Stony Brook University

ESE 531: Statistical Learning and Inference

Spring 2024

Instructor

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Office Hours

Light Engineering, Room 258A
W 3:00PM-5:00PM
(or by appointment)

Class Meetings

Frey Hall 326
W 5:30PM-8:20PM

Course Overview

Course Prerequisites

ESE 503 or permission of instructor.

Course Goals

The goal of the course is to teach students the basics of estimation and detection theory. More specifically, it is to introduce the students to classical and Bayesian estimators, estimation bounds, hypothesis testing, and several detectors of signals in noise. Exposing the students to applications of estimation and detection is another important goal.

Course Objectives

Upon completion of this course, students will be able to solve problems that involve estimation of signal parameters or detection of signals or problems where joint detection and estimation is required. The students will also be able to solve problems with practical context.

Course Schedule

A course schedule will be posted on Brightspace and will outline covered topics, assignments, exam dates, and due dates for any project milestones.

Recommended Course Materials

Material covered in this course will be loosely based on material from the following textbooks:

- *Fundamentals of Statistical Signal Processing: Estimation Theory*, S. M. Kay, Prentice Hall, 1993.
- *Fundamentals of Statistical Signal Processing: Detection Theory*, S. M. Kay, Prentice Hall, 1998.
- *Statistical Inference*, 2nd ed., G. Casella and R. Berger, Duxbury Press, 2002.

Recommended textbook readings will be assigned from the above texts but are not required.

Grading

Attendance (10%)

Class attendance is mandatory and counts towards the student's final grade. *Students are allowed to miss two*

classes over the course of the semester; however, student attendance for midterm examinations and project presentations is required. Attendance will be taken in one of two ways: 1.) The instructor will roll call attendance; or 2) The instructor will give an ungraded quiz to the class.

Midterm Exams (50%)

There will be two midterm exams, each worth 25% of the student's final grade. Midterm exams are out of 100 total points and will consist of five questions, each worth the same number of points. *For each exam, the question for which the student receives the lowest score will be dropped and will not count toward the exam grade.* Students can prepare for midterm exams by: (1) reviewing lecture notes, (2) completing the recommended textbook readings, (3) completing the ungraded homework assignments, and (4) reviewing the ungraded quizzes.

Final Project (40%)

While there is no final exam in this course, there will be a final project that will count towards the majority of the student's grade. The project will give students an opportunity to apply some of the techniques they have learned throughout the semester to a real-world problem or a research project. The project will consist of three main components: (1) project proposal, (2) project report, and (3) project presentation. Project proposals will be due sometime in the middle of the semester. The final project report will be due at the beginning of the final exam period. Project presentations will be conducted during the final exam period. *Students will be allowed to work individually on the project or in a team of two students. In the case that students work in a team of two, students will be required to submit a "Contributions" section of their final project report which outlines the contributions of each team member.* Project details and grading breakdown will be posted in a separate document on Brightspace.

Course Topics

- **Properties of random samples** – definition of a random sample, population distribution, definition of a statistic, sampling distribution, sample mean, sample variance, probability inequalities, convergence of random variables, weak and strong law of large numbers, central limit theorem, delta method,
- **Point estimation** – maximum likelihood estimation, method of moments estimation, sufficient statistics, exponential families, single and multi-parameter estimation, methods for estimation (e.g., analytical, and numerical optimization, expectation maximization), point estimation under parameter constraints, Gaussian mixture models,
- **Evaluation of estimators** – mean-squared error criterion, bias-variance tradeoff, unbiased estimators, minimum variance criterion; existence of minimum variance unbiased estimators, Fisher information, Cramer-Rao bounds, properties of maximum likelihood estimators, predictive performance,
- **Linear models** – definition and properties, maximum likelihood estimation for linear models, noise model, colored noise model, best linear unbiased estimator
- **Bayesian estimators** – Bayesian vs. frequentist philosophies, Bayes' theorem, conjugate priors, MAP estimation, MMSE estimation, Jeffrey's prior, examples of Bayesian inference, approximate Bayesian inference, Laplace approximation, Monte Carlo methods, Metropolis-Hastings algorithm,
- **Detection theory** – Binary hypothesis testing, type-I and type-II errors, simple and composite hypothesis testing, Neyman-Pearson theorem, likelihood ratio test, receiver operating characteristics, probability of error, multiple hypothesis testing, generalized likelihood ratio test, examples of various detectors

University Policies

Student Accessibility Support Center Statement

If you have a physical, psychological, medical, or learning disability that may impact your course work, please contact the Student Accessibility Support Center, Stony Brook Union Suite 107, (631) 632-6748, or at sasc@stonybrook.edu. They will determine with you what accommodations are necessary and appropriate. All information and documentation is confidential. Students who require assistance during emergency evacuation are encouraged to discuss their needs with their professors and the Student Accessibility Support Center. For

procedures and information go to the following website: https://ehs.stonybrook.edu//programs/fire-safety/emergency-evacuation/evacuation-guide-disabilities and search Fire Safety and Evacuation and Disabilities.

Academic Integrity Statement

Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty is required to report any suspected instances of academic dishonesty to the Academic Judiciary. Faculty in the Health Sciences Center (School of Health Professions, Nursing, Social Welfare, Dental Medicine) and School of Medicine are required to follow their school-specific procedures. For more comprehensive information on academic integrity, including categories of academic dishonesty please refer to the academic judiciary website at http://www.stonybrook.edu/commcms/academic_integrity/index.html

Critical Incident Management

Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of Student Conduct and Community Standards any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students' ability to learn. Faculty in the HSC Schools and the School of Medicine are required to follow their school-specific procedures. Further information about most academic matters can be found in the Undergraduate Bulletin, the Undergraduate Class Schedule, and the Faculty-Employee Handbook.

Course Materials and Copyright Statement

Course material accessed from Brightspace, Zoom, Echo 360, VoiceThread, etc. is for the exclusive use of students who are currently enrolled in the course. Content from these systems cannot be reused or distributed without written permission of the instructor and/or the copyright holder. Duplication of materials protected by copyright, without permission of the copyright holder is a violation of the Federal copyright law, as well as a violation of Stony Brook's Academic Integrity.

Electronic Communication

Email and especially email sent via Brightspace is one of the ways the faculty officially communicates with you for this course. It is your responsibility to make sure that you read your email in your official University email account. For most students that is Google Apps for education (http://www.stonybrook.edu/mycloud). If you choose to forward your official University email to your another off-campus account, faculty are not responsible for any undeliverable messages to your alternative personal accounts. You can setup Google mail forwarding using these DoIT-provided Instructions found at http://it.stonybrook.edu/help/kb/seeting-up-mail-forwarding-in-google-mail.If you need technical assistance, please contact Client Support at 631-632-9800 or supportteam@stonybrook.edu.

Additional Resources

- To access mental health services, call Counseling and Psychological Services (CAPS) at 631-632-6720; Counselors are available to speak with 24/7.
- For updated information on the Academic Success and Tutoring Center (ASTC), please check www.stonybrook.edu/tutoring for the most up-to-date information.
- For IT Support: Students can visit the Keep Learning website at https://sites.google.com/stonybrook.edu/keeplearning for information on the tools you need for alternative and online learning.
- Need help? Report technical issues at https://it.stonybrook.edu/services/itsm or call 631-632-2358.
- For information on Library services and resources, please visit https://library.stonybrook.edu