Fundamentals of numerical optimization

Doctoral course (25 h)

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Objectives and methodology

This course has two main objectives.

Firstly, it is aimed at providing the students with theory foundations of numerical optimization algorithms, which naturally arise in all engineering fields, with a focus on problems with continuous variables. Starting from recaps of linear algebra and calculus, algorithms for unconstrained optimization are elaborated, and the constrained optimization algorithms for linear and nonlinear problems are presented.

Secondly, the course aims at presenting how optimization problems can be posed and solved using Python language, also in conjunction with CasADi for efficient solution of large-scale problems. To this end, at least 30% of the course will be “hands on”.

Syllabus

Theory

Part 1: introduction

Introduction to optimization problems, sets, linear algebra basics, derivatives, convex sets and functions.

Part 2: Unconstrained Optimization

Introduction to unconstrained optimization, line search methods, trust region methods. Conjugate gradient methods, Quasi-Newton methods, derivative calculations. Least-squares optimization problems, nonlinear systems of equations.

Part 3: Constrained Optimization

Introduction, local and global solution, heuristic solution of simple problems. Lagrange function, linear independence constraint qualification, KKT conditions, duality. Linear programming: KKT and solution via interior-point methods. Quadratic programming via active set methods. Nonlinear programming: penalty methods, augmented Lagrangian methods, sequential quadratic programming (SQP), interior-point methods.

Applications

Part 4. Numerical optimization problems using Python

Basic operations in Python, Solution of systems of equations, solution of LPs and NLPs.

Part 5. Numerical optimization problems using Python-CasADi

Solution of basic scientific problems in the Python-CasADi framework: linear algebra, root finding and basic optimization problems in CasADi. Solution of a trajectory planning problem for a constrained mechanical system as an NLP using the direct collocation method. The direct multiple shooting method for the solution of optimal control problems.

Timetable

Lecture #	Date	Time
1	Jan 31, 2020	11-13
2	Jan 31, 2020	14-17
3	Feb 5, 2020	11-13
4	Feb 5, 2020	14-17
5	Feb 14, 2020	11-13
6	Feb 14, 2020	14-17
7	Feb 21, 2020	11-13
8	Feb 21, 2020	14-17
9	Feb 28, 2020	11-13
10	Feb 28, 2020	14-17

Room: *Aula DIA della sede di Ingegneria Aerospaziale, Via G. Caruso 8, Pisa*