AE/ME 5335, OPTIMAL CONTROL OF DYNAMIC SYSTEMS
Fall 2016

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Office hours: TuTh 0930–1030 HRS & 1230–1330 HRS OR By Appointment

Time and Place of Class Meetings: TuTh 1400 – 1520 HRS at NH 108

Description of Course Content: AE/ME 5335 - Optimal Control of Dynamic Systems (3-0) 3 hours credit. To learn about linear and nonlinear optimization methods; optimal control; continuous time Riccati equation; bang-bang control; singular arcs; differential inclusions; collocation techniques; design of optimal dynamic system trajectories for modern dynamic systems found in aerospace, mechanical and electrical engineering disciplines.

Prerequisites: Basic courses in Linear Systems and/or Automatic Control

Teaching Assistant(s): None

Course Content: The topics to be covered are listed below.

1. Parameter optimization problems
   (a) Unconstrained optimization
   (b) Constrained optimization - equality constraints, inequality constraints, neighboring optimum solutions
   (c) Numerical solutions
   (d) Linear programming problems
2. Optimization problems for dynamic systems
   (a) Single-stage systems
   (b) Multistage systems; no terminal constraints, fixed number of stages
   (c) Continuous systems; no terminal constraints, fixed terminal time
   (d) Continuous systems; state variable constraints (functions of state variables) specified at fixed terminal time
   (e) Continuous systems; state variable constraints (functions of state variables) at an unspecified terminal time (including minimum time problems)
   (f) Applications: Spacecraft and aircraft maneuvers
3. Optimization problems for dynamic systems with path constraints
   (a) Integral constraints
   (b) Control variable equality constraints
   (c) Equality constraints on functions of control and state variables
   (d) Interior-point constraints
   (e) Discontinuities at interior points

(f) Inequality constraints
(g) Bang-Bang Control
(h) Inequality constraints on functions of control and state variables
(i) Corner conditions
(j) Applications: Spacecraft and aircraft maneuvers

4. Optimal Feedback Control
   (a) The extremal field approach
   (b) Dynamic Programming
5. Linear systems with quadratic criteria: linear feedback
   (a) Review of Linear Systems - State Space representations of linear systems, controllability, observability, stability, discrete-systems.
   (b) Terminal controllers and regulators
   (c) Quadratic penalties on terminal errors
   (d) Zero terminal error and controllability
   (e) Regulators and stability
   (f) Linear quadratic trackers
   (g) Non-zero set point tracking
   (h) Applications: Aircraft control, Robotics.
6. Differential games
   (a) Discrete, continuous and differential games
   (b) Linear quadratic pursuit-evasion games
   (c) A minimax-time intercept problem with bounded controls
   (d) Applications: Aircraft control, Missile-Target engagement
7. Reinforcement Learning based Control
   (a) Reinforcement Learning
   (b) Markov decision processes
   (c) Reinforcement learning for adaptive control
   (d) Applications: Aircraft control, Robot manipulator control

Student Learning Outcomes: This course will assess the following,

Analysis: understanding the optimal control process, objective functions, optimization principles

Design: use linear/nonlinear techniques to optimize parameters and/or synthesize optimal controls to optimize performance of a dynamic system

Software: learn to use computer aided design and analysis tools for control design (MATLAB/SIMULINK).

Course Materials for Reference: The following materials are *suggested for reference* for the class.

- Optimal Control (Third Edition) by Frank L. Lewis, Draguna L. Vrabie, Vassilis L. Syrmos, John Wiley & Sons, 2012.
- Applied Optimal Control: Optimization, Estimation and Control, Arthur E. Bryson Jr. and Yu-Chi Ho, Taylor & Francis Group, 1975.
- Optimal Control and Estimation, Robert F. Stengel, Dover Publications.
- (Software) MATLAB Student Edition/Control Toolbox by Mathworks Inc.

Descriptions of major assignments and examinations: The students will be tested using the following instruments.

Homework/Projects: Several homework/project assignments will be given during this course. Homework is due in class on the assigned date before the actual class begins. Late homework will not be accepted, unless in cases of unforseen circumstances such as medical conditions. Each such instance will be dealt with on a case by case basis. MATLAB/SIMULINK will be used extensively for homework. Students are allowed to discuss concepts. Any other form of collaboration such as sharing code, results is not allowed.

Exams: There are no exams for this class.

All homework/project submissions need to adhere to the following:

- Work will be neatly hand-written or typeset using MS Word or LaTeX. If typeset, a minimum font size of 11 pt with 1 inch margin on all sides.
- All code listings will be attached as appendices.
- Figures should be discussed in the write up
- You are encouraged to conduct numerical experiments to test your assumptions, optimality, robustness and like. Such studies will merit additional credit (upto 10%) at the discretion of the instructor.
- *All code should also be submitted as a single archive (.zip) and named as* AE(ME)5335-Fall2016-HW#(Proj#)-Lastname-Firstname.zip

Attendance: Students are expected to attend class! Timely attendance is expected.

Grading: Grading follows the standard format. A = 90% and above, B = 80% - 89%, C = 70% - 79%, D = 60% - 69%.
Weightages for final grade calculation: Homeworks and Projects 100%.

Grade Grievances: Any appeal of a grade in this course must follow the procedures and deadlines for grade-related grievances as published in the current undergraduate calalog. See
http://catalog.uta.edu/academicregulations/grades/#graduatetext
See http://www.uta.edu/deanofstudents/student-complaints/index.php.

Drop Policy: Students may drop or swap (adding and dropping a class concurrently) classes through self-service in MyMav from the beginning of the registration period through the late registration period. After the late registration period, students must see their academic advisor to drop a class or withdraw. Undeclared students must see an advisor in the University Advising Center. Drops can continue through a point two-thirds of the way through the term or session. It is the student's responsibility to officially withdraw if they do not plan to attend after registering. Students will not be automatically dropped for non-attendance. Repayment of certain types of financial aid administered through the University may be required as the result of dropping classes or withdrawing. For more information, contact the Office of Financial Aid and Scholarships (http://wweb.uta.edu/aao/fao/).

Disability Accommodations: UT Arlington is on record as being committed to both the spirit and letter of all federal equal opportunity legislation, including The Americans with Disabilities Act (ADA), The Americans with Disabilities Amendments Act (ADAAA), and Section 504 of the Rehabilitation Act. All instructors at UT Arlington are required by law to provide "reasonable accommodations" to students with disabilities, so as not to discriminate on the basis of disability. Students are responsible for providing the instructor with official notification in the form of a letter certified by the Office for

Students with Disabilities (OSD). Only those students who have officially documented a need for an accommodation will have their request honored. Students experiencing a range of conditions (Physical, Learning, Chronic Health, Mental Health, and Sensory) that may cause diminished academic performance or other barriers to learning may seek services and/or accommodations by contacting:

The Office for Students with Disabilities, (OSD) www.uta.edu/disability or calling 817-272-3364. Information regarding diagnostic criteria and policies for obtaining disability-based academic accommodations can be found at www.uta.edu/disability.

Counseling and Psychological Services, (CAPS) www.uta.edu/caps/ or calling 817-272-3671 is also available to all students to help increase their understanding of personal issues, address mental and behavioral health problems and make positive changes in their lives.

Non-Discrimination Policy: The University of Texas at Arlington does not discriminate on the basis of race, color, national origin, religion, age, gender, sexual orientation, disabilities, genetic information, and/or veteran status in its educational programs or activities it operates. For more information, visit uta.edu/eos.

Title IX Policy: The University of Texas at Arlington ("University") is committed to maintaining a learning and working environment that is free from discrimination based on sex in accordance with Title IX of the Higher Education Amendments of 1972 (Title IX), which prohibits discrimination on the basis of sex in educational programs or activities; Title VII of the Civil Rights Act of 1964 (Title VII), which prohibits sex discrimination in employment; and the Campus Sexual Violence Elimination Act (SaVE Act). Sexual misconduct is a form of sex discrimination and will not be tolerated. For information regarding Title IX, visit www.uta.edu/titleIX or contact Ms. Jean Hood, Vice President and Title IX Coordinator at (817) 272-7091 or jmhood@uta.edu.

Academic Integrity: Students enrolled in this course are expected to adhere to the UT Arlington Honor Code:

I pledge, on my honor, to uphold UT Arlington's tradition of academic integrity, a tradition that values hard work and honest effort in the pursuit of academic excellence. I promise that I will submit only work that I personally create or contribute to group collaborations, and I will appropriately reference any work from other sources. I will follow the highest standards of integrity and uphold the spirit of the Honor Code.

UT Arlington faculty members may employ the Honor Code as they see fit in their courses, including (but not limited to) having students acknowledge the honor code as part of an examination or requiring students to incorporate the honor code into any work submitted. Per UT System Regents' Rule 50101, section 2.2, suspected violations of university's standards for academic integrity (including the Honor Code) will be referred to the Office of Student Conduct. Violators will be disciplined in accordance with University policy, which may result in the student's suspension or expulsion from the University. Additional information is available at https://www.uta.edu/conduct/.

Student Support Services: UT Arlington provides a variety of resources and programs designed to help students develop academic skills, deal with personal situations, and better understand concepts and information related to their courses. Resources include tutoring, major-based learning centers, developmental education, advising and mentoring, personal counseling, and federally funded programs. For individualized referrals, students may visit the reception desk at University College (Ransom Hall),

call the Maverick Resource Hotline at 817-272-6107, send a message to resources@uta.edu, or view the information at http://www.uta.edu/universitycollege/resources/index.php.

Electronic Communication: UT Arlington has adopted MavMail as its official means to communicate with students about important deadlines and events, as well as to transact university-related business regarding financial aid, tuition, grades, graduation, etc. All students are assigned a MavMail account and are responsible for checking the inbox regularly. There is no additional charge to students for using this account, which remains active even after graduation. Information about activating and using MavMail is available at http://www.uta.edu/oit/cs/email/mavmail.php

Campus Carry : Effective August 1, 2016, the Campus Carry law (Senate Bill 11) allows those licensed individuals to carry a concealed handgun in buildings on public university campuses, except in locations the University establishes as prohibited. Under the new law, openly carrying handguns is not allowed on college campuses. For more information, visit http://www.uta.edu/news/info/campus-carry/

Student Feedback Survey: At the end of each term, students enrolled in classes categorized as "lecture," "seminar," or "laboratory" shall be directed to complete an online Student Feedback Survey (SFS). Instructions on how to access the SFS for this course will be sent directly to each student through MavMail approximately 10 days before the end of the term. Each student's feedback enters the SFS database anonymously and is aggregated with that of other students enrolled in the course. UT Arlington's effort to solicit, gather, tabulate, and publish student feedback is required by state law; students are strongly urged to participate. For more information, visit http://www.uta.edu/sfs

Final Review Week: A period of five class days prior to the first day of final examinations in the long sessions shall be designated as Final Review Week. The purpose of this week is to allow students sufficient time to prepare for final examinations. During this week, there shall be no scheduled activities such as required field trips or performances; and no instructor shall assign any themes, research problems or exercises of similar scope that have a completion date during or following this week unless specified in the class syllabus. During Final Review Week, an instructor shall not give any examinations constituting 10% or more of the final grade, except makeup tests and laboratory examinations. In addition, no instructor shall give any portion of the final examination during Final Review Week. During this week, classes are held as scheduled. In addition, instructors are not required to limit content to topics that have been previously covered; they may introduce new concepts as appropriate.

Emergency Exit Procedures: Should we experience an emergency event that requires us to vacate the building, students should exit the room and move toward the nearest exit. When exiting the building during an emergency, one should never take an elevator but should use the stairwells. Faculty members and instructional staff will assist students in selecting the safest route for evacuation and will make arrangements to assist handicapped individuals.

Course Schedule: Please see the table below.

Date	Topics	Reading Assignment	Deliverables
Week 1	1 (a) - (d)		Project 1 assigned
Week 2	2 (a) - (f)		Project 1 due, Project 2 assigned
Week 3	3 (a) - (j)		Discuss Major Project
Week 4	3 (a) - (j)		Project 2 due, Project 3 assigned
Week 5	4 (a) - (b)		
Week 6	5 (a) - (h)		Project 3 due, Project 4 assigned
Week 7	5 (a) - (h)		
Week 8	5 (a) - (h)		Project 4 due, Project 5 assigned
Week 9	5 (a) - (h)		
Week 10	6 (a) - (d)		Project 5 due, Project 6 assigned
Week 11	6 (a) - (d)		
Week 12	6 (a) - (d)		Project 6 due, Project 7 assigned
Week 13	7 (a) - (d)		
Week 14	7 (a) - (d)		Project 7 due
Week 15	7 (a) - (d)		
12–13–2016	**Submit Major Project**		

Notice: As the instructor for this course, I reserve the right to adjust this schedule in any way that serves the educational needs of the students enrolled in this course. Kamesh Subbarao