AE 598: Estimation of Dynamical Sytems

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Overview

This course presents a rigorous mathematical foundation for the estimation of general linear and nonlinear systems, with some examples from aerospace systems. It especially focuses on derivations of formal performance guarantees of various estimation tools for their trustworthy use in the real world.

Prerequisites

STAT 361, STAT 400, MATH 461, AE 353 (or something equivalent), and familiarity with a programming language (Python, Matlab, etc.)

Web Page

https://canvas.illinois.edu/courses/49009/

Lecture Time and Location

12:30 PM - 01:50 PM on Tuesdays and Thursdays, 410C1 Engineering Hall

Instructor's Office Hours

TBD

Objectives

Upon completion of this course, a student will learn to:

- Design appropriate estimators for given linear/nonlinear dynamical/static systems
- Derive formal mathematical guarantees for these estimators given real-world data
- Implement them in aerospace systems

Topics

To various levels of detail, this course would cover:

- Brief review of probability and statistics

- Least-squares estimation
- Minimum variance estimation
- Maximum likelihood estimation
- Gradient descent and learning
- Lyapunov theory in estimation
- Bayesian filtering
- Luenberger observer
- Optimal estimation
- Kalman filtering and its variations
- Nonlinear estimation tools
- Sampling-based estimation
- Estimation in aerospace and robotic systems systems

Course Format

This course will be taught primarily using slides to be posted on Canvas. Some of the mathematical derivations on these slides will be given on blackboards during the lectures.

Recommended Textbooks

There are no required textbooks but some of the course topics are based on:

- Introduction to Random Signals and Applied Kalman Filtering
- Optimal Estimation of Dynamical Systems
- Statistical Orbit Determination

Assignments and Exams

There will be up to 5 assignments depending on the progress. Midterm and final will be take-home and closed book. They will be posted on and submitted trhough Canvas. Collaboration is strongly encouraged for assignments but is not allowed for exams. All students must adhere to the honor code (see below) when taking exams. Violations of the honor could result in failure of the course.

Grading

The grades will be weighed as follows

- Assignments: 60%
- Midterm: 20%
- Final: 20%

Anticipated Course Schedule

This is a newly established course so the schedule may vary significantly depending on the students' levels of understanding:

- Week 1: Introduction & Brief review of probability and statistics (8/26 – 8/30)
- Week 2: Minimum variance estimation and Maximum likelihood estimation (9/2 – 9/6)
- Week 3: Nonlinear least squares (9/9 – 9/13)
- Week 4: Gradient descent and machine learning (9/16 – 9/20)
- Week 5: Dynamical systems and Lyapunov theory (9/23– 9/27)
- Week 6: Bayesian estimation and Kalman filter (9/30 – 10/4)
- Week 7: Optimal estimation and Kalman filter (10/7 – 10/11)
- Week 8: Riccati equation and Kalman filter (10/14 – 10/18)
- Week 9: Variations of Kalman filter (10/21 – 10/25)
- Week 10: Midterm (TBD) & Nonlinear estimation tools (10/28 – 11/1)
- Week 11: Nonlinear estimation and Lyapunov theory (11/4 – 11/8)
- Week 12: Sampling-based estimation (11/11 – 11/15)
- Week 13: Thanksgiving week (11/18 – 11/22)
- Week 14: Parameter estimation and adaptation (11/25 – 11/29)
- Week 15: Estimation in aerospace and robotic systems (12/2 – 12/6)
- Week 16: Estimation in aerospace and robotic systems (12/9 – 12/11)
- Week 17: Final (TBD) (12/13 – 12/19)

Honor Code

The details can be found here (https://studentcode.illinois.edu/article1/part4/1-401/). There is also a good summary of the honor code here (https://siebelschool.illinois.edu/academics/honor-code) from the School of Computing and Data Science