calculus.

ORGANIZATION: The course consists of a lecture series of mathematical material, a guest lecture series of practical material, computer exercises, project assignment work, opposition, and student presentations of the assignments.

COURSE LITERATURE: Available at Cremona in Swedish and English.

(i) Optimization (English, ISBN 9144053088, 2010)/Optimeringslära (Swedish, ISBN 9144053142, 2008). J. Lundgren, M. Rönnqvist, P. Värbrand. Studentlitteratur.

(ii) Optimization Exercises (English, ISBN 914405310X, 2010)/Optimeringslära Övningsbok (Swedish, ISBN 9144053126, 2008). M. Henningsson, J. Lundgren, M. Rönnqvist, P. Värbrand. Studentlitteratur.

(iii) Hand-outs from books and articles and descriptions of exercises and assignments.

COURSE REQUIREMENTS: The course content is defined by the literature references **(i)**, **(ii)**, and **(iii)** in the course plan below. The importance of each moment of the course is defined by the respective emphasis given by the lectures, exercises, and assignment tasks.

EXAMINATION:

- Exercises 1 and 2 are recommended to complete but not compulsory.
- Written reports of three assignments (for Assignment 3 there are four alternative project topics).
- A written opposition to Assignment 2.
- An oral presentation of Assignment 3.
- To be able to receive a grade higher than 3 or G, the written reports and opposition as well as the oral presentation must be of high quality. Students aiming at grade 4, 5, or VG must also pass an oral exam.

SCHEDULE:

Lectures are given Mondays 13.15–15.00, Thursdays 10.00–11.45, and Fridays 10.00–11.45, starting on Monday 21 March 2011; see the course plan below and the schedule at `timeedit.ita.chalmers.se`. The lectures are given in English (if not all involved understand Swedish).

Assignments are performed in groups of maximum two persons. Deadlines for handing in reports are indicated in the course plan below.

Oral presentations of Assignment 3 are held by the students according to the course plan below. *Presence is compulsory at at least one of Lectures 19–21.*

Computer elaboration times: The Linux classroom F-T4009 is reserved according to the plan below; presence is *not* compulsory.

Assignment and computer exercise material, lecture notes, and most hand-outs will be continuously posted at `www.math.chalmers.se/Math/Grundutb/CTH/mve165/1011`

COURSE PLAN with literature references (sections in parentheses are less emphasized)

Week 12

Lecture 1 — Monday 21/3, 13–15, FL61
Introduction; course map; operations research; modelling optimization applications; graphic solution. **(i)** Chapter 1, 2.1–2.5, 3.

Computers reserved — Wednesday 23/3, 15–19, F-T4009

Lecture 2 — Thursday, 24/3, 10–12, FL51
Convexity; basic feasible solution; the simplex method; degeneracy; unbounded solution.
(i) Chapter 2.4, 4.1–4.7, (7.1).

Lecture 3 — Friday 25/3, 10–12, Pascal
Infeasibility; starting solutions; duality; economic interpretation.
(i) Chapter 4.8–4.10, 6, (7.2–7.5).

Week 13

Lecture 4 — Monday 28/3, 13–15, Pascal
13–14, Fredrik Hedenus: *Application to energy system modelling (Assignment 1).*
14–15, *Post-optimal and sensitivity analysis.* **(i)** Chapter 5.1–5.5, (5.6).

Computers reserved — Wednesday 30/3, 15–19, F-T4009

Lecture 5 — *Exercises on linear optimization* — Thursday 31/3, 10–12, EC

Lecture 6 — Friday 1/4, 10–12, Pascal
Discrete optimization models and applications; complexity. **(i)** Chapter 13, 2.6.

Week 14

Lecture 7 — Monday 4/4, 13–15, Pascal
Theory and algorithms for discrete optimization models.
(i) Chapter 14.1–14.5, (14.6), 15.1–15.3, 16.1–16.2, 17.1–17.2, (17.3–17.4).

Computers reserved — Wednesday 6/4, 15–19, F-T4009

Lecture 8 — *Exercises on discrete optimization.* — Thursday 7/4, 10–12, EC

Lecture 9 — Friday 8/4, 10–12, Pascal
Shortest paths; maximum flows; linear programming formulations of flows.
(i) 8.1–8.2, 8.4, (8.5), 18.1–18.5 (18.6–18.7).

Deadline: Assignment 1 — *Hand in report.* — Friday 8/4, 17.00

Week 15

Lecture 10 — Monday 11/4, 13–15, Pascal
13–14, Michael Patriksson: *Application to maintenance planning (Assignment 2).*
14–15, *Minimum cost network flow models.* **(i)** Chapter 8.6, 13.5.

Computers reserved — Wednesday 13/4, 15–19, F-T4009

Lecture 11 — Thursday 14/4, 10–12, EC
10–11, *Algorithms for minimum cost network flows.* **(i)** Chapter 8.7.
11–12, *Exercises on network models.*

Lecture 12 — Friday 15/4, 10–12, Pascal
Combinatorial optimization models, theory, and algorithms.
(i) Chapter 8.3, 13.10–13.11, 15.4, (15.5), 16.3–16.6.

Easter break		**W. 16–17**
Lecture 13 Monday 2/5, 13–15, FL61 13–14, *Optimization under uncertainty.* **(iii)** Hand-outs. 14–15, Emil Gustafsson: *Application to the travelling salesperson problem (Assignment 3a).*		**Week 18**
Deadline: Assignment 2 *Hand in report, also to opponents.* Monday 2/5, 17.00		
Computers reserved Wednesday 4/5, 15–19, F-T4009		
Lecture 14 Thursday 5/5, 10–12, EC 10–11, Ola Carlson: *Application to windpower generation (Assignment 3b).* 11–12, *Multiple objective optimization.* **(iii)** Hand-outs.		
Lecture 15 Friday 6/5, 10–12, Pascal 10–11, Mehdi Sharif Yazdi: *Application to sugar distribution (Assignment 3c).* 11–12, Elin Svensson: *Application to investment planning (Assignment 3d).*		
Deadline: Opposition of Assignment 2 *Hand in report.* Friday 6/5, 17.00		
Lecture 16 Monday 9/5, 13–15, FL61 *Overview of non-linear optimization* **(i)** Chapter 2.5.1, 9–12.		**Week 19**
Computers reserved Wednesday 11/5, 15–19, F-T4009		
Lecture 17 *Exercises.* Thursday 12/5, 10–12, EC		
Lecture 18 *Exercises.* Friday 13/5, 10–12, Pascal		
Deadline: Assignment 3 *Hand in report.* Friday 13/5, 17.00		
Lecture 19 Monday 16/5, 13–15, FL61 *Students' presentations of Assignment 3, discussions.* This lecture may be longer than two hours, depending on the number of presentations.		**Week 20**
Computers reserved Wednesday 18/5, 15–19, F-T4009		
Lecture 20 Thursday 19/5, 10–12, Euler *Students' presentations of Assignment 3, discussions.* This lecture may be longer than two hours, depending on the number of presentations.		
Lecture 21 Friday 20/5, 10–12, Euler *Students' presentations of Assignment 3, discussions.* This lecture may be longer than two hours, depending on the number of presentations.		
Oral examination for higher grades Monday 23/5 9.00–Friday 27/5 17.00 *Students having accomplished reports and presentations of quality high enough may book a time slot for the oral examination.*		**Week 21**