The University of Texas at San Antonio — ECE Department
EE 5243 — Optimization & Control of Cyber-Physical Systems
Spring 2021

Instructor:	Ahmad F. Taha	**Time:**	None (Virtual)
Email:	ahmad.taha@utsa.edu	**Location:**	Virtual

Important: Course Content

- For lecture notes, homework postings, uploads, projects, and readings please visit the course webpage on UTSA Blackboard: http://utsa.blackboard.com
- **For video lecture recordings**, please visit this Dropbox link and **download the videos to watch them offline** https://bit.ly/35GQafc.
- You will need to download the VLC paper on Mac/Windows to view the videos offline. The Dropbox video player cuts the videos so you shouldn't view the videos using that player.
- I will be uploading the videos for the week at the beginning of it.

Office Hours:

- Tuesdays and Thursdays, 9:00am–10:30am
- Office hours will be virtual through Zoom: https://utsa.zoom.us/j/97557156027
- Or by appointment

Course Description: Modeling, analysis and design of cyber-physical systems (CPS). The course serves as an introductory graduate-level class for students interested in CPSs in general, and control and optimization of CPSs in specific. The fundamentals of CPSs are covered in the class, with emphasis on the control and the optimization aspects. Covered CPS topics include: networked control systems, cyber-attacks, linear systems theory and design, state-estimators, fault-tolerant controllers and observers, and convex, multi-objective, bi-level & multi-time scale optimization. Applications to different urban infrastructure are discussed.

Main References: No textbook is required for the class. **Lecture notes will be provided as handouts or presentation slides (all posted on Blackboard).** However, you may need to refer to books on linear and nonlinear systems theory, optimization, cyber-physical systems, and networked control and estimation. In what follows is a list of textbooks that might be useful for graduate students interested in control and optimization of CPSs (most are freely available online):

- C. T. Chen, *Linear System Theory and Design*, Oxford University Press, 1995.
- F. Y. Wang and D. Liu, *Networked Control Systems, Theory and Applications*, Springer-Verlag London, 2008.
- S. Boyd, L. El Ghaoui, E. Feron and V. Balakrishnan, *Linear Matrix Inequalities in System and Control Theory*, SIAM, 1994. Book webpage: http://web.stanford.edu/~boyd/lmibook/.
- S. Boyd and L. Vandenberghe, *Convex Optimization*, Cambridge University Press, 2004. YouTube videos for the class: https://www.youtube.com/watch?v=McLq1hEq3UY and book webpage: http://web.stanford.edu/~boyd/cvxbook/.

Note that during the class, we will be reading papers together, and I will send PDFs for these papers. Please do not purchase any books for this class.

Course Objectives & Expected Outcomes:

This course is designed for graduate students who are interested in learning about optimization and control of cyber-physical systems. This includes a wide range of topics related to CPSs: state-estimation, networked control systems, optimization, observer-design of linear and nonlinear systems, multi-time scale operation, cyber-attacks and fault detection, CPS applications in smart-grids and robotics, etc... At the end of the semester, students are expected to have a good understanding of the basic principles governing CPSs' operation and a reasonable depth related to a specific CPS topic that relates to their projects.

Prerequisites:

An undergraduate-level understanding of probability, multi-variable calculus, control theory and feedback systems, linear algebra, basic optimization principles, and algorithms is assumed. Nonetheless, basics related to the aforementioned topics will be covered in the first two weeks of classes.

Grading Policy

- Homework (25%)
- One exam (25%)
- Project (50%) — divided as follows: initial proposal (20%), progress report (20%), final report (60%)
- Attendance and instructor evaluation (5%)

Course Grade Cutoffs:

- A-, A, A+: 85–100
- B-, B, B+: 70–84
- C-, C, C+: 55–69
- D-, D, D+: 40–54
- F: ≤ 39

Important Dates:

Project Proposal	February 10th, 23:59:59
Progress Report	March 27th, 23:59:59
Exam	April 20, time TBA
Final Report	May 10, 23:59:59

Programming Tools:

MATLAB will be required for homework assignments and course projects. Students can obtain the discounted student version of MATLAB online or through the university bookstore. Also, students are encouraged to use LaTeX for their homework assignments and course projects.

Class Policy:

- Students can choose a project of their choice, subject to the approval of the course instructor.

- The **aim of the project** is to help students understand research in CPSs and encourage them to learn more about relevant research challenges related to the optimization and control aspects of CPSs. Hence, students should think of the course project as a learning, beneficial research exercise rather than a bland assignment that has to be done for grade credit. Students who produce excellent project reports, research papers, and demonstrate high competence will be given substantial grade bonuses.
- **Late submission policy:** besides medical and family emergencies (a written verification is required), there will be no extensions granted for project submissions. Late submissions will be scaled according to lateness, removing 10% from your assignment/project grade per day late, up to a maximum of 50%. Submissions more than 5 days late will be assigned a score of 0.
- **Changes to the syllabus:** students will be regularly informed about any changes for the course syllabus.

Tentative Course Outline:

Part I — CPS Review & Background . . . . $\approx$ 5–6 classes
Course introduction & syllabus, prerequisites, major applications, course overview

Part II — Linear & Nonlinear Networked Systems Theory . . . . $\approx$ 4–5 classes
Recent relevant theories on linear and nonlinear systems

Part III — State Observation & Estimation of CPSs . . . . $\approx$ 4–5 classes
Dynamic state estimation of dynamic CPSs

Part IV — CPSs & Convex Optimization . . . . $\approx$ 3–4 classes
Basic principles on convex optimization for generic systems

Part V — Progress Reports Presentations . . . . $\approx$ 1–2 classes
Students will give short presentations on their progress reports

Part VI — Control of CPSs . . . . $\approx$ 1–2 classes
Linear quadratic regulator, optimal state-feedback control, principle of optimality

Part VII — Exam . . . . 1 class
In class exam

Part VIII — Networked Control Systems . . . . $\approx$ 1–2 classes
Recent results on networked control systems, fault detection, cyber-attacks

Part IX — Applications . . . . $\approx$ 1–2 classes
Smart-grids, water networks, transportation

Part X — Project Presentations . . . . $\approx$ 2–3 classes
Students will present their projects

Collaboration Policy and Academic Honor Code:

You are responsible for your own work in this course. You may consult with classmates but copying from another student's work is considered CHEATING and will have severe consequences. Ask yourself whether you are compromising your integrity. If in doubt, ask first.

A. Preamble

The University of Texas at San Antonio community of past, present and future students, faculty, staff, and administrators share a commitment to integrity and the ethical pursuit of knowledge. We honor the traditions of our university by conducting ourselves with a steadfast duty to honor, courage, and virtue in all matters both public and private. By choosing integrity and responsibility we promote personal growth, success, and lifelong learning for the advancement of ourselves, our university, and our community.

B. Honor Pledge

In support of the ideals of integrity, the students of The University of Texas at San Antonio pledge: *As a UTSA Roadrunner, I live with honor and integrity.*

C. Shared responsibility

The University of Texas at San Antonio community shares a commitment to integrity, the ethical pursuit of knowledge, and adheres to the UTSA Honor Code. http://utsa.edu/about/honorcode/

D. Academic Dishonesty:

As an entity of The University of Texas at San Antonio, ECE Department is committed to the development of its students and to the promotion of personal integrity and self responsibility.

The assumption that a student's work is a fair representation of the student's ability to perform forms the basis for departmental and institutional quality. All students within the Department are expected to observe appropriate standards of conduct. Acts of scholastic dishonesty such as cheating, plagiarism, collusion, the submission for credit of any work or materials that are attributable in whole or in part to another person, taking an examination for another person, any act designated to give unfair advantage to a student, or the attempt to commit such acts will not be tolerated. Any case involving academic dishonesty will be referred to the Office of Student Judicial Affairs who will investigate the charge and set a preliminary meeting with the student to discuss disposition. Consequences of academic dishonesty may be as severe as dismissal from the University.

E. Road Runner Creed

The University of Texas at San Antonio is a community of scholars where integrity, excellence, inclusiveness, respect, collaboration, and innovation are fostered. As a Roadrunner, I will:

- Uphold the highest standards of academic and personal integrity by practicing and expecting fair and ethical conduct;
- Respect and accept individual differences, recognizing the inherent dignity of each person;
- Contribute to campus life and the larger community through my active engagement; and
- Support the fearless exploration of dreams and ideas in the advancement of ingenuity, creativity, and discovery.

Guided by these principles now and forever, *I am a Roadrunner!*

F. UTSA policies

Students are expected to follow the student code of conduct as explained in http://catalog.utsa.edu/informationbulletin/appendices/studentcodeofconduct/ and scholastic dishonesty under Section 203.