Bachelor Theses/Master's Theses

Message Passing Approaches to Estimation and Control

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Project Background

Factor graphs are graphical models for representing the dependency structure of factorizable functions. In a stochastic framework, they are useful for formulating and exploiting conditional independence in associated algorithms. In conjunction with the factorization imminent from the graph, efficient algorithms can be formulated that are subsumed under the term "message passing". In a divide-and-conquer-manner, the underlying philosophy amounts to applying the distributive law in such a manner that a global algorithm can be understood as a composition of local algorithms. Assumptions on probability distributions of the associated variables, e.g., Gaussian distributions, allow to execute message passing by following simple algebraic computation rules on the nodes of the factor graph.

The potential as a unified language for representing algorithms as special cases of the sum-product and max-product algorithms—a.k.a. belief propagation—using message passing on factor graphs has been recognized in many fields ranging from machine learning, statistics to signal processing. As a famous example, the Kalman Filter can be easily understood and derived from a factor graph representation of a linear dynamic system [1]. Recent efforts have even resulted in a signal processor design specifically tailored to Gaussian message passing that outperforms other state-of-the-art digital signal processors [4].

It appears thus that factor graphs have a strong potential also in system's theory. The goal of a particular line of research carried out at the Institute for Electrical Engineering in Medicine consist in exploring a more control-oriented perspective on factor graphs [2, 3].

In this vein, Forney-style factor graphs (FFGs) may be adopted for developing a new perspective on adaptive control algorithms, in which relevant dynamic properties of a system are at the same time estimated and used for future control inputs. Factor graphs provide a potentially unified graphical language in which combined algorithms for these problems can be visualized and solved. Research on these topics can range from applying initial ideas on interesting real-world problems to validate the effectiveness of the approach as well as to delving into the theory behind it.

This project description thus acts as a container for numerous more concrete tasks that can be tailored to the abilities and interests of respective students.

References

[1] Loeliger, Hans-Andrea; Dauwels, Justin; Hu, Junli; Korl, Sascha; Ping, Li; Kschischang, Frank R. (2007): The Factor Graph Approach to Model-Based Signal Processing. In *Proc. IEEE* 95 (6), pp. 1295–1322. DOI: 10.1109/JPROC.2007.896497.

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[3] Hoffmann, Christian; Rostalski, Philipp (2016): A Factor Graph Approach to Optimal and Predictive Control. Submitted to the 20th IFAC World Congress. Toulouse, France.

[4] Kröll, Harald; Zwicky, Stefan; Odermatt, Reto; Bruderer, Lukas; Burg, Andreas; Huang, Qiuting (2014): A Signal Processor for Gaussian Message Passing. Available online at http://arxiv.org/pdf/1404.3162v1.