Berlin Doctoral Program – Ph.D. Course

Sequential Decision Making Under Uncertainty

DRAFT

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COURSE DESCRIPTION

This course is concerned with situations in which decisions are made sequentially. The fundamental tradeoff at stake consists in balancing immediate reward with unpredictable future payoffs. Situations such as these arise in a wide variety of areas raging from marketing (e.g. dynamic pricing) to the environment (e.g. water management). In this course, we will primarily focus on applications in the field of management science.

The approach is based on (stochastic) Dynamic Programming (referred to as DP in the following), which provides a set of general methods for making sequential decisions under uncertainty.

Objectives of the courses

- Learn to formulate and solve dynamic programming problems
- Develop modeling skills to tackle issues in Operations and Management Science
- Gain knowledge on conducting research in Operations and Management Science

COURSE MATERIALS AND BOOKS:

Course material will be distributed in class (problem sets, articles etc.). However, we will extensively use the following textbook:

"Dynamic Programming and Optimal Control (Vol. I)", Bertsekas, 2005

I will also sometimes refer to and summarize results from the followings books that are not required:

Other books

"Dynamic Programming and Optimal Control (Vol. II)", Bertsekas, 2007
"Stochastic Models in Operations Research", Heyman and Sobel, 1984
"Foundations of Stochastic Inventory Theory", Porteous, 2002
"Stochastic Dynamic Programming and the Control of Queuing Systems", Sennott, 1998
"Supermodularity and Complementarity", Topkis, 1998

COURSE REQUIREMENTS

Final Exam (45%): There will be a 3h final exam in the last section.

Project (35%): Throughout the course, you will be asked to apply the techniques seen in class to a project of your choice. This will be done in several steps with intermediary presentations so as to collect feedback from the class and adjust your work accordingly. This is a group assignment.

Class participation (20%): Graded for each class. I am evaluating to which extend you come prepared to class as well as the quality and frequency of your interventions in class.

Summary of Assignments:

First Presentation	Propose a managerial problem and present its mathematical formulation	Session 5
Second Presentation	Refine the previous formulation and present the corresponding optimality (Bellman) equations.	Session 7
Final Presentation (graded)	Numerically solve the previous optimality equations and present the resulting policy. Submit a paper version of the presentation.	Session 9
Final Exam (graded)	Focus on mathematically solving dynamic Programs	Session 10

TENTATIVE SCHEDULE (subject to change)

I will try to follow the following out line but will adjust the content depending on the class need and learning rate.

Sessions 1-2 (Oct 27) – Introduction to decision trees and dynamic programming

During these two sessions we will introduce the notion of stochastic dynamic problems, which is the mathematical framework to study sequences of decisions under uncertainty. We will first focus on a subclass of these problems – decision trees – that we will generalize to the dynamic programming framework.

Readings:
You should briefly read Vol. I, Chapters 1.1, 1.2, 1.5. I am not expecting you to fully master this chapter, but having an overview of the topic will be useful to follow the sessions.

Sessions 5-6 (Nov 10) – Modeling dynamic decision problems

In these sessions, we will learn how to apply dynamic programming to model managerial decision problems. To that end, each group will have to present a project proposal (see below), which will then be discussed by the rest of the class. We will then introduce the Bellman's equations and a general approach to solve them.

Readings:
You should now be familiar with Chapters 1.
To get ideas on possible project topics you may want to focus on the examples provided in Chapter 1 and perhaps in Chapter 4.3, pages 170-174.

Assignment: Project proposal
The assignment consists in identifying and modeling a managerial/economics problem of your choice, which involves a sequence of decisions under uncertainty.

- You should pick a problem of your choice but make sure the state space has no more than 2 dimensions. Choosing this topic may require further readings (see above for a start).
- Once you have identified your problem, you should model it in the dynamic programing framework introduced in sessions 1-2.
- You should then prepare a 5-10 minutes presentation that
    1. Describes in words the managerial problem,
    2. Presents the mathematical formulation and justifies your modeling choices.

Sessions 7-8 (Dec 01) – Characterizations of optimal policies

In these sessions, we will learn how to mathematically solve dynamic programming problems, and the Bellman equations in particular. We will practice different techniques and solve problems in class.

Readings:
You should briefly read Vol. I, Chapters 4.2

Assignment: Project – Bellman equations
The assignment consists in presenting the final version of your problem and its mathematical representations. In addition, you should write down the optimality (Bellman) equations corresponding to your model.

- You should then prepare a 5-10 minutes presentation that
    1. Describes the dynamic programming problem you want to solve,
    2. Presents the corresponding optimality equations.

Session 9 (Dec 08) – Project Final Presentation and Practice

In this session you will present your project. We will also practice and solve dynamic programs in class.

Assignment: Project – Bellman equations
The assignment consists in solving the Bellman equations of your problem and presenting the corresponding optimal policy. I am not expecting you to characterize the optimal policy mathematically but rather to describe it numerically. This means implementing (using the programming language of your choice) the value iteration algorithm to solve these bellman equations, a displaying the corresponding policy.

- You should then prepare a 15-20 minutes final presentation that
    1. Describes in words the managerial problem,
    2. Presents the mathematical formulation,
    3. Presents the optimality equations,
    4. Presents the algorithm you used to solve them,
    5. Depicts the resulting optimal policy
    6. Describe in words how the policy works.
- Submit a printed version of your presentation. You can add notes to your presentation if you want to provide more detail.

Session 10 (Dec 15) – Final Exam