ECE 686: Filtering and Control of Linear Stochastic Systems :
Winter 2022

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Lecture Schedule: Tuesdays and Thursdays at 13.00-14.20 (1pm-2.20pm) in EIT 3151/3
Additional lectures: Wednesday Jan 5, 2022 and Wednesday Jan 12 : 13.00-14.20 EIT 3151/3
There will be no lectures during the week of January 17-21, 2022.
Midterm date: TBA

Class website: Waterloo LEARN

Office hours: When not busy in my office or by appointment (please send me an e-mail to set up an appointment).

Pre-requisites: ECE604 or a good undergrad probability course (ECE307), linear algebra (MATH215 or equivalent) and ideally Linear Multivariable Control (ECE682).

Aims: Broadly speaking, this is a course on decision making under uncertainty. Specifically, the course focuses on the study of stochastic systems that have Markovian characteristics. The idea is to impart an understanding of the models, tools and key results. The course will cover both estimation and control of such systems. More importantly the students will be exposed to the key ideas of dynamic programming and conditional expectations and the notions of information flows.

Essentially the course will introduce the student to two important classes of problems that arise in the context of optimizing under uncertainty. The first is the control of systems with linear dynamics with additive random noise and noisy observations. We will first begin with the problem of state estimation based on noisy observations and then study the problem of optimal control with quadratic costs, the LQG problem. In this context we will see the celebrated Kalman filter and the important principle of separation between control and estimation.

The second important class of problems we will study is Markov Decision Processes (MDPs). In particular we will look at two important paradigms. The discounted cost and the ergodic cost problems and we will focus on two important classes of problems namely optimal stopping problems and bandit problems. These problems are playing an important role in today’s machine learning algorithms.

COURSE OUTLINE

Introduction and Mathematical Background

- Review of some basic matrix theory and linear systems.
Linear Stochastic Filtering

- The geometry of linear recursive estimation. The projection and the innovations process
- Discrete-time Kalman filters: Structure and asymptotic behaviour.

Stochastic Optimal Control: The LQG problem

- Dynamic programming and Bellman’s Principle of Optimality
- Linear Quadratic control of stochastic systems with complete and partial observations. Separation principle
- Steady-state theory and connections to ARMA models. Minimum variance control.

Control of Markov Chains: Markov Decision Processes (MDP)

- Overview of Markov chains. Markov decision processes.
- Discounted and average cost problems. Poisson equation.
- Optimal stopping problems.
- Bandit problems. Gittin’s Index
- The regret approach and optimal regret policies.

TEXT AND REFERENCES

There is no text for this course. Typed class notes will be posted on the website from time to time. The notes will be fairly detailed.

The following references will be useful for a deeper understanding and seeing more examples

References:

There are a number of books that cover the material but with variable treatment of the topics.


2. M. H. A. Davis and R. B. Vinter, Linear Estimation and Stochastic Control, Chapman and Hall, 1977

Course Evaluation

Bi-weekly problem sets will be posted on the website. The solutions will be posted before the midterm and final. There will be one midterm and a final exam the dates will be announced later.

Marks distribution: Homework: 20% , Midterm= 30%, Final Exam = 50%
Auditors will be required to take the midterm exam and score around the mean for the class.

Additional remarks

Procedures because of the current COVID situation

The COVID pandemic has forced all of us to learn to understand and adapt to a highly dynamic situation. In event of in-person restrictions the lectures will be taped and posted on LEARN. In case we move to a purely on-line mode, both the Midterm and the Final exam will be given as take home exams that require you to follow an honour code.

In event of an on-line course offering I will be available over Zoom and I will post consultation times on LEARN.

Finally:

• All exams will be open notes.

• If you miss the midterm exam no make-up exam will be given. If you have a valid reason then your final marks will be based on your performance in the rest of the course.

• Students are advised to be regular and attempt to solve the problem sets on their own.