Course syllabus

Modelling and Learning from Data
Modellering och inlärning från data

FRTN65, 7.5 credits, A (Second Cycle)

Valid for: 2024/25
Faculty: Faculty of Engineering LTH
Decided by: PLED F/Pi
Date of Decision: 2024-04-15
Effective: 2024-05-08

General Information

Main field: Machine Learning, Systems and Control **Depth of study relative to the degree requirements:** Second cycle, in-depth level of the course cannot be classified
Mandatory for: MMSR1
Elective mandatory for: MVAR2
Elective for: BME4-sbh, C4, D4-ssr, D4-mai, E4-ss, E4-ra, F4, F4-r, F4-mai, Pi4-ssr
Language of instruction: The course will be given in English

Aim

The course provides an introduction to the problem of learning from data, focusing on dynamical systems and on the basic concepts behind data analysis. The aim of the course is that students should learn principles and fundamental limitations of what can be learned from data, with techniques coming both from the machine learning and system identification domains.

Learning outcomes

Knowledge and understanding
For a passing grade the student must

- be able to define the basic concept behind data analysis.
- understand the limitations of the learning paradigm and the guarantees and confidence in the learning process.
- have knowledge about the different model types and alternatives that can be used to describe the data.
- understand and follow the different phases in the process of building models, from the design of the learning process to its application to a set of data, and

validation of the obtained model.
- describe and motivate basic properties of both machine learning models (such as regression, neural networks, and classifiers) and system identification methods (such as least squares, prediction error methods, and recursive identification procedures).

Competences and skills
For a passing grade the student must

- be able to implement machine learning algorithms and reason about the best choice for a given set of data.
- be able to implement system identification procedures and perform model selection and determine how to analyze a given set of data.
- be able to use acausal, equation-based modeling to simulate and understand dynamical multidomain systems.
- be able to use structured causal models and directed acyclic graphs to determine causal relations from data.
- solve learning problems by writing and using computer programs.

Judgement and approach
For a passing grade the student must

- understand the confidence that it is possible to achieve with data analysis.
- understand the difference between correlation and causality.
- master teamwork and collaboration in laboratory exercises.

Contents

The course gives a solid foundation and hands-on experience to students that want to understand how to build models and learn from data. Special focus is given to models for dynamical systems suitable for control. The course combines physics based modeling of linear and nonlinear static and dynamical systems with data-driven approaches from machine learning and system identification. Throughout the course, theory is mixed with coding examples.

The first part of the course is dedicated to machine learning problems and algorithms. In the supervised learning framework the course treats classification and regression. In the unsupervised learning framework the course includes clustering techniques. The student gets hands-on experience using modern tools on interesting data sets.

The second part describes structured causal modeling and how directed acyclic graphs can be described to do causal inference from data via valid adjustment sets, the backdoor criterion or the frontdoor criterion.

The third part of the course is dedicated to system identification problems and describes the concepts of gray-box and black-box models and techniques to perform the identification procedure. In particular, the course treats linear regression, maximum likelihood estimation, prediction error methods, and experiment design. The advantages of acausal equation based modeling are described.

Laboratories: Classification assignment; Modeling and simulation assignment; Identification of dynamical systems models.

Examination details

Grading scale: TH - (U, 3, 4, 5) - (Fail, Three, Four, Five)
Assessment: Written exam, three laboratory exercises including three hand-in assignments. In the case of less than 5 registered students, the retake exams may be given in oral form.

The examiner, in consultation with Disability Support Services, may deviate from the regular form of examination in order to provide a permanently disabled student with a form of examination equivalent to that of a student without a disability.

Modules
Code: 0120. **Name:** Modelling and Learning from Data.
Credits: 4.5. **Grading scale:** TH - (U, 3, 4, 5). **Assessment:** Written exam
Code: 0220. **Name:** Laboratory Work 1.
Credits: 1.0. **Grading scale:** UG - (U, G). **Assessment:** Completed laboratory work and hand-in assignment.
Code: 0320. **Name:** Laboratory Work 2.
Credits: 1.0. **Grading scale:** UG - (U, G). **Assessment:** Completed laboratory work and hand-in assignment.
Code: 0420. **Name:** Laboratory Work 3.
Credits: 1.0. **Grading scale:** UG - (U, G). **Assessment:** Completed laboratory work and hand-in assignment.

Admission

Assumed prior knowledge: FRTF05 Automatic Control, Basic Course, or FRTF01 Physiological Models and Computations
The number of participants is limited to: 60
Selection: Completed university credits within the programme. Priority is given to students enrolled on programmes that include the course in their curriculum. Among these students priority is given to those in the master's programme in Machine Learning, Systems and Control, for whom the course is compulsory.
Kursen överlappar följande kurser: FRTN35 FRT041

Reading list

- Lennart Ljung, Torkel Glad and Anders Hansson: Modeling and Identification of Dynamic Systems (2nd Ed). Studentlitteratur, 2016, ISBN: 978914415345-2.
- Andreas Lindholm, Niklas Wahlström, Fredrik Lindsten, and Thomas B. Schön: Supervised Machine Learning. Cambridge University Press, 2021. Textbook manuscript available online.

Contact

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