Welcome

Introduction to (Bayesian) Estimation
MAE 5020

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Course logistics

- Syllabus available online `my.okstate.edu`
- Class meetings: Monday, Wednesday 2:30 - 3:45 pm, online/asynchronous video recording
  (Classroom Building 322 reserved for discussions and exams).
- Prerequisites: Undergraduate probability theory, statistics, and linear algebra. Familarity with MATLAB/Python.
- Textbook (Reference): Lessons in Estimation Theory for Signal Processing,Communications, and Control, 2nd Edition.

Course logistics

- Grading: Homework -25%, Project - 20%, Quizzes - 5%, Exams (25%, 25%).
- Two-week advance notice will be given for the mid-term exam. The final exam will be in the finals week.
- Office hour: online by appointment
- Contact info: `he.bai@okstate.edu`
- Academy integrity: `academicintegrity.okstate.edu`
- Current syllabus attachment: `https://academicaffairs.okstate.edu/student-support/index.html`
- Class notes/videos will be available online.

Ground rules

- No TA: Use office hours and emails
- Attendance
- Minimize cell phone usage (silent or airplane mode)
- Late HWs will be penalized (n days late $= n \times 10\%$ off).
- Discussions and questions are always welcome.
- Exams: take-home/in-person (close book with one cheat sheet; basic calculator)

Online teaching: Two modes

- Microsoft Teams used for live streaming
- Asynchronous video recordings
- Starting in the 3rd week, weekly online discussions (30 min): indicate your availability `https://www.when2meet.com/?20812701-jIb1k` by end of September 1st, 2023.

Introduction: About you and your academic interests

About this course

- Motivation
- Content: estimation theory + Bayesian perspective + Applications
- Specifics: Least squares, Maximum likelihood, Bayes theorem, Maximum A Posterior, Sampling, Variational Bayesian, Kalman filters, ...

Introduction: Estimation

- Widely used in many scence and engineering branches.
  - Submarine, aircraft, spacecraft, power systems
- To determine performance of a system and eventually control a systems, engineers must know what the system is "doing".
  - Physical systems subject to random disturbances: system state can be random
  - Measuring device produce noisy measurements (caused by electric and mechanical components)
- Estimation: Process of determining the state of a system from noisy measurements

Estimation is a product of need and technology

- Karl Friederich Gauss needed to predict motion of plantes and comets from telescopic measurements: Least squares
- Digital computer technology created the need for recursive algorithms, including Kalman filters used for many navigation problems.
- Autonomous systems nowadays all have some kind of estimation/navigation/localization systems onboard.
- Estimation is also widely used in system identification, monitoring, and diagnosis, and CONTROL.

Philosophy of the book

- Discrete-time viewpoint: simpler, practical, discretize the model upfront
- Estimation theory is the extension of classical signal processing to the design of digital filters that process uncertain data in an optimal manner.
- Computation: left to the experts

Example: Sample mean

Suppose we have a collection of k measured values of quantity X, i.e., $x(1), \cdots, x(k)$. Its sample mean $\bar{x}(k)$ is given by (batch process)

- Can we make it recursive? The sample mean for data up to $i+1$ only depends on 'new data' $x(i+1)$ and previous mean $\bar{x}(i)$

- Observation:

Role of estimation to modeling

- Modeling: representation, measurement, estimation, validation

1. Representation:

2. Measurement (parameter vs. signal):

3. Estimation problems (parameter vs. signal)

4. Validation: