Title: Algorithms for Estimation of Noise Parameters in State Space Models

Proposers: Ondřej Straka, University of West Bohemia, Czech Republic
Jindřich Duník, University of West Bohemia, Czech Republic

Length of the tutorial:

Half-day

Intended audience: The tutorial is intended for researchers in academia and industry, engineers, and graduate students interested in state estimation, target tracking, navigation, decision-making, and system identification.

Prerequisites: Basic knowledge of probability theory, statistics, and linear algebra

Tutorial description:

Knowledge of a system model is a prerequisite for many state estimation, signal processing, fault detection, and optimal control problems. The model is often designed to be consistent with the random behavior of the system quantities and properties of the measurements. While the deterministic part of the model often arises from mathematical modeling based on physical, chemical, or biological laws governing the behavior of the system, the statistics of the stochastic part are often difficult to find by the modeling and have to be identified using the measured data. Incorrect description of the noise statistics may result in a significant worsening of estimation, signal processing, detection, or control quality or even failure of the underlying algorithms. The tutorial introduces a more than six decades-long history as well as recent advances and state-of-the-art methods for estimating the properties of the stochastic part of the model. In particular, estimating state-space model noise means, covariance matrices, and other parameters is treated.

Learning objectives:

The tutorial covers all major groups of noise statistics estimation methods, including correlation methods, maximum likelihood methods, covariance matching methods, and Bayesian methods. The methods are introduced in the unified framework highlighting their basic ideas, key properties, and assumptions. Algorithms of individual methods will be described and analyzed to provide a basic understanding of their nature and similarities. The performance of the methods will also be compared using a numerical illustration.

Material:

The attendees will be provided with course notes and sample implementations of the selected methods.

Tutorial outline:

Part I. Introduction, Motivation, and Basic Design Procedures (40 mins)
Part II. Correlation Methods (40 mins)
Part III. Maximum Likelihood, Covariance Matching, and Bayesian Methods (40 mins)
Part IV. Numerical Comparison and Illustration (40 mins)
Part V. Estimation of Means and Parameters (40 mins)
Part VI. A showcase of noise parameter applications in real-world problems (20 mins)
Part VII. Implementation (10 mins)

Presenters: Ondřej Straka, Jindřich Duník; University of West Bohemia, Czech Republic

Biographical sketches:

Ondřej Straka received his M.Sc. and Ph.D. degrees in cybernetics from the University of West Bohemia, Pilsen, Czech Republic, in 1998 and 2004, respectively. Since 2015, he has been an Associate Professor with the Department of Cybernetics, University of West Bohemia. He has sixteen years of teaching experience at the UWB. Currently, he is a lecturer for graduate and post-graduate courses on estimation theory, stochastic systems and processes, and mathematical control theory. He has published over 140 journal and conference papers and was involved in the development of several software frameworks for nonlinear state estimation and system identification. He has participated in several projects of fundamental research and in several projects of applied research (e.g., GNSS-based safe train localization and attitude and heading reference system). His current research interests include local and global nonlinear state estimation methods, system identification, noise covariance matrix estimation in state-space models, performance evaluation, and fault detection in navigation systems. Dr. Straka was a recipient of the Werner von Siemens Excellence Award in 2014 for the most important result in basic research.

Jindřich Duník is an Associate Professor at the Department of Cybernetics, University of West Bohemia (UWB), Czech Republic and at the Aerospace Advanced Technology Europe, Honeywell International. He received his Ing. (M.Sc.) and Ph.D. degrees in Automatic Control in 2003 and 2008, respectively, both from the UWB. Until 2010, he was with the UWB. From 2010 he is with Honeywell and from 2013 again with the UWB working in the areas of state estimation and navigation system design and integration. Since 2020, he has been an Associate Professor with the Department of Cybernetics, UWB. He is the author or co-author of more than 70 technical papers (both journal and conference) and granted patents. He has 8 years of teaching experience at the UWB and, currently, he is teaching graduate courses on “System Identification and Filtering” and “Adaptive Systems”. Dr. Dunik is an IEEE Senior Member and was a recipient of the Werner von Siemens Excellence Award in 2014 for the most important result in basic research and Honeywell Aerospace Technology Achievement Award in 2016, 2019 for the navigation system design.

The presenters organized the tutorial during conferences FUSION 2017, FUSION 2018, FUSION 2020, FUSION 2021, and FUSION 2022. For samples and video recordings of the past tutorials, please refer to the materials used for the tutorial during FUSION 2020.