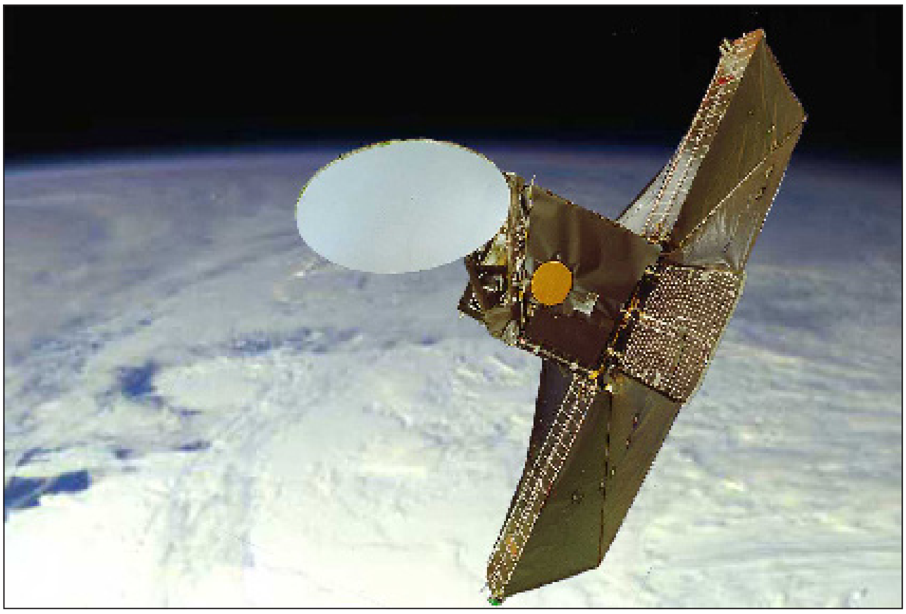
KTH Electrical Engineering



Modeling of Dynamical Systems

EL2820
7.5 hp, per 1

Aim

The aim of the course is to teach how to systematically build mathematical models of industrial systems from basic physical laws and from measured signals. The course is of an interdisciplinary character and will give insights which can be applied in most fields.

Syllabus

The course consists of 12 lectures, 9 exercise sessions, 3 computer exercises and 3 labs, one of which involves collecting data from a real process and developing an experimental model. Topics:

- Introduction: systems, types of models, state-space descriptions and linearizations
- Physics / Mechanics / Electronics - overview
- Model approximation and validation
- Systematic construction of physical models
- Differential-algebraic equations
- Object oriented modeling
- Sampling and disturbance models
- Parameter estimation
- System identification for modeling
- Nonlinear identification

Prerequisites

Appropriate background is provided by courses in elementary physics and mathematical statistics or corresponding knowledge.

Requirements

Written exam 4.5 hp, Lab projects 3.0 hp

Literature

L. Ljung and T. Glad, Modeling of Dynamic Systems, 2nd Ed, Prentice Hall

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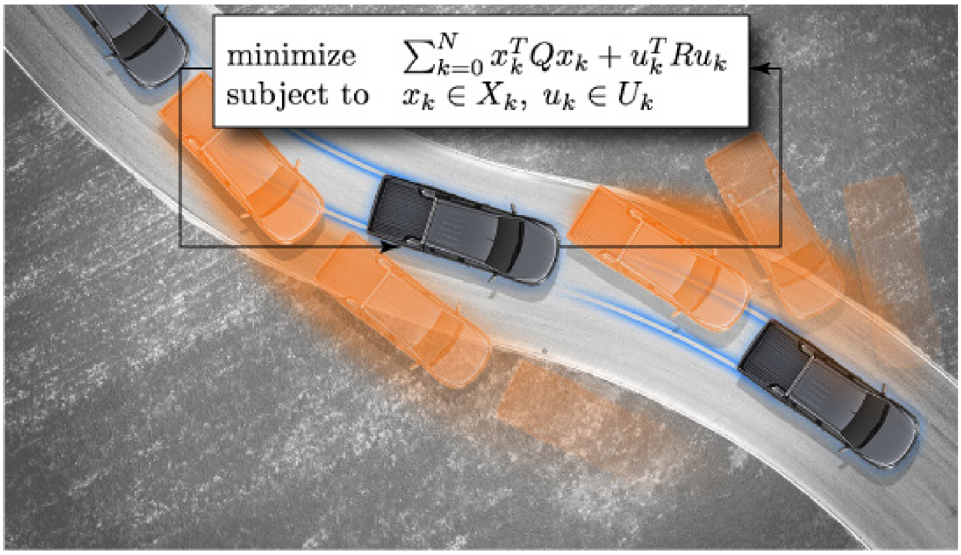

Model Predictive Control

EL2700
7.5 hp, per 1

Coordinator
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Introduction

Model predictive control (MPC) is one of few control design methods that deals with dynamical systems with hard constraints on states and control variables. Contrary to many of the classical controllers, where the control action is an explicit function of the measurements, MPC relies on solving an optimization problem to predict the best future control actions in every sample. MPC has a long history in process control but recent algorithmic advances and increases in computing power enable a plethora of new applications.

Aim

After the course, you should be able to

- analyze properties of discrete-time linear systems in state-space form
- compute optimal open-loop controls for state transfer using linear and quadratic programming
- use dynamic programming to design state estimators and linear controllers that minimize a quadratic cost criterion in the states and controls (LQG-optimal controllers)
- understand the receding-horizon idea and how MPC extends LQG-optimal control to deal with state and control constraints
- design MPC controllers for engeinering systems, making effective use of its tuning parameters to meet closed-loop performance targets
- have a basic understanding of stability properties of MPC controllers
- know how MPC can be implemented as either an nonlinear control law or using on-line optimization

Prerequisites

Automatic Control, Basic Course, or permission by the coordinator.

Requirements

Lab projects 4.5hp, Written exam 3hp

Course literature

J. B. Rawlings and D. Q. Mayne, Model Predictive Control: Theory and Practice, Nob Hill Publishing, 2015.

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Reinforcement Learning

EL2805
7.5 hp, per 2

Aim

The course provides an in-depth treatment of the modern tools used to devise and analyze Reinforcement Learning algorithms. It includes an introduction to RL and to its classical algorithms such as Q-learning, and SARSA, but further presents the rationale behind the design of more recent algorithms.

Syllabus

The course covers both classical RL algorithms and those used in recent RL success stories, i.e., deep RL algorithms. You will learn to:

- Model controlled discrete-time stochastic systems via MDPs
- Solve MDPs using Dynamical Programming
- Derive solutions of MDPs using the value and policy iteration methods
- Control stochastic systems with unknown dynamics using Q-learning or SARSA algorithms
- Address on-policy and off-policy RL problems
- Develop and implement RL algorithms with function approximation (e.g. deep RL algorithms)

Requirements

Written exam, 1 homework, and 2 computer labs.

Literature

Sutton and Barto, Introduction to Reinforcement Learning, MIT Press

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Nonlinear Control

EL2620
7.5 hp, per 2

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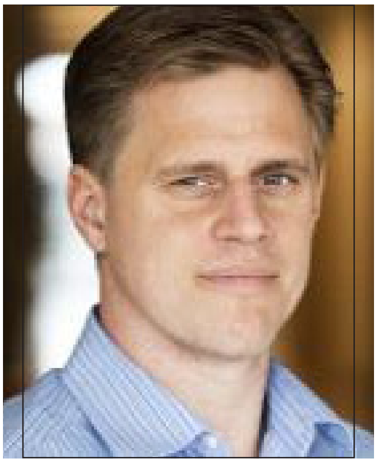

Aim

After finished course, the students will have knowledge in analysis of nonlinear dynamical systems using tools from control theory, such as linearization and Lyapunov methods. They will be able to use computer-based tools for modeling, simulation and control design of nonlinear systems. They will have knowledge about advanced nonlinear control design methods. The theory is illustrated by many examples from mechanical, electrical, chemical and aeronautical engineering, as well as from bioengineering and finance.

Syllabus

Nonlinear models and phenomena. Feedback analysis: linearization, stability theory, Lyapunov functions. Control design: compensation, high-gain design, Lyapunov methods, state feedback and output feedback, robust stabilization, observers, tracking. Compensation for saturation and friction, etc. Overview of alternative methods.

Prerequisites

Automatic Control, Basic Course, (EL1000 Reglerteknik allmän kurs or equivalent) or permission by the coordinator.

Requirements

Homeworks 6.0hp, Written exam 1.5hp

Literature

Khalil, H. K., Nonlinear Control, (Global edition, 2015, Pearson Education Ltd, ISBN 978-1-292-06050-7). Plus additional hand-out material

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Hybrid and Embedded Control Systems

EL2450
7.5 hp, per 3

Coordinator
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Introduction

Hybrid and Embedded Control Systems is a course on analysis, design, and implementation of control algorithms in emerging networked embedded systems.

Syllabus

The course consists of 14 lectures, 14 exercises, and 3 homeworks one of which is a laboratory exercise with a real robotic platform. The topics discussed are the following:

Introduction: course outline, motivating examples, review of sampled signals

Time-triggered control: models, analysis, implementation

Event-triggered control: real-time operating systems, models of computation, scheduling

Hybrid control: Modeling time-triggered and event-triggered systems, control and verification of hybrid systems

Prerequisites

EL 1000 Reglerteknik allmän kurs or equivalent Basic Course on Automatic Control. Background on state-space approach is necessary..

Requirements

Written exam (5,5 hp), three homework assignments (2 hp).

Literature

Lecture notes, slides and reading material.

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Control Theory and Practice, Advanced Course

EL2520
7.5 hp, per 4

Aim

This course introduces basic theory and methodologies required for analyzing and designing advanced control systems. After the course, you should be able to

Understand basic properties of multivariable linear systems

Compute signal norms and system gains, and analyze closed-loop stability

Perform a thorough analysis of a closed-loop control system

Quantify fundamental limitations on control system performance

Analyze the robustness of multivariable control systems

Analyze interactions and propose decentralized control structures

Derive LQG-, H2- and H_infinity- optimal controllers

Develop anti-windup control strategies to deal with control signal limitations

Syllabus

Mathematical descriptions of linear multivariable systems, fundamental limitations on achievable performance, robustness to model uncertainties, design of multivariable controllers, linear quadratic control, H2- och H-infinity optimal control, brief introduction to model predictive control.

Prerequisites

EL 1000 Reglerteknik, allmän kurs or equivalent

Requirements

Written exam, a lab project and a computer project.

Literature

Torkel Glad and Lennart Ljung, Control Theory - Multivariable and Nonlinear Methods, Taylor and Francis Ltd

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Automatic Control Project Courses

Aim

The student should after the course be able to work in control related projects. He/she should be able to do modelling, control design, analysis and implementation of a control system for laboratory process. In particular, the students should be able to:

- work effectively in a smaller project group

- systematically design, implement, test and demonstrate a prototype control system that meets given specifications

- use adequate engineering tools and methods and aquire new knowledge and skill when needed

- document and communicate results in written and oral presentations

Syllabus

The course consists of a project, where the students design and implement a control system on a physical system. Given specifications should be satisfied. The work can be divided into three phases: Physical and experimental modelling; Controller design, analysis and simulation; Implementation in a real time control system.

The work is done in groups 4-10 students, depending on the project, and is documented in a report and an oral presentation at a seminar, including a live demo of the implemented solution.

The course is given in two versions, EL2421 is 15 hp and the smaller version EL2425 is 7.5 hp.

Prerequisites

EL1000 Basic control or equivalent. At least one of the following courses: EL2520 Control Theory and Practice, EL2450 Hybrid and Embedded Control Systems, EL2620 Nonlinear Control, EL2700 Model Predictive Control, EL2800 Stochastic Control and Optimization, or EL2805 Reinforcement Learning. EL2820 Modeling of Dynamical Systems is recommended.

Requirements

The group should deliver a project plan, pass the halftime review, deliver a control system which meets given specifications, give an oral presentation at a seminar and deliver a final project report and documentation of the work.

EL2421

15 hp, per 1+2

EL2425

7.5 hp, per 2

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