CS-479 **Learning in neural networks**

Gerstner Wulfram

Cursus	Sem.	Type
Computer science	MA2, MA4	Opt.
Cybersecurity	MA2, MA4	Opt.
Data Science	MA2, MA4	Opt.
Neuro-X minor	E	Opt.
Neuro-X	MA2, MA4	Opt.
SC master EPFL	MA2, MA4	Opt.

Language of teaching	English
Credits	6
Session	Summer
Semester	Spring
Exam	Oral
Workload	180h
Weeks	14
Hours	**4 weekly**
Lecture	2 weekly
Exercises	1 weekly
Labs	1 weekly
Number of positions	

Summary

Artificial Neural Networks are inspired by Biological Neural Networks. One big difference is that optimization in Deep Learning is done with the BackProp Algorithm, whereas in biological neural networks it is not. We show what biologically plausible learning algorithms can do (and what not).

Content

- Why BackProp is biologically not plausible. Biological two-factor rules and neuromorphic hardware
- Hebbian Learning (two-factor rules) for PCA and ICA
- Two-factor rules for dictionary learning (k-means/competitive learning/winner-takes-all)
- Three-factor rules and neuromodulators (theory and neuroscience)
- Three-factor rules for reward-based learning (theory)
- Three-factor rules for TD reinforcement-learning (algorithmic formulations)
- Actor-critic networks
- Reinforcement learning in the brain
- Learning by surprise and novelty: exploration and changing environments (algorithmic)
- Surprise and novelty in the brain
- Learning representations in multi-layer networks (algorithms without backprop)
- Learning to find a goal: a bio-plausible model with place cells and rewards
- Neuromorphic hardware and in-memory computing

Keywords

- Hebbian learning and two-factor rules
- distributed local algorithms,
- Principal Component Analysis/Independent Component Analysis (PCA and ICA)
- Reinforcement Learning (RL)
- surprise and novelty
- three-factor rules
- neuromorphic hardware

Learning Prerequisites

Required courses

Linear Algebra AND Analysis.
Machine learning

Recommended courses

Signal processing

Important concepts to start the course

Optimization, Gradient Descent, Filtering, Loss function, Eigenvalues,

Learning Outcomes

By the end of the course, the student must be able to:

- Translate concepts from machine learning and signal processing into bio-plausible algorithms
- Translate neuroscience of learning into algorithms
- Explain differences between and similarities of various algorithms
- Discriminate imitations and advantages of various learning algorithms for implementation in biology or hardware

Transversal skills

- Plan and carry out activities in a way which makes optimal use of available time and other resources.
- Set objectives and design an action plan to reach those objectives.
- Evaluate one's own performance in the team, receive and respond appropriately to feedback.
- Give feedback (critique) in an appropriate fashion.
- Manage priorities.
- Continue to work through difficulties or initial failure to find optimal solutions.

Teaching methods

Ex cathedra, Exercises, and Miniproject

Expected student activities

Participation in Class, Solution of Exercises, Miniproject.

Assessment methods

Oral exam (70 percent) plus miniproject (30 percent). If more than 45 students participate, the oral exam is replaced by a written exam.

Supervision

Office hours	No
Assistants	Yes
Forum	Yes

Resources

Moodle Link

- https://go.epfl.ch/CS-479