Multitarget Tracking and Multisensor Information Fusion: Recently Developed Advanced Algorithms

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FUSION 2023 Tutorial

Objectives: This tutorial will provide to the participants several of the latest state-of-the art advanced algorithms to estimate the states of multiple targets in clutter and multisensor information fusion. These form the basis of automated decision systems for *advanced surveillance* and *targeting*.

Advanced algorithms, including the track-to-track fusion from heterogeneous sensors and the cross-covariance between different dimension state space estimators based on the "mapped process noise" between active and passive sensors are discussed. Optimal measurement extraction from optical sensors, together with their accuracies, and enhanced resolution for closely-spaced objects using FPA offset are presented. The Maximum Likelihood Probabilistic Data Association algorithm for VLO targets is presented together with its application to real data, where it is shown to provide earlier track detection compared to the MHT.

Eligibility: Engineers/scientists with prior knowledge of basic probability and state estimation (see, e.g., [2]). This is an intensive course in order to cover several important recent advances and applications.

OUTLINE

[582V] **Heterogeneous and Asynchronous Information Matrix Fusion**

The Information Matrix Fusion (IMF) algorithm for nonlinear, asynchronous (with arbitrary local tracker sampling times for full rate as well as reduced-rate communication) and heterogeneous systems is presented. The main application of these results is the fusion of tracks from radar and electrooptical sensors.

Reference: (582) K. Yang, Y. Bar-Shalom and K. C. Chang, "Heterogeneous and Asynchronous Information Matrix Fusion", **J. of Advances in Information Fusion**, 15(2):101–111, Dec. 2020

[571V] **Asynchronous and Heterogeneous Track-to-Track Fusion with Mapped Process Noise and Cross-Covariance**

The relationship between the process noise covariances of a target's motion models in different state spaces (Cartesian and angle-only) is presented. The crosscovariance of the local estimation errors is then derived. Both the synchronous and asynchronous systems are considered. A linear minimum mean square error fusion is carried out for a scenario involving tracks from two LTs: one from an active sensor and one from a passive sensor

Reference: (571) K. Yang, Y. Bar-Shalom and P. Willett, "Asynchronous and Heterogeneous Track-to-Track Fusion with Mapped Process Noise and Cross-Covariance", **J. of Advances in Information Fusion**, 15(1):39–47, June 2020.

[543V] **Measurement Extraction for a Point Target from an Optical Sensor**

The optimal extraction of the location of an object from an FPA using the ML technique is presented. The calculated accuracy is shown to meet the CRLB, i.e., the ML extractor is statistically efficient, Also the pixel size selection based on the optics (the point spread function) is discussed.

Reference: (543) Q. Lu, Y. Bar-Shalom and P. Willett, "Measurement Extraction for a Point Target from an Optical Sensor", **IEEE Trans. Aerosp. Electronic Systems**, 54(6):2735–2745, Dec. 2018. DOI 10.1109/TAES.2018.2828259

[612V] Use of Focal Plane Array (FPA) offset to enhance in an optical sensor the resolution of closely spaced targets. FPA offset can be obtained via a piezoelectric actuator and the use of two consecutive frames with the second shifted by 1/2 pixel is shown to improve the resolution of two closely spaced point targets.

Reference: (612) Z. Tian, A. Finelli, B. Milgrom, K. Yang, Y. Bar-Shalom and P. Willett, “Enhanced Resolution for Closely-Spaced Objects from Optical Sensor Using FPA Offset”, **IEEE Trans. Aerosp. Electronic Systems**, 59(): 2023.

[210V] Acquisition of a 4 dB SNR TBM target with an ESA radar.

The acquisition of a very low observable (VLO) incoming tactical ballistic missile using the measurements from a surface based electronically scanned array (ESA) radar is presented. We present a batch maximum likelihood (ML) estimator to acquire the missile while it is exoatmospheric. The proposed estimator, which combines ML estimation with the probabilistic data association (PDA) approach resulting in the ML-PDA algorithm to handle false alarms, also uses target features. Thhis algorithm acts as an effective “power multiplier” for the radar by about an order of magnitude. The Cramer-Rao lower bound (CRLB), quantifying the attainable estimation accuracies and shown to be met by the ML-PDA estimator.

Reference: (210) S. Sivananthan, T. Kirubarajan and Y. Bar-Shalom, “A Radar Power Multiplier Algorithm for Acquisition of LO Ballistic Missiles Using an ESA Radar”, **IEEE Trans. Aerosp. Electronic Systems**, AES-37(2):401–418, April 2001.

[225BBB] The ML-PDA estimator applied to real EO data. Comparison with the MHT.

Reference: (225) M. R. Chummun, T. Kirubarajan and Y. Bar-Shalom, “An Adaptive Early-Detection ML/PDA Estimator for LO Targets with EO Sensors”, **IEEE Trans. Aerosp. Electronic Systems**, 38(2):694-707, April 2002.

The tutorial presentations will be emailed to the tutorial attendees.

Background texts (available from amazon.com):

[1] Y. Bar-Shalom, P. K. Willett and X. Tian, **Tracking and Data Fusion**, YBS Publishing, 2011.

[2] Y. Bar-Shalom, X. R. Li and T. Kirubarajan, **Estimation with Applications to Tracking and Navigation: Algorithms and Software for Information Extraction**, Wiley, 2001.

Free video online course: “Information Modeling and Extraction” (a simplified version of [2] with some additional material) available at

http://www.ee.uconn.edu/graduate-program/gradcourses/graduate-course-live-channel

Brief Biography of Instructor

Yaakov BarShalom was born on May 11, 1941. He received the B.S. and M.S. degrees from the Technion, Israel Institute of Technology, in 1963 and 1967 and the Ph.D. degree from Princeton University in 1970, all in electrical engineering. Currently he is Board of Trustees Distinguished Professor in the Dept. of Electrical and Computer Engineering and Marianne E. Klewin Professor in Engineering at the University of Connecticut. His current research interests are in estimation theory and target tracking and has published over 650 papers and book chapters in these areas and in stochastic adaptive control. He coauthored and edited 8 books. He has consulted to numerous companies and government agencies, and originated the series of Multitarget-Multisensor Tracking short courses. He served as General Chairman of FUSION 2000, President of ISIF in 2000 and 2002 and Vice President for Publications in 2004-13. Since 1995 he is a Distinguished Lecturer of the IEEE AESS and has given numerous keynote addresses at major national and international conferences. He is corecipient of the M. Barry Carlton Award for the best paper in the IEEE Transactions on Aerospace and Electronic Systems in 1995 and 2000. In 2002 he received the J. Mignona Data Fusion Award from the DoD JDL Data Fusion Group. He was awarded the 2008 IEEE Dennis J. Picard Medal for Radar Technologies and Applications and was listed in "top authors in engineering" by academic.research.microsoft as the #1 cited author in Aerospace Engineering. He is the recipient of the 2015 ISIF "Lifetime of Excellence in Information Fusion" award, renamed as "ISIF Yaakov Bar-Shalom Award for Lifetime of Excellence in Information Fusion" for recipients starting 2016. He has the following Wikipedia page: https://en.wikipedia.org/wiki/Yaakov Bar-Shalom. In 2022 he received (with Henk Blom) the IEEE AESS Pioneer Award for "Development of the IMM approach for multi-model estimation and maneuvering target tracking".

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