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Guest Editorial: Foreword to the Special Issue on Nonlinear Derivative-Free Filters: Theory and Applications

State estimation, or filtering, is a focal point for navigation, positioning, and tracking systems. State estimation also plays a crucial role in various areas and applications, where knowledge of the state is required for a (multistep) prediction, control, fault detection, or generally for decision making.

The special issue is focused on the design of local, i.e., nonlinear Kalman-filter-based, derivative-free filters for nonlinear stochastic dynamic time-varying systems with an emphasis on the theoretical advances in the field of study. In particular, the focus of the issue is laid on both the design of novel algorithms for state and parameter estimation and the in-depth analysis and further development of existing methods.

The special issue consists of six papers all from renowned research groups systematically working in the area of the state estimation. Some of the papers are significantly extended versions of the papers presented at the 17th International Conference on Information Fusion (FUSION 2014) within the special session "Advanced Sigma-Point Filters: Analysis, Sigma-Point Set Design, and Applications".

The opening paper of this special issue, the paper entitled "Partitioned Update Kalman Filter" by M. Raitoharju, R. Piché, J. Ala-Luhtala, and S. Ali-Löytty, is devoted to the design of the state estimation algorithm inherently measuring or assessing the nonlinearity of the function in the measurement equation of the state-space model at the actual estimator working point. Depending on the computed measure of nonlinearity, the particular elements of the measurement vector are processed starting from those having the lowest measure, i.e., from those with the lowest expected approximation error.

The second paper entitled "Sigma-Point Filtering based Parameter Estimation in Nonlinear Dynamic Systems" by J. Kokkala, A. Solin, and S. Särkkä, deals with the estimation of unknown parameters in nonlinear state-space models based on the maximum marginal

likelihood. The marginalized likelihood is computed using two approximate methods, namely a direct likelihood method and the expectation-maximisation algorithm, evaluated by means of approximate nonlinear filtering and smoothing techniques. The considered techniques take advantage of a higher-order unscented transformation and the Gauss-Hermite integration rule.

The third paper entitled "On the Relation between Gaussian Process Quadratures and Sigma-point Methods" by S. Särkkä, J. Hartikainen, L. Svensson, and F. Sandblom, is dedicated to a numerical evaluation of the Gaussian weighted integrals based on Gaussian process regression methods, i.e., Gaussian process quadratures. Special attention is paid to the interpretation of derivative-free sigma-point approximate methods for the evaluation of integrals typically appearing in the local filter design (for conditional moment computation) as a special case of Gaussian process quadratures. As a consequence, a set of novel local methods for nonlinear state estimation is proposed.

The fourth paper entitled "Nonlinear Kalman Filters Explained: A Tutorial on Moment Computations and Sigma Point Methods" by M. Roth, G. Hendeby, and F. Gustafsson, is concerned with an in-depth and widespread survey of nonlinear local estimation algorithms published so far. The algorithms are introduced in a unified framework and particular approximation techniques, both derivative-free and with an explicit derivative, used for integral evaluation are analysed with respect to the structure and properties of the considered integrals and nonlinear functions.

The fifth paper entitled "The Smart Sampling Kalman Filter with Symmetric Samples" by J. Steinbring, M. Pander, and U. D. Hanebeck, is aimed at a design of a novel local filtering algorithm suitable even for high-dimensional tasks. The algorithm is based on the deterministic symmetric equally-weighted sample set, which is used by an integration rule computing the conditional moments. The set is computed prior to the estimation experiment by an optimization procedure, thus not affecting the computational complexity of the filter.

The last, the sixth, paper entitled "Sigma-Point Set Rotation for Derivative-Free Filters in Target Tracking Applications" by J. Duník, O. Straka, M. Šimandl, and E. Blasch, is focused on a thorough analysis of the impact of user-defined parameters on the estimation performance of the derivative-free local filters. In particular, the sigma-point (or sample) set rotation determined either by a selected covariance matrix factorisation technique or by an additional sigma-point set rotation is treated. Recommendations for optimal and sub-optimal set rotations are provided and justified.

Overall, the special issue covers numerous perspectives of local nonlinear state estimation and represents an excellent overview of the state-of-the-art and current trends of the research in the area. We hope that you will find the special issue attractive, educational, and motivating and enjoy reading the papers. Finally, we would like to thank the Journal of Advances in Information Fusion (JAIF) Editorial Board for the possibility to prepare this special issue and the Editor-in-Chief, Prof. Uwe D. Hanebeck, for his encouragement and continuous support. We also greatly appreciate the authors and the reviewers for their outstanding effort and contribution to the special issue.

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