**THE UNIVERSITY OF TEXAS AT AUSTIN**
**Department of Aerospace Engineering & Engineering Mechanics**

# ASE 381P6 - Statistical Estimation Theory
**Fall 2024**

## SYLLABUS

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| **Unique Number:** | 14410 |
| **Instructor:** | Dr. Brandon A. Jones (he/him/his)<br>Phone: 512-471-4743<br>Email: brandon.jones@utexas.edu<br>Office: ASE 3.230 |
| **Class Time:** | MW 8:00 - 9:30am |
| **Class Location:** | ETC 2.114 |
| **Web Page:** | Documents will be posted on the course **Canvas** website:<br>https://canvas.utexas.edu |

**Catalog Description:** Modeling static and dynamic systems, linear and nonlinear estimation, Bayesian estimation, batch least squares, Kalman filtering, square-root and information filtering, introduction to advanced estimation methods.

**Prerequisites:** None

**Knowledge, Skills, and Abilities Students Should Have Before Entering This Course:**

- Basic understanding of dynamical systems and modeling
- Fundamental understanding of linear algebra and vector spaces
- Familiarity with a programming language (MATLAB, Python, etc.)

**Knowledge, Skills, and Abilities Students Gain from this Course (Learning Outcomes):** Upon completion of this course, a student will be able to:

- Derive an estimator to generate a probabilistic representation of our knowledge of a state vector when given necessary models, observations, and performance constraints,
- Using a derived/selected estimator and knowledge of dynamics and measurement models, process data to generate an *a posteriori* solution, and
- Derive and/or numerically characterize the expected performance of the estimator.

**Course Topics:** To various levels of detail, the course shall cover:

- Brief review of linear algebra needed for course
- Probability and statistics for stochastic estimation
- Dynamics and measurement modeling
- Basics of the estimation problem and general classes of estimators
- Least-Squares estimation for static and dynamic systems
- Nonlinear least-squares estimation

- The Kalman Filter (KF) (formulation, variations, issues)
- The Extended Kalman Filter (EKF)
- The Unscented Kalman Filter (UKF)
- Smoothing for sequential estimation
- Square-root methods, why they are needed and general approach
- The information filter
- Multiple-model estimation
- Particle filtering

**Required Materials:** A student is required to have regular access to the following materials and resources:

- A camera or scanner to aid in submitting exams, and
- Computer with a programming language of choice (e.g., MATLAB, Python, Julia, etc.).

**Text:** There is one required textbook for this class:

- Bar-Shalom, Y., X. R. Li, and T. Kirubarajan, *Estimation with Applications to Tracking and Navigation*, John Wiley and Sons, Inc., New York, 2001.
  **Note: A PDF copy of the text is available via the UT Library. A physical copy is not required due to cost.**

The following are additional texts that may assist in understanding the material in this course. They are not required and the instructor will not assume you have acquired a copy.

- Tapley, B.D., B. E. Schutz, and G. H. Born, *Statistical Orbit Determination*, Elsevier Academic Press, Burlington, MA, 2004.
- B. Ristic, S. Arulampalam, and N. Gordon, *Beyond the Kalman Filter: Particle Filters for Tracking Applications*, Artech House, Boston, MA, 2004.
- Särkkä, S., *Bayesian Filtering and Smoothing*, Cambridge University Press, 2013. PDF provided by the author at https://users.aalto.fi/∼ssarkka/pub/cup_book_online_20131111.pdf

**Class Format:** This course is a lecture/discussion course. In-person lectures will be conducted twice a week during the scheduled time. Attendance is expected (see Attendance policy below).

In the event that the instructor is on travel, lectures may be pre-recorded or held virtually. Virtual lectures will be recorded to mitigate connectivity issues you (the student) may have in real time. The next lecture after the instructor's return will assume all students have reviewed the recorded material. Any recorded lectures will be posted to Canvas via the 'Panopto' tab for offline review.

**Class Website:** This class will use Canvas (a Web-based course management system with password protected access at http://canvas.utexas.edu) to distribute course materials, to communicate and collaborate online, to post grades, and for course announcements. You can find support in using Canvas at the ITS Help Desk at 475-9400, Monday through Friday, 8 a.m. to 6 p.m., so plan accordingly

**Grading:** The grades in this course will be weighted among the following required components:

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| Midterm Exam #1 | 33% |
| Midterm Exam #2 | 33% |
| Final Exam | 34% |
| **Total** | **100%** |

Final grades will be determined on the basis of the following rubric. This rubric may be adjusted at the end of the semester, but the minimum score for a given range would only be reduced and not increased. To ensure fairness, all numbers are absolute and will not be rounded down or up. The University does not recognize a grade of A+.

| <59 | 60-63 | 64-66 | 67-69 | 70-73 | 74-76 | 77-79 | 80-83 | 84-86 | 87-89 | 90-93 | 94-100 |
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| F | D- | D | D+ | C- | C | C+ | B- | B | B+ | A- | A |

**Schedule of Assessment Due Dates:** The exams are scheduled for:

- Midterm Exam #1 – October 9
- Midterm Exam #2 – November 13
- Final Exam – December 13-14 (see Final Exam section below)

**Homework:** Homework assignments will be provided to the students. As a whole, they will not be collected or graded. Homework problems may be requested as part of an exam. Solutions will only be posted for a subset of the problems. Students may freely discuss homework with the instructor, other students, etc., except during "black-out" times for a given exam. Students cannot exchange their answers.

**Midterm Exams:** The midterm exam will be distributed online via Canvas, completed outside of lecture, and submitted via Gradescope. This component of the exam is open book and open notes, but students cannot collaborate or seek outside help (e.g., post to an online forum). Where appropriate for a given problem, a student may use a programming language. Exams submitted after the due date/time will be assessed a penalty at the discretion of the instructor, which can include a grade of zero. Legible scans/photos of your work must be turned in. The instructor will determine if a problem is legible. To summarize: **only problems, or parts of a problem, that are legible and included in the provided document can be graded.**

**It is the responsibility of the student to make sure the upload is completed without error and by the deadline.** Be sure to allow sufficient time to verify the upload is correct. Students have incorrectly thought a document uploaded successfully, but failed to verify this and the assignment was designated as tardy. Note that Gradescope can require some additional time to tag problems to specific pages (when applicable). It is the student's responsibility to allocate sufficient time for this process.

**Final Exam:** The final exam will be take home. As of the first day of class, the Registrar's schedule sets the final exam for this class to December 14. Hence, the final will be released at 1pm on Dec. 13 and due 24 hrs. later at 1pm on Dec. 14. If the registrar changes the final exam schedule, the day/time of the exam may be subject to change. More details will be provided during the last week of class.

**Re-Grading:** A requested change in a numeric grade must be submitted via Gradescope as a regrade request and within two weeks of initial distribution of graded assignments. The request shall include a justification for the change in the appropriate field on Gradescope. **We reserve the right to regrade the full assignment when submitted for regrading.**

**Attendance:** Attendance in this class is expected. Medical and professional absences are accepted, and the student should notify the instructor in advance of such events if possible. Excessive absences can be justification for selecting a lower grade in the case of borderline cases.

**Office Hours:** Office hours are:

- Monday 10-11am
- Tuesday 2-3pm

- Wednesday 1-2pm

Meetings outside of these times may be scheduled at least 24 hours in advance and are subject to instructor availability. In-person sessions will be in ASE 3.230 or an announced conference or classroom.

**Important Dates:** Important dates to keep in mind throughout the semester include:

- Aug. 26: First day of classes
- Aug. 29: Official add/drop period ends
- Nov. 25: Last day a graduate student may change registration to/from credit/no credit basis.
- Dec. 9: Last class day. Last day a graduate student may drop a class or withdraw from the University (with required approvals)

In the event that there is an error in any of these dates, the official academic calendar published by the Office of the Registrar is considered correct.

**Contacting Instructor:** Questions related to the course not asked in person should be submitted via email. The instructor may respond to a question in a message to the full class when others may benefit from the answer, in which case every effort will be taken to anonymize the question. During normal business hours (M-F, 8-5pm excluding holidays), email will be answered within 24 hours. When on travel, during the weekend, or a holiday, email may be delayed. While listed on the syllabus for completeness, the instructor does not recommend attempting to call his office phone. Many spam phone calls are received on his work phone, and unrecognized numbers are sent to voicemail.

**Academic Integrity:** The core values of The University of Texas at Austin are learning, discovery, freedom, leadership, individual opportunity, and responsibility. Each member of the university is expected to uphold these values through integrity, honesty, trust, fairness, and respect toward peers and community.

Each student in this course is expected to abide by the University of Texas Honor Code. For more information please see:

http://www.engr.utexas.edu/undergraduate/policies/honorcode

Violations of the Honor Code or the Academic Integrity policy of this class can vary from a grade of zero on a given assignment or exam to failure of the course and University disciplinary action.

Any work submitted by a student in this course for academic credit will be the student's own work. You are encouraged to study together and to discuss information and concepts covered in lecture with other students. You can give "consulting" help to or receive "consulting" help from such students. The exchange of answers or software is considered a violation of the academic integrity policy. Should copying occur, both the student who copied work from another student and the student who gave material to be copied will be penalized at the discretion of the instructor. During examinations and quizzes, you must do your own work. Communicating with another student or seeking outside assistance is not permitted during the exams, nor may you compare papers, copy from others, or collaborate in any way.

Understanding how and when to use generative AI tools (such as ChatGPT, DALL-E) is quickly emerging as an important skill for future professions. To that end, you may use generative AI tools in this class as long as it aligns with the learning outcomes or goals associated with assignments. For example, when prompted to explain a result or expected behavior, the answer should be yours and not generated via AI. You are fully responsible for the information you submit based on a generative AI query (such that it does not violate academic honesty standards, intellectual property laws, etc.). Your use of generative AI tools must be properly documented and cited for any work submitted in this course. You are also responsible for

making sure that the output generated is correct and meets the requirements of the given exam problem(s).

**Religious Observances:** Accommodations may be provided to students so they may observe religious holidays. A student is required to notify the instructor at least fourteen days prior to the date of observance of a religious holy day, and preferably as early as possible. If you must miss a class, an examination, a homework assignment, or a project in order to observe a religious holy day, you will be given an opportunity to complete the missed work either before or after the absence.

**Special Notes:** The University of Texas at Austin provides, upon request, appropriate academic accommodations for qualified students with disabilities. For more information, contact the Office of the Dean of Students at 471-6259, 471-4641 TDD or the College of Engineering Director of Students with Disabilities at 471-4321. Any requests must be made in writing at least two weeks before they are required (e.g., two weeks before an exam), and preferably as soon as possible.

**Course Evaluation:** The Measurement and Evaluation Center forms for the College of Engineering will be used during the final two weeks of class to evaluate the course and the instructor. These evaluations are not made available to the instructor until approximately one month after the end of the semester.

**Sharing of Course Materials:** General recommendations from UT-Austin are to prohibit distribution of course materials to anyone not enrolled in the class. I acknowledge that this class is required for the Systems Written Qualifying Exam (WQE) in the Aerospace Engineering Ph.D. program. Homework and exams from previous semesters are used as a study guide and shared with other students that took the class from a different instructor. To accommodate this element of studying for the WQE, this course will use the following policy in regards to sharing course materials.

No written materials used in this class, including, but not limited to, lecture hand-outs, videos, assessments (quizzes, exams, papers, projects, homework assignments), in-class materials, review sheets, and additional problem sets, may be shared online or with anyone outside of the class unless you have my explicit, written permission or for the sole use of studying for the Systems WQE after completing this course. The instructor is well aware of the websites used for sharing materials, and any materials found online that are associated with you, or any suspected unauthorized sharing of materials, will be reported to Student Conduct and Academic Integrity in the Office of the Dean of Students. These reports can result in sanctions, including failure in the course.

**Class Recordings:** Class recordings are reserved only for students in this class for educational purposes and are protected under FERPA. The recordings should not be shared outside the class in any form. This includes for WQE studying. Violation of this restriction by a student could lead to Student Misconduct proceedings.

**Prepared by:** Brandon Jones on August 25, 2024.

This syllabus is subject to change. The current syllabus will be posted on Canvas with changes in red font and with an email notification of the change.