MATH-520

Topics in machine learning

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Cursus	Sem.	Type
Ing.-math	MA1, MA3	Opt.
Mathématicien	MA1, MA3	Opt.

Language of teaching	English
Credits	5
Session	Winter
Semester	Fall
Exam	During the semester
Workload	150h
Weeks	14
Hours	**4 weekly**
Lecture	2 weekly
Exercises	2 weekly
Number of positions	

Summary

Mathematical analysis of modern supervised machine learning techniques, from linear methods to artificial neural networks.

Content

- Introduction (supervised learning, risk, error decomposition, over-fitting and capacity control + cross-validation, Bayes predictor for classification and regression)
- Differentiable programming (backpropagation algorithm) and theoretical challenges posed by modern methods (large deep neural networks)
- Statistical analysis of Empirical Risk Minimization (learning theory, from finite number of hypotheses to Rademacher / covering numbers)
- First-order methods for optimization (gradient descent, stochastic gradient descent).
- Kernel methods (positive-definite kernels and Reproducing Kernel Hilbert Spaces)
- Algorithmic regularization of gradient descent (reparameterized models, least-squares, mirror descent, logistic loss and max-margin)
- Dynamics of wide neural networks (parameterizations, neural tangent kernel and feature-learning limits)

Keywords

Supervised learning, Machine learning, Neural networks, Optimization, Statistics

Learning Prerequisites

Required courses

Analysis, Linear Algebra, Probability and Statistics

Important concepts to start the course

- A good knowledge of undergraduate mathematics is important.
- Ability to code in a scientific computing programming language of your choice (e.g. Python, Matlab, Julia). The course will involve coding exercises and assignments.
- Having followed an introductory class on machine learning is beneficial.

Learning Outcomes

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

- Contextualise the research literature on theoretical machine learning
- Interpret he practical behavior of complex machine learning pipelines through the lens of mathematical theory
- Implement simple supervised learning algorithms from scratch
- Reason on how statistical and optimization phenomena interact in machine learning practice
- Distinguish between what is known and what is not known in the theory of deep learning

Assessment methods

Homeworks, projects, presentation

Resources

Moodle Link

- https://go.epfl.ch/MATH-520