Proposal for Half-Day Tutorial

Graph-Based Localization, Tracking, and Mapping

Localization and tracking are increasingly important capabilities in emerging applications, including autonomous navigation, applied ocean sciences, asset tracking, future communication networks, and the internet of things. These applications pose new theoretical and methodological challenges to information fusion due to the use of heterogeneous sensors. Processing measurements is often complicated by uncertainties beyond Gaussian noise, like missed detections and clutter, an uncertain origin of measurements, and an unknown and time-varying number of objects to be localized or tracked.

Methodologically, these challenges can be well addressed by inference that leverages graphical models. The graph-based inference approach has important advantages regarding performance, scalability, versatility, and implementation flexibility. It provides a powerful theoretical framework and a rich set of tools for modeling and exploiting the statistical structure of an inference problem. An inherent advantage of graph-based inference is that it can provide scalable solutions to high-dimensional problems. It also introduces lucidity and modularity into algorithm design since different functional units of the overall problem appear as distinct parts in the graph. Due to these desirable properties, new graph-based modeling and inference techniques are advancing the field of localization and tracking. The proposed tutorial, “Graph-Based Localization, Tracking, and Mapping,” will present the following topics.

1. Probabilistic Graphical Models and Their Properties
2. Factor Graphs and the Message Passing Algorithms
3. Graph-Based Probabilistic Data Association
4. Graph-Based Multiobject Tracking
5. Graph-Based Simultaneous Localization and Mapping Based on Radio Signals

Conference attendees that attend this tutorial will be able to

- Develop a factor graph for the statistical model of a localization, tracking, or mapping problem
- Derive a message-passing algorithm for parameters estimation based on the graphical model

The intended audience is graduate students or postdocs with a background in engineering. Recommended prerequisites for this tutorial are probability theory, statistical signal processing, linear algebra, and sequential state-space filtering.

Lecturers

Erik Leitinger received the Dipl.-Ing. (M.Sc.) and Ph.D. degrees (with highest honors) in electrical engineering from Graz University of Technology, Austria, in 2012 and 2016. He is currently a Senior Research Scientist with the Graz University of Technology. From 2016 to 2018, he was a Postdoctoral Researcher at the Department of Electrical and Information Technology at Lund University.

Dr. Leitinger received an Award of Excellence from the Federal Ministry of Science, Research and Economy (BMWFW) for his Ph.D. Thesis. He served as co-chair of the special session "Synergistic Radar Signal Processing and Tracking" at the IEEE Radar Conference in 2021 and co-organizer of the special issue "Graph-Based Localization and Tracking" in the Journal of Advances in Information Fusion (JAIF). His research interests include statistical signal processing, nonlinear estimation and detection, inference on graphs, localization and navigation, SLAM, estimation of radio channels, and estimation/detection theory.

Augustin A. Saucan received the the Dipl.-Ing. (M.Sc.) and Ph.D. degrees from *Institut Mines Télécom Atlantique*, Brest, France, in 2012 and 2016. He is currently a *maître de conferences* (equivalent to an associate professor) at *Télécom SudParis, Institut Polytechnique de Paris (IP Paris)*, Paris, France. Prior to joining *Télécom SudParis*, he was a postdoctoral associate at the *Laboratory for Information & Decision Systems* at the *Massachusetts Institute of Technology*, Cambridge, MA in 2019-2022. From 2017 to 2019, Dr. Saucan was a postdoctoral researcher at Syracuse University, Syracuse, NY, and between 2016 and 2017, he was a postdoctoral researcher at McGill University, Montreal, Canada. His current research interests include statistical signal processing, graphical-model based inference, Monte Carlo methods, reinforcement learning, localization and tracking.

Florian Meyer received the MSc and Ph.D. degrees (with highest honors) in electrical engineering from TU Wien, Vienna, Austria, in 2011 and 2015. He is an Assistant with the University of California San Diego, La Jolla, CA, jointly between the *Electrical and Computer Engineering Department* and the *Scripps Institution of Oceanography*. From 2017 to 2019, he was a Postdoctoral Fellow and Associate with the *Laboratory for Information & Decision Systems* at the *Massachusetts Institute of Technology*, Cambridge, MA. From 2016 to 2017, Dr. Meyer was with the *NATO Centre for Maritime Research and Experimentation*, La Spezia, Italy as a Research Scientist.

Prof. Meyer is the recipient of the *2021 ISIF Young Investigator Award* and a *2022 NSF CAREER Award*. He was a keynote speaker at the *IEEE Aerospace Conference* in 2020 and the lecturer of the invited IEEE Signal Processing Society Webinar: “Distributed Localization and Tracking of Mobile Networks.” Prof. Meyer regularly teaches graduate and undergraduate level classes on signal processing, parameter estimation, and probabilistic graphical models at the *University of California San Diego*.