AAE 590: Applied Control in Astronautics

Instructor: Prof. Kenshiro Oguri (koguri@purdue.edu)

Level: This course is intended for graduate students and senior undergraduate students with basic background in orbital mechanics and linear systems/controls.

Prerequisites: The following courses are recommended (but not required) to take beforehand: AAE 490 orbital analysis, AAE 532, or equivalent.

Course Description: Dynamical systems considered in the context of spaceflight are largely different from those of ground-based systems. The objective of this course is to introduce students to the theoretical and practical foundations of control techniques with an emphasis on its application to dynamical systems in astronautics.

Learning Objectives: By the end of the course, students will be able to

- acquire fundamental knowledge about control techniques for dynamical systems in astronautics;
- apply the learned theories to design controllers for a range of spaceflight problems;
- develop original computation software using a programming language to numerically simulate the spacecraft motion under control;
- assess the controller performance and resulting dynamical properties analytically and numerically;
- present and communicate their technical approaches to problems, their analysis/numerical results, and their interpretation in written and presentation formats

Topics: Each topic, described below, consists of two parts: theory and its space applications.

- brief review of orbital mechanics and linear systems;
- optimal control via Pontryagin's minimum principle for space trajectory optimization;
- nonlinear feedback control via Lyapunov stability for spacecraft orbit control;
- optimization-based control via convex programming for space trajectory control & optimization;
- stochastic process & performance evaluation for controlled space systems under uncertainty.
- robust control for autonomous maneuver planning and asteroid/planetary landing.

Grading is based on several problem sets, a take-home midterm exam, and a final project.

Project: The open-ended final project will encourage students to explore spaceflight problems of their interest and apply the learned (or relevant) control techniques. Topics can be either new theoretical development or application of existing techniques to your problems, but should involve some computational investigation. Students can form groups (up to three people) to work on the project. At the end of the semester, each group will deliver a brief presentation and a technical report that summarize their project. Some examples of previous projects can be found at `https://engineering.purdue.edu/OguriGroup/teaching`.

Textbook: None required. The following textbooks are helpful for deeper understanding of the materials:

- Battin, R., *An Introduction to Mathematics and Methods of Astrodynamics*, AIAA, 1999
- Bryson, A. E., and Ho, Y. C., *Applied Optimal Control*, Taylor & Francis, 1975
- Schaub, H., and Junkins, J. L., *Analytical Mechanics of Space Systems*, AIAA Education Series, 2003
- Sastry, S., *Nonlinear Systems: Analysis, Stability, and Control*, SpringerVerlag, 1999
- Boyd, S., and Vandenberghe, L., *Convex Optimization*, Cambridge U. Press, 2004.