Artificial Neural Networks/Reinforcement Learning

Wulfram Gerstner

EPFL, Lausanne, Switzerland

Overview of class

Course WEB page: Moodle

Video Lectures:
Several short videos (10-20 min each) on RL
https://www.youtube.com/@gerstnerlab/playlists
Overview of contents of videos:
https://lcnwww.epfl.ch/gerstner/VideoLecturesRL-Gerstner.html

Your notes:

Normally each visible slide is followed by a hidden comment slide.

Overview (planned Version 2024)

1. Intro and RL1: Reinforcement Learning for Bandit problems
2. RL1: Bellman Equation and SARSA
3. RL 2a: Markov Processes and Convergence of SARSA(Dr. Brea)/first python
4. RL2b: Q-Learning, n-step TD learning, continuous space, eligibility traces
5. RL3: TD-learning and Function approximation
6. RL 4: Policy gradient algorithms
7. RL 5: From Policy gradient to Actor-Critic: eligibility traces again

Basic RL

8. Deep RL1: Applications of Model-free Deep RL (Dr. Johanni Brea)
9. Deep RL 2 Applications of Model-based Deep RL (Dr. Johanni Brea)
10a Deep RL3 RL from Human Feedback (Prof Caglar Gulcehre)

Deep RL

10b. Deep RL4: Ethics, AI, and RL
11. RL, Dopamine, and the Brain
12. From Brain-style computing to neuromorphic hardware
13. Surprise and Novelty in RL
14. Curiosity-driven Exploration (Alireza)

Interdisciplinary RL

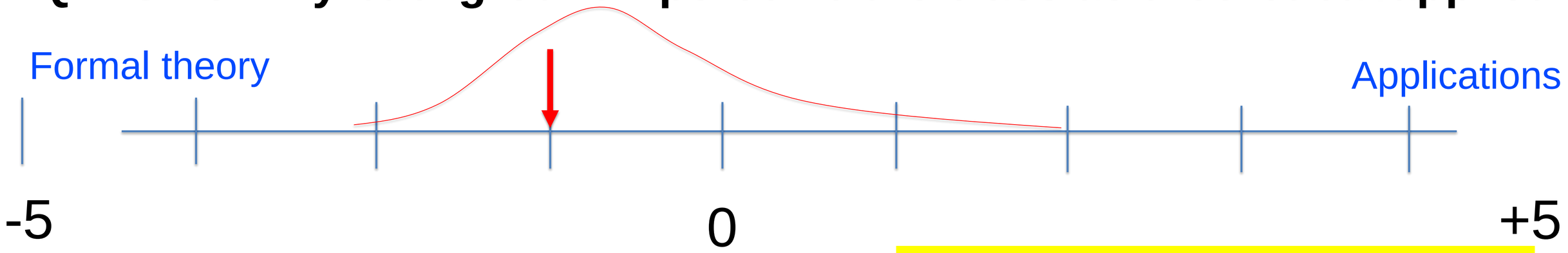
Student Feedback

I show the theory, but with reduced formalism

'The class is not formal enough: Derivations should be more formal'

'The class is not practical enough: Need more computer exercises'

Q1: Given my background I perceive the class as theoretical/applied:



Simple examples, coding of toy model (in python)

Miniprojects (MP): we support you with PyTorch

- MP is on Reinforcement Learning
- hand in 1 (not 2) out of 2 projects
- graded on a scale of 1-6
- grade of MP counts 30% toward final grade
- we do **fraud detection interviews**
- MP done in groups of two students (not alone)
- interview for MP is in last week of classes
  or first week after end of classes (your choice!)

→ **plan ahead!!**

Written exam:

- counts 70 percent toward final grade
- 1 page A5 double-sided handwritten notes, but no other tools allowed
  (no calculator, no cell phone, no slides, no book)
- ‘mathy’, similar to exercises

Written exam is ‘orthogonal’ to miniproject:

we ask for different things (theory)

In-Class Exercises: Typical Tuesday

11h15 – 12h00 lecture1 -
12h05 – 12h50 exercise
LUNCH BREAK
14h15 - 15h00 lecture2
15h15 - 16h00 exercise

Results of **Exercises with *** are needed for lecture 2

Head TA: Sophia Becker)
TA's (PhD students):
Ariane Delrocq, Lucas Gruaz
Skander Moalla, Anja Surina
TA's (master students):
Max Conti, Michael Hauri, Lazar Milikic

About 90 Short Videos, each about 10 min

https://lcnwww.epfl.ch/gerstner/VideoLecturesRL-Gerstner.html
OR directly on: https://www.youtube.com/@gerstnerlab

Previous slide.

For the in-class exercises it is important that you really try to solve them. No problem if you fail (some exercises are harder than others). But it is important that you start to think about how you would or will solve the exercise. Sometimes you will get stuck – this is part of the learning process!

Artificial Neural Networks/RL

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- The math is developed on the blackboard
- There are no written course notes!!
- All of the contents are **standard textbook material**

Choose a textbook that you like! I recommend

For **reinforcement learning lectures:**

- *Reinforcement learning,* R. Sutton+ A. Barto (2^{nd} ed, online)

Previous slide.

Work with a textbook that you like. If you study at home, slides are not sufficient.

The book of
Sutton and Barto
is the basis of the class. It is available online in pdf format as preprint for free.

Artificial Neural Networks/RL

Prerequisits:

CS433, Machine Learning

(Profs Jaggi+Flammarion)

Rules:

If you have taken CS433: you are well prepared

If you have taken a similar other class: same

If you have not taken this class: you can take my class,
but please do not complain if I refer to material
that you have not seen before.

Previous slide.

The overlap with the class of Jaggi+Urbanke is minimal (main overlap for ‘regularization’). But we need quite a few of their results as a basis!

Some students have taken a very similar class and then this is also fine.

Students who did not take the above class (or something very similar) are not admitted to the class ‘Artificial Neural Networks’. If they attend, it is at their own risk; they should not ask questions, but fill the knowledge gaps on their own. They should not complain if they find the class too hard.

Artificial Neural Networks/Reinforcement Learning

Learning outcomes:

- apply reinforcement learning in deep networks to real data
- assess/evaluate performance of learning algorithms
- elaborate relations between different mathematical concepts of reinforcement learning
- judge limitations of reinforcement learning algorithms
- propose models for learning in deep networks

Transversal skills:

- access and evaluate appropriate sources of information
- manage priorities
- work through difficulties, write a technical report

Previous slide.

Access and evaluate appropriate sources of information
→ this means: you should learn to read textbooks. It is not sufficient to just look at slides.

Manage priorities
→ this means: the miniprojects only count 30 percent. Don’t write a program with bells and whistles, but really focus on the things you are asked to do.

work through difficulties,
→ this means: some things will look hard at the beginning, be it in the miniproject or in the mathematical calculations. That’s normal, but you have to work through this.

write a technical report
→ this means: we would like to receive a readable technical report for the miniprojects. Concise, to the point, not too long.

Artificial Neural Networks/RL

Work load:

6 credit course → 9 hours per week for 18 weeks

(this count includes the 4 weeks of exam preparation)

1 ECTS = 27 hours of work

Previous slide.

Including exam preparation, the term has 18 weeks for 14 weeks of lectures:

The statement made by a student in an official evaluation that

‘An exercise session of 45 minutes is not enough to solve all the exercises’

is correct. You need additional time at home to solve the exercises. Solving the exercises is a good preparation for the exam and necessary to understand the mathy parts of the class.

Two ways to study for this class

A: Self-paced self-study

1. Read slides 1+2 each week
   (objectives and reading)
2. Start exercise n.
3. If stuck, read book chapter
   Return to 2.
4. Compare with solutions
5. n←n+1
6. Do quizzes in slides
   (yellow pages)

Hand-in miniproject.

Note: Slides are not meant for self-study. For self-study use textbook!

B: Lecture-based weekly

1. Follow lecture
   - annotate slides
   - participate in quizzes
   - try to solve all exercises

2. Go to Exercise session
3. redo exercises
   and Compare with solutions.

Hand-in miniproject.

Note: Do not forget to annotate slides so that you can use them.

Previous slide.

You don’t need to come to class, since all material is textbook material. But then you really have to study the textbooks!
Slides are not meant to replace textbooks.
Slides are self-contained under the assumption that you attend class and exercise sessions.

For the final exam, it is very important that you worked through all the exercises.

Sample examples from previous years are online: have a look before you decide to take the class.

Your Semester planning

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The course **'Deep Learning'** (Cavallaro/STI)
and the course **'Artificial Neural Networks/RL'** (Gerstner)
have no overlap.
You can take either one or the other or both (OR),

The course **'Reinforcement Learning'** (Cevher/STI))
and the course **'Artificial Neural Networks/RL'** (Gerstner)
have 80 percent overlap (10 of 14 weeks)
You can take either one or the other (XOR).

Students from STI or Management of Technogoly

→Cevher

Students from IC or SV or NeuroX or Comp.Sci or Financical Eng

→ Gerstner

Previous slide.
The class ‘Deep Learning’ is planned for STI students and does not have any prerequisits (except engineering bachelor)
The class ‘Deep learning’ treats backpropagation, tricks of the trade, convolutional networks with an applied focus. It does not contain any reinforcement learning.

The class ‘Artificial Neural Networks/Reinforcement Learning’ is planned for IC students who have already taken the class ‘Machine Learning’ by Jaggi-Flammarion. It it also open to several other sections. It focuses on Reinforcement Learning and has been taught for several years. Examples of past exams are available.

The class ‘Reinforcement learning’ by Cevher is a new class. It is planned for STI students and offered to master students in STI and Management of Technology.

Quiz: Classification versus Reinforcement Learning

[ ] Classification aims at predicting the correct category such as ‘car’ or ‘dog’
[ ] Classification is based on rewards
[ ] Reinforcement learning is based on rewards
[ ] Reinforcement learning aims at optimal action choices

I structure the lecture with Quizzes

Your notes:

Quizzes appear at the end of most sections.
The exam contains a section with similar multiple-choice questions

Reading for this week:

Sutton and Barto, Ch. 1.1 and 1.2 of

Reinforcement Learning

Previous slide.

The suggested reading is important, in particular if you are not able to attend the class in a given week.

In all the following weeks, the suggested reading will always be listed on slide 2, at the beginning of the lecture, so that it is easy to find.

If you have understood everything, and are able to solve the exercises, then you do not have to go through the reading.

Artificial Neural Networks/RL: Lecture 10

XXX

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Objectives for today:

-

-

Your notes:

Objectives are not a list of contents but refer to learning outcomes/insights.

Recommended exam preparation

(1) do (or redo) **exercises** yourself

(2) if stuck, read the relevant chapter of the **textbook** (see page 2 of slides of each week)

(3) check the solution of exercise

(4) look at the **quiz question** (always orange slides)

(5) if stuck, read the relevant chapter of the **textbook** (see page 2 of slides of each week)

(6) Look at **past exams** (solutions: see analog exercises)

NOTE: the slides are most useful if you have followed and annotated them yourself during the lecture.

This is what successful students said about exam preparation:

Student A:

“For me, going through the exercises was very helpful, along with the slide quizzes. We also discussed theoretical questions from the lectures with my teammate and friends”

Student B:

“During the semester I have read the commented version of the slides in order to carry out the 2 miniprojects. I took care to understand each remark and I did the exercises when I had trouble in learning a topic. Before the exam, I felt that I was remembering well so I could focus only on Reinforcement Learning. In this case I found more useful solving the exercises to understand some key differences between the different algorithms e.g. off-policy versus on-policy.”

This is what successful students said about exam preparation:

Student C:

« I first went through all the lecture slides which I had taken notes on during lectures to reinforce my memory of various notions introduced in this course, and I want to stress that the comment pages were truly helpful. Afterwards, I went over all the exercises and collected a few questions to pose in the revision session held by TAs and got satisfactory clarification for most of them. »

Student D:

« I prepared for the exam by reading slides over and over again. I think the comments slides helped me a lot in understanding and reading them over again helped me to build the structure of the overall course.
Exercises helped as well since it turns out that the exam is quite similar to exercises. »

This is what successful students said about exam preparation:

Student E:

“I attended nearly every class and made sure I understood the blackboard proofs properly because these were usually very useful for understanding the main concepts. During the exam preparation, I mostly just went through the class slides again and solved all of the exercises.”

Student F:

“I never came to class but I did all the exercises and studied the books on Reinforcement Learning and Deep Learning.”

Questions?

…

First ‘real exercise’ starts at 12h05

→ Exercise 1 and 3 now (marked with *)!!!

First ‘real lecture’ starts at 14h15.