Syllabus: MF 850, Fall 2022

September 6, 2022

Lectures

D1	Thursdays	2:00–4:45 PM	HAR 412
E1	Thursdays	6:30–9:15 PM	HAR 312

Instructor

Prof. A. Max Reppen `amreppen@bu.edu`

Teaching assistant

Dapeng Shang `dpshang@bu.edu`

Office hours

Max Reppen	TBD	HAR 532
Dapeng Shang	TBD	HAR 427

Topics

The course covers topics ranging from solving optimal control problems to optimization methods and machine learning. These topics constitute two overlapping themes: The first focuses on numerical schemes for problems in mathematical finance, whereas the second is data-centric.

- Some recap and new on numerically solving PDEs
- The dynamic programming algorithm
- Policy and value iteration for stochastic control problems, including optimal stopping
- Filtering
- Linear regression-based regularization and model selection techniques
- Gradient descent optimization

- Neural networks
- Model selection methods and dimensionality reduction
- Tree methods, including random forests
- Validation methods
- Unsupervised learning
- Reinforcement learning (if time allows)

Prerequisites

Required: MF 793, MF 795, and MF 796.

Recommended: MF 810 and MF 815.

The course makes heavy use of probability theory. Familiarity with differential equations and their discretization is also expected, in particular stochastic differential equations and partial differential equations. This includes Itô's lemma, the Feynman–Kac formula, and their prerequisites. You are also expected to be familiar with a number of statistical concepts, like simulation, bias-variance trade-off, regression analysis, and principal component analysis.

Additionally, this is a computational course, so you are expected to be well versed in programming and common numerical libraries. Examples and solutions will be provided in the Julia language. Julia is syntactically very similar to Numpy (Python) and MATLAB but offers many advantages. A quickstart session will be provided during the first lecture.

Recommended literature

The following books collectively cover most material taught in this course, and much more. Following this course does not require any of these books, but each is a great resource on their respective topics. All except the first are available for free online, see links below.

[1] M. L. Puterman. *Markov decision processes: discrete stochastic dynamic programming.* John Wiley & Sons, 2014:

Covers both theory, applications, and numerical methods for Markov decision processes and dynamic programming.

[2] W. H. Fleming and H. M. Soner. *Controlled Markov processes and viscosity solutions*, volume 25. Springer Science & Business Media, 2006:

This book is one of the de-facto standard mathematical references for optimal control and dynamic programming in continuous time.

[3] G. James, D. Witten, T. Hastie, and R. Tibshirani. *An introduction to statistical learning*, volume 112. Springer, 2013:

A well regarded introduction to many statistical learning topics. It is very easy to read, but does not provide any mathematical detail. Rich in examples and figures.

Is made available for free by the authors: `http://faculty.marshall.usc.edu/gareth-james/ISL/`

[4] T. Hastie, R. Tibshirani, and J. Friedman. *The elements of statistical learning: data mining, inference, and prediction*. Springer Science & Business Media, 2009:

The advanced version of [3]. It complements [3] with more mathematical detail and insight and is aimed primarily towards graduate students.

Is made available for free by the authors: `https://web.stanford.edu/~hastie/ElemStatLearn/`

[5] R. S. Sutton and A. G. Barto. *Introduction to reinforcement learning*, volume 135. MIT press Cambridge, 1998:

Great book for an introduction to reinforcement learning.

Is made available for free by the authors: `http://incompleteideas.net/book/the-book-2nd.html`

Grading weights

Midterm: 30%

Exam: 35%

Homework: 30%

Attendance: 5%

Attendance and participation will be used as a tie-breaker for students in-between grades.

Midterm

A midterm exam is tentatively scheduled around week 7. The precise date along with format will be set during the first weeks of the semester. A review session will be offered in advance of the midterm. The date for the review session will be communicated in class.

Homework

Homework will be assigned on a regular basis. The best way to understand numerical methods and learn programming is to write the code. You may work in pairs on these assigments. Each student or pair of students is expected to hand in their own solution to each homework assignment.

Submissions should include answers to questions, both in writing or math, and any comments relevant to the solution, as well as accompanying code for coding problems. Helping classmates with programming difficulties (but not assignment specifics) is encouraged. Collaboration in the form of high-level discussion of problem specifics must be declared in the submission. **Detailed discussion of problems (aside from in the pairs you work in) is prohibited and considered cheating. Any other form of collaboration is also considered cheating.**

Homework solutions must be submitted on time.