MINISTERUL EDUCAŢIEI ŞI CERCETĂRII

UNIVERSITATEA TEHNICĂ CLUJ-NAPOCA

Department of Automation

OPTIMIZATION TECHNIQUES

Course outline

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Course type: Lecture/Exercises/Project
Semester: 9th semester
ECTS credits: 5
Hours/week (L: lectures, Ex: exercises, P: Project): 2 L / 1 Ex / 1 P

Course description: The course covers the basic concepts, techniques, and tools related to optimization and optimal control for dynamical systems. Major topics include classical theory of maxima and minima, single variable search techniques, multivariable optimization procedures, calculus of variations, minimum principle, dynamic programming. Both continuous systems and discrete time systems are addressed.

Course objectives: This course is intended to introduce optimization and optimal control in a practical enough way that the student can develop the problem-solving skills, but with enough theoretical background to justify the techniques and provide a foundation for advanced research.

Prerequisites: Systems theory, Control engineering, Differential equations.

Assessment: Practical exercises: 20%
Project: 30%
Final exam: 50%

Detailed description:

Introduction to optimal control theory. Formulation of optimal control problems, performance measures, minimum-time problems, minimum control-effort problems, tracking problems, regulator problems.

Static optimization. Theory of maxima and minima. Unconstrained optimization; necessary conditions for maxima and minima, sufficient conditions for maxima and minima; constrained optimization, Lagrange multipliers.

General introduction to nonlinear programming methods. Direct methods, single variable search techniques, basic descent methods. Multivariable optimization procedures. Newton methods, quasi-Newton methods, gradient methods, Nelder-Mead method.

Dynamic programming. The principle of optimality, the recurrence relation of dynamic programming, computer implementation issues. Analytical approach of dynamic programming, the discrete linear quadratic regulator (LQR) problem. Hamilton-Jacobi-Bellman equation.

Calculus of variations. The Euler-Lagrange equation. Transversality conditions. Constrained minimization of functionals.

Pontryagin's minimum principle. Necessary conditions for optimal control. Optimal control with constraints on inputs. Solution to minimum time problems, bang-bang control. Solution to minimum energy problems.

Exercises: The exercises in this course familiarize the student with the numerical implementation of the optimization techniques using a computational environment (Matlab or similar). They are intended to deepen the understanding of the theory and to provide hands-on experience to match theoretical optimization with practical situations.

Project: The purpose of the project is to apply some of the techniques that you learn in class to controller design using an optimal criterion. The project topic will be selected in consultation with the instructor and it will be an application of the optimal control theory.

Textbooks:

1. Lecturer's notes for the course will be available on the course webpage.
2. *Optimal Control Theory. An introduction*, D. E. Kirk, Prentice Hall
3. *Optimal Control.* Purdue University.
4. *Optimization Techniques with Applications to Aerospace Systems,* G.Leitman–editor, Academic Press.
5. *Optimization for Engineering Systems,* Ralph A. Pike, Louisiana State University