COURSE DESCRIPTOR

Model Based Signal Processing
Modellbaserad Signalbehandling
Third-cycle course
Corresponds to 7.5 higher education credits (högskolepoäng)

1. Aim of the course
The goal of this course is to give a solid background in statistical estimation theory and some detection theory. This should provide the student with an excellent toolbox for model-based analysis of measured data. The tools are useful in a multitude of application areas that involve data and mathematical models, such as Wireless Communications, Radar and Sonar Systems, Image Analysis, Control and Mechatronic Systems, Remote Sensing and Environmental Surveillance, Seismology, Astronomy and many others. The focus is on the fundamental theory, which is exemplified using real-world examples.

2. Content
Mathematical Statistics Basics, Minimum Variance Unbiased Estimation and the Cramer-Rao Lower Bound, Best Linear Unbiased Estimators, Maximum Likelihood Estimation, Least Squares, Method of Moments and Instrumental Variables, Bayesian Estimation, Wiener and Kalman Filters. Introduction to Detection Theory: Binary Hypothesis, Likelihood Ratio Tests, Information-Theoretic Criteria. Application examples from Wireless Communications, Radar Systems.

3. Prerequisites
A working knowledge of Mathematical Statistics and Linear Algebra is assumed, as well as some basic Signals and Systems. Although a background in Signal Processing or Automatic Control is helpful, it will not be needed to follow the course.

4. Objectives
Knowledge and understanding
- In-depth knowledge of statistical estimation theory
- Basic knowledge of statistical detection theory

Competence and skills
- Ability to formulate and solve data analysis tasks using statistical models and techniques.

Judgement and approach
- Ability to reflect on optimal and suboptimal approaches to estimation and detection theory and understand trade-offs between statistical accuracy and computational complexity.

5. Learning and teaching
The course is given in the form of lectures and problem-solving sessions. After each lecture, a number of problems are assigned, both theoretical and computer simulations (Matlab). During the problem-solving session, the students are expected to present their own solutions to the assigned problems. The course is taught in English.

6. Lecture plan

- Lecture 0: Brief review of probability and mathematical statistics. Some linear algebra basics.
- Lecture 1: Planning, Introduction. Chapter 1. Minimum variance unbiased estimation (MVUE). The Cramér-Rao Lower Bound (CRLB). Chapters 2-3.
- Lecture 2: Linear models. Best linear unbiased estimation (BLUE). Chapters 4 and 6.
- Lecture 3: Sufficient statistics. Maximum Likelihood Estimation (MLE). Chapters 5 and 7.
- Lecture 4: Least-squares estimation. Method of moments. Chapters 8-9.
- Lecture 5: Bayesian estimation. Chapters 10-11.
- Lecture 6: Linear MMSE estimation. Chapters 12-13.
- Lecture 7: Detection, Classification and model order selection. Hand-out material to be distributed.
- Lecture 8: Summary and extensions. Chapters 14-15.

7. Schedule (preliminary), spring 2025

- Background: Lecture 0 on Tuesday, February 18 at 10.15 – 12.00. Location: J3506 Platon. For those who might need it.
- Lectures every Tuesday at 10.15 – 12.00, starting at February 25 and ending at April 15. Location: J3506 Platon.
- Tutorials every Monday at 10.15 – 12.00, starting at March 3 and ending at April 14. Location: J3506 Platon.

8. Assessment and grading

A take-home exam is given at the end of the course. To pass the course requires at least 50% of the points from the take-home exam. To access the take-home exam further requires attending at least 5 tutorials and solving at least 80% of the problems assigned during the course. Assessment of the course is the grade pass / fail.

9. Course evaluation

The course responsible is responsible for assuring that the doctoral student can comment on the course.

10. Course literature and other teaching material

Steven M. Kay: "Fundamentals of Statistical Signal Processing: Estimation Theory", Prentice-Hall, Englewood Cliffs, N.J., 1993. Hand-out material on Signal Detection.

11. Course responsible

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