University of Illinois at Urbana-Champaign
Department of Aerospace Engineering
Fall 2020

AE 353: Aerospace Control Systems

4 credit hours

This syllabus is not an exhaustive description of all details of the course; the students are free to contact the instructor with any additional questions or concerns at any time. Because of the ongoing situation regarding the COVID-19 pandemic, the syllabus may be modified in substantial ways at any time.

Personnel

Instructor: Melkior Ornik (mornik@illinois.edu)
Teaching assistant (TA): Pranay Thangeda (pranayt2@illinois.edu)

Contact and Office Hours

The primary mode of communication will be Piazza. The course website for this semester is https://piazza.com/illinois/fall2019/ae353. Students should make sure to join Piazza for this course. *All important announcements will be communicated over Piazza*.

Students are welcome to either send a Piazza message or email the instructor or the TA with questions about the course logistics, but all questions on the course material *must* be posted on Piazza – publicly, if there is no reason to do otherwise. Any emailed questions on the material will remain unanswered. Students are encouraged to answer each other's questions; the instructor and the TA will answer the questions that have not been answered by students after an appropriate amount of time.
Due to the ongoing restrictions on in-person meetings, the instructor's and TA's office hours are both held over Zoom by previous appointment. Office hours are primarily intended for high-level conceptual help: students should make sure to try to find an answer to any specific questions, first by themselves and then by posting the question to Piazza, before arranging for office hours.

Course Delivery

The course material will be delivered partly in person, with all material divided over multiple web sites:

- **Piazza** will be used for all announcements, all written course material, and discussions on the material,
- **Echo360 and/or Illinois Media Space** will be used for videos on the material and recordings of the in-person sessions,

- **PrairieLearn** will be used for homeworks, quizzes, and final exam,
- **Compass2g** will be used for submission of design projects and for grade accounting,
- **Zoom** will be used for occasional proctoring during quizzes and final exams, and for office hours.

It is the students' responsibility to sign up and remain active on course-related elements of all of the above web sites.

The material will be primarily delivered online, through asynchronous videos and companion notes. The optional in-person element will consist of weekly meetings (also recorded for online consumption) which will seek to answer students' questions and provide examples.

The in-person sessions will be held according to the following schedule:

- students with last names Rn to Z should come on *Mon, 12-12:50pm*, to *Everitt 2233*
- students with last names Gt to Rm should come on *Wed, 12-12:50pm*, to *Everitt 2233*
- students with last names A to Gs should come on *Fri, 12-12:50pm*, to *Everitt 2233*

All sections in the same week will broadly follow the same topic, based on materials posted to Piazza in the previous week. Attendance at the sessions is *not* mandatory. Students are welcome to adjust their course experience to their learning style, as long as doing so does not disturb learning styles of the others. Students are also welcome to come to sections other than the ones they are assigned to, as long as no more than 19 students are present in the classroom at any given time. Class times, and their existence, may be adjusted during the semester, e.g., due to holidays and the public health situation.

Students are required to follow the campus COVID-19 testing protocol. Students who feel ill must not come to class. In addition, students who test positive for COVID-19 or have had an exposure that requires testing and/or quarantine must not attend class.

Following University policy, all students are required to engage in appropriate behavior to protect the health and safety of the community, including wearing a facial covering properly, maintaining social distance (at least 6 feet from others at all times), disinfecting the immediate seating area, and using hand sanitizer. Students who fail to abide by these rules will first be asked to comply; if they refuse, they will be required to leave the classroom immediately.

Course Description

AE 353 is a modern, challenging aerospace take on a standard undergrad controls course. It seeks to use formal mathematical methods to answer a fundamental engineering question: *How can I ensure that the system does what I want it to do?*

On a more technical level, the primary objective of the course is to expose students to the notion of continuous-time, continuous-space controlled system dynamics, and explore the design of control signals to drive the system to a desired outcome. We will do so by formulating *state space representations*, relating the system's control inputs, states, and outputs through a set of ordinary differential and algebraic equations. Even when such relationships are simple, performing control design in such a representation will require us to develop the method for computing a solution to a system of ordinary differential equations: the notion of a *matrix exponential* plays a significant role. Using a significant amount of linear

algebra, we will then devote a large part of the course to discussing some of the central questions of control theory: *can I drive the system to a particular state?* (controllability)*, how can I do it in the quickest or cheapest way possible?* (optimal control), and *can I do it even if I don't know everything about the system at every given time?* (observability)*.* Finally, we will connect the developed machinery of modern state-space-based control design to a classical method of frequency-domain-based control design – a "dual" of the state space representation that often simplifies control design methods, but pays the price of reduced applicability to more complicated dynamics models and control objectives.

Deliverables and Grading

The deliverables for the course will consist of:

- many (~26) homework assignments,
- four 50-minute quizzes (with optional retakes),
- four design projects, and
- a 3-hour final exam.

The weights for the deliverables will be nominally distributed as follows:

- Homeworks: 20% total (around 0.77% each)
- Quizzes: 20% total (5% each)
- Design projects: 40% total (10% each)
- Final exam: 20%

Additional extra credit may be offered during the semester.

The final grades will be calculated by the following formula: A-/A/A+ = 90-100, B-/B/B+ = 80-89.99, C-/C/C+ = 70-79.99, D-/D/D+ = 60-69.99, F = 0-59.99, where the "-" modifier will be assigned to those grades with the unit digit 0-1 (e.g., 91.87 = A-) and "+" modifier to those grades with the unit digit 8-9 (e.g., 78.02 = C+). The grades will *not* be rounded up, rounded down, nor "curved".

Submission of Deliverables

Homework assignments will be completed online using PrairieLearn. Students are allowed, and encouraged, to discuss these assignments with their peers.

Quizzes and the final exam will be completed online using PrairieLearn. Students are not allowed to communicate with the outside world during the quizzes. While completing these deliverables, students *must* also join the Zoom meeting indicated by the instructor and/or the TA, with their cameras and microphones turned on. The instructor or the TA may join the meeting at any time.

The students will be responsible for scheduling their own quiz within a given interval of dates, at any time between *tentatively* 2pm and 8pm (Central time). The tentative schedule of quizzes is:

- Quiz 1: Sep 28-30
- Quiz 2: Oct 12-14
- Quiz 3: Oct 26-28
- Quiz 4: Nov 16-18

Each quiz will last 50 minutes. The students will receive the results immediately, and will be allowed to retake each quiz *exactly once*. The retakes will take place one or two weeks after the original attempts. The tentative schedule of retakes is:

- Retake 1: Oct 5-7
- Retake 2: Oct 19-21
- Retake 3: Nov 2-4
- Retake 4: Nov 30-Dec 2

If a student retakes a quiz, the overall quiz score will be computed as follows: 0.9x(amount of points on the better attempt) + 0.1x(amount of points on the worse attempt). Practice quizzes will be provided prior to the quiz dates, but they do not bring any amount of credit.

The design projects will require students to submit MATLAB code and a report written in LaTeX. Both will be submitted online, preferably using Compass2g. Students are encouraged to talk with your colleagues about these design projects, so long as the project report acknowledges the colleagues with whom they talked in the report. Materials submitted must be the students' own. Students may also be required to review several of their peers' submissions as a second stage of each project.

The final exam will also be taken using PrairieLearn, with the Zoom element as discussed for quizzes. The final exam will last 3 hours, and cannot be retaken. Its tentative date is *Dec 14, 6pm-9pm (Central time)*. Students who have conflicts or other issues with the time should discuss possible alternatives with the instructor before the exam. Students are not allowed to communicate with the outside world during the exam.

Students are responsible for timely submission of the deliverables. Late submission of a particular deliverable, if not agreed with the instructor, may be penalized at the rate of up to 50% of the total weight of the deliverable. There may be bonus points for early submissions, equaling no more than 5% of the total weight of the deliverable.
Emergencies do happen in regular times, and everything is even more fluid in Fall 2020; when faced with unavoidable obstacles, students should contact the instructor for any modifications to the submission schedules.

Prerequisites and Literature

The formal prerequisites for the course are credit in MATH 225, MATH 285, and TAM 212 (or equivalent). The course cannot be taken for credit if a student already has credit in GE 320 or ME 340.

There is no required text for the course. With possible small exceptions intended for independent study, all new topics required for success in the course will be discussed by the instructor. The course material will partly overlap with the following textbooks:

- *Feedback Systems: An Introduction for Scientists and Engineers*, K. J. Åström and R. M. Murray
- *Control System Design: An Introduction to State-Space Methods*, B. Friedland
- *Feedback and Control for Everyone*, P. Albertos Pérez and I. Mareels
- *Modern Control Engineering*, K. Ogata
- *Modern Control Systems*, R. C. Dorf and R. H. Bishop

Students are not required to purchase any textbooks or other materials. The first book on the list above was made freely available by the authors and can be found online. All of the books on the list should be available in electronic format from the university library. Please note that, while each of above books has substantial overlap with the course material, the material covered will be significantly smaller than the material of the union of these books.

Academic Integrity

While students are welcome to consult peers on their homework assignments and design projects, they are required to write solutions and on their own *and* respond to any subsequent questions on the material posed by the instructor. The answers to the instructor's questions may play a role in the assigned grade. Students are expected to work entirely alone on the quizzes and the final exam.

Students are required to familiarize themselves with the University's Academic Integrity Policy and Procedure, available at http://studentcode.illinois.edu/article1/part4/1-401/, and abide by that policy in full.

Accommodations

To obtain disability-related academic adjustments and/or auxiliary aids, students that require special accommodations must contact the instructor and the Disability Resources and Educational Services (DRES) as soon as possible. Students are welcome to contact the instructor at any time with any accommodation-related needs. To contact DRES, visit 1207 S. Oak St., Champaign, call 217-333-4603 (V/TTY), e-mail a message to disability@illinois.edu, or visit https://www.disability.illinois.edu. If a student is concerned that they have a disability-related condition that is impacting their academic progress, there are academic screening appointments available that can help diagnosis a previously undiagnosed disability. These may be accessed by visiting the DRES website.

Illinois law requires the University to reasonably accommodate its students' religious beliefs, observances, and practices in regard to admissions, class attendance, and the scheduling of examinations and work requirements. If there is a conflict between course deadlines and any religious observances, students should notify their instructor and follow the procedure at https://odos.illinois.edu/community-of-care/resources/students/religious-observances/ to request appropriate accommodations. These steps should be conducted in the first two weeks of classes.

Privacy and Reporting

The University of Illinois is committed to combating sexual misconduct. Faculty and staff members are required to report any instances of sexual misconduct to the University's Title IX Office. In turn, an individual with the Title IX Office will provide information about rights and options, including accommodations, support services, the campus disciplinary process, and law enforcement options. A list of the designated University employees who, as counselors, confidential advisors, and medical

professionals, do not have this reporting responsibility and can maintain confidentiality, can be found here: https://wecare.illinois.edu/resources/students. Other information about resources and reporting is available here: https://wecare.illinois.edu.

Any student who has suppressed their directory information pursuant to Family Educational Rights and Privacy Act (FERPA) should self-identify to the instructor to ensure protection of the privacy of their attendance in this course. See https://registrar.illinois.edu/academic-records/ferpa/ for more information on FERPA.

Campus Emergency Plan

The university's emergency response recommendations can be found at the following website: http://police.illinois.edu/emergency-preparedness/. Students should review this website and the appropriate campus building floor plans website within the first 10 days of class: http://police.illinois.edu/emergency-preparedness/building-emergency-action-plans/.

Modifications to the Syllabus

The instructor reserves the right to modify any and all parts of this syllabus throughout the semester. All modifications will be made solely in the interest of time scheduling, beneficial adaptation to changing public health circumstances, accurate measurement of the students' success, and improvement of the students' educational outcomes. Any modifications will be transparently communicated to the students.