MAR14-2013-000693
Abstract for an Invited Paper
for the MAR14 Meeting of
the American Physical Society

The Cavity Method, Belief Propagation, and Phase Transitions in Community Detection

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The stochastic block model is a popular model of social and biological networks. Each vertex belongs to one of k groups, and the probability of an edge depends on the groups to which its endpoints belong. It allows both "assortative" communities where vertices tend to connect to others in the same group, and "disassortative" and directed community structures, like those in food webs, where predators form a community because they feed on similar prey. Given a network, we would like to infer the most likely block model: both the group labels of the nodes, and the parameters of the model. I will describe an efficient algorithm for this problem based on belief propagation, or equivalently the cavity method of statistical physics. Physically, the model corresponds to a generalized Potts model with strong interactions on the links of the network, and weak interactions along the non-links. Our analysis also reveals phase transitions in the detectability of communities, including an undetectable phase where no algorithm can do better than chance. There is also a regime where the accuracy we can achieve jumps discontinuously as a function of the fraction of nodes we have prior information about, and a tricritical point where this discontinuity disappears. This is joint work with Aurelien Decelle, Florent Krzakala, Lenka Zdeborová, and Pan Zhang.