

PHYS-512

Statistical physics of computation

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Cursus	Sem.	Type
Ing.-phys	MA1, MA3	Opt.
Physicien	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 passing 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.

The course is designed to be accessible to graduate students and researchers of all natural science, engineering and mathematics disciplines with a knowledge of basic concepts in probability and analysis. Advanced training in any of the above fields is not requisite. This course exposes advanced theoretical concepts and methods, with exercises in the analytical methods and usage of the related algorithms.

Learning Prerequisites**Important concepts to start the course**

Basic notions in probability. For physics students Statistical physics I, II, III or analogous will be a very useful background. This lecture is also accessible to non-physicists with some background in high-dimensional statistics, probability, signal processing or learning, without any previous training in statistical physics.

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 exercise

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>

Notes/Handbook

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