MAE 6292: Special Topic - Applied Optimal Control and Estimation

Spring 2020

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Prerequisite Linear algebra, Differential equations

Goal Understand fundamental properties of parametric optimization, optimal control, stochastic processes, and estimation. Use MATLAB for numerical analyses and simulations.

Contents

- Optimal Control
  - Parameter optimization
  - Optimization of dynamic systems
  - Optimal control of dynamic systems
  - Optimal feedback control
  - Numerical approaches
- Estimation
  - Probability
  - Stochastic process
  - Parameter estimation
  - Estimation of dynamic systems
  - Kalman filters
  - Bayesian filters
- Applications

Textbook

- A. Bryson and Y. Ho, *Applied optimal control*, Halsted Press, 1975

Additional Readings

- A. Bryson, *Applied Linear Optimal Control*, Cambridge, 2002
- J. Melsa and A. Sage, *An introduction to probability and stochastic processes*, Prentice hall, 1973
- E. Kirt, *Optimal Control Theory*, Prentice Hall, 1970
- S. Thrun, W. Burgard, and D. Fox, *Probabilistic Robotics* , MIT Press, 2006
- MATLAB Tutorial by Mathworks: http://www.mathworks.com/academia/student_center/tutorials/

Grading Homework 35%, Attendance 5%, Midterm Exam 30%, Final Exam 30%

Course Learning Objectives At the end of this course, students will be able to:

1: Describe necessary and sufficient conditions for optimality
2: Find the optimal parameters of a system to minimize a certain cost function
3: Find the optimal input trajectories of a dynamic system to minimize a certain cost function
4: Deals with constraints in optimization
5: Estimate the parameters of a system based on noisy measurements
6: Estimate the states of a dynamic system based on noisy measurements
7: Describe the framework of Bayesian filtering
8: Implement Kalman filters and their variations

Course Policy

- **Check your GW email account daily**. All of the important announcements of this class will be made through your email.
- I will not respond to emails which are composed in an unprofessional manner, or which violates basic email etiquette. Think professional business letter to a potential employer, as opposed to a text message to your friend.
- Homework will be due at the **beginning of class**. **Late homework will not be accepted**. If you plan on being absent on a day that a homework set is due, you may either turn it in earlier or have a friend turn it in for you.
- Grading of the homework will emphasize your effort to present the solution in a near and orderly fashion.
  - Use one side of a clean paper (graphed or lined is okay) that is not torn from a spiral notebook.
  - Write your name, ID number, and section clearly on the front page of your completed assignment.
  - Clearly number each solution and present them in numerical order.
  - Leave at least one line of space between each problem.
  - Write clearly and legibly.
  - Use a stapler.
- Please keep all your exams and homeworks; if you believe there has been an error in the recording of your grades they are the only way to validate your claim.
- A student may discuss homework problems with other students to develop and clarify his/her approach. But, the written solution should be an independent and individual effort that reflects his/her own understanding of the problem. As a general guide, a student should be able to independently reproduce any submitted solution. **Copying or allowing another student to copy your work or solution manual is considered cheating**.
- There are one midterm exam and final exam. **Make-up exams will not be given except in exceptional circumstances** such as family emergency or medical emergency. In emergency situations, students should notify the occurrences **as early as possible**, and students will be expected to provide **a certified document** such as a doctor's letter indicating the nature and time of the medical emergency.

Academic Integrity This class follows the GW Code of Academic Integrity. It states: *"Academic dishonesty is defined as cheating of any kind, including misrepresenting one's own work, taking credit for the work of others without crediting them and without appropriate authorization, and the fabrication of information."* For the remainder of the code, see: `https://studentconduct.gwu.edu`

Course Calendar[1]

Week	Topics
1	Parameter optimization
	Conditions for local optimality
	Optimization with equality constraints
	Optimization with inequality constraints
	Numerical approaches
	Linear programming
2-3	Optimization of dynamic systems
	Calculus of variations
	Types of terminal conditions
	Piecewise smooth functions
	Lagrange multipliers
4-5	Optimal control of dynamic systems
	Pontryagin's minimum principle
	Linear quadratic regulators
	Minimum-time optimal control
6-7	Optimal feedback control
	Dynamic programming
	Hamilton-Jacobi-Bellman equations
	Numerical Approaches for optimal control
8-9	Probability and stochastic process
	Random variables
	Probability density and distribution
	Joint and marginal density and distribution
	Independence and correlation
	Mean and variance
	Gaussian density
	Stationary process
	Gaussian and Markov process
10-11	Parameter estimation
	Least square estimation
	Maximum likelyhood estimation
	Minimum variance estimation
	Bayesian estimation
12-14	Estimation of dynamic systems
	Recursive state estimation
	Kalman filters
	Unscented filters
	Particle filters

[1] This calendar is subject to revision.