Course program

Course code	ISS0031
Subject title	Modeling and Identification
Subject title (in estonian)	Modelleerimine ja Identifitseerimine
Lecturer	Juri Belikov
Course volume ECTS	5
Stationary study (weekly hours)	lectures: 2, exercises: 2
Assessment form	examination
Teaching semester	autumn

Prerequisites

Recommended preparation: The students should be proficient in Linear Algebra (YMA3710) and know basics of Mathematical Analysis (YMM3731). Knowledge of some scientific programming language (e.g., MATLAB or *Mathematica*) is useful. Basic knowledge of controls concepts (at the level of ISS0010 and ISS0021) is helpful.

Course aims

- to show connections between mathematics, economics and control theory;
- to give an overview of the basic analysis, modeling and optimization problems, and methods for their solution;
- to develop the ability to think systematically, formulate and analyze problems.

Learning outcomes of the subject

- knows and understands the basics of mathematical programming and control theory;
- knows the basic modeling and optimization problems;
- can formulate linear programming problems;
- can apply different methods to solve linear programming problems;
- can describe systems by using mathematical models (state-space models, input-output models, etc.);
- knows how to derive mathematical models;
- knows advanced control theory (including fractional-order theory, neural networks, and differential algebra);
- can use MATLAB environment to analyze and solve different mathematical programming and control problems.

Course content and schedule

Class		Content
#	Date	
1	Sep 5	Introduction to mathematical programming. Problem statement. Linear programming problem. Basic notions: objective function, constraints, feasible solutions
2	Sep 12	Linear programming problem: a geometric approach. Unique solution
3	Sep 19	Fractional-order modeling
4	Sep 26	Neural Networks based identification
5	Oct 3	First steps in MATLAB (practice)
6	**Oct 10**	**First Test**
7	Oct 17	Presentations. FAQ from the first test
8	Oct 24	Convex set and function. Convex optimization problem. Linear programming problem as a case of convex planning problem
9	Oct 31	Simplex method. Slack and surplus variables. Minimization and maximization
10	Nov 7	The transportation problem. Solvability. Basic theorems. Solution of the transportation problem: North-West corner rule, Lowest cost entry method
11	**Nov 14**	**Second Test**
12	Nov 21	Presentations. FAQ from the second test
13	Nov 28	Introduction to control theory. Basic notions: state-space and input-output system, transfer function, controllability, observability, stability
14	Dec 5	Algebraic framework of differential forms
15	Dec 12	Common nonlinear control problems (practice)
16	**Dec 19**	**Defense of the project (first attempt)**

Independent work

Students have to be able to apply learned concepts and demonstrate understanding. During the semester a project has to be completed.

Assessment format

The final grade consists of two parts: Test – 40% (2 assignments) and Final Project – 60% (7-10min. project proposal is due on October 17th in class presentation).

Projects

A project has to be self-sufficient, i.e., it has to contain: a brief introduction, description of a problem, solution of a problem, examples/practical results, list of references, etc. The following two types of projects are possible:

1. Solution of a research problem relevant to the student's area of interest.

2. Independent study of a topic not covered in the course (e.g., reading a scientific article or book chapter).

Several project ideas:

- **Topic:** Application of linear programming in game theory
  To study: E. Rasmusen. Games and Information: An Introduction to Game Theory. Basil Blackwell, MA, USA, 2006.

- **Topic:** Survey on algebraic framework of differential forms
  To study: G. Conte, C. H. Moog and A. M. Perdon. Algebraic Methods for Nonlinear Control Systems. London: Springer-Verlag, 2007.

- **Topic:** A realization problem (input-output to state-space)
  To study: Ü. Kotta and T. Mullari. Equivalence of Realizability Conditions for Nonlinear Control Systems. Proceedings of the Estonian Academy of Sciences, 55(1):24–42, 2006.

- **Topic:** Implementation of scientific results in *Mathematica* or MATLAB environments
  To study: `http://www.nlcontrol.ioc.ee`

- **Topic:** Time Scales theory based toolbox for MATLAB
  To study: `http://www.timescales.org/`

- **Topic:** Survey on structural properties of linear switched
  To study: D. Liberzon, Switching in Systems and Control, Birkhäuser, Boston, 2003. Z. Sun and S. S. Ge, Switched Linear Systems, Springer, 2005.

- **Topic:** Survey on networked control systems
  To study: A. Bemporad, M. Heemels, and M. Johansson, Networked Control Systems, Springer-Verlag Berlin Heidelberg, 2010.

- **Topic:** Modeling a laboratory object
  To study: `http://www.a-lab.ee/equipment`

- **Topic:** Modeling and implementation of fractance networks for control applications
  To study: A. S. Elwakil, Fractional-Order Circuits and Systems: An Emerging Interdisciplinary Research Area. Circuits and Systems Magazine, 10(4):40–50, 2010.

Study literature

Most of the material taught is covered by the following references:

1. Ü. Kaasik, L. Kivistik, Operatsioonianalüüs, Valgus, Tallinn, Eesti, 1982.
2. Ü. Kaasik, Matemaatiline planeerimine, Valgus, Tallinn, Eesti, 1967.
3. E. Übi, Planeerimise ja juhtimise matemaatika, Külim, Tallinn, Eesti, 1998.
4. E. Übi, Ekstreemumülesanded majanduses ja tehnikas, Külim, Tallinn, Eesti, 2002.
5. H. Sillamaa, Süsteemiteooria, TTÜ, Tallinn, Eesti, 1999.
6. T. S. Ferguson, Linear Programming: A concise introduction, e-version is available at `http://www.math.ucla.edu/~tom/LP.pdf`, 2012.
7. K. Ogata, Modern Control Engineering, 5th edition, Prentice Hall, 2009.
8. S. Huang, K. K. Tan, K. Z. Tang, Neural Network Control: Theory and Applications, Baldock: Research Studies, 2004.
9. C. A. Monje, Y. Q. Chen, B. M. Vinagre, D. Xue, V. Feliu, Fractional-order Systems and Controls: Fundamentals and Applications, Springer-Verlag, London, UK, 2010.
10. D. Xue, Y. Q Chen, D.P. Atherton, Linear Feedback Control: Analysis and Design with MATLAB, SIAM, Philadelphia, USA, 2007.