EPFL

PHYS-512 | **Statistical physics of computation**

Krzakala Florent, Zdeborová Lenka

Cursus	Sem.	Type
Computer science	MA1, MA3	Opt.
Cybersecurity	MA1, MA3	Opt.
Data Science	MA1, MA3	Opt.
Ing.-phys	MA1, MA3	Opt.
Physicien	MA1, MA3	Opt.
SC master EPFL	MA1, MA3	Opt.

Language of teaching	English
Credits	4
Session	Winter
Semester	Fall
Exam	Written
Workload	120h
Weeks	14
Hours	**4 weekly**
Lecture	2 weekly
Exercises	2 weekly
Number of positions	

Summary

This course covers the statistical physics approach to computer science problems ranging from graph theory and constraint satisfaction to inference and machine learning. In particular the replica and cavity methods, message passings algorithms, and analysis of the related phase transitions.

Content

Interest in the methods and concepts of statistical physics is rapidly growing in fields as diverse as theoretical computer science, probability theory, machine learning, discrete mathematics, optimization, signal processing and others. Large part of the related work has relied on the use of message-passing algorithms and their connection to the statistical physics of glasses and spin glasses.

This course covers this active interdisciplinary research landscape. Specifically, we will review the statistical physics approach to problems ranging from graph theory (e.g. community detection) to discrete optimization and constraint satisfaction (e.g. satisfiability or coloring) and to inference and machine learning problems (learning in neural networks, clustering of data and of networks, compressed sensing or sparse linear regression, low-rank matrix factorization).

We will expose theoretical methods of analysis (replica, cavity, ...) algorithms (message passing, spectral methods, etc), discuss concrete applications, highlight rigorous justifications as well as present the connection to the physics of glassy and disordered systems.

This is an advanced theoretical course that is designed for students with background in mathematics, electrical engineering, computer science or physics. This course exposes advaced theoretical concepts and methods, with exercises in the analytical methods and usage of the related algorithms.

Learning Prerequisites

Important concepts to start the course

For physics students Statistical physics I and II (or equivalent) is required.
This lecture is accessible to students in mathematics, electrical engineering, computer science without any previous training in statistical physics. Those students are expected to have strong interest in theory, probabilistic approaches to analysis of algoriths, high-dimensional statistics or probabilistic signal processing.

Learning Outcomes

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

- Analyze theoretically a range of problems in computer science and learning.
- Derive algorithms for a range of computational problems using technics stemming from statistical physics.

Teaching methods

2h of lecture + 2h of excercise

Assessment methods

Final written exam counting for 50% and several graded homeworks during the semester counting for the other 50%.

Resources

Bibliography

Information, Physics and Computation (Oxford Graduate Texts), 2009, M. Mézard, A. Montanari

Statistical Physics of inference: Thresholds and algorithms, Advances in Physics 65, 5 2016, L. Zdeborova & F. Krzakala, available at https://arxiv.org/abs/1511.02476

Ressources en bibliothèque

- Information, Physics and Computation / Mézard

Notes/Handbook

Policopié "Statistical Physics methods in Optimization & Machine Learning" by L. Zdeborova & F. Krzakala (available as pdf on the course website)

Moodle Link

- https://go.epfl.ch/PHYS-512