Workshop on

Techniques and Challenges

from Statistical Physics

Centre de Recerca Matemàtica
Bellaterra

October 14 to 16, 2009

Coordinators

Elitza Maneva, Universitat Politècnica de Catalunya

Matteo Palassini, Universitat de Barcelona

Speakers

Erik Aurell, KHT Royal Institute of Technology, Sweden

Amin Coja-Oghlan, University of Edinburgh, United Kingdom

Hervé Daudé, Université d'Aix Marseille 1, France

Martin Dyer, University of Leeds, United Kingdom

Gabriel Istrate, e-Austria Research Institute, Romania

Yoshiyuki Kabashima, Tokyo Institute of Technology, Japan

Lefteris Kirousis, University of Patras, Greece

Roman Kotecky, Charles University, Czech Republic

Florent Krzakala, ESPCI Paristech and CNRS, France

Gábor Lugosi, Universitat Pompeu Fabra, Spain

Fabio Martinelli, Università degli Studi di Roma Tre, Italy

Alexander Mozeika, Aston University, United Kingdom

Federico Ricci-Tersenghi, Università degli Studi di Roma "la Sapienza", Italy

Antonello Scardicchio, The Abdus Salam International Center for Theoretical Physics, Italy

Guilhem Semerjian, École Normale Supérieure, France

Lenka Zdeborova, Los Alamos National Laboratory, USA

Riccardo Zecchina, Politecnico di Torino, Italy

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Contents

1. Practical Information

Lecture room:

The Course will take place in the CRM "Auditori" located in the Sciences Building (Edifici de Ciències), Universitat Autònoma de Barcelona in Bellaterra. The Course lecture room is equipped with a multimedia projector connected to a computer. An overhead projector and blackboards are also available.

Secretariat:

The CRM Administration will be available to the participants from Wednesday to Friday from 9:00 am to 5:00 pm.

Computer facilities:

The computer space of the CRM will be available for the participants of the Course.

The CRM premises as well as most of the UAB campus have wireless access.

Breaks:

Coffee and cookies will be served during the morning breaks to all participants.

Questionnaire:

Following the directions of the CRM Governing Board, we give a questionnaire to all the people participating in activities at the CRM in order to assess their level of satisfaction. The questionnaire is anonymous and not mandatory, but we would greatly appreciate it if you could answer the questions and return it to us. Thank you for your cooperation.

Local emergency numbers:

Medical emergency campus number (inside the University premises)	1800 / 1900 during office hours 2525 at other times
UAB's Science Faculty reception office (inside the University premises)	1055
General emergency (police, fire- fighters, ambulances)	112

2. Schedule

Wednesday, October 14	
9:00 – 9:15	Registration
9:15 – 10:15	Lefteris Kirousis *Coloring random graphs.*
10:15 – 10:45	Coffee Break
10:45 – 11:15	Guilhem Semerjian *On message passing guided algorithms for solving constraint satisfaction problems.*
11:15 – 11:45	Yoshiyuki Kabashima *On spectral analysis of large low-density random matrices: rigorous vs. cavity analysis.*
11:45 – 12:00	Break
12:00 – 13:00	Amin Coja-Oghlan *A spectral perspective on belief propagation.*
13:00 – 15:00	Lunch
15:00 – 16:00	Florent Krzakala *Where are the* REALLY *hard problems,* REALLY*?*
16.00– 16:30	Break
16:30 – 17:00	Gabriel Istrate *Random graph bisection revisited.*
17:00 – 17:30	Antonello Scardicchio *Random quantum SAT.*

Thursday, October 15	
9:15 – 10:15	Hervé Daudé *Some results on symmetric constraint satisfaction problems.*
10:15 – 10:45	Coffee Break
10:45 – 11:45	Lenka Zdeborova *Planted ensemble, reconstruction on trees, and behavior of belief propagation on random CSPs.*
11:45 – 12:00	Break
12:00 – 12:30	Gábor Lugosi *The longest minimum-weight path in a complete graph.*
12:30 – 13:00	Alexander Mozeika *Computing with noise - a statistical physics approach.*
13:00 – 15:00	Lunch
15:00 – 16:00	Fabio Martinelli *Glauber dynamics for the Ising model at low temperature.*
16.00– 16:30	Break
16:30 – 17:00	Federico Ricci-Tersenghi *Replica cluster variational method for spin glasses.*
17:00 – 17:30	Roman Kotecky *Long range order in perfect colourings.*

Fryday, October 16	
9:15 – 10:15	Erik Aurell *Gaussian belief with dynamic data and in dynamic network.*
10:15 – 10:45	Coffee Break
10:45 – 11:45	Martin Dyer *The dynamics of games on graphs.*
11:45 – 12:00	Break
12:00 – 13:00	Ricardo Zecchina *Statistical mechanics of large scale inverse problems.*
13:00 – 15:00	Lunch
15:00 – 16:00	Posters and independent discussions

3. Abstracts of Speakers

Erik Aurell

Gaussian belief with dynamic data and in dynamic network.

Abstract: Data aggregation is an important task in sensor networks and network management. In both settings distributed data aggregation and distributed control, where decisions are taken locally with respect to locally available information, is also of interest. Two important paradigms for distributed data aggregation are, respectively, diffusion-based algorithms, also denoted gossiping, and tree-based algorithms. Both have drawbacks e.g. in dynamic networks, where nodes/peers come and go. This motivated the introduction of Consensus Propagation (CP) (Moallemi & Van Roy, 2006), which is equivalent to Belief Propagation over a class of Gaussian models. Models in this class are walksummable in the sense of (Malioutov, Johnson, Willsky, 2006); CP is hence guaranteed to converge in a static network with static data. We note that CP has (at least at present) the drawback that it is limited to computing averages, and not e.g. quantiles or max/min values.

We have performed a systematic study of CP in settings where both data may fluctuate (dynamic data), and the network may change (dynamic network). System response to dynamic data is determined by the leading eigenvalue of an associated Ruelle-Perron-Frobenius operator introduced by (Malioutov, Johnson, Willsky, 2006). Our numerical data suggests that for Gaussian models on Erdös-Rényi graphs with random coupling strengths this leading eigenvalue is self-averaging, does not depend on the size of the instances as these become large, and furthermore stays below unity. We have no good explanation of these observations. They do however suggest that CP with dynamical data has good scaling properties, being essentially a linear averaging procedure where the Ruelle-Perron-Frobenius operator determines the averaging kernel, and its leading eigenvalue determines the rate at which old data is forgotten.

The response to changes in the network is faster than to changes in the data only, in agreement with the intuitive picture that network churn can only improve mixing properties, which in turn determines averages. In some cases we have observed abnormally fast responses to changes in the network, i.e. restarting CP from all-zero messages can avoid the leading linear decay from dynamic data. These cases will be described in the talk.

This is joint work with Rene Pfitzner, University of Jena, Germany, available as `arXiv:0905.0266` and in press in Europhys Lett.

Contact address: `eaurell@kth.se`

Amin Coja-Oghlan
A spectral perspective on belief propagation.

Abstract: Contributing to the rigorous understanding of BP, we relate the convergence of BP to spectral properties of the graph. This encompasses a result for random graphs with a "planted" solution; thus, we obtain the first rigorous result on BP for graph coloring in the case of a complex graphical structure (as opposed to trees). In particular, the analysis shows how Belief Propagation breaks the symmetry between the possible permutations of the color classes.

Contact address: `acoghlan@staffmail.ed.ac.uk`

Hervé Daudé
Some results on symmetric constraint satisfaction problems.

Abstract: We will consider Constraints Satisfaction Problems defined in terms of a set F of Boolean functions having the same arity, say k. Such a problem is called CSP(F), the archetype being the k SATisfiability of CNF formula. The complexity and the nature of the phase transition associated to CSP(F) will be made precise in using a simple criterion on the functions appearing in F. When the operations of permutation and (or) complementing one or more of the k variables leaves F inchanged, then CSP(F) exhibits symmetry properties. In studying the number N of locally maximal solutions for symmetric CSP, we will highlight the role of the sensitivity of the functions in F for the evolution of the expected value of N.

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Martin Dyer
The dynamics of games on graphs.

Abstract: We consider simple games played on the edges of a graph by agents situated at the vertices. These resemble particle systems, though the dynamics considered are rather different. A particular object of study is the evolution of cooperation amongst the agents.

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Gabriel Istrate
Random graph bisection revisited.

Abstract: We discuss two results on random graph bisection: first we give an upper bound on the bisection width via a probabilistic analysis of a so-called "core peeling" algorithm. Second, we formulate graph bisection as a constraint satisfaction problem and give belief propagation equations. Some other open issues will be discussed.

Contact address: `gabrielistrate@acm.org`

Yoshiyuki Kabashima

On spectral analysis of large low-density random matrices: rigorous vs. cavity analysis.

Abstract: Spectral analysis has been used for design and analysis of various algorithms. For this purpose, it is sometimes important to analyze not only eigenvalues but also the shape of eigenvectors, which has been difficult for sparse random matrices. Here we propose one approach from statistical physics and discuss possiblities of using it for rigorous analyses of algorithms.

Contact address: `kaba@dis.titech.ac.jp`

Lefteris Kirousis

Coloring random graphs.

Abstract: We will survey several recent results concerning the chromatic number of random graphs. The setting is as follows: We consider a probability space with graphs of a given average degree and n vertices. In the first case, (the Erdös-Rényi graphs), the probability space is uniform and comprises all graphs with the given average degree and n vertices. In the second case (regular graphs), the probability space is again uniform but the space comprises only graphs where all n vertices have the same degree (necessarily equal to the one given as average).

In both cases the chromatic number exhibits interesting threshold behavior: for a given average degree (given constant degree, for the regular case, respectively), the chromatic number of (asymptotically with n) almost all graphs lies within a common, small window of 1–3 integers. However as the degree increases, at specific values, this window undergoes abrupt changes.

Contact address: `kirousis@ceid.upatras.gr`

Roman Kotecky

Long range order in perfect colourings.

Abstract: A case of long range order in 3-colouring ($q = 3$ Potts antiferromagnet at zero temperature) will be discussed. The meaning and the cause of the order will be explained.

It can be traced to the existence of purely entropical barriers between ordered states.

Contact address: `kotecky@cucc.ruk.cuni.cz`

Florent Krzakala
Where are the REALLY hard problems, REALLY?.

Abstract: It is well known that for many NP-complete problems, such as K-Sat or coloring, typical cases are often easy to solve and the hunt for really hard problems in random instances is a tough (and long-standing) one.

In this talk, I will review this story briefly and present a tutorial discussion on the scenario we have reached following 15 years of research in statistical physics. Some aspect of this scenario are still not proven, and I will thus discuss some of these "rigorously unproven" conjectures, and show how they can be tested with amazing accuracy in very large instances.

As asked by the organizers, and in order to boost future developments and interactions between physics and computer science, brave conjectures and bold challenges will be proposed to the audience.

Contact address: `florent.krzakala@espci.fr`

Gábor Lugosi
The longest minimum-weight path in a complete graph.

Abstract: We consider the minimum-weight path between any pair of nodes of the n-vertex complete graph in which the weights of the edges are i.i.d. exponentially distributed random variables. We show that the longest of these minimum-weight paths has about $\alpha \log n$ edges where $\alpha \approx 3.5911$ is the unique solution of the equation $\alpha \log \alpha - \alpha = 1$.

Contact address: `lugosi@upf.es`

Fabio Martinelli
Glauber dynamics for the Ising model at low temperature.

Abstract: Consider the standard Ising model on a finite $n \times n$ grid at low temperature. If the boundary spins are held fixed equal to $+1$ it is believed that the mixing time of the corresponding Glauber dynamics (Gibbs sampler) is poly(n). Although such a result is still far from being proved, recently there has been some interesting progresses using the "censoring inequalities" of Y. Peres and P. Winkler. I will describe these new results as well some other work on closely related problems.

Contact address: `martin@mat.uniroma3.it`

Alexander Mozeika
Computing with noise - a statistical physics approach.

Abstract: We show how models of random formulae can be mapped onto a physical framework and employ methods of statistical physics, developed specifically to analyze the typical behavior of random disordered systems, to gain insight into the behavior of noisy Boolean random formulae. The stability of the circuit towards input-layer perturbations and its dependence on the input magnetization have been studied to establish the main characteristics of the generated formulae. To investigate the properties of noisy circuits we consider two copies of the same topology with different temperatures representing the noisy and noiseless versions of the same circuit. We show that the typical-case macroscopic behavior observed corresponds straightforwardly to the bounds obtained in the information theory literature for specific cases. Being very general, the framework is extended to consider further properties of random Boolean formulae for different gates, the level of error and function-bias expected at any depth, the sensitivity to input perturbations and expected convergence rate depending on the input bias, gate properties and gate-noise level. This framework enables one to discover typical properties of noisy computation that are inaccessible via traditional methods of information theory and complements the analysis carried out in the theoretical computer science and information theory communities.

Contact address: `a.s.mozeika@aston.ac.uk`

Federico Ricci-Tersenghi
Replica cluster variational method for spin glasses.

Abstract: We have developed a replica cluster variational method, which improves over mean-field and Bethe approximations for disordered models defined on regular lattices. We have applied it to spin glasses, in particular to the Edwards-Anderson model in 2, 3 and 4 dimensions, using the plaquette as the largest region. On the 2d square lattice, we find that the paramagnetic phase is stable for any positive temperature, thus confirming the scenario with $T_c = 0$. Moreover we have developed a message-passing algorithm which converges to a fixed point for any temperature and provides very good marginal probabilities. Using these marginals and the decimation algorithm we have been able to find ground state configurations.

Contact address: `federico.ricci@roma1.infn.it`

Antonello Scardicchio
Random quantum SAT.

Abstract: I will introduce an ensemble of random Quantum SAT problems with a SAT/UNSAT transition and describe the presence of a non-classical phase where the problem is still SAT but does not seem to have a classical certificate.

Contact address: `ascardic@ictp.it`

Guilhem Semerjian

On message passing guided algorithms for solving constraint satisfaction problems.

Abstract: The statistical mechanics studies of computer science optimization problems have had two main outcomes. On the one hand they proposed a rich picture of the phase diagram of random instances, and on the other they led to new efficient heuristics (Survey Propagation) for practically solving given instances. The theoretical understanding of these new algorithms is not yet completely satisfactory. In this seminar I will review general ideas about message passing guided algorithms and present recent results on the analysis of a representant of this class of procedures (Belief Propagation).

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Lenka Zdeborova

Planted ensemble, reconstruction on trees, and behavior of belief propagation on random CSPs.

Abstract: I will review phase transitions in constraint satisfaction problems on the planted random ensemble. I will discuss relations to the problem of reconstruction of trees, and implications for algorithmic hardness of instances from the planted ensemble. This has also interesting implications for the (initial condition dependent) convergence properties of the belief propagation scheme. The tutorial is based on results of arXiv:0901.2130v2, arXiv:0902.4185v1, and arXiv:0909.3820v1.

Contact address: lenka.zdeborova@gmail.com

Riccardo Zecchina

Statistical mechanics of large scale inverse problems.

Abstract: We will review some recent results in the statistical mechanics approaches to inverse problems and discuss their application in computational biology.

Specifically we will show how statistical physics algorithms for inverse Ising, Inverse Potts and generalized minimum Steiner trees can be used to unveil interactions in biological systems from large scale data (in neural circuits, in protein contacts and in cell signaling respectively).

For the Steiner tree case we will discuss in more detail the message-passing algorithm, its applications to the identification of cell signaling pathways in yeast and the validation of the predictions through genetic experiments.

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4. List of Participants

Name	Institution
Atserias, Albert	Universitat Politècnica de Catalunya
Aurell, Erik	KHT Royal Institute of Technology
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Charilaos, Efthymiou	University of Edinburgh
Coja-Oghlan, Amin	University of Edinburgh
Dall'asta, Luca	The Abdus Salam International Center for Theoretical Physics
Daudé, Hervé	Université Aix-Marseille 1
Deluca Silberberg, Anna	CRM
Diaz Cort, Josep	Universitat Politècnica de Catalunya
Dyer, Martin	University of Leeds
Istrate, Gabriel	University of the West Timisoara
Kabashima, Yoshiyuki	Tokyo Institute of Technology
Kirousis, Lefteris M.	University of Patras
Koiller, Jair	Fundaçao Gehilio Vargas
Kotecky, Roman	Charles University
Krzakala, Florent	ESPCI, Paristechand CNRS
Lacasa Saiz de Arce, Lucas	Universidad Politécnica de Madrid
Lugosi, Gábor	Universitat Pompeu Fabra
Mahmoudi, Hamed Gheydari	University of Helsinki
Mandrà, Salvatore	Univ. degli Studi Milano-Bicocca
Maneva, Elitza	Universitat Politècnica de Catalunya
Marciniak, Dorota	Polish Academy of Science
Martinelli, Fabio	Università degli Studi di Roma Tre
Martínez, Ángel	Fundació Sant Joan de Déu
Martínez, Conrado	Universitat Politècnica de Catalunya
Mittsche, Dieter	Universitat Politècnica de Catalunya
Mozeika, Alexander	Aston University

Name	Institution
Oliva, Sergi	Universitat Politècnica de Catalunya
Palassini, Matteo	Universitat de Barcelona
Pretti, Marco	Politecnico de Torino
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Semerjian, Guilhem	École Normale Supérieure
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Zdeborova, Lenka	Los Alamos National Laboratory
Zecchina, Riccardo	Politecnico di Torino