Chalmers University of Technology/Göteborg University
Mathematical Sciences
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MVE165
Applied optimization
Course information 2008
6th May 2008

UPDATED VERSION 6TH MAY 2008

MVE165 Applied Optimization, 7.5 hec

A main purpose of this course is to present a number of application areas where optimization problems arise frequently, including an overview of some important practical techniques for their solution. The course aims to provide both theoretical and application related insights in the problem areas, such as analysis of a problem, model choice, suitable solution approaches, and interpretation and analysis of the solution.

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

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GUEST LECTURER: Fredrik Hedenus, Lic.Eng., physical resource theory, Department of Energy and Environment, Chalmers, e-mail: hedenus@chalmers.se

GUEST LECTURER: Mats Viberg, professor of signal processing, Department of Signals and Systems, Chalmers, e-mail: viberg@chalmers.se

GUEST LECTURER: 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 from other departments at Chalmers and Göteborg University. 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.

Over the years, the content of the course may include a variety of typical applications: Investment planning, Blending, Production planning, Queueing theory, Routing and transport, Multi-objective optimization, and Inventory planning. Among the the algorithm techniques discussed there are the Simplex Method and Interior points methods for Linear programming, Gradient based algorithms for Non-linear programming, Branch and Bound for Integer linear programming, Dynamic programming, Markov chains, Heuristics, Simulation etc. The software used to solve practical problems will be AMPL, Cplex, Matlab, and Tomlab.

PREREQUISITES: Passed courses on 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:

(i) Main course book: *Operations Research, 8th edition* by H.A. Taha, published by Upper Saddle River, N.J., Pearson/Prentice Hall, 2007, found at Cremona.

(ii) Alternative course book: *An Introduction to Optimization* by N. Andréasson, A. Evgrafov, and M. Patriksson, published by Studentlitteratur in 2005, found at Cremona. (This book covers parts of the course material; see the plan below.)

(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)** and **(iii)** in the plan below. The importance of each moment of the course is defined by the respective emphasis given during the lectures.

EXAMINATION:

- Two correctly solved computer exercises (oral examination).
- Written reports of three assignments (Assignments 1, 2, and 3a or 3b).
- Written opposition to Assignment 2.
- An oral presentation of Assignment 3a or 3b.
- To be able to receive a higher grade than 3, the written reports and opposition as well as the oral presentation must be of high quality. To distinguish between grades 4 and 5, an oral exam is to be passed.

SCHEDULE:

Lectures are given on Tuesdays and Thursdays 13.15–15.00 and on Fridays 10.00-11.45 in room MV:H11 (see the schedule below). The first lecture is on Tuesday 1/4. The lectures are given in English.

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

Oral presentations of the respective Assignments 3 (a or b) are held by the students in week 21, Tuesday (3a) 13.15–15.00 and Friday (3b) 10.00–11.45 in room MV:H11. *Presence at each of these two occasions is compulsory!*

Computer laborations: MV:F25 is booked on Tuesdays and (some) Thursdays, 17.15–21.00 (see the schedule below, presence is *not* obligatory). Teachers are available for questions and oral examination of the exercises on 8/4 and 6/5, 17.15–19.00.

Information about the assigmnents and exercises are found on the web page
`http://www.math.chalmers.se/Math/Grundutb/CTH/mve165/0708`
This course information, the course literature, assignment and computer exercise materials, most hand-outs, and previous exams will also be found on this page.

COURSE PLAN (indicated exercises are preliminary, will be specified during the course):

Week 14

Lecture 1 (Tuesday 1/4, 13–15, MV:H11, Ann-Brith) *Introduction, course map, modelling linear programming applications, graphical solution, solvers.* **(i):** Ch. 1–2. Exc. 2.1A, 2.2A–B, 2.3A–G. **(ii):** Ch. 1.1, 7.1–3, 8.1. Exc. 1.1–2, 1.4, 8.1–2, 8.7.

Lecture 2 (Thursday, 3/4, 13–15, MV:H11, Ann-Brith) *Basic feasible solutions, the simplex method, degeneracy, unbounded solutions, starting solutions.* **(i):** Ch. 3.1–5, 7.1–2. Exc. 3.1A–B, 3.2A, 3.3A–B, 3.4A–B, 3.5A–D, 7.1A–C, 7.2A–B. **(ii):** Ch. 8.2, 9. Exc. 8.4–6, 9.1–2.

Lecture 3 (Friday 4/4, 10–12, MV:H11, Ann-Brith) *Sensitivity analysis, duality, economic interpretation, post-optimal analysis. Information on Exercise 1.* **(i):** Ch. 3.6, 4, 7.4. Exc. 3.6A–B, E, 4.1A, 4.2B–D, 4.3A–B, 4.5A, 7.4A–B. **(ii):** Ch. 7.4–5, 10. Exc. 10.1–2, 10.7–8, 10.13–14.

Week 15

Lecture 4 (Tuesday 8/4, 13–15, MV:H11, Fredrik) *Application to Resource Theory. Information on Assignment 1.* **(iii):** Hand-outs.

Computer laboration time (Tuesday 8/4, 17–21, MV:F25) *Oral examination 17–19.*

Lecture 5 (Thursday 10/4, 13–15, MV:H11, Birgit) *Transportation models.* **(i):** Ch. 5. Exc. 5.1A, 5.2A, 5.3A–C, 5.4A, 5.5A. **(ii):** Ch. 8.1.

Lecture 6 (Friday 11/4, 10–12, MV:H11, Birgit) *Network models.* **(i):** Ch. 6.1–4. Exc. 6.1A, 6.2A, 6.3A–D, 6.4A–B.

Deadline Exercise 1 (Friday 11/4, 18.00)

Week 16

Lecture 7 (Tuesday 15/4, 13–15, MV:H11, Birgit) *Integer linear programming, applications.* **(i):** Ch. 9.1. Exc. 9.1A–D.

Computer laboration time (Tuesday 15/4, 17–21, MV:F25)

Lecture 8 (Thursday 17/4, 13–15, MV:H11, Birgit) *Integer linear programming algorithms, the traveling salesperson problem.* **(i):** Ch. 9.2–3. Exc. 9.2A–B, 9.3A–B.

Lecture 9 (Friday 18/4, 10–12, MV:H11, Ann-Brith) *Application to Maintenance Planning. Information on Assignment 2.* **(iii):** Hand-outs.

Deadline Assignment 1 (Friday 18/4, 18.00) *Hand in report.*

Week 17

Lecture 10 (Tuesday 22/4, 13–15, MV:H11, Ann-Brith) *Unconstrained non-linear programming and algorithms.* **(i):** Ch. 18.1, 19.1. Exc. 18.1A, 19.1A–B. **(ii):** Ch. 4.1–3, 11.1–5. Exc. 4.2–3, 11.2–6.

Computer laboration time (Tuesday 22/4, 17–21, MV:F25)

Lecture 11 (Friday 25/4, 10–12, MV:H11, Ann-Brith) *Constrained non-linear programming.* **(i):** Ch. 18.2. Exc. 18.2A–D. **(ii):** Ch. 4.4, 5. Exc. 4.1, 4.6–7, 5.3–6, 5.8–9.

Week 18

Deadline Assignment 2 (Monday 28/4, 18.00) *Hand in report, also to opponent.*

Lecture 12 (Tuesday 29/4, 13–15, MV:H11, Ann-Brith) *Algorithms for constrained non-linear programming. Information on Exercise 2.* **(i):** Ch. 19.2. Exc. 19.2B, 19.2D. **(ii):** Ch. 12.1–2. Exc. 12.3–5.

Computer laboration time (Tuesday 29/4, 17–21, MV:F25)

Week 19

Deadline Opposition of Assignment 2 (Monday 5/5, 18.00) *Hand in report.*

Lecture 13 (Tuesday 6/5, 13–15, MV:H11, Mats) *Application to Digital Filter Design. Information on Assignment 3a.* **(iii):** Hand-outs.

Computer laboration time (Tuesday 6/5, 17–21, MV:F25) *Oral examination 17–19.*

Lecture 14 (Thursday 8/5, 13–15, MV:H11, Caroline) *Application to Radiation Therapy. Information on Assignment 3b.* **(iii):** Hand-outs.

Lecture 15 (Friday 9/5, 10–12, MV:H11, Ann-Brith & Birgit) *Optimization under uncertainty, constraint programming.* **(i):** Ch. 13.2–3, 19.2.3. **(iii):** Hand-outs.

Deadline Exercise 2 (Friday 9/5, 18.00)

Week 20

Computer laboration time (Tuesday 13/5, 17–21, MV:F25)

Computer laboration time (Thursday 15/5, 17–21, MV:F25)

Deadline Assignment 3 (Friday 16/5, 18.00) *Hand in report.*

Week 21

Lecture 16 (Tuesday 20/5, 13–15, MV:H11) *Students' presentations of Assignment 3a, discussions.* **Presence is compulsory**

Computer laboration time (Tuesday 20/5, 17–21, MV:F25)

Lecture 17 (Thursday 22/5, 13–15, MV:H11)

Computer laboration time (Thursday 22/5, 17–21, MV:F25)

Lecture 18 (Friday 23/5, 10–12, MV:H11) *Students' presentations of Assignment 3b, discussions.* **Presence is compulsory**