T5. Factor Graphs for Centralized and Distributed Processing: Theory and Practice

Abstract:
Graphical models, such as factor graphs, are gaining increasing importance in the systematic development of algorithms in communication receivers and communication networks. Recent developments have revealed ties between graphical models, statistical physics, variational methods (see Figure 1), and convex optimization. While most of these developments originate from the machine learning and statistics communities, there is an urgent need for communications researchers to become aware of these developments and apply state-of-the-art inference methods to important problems in our own field. This tutorial strives to address this need. The goal of this tutorial is to provide an overview of the theory behind graphical models and explore deeper connections between different algorithms. This theory will then be applied to two real-world problems in wireless communications: the centralized problem of receiver design and the distributed problem of cooperative tracking.

Outline: The tutorial comprises 6 parts, and will contain hands-on examples that participants will solve during the tutorial.

1. *Optimal Detection and Estimation:* We introduce optimal detection in an abstract setting. We develop optimal detection/estimation strategies, including maximum a posteriori (MAP)detection and minimum mean square error (MMSE) estimation. We show that one key problem is the computation of marginals.
2. *Factor Graphs and the Sum-Product Algorithm:* We describe factor graphs, and, using simple examples, show how they can be used to compute marginals of a function.
3. *Statistical Inference with Factor Graphs:* We link factor graphs with optimal detection, and describe several statistical inference problems that can be solved using factor graphs. We go into details of message representation, message computation, and iterative processing.
4. *Variational Interpretation:* We now consider the broader context and provide interpretations of factor graphs and the sum-product algorithms from the viewpoint of variational methods. This viewpoint allows us to describe other, similar, proposed message passing methods in a systematic way.
5. *Application to Centralized Processing:* Tying everything together, we apply factor graphs to the problem of developing a near/optimal iterative receiver. Key functionalities of a receiver are presented in a unified framework.
6. *Application to Distributed Processing:* Recently, there has been a great deal of interest in distributed inference for wireless networks. We show how factor graphs can be employed in developing algorithms for distributed inference. We consider the important topic of geonavigation, and present a solution based on factor graphs.

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Henk Wymeersch is Assistant Professor with the Department of Signals and Systems at Chalmers University of Technology, Sweden. Prior to joining Chalmers, during 2006-2009 he was a Postdoctoral Associate with the Laboratory for Information and Decision Systems (LIDS) at the Massachusetts Institute of Technology (MIT). Henk Wymeersch obtained the Ph.D. degree in Electrical Engineering/applied sciences in 2005 from Ghent University, Belgium. He is a member of the IEEE, Associate Editor for IEEE Communication Letters and author of the book Iterative Receiver Design (Cambridge University Press, 2007). His current research interests include algorithm design for wireless transmission, statistical inference, and distributed processing. His accolades include several best paper awards, the Alcatel-Bell Scientific Award, and the L3 Communications Prize at the 2009 Soldier Design Competition.