AAE 590PET – Probabilistic Estimation and Tracking
Fall 2024
Prof. Keith LeGrand
Office: ARMS 3213
Office Hours:

- Tuesdays 11:30 AM – 1:00 PM

Email: klegrand@purdue.edu
Submit all course-related questions on Piazza

1. **Teaching Assistants**
   - Disip Chaturvedi, dchaturv@purdue.edu

   TA Office hours:
   - Mondays 3:00 PM – 5:00 PM, ARMS 3305
   - Fridays 1:30 PM – 3:30 PM, HAMP 2117 (EXCEPT AUG 30)
   - Friday, Aug 30: 1:30 PM – 3:30 PM, HAMP 2113
2. **Course Description**

   Probabilistic estimation and tracking theory, with a focus on aeronautics and astronautics applications. Topics include extended/unscented Kalman filtering, Gaussian mixture filtering, particle filtering, multi-sensor fusion, and target tracking.

   Prerequisites

   AAE 340, STAT 511(or equivalent probability and statistics course)

   Necessary Background
   - Basic probability and statistics
   - Linear algebra
   - Differential equations
   - Formulation and solution of state space equations

   Learning Outcomes

   The goal of this course is twofold: 1) understand the fundamentals of probabilistic estimation theory needed to conduct novel research and 2) learn practical techniques needed to apply estimation algorithms to real engineering problems.

   At the conclusion of this course, successful students will be able to:
   1. Identify problems and applications suitable for state estimation based solutions.
   2. Model key dynamic and measurement processes for continuous and discrete stochastic dynamical systems.
   3. Understand the most commonly used probabilistic state estimation algorithms, their advantages, and their limitations.
   4. Test, troubleshoot, and evaluate state estimation algorithm performance.
   5. Independently apply the covered techniques to a unique problem of their interest.

   Textbook: Course notes

   The course notes will be published on Brightspace. However, taking your own notes is highly encouraged and will improve learning and class performance.

   Some suggested texts are:

- Särkkä, Simo. *Bayesian Filtering and Smoothing*. 1st ed. Cambridge University Press, 2013. (free pdf available online courtesy of author)
- Crassidis, John L., and John L. Junkins. *Optimal Estimation of Dynamic Systems*, 2004.
- Bar-Shalom, Yaakov and X. Rong Li. *Estimation with Applications to Tracking and Navigation*. John Wiley & Sons, Inc, 2001.
- Tapley, Byron D., Bob E. Schutz, and George H. Born. *Statistical Orbit Determination*. Amsterdam ; Boston: Elsevier Academic Press, 2004.
- Grewal, Mohinder S., and Angus P. Andrews. *Kalman Filtering: Theory and Practice Using MATLAB*. Fourth edition. Hoboken, New Jersey: John Wiley & Sons Inc, 2015.

3. **Topics**

   This is an experimental course being offered for the first time. Topics are subject to change based on pace and student feedback.

   a. Review of linear algebra and probability concepts
   b. Parameter estimation and least squares
   c. Kalman filtering
   d. Practical considerations
   e. General Gaussian filtering
   f. Smoothing
   g. Gaussian mixture filtering
   h. Particle filtering
   i. Multisensor fusion
   j. Introduction to multiobject tracking

4. **Homework**

   a. Approximately 5-6 homework assignments. Each homework will consist of a mix of theory questions and application problems.
   b. All homework is to be submitted via Gradescope. The assignments must be uploaded at the time indicated on the homework sheet. Although late homework assignments are graded for the benefit of the student, homework submitted after the due date/time will receive a score of zero.
   c. Homework rules
      - must be neat and legible
      - on 8. x 11-inch letter paper or electronic equivalent (any style)
      - adhere to **the formatting outlined in the separate documents**.
      - The result must be boxed and clearly marked.
      - It must be your own work (copying will result in a grade divided by the number of students involved). Points will be taken off for not following all these rules.
      - All computer code must be attached to the homework submission.
      - Code should be thought of as an appendix to your work. All equations, assumptions, approximations, derivations, etc. should be written in the handwritten/typed portion of your submission and not hidden in your code.
      - A discussion should accompany every plot. Potential questions to answer are: are your results satisfactory? Why or why not? What are the convergence properties? What is the overall behavior of the plot? Are there any anomalies? If so, what might have caused them? How might your plots change if the

problem or model was varied slightly?

d. Solutions for selected problems will be available on the course site on Brightspace.

5. **Project**
   a. Student-designed independent project, including a proposal and final report.
6. **Grading**

HW	50% of total grade
Paper Review	10% of total grade
Project	40% of total grade
Course evaluation	1 bonus point on the accumulated homework grade will be given to the students that submit a course evaluation for AAE 590 and submit proof via screenshot of the submission page to Gradescope.

Letter grades will not include plus or minus, with the possible exception that some A grades may be raised to an A+ at the discretion of the instructor.

7. **Regrade Requests**
   Regrade requests may be made in person during office hours.
8. **Attendance**
   This course follows Purdue's academic regulations regarding attendance, which states that students are expected to be present for every meeting of the classes in which they are enrolled. In cases falling under excused absence regulations, the student or the student's representative should contact or go to the Office of the Dean of Students (ODOS) website to complete appropriate forms for instructor notification. Under academic regulations, excused absences may be granted **by ODOS** for cases of grief/bereavement, military service, jury duty, parenting leave, or emergent medical care.
9. **Course Materials**
   All course materials posted on Brightspace are the intellectual property of the author and may not be sold, shared, or published **(including on websites such as CourseHero**) without the written permission of the instructor. Violations of this policy constitute academic misconduct and will result in a failing grade and potential disciplinary action.
10. **AI and Large Language Models**
    Large language model-based AI tools, such as ChatGPT, are an exciting technology that will undoubtedly shape the future of engineering. In fact, ChatGPT is capable of writing the majority of coding assignments given in this class. While this technology has a place in the engineering profession, its usage in completing homework assignments will rob you of all educational value. Your deepest learning (pun not intended) will occur when your homework and project code isn't working. Embrace the struggle. Using ChatGPT to do your homework is like going to the gym and paying someone $20 to do pushups for you. Somebody got stronger, but it wasn't you. For these reasons, usage of AI-assisted technology in this class will be considered academic dishonesty unless otherwise authorized by Prof. LeGrand.
11. **Mental Health/Wellness Statement sample language:**
    If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try Therapy Assistance Online (TAO), a web and app-based mental health resource available courtesy of Purdue Counseling and Psychological Services (CAPS)**.** TAO is available to all students at any time by creating an account on the TAO Connect website, or downloading the app from the App Store or Google Play. It offers free, confidential well-being resources through a self-guided program informed by

psychotherapy research and strategies that may aid in overcoming anxiety, depression and other concerns. It provides accessible and effective resources including short videos, brief exercises, and self-reflection tools.

If you need support and information about options and resources, please contact or see the Office of the Dean of Students. Call 765-494-1747. Hours of operation are M-F, 8 a.m.- 5 p.m.

If you find yourself struggling to find a healthy balance between academics, social life, stress, etc., sign up for free one-on-one virtual or in-person sessions in West Lafayette with a Purdue Wellness Coach at RecWell. Student coaches can help you navigate through barriers and challenges toward your goals throughout the semester. Sign up is free and can be done on BoilerConnect. Students in Indianapolis will find support services curated on the Vice Provost for Student Life website.

If you're struggling and need mental health services: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS offices in West Lafayette or Indianapolis.

12. Emergency Preparation

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructors or TAs via email or phone. You are expected to read your @purdue.edu email on a frequent basis.
A link to Purdue's Information on Emergency Preparation and Planning is located on our Brightspace under "University Policies and Statements." This website covers topics such as Severe Weather Guidance, Emergency Plans, and a place to sign up for the Emergency Warning Notification System. I encourage you to download and review the *Emergency Preparedness for Classrooms document*.

The first day of class, I will review the **Emergency Preparedness plan for our specific classroom**, following Purdue's required Emergency Preparedness Briefing. Please make note of items like:

- The location to where we will proceed after evacuating the building if we hear a fire alarm.
- The location of our Shelter in Place in the event of a tornado warning.
- The location of our Shelter in Place in the event of an active threat such as a shooting.

13. Nondiscrimination Statement

Purdue University is committed to maintaining a community that recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. A hyperlink to Purdue's full Nondiscrimination Policy Statement is included in our course Brightspace under University Policies and Statements.

The School of Aeronautics and Astronautics is also committed to a climate of inclusion; if you need to report an issue of hate or bias, you may use the link at the top right of our page here: https://engineering.purdue.edu/AAE/aboutus/Diversity/index_html.