Bocconi University
PhD in Statistics & Computer Science

41002: Statistical Mechanics and Methods for Complex Systems
Instructor: Marc MÉZARD

Summary:
In recent years, a new scientific field has appeared, at the interface between statistical physics, information theory, and computer science, with many links to probability and statistics. In statistical physics it is the study of disordered systems, glasses of all types. In information theory, the main topics are data compression, error correction codes and compressed data acquisition. In computer science, one thinks of constraint satisfaction problems, but also of inference, especially machine learning by neural networks. Clearly, this is a very broad field. This course, designed to be accessible to PhD students with various backgrounds (physics, math, computer science), does not aim at providing a complete presentation of the field, nor will it lead to study its latest developments. It is rather an introduction built from selected pieces, providing the basic conceptual framework necessary in each of the topics. It is thus a kind of guided tour, in large dimension, allowing to glimpse deep links between different subjects...

Syllabus:

    1- *Introduction to statistical physics of disordered systems.*
Thermodynamic potential, disordered ensembles, quenched and annealed averages, random energy model and glass transition

    2- *Introduction to information theory.*
Basic notions, entropy, mutual information, Markov chains, code ensembles and Shannon's theorem for communication

    3- *Some tools for high-dimensional probabilistic analysis.*
Large deviations, asymptotic equipartition, Sanov theorem, Monte-Carlo Markov chains

    4- *Introduction to statistical inference and statistical physics*
Bayesian inference, machine learning; example of learning in the perceptron

    5- *Spin glasses*
Sherrington-Kirkpatrick model, replica method, cavity method

    6- *Mean field and message passing algorithms*
Naïve mean field, reaction terms, belief propagation, TAP equations

    7- *Error correcting codes for communication.*
Low density parity check code ensembles, information theoretic threshold, algorithmic thresholds

Textbook: "Information, Physics and Computation", Marc Mézard and Andrea Montanari, Oxford University Press 2009