FUSION 2017 Tutorial

MANEUVERING TARGET TRACKING: OVERVIEW AND NONLINEAR FILTERING METHODS

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Abstract:

The principal challenges for tracking a maneuverable target are nonlinearity in both target motion and measurement models as well as the uncertainty in the pattern of target motion. This tutorial presents theoretical and algorithmic means available to meet these challenges. The overview part elucidates a well organized panorama of maneuvering target tracking. The other part presents an in-depth coverage of recent advances in nonlinear filtering for maneuvering target tracking, including some of the instructors' results and insights as well as better known methods. The tutorial highlights the underlying ideas and pros and cons of approaches and techniques as well as inter-relationships among them. It is an outgrowth of the instructors' ongoing comprehensive survey and several short courses of the same subject as well as a graduate course on target tracking taught at the Electrical Engineering Department of the University of New Orleans.

Topic Area:

Algorithms: nonlinear filtering and smoothing, tracking and localization

Motivation:

The recent years have witnessed significant advances in nonlinear filtering methods for maneuvering target tracking. Many of these advances are not generally known to the information fusion community. There is no doubt that research for lower-level fusion has made great progress in the past years, and maneuvering target tracking is one such area. It deserves tutorials like what we are proposing to make these exciting advances more accessible to a larger audience, especially to newcomers to data fusion such as graduate students. This is important for the growth of data fusion research and development. Our proposed tutorial provides a systematic coverage of nonlinear filtering methods for target tracking that is not found elsewhere yet valuable for the data fusion community. Also, the scientific approach that enables the great success of lower-level fusion research is not so fitting for the higher-level fusion, and so higher-level fusion research cannot have a great expectation. This has several reasons. For example, the higher-level fusion is much more subjective and equivocal than lower-level fusion. We hope that the proposed tutorial will contribute to correcting the questionable current trend.

Potential Audience:

- The tutorial is intended for researchers, engineers, and graduate students interested in target tracking and data processing in general. It does not require prior knowledge in nonlinear filtering.

Objective:

- Provide up-to-date systematic treatment of state-of-the art nonlinear filtering techniques, algorithms, and performance studies for tracking a maneuverable target in a non-cooperative environment, particularly recent advances.

Outline:

Morning (3 hours)

- **Overview of maneuvering target tracking**: Introduction and major challenges. Target dynamic models. Measurement models and techniques. Decision-based methods. Multiple-model methods. Nonlinear filtering (point estimation and density estimation).
- **Nonlinear filtering**: (a) Point Estimation: Three classes of approximation techniques: deterministic function approximation (Taylor approximation, interpolation), moment approximation (unscented transformation, Gaussian quadrature), and stochastic (e.g., statistical and optimal) model approximation. Filtering with nonlinear measurements by linear MMSE and two-step LS. Comparative case study. (b) Density Estimation: Various approximation techniques, including numerical, spectral, and parametric methods, including particle filtering, deterministic grid, finite sum, and parametric approximation. The emphasis is on those particularly suitable for handling nonlinearity in the system dynamics and/or observation systems encountered in target tracking.

Course Material:

- Lecture notes and additional reference materials will be provided to all students.

Authors' biographies:

X. Rong Li received the B.S. and M.S. degrees from Zhejiang University, Hangzhou, Zhejiang, PRC, in 1982 and 1984, respectively, and the M.S. and Ph.D. degrees from the University of Connecticut, USA, in 1990 and 1992, respectively. He joined the Department of Electrical Engineering, University of New Orleans in 1994, where he is now Chancellor's University Research Professor. He has authored or coauthored four books, ten book chapters, and more than 300 journal and conference proceedings papers. His current research interests include signal and data processing, target tracking, information fusion, stochastic systems, statistical inference, and electric power.

Dr. Li is an internationally recognized leading expert in target tracking and data fusion, and in a U.S. National Science Foundation panel of experts' words, "*has made a groundbreaking contribution*" in these areas. He was elected to IEEE Fellow in 2003 and was elected to the President of the International Society of Information Fusion in 2003. He has served as the General Chair for several international conferences on information fusion and as Editor for four academic journals, including the *IEEE Transactions on Aerospace and Electronic Systems* (1996–2003); delivered invited plenary speeches in several international conferences; given more than 150 invited seminars in America, Asia, Europe, and Oceania; received several honored professorships in universities; and received CAREER award from the U.S. National Science Foundation. He has given numerous plenary and invited talks, tutorials, and short courses in North America, Europe, Asia, and Australia, including tutorials on Maneuvering Target Tracking in many Fusion conferences. He is the principal investigator of more than 40 research projects from various government agencies and the private sector.

Vesselin P. Jilkov received his B.S. and M.S. degree in mathematics from the University of Sofia, Bulgaria in 1982, the Ph.D. degree in the technical sciences in 1988, and the academic

rank Senior Research Fellow of the Bulgarian Academy of Sciences in 1997. In 1999 he joined the Department of Electrical Engineering, University of New Orleans, where he is at present the Riley Parker Endowed Professor. He has taught numerous courses in the areas of signal, systems & control, and taught jointly with Dr. X. Rong Li the Fusion conference tutorials on Maneuvering Target Tracking. Dr. Jilkov's current research includes applied estimation and decision, nonlinear filtering, target tracking, information fusion, optimization, parallel processing. He has conducted research as principal investigator (PI) or Co-PI of several projects funded by US Army, Navy and DoD. Dr. Jilkov is author/coauthor of over 100 journal articles and conference papers. He is a member of ISIF, IEEE, and SIAM.