EE 105: Feedback Control Systems

Fall 2024
M/W 1:30-2:45pm, Anderson 309

Control systems are everywhere: in your house, in your car, in your body, and even in social structures. Anything that measures a result and adjusts in response is a feedback control system. In EE 105, we apply linear systems theory and linear algebra first to understand these systems, and then to make them do our bidding — automatically.

This course will give you a toolbox full of theoretical methods for designing control systems, the ability to use computational tools for control systems analysis, and hands-on experience building ~~a digital feedback control system with real hardware.~~ a quadrotor drone.

After successfully completing this course, you will be able to:

- Begin with a physical system with known dynamics, and formulate models using differential equations, transfer functions, and state space methods.
- Analyze single-input-single-output (SISO) feedback systems using time domain, root locus and frequency response techniques.
- Analyze both SISO and MIMO systems using state space methods.
- Design feedback controllers using lead/lag compensation, PID, and pole placement.
- Write software to implement feedback control on a real embedded system.

Who cares?

There are some areas where feedback control is obviously important, such as robots, airplanes, drones, self-driving cars, and so on. These all have numerous sensors and actuators, and the control algorithm is what makes the thing function.

But there are many other areas that are less obvious! For example, an op-amp uses feedback control, as does a phase-locked-loop (PLL). And any time you've got an electrical circuit with a feedback loop, transient behavior in some other part of the circuit can suddenly affect its behavior. So if you understand how and why feedback control works, you'll be able to work more intelligently in all sorts of areas.

Where should I look for information?

The **course schedule and materials** will be posted on the course website: `http://www.ece.tufts.edu/ee/105`.

Course announcements and Q&A will be on Piazza. You should receive an email invitation just before the course starts.

The **textbook** is "Franklin, Powell, & Emami-Naeini, *Feedback Control of Dynamic Systems, 8th Edition*." ISBN: 978-0134685717

Another book that may be useful is "Katsuhiko Ogata, *Modern Control Engineering, 5th Edition*." ISBN: 978-0136156734. It takes a slightly more theoretical and math-centric approach, which some of you may appreciate.

How will we measure my learning?

This course will be a mix of theory and application, and the work you complete will reflect this.

Homework will generally be assigned weekly, and will consist of problems from the textbook or other problems intended to build up your conceptual skills. This will be a mix of pencil-and-paper work and Matlab problems.

Projects will be assigned roughly every other week, and will be more involved than the homework. Some projects will require detailed analysis of a physical system or the design of a feedback control algorithm in Matlab, others will require to you develop components of the drone system, leading up to our goal of flying a fully-functional quadcopter.

There will not be any traditional exams in the course; almost all of the interesting problems in this course require a computer and more than a couple minutes of thinking to solve.

The exact grading breakdown will be determined based on the number of assignments, but I intend roughly a 40/60 split between homework and project work.

What else should I know?

Instructor contact:

Steven Bell `sbell@ece.tufts.edu`

Halligan 112 (click here for directions)

Office hours:

- Mondays 3pm-4:30pm
- Thursdays 10am-11:30pm
- I'm also available other times by appointment (generally mornings Monday-Thursday, as all of my classes are scheduled for the afternoons).

To minimize distraction, I generally only check email 2-3 times a day. However, I will make a strong effort to answer all messages within 24 hours on weekdays.

Prerequisites:

You need to have taken EE 23 (Linear systems) and MATH 70 (Linear algebra), or their equivalents if you're a grad student. This is a math-heavy course and we'll be making regular use of differential equations, Laplace transforms, matrices, eigenvectors, and so on.

Late work:

After the deadline, homework and project writeups will be accepted for 70% credit until graded homework has been returned or solutions have been posted.

Collaboration:

I encourage you to work in groups to solve the homework problems and to study — one of the biggest predictors of success in courses like EE 105 is whether or not you have a study group. However, each person must write up and submit their own assignment. For code-based questions, this means that it is fine to dicuss ideas and algorithms and to compare results, but each person must write their own code.

Schedule:

The schedule of class topics, assignments, and corresponding readings will be posted on the course website. It will almost certainly be adjusted to meet the needs and pace of the class.