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Course PM

SF2812 Applied Linear Optimization, 7.5hp, 2020/2021

Instructor and examiner

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Office hours: By agreement.

Exercise leader and project leader

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Office hours: By agreement.

Course material

- [Linear and Nonlinear Optimization](#), second edition, by I. Griva, S. G. Nash och A. Sofer, SIAM, 2009.
(The book can be ordered from several places. Please note that you can become a [SIAM member for free](#) and obtain a discount at the SIAM bookstore.)
- *Exercises in applied linear optimization, 2019/2020*. Available via [Canvas](#).
- *Lecture notes in applied linear optimization, 2019/2020*. Available via [Canvas](#).
- *Supplementary course material in applied linear optimization, 2019/2020*. Available via [Canvas](#).
- *Theory questions in applied linear optimization, 2019/2020*. Available via [Canvas](#).
- *GAMS, A user's guide*. Available at the [GAMS web site](#).
- *GAMS*. GAMS is installed in the KTH linux computer rooms. It may also be downloaded from the [GAMS web site](#) for use on a personal computer.
- Two project assignments that are handed out during the course, January 30 and February 13 respectively.

Additional notes that may be handed out during the course are also included.

Course goals

After completed course, the student should be able to:

- explain fundamental concepts of linear programming and integer linear programming;
- explain how fundamental methods for linear programming and integer linear programming work;
- illustrate how these methods work by solving small problems by hand calculations;
- starting from a suitably modified real problem, formulate a linear program or an integer linear program; make a model in a modeling language and solve the problem;
- analyze the solutions of the optimization problem solved, and present the analysis in writing as well as orally;
- interact with other students when modeling and analyzing the optimization problems.

Examination

The examination is in two parts, projects and final exam. To pass the course, the following requirements must be fulfilled:

- Pass project assignment 1, with presence at the compulsory presentation lecture on Monday February 15 and presence at the following discussion session.
- Pass project assignment 2, with presence at the compulsory presentation lecture on Monday March 1 and presence at the following discussion session.
- Pass final exam.

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Course registration

Due to the project based nature of this course, students must register no later than January 31. Registration is made by the students online following KTH standard procedures.

Project assignments

The project assignments are performed in groups, where the instructor determines the division of project groups. This division is changed between the two assignments. The assignments are carried out by the modeling language GAMS. The project assignments *must* be carried out during the duration of the course and completed by the above mentioned presentation lectures. It is the responsibility of each student to allocate time so that the project group can meet and function. Presence at the presentation lectures is compulsory. For passing the projects, the following requirements must be fulfilled:

- No later than the night before the presentation lecture, each project group must hand in a well-written report which describes the exercise and the project group's suggestion for solving the exercise through Canvas as a pdf file. Suitable word processor should be used. The report should be on a level suitable for another participant in the course who is not familiar with the group's specific problem.
- At the beginning of the presentation lecture, each student should hand in an individual sheet with a brief self-assessment of his/her contribution to the project work, quantitatively as well as qualitatively.
- At the presentation lecture, all assignments will be presented and discussed. The presentations and discussions will be made in small presentation groups, first in presentation groups where each student has worked on the same project assignment, and then in presentation groups where the students have worked on different project assignments. Each student is expected to be able to present the assignment of his/her project group, the modeling and the solution. In particular, each student is expected to take part in the discussion. The presentation and discussion should be on a level such that students having had the same assignment can discuss, and students not having had the same assignment can understand the issues that have arisen and how they have been solved. Each student should bring a copy of the project group's report to the presentation lecture, either in paper or electronically.
- Each project group should make an appointment for a discussion session with the course leaders. There is no presentation at this session, but the course leaders will ask questions and give feedback. There will be time slots available the days after the presentation session. One week prior to the presentation lecture, a list of available times for discussion sessions will be made available at Doodle, announced via Canvas. Each project group should sign up for a discussion session prior to the presentation lecture.

Each project assignment is awarded a grade which is either fail or pass with grading E, D, C, B and A. Here, the mathematical treatment of the problem as well as the report and the oral presentation or discussion is taken into account. The exercises are divided into basic exercises and advanced exercises. Sufficient treatment of the basic exercises gives a passing grade. Inclusion of the advanced exercises is necessary for the higher grades (typically A-C). Normally, the same grade is given to all members of a project group. A student who has not worked on the advanced exercises says so in the self assessment form.

Each project group must solve their task independently. Discussion between the project groups concerning interpretation of statements etc. are encouraged, but each project group must work independently without making use of solutions provided by others. All project groups will not be assigned the same exercises.

Final exam

The final exam consists of five exercises and gives a maximum of 50 points. At the exam, the grades F, Fx, E, D, C, B and A are awarded. For a passing grade, normally at least 22 points are required. In addition to writing material, no other material is allowed at the exam. Normally, the grade limits are given by E (22-24), D (25-30), C (31-36), B (37-42) and A (43-50).

The grade Fx is normally given for 20 or 21 points on the final exam. An Fx grade may be converted to an E grade by a successful completion of two supplementary exercises, that the student must complete independently. One exercise among the theory exercises handed out during the course, and one exercise which is similar to one exercise of the exam. These exercises are selected by the instructor, individually for each student. Solutions have to be handed in to the instructor and also explained orally within three weeks of the date of notification of grades.

The final exam is given Thursday March 11 2021, 8.00-13.00.

Final grade

By identifying A=7, B=6, C=5, D=4, E=3, the final grade is given as

$$\text{round}((\text{grade on proj 1}) + (\text{grade on proj 2}) + 2 * (\text{grade on final exam})) / 4),$$

where the rounding is made to nearest larger integer in case of a tie.

Preliminary schedule

"L" means lecture, "E" means exercise session, "P" means project session.

Type	Day	Date	Time	Room	Subject
L1	Mon	Jan 18	15-17	Zoom	Introduction. Linear programming models.
L2	Wed	Jan 20	10-12	Zoom	Linear programming. Geometry.
L3	Thu	Jan 21	8-10	Zoom	Lagrangian relaxation. Duality. LP optimality.
L4	Fri	Jan 22	8-10	Zoom	Linear programming. The simplex method.
E1	Mon	Jan 25	15-17	Zoom	Linear programming. The simplex method.
L5	Wed	Jan 27	10-12	Zoom	More on the simplex method.
P1	Fri	Jan 29	8-10	Zoom	Introduction to GAMS.
P2	Mon	Feb 1	15-17	Zoom	GAMS exercise session.
E2	Wed	Feb 3	15-17	Zoom	Linear programming. The simplex method.
L6	Thu	Feb 4	10-12	Zoom	Stochastic programming.
E3	Fri	Feb 5	8-10	Zoom	Stochastic programming.
L7	Mon	Feb 8	15-17	Zoom	Interior methods for linear programming.
E4	Wed	Feb 10	10-12	Zoom	Interior methods for linear programming.
L8	Fri	Feb 12	8-10	Zoom	Integer programming models.
P3	Mon	Feb 15	15-17	Zoom	Presentation of project assignment 1.
L9	Wed	Feb 17	10-12	Zoom	Branch-and-bound.
E5	Thu	Feb 18	10-12	Zoom	Integer programming.
L10	Fri	Feb 19	8-10	Zoom	Decomposition and column generation.
E6	Mon	Feb 22	15-17	Zoom	Decomposition and column generation.
L11	Wed	Feb 24	13-15	Zoom	Lagrangian relaxation. Duality.
E7	Thu	Feb 25	8-19	Zoom	Lagrangian relaxation. Duality.
P4	Mon	Mar 1	15-17	Zoom	Presentation of project assignment 2.
L12	Wed	Mar 3	8-10	Zoom	Subgradient methods.
E8	Thu	Mar 4	8-10	Zoom	Subgradient methods.

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Mapping of exercises to lectures

The sections in the exercise booklet may roughly be mapped to the lectures as follows:

1. The simplex method. After L4.
2. Sensitivity analysis. After L4.
3. Interior point methods. After L7.
4. Decomposition and column generation. After L10.
5. Linear programming - remaining. After L7.
6. Stochastic programming. After L6.
7. Formulation - integer programming. After L8.
8. Lagrangian relaxation and duality. After L11.
9. Subgradient methods. After L12.

Overview of course contents

• Linear programming

Fundamental LP theory with corresponding geometric interpretations. The simplex method. Column generation. Decomposition. Duality. Complementarity. Sensitivity. Formulations of LPs. Interior methods for linear programming, primal-dual interior methods in particular.

(Chapters 4-7 in Griva, Nash and Sofer, except 5.2.3, 5.2.4, 5.5.1, 6.5, 7.5, 7.6. Chapter 9.3 in Griva, Nash and Sofer.

Chapter 10 in Griva, Nash and Sofer, except 10.3, 10.5.)

- **Stochastic programming**
Fundamental theory. (Supplementary course material.)
- **Integer programming**
Formulations of integer programs. Branch-and-bound. Lagrangian relaxation and subgradient methods applied on integer programs with special structure.
(Supplementary course material.)

Support for students with disabilities

Students with disabilities may have the right to certain compensatory support for example during examination.

KTH has coordinators for students with disabilities, [Funka](#), who deals with issues relating to functional disabilities. You should turn to Funka at funka@kth.se for information about support.

Welcome to the course!

Instructions for GAMS

- GAMS at the KTH linux computers.
 - Type "module add gams" or add it to a suitable login file.
 - Use an editor, for example emacs, to create/modify model files (".gms") and reading output files (".lst").
 - Put the model files in your home catalog. Run GAMS from that catalog, e.g. "gams trans1".
 - Please note that there is a whole library of example files at GAMS subdirectory "modlib".
- GAMS on your own computer.
 - The demo version of GAMS (which we use) can be downloaded from [the GAMS website](#).
- GAMS resources
 - [GAMS documentation](#)
 - [GAMS user's guide](#)

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