

## THE UNIVERSITY OF TEXAS AT AUSTIN

### Department of Aerospace Engineering and Engineering Mechanics ASE 381P.3 – Optimal Control Theory Spring 2021

## SYLLABUS

### General Information

**Unique Number:** 13800

**Instructor:** Efstathios Bakolas

Office: ASE 4.232, Phone: (512) 471-4250,

Email: [bakolas@austin.utexas.edu](mailto:bakolas@austin.utexas.edu)

**Time:** TTH 11:00am-12:30am **Location:** online / zoom

**Web Page:** <http://canvas.utexas.edu/> (Canvas)

### Catalog Description

Unconstrained and constrained finite-dimensional optimization, introduction to calculus of variations, necessary and sufficient conditions for optimality, Pontryagin's Maximum Principle, minimum-time control, linear quadratic optimal control theory, dynamic programming, Hamilton-Jacobi-Bellman equation.

### Course Objectives

Introduce students to the fundamental elements of optimal control theory and its applications in modern science and engineering problems.

### Prerequisites

Good familiarity with state-space control systems is expected (ASE 381P.1: Linear Systems Analysis or equivalent). Familiarity with the material covered in ASE 381P.2 (Multi-variable Control Systems) may also be helpful but is not required.

### Topics

- Unconstrained finite-dimensional optimization
- Constrained finite-dimensional optimization (Introduction to Nonlinear Programming)

- Introduction to calculus of variations, weak and strong variations, weak and strong first order optimality, Euler-Lagrange equation, Legendre condition, Jacobi condition, conjugate and focal points, Weierstrass condition, corner condition,
- Introduction to optimal control problems (classical, variational approach)
- Pontryagin's Maximum Principle
- Linear Quadratic (LQ) optimal control theory
- Minimum-time problems for linear dynamical systems
- Dynamic programming, Hamilton-Jacobi-Bellman equation
- Applications of optimal control, advanced topics in optimal control theory, connections with robust control and differential games

### **Professionalism Topics**

Discussion of ethics and teamwork based on instructor's professional experience will be given periodically throughout the semester.

### **Laboratory Assignments**

There will be no laboratory assignments.

### **Computer**

Students are strongly encouraged to use computers in order to become familiar with the computational techniques for the numerical solution of optimal control problems for dynamical systems.

### **Text**

The following textbook is recommended but not required: Liberzon, D. "Calculus of Variations and Optimal Control Theory: A Concise Introduction," Princeton University Press, 2012.

A short list of other useful references for this course is the following:

1. Athans, A. and Falb, P.L. "Optimal Control: An introduction to the theory and applications," Dover Publications, 2006.
2. Speyer, J. L. and Jacobson, D. H. "Primer on Optimal Control Theory," SIAM, 2010.
3. Kirk, D. E. "Optimal Control Theory: An Introduction," Dover Publication, 2004.
4. Naidu, D. S. "Optimal Control Systems," CRC Press, 2002.
5. Bryson, A. E. Jr. and Ho, Y. C. "Applied Optimal Control: Optimization, Estimation and Control," CRC Press, Revised Edition, 1975.
6. Anderson, B. D. O. and Moore, J. B. "Optimal Control: Linear Quadratic Methods," Dover Publications, 2007.
7. Bertsekas, D. "Nonlinear Programming," Athena Scientific, 1999.
8. Luenberger, D. G. and Ye, Y. "Linear and nonlinear programming," Springer 1984.

### **Class Format: Online Class (Internet)**

Lecture format (two 1 1/2 hr lectures per week). This is an online class. An online class is a class

designed from the ground up assuming that all students will attend the main class experience online. Material in these classes may be presented synchronously or asynchronously (most of the lectures will be delivered asynchronously but exams and discussion session before exams may be held during regular lecture times; you are required to keep the time slots corresponding to the lectures blocked throughout the semester).

### **Grading Policy**

1 mid-semester exam (in-class or take-home):	30%
Homework & Projects:	20%
Final Exam (in-class):	50%

Note: This course will adopt the Plus/Minus Grading Policy.

### **Homework Policy**

There will be six to eight homework assignments during the semester (due to the extension of the spring break, the number of assignments will be 6 or 7 at most). No late homework will be accepted unless I give permission in exceptional circumstances (advance notice for this is required). Until the end of the semester, only electronic submission of your homework assignments will be allowed.

Special instructions about homework format:

1. The homework should be well organized, clearly demonstrating the student's work. Points will be deducted for sloppiness.
2. Students must write clearly using pencils and erasers. Students are not allowed to write using pens.
3. Students should write only on one side of the sheets (the students are strongly encouraged to use engineering paper) and staple all sheets together (clips are not allowed).

### **Examinations**

There will be a mid-semester exam and a final exam. Both of them will be take-home exams. The mid-term exam is scheduled for **TBA** (typically, the week before or after the spring break). Details on the final exam will be provided later in the semester.

### **Policy on Academic Integrity**

Students who violate University rules on scholastic dishonesty are subject to disciplinary penalties, including the possibility of failure in the course and/or dismissal from the University. Since such dishonesty harms the individual, all students, and the integrity of the University, policies on academic dishonesty will be strictly enforced. For further information please visit the Student Judicial Services web site: <http://deanofstudents.utexas.edu/sjs/>

### **Office hours**

Instructor's office hours: TBA. The easiest way to reach me is via e-mail. I may hold one or two review meetings via zoom latter in the semester. More details on that on a later announcement.

### **A notice regarding accommodations for religious holidays**

By UT Austin policy, a student must notify me of his/her pending absence at least fourteen days prior to the date of observance of a religious holy day. If the student must miss a class, an examination, a work assignment, or a project in order to observe a religious holy day, he/she will be given an opportunity to complete the missed work within a reasonable time after the absence.

### **Special Notes**

The University of Texas at Austin provides upon request appropriate academic adjustments for qualified students with disabilities. For more information, contact the Office of the Dean of Students at 471-6259, 471-4641 TDD or the College of Engineering Director of Students with Disabilities at 471-4321.

### **Evaluation**

Measurement and Evaluation Center forms for the College of Engineering will be used during the scheduled time (typically the last week of class) to evaluate the course and the instructor.

### **Safety and Class Participation/Masks:**

We will all need to make some adjustments in order to benefit from in-person classroom interactions in a safe and healthy manner. Our best protections against spreading COVID-19 on campus are masks (defined as cloth face coverings) and staying home if you are showing symptoms. Therefore, for the benefit of everyone, this is means that all students are required to follow these important rules.

- **Every student must wear a cloth face-covering properly in class and in all campus buildings at all times.**
- **Students are encouraged to participate in documented daily symptom screening.** This means that each class day in which on-campus activities occur, students must upload certification from the symptom tracking app and confirm that they completed their symptom screening for that day to Canvas. Students should not upload the results of that screening, just the certificate that they completed it. If the symptom tracking app recommends that the student isolate rather than coming to class, then students must not return to class until cleared by a medical professional.
- Information regarding safety protocols with and without symptoms can be [found here](#).

If a student is not wearing a cloth face-covering properly in the classroom (or any UT building), that student must leave the classroom (and building). If the student refuses to wear a cloth face covering, class will be dismissed for the remainder of the period, and the student will be subject to disciplinary action as set forth in the university's Institutional Rules/General Conduct 11-404(a)(3). Students who have a condition that precludes the wearing of a cloth face covering must follow the procedures for [obtaining an accommodation](#) working with [Services for Students with Disabilities](#).

### **Sharing of Course Materials is Prohibited**

No materials used in this class, including, but not limited to, lecture hand-outs, videos, assessments (quizzes, exams, papers, projects, homework assignments), in-class materials, review sheets, and additional problem sets, may be shared online or with anyone outside of the class unless you have my explicit, written permission. Unauthorized sharing of materials promotes cheating. It is a violation of the University's Student Honor Code and an act of academic dishonesty. I am well aware of the sites used for sharing materials, and any materials found online that are associated with you, or any suspected unauthorized sharing of materials, will be reported to Student Conduct and Academic Integrity in the Office of the Dean of Students. These reports can result in sanctions, including failure in the course.

### **Class Recordings**

Class recordings are reserved only for students in this class for educational purposes and are protected under FERPA. The recordings should not be shared outside the class in any form. Violation of this restriction by a student could lead to Student Misconduct proceedings. Guidance on public access to class recordings can be found [here](#).

### **COVID Caveats**

To help keep everyone at UT and in our community safe, it is critical that students report COVID-19 symptoms and testing, regardless of test results, to [University Health Services](#), and faculty and staff report to the [HealthPoint Occupational Health Program](#) (OHP) as soon as possible. Please see this [link](#) to understand what needs to be reported. In addition, to help understand what to do if a fellow student in the class (or the instructor or TA) tests positive for COVID, see this [University Health Services link](#).