The University of Texas at San Antonio — ECE Department

EE 5243 — Introduction to Cyber-Physical Systems

Fall 2015

Instructor:	Ahmad F. Taha	**Time:**	MW 18:00 – 19:15
Email:	ahmad.taha@utsa.edu	**Place:**	AET 0.214

Course Pages:

- UTSA Blackboard: http://utsa.blackboard.com
- My Webpage: http://engineering.utsa.edu/~taha

Office Hours:

- Mondays, 14:00 – 15:00
- Wednesdays, 16:00 – 17:30
- 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 is smart-grids 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.
- E. Lee and S. Seshia, *Introduction to Embedded Systems, A Cyber-Physical Systems Approach*, Second Edition, LeeSeshia.org, 2015. Book available online: http://leeseshia.org/releases/LeeSeshia_DigitalV2_0.pdf.
- 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/.

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 assignments and quizzes (20%)
- One Exam (30%)
- Project (40%) — divided as follows: initial proposal (20%), progress report (20%), final presentation (20%), final report (40%)
- Attendance and instructor evaluation (10%)

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 ..... Friday, September 18, 2015, 23:59:59
Progress Report ..... Sunday, November 1, 2015, 23:59:59
Exam ..... Wednesday, November 11, 2015, In Class
Final Report ..... Tuesday, December 8, 2015, 23:59:59

Programming Tools:

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

Class Policy:

- Few course projects will be proposed. However, students can choose a project of their choice, subject to the approval of the course instructor.

- **Regular attendance** is essential and expected. The course instructor will occasionally take attendance and this will be counted towards the overall course grade. Students are allowed to miss one class when the attendance is recorded.
- **Emailing the instructor**: we all receive tons of emails every day. Students are required to write exactly the following in the subject line of the email: [EE 5243] – ABC, where ABC is the usual subject of the email. Your email might be ignored if you do not include that in the subject line of your email.
- Students are expected to show few minutes **before** the start of the class. It is the student's responsibility to plan ahead of time and inform the course instructor of any emergencies. In case the student anticipates that they will be late for class, he/she should email the instructor before the class starts. Late arrival to class will negatively influence the attendance and instructor's evaluation grade.
- 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 ..... ≈ 5–6 classes
Course introduction & syllabus, prerequisites, major applications, course overview
Part II — Linear & Nonlinear Networked Systems Theory ..... ≈ 4–5 classes
Recent relevant theories on linear and nonlinear systems
Part III — State Observation & Estimation of CPSs ..... ≈ 4–5 classes
Dynamic state estimation of dynamic CPSs
Part IV — CPSs & Convex Optimization ..... ≈ 3–4 classes
Basic principles on convex optimization for generic systems
Part V — Progress Reports Presentations ..... ≈ 1–2 classes
Students will give short presentations on their progress reports
Part VI — Optimal Control of CPSs ..... ≈ 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 ..... ≈ 1–2 classes
Recent results on networked control systems, fault detection, cyber-attacks
Part IX — Applications ..... ≈ 1–2 classes
Smart-grids, transportation networks, robotics
Part X — Project Presentations ..... ≈ 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.