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

ASE 381P6 - Statistical Estimation Theory
Fall 2020

SYLLABUS

Unique Number:	13210 (Hybrid/Blended) and 13211 (online)
Instructor:	Dr. Brandon A. Jones
Pronouns:	he/him/his
Contact Info:	Phone: 512-471-4743 Email: brandon.jones@utexas.edu Office: ASE 3.230
Class Time:	MW 9:30 - 11:00am
Class Location:	CPE 2.216
Office Hours:	T 4-5pm, Th 1-2pm Meetings outside of office hours may be arranged via email.
Course Text:	No single text is required, but students should consider purchasing one or more of the recommended texts listed later in the syllabus.
Prerequisites:	Basic understanding of dynamical systems and modeling Fundamental understanding of linear algebra and vector spaces Familiarity with a programming language (MATLAB, Python, etc.)
Web Page:	Documents will be posted on the course **Canvas** website. https://canvas.utexas.edu

Learning Objectives: 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
- Brief introduction to stochastic control
- 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 quizzes,
- Access to a programming language of choice (e.g., MATLAB, python, Julia, etc.),
- Regular internet access,
- Registration to use the Piazza discussion forum through the Canvas learning management system, and
- Use of the Protect Texas Together app for daily symptom self-checks if coming to campus (highly recommend, not required).

Recommended Texts: There are no required textbooks, but it will benefit the student to have one or more available to supplement the course notes. This course will use information found in:

- Bar-Shalom, Y., X. R. Li, and T. Kirubarajan, *Estimation with Applications to Tracking and Navigation*, John Wiley and Sons, Inc., New York, 2001.
- 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

If the student wishes to purchase a book, the Bar-Shalom, et al. text may be the best, albeit most expensive, choice from a technical perspective. Tapley et al. is a good book for application, but does not use a Bayesian estimation approach. The Ristic, et al. book focuses on particle filters as a means for Bayesian estimation, but is an excellent illustration of how to develop an estimator from a prescribed model. The fourth book has received good reviews, provides a more detailed description of the UKF, and is provided online by the author for free. There are many other excellent books available at the library or online.

Class Format: This course is taught primarily as a lecture/discussion course. In-person lectures will be conducted twice a week during the scheduled time. Lectures will use Zoom for remote students to log in or review asynchronously. Aside from the expected delivery of the lectures, there are no differences between the hybrid and online sections. There are three lectures that will be conducted via Zoom after the Thanksgiving break during the normal designated class days/times up to the last class day. Recorded lectures will be made available on Canvas within 24 hours of their completion.

Please keep in mind that the current situation with the pandemic is constantly evolving. A need may arise to move both sections of this course to an online-only format. Should that occur, the lecture days/times will not change. The lecture will be conducted remotely via Zoom and recorded as outlined above.

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:

Bi-Weekly Quizzes	50%
Final Exam	25%
Project	20%
Participation	5%
Total	**100%**

Final grades will be determined on the basis of the following rubric. This rubric may be adjusted in the semester, but the minimum score for a given range will 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
F	D-	D	D+	C-	C	C+	B-	B	B+	A-	A

Schedule of Assessment Due Dates: Assessments that the student is required to submit include the quizzes, the final exam, and the project. Details on each are provided in the following sections. The due dates for each are provided in Table 1. Due dates and material covered may be adjusted based on course needs and with a minimum notice of one week.

Table 1: Table Of Due Dates for Course Assessments

Assessment	**Material**	**Due Date**
Quiz 1	Lectures 1-4	9/11/2020
Quiz 2	Lectures 5-8	9/25/2020
Quiz 3	Lectures 9-12	10/9/2020
Quiz 4	Lectures 13-16	10/23/2020
Quiz 5	Lectures 17-20	11/6/2020
Quiz 6	Lectures 21-24	11/20/2020
Project	N/A	12/4/2020
Final Exam	TBD	12/14/2020

Homework: Homework assignments will be provided to the students. They will not be collected or graded. Solutions will not be posted. Students may freely discuss homework with the instructor, other students, etc., except during "black-out" times for a given quiz.

Quizzes: Quizzes will be distributed online via Canvas and completed outside of lecture. Each quiz is closed book, closed notes, and no electronic device may be used except to complete the submission requirements. While the time available may change, each quiz will be approximately 30 minutes in length. The quiz will be available during a specified window and each student is required to upload their solution by the end of the window. Time will be added to account for this process. Quizzes submitted after the due date/time may be assessed a penalty at the discretion of the instructor, which can include a grade of zero.

Students will upload their solution to Canvas via the Gradescope plugin. Legible scans/photos of your work must be turned in. The instructor will determine if a problem is legible. It is the student's responsibility to make sure edges are not cropped in the images. 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.

The student's lowest quiz grade will be dropped. The total quiz grade will be based on an average of the remaining five (5) quizzes.

Course Project: There will be one course project with details to be provided in September. The project will be submitted on Canvas via one or more plugins. The tentative due date for the project is included in Table 1. Note that this is during the last full week of class and following the Thanksgiving break. This prevents an overlap between the final project and any quizzes/exams, but it does mean you should account for the holiday when managing your time. The instructor expects that material required to complete the project will be completed by the end of Lecture 18 (early November).

Final Exam: The final exam will be take home. The Registrar final exam schedule nominally assigned the final exam for this class to December 14. Hence, the final will be released at 5pm on December 13 and due 24 hours later. It is comprehensive, but will focus on material after Lecture 18. In addition to traditional derivation problems, it will require computer programming to complete. More details will be provided during the last week of class.

Participation: The participation part of the course grade will be based on *obvious engagement* in the online discussion forum. In this context, *obvious engagement* refers to the student contributing to the class community to aid in their learning and/or the learning of others. The intentions of the forum are:

- Enable student-to-student engagement in the class over both the in-person and online sections,
- Allow students to engage with the instructor in a less stressful environment,
- Provide a single resource to seek answers to common questions, and
- Enable asynchronous learning and Q&A for all students.

The online forum will use Piazza, which may be accessed through Canvas. The participation grade will also be based on a student's satisfaction of the following expectations and guidelines:

- **Respect for others is vital.** In all elements of the class, you are expected to work individually and with others, to create an atmosphere that is safe, valuing of one another, and open to diverse perspectives. Everyone is expected to show courtesy, civility, and respect for one another. Comments or postings that degrade or ridicule another, whether based on individual or cultural differences, are unacceptable. While you can post anonymously to your classmates, the instructor will be able to identify the author of a post.
- Do engage with other students and attempt to offer answers. This will aid in the learning of all students.
- Posts shall start a new discussion or contribute to the progression of existing discussions. There are ways (depending on the type of post) to endorse answers, offer thanks for questions, up vote, etc., without posting a new message. Students should minimize posts that do not actively contribute to reduce "noise" on the discussion boards.
- Please be patient when waiting on a response from the instructor. The instructor will likely not respond to posts between the hours of 5pm to 9am or on the weekends. Additionally, the instructor will intentionally not answer some questions after initially reviewing them to allow for fellow students to attempt to answer.

- If you have any questions regarding software issues, debugging, etc., please use a private post. The instructor will then choose if a post will be shared with the class if it can be a common source of confusion.
- Private messages (e.g., those may contain sensitive information) should be sent via a private message or an email to the instructor.
- Under no circumstances can a student post solutions to any quiz, homework, or project problems, especially parts that will be submitted to the instructor (e.g., software for the project, answers to exam questions, etc.). These will be considered a violation of the course academic integrity policy.

Note that the discussions will temporarily be disabled during exams and quizzes.

No other electronic fora for discussing course material are allowed, and the use of other methods will be a violation of the academic integrity policy. This course-provided forum is intended for all to participate and should be used by all students openly. It also allows for reviewing comments and making sure students do not accidentally share material that may create an ethics issue. Other tools, e.g., Slack and GroupMe, are not allowed.

The instructor reserves the right to adjust the guidelines and expectations for the use of the online discussion boards as necessary. Students will be notified of such changes via the discussion board, email/announcement, and/or a classroom announcement.

Re-Grading: A requested change in a numeric grade for any form of assessment 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 quiz/project/exam when submitted for regrading.**

Attendance: Given the nature of the class this semester, attendance will not be factored into one's grade. This allows for a student to review lecture materials asynchronously. Attendance (in-person or virtual) is encouraged. This provides an opportunity to ask questions and take advantage of discussions.

Office Hours: Office hours will be held online via Zoom. Meetings outside of these times may be scheduled at least 24 hours in advance and are subject to instructor availability.

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

- Aug. 26: First day of classes
- Aug. 31: Official add/drop period ends
- Nov. 23: Last day a graduate student may change registration to/from credit/no credit basis.
- Dec. 7: 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 material, homework, clarifications, etc., should be submitted via the online forum (see discussion in Participation section). Email and private posts may be used when communicating about sensitive material. During normal business hours (M-F, 8-5pm excluding holidays), messages and email (pertinent to the course) will be answered within 24 hours Monday through Friday. When on travel, during the weekend, or a holiday, email and Piazza communication 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 often 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

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. However, this permissible cooperation should never involve one student having possession of a copy of all or part of work done by someone else (hard copy or electronic).

Any software turned in as part of an assignment must be written and developed by the student. Two students may not turn in the same software because they worked on it together. A general recommendation is to write the software on one's own, and, if issues arise or answers appear to be incorrect, then ask a peer or teaching assistant to consult.

Should copying occur (including plagiarism/copying from internet source or any other source), 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. Violations of the Honor Code can vary from a grade of zero on a given assignment or exam to failure of the course and University disciplinary action.

During examinations and quizzes, you must do your own work. Communicating with another student is not permitted during the quizzes, nor may you compare papers, copy from others, or collaborate in any way. Any collaborative behavior during the examinations may result in failure of the exam, failure of the course, and/or University disciplinary action.

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 instructor or 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.

COVID-19 Update

While we will post information related to the contemporary situation on campus, you are encouraged to stay up-to-date on the latest news as related to the student experience:

https://coronavirus.utexas.edu/students

Counseling and Mental Health Center: Do your best to maintain a healthy lifestyle this semester by eating well, exercising, avoiding drugs and alcohol, getting enough sleep and taking some time to relax. This will help you achieve your goals and cope with stress.

All of us benefit from support during times of struggle. You are not alone. There are many helpful resources available on campus and an important part of the college experience is learning how to ask for help. Asking for support sooner rather than later is often helpful.

If you or anyone you know experiences any academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support:

http://www.cmhc.utexas.edu/individualcounseling.html

Safety and Class Participation/Masks: For every face-to-face class experience, we will all need to make some adjustments in order to benefit from in-person classroom interactions in a safe and healthy manner. Our best protections against spreading COVID-19 on campus are masks (defined as cloth face coverings) and staying home if you are showing symptoms. Therefore, for the benefit of everyone, this is means that all students are required to follow two important rules:

- **Every student must wear a cloth face covering properly in class and in all campus buildings at all times.**
- **Every student must engage in documented daily symptom screening.** This means that each class day in which on campus activities occur, students must upload certification from the symptom tracking app and confirm that they completed their symptom screening for that day to Canvas. Students should not upload the results of that screening, just the certificate that they completed it. If the symptom tracking app recommends that the student isolate rather than coming to class, then students must not return to class until cleared by a medical professional.

If a student is not wearing a cloth face covering properly in the classroom (or any UT building), that student must leave the classroom (and building). If the student refuses to wear a cloth face covering, class will be dismissed for the remainder of the period, and the student will be subject to disciplinary action as set forth in the university?s Institutional Rules/General Conduct 11-404(a)(3). Students who have a condition that precludes the wearing of a cloth face covering must follow the procedures for obtaining an accommodation:

https://orientation.utexas.edu/students-with-disabilities

Sharing of Course Materials is Prohibited: 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 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. Lecture recordings are the only exception to this policy and may only be shared with my explicit, written permission. Unauthorized sharing of materials promotes cheating. It is a violation of the University's Student Honor Code and an act of academic dishonesty. I am well aware of the sites 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. Violation of this restriction by a student could lead to Student Misconduct proceedings.

COVID Caveats: To help keep everyone at UT and in our community safe, it is critical that students report COVID-19 symptoms and testing, regardless of test results, to University Health Services, and faculty and staff report to the HealthPoint Occupational Health Program (OHP) as soon as possible. Please see this link to understand what needs to be reported. In addition, to help understand what to do if a fellow student in the class (or the instructor or TA) tests positive for COVID, see:

https://healthyhorns.utexas.edu/coronavirus_exposure_action_chart.html

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Prepared by: Brandon Jones on August 25, 2020.

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.