ECE686   Filtering and Control of Stochastic Linear Systems   Winter 2019

Course Motivation: Broadly speaking, this is a course on decision making under uncertainty. Specifically, the course focuses on the study of stochastic linear systems where the dynamics have certain components of a stochastic nature. The course will cover both estimation and control of such systems. The first half of the course establishes the fundamentals of the estimation problem, culminating in the derivation of the fact that state estimation in linear systems is equivalent to projection onto a closed linear subspace generated by an observation process in a Hilbert space of random variables. This leads to the Kalman filter, which finds use in many applications ranging from aerospace to finance. The course will then cover the issues of stochastic optimal control (based on dynamic programming), control of Markov chains, and optimal stopping time problems (e.g., when is the optimal time to buy or sell a product?).

Instructor: Prof. Stephen L. Smith   (stephen.smith@uwaterloo.ca; Office: ███████)

- Please put "ECE686" at the front of your subject line for all course related email.

Lectures: ████████████████████████████

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Course Outline: The following is tentative list of topics that will be covered in the course.

1. Introduction and Mathematical Background

   - Motivation and overview
   - Review of probability theory and stochastic processes

2. Derivation of the Projection Theorem

   - Metric and linear spaces
   - Hilbert spaces and the projection theorem for linear estimation

3. Estimation of Discrete-Time Linear Systems

   - Least-squares and recursive estimation
   - The discrete-time Kalman filter

4. Stochastic Optimal Control

   - Dynamic programming and the principle of optimality
   - Optimal control with complete and partial observations
   - Linear quadratic regulators

5. Control of Markov Chains

   - Overview of Markov chains
   - Markov policies and the cost of optimal policies

6. Optimal Stopping Time Problems

Textbook: There is no required textbook. Parts of the course are based on notes by Prof. Andrew Heunis, and the following book:

1. P. R. Kumar and P. Varaiya, *Stochastic Systems: Estimation, Identification and Adaptive Control*, 1986.

The following textbooks may also be useful for additional information:

1. J. L. Speyer and W. H. Chung, *Stochastic Processes, Estimation and Control*, 2008
2. D. P. Bertsekas, *Dynamic Programming and Optimal Control*, 2005

Grading: The course will consist of three or four assignments, a project in which you will present a paper (or implement an algorithm) on filtering or control for stochastic systems, and a final exam. There will be a total of four homework assignments, given roughly once every three weeks. The grading scheme is

- Assignments: 30%
- Project: 20%
- Final Exam: 50%

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Academic Integrity: In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. Check `http://www.uwaterloo.ca/academicintegrity/` for more information.

Grievance: A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4, `http://www.adm.uwaterloo.ca/infosec/Policies/policy70.htm`.

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For typical penalties check Guidelines for the Assessment of Penalties, `http://www.adm.uwaterloo.ca/infosec/guidelines/penaltyguidelines.htm`.

Appeals: A decision made or penalty imposed under Policy 70 (Student Petitions and Grievances) (other than a petition) or Policy 71 (Student Discipline) may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to Policy 72 (Student Appeals) `http://www.adm.uwaterloo.ca/infosec/Policies/policy72.htm`.

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