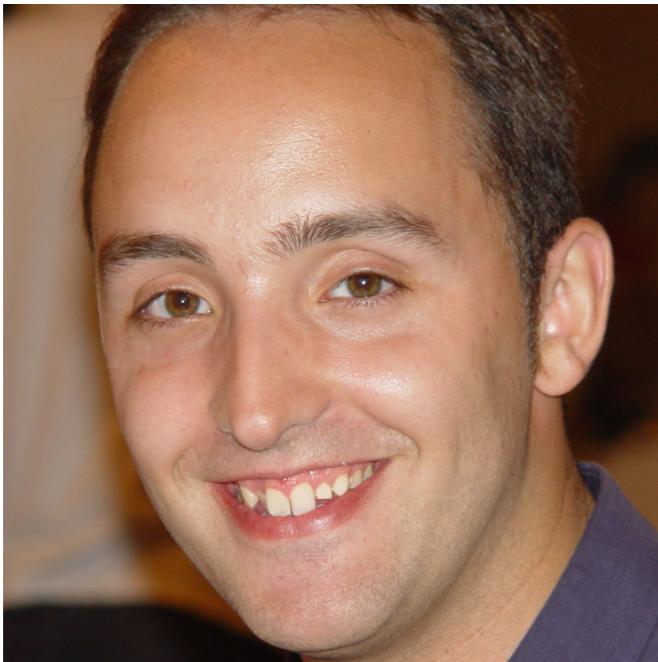


Planning, Learning and Decision Making

Course overview

Faculty



Francisco S. Melo

OFFICE TIME:

- **Tuesday, 14h00-15h30**
- **Friday, 9h30-11h00**

Faculty



OFFICE TIME:

- **Tuesday, 9h30-11h00**

Alberto Sardinha

Faculty



João Ribeiro

OFFICE TIME:

- **Monday, 10h00-11h30**

Faculty



Miguel Faria

OFFICE TIME:

- **Wednesday, 9h00-10h30**

Faculty



OFFICE TIME:

- Thursday, 9h00-10h30

Miguel Vasco

Faculty



OFFICE TIME:

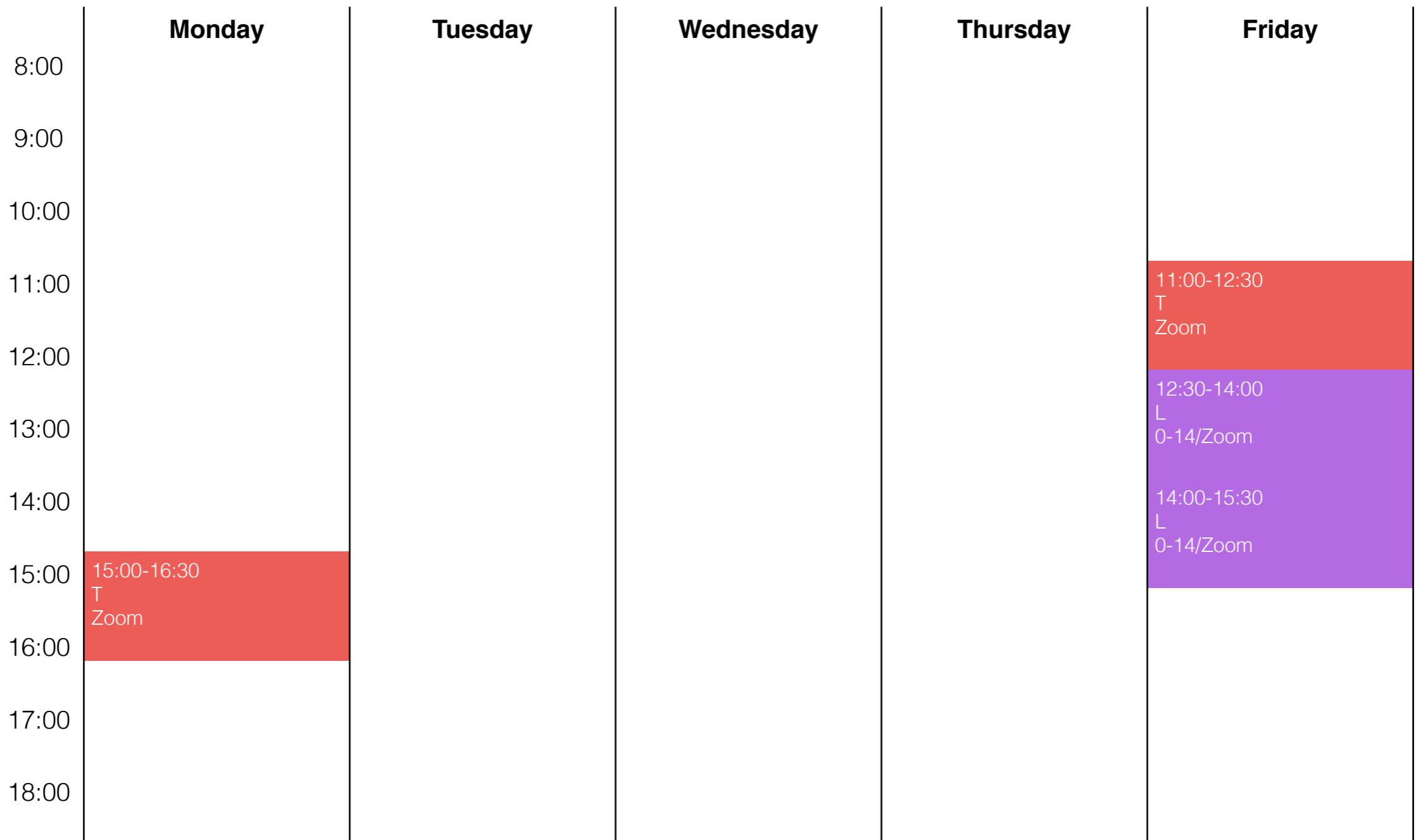
- Friday, 8h00-9h30

Diogo Carvalho

Schedule (Alameda)

Monday	Tuesday	Wednesday	Thursday	Friday
		8:00-9:30 L LAB 8/Zoom		
	11:00-12:30 L LAB 11/Zoom	11:00-12:30 L LAB 13/Zoom		
	12:30-14:00 T Zoom		12:30-14:00 L LAB 11/Zoom	
			14:00-15:30 T Zoom	
		15:00-16:30 L LAB 13/Zoom	15:30-17:00 L LAB 13/Zoom	
	17:00-18:30 L LAB 11/Zoom			

Schedule (TagusPark)



Schedule (office time)

Contact

padi@padi.tecnico.ulisboa.pt

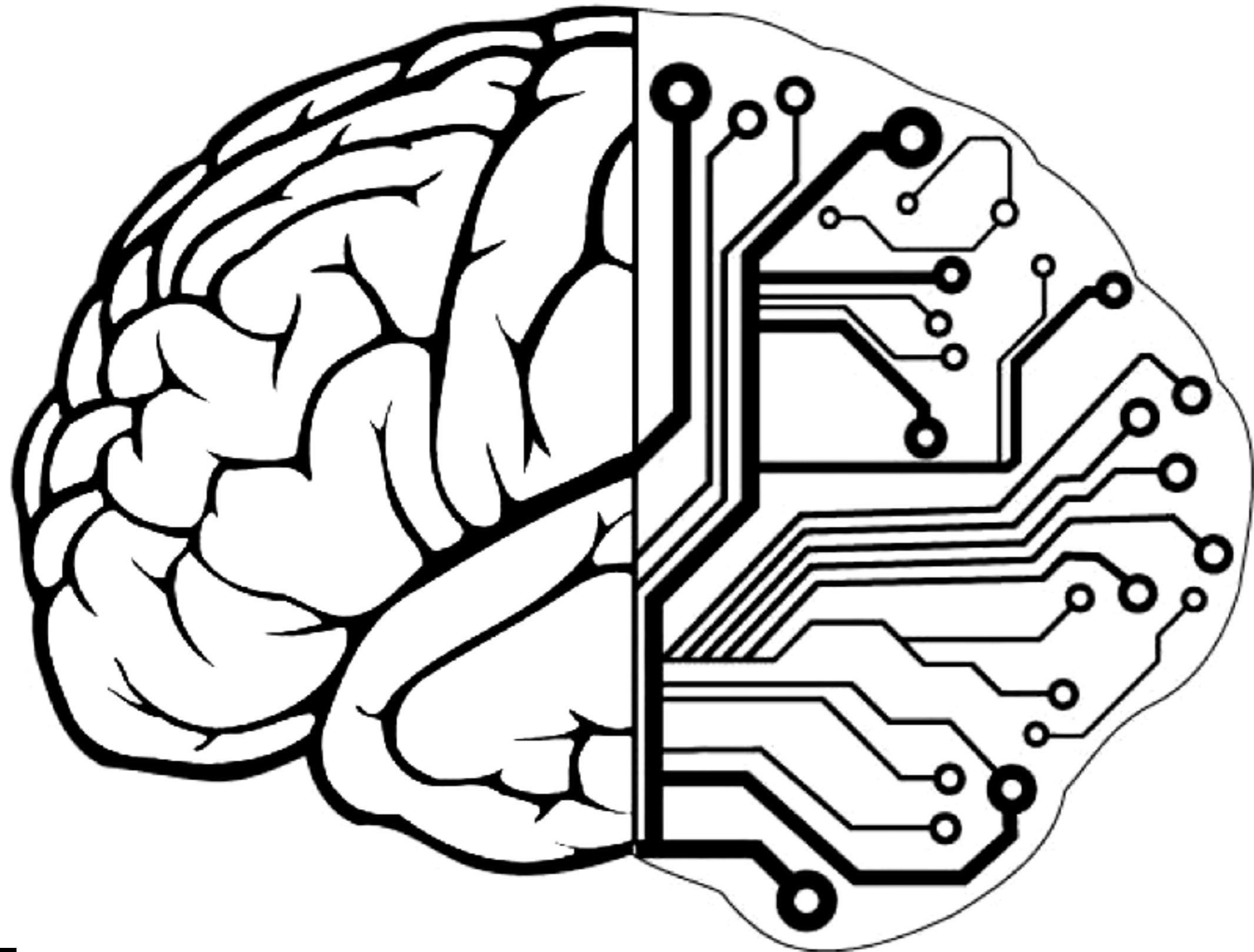
- For matters concerning the “logistics” of the course
- **Questions about course material → office hours.**

“I’m wondering, why are you here?”

-Master Yoda, Star Wars V

Why I am here

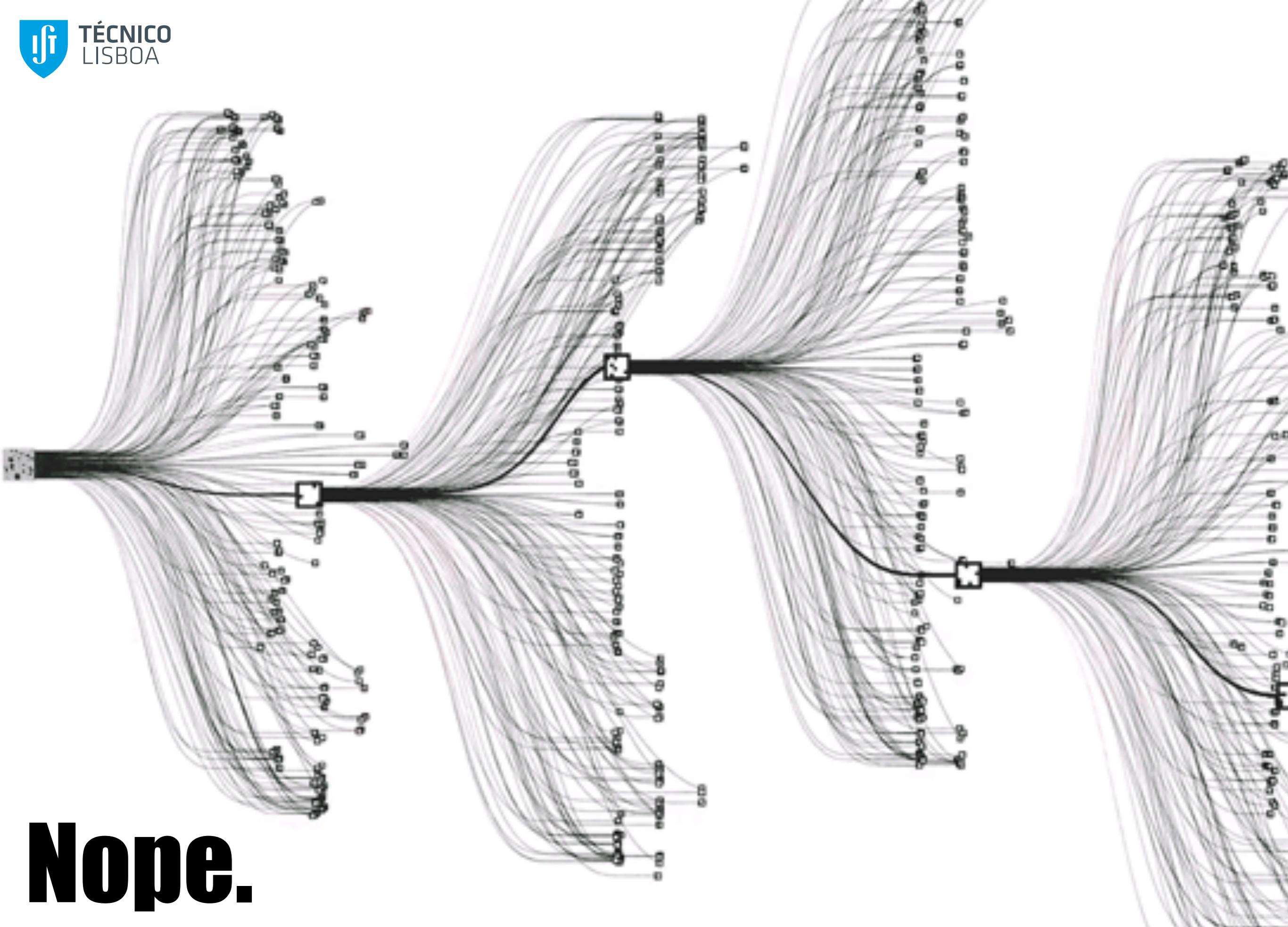




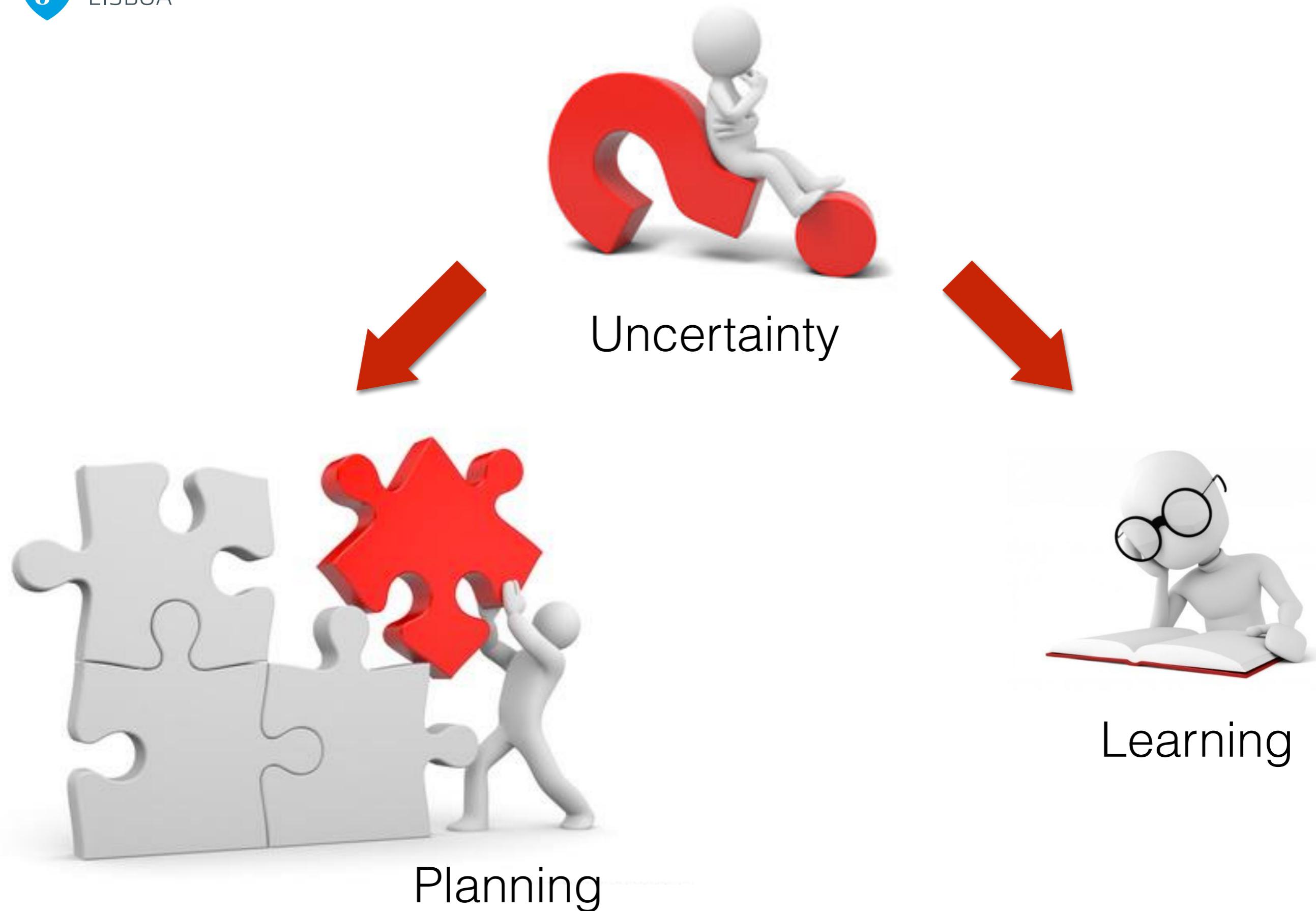
A.I.



Are you talkin' to
ME??



Nope.





DECISION MAKING

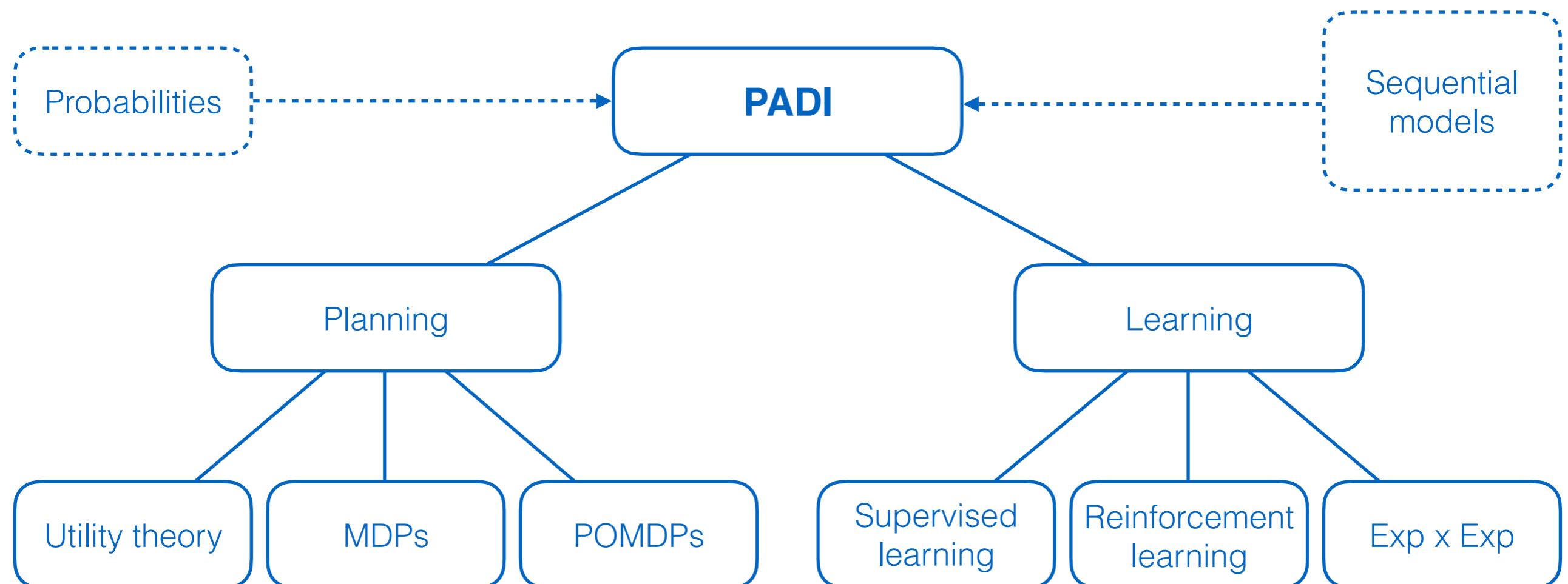
The course



Goals

- Understand the main issues involved in **decision making**, in face of **uncertainty**
- Familiarize with some of the main tools for **planning** and **learning** in such settings

Learning and Decision Making



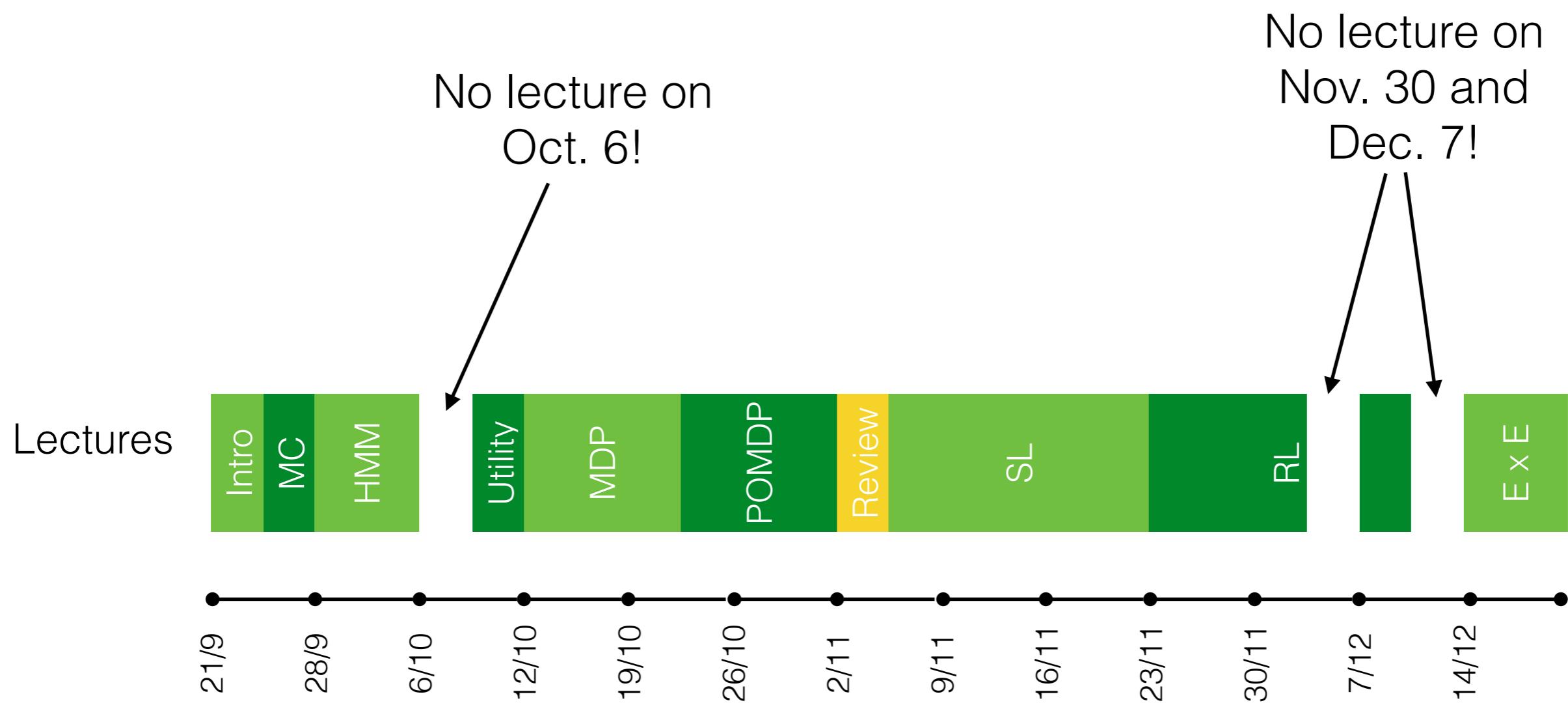
Syllabus

- **Introduction**
 - Chance and uncertainty
 - Modeling sequential processes
- **Decision making**
 - Making simple decisions
 - Sequential decision problems
 - Deciding with incomplete information
- **Learning**
 - Learning from examples
 - Learning by trial and error
 - Predictions, gambling and luck
- **Applications**

Syllabus

- **Introduction**
 - Review of probabilities
 - Markov chains and hidden Markov models
- **Decision making**
 - Utility theory
 - Markov decision problems
 - Partially observable Markov decision problems
- **Learning**
 - Supervised learning
 - Reinforcement Learning
 - Exploration vs. exploitation
- **Applications**

Lecture plan

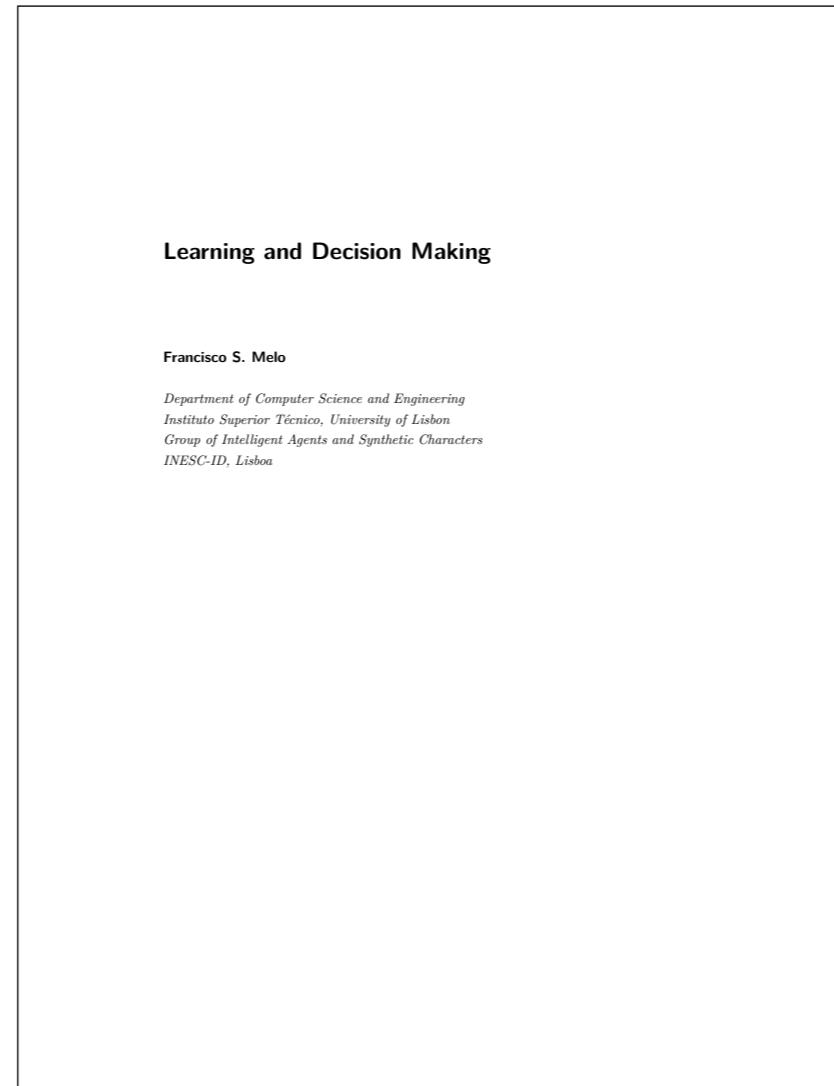


Bibliography



Bibliography

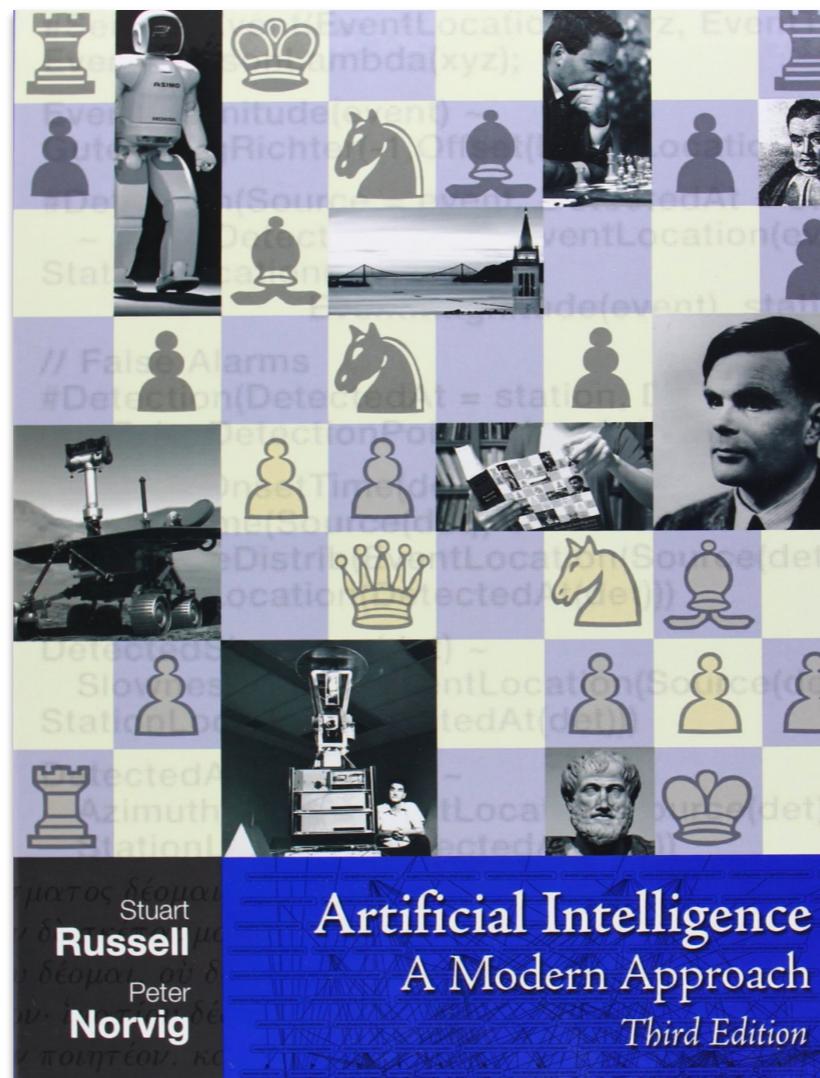
- Main reference:



Updated version from last year

Bibliography

- You can also find most material here



Some topics not covered

Variable level of detail in presentation

Different notation

Other support material

Support material · Learning and Intelligent Decision-Making · Francisco

<https://fenix.tecnico.ulisboa.pt/disciplinas/PADInt./2018-2019/1-semestre/material-de-apoio>

GMAIL Calendar Google Drive DEI Drive Scholar Fénix PADI Caixa Directa Sci-hub RLDM Music AI & Computers Starbucks login

Other Bookmarks

 TÉCNICO LISBOA

Learning and Intelligent Decision-Making PT / EN

Support material

Please find below the lecture notes chapters regarding the material already covered. If you spot any typos or errors, please point them out to [Prof. Francisco Melo](#). As a reward, you will be mentioned in the acknowledgements of the published version of the book.

- Introduction
- Markov chains
- Hidden Markov models
- Utility theory
- Markov decision problems
- Partially observable Markov decision problems
- Supervised learning
- Reinforcement learning (excerpt from the book "RL: An Introduction", by R. Sutton and A. Barto, 2018)
- Exploration vs. exploitation
- Appendices (background)

Lecture notes (chapters)

Slides

- Slides lecture 1 ([introduction, probabilities](#))
- Slides lecture 2 ([Markov chains](#))
- Slides lecture 3 ([HMMs](#))
- Slides lecture 4 ([FB and Viterbi algorithms](#))
- Slides lecture 5 ([utility theory](#))
- Slides lecture 6 ([MDPs](#))
- Slides lecture 7 ([MDPs - continued](#))
- Slides lecture 8 ([MDPs - continued](#))
- Slides lecture 9 ([POMDPs](#))
- Slides lecture 10 ([POMDPs - continued](#))
- Slides lecture 11 ([POMDPs - continued](#))
- Slides lecture 12 ([supervised learning](#))
- Slides lecture 13 ([supervised learning - continued](#))

Initial Page

Groups

Evaluations

Bibliographic References

Schedule

Evaluation Methods

Objectives

Planning

Syllabus

Shifts

Announcements

Summaries

Marks

Support material

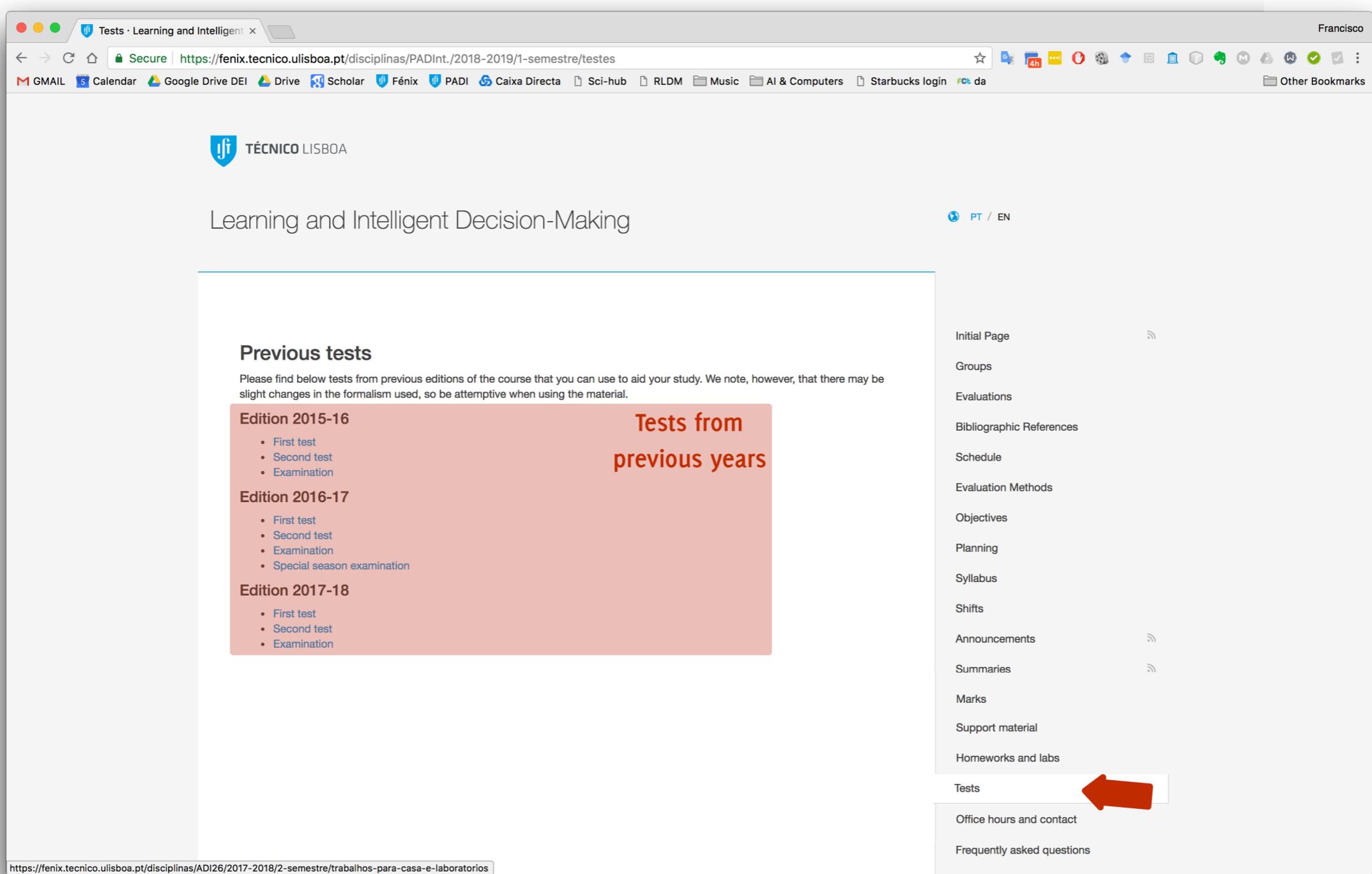
Homeworks and labs 

Tests

Office hours and contact

Frequently asked questions

Other support material



The screenshot shows a web browser window for 'Tests - Learning and Intelligent Decision-Making'. The URL is <https://fenix.tecnico.ulisboa.pt/disciplinas/PADInt./2018-2019/1-semestre/testes>. The page title is 'Learning and Intelligent Decision-Making'. The sidebar on the right lists various course topics: Initial Page, Groups, Evaluations, Bibliographic References, Schedule, Evaluation Methods, Objectives, Planning, Syllabus, Shifts, Announcements, Summaries, Marks, Support material, Homeworks and labs, Tests (highlighted with a red arrow), Office hours and contact, and Frequently asked questions.

Initial Page

Groups

Evaluations

Bibliographic References

Schedule

Evaluation Methods

Objectives

Planning

Syllabus

Shifts

Announcements

Summaries

Marks

Support material

Homeworks and labs

Tests

Office hours and contact

Frequently asked questions

Previous tests

Please find below tests from previous editions of the course that you can use to aid your study. We note, however, that there may be slight changes in the formalism used, so be attemptive when using the material.

Edition 2015-16

- First test
- Second test
- Examination

Edition 2016-17

- First test
- Second test
- Examination
- Special season examination

Edition 2017-18

- First test
- Second test
- Examination

Tests from previous years

<https://fenix.tecnico.ulisboa.pt/disciplinas/ADI26/2017-2018/2-semestre/trabalhos-para-casa-e-laboratorios>

Other support material

Frequently asked questions · L x Francisco

Secure | <https://fenix.tecnico.ulisboa.pt/disciplinas/ADI26/2017-2018/2-semestre/perguntas-frequentes>

GMAIL Calendar Google Drive DEI Drive Scholar Fénix PADI Caixa Directa Sci-hub RLDM Music AI & Computers Starbucks login FCL da Other Bookmarks

TÉCNICO LISBOA

Learning and Intelligent Decision-Making PT / EN

General:

- **How do we submit the homeworks?**

Homeworks are submitted in pdf during the corresponding lab to the e-mail address included in the lab handout (to be provided). The pdf should contain your answer, either handwritten or typeset, but you should make sure that it is **clear and legible**.

The right way

b)
 seja $\ell(D, \pi) = \sum_{n=1}^N a_n \log(\pi(x, w) + (1-a_n) \log(1-\pi(x, w)))$

Queremos

$$\text{gradient} = \frac{\delta}{\delta w} \ell(D, \pi)$$

Cálculos auxiliares:

$$\log\left(\frac{1}{1+e^{-w^T x}}\right) = 0 - \log(1+e^{-w^T x})$$

$$\frac{\delta}{\delta w} (-\log(1+e^{-w^T x})) = \frac{x e^{-w^T x}}{1+e^{-w^T x}} = x \left(1 - \frac{1}{1+e^{-w^T x}}\right)$$

$$\log\left(1 - \frac{1}{1+e^{-w^T x}}\right) = -w^T x - \log(1+e^{-w^T x})$$

$$\frac{\delta}{\delta w} \log\left(1 - \frac{1}{1+e^{-w^T x}}\right) = -x + x \left(1 - \frac{1}{1+e^{-w^T x}}\right) = -\frac{x}{1+e^{-w^T x}}$$

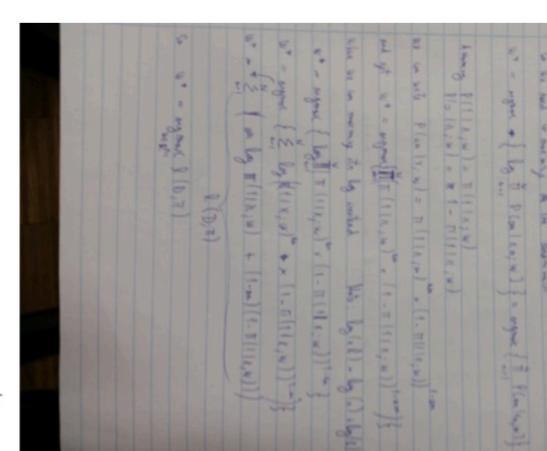
$$\frac{\delta}{\delta w} \ell(D, \pi) = \sum_{n=1}^N a_n x_n \left(1 - \frac{1}{1+e^{-w^T x}}\right) - (1-a_n) x_n \frac{1}{1+e^{-w^T x}}$$

$$= \sum_{n=1}^N a_n x_n - a_n x_n \frac{1}{1+e^{-w^T x}} - x_n \frac{1}{1+e^{-w^T x}} + a_n x_n \frac{1}{1+e^{-w^T x}}$$

$$= \sum_{n=1}^N a_n x_n - x_n \frac{1}{1+e^{-w^T x}}$$

$$= \sum_{n=1}^N x_n \left(a_n - \frac{1}{1+e^{-w^T x}}\right) \quad \text{substituindo novamente}$$

The wrong way



Initial Page Groups Evaluations Bibliographic References Schedule Evaluation Methods Objectives Planning Syllabus Shifts Announcements Summaries Marks Homeworks and labs Support material Tests Office hours and contact Frequently asked questions

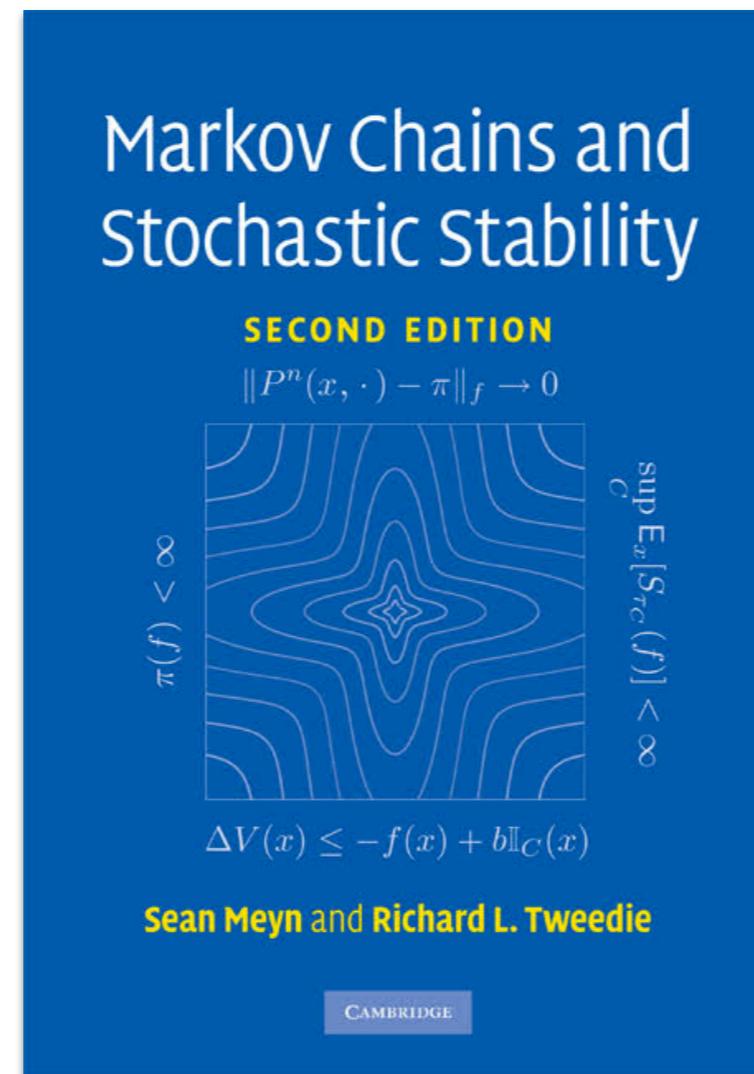
A red arrow points from the "Frequently asked questions" link back to the top left of the page.

Bibliography



Bibliography

- Markov chains

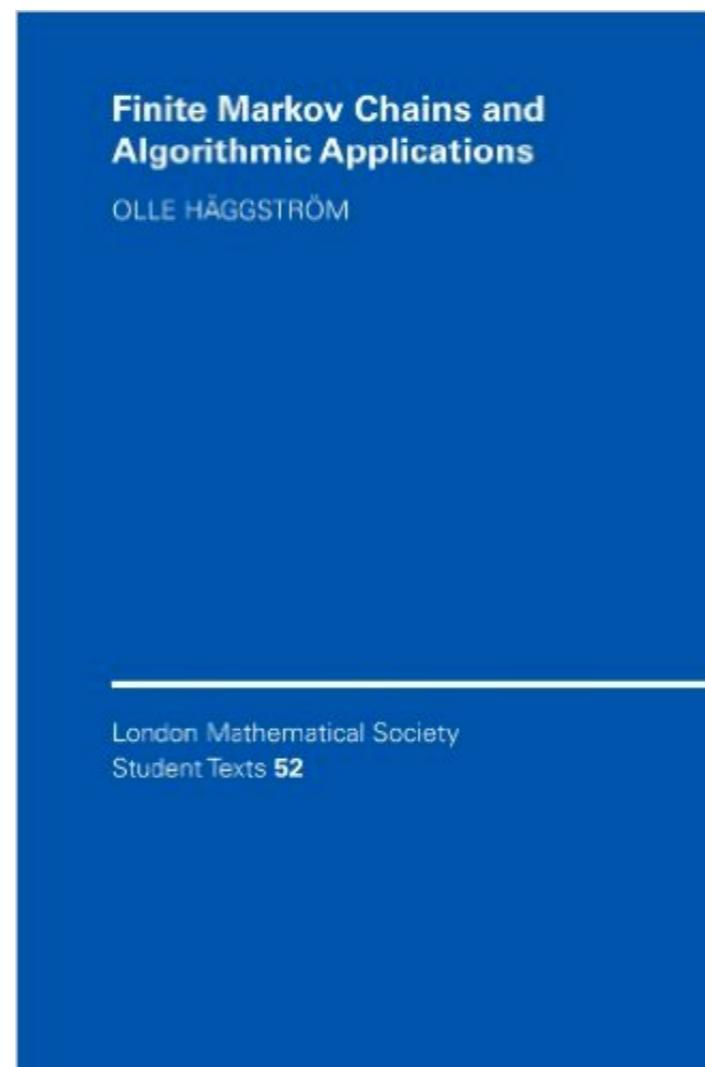


Very complete — focus on stability

Hard core math

Bibliography

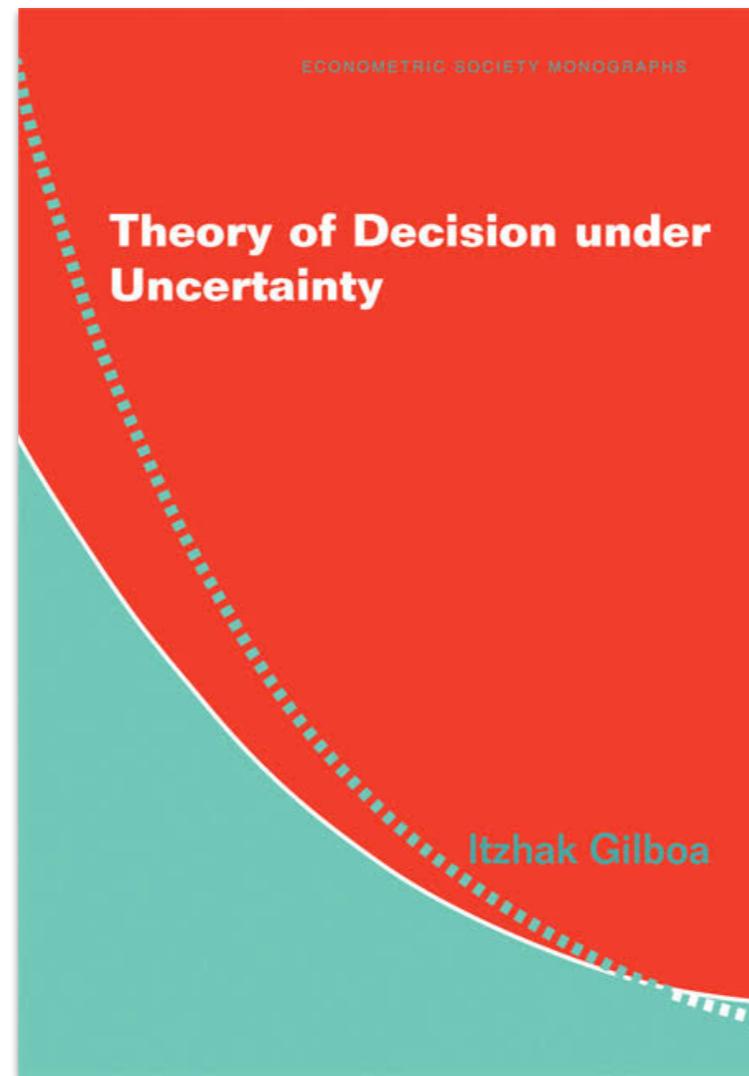
- Hidden Markov models



Accessible and complete
Focus on algorithms and sampling

Bibliography

- Utility theory

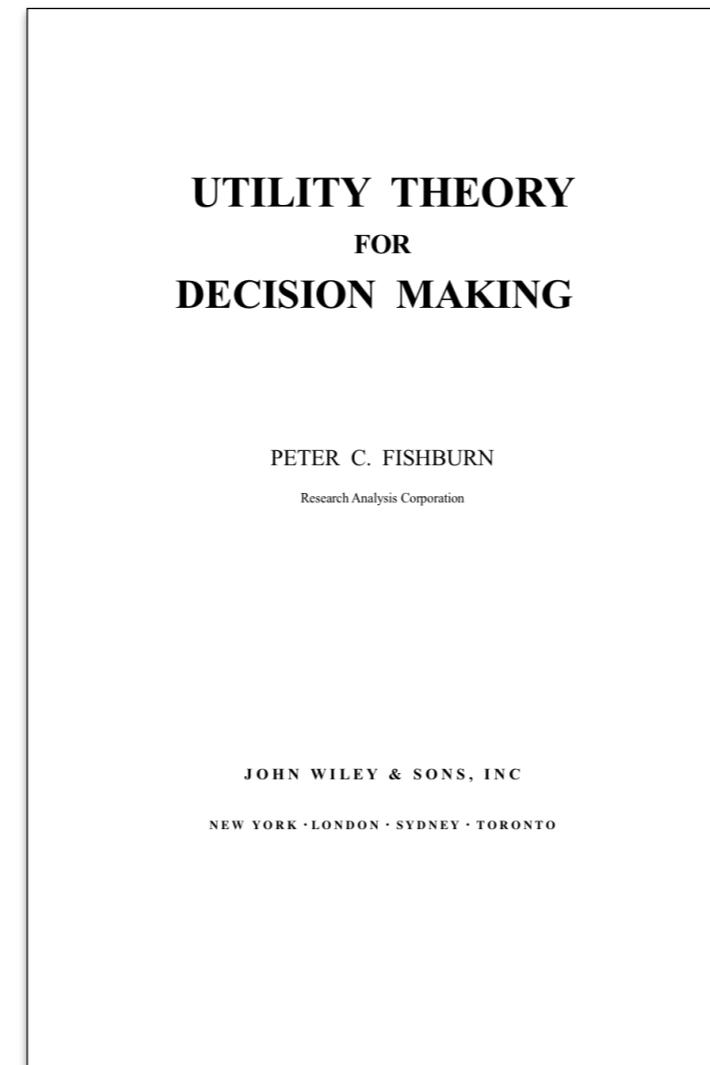


Not very mathematical

More philosophical — very interesting

Bibliography

- Utility theory

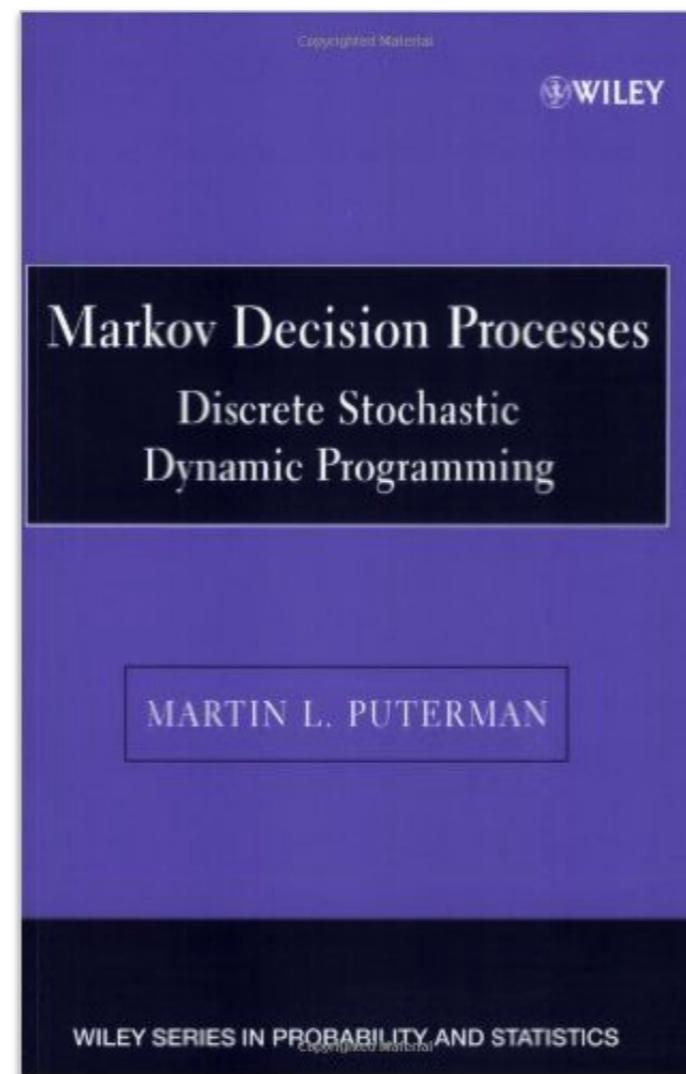


Classical text

Very complete — and very mathematical

Bibliography

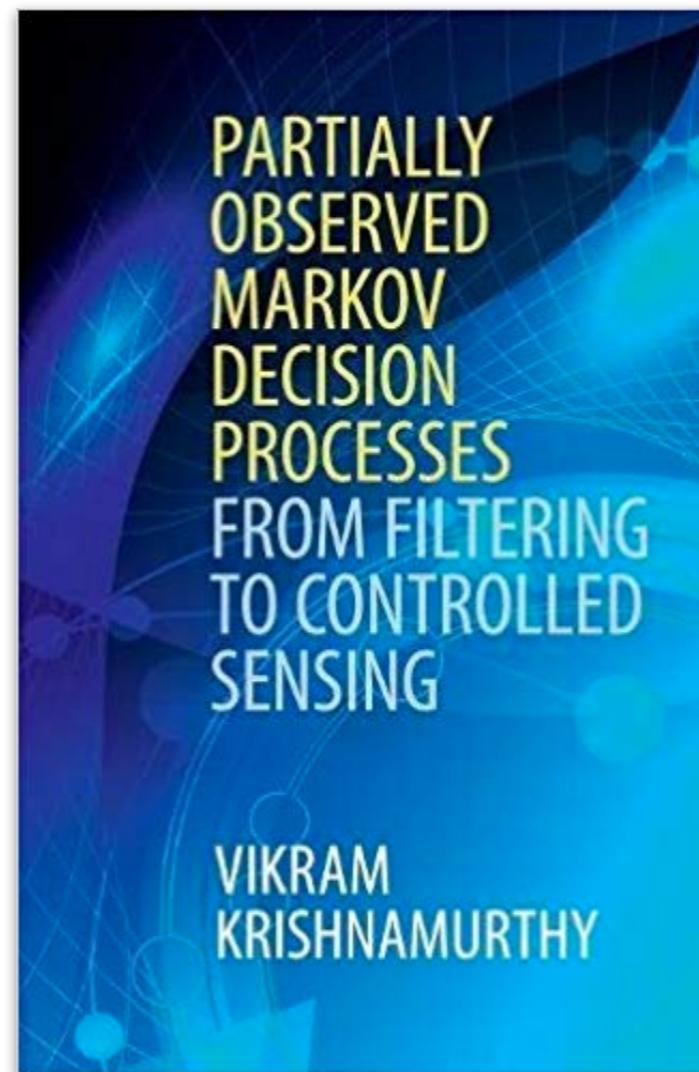
- Markov decision problems



THE reference

Bibliography

- Partially observable MDPs

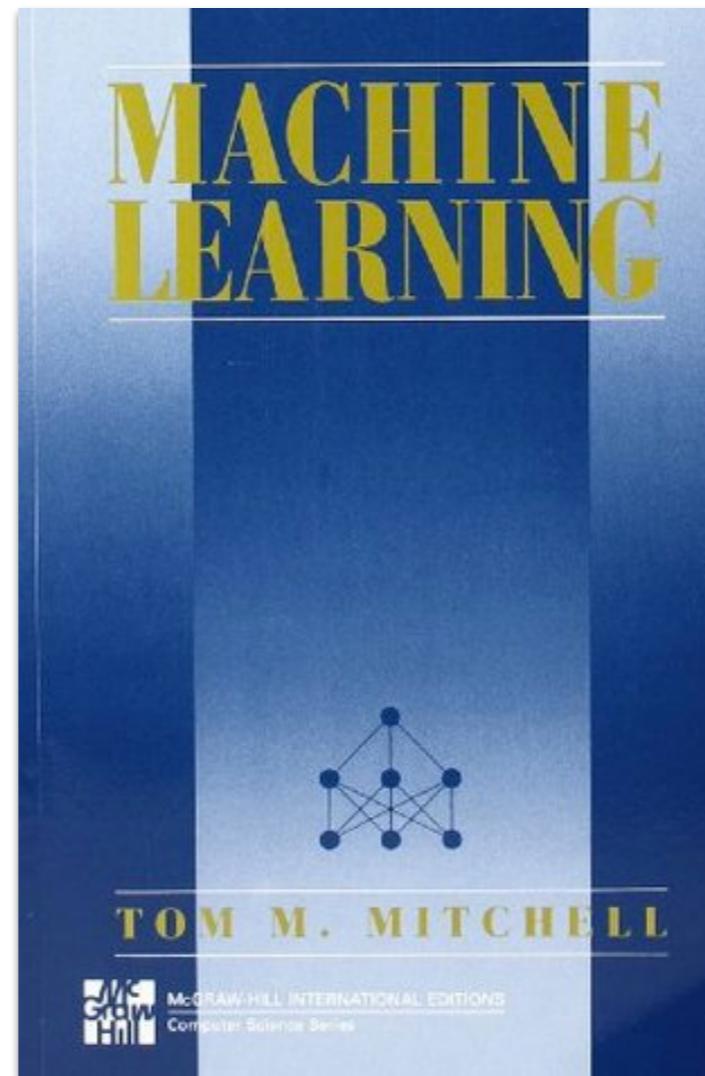


Covers **a lot** more than we need

Somewhat math intensive

Bibliography

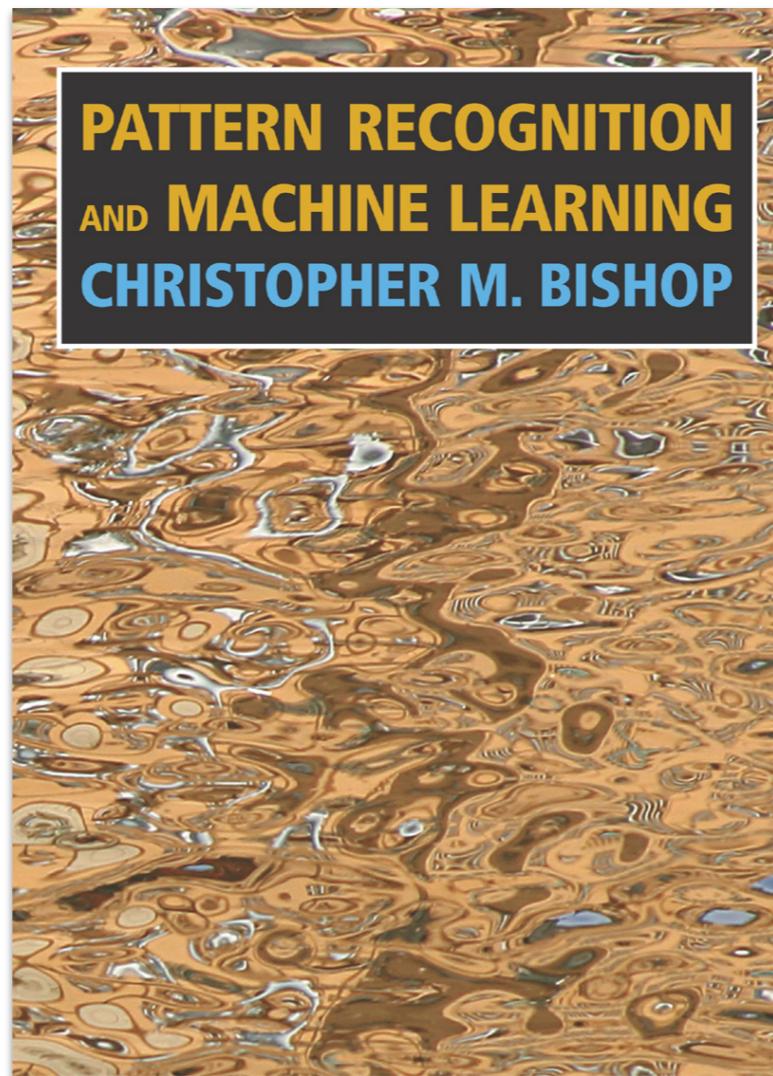
- Supervised learning



Great introductory book
Very accessible
Somewhat outdated

Bibliography

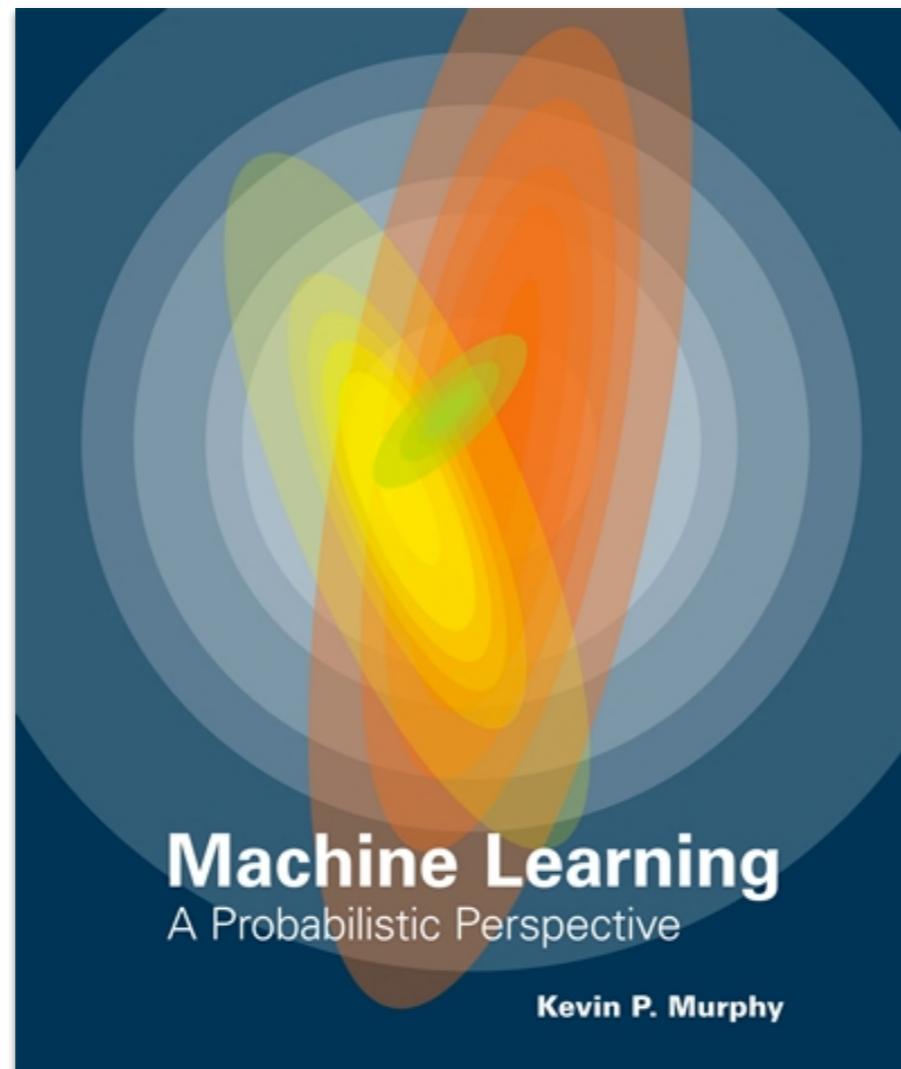
- Supervised learning



One of the best books (in my opinion)

Bibliography

- Supervised learning



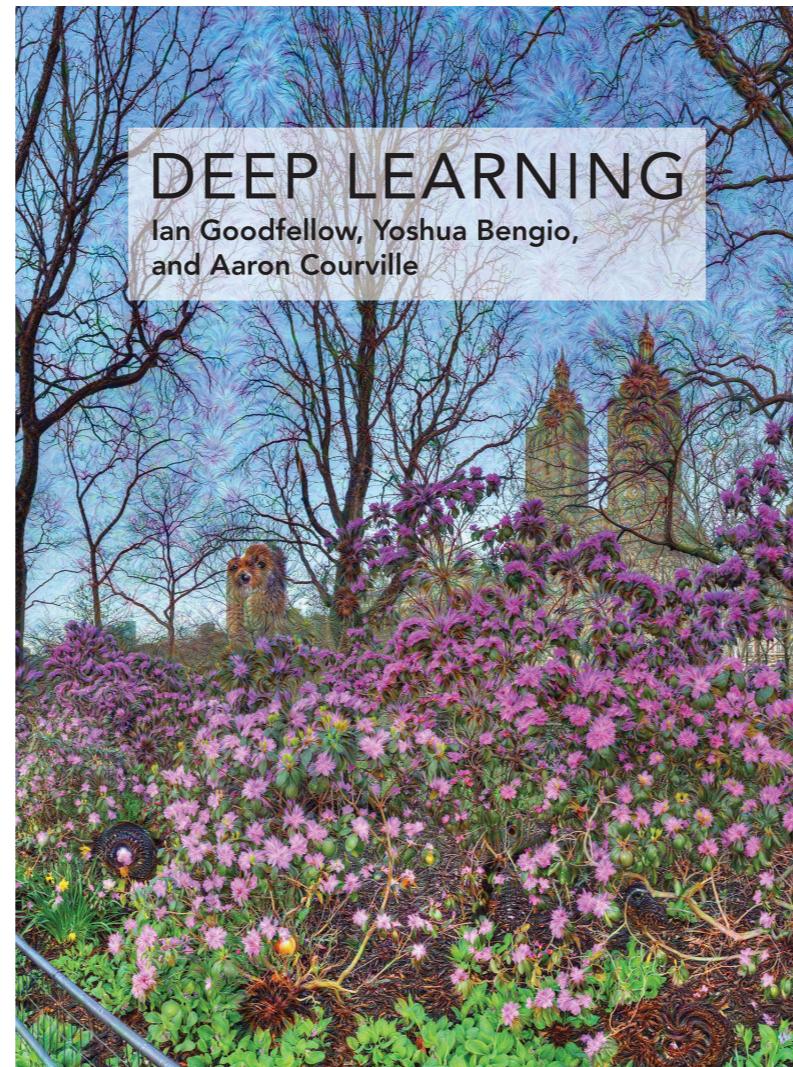
Very complete

Very up-to-date

Variable level of detail

Bibliography

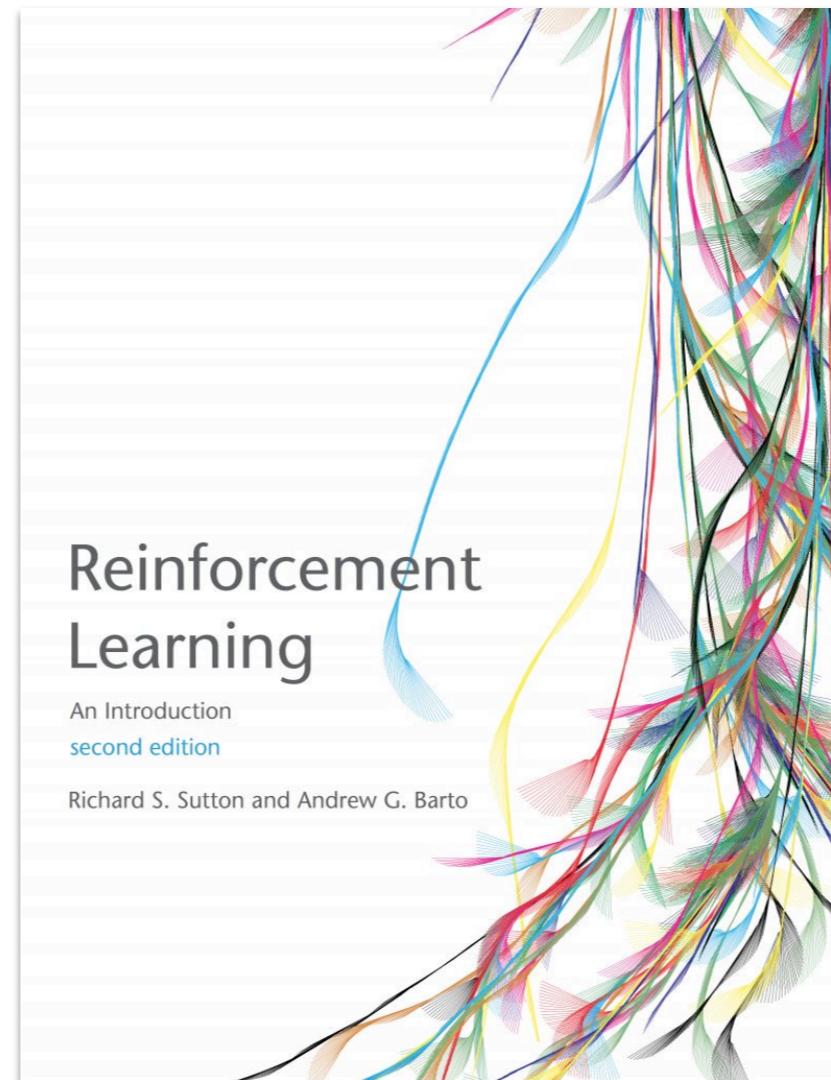
- Supervised learning



For those more “trendy”
Great reference
Available online

Bibliography

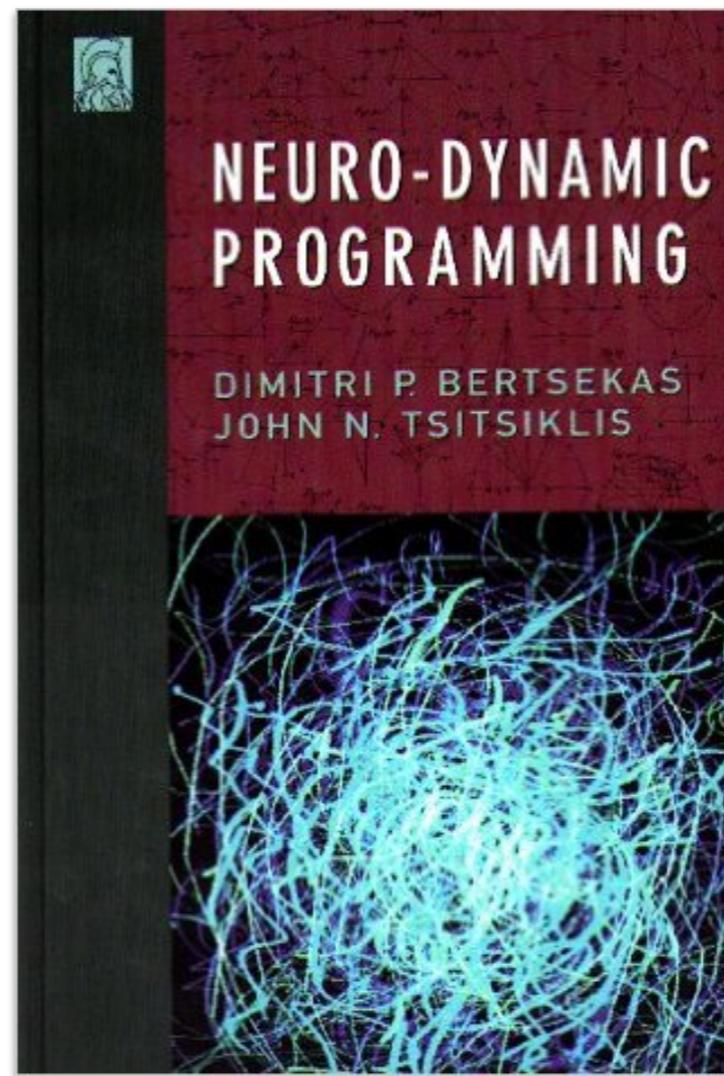
- Reinforcement learning



Great introduction
New edition

Bibliography

- Reinforcement learning

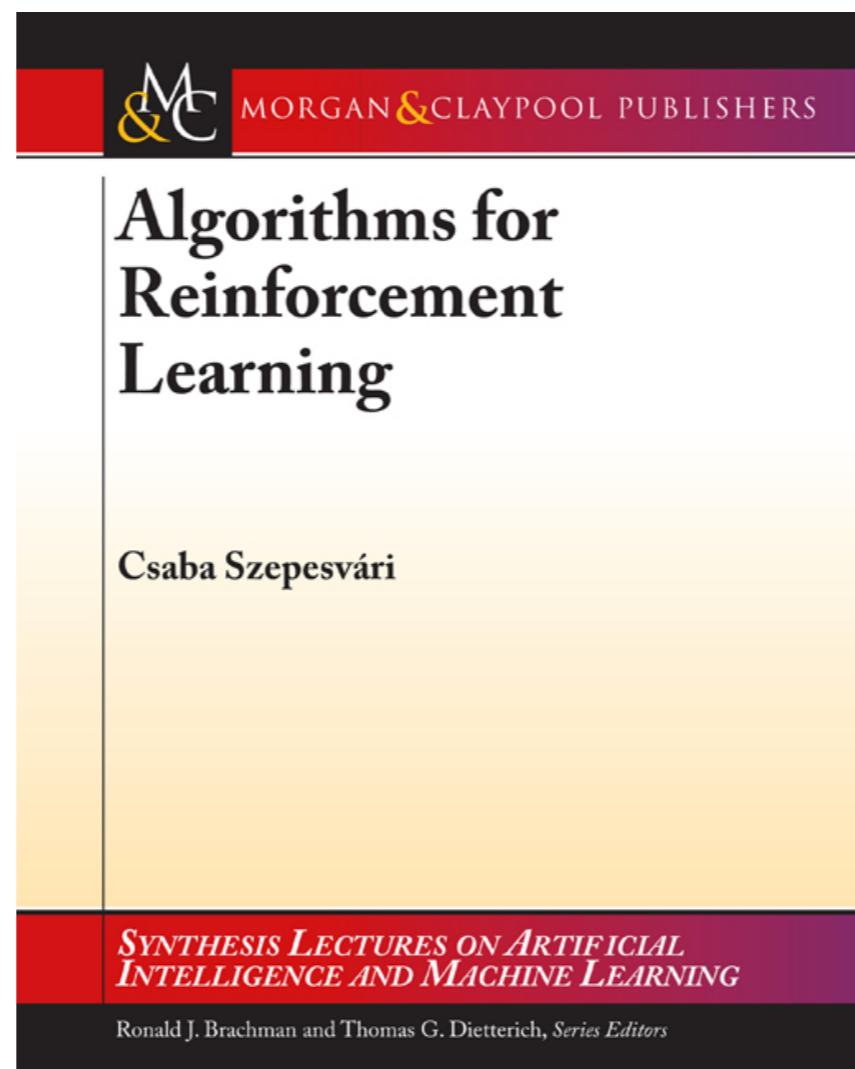


More in-depth coverage

Very mathematical

Bibliography

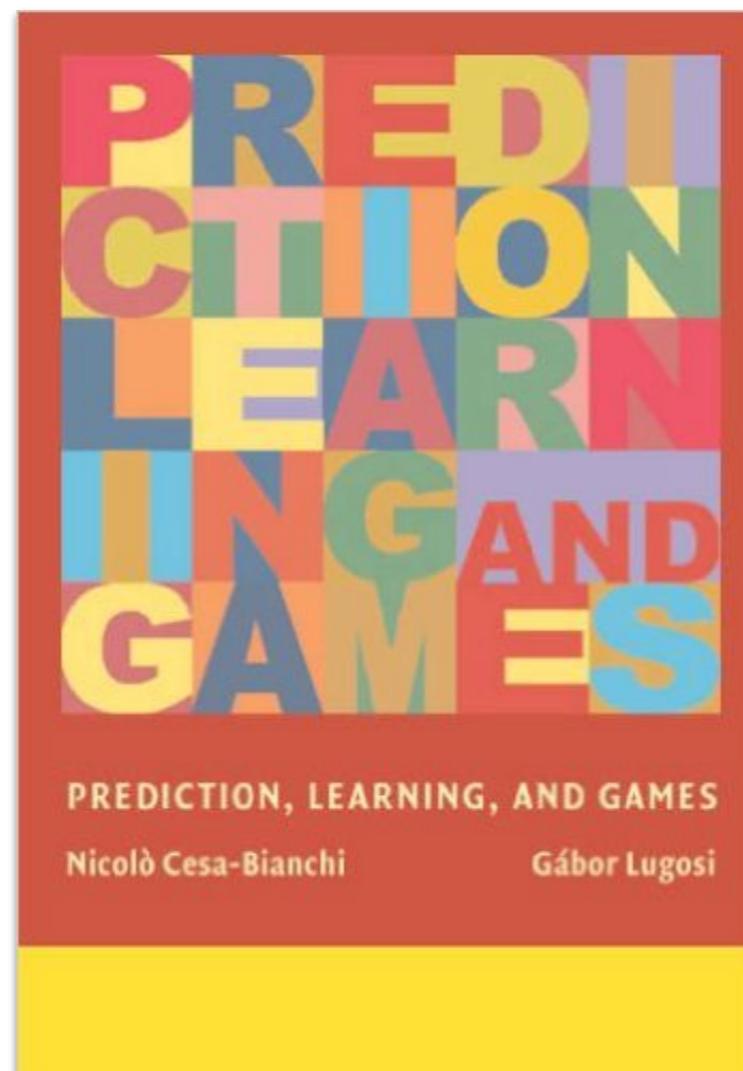
- Reinforcement learning



Up-to-date reference
Very concise

Bibliography

- Exploration vs exploitation



Very complete and unified

Somewhat hard to parse

Very mathematical

Bibliography



Labs



Labs

- Work in groups
- 2 people (no more, no less)
- Groups are defined upon registration

Lab registration

- Through Fenix, 23/09/2019 (9.00-17.00)
- Registrations work in a first come - first served basis
- You must register **the group**
(individual registrations not possible)
- Ideal group should have a **student A** and a **student B**

Lab registration

- If you don't have a group, we will find you a group, but you will be subject to the shifts available at the time
- If you have schedule limitations, you should be pro-active and try to find a group by yourself

Lab registration

No group registrations:

- Thursday, 24/09, 12h30-14h00
- Zoom link for registration will be made available in the course's webpage

Labs

- Total of **5 lab assignments**, each with one specific topic
- Each lab assignment includes:
 - **1 (one) homework task**, completed during the week before, in preparation for the lab
 - **2 (two) lab sessions**, where you do the actual lab work

Labs

- At the end of a lab assignment, you will have submitted:
 - Answer to homework in **pdf** format (by the end of **first lab session**)
 - Lab work as in **.py** format (by the end of the **second lab session**)

Items submitted in formats other than those above **will not be graded**

Homework

b)

$$\text{seja } \ell(D, \pi) = \sum_{n=1}^N a_n \log \pi(z|x, w) + (1-a_n) \log(1-\pi(z|x, w))$$

Queremos

$$\text{gradiente} = \frac{\delta}{\delta w} \ell(D, \pi)$$

Calculos auxiliares:

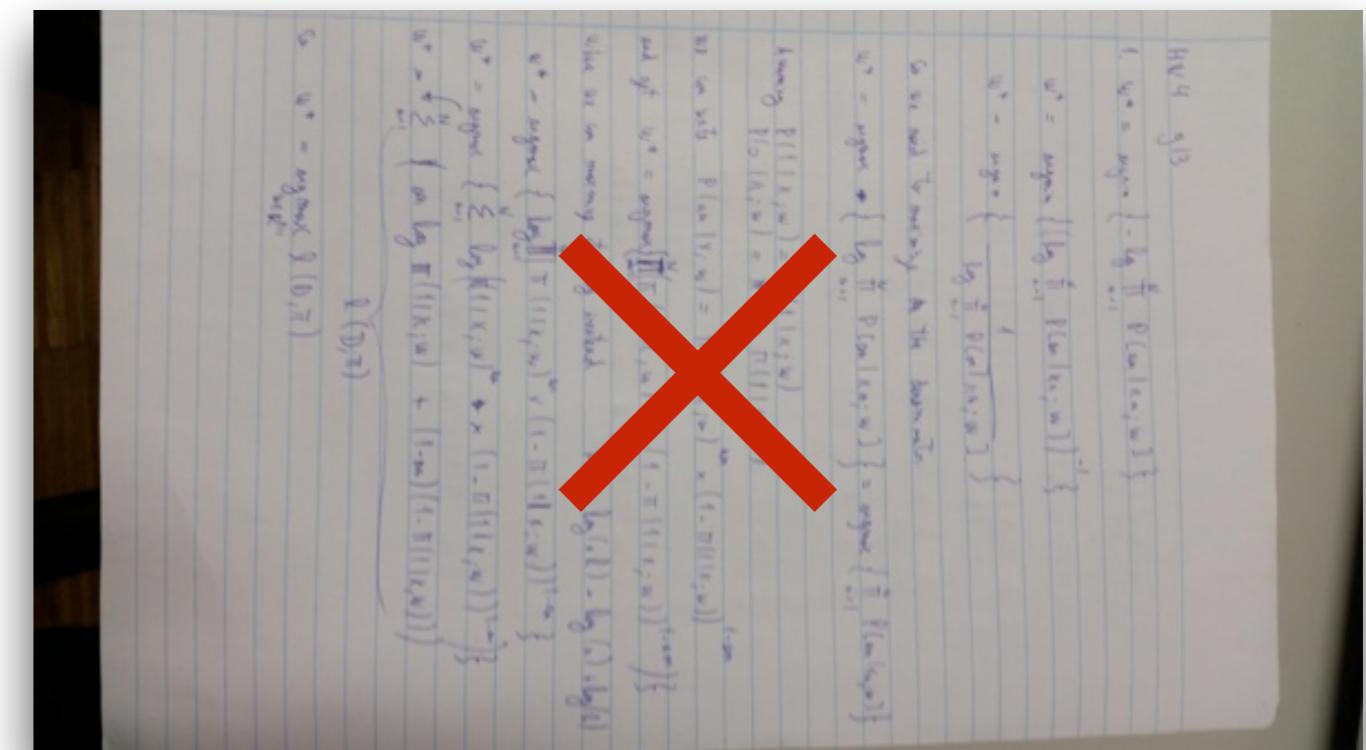
$$\log \left(\frac{1}{1+e^{-w^T x}} \right) = 0 - \log(1+e^{-w^T x})$$

$$\frac{\delta}{\delta w} (-\log(1+e^{-w^T x})) = \frac{x e^{-w^T x}}{1+e^{-w^T x}} = x \left(1 - \frac{1}{1+e^{-w^T x}} \right)$$

$$\log \left(1 - \frac{1}{1+e^{-w^T x}} \right) = -w^T x - \log(1+e^{-w^T x})$$

$$\frac{\delta}{\delta w} \log \left(1 - \frac{1}{1+e^{-w^T x}} \right) = -x \cdot \cancel{1} - \frac{1}{1+e^{-w^T x}} \cdot x$$

$$\begin{aligned} \frac{\delta}{\delta w} \ell(D, \pi) &= \sum_{n=1}^N a_n x_n \left(1 - \frac{1}{1+e^{-w^T x}} \right) - (1-a_n) x_n \frac{1}{1+e^{-w^T x}} \\ &= \sum_{n=1}^N a_n x_n - a_n x_n \cancel{\frac{1}{1+e^{-w^T x}}} - x_n \cancel{\frac{1}{1+e^{-w^T x}}} + a_n x_n \cancel{\frac{1}{1+e^{-w^T x}}} \\ &= \sum_{n=1}^N a_n x_n - x_n \frac{1}{1+e^{-w^T x}} = \\ &= \sum_{n=1}^N x_n \left(a_n - \frac{1}{1+e^{-w^T x}} \right), \text{ substituindo novamente} \\ &= \sum_{n=1}^N x_n (a_n - \pi(z|x_n, w)) \quad \text{c.q.d.} \end{aligned}$$

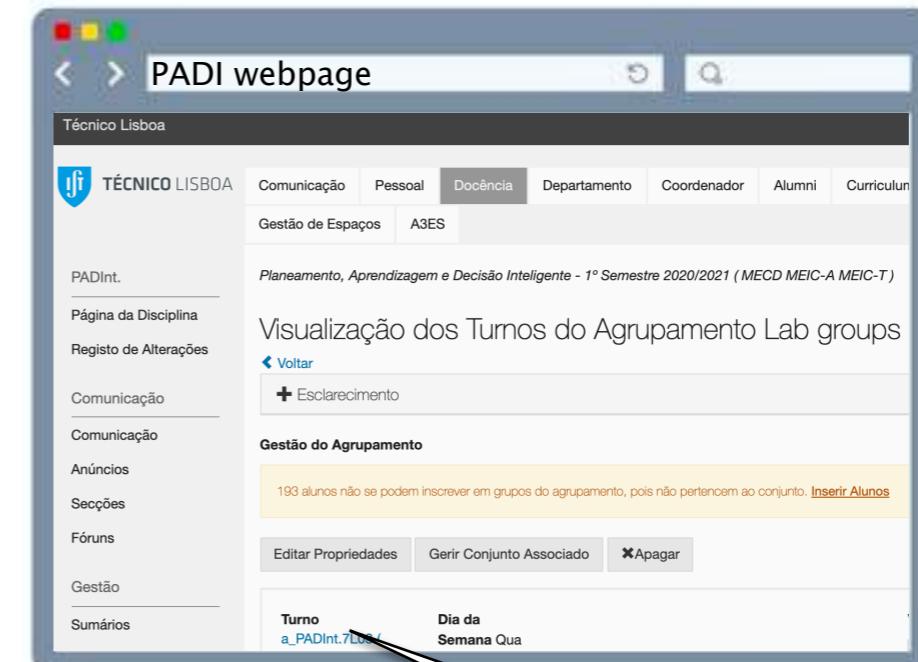


Labs

- Submit to:
 - adi.tecnico@gmail.com
 - Topic: [<group n.>] LAB <lab n.>

**This e-mail is strictly for submissions
(we do not reply to messages sent here)**

Lab attendance



The screenshot shows a web interface for managing lab groups. The top navigation bar includes links for Comunicação, Pessoal, Docência (selected), Departamento, Coordenador, Alumni, and Curriculums. Below this, a sub-menu for 'Gestão de Espaços' and 'A3ES' is visible. The main content area displays a message: 'Planeamento, Aprendizagem e Decisão Inteligente - 1º Semestre 2020/2021 (MECD MEIC-A MEIC-T)'. It then shows 'Visualização dos Turnos do Agrupamento Lab groups' with a 'Voltar' link and an 'Esclarecimento' button. A warning message states: '193 alunos não se podem inscrever em grupos do agrupamento, pois não pertencem ao conjunto. [Inserir Alunos](#)'. Below this are buttons for 'Editar Propriedades', 'Gerir Conjunto Associado', and 'Apagar'. A table header for 'Turno' and 'Dia da Semana Qua' is partially visible.

Shift L1 - Group 1:

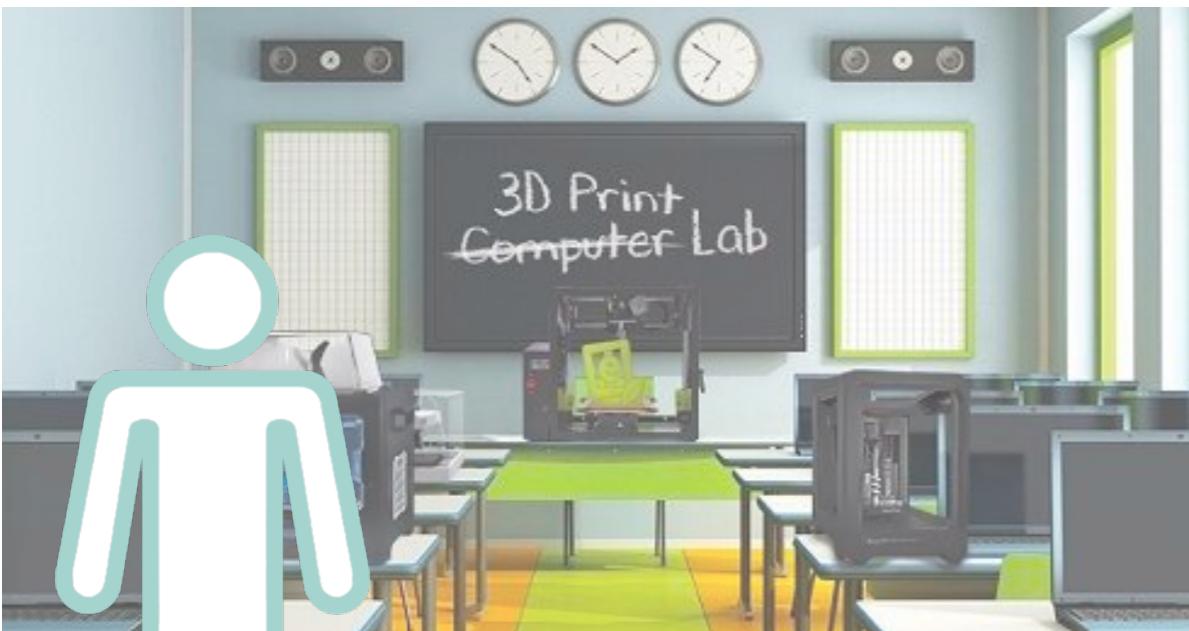
12345

67890

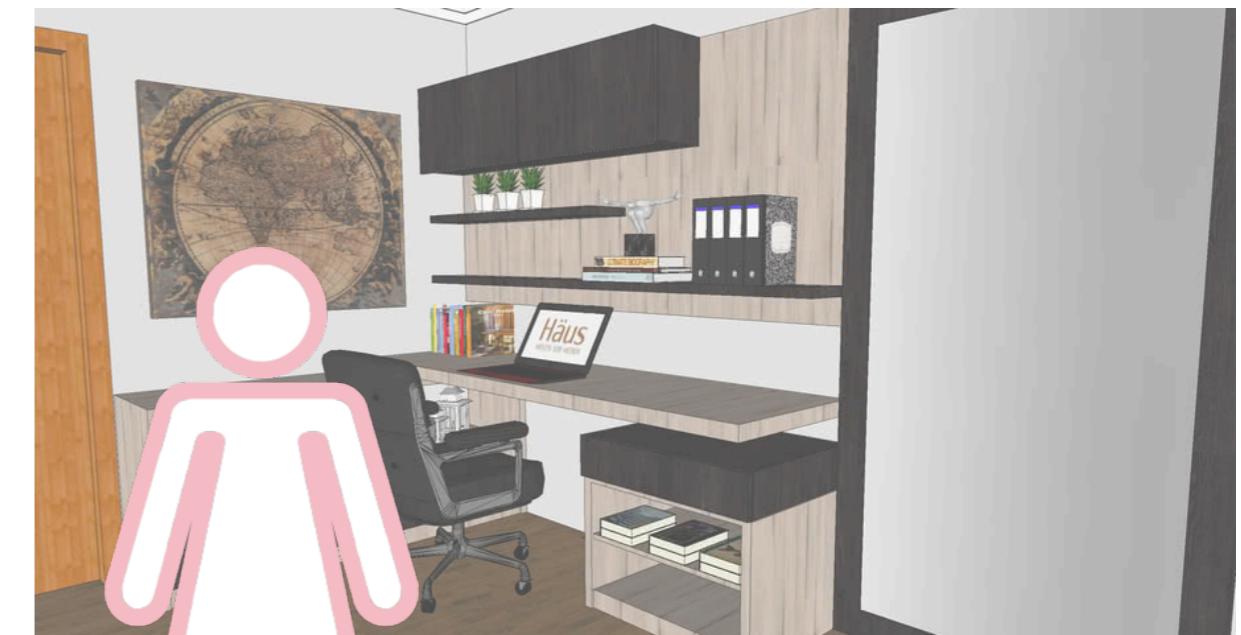
Ignore the distinction between shifts A or B

Lab attendance

- Lab 1, first session



Physically
present at the lab



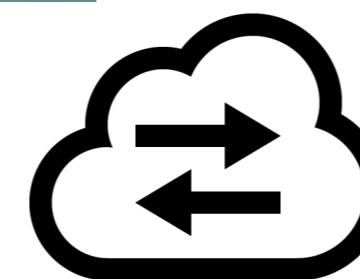
Remotely
connected to the
lab

Lab attendance

- Lab 1, second session



Physically
present at the lab



Remotely
connected to the
lab

Lab attendance

For grading purposes, only those elements submitted by students that attended the corresponding lab session will be considered.



Lab attendance

- Each student is expected to attend 10 lab sessions, 5 physically present, and 5 remotely
- When attending physically, you should attend at least 60 minutes of the class and have the teacher sign your presence;
- When attending remotely, you should attend at least 60 minutes of the class and be present when faculty visits the breakout room

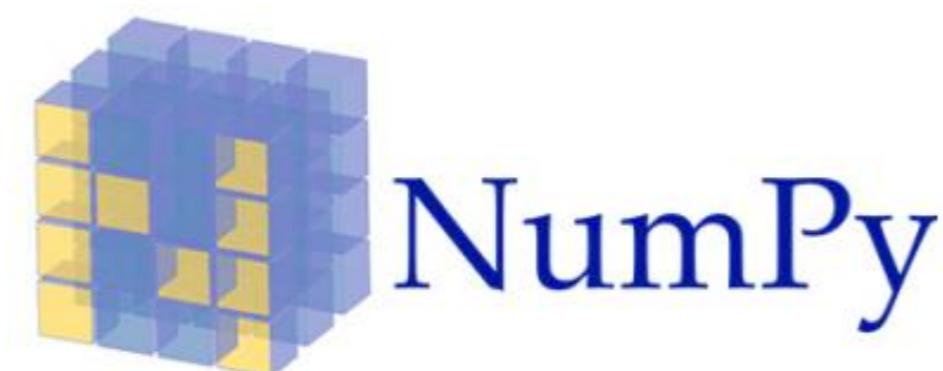
Labs

Homework and lab assignments are to be completed by each group individually. Any cheating will lead to immediate failing of all students involved.



Labs

- Lab “zero” (to do at home)
- Introduction to Python scientific computing



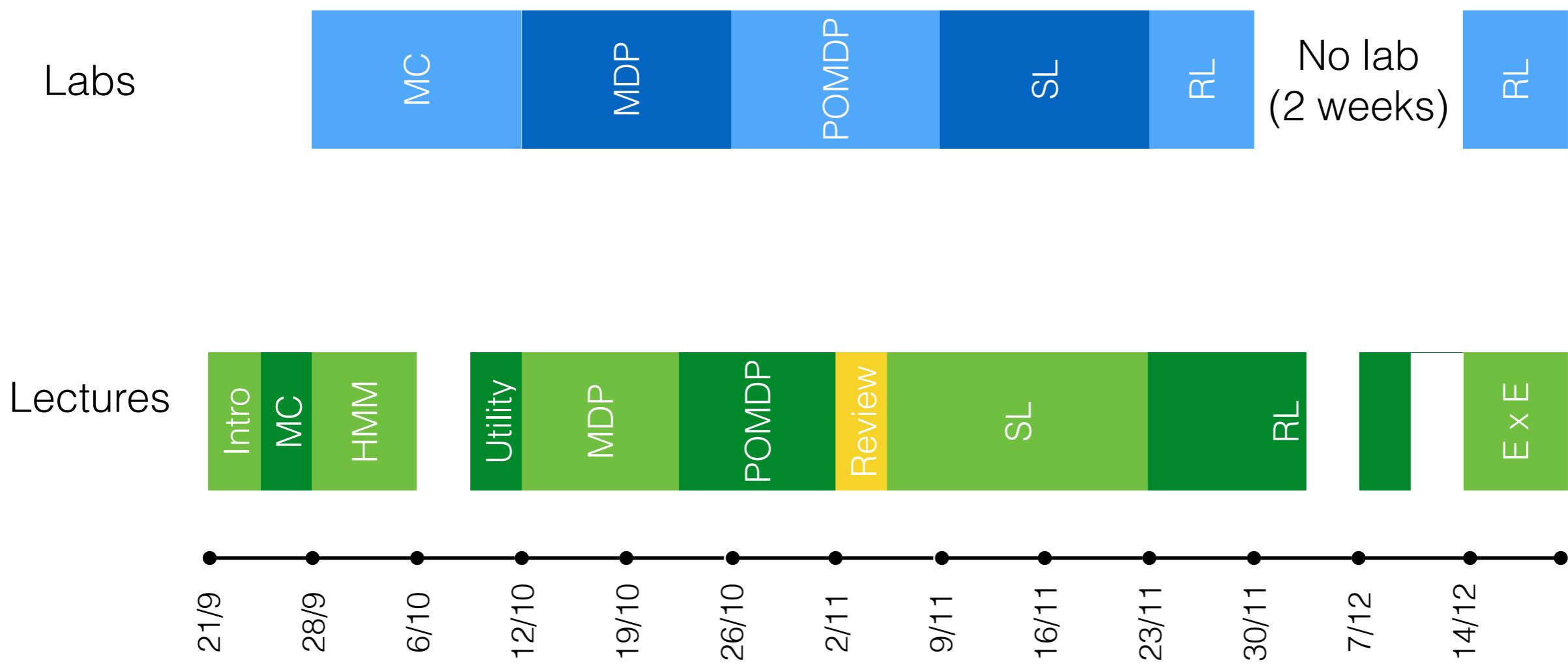
Labs

- To install in your own computer:

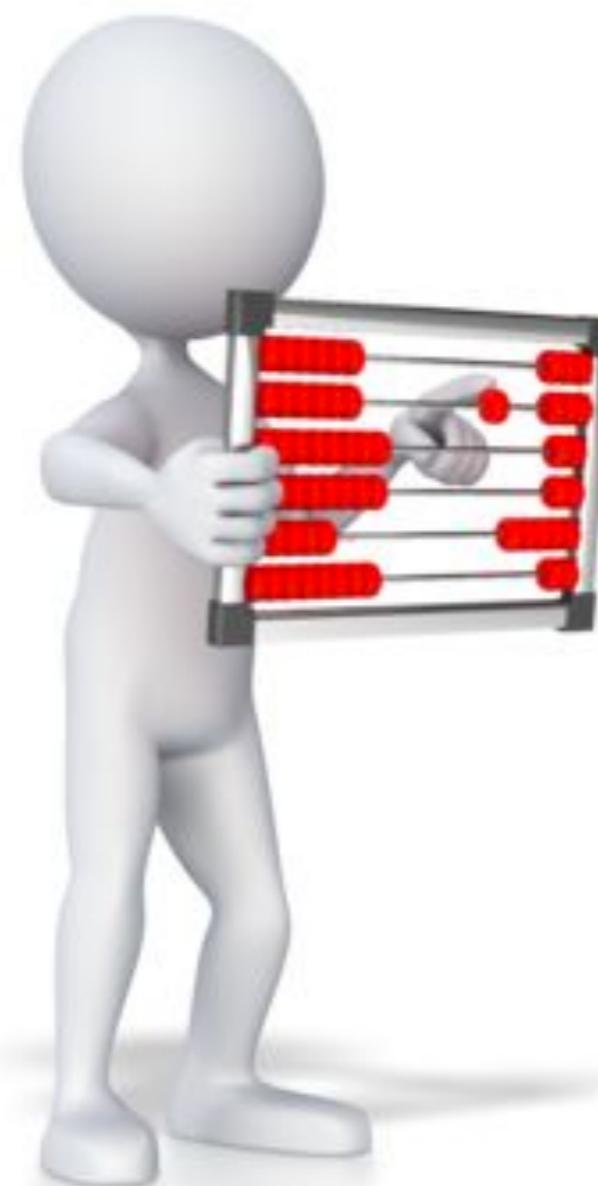


*Note: make sure you use **Python 3** to ensure compatibility with code that may be provided*

Lab plan



Grading



Grading

- Labs (NL)
- Tests (NT)
- The final grade (NF) is computed as:

$$NF = 0.5 \times NL + 0.5 \times NT$$

Grading

- NT is the average test grade:

$$NT = 0.5 \times T1 + 0.5 \times T2$$

Grading

- NL is the average lab grade:

$$NL = (HW1 + \dots + HW5 + L1 + \dots + L5 - M1 - M2) / 4$$

- HW1, ... HW5 are the homework grades (between 1 and 10)
- L1, ... L5 are the lab grades (between 1 and 10)
- M1, M2 are the two worse among HW1, ..., HW5, L1, ..., L5

Grading

- Passing requirements:
 - $NT \geq 8.0$
 - $NL \geq 9.5$
 - $NF \geq 9.5$

Tests

- First test: November 12, 2020 (18:30-20:00)
- Second test: January 26, 2021 (11:30-13:00)
- Repetition: February 10, 2021 (15:00-18:00)

Grading plan

