Stochastic Dynamic Programming

Course Objectives

The aim of this course is to integrate fundamental concepts, theories, and methods from Dynamic Programming (DP) and Control, Stochastic Programming, and Reinforcement Learning. It provides students with a strong theoretical foundation for addressing decision-making problems under uncertainty. Students will engage with state-of-the-art research and computational tools, equipping them to contribute to both methodological advancements and practical implementations in their respective fields.

After having participated in the course, the student will be able to demonstrate:

Knowledge:

- of the theoretical foundation in stochastic dynamic programming (SDP) and stochastic programming (SP).
- of the differences and similarities between SDP and DP.
- of key methods and algorithms for solving SDP and SP problems.
- of the foundation of reinforcement learning (RL), in particular multi-armed bandits and related methods
- of programming techniques using software such as Python.

Skills:

- to formulate SDP or SP models for real-world decision-making problems under uncertainty, in various domains such as revenue management, healthcare, inventory management, transportation, etc.
- to select and implement appropriate methods for solving these problems.
- to select and implement appropriate reinforcement learning methods.
- to contribute to the development of frontier algorithms in SDP, SP and RL.

Contents and Schedule

Day 1

- 9:00 - 9:45 Introduction to the course
- 10:00 - 10:45 Introduction to Markov Chain
- 11:00 - 11:45 Introduction to Markov Decision Processes

Lunch

- 13:00 - 13:45 Introduction to Dynamic Programming
- 14:00 - 15:45 Seminar on DP and Introduction to the Assignment

Day 2

- 9:00 - 10:45 Infinite Horizon Dynamic Programming
- 11:00 - 11:45 Applications of DP

Lunch

- 13:00 - 14:45 Workshop: Implementation of Python to Solve a DP Problem

Day 3

- 9:00 - 9:45 Approximate Dynamic Programming (ADP)
- 10:00 - 10:45 Introduction to Reinforcement Learning
- 11:00 - 11:45 Temporal Difference Methods: *Q*-learning and SARSA

Lunch

- 13:00 - 14:45 Workshop: Implementation of *Q*-learning and SARSA

Day 4

- 13:00 - 13:45 Classical Multi Armed Bandit Problems
- 14:00 - 14:45 Markovian Multi Armed Bandit Problems
- 15:00 - 16:45 Restless Bandit Problems and Whittle Index

Day 5

- 9:00 - 10:45 Stochastic Programming
- 11:00 - 11:45 The Research Frontier of SDP, SP and RL

Lunch

- 13:00 - 14:45 Presentation of the Assignment and Assessment

18:00 – Course dinner

Feedback

The following types of feedback are used in this course:

- Discussions in class
- Self-assessments
- Feedback on assignments.

Evaluation:

A group work on modelling, formulating and solving a given decision-making problem under uncertainty. Each group will present their results through a 20-minute presentation, plus 10-minute questions and answers about the presentation and broader area of the topics.

Grading scale: Pass or not Pass

Instructor

Professor Dong Li, Department of Management Science, Lancaster University, UK

Course coordinator

Hongyan Jenny Li, hojl@econ.au.dk

Academic prerequisites

The student should have fair understanding of probability, optimisation, and simulation. The student is also expected to have a basic knowledge on using Python.

Forms of instruction: Lectures, workshops

Comments on form of instruction

Literature

- Bertsekas, D., 2012. Dynamic Programming and Optimal Control. Volume 1, Athena Scientific.
- Bertsekas, D., 2012. Dynamic Programming and Optimal Control: Approximate Dynamic Programming. Volume II. Athena Scientific.
- Birge, J. R., Louveaux, F., 2011. Introduction to Stochastic Programming. Springer.
- Petropoulos, F. et al. 2023. Operational Research: Methods and Applications, Journal of the Operational Research Society, 75(3), pp. 423–617.

- Puterman, M.L., 2014. Markov Decision Processes: Discrete Stochastic Dynamic Programming. John Wiley & Sons.

ECTS: 5

Period: Week 40, 29.09.2025-03.10.2025

Level: PhD

Department: Department of Economics and Business Economics

Faculty: Aarhus BSS