Annex F1

Feedback to the MSE Board on the Adv_Control 2018 module
Application for an additional module «Model Predictive Control» (MPC)

a. Is a change required to the module content? If so, what change?

The contents of the Adv_Ctr module were discussed in several meetings of the module group. The analysis showed that

- Important topics, especially model predictive control (MPC), cannot be covered in the module due to time constraints
- The final part touches on too many topics, without the students acquiring the competence to really apply the content
- The extremely different levels of students' prior knowledge have prompted discussions as to whether the level of the module should be lowered
- It was also acknowledged that the MSE does not offer anything in the field of modelling mechatronic systems (multibody dynamics especially for robotics)

Different solution variants were discussed and it was decided to propose the following variant to the MSE Board:

- The contents of the existing Adv-Ctr module will be reduced. The part on non-linear control will be deleted. The tuition time made available in this way will be used to extend the parts on state control, discrete time control and robust control by one week of tuition in each case. An adapted module description is enclosed. The requirements for the module have been marginally reduced. Knowledge of state control is no longer required. Students are, however, required to have knowledge of state-space models.
- An application is being submitted to offer a new module on Model Predictive Control (MPC). With the computer hardware available today, MPC offers the opportunity to calculate optimum control variables in real time with consideration to boundary conditions and predictions. The field of application for MPC is vast and ranges from energy-optimised building control, via process engineering, through to the control of electrical networks. The flood of publications on MPC furnish proof of the major potential of this controller design method, and we consider it absolutely necessary to be able to offer students MPC as an independent MSE module. A module description is enclosed.

b. Could the organisation of the module by the lecturers involved be improved? If so, what measures do you propose?

A well-established team is in place and hence there is no need.

c. Concerning module content and/or organisation: What has proved successful in your module and must absolutely be retained in future?

The division into 2 hours of theory and a one-hour tutorial has proved successful and is also welcomed and demanded by the students. What has not proved successful, however, is the addition of a second tutorial hour. That was very unfavourable in time terms for a large number of students. If they had made use of the second tutorial hour, they would have had to go directly to the next module without a lunch break.

d. Could the general organisation and the planning be improved? If so, what specific suggestions do you have?

The room used for teaching in Zurich on the top storey of the building is more reminiscent of an improvised solution in a developing country. The blackboard is too small, scarcely legible from the back and much too close to the front row. The lecturer hardly has any room to move around properly, and if the blackboard has to be turned around, the students there have to close their laptops and lean back.

e. Have you any other suggestions or comments that you would like to convey to the MSE Board?

The same suggestions for improvement that were made last year still apply, since a solution has still not been found.
It must be possible to communicate with students via Moodle at least 4-6 weeks before the start of the semester already. Only in this way can things be organised in preparation for the module.

MSE | MASTER OF SCIENCE IN ENGINEERING

Modulbeschrieb

Fortgeschrittene Regelungstechnik

Allgemeine Informationen

Anzahl ECTS-Credits

3

Modulkürzel

TSM_AdvContr

Version

2. Juli 2018

Modulverantwortliche/r

Jürg Keller, FHNW

Sprache

	Lausanne	Bern	Zürich
Unterricht	☐ E ☒ F	☐ D ☐ E ☐ F	☒ D ☒ E
Unterlagen	☒ E ☐ F	☐ D ☐ E ☐ F	☐ D ☒ E
Prüfung	☐ E ☒ F	☐ D ☐ E ☐ F	☒ D ☒ E

Modulkategorie

☐ Erweiterte theoretische Grundlagen

☒ Technisch-wissenschaftliche Vertiefung

☐ Kontextmodule

Lektionen

☒ 2 Vorlesungslektionen und 1 Übungslektion pro Woche

☐ 2 Vorlesungslektionen pro Woche

Kurzbeschreibung /Absicht und Inhalt des Moduls in einigen Sätzen erklären

Modellbasierter Reglerentwurf ist die Schlüsseltechnologie zur Beherrschung komplexer dynamischer Systeme und technologische Voraussetzung etlicher bedeutender Innovationen der vergangenen Jahre. In diesem Modul werden wichtige Elemente des Entwicklungsprozesses behandelt: Systemidentifikation, LQR/LQG-Reglerentwurf und Reglerimplementierung. Da Modelle immer mit Modellunsicherheit verbunden sind, wird im letzten Abschnitt das Thema der Robusten Regelung behandelt

Ziele, Inhalt und Methoden

Lernziele, zu erwerbende Kompetenzen

Die Studierenden sind in der Lage...

- eine modellbasierte, robuste Regelung vollständig zu erstellen, Parameterschätzung, Systemanalyse, Reglerentwurf und Reglerimplementierung

Modulinhalt mit Gewichtung der Lehrinhalte

- LQR/LQG-Reglerentwurf (5W)
  - Zustandsraummodelle und deren Eigenschaften, Linearisierung um Arbeitspunkt,
  - Realisierungstheorie, Zustandsregelung
  - Entwurf von Beobachtern
  - Singularwertzerlegung
  - LQR/LQG-Reglerentwurf für SISO- und MIMO-Systeme mit Loop Transfer Recovery (inkl. Integralregler)
- Einführung in die Systemidentifikation (4W)
  - Modelltypen, abgetastete Systeme (Zero-Order-Hold), Versuchsplanung, Signalaufbereitung
  - Least Square, rekursive Methoden
- Wichtige Aspekte der Reglerimplementierung (2W)
  - Reglerdiskretisierung, Abtastzeit
  - Probleme der Quantisierung
- Robuste Regelung (3W)
  - H_∞-Reglerentwurf

Lehr- und Lernmethoden

- Vorlesungen, Übungen, Fallstudien
- Für das Modul steht eine Prüfung zur Selbstevaluation und zum Erkennen von Lücken zur Verfügung und soll vor dem Modulstart selbständig gelöst werden

Voraussetzungen, Vorkenntnisse, Eingangskompetenzen

- Differential- und Differenzengleichungen
- Übertragungsfunktion (zeitkontinuierliche und zeitdiskrete Systeme)
- PID-Reglerentwurf und Implementierung, inkl. Anti-Windup-Strategien
- Regelsystemstrukturen: Feed-forward, Kaskadenregelung
- Analyse von Regelkreisen (Stabilität, Amplituden- und Phasenrand, Regelgüte im Zeit- und Frequenzbereich)
- Zustandsraummodelle
- Loop-Shaping-Reglerentwurf
- Lineare Algebra (Eigenwertzerlegung)
- Das Modul erfordert mindestens 2 Semester Regelungstechnik im Bachelorstudium

Bibliografie

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Leistungsbewertung

Zulassungsbedingungen für die Modulschlussprüfung (Testatbedingungen)

Keine

Schriftliche Modulschlussprüfung

Prüfungsdauer :	120 Minuten
Erlaubte Hilfsmittel:	Bücher, Skript, eigene Unterlagen

Module Description

Advanced Control

General Information

Number of ECTS Credits

3

Abbreviation

TSM_AdvContr

Version

2. Juli. February 2018

Responsible of module

Jürg Keller, FHNW

Language

	Lausanne	Bern	Zürich
Instruction	☐ E ☒ F	☐ D ☐ E ☐ F	☒ D ☒ E
Documentation	☒ E ☐ F	☐ D ☐ E ☐ F	☐ D ☒ E
Examination	☐E ☒ F	☐ D ☐ E ☐ F	☒ D ☒ E

Module category

☐ Fundamental theoretical principles

☒ Technical/scientific specialisation module

☐ Context module

Lessons

☒ 2 lecture periods and 1 tutorial period per week

☐ 2 lecture periods per week

Brief course description of module objectives and content

Model-based controller design is a key technology to control systems with complex dynamics. It was the enabling technology for many innovations in the last decade. In this module, the key elements of the development process are addressed: system identification, LQR/LQG-Controller design and controller implementation. Since there is always model uncertainty, the course end with an introduction to robust controller design using H_∞.

Aims, content, methods

Learning objectives and acquired competencies

- The student is able to
- completely design a model-based, robust feedback control law, including modelling, parameter estimation, system analysis, controller design and controller implementation
- design a robust H_∞-optimal controller.

Contents of module with emphasis on teaching content

- LQR/LQG-Controller design (5W
  - State space models and their properties, linearization, singular values, realisation theory, basic state feedback control
  - Observer design
  - LQR/LQG controller design with Loop Transfer Recovery (incl. integral controller action), SISO and MIMO-Systems
- Introduction to system identification (4W)
  - Models, design of experiments, signal conditioning Least Square, recursive methods
- Important aspects of controller implementation (2W)
  - Controller discretization, sampling time
  - Quantisation effects
- Robust Control (3W)
  - H_∞-controller design

Teaching and learning methods

Lectures, exercises, case studies

A self-evalutaion exam is provided to check the skills necessary to follow the course

Prerequisites, previous knowledge, entrance competencies

- Differential equations, Transfer functions
- PID-controller design and implementation incl. anti-windup strategies
- control system structures: feed-forward, cascaded control
- Analysis of feedback control systems (stability, phase/gain margin, performance in time and frequency domain)
- State space models
- Loop shaping controller design
- Linear algebra (Eigenvalue Decomposition)
- It is necessary, that the student has successfully completed 2 semester courses in feedback control

Literature

Assessment

Certification requirements for final examinations (conditions for attestation)

No requirements

Written module examination

Duration of exam :	120 minutes
Permissible aids:	Books, scripts, student's documents

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Module Description

Model Predictive Control

General Information

Number of ECTS Credits

3

Abbreviation

TSM_MPC

Version

July 3, 2018

Responsible of module

Konrad Stadler ZHAW / Thomas Besselmann FHNW

Language

	Lausanne	Bern	Zürich
Instruction	☐ E ? F	☐ D ☐ E ☐ F	☒ D ☒ E
Documentation	☒ E ☐ F	☐ D ☐ E ☐ F	☐ D ☒ E
Examination	☐E ? F	☐ D ☐ E ☐ F	☐ D ☒ E

Module category

☐ Fundamental theoretical principles

☒ Technical/scientific specialisation module

☐ Context module

Lessons

☒ 2 lecture periods and 1 tutorial period per week

☐ 2 lecture periods per week

Brief course description of module objectives and content

Model Predictive Control (MPC) is an optimisation-based approach to control systems and processes. The general mathematical formulation of MPC allows it to be applied to a broad range of systems and considers system constraints intrinsically. The advances in optimisation methods and available computational power have made MPC a valuable alternative to classical control approaches also for fast dynamic systems. Today, MPC applications can be found from the original chemical process control systems to the control of frequency converters with sampling periods down to a few microseconds.
This module focuses on introducing MPC from the theoretical basics to the use of tool kits to support the implementation and generation of working code. As the classical frequency domain control methods are not considered here, this module does not need in-depth knowledge of control systems. A general affinity to mathematics and programming skills are beneficial.

Aims, content, methods

Learning objectives and acquired competencies

The student is able to

- formulate an optimisation problem and solve it with appropriate tool kits
- formulate model predictive control problems
- apply the MPC concepts to systems and generate working code which can be used in control systems

Contents of module with emphasis on teaching content

- Basic concepts (3W)
    - Introduction to state space models in continuous and discrete time
    - Introduction to optimisation (linear and quadratic programs) using tool kits like YALMIP
    - Introduction to optimisation with constraints
- Basic MPC (3W)
    - MPC problem formulation
    - Receding horizon concept
    - Link to LQR (stability/constraints)
- MPC Extensions (8W)
    - State observation/Kalman filter and offset-free control

- Nonlinear optimisation
- MPC with nonlinear models
- Real-time implementation (from problem to code) using tool kits like ACADO
- Explicit MPC versus online MPC
- Scheduling

Teaching and learning methods

Lectures, exercises, case studies

Prerequisites, previous knowledge, entrance competencies

- Linear Algebra differential equations
- Basic feedback control systems
- Basic programming skills in Matlab or Python
- General affinity to mathematics(!)
- It is necessary, that the student has successfully completed 1 semester course in basic feedback control

Literature

Assessment

Certification requirements for final examinations (conditions for attestation)

No requirements

Written module examination

Duration of exam :	120 minutes
Permissible aids:	Books, lecture notes, student’s documents