Chalmers University of Technology/University of Gothenburg
Mathematical Sciences
Optimization
Docent Ann-Brith Strömberg

MVE165/MMG630
Applied Optimization
Course information 2010
February 25, 2010

MVE165/MMG630 Applied Optimization, 7.5 hec

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 a application and theoretical perspective, including the the analysis of an optimization model and suitable choices of solution approaches. Work with concrete problems during the course enable 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 optimizationproblems. 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 parts of the chain modelling → model analysis → implementation in suitable algorithm/software → (sensitivity) analysis of an optimal solution.

EXAMINER/LECTURER: Ann-Brith Strömberg, Docent, Department of Mathematical Sciences, room L2087; tel: 772 5378; e-mail: anstr@chalmers.se

GUEST LECTURERS:
- Fredrik Hedenus, Ph.D., Physical Resource Theory, Department of Energy and Environment, Chalmers, e-mail: hedenus@chalmers.se
- Michael Patriksson, Prof. Applied Mathematics, Department of Mathematical Sciences, Chalmers and GU, e-mail: mipat@chalmers.se
- Elin Svensson, Lic.Eng., Heat and Power Technology, Department of Energy and Environment, Chalmers, e-mail: elin.svensson@chalmers.se
- Caroline Olsson, M.Sc., Radiation Physics, Institute of Clinical Sciences, Sahlgrenska Academy, GU, e-mail: caroline.olsson@vgregion.se

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 assignments, which constitute the main basis for examination.

The variety of problems covered often over the years include 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, gra-

dient 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, assignments, and student presentations of the assignments.

COURSE LITERATURE: The course book is available in both Swedish and English. The English version will be published in April 2010, but we have been allowed by Studentlitteratur to distribute paper copies of the first chapters until this book is available. The books will be sold by Cremona.

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

(ii) Optimization Exercises (English, ISBN 914405310X, 2010)/Optimeringslära Övningsbok (Swedish, ISBN 9144053126, 2008), by M. Henningsson, J. Lundgren, M. Rönnqvist, and 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:

- A correct solution of computer Exercise 2 (oral examination at the computer or a written report). (Exercise 1 is recommended but not compulsory.)
- Written reports of three assignments (1, 2, and 3a or 3b).
- A written opposition to Assignment 2.
- An oral presentation of Assignment 3a or 3b.
- 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 on Tuesdays 13.15–15.00 in Euler, Thursdays 10.00–11.45 in MV:F31, and Fridays 10.00-11.45 in MV:F31, according to the course plan below. The first lecture is on Tuesday 16 March 2010. The lectures are given in English (if not all involved understand Swedish).

Exercises and assignments can be performed individually, but preferably in groups of two persons. Deadlines for handing in reports are indicated in the course plan below.

Oral presentations of the respective Assignments 3 (a or b) are held by the students according to the course plan below. *Presence at one of Lectures 19–21 is compulsory.*

Computer laboration times: The Linux classroom MV:F25 is reserved according to the plan below; presence is *not* compulsory. Teachers are available for questions and oral examination of Exercise 2 according to the plan—at all other times, work is done individually.

Information about the assigments and exercises are found on the homepage
`http://www.math.chalmers.se/Math/Grundutb/CTH/mve165/0910`
This course information, assignment and computer exercise materials, and most hand-outs will also be found on the homepage.

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

Lecture 1 Tuesday 16/3, 13–15, Euler **Week 11**
Introduction; course map; modelling optimization applications; linear, nonlinear and integer programs; graphic solution; software solvers. **(i)** Chapter 1, 2.1–2.5, 3.

Computers reserved Tuesday 16/3, 15–19, MV:F25

Lecture 2 Thursday, 18/3, 10–12, MV:F31
Basic feasible solutions; the simplex method; degeneracy; unbounded solutions; starting solutions. **(i)** Chapter 2.4, 4.1–4.7, 4.9–4.10, (7.1).

Lecture 3 Friday 19/3, 10–12, MV:F31
Sensitivity analysis; duality; economic interpretation; post-optimal analysis.
Information on Exercise 1. **(i)** Chapter 4.8, 5.1–5.5, (5.6), 6, (7.2–7.5).

Lecture 4 (Fredrik Hedenus) Tuesday 23/3, 13–15, Euler **Week 12**
Application to Energy System Modelling. Information on Assignment 1. **(iii)** Hand-outs.

Computers reserved *Teachers are present 16–18.* Tuesday 23/3, 15–19, MV:F25

Lecture 5 Thursday 25/3, 10–12, MV:F31
Shortest paths; maximum flows; linear programming formulations of flows.
(i) 8.1–8.4, (8.5), 18.1–18.5 (18.6–18.7).

Lecture 6 Friday 26/3, 10–12, MV:F31
Network flows, transportation and assignment models. **(i)** Chapter 8.6–8.7, 13.5.

Lecture 7 Tueday 13/4, 13–15, Euler **Week 15**
Discrete optimization models, applications. **(i)** Chapter 13, 2.6.

Computers reserved *Teachers are present 16–19.* Tuesday 13/4, 15–19, MV:F25

Lecture 8 Thursday 15/4, 10–12, MV:F31
Algorithms for discrete optimization models.
(i) Chapter 14.1–14.5, (14.6), 15.1–15.4, (15.5), 16.1–16.4, (16.6), 17.1–17.2, (17.3–17.4).

Lecture 9 (Michael Patriksson) Friday 16/4, 10–12, MV:F31
Application to Maintenance Planning. Information on Assignment 2. **(iii)** Hand-outs.

Deadline: Assignment 1 *Hand in report.* Friday 16/4, 17.00

Lecture 10 Tuesday 20/4, 13–15, Euler **Week 16**
Exercises on linear programming, network models and integer linear programming.

Computers reserved Tuesday 20/4, 15–19, MV:F25

Lecture 11 Thursday 22/4, 10–12, MV:F31
Unconstrained non-linear programming. **(i)** Chapter 2.5.1, 9, 10.4.

Lecture 12 Friday 23/4, 10–12, MV:F31
Unconstrained non-linear programming algorithms. **(i)** Chapter 10.1–10.3, 11.

Deadline: Assignment 2 *Hand in report, also to opponent.* Monday 26/4, 17.00 **Week 17**

Lecture 13 Tuesday 27/4, 13–15, Euler
Constrained non-linear programming and algorithms, optimality conditions. Information on Exercise 2. **(i)** Chapter 12.

Computers reserved *Teachers are present 16–18.* Tuesday 27/4, 15–19, MV:F25

Lecture 14 Thursday 29/4, 10–12, MV:F31
Multiple objective optimization and optimization under uncertainty. **(iii)** Handouts

Deadline: Opposition of Assignment 2 *Hand in report.* Monday 3/5, 17.00 **Week 18**

Lecture 15 (Caroline Olsson) Tuesday 4/5, 13–15, Euler
Application to Radiation Therapy. Information on Assignment 3a. **(iii)** Hand-outs.

Computers reserved Tuesday 4/5, 15–19, MV:F25
Teachers are present at 16–19 for oral examination of Exercise 2.

Lecture 16 (Elin Svensson) Thursday 6/5, 10–12, MV:F31
Application to Investments in Process Integration. Information on Assignment 3b.
(iii) Hand-outs.

Computers reserved Thursday 6/5, 15–19, MV:F25
Teachers are present at 16–19 for oral examination of Exercise 2.

Lecture 17 *Exercises on non-linear programming.* Friday 7/5, 10–12, MV:F31

Lecture 18 *Exercises.* Tuesday 11/5, 13–15, Euler **Week 19**

Computers reserved Tuesday 11/5, 15–19, MV:F25
Teachers are present at 16–19 for oral examination of Exercise 2.

Deadline: Exercise 2 Wednesday 12/5, 17.00

Deadline: Assignment 3a *Hand in report.* Friday 14/5, 17.00

Deadline: Assignment 3b *Hand in report.* Monday 17/5, 17.00 **Week 20**

Lecture 19 Tuesday 18/5, 13–15, Euler
Students' presentations of Assignment 3a, discussions.
This lecture may be longer than two hours, depending on the number of presentations.

Computers reserved Tuesday 18/5, 15–19, MV:F25

Lecture 20 Thursday 20/5, 10–12, MV:F31
Students' presentations of Assignment 3b, discussions.
This lecture may be longer than two hours, depending on the number of presentations.

Lecture 21 Friday 21/5, 10–12, MV:F31
Students' presentations of Assignment 3b, discussions.
This lecture may be longer than two hours, depending on the number of presentations.

Oral examination for higher grades Monday 24/5, 9.00–Friday 28/5, 17.00 **Week 21**
Students having accomplished reports and presentations of enough high quality may book a time slot for the oral examination.
