FUSION2021 TUTORIAL PROGRAMME INFORMATION

Tutorials:

T1. Multitarget Tracking and Multisensor Information Fusion: Recently Developed Advanced Algorithms

Speaker(s): Yaakov Bar-Shalom
Duration: 3 hours
Abstract: This tutorial will provide to the participants several of the latest state-of-the art advanced algorithms to estimate the states of multiple targets and multisensor information fusion. These form the basis of automated decision systems for advanced surveillance and targeting. Advanced algorithms, including the recently solved track-to-track fusion from heterogeneous sensors and the cross-covariance for heterogeneous sensors are discussed. Target-of-interest selection in a multitrack environment, optimal measurement extraction from optical sensors together with their accuracies, bias estimation for collocated sensors, and an algorithm for VLO track extraction using features are also discussed.

T2. Evaluation of Technologies for Uncertainty Reasoning

Speaker(s): Paulo Costa, Kathryn Laskey, and Gregor Pavlin
Duration: 3 hours
Abstract: The ETUR Tutorial will explore three topics: (1) summarize the state of the art in uncertainty analysis, representation, and evaluation, (2) introduce the main aspects of the Uncertainty Representation and Reasoning Framework (URREF), and (3) explain its use via a series of case studies that apply the framework. The impact to the ISIF community would be a tutorial exploring the overall topic of uncertainty representation and evaluation. In addition to the theoretical background on the topic, the audience will be exposed to a number of use cases that have been part of the ongoing discussions within the ISIF Working Group that created the framework. Among the subjects covered, the attendees will have some guidelines to draft requirements documentation, the gain of fusion systems over current uncertainty representation techniques, as well as issues that are important in information fusion systems designs. One of the main goals of information fusion is uncertainty reduction, which is dependent on the representation chosen. Uncertainty representation differs across the various levels of Information Fusion (as defined by the JDL/DFIG models). Given the advances in information fusion systems, there is a need to determine how to represent and evaluate situational (Level 2 Fusion), impact (Level 3 Fusion) and process refinement (Level 5 Fusion), which is not well standardized for the information fusion community. This tutorial will introduce a framework developed to address these issues.

T3. Fusion using belief functions: source reliability and conflict

Speaker(s): Frédéric Pichon and Anne-Laure Jousselme
Duration: 3 hours
Abstract: Information fusion is one of the key applications of the theory of belief functions (aka evidence theory or Dempster-Shafer theory), as shows the regular sessions on belief functions at the FUSION conference. This tutorial will provide an opportunity for students and researchers to learn about fundamental and advanced aspects of the multi-source (either sensors or humans) information fusion within the theory of belief functions. Rather than surveying the different combination rules, this tutorial will specifically address the problem of combining information from partially reliable sources, explaining how to properly use meta-knowledge about the sources reliability in the fusion process. A general approach to information fusion will be presented, allowing going beyond reliability such as truthfulness and reinforcing the relevance of belief function theory for information fusion. Means to tackle practical fusion problems will also be provided. When meta-knowledge about the source reliability is not available, the validity of assumptions on the source reliability can be evaluated thanks to the notion of consistency. One interpretation of the conflict (or lack of consistency) between sources is indeed that it is due to the unreliability of some of the sources involved in the reasoning. The second part of the tutorial will present recent advances on the measurement of consistency and conflict in evidence theory. A family of measures of consistency extends the consistency between sets and brings under the same umbrella existing measures while defining new ones, offering a finer characterization of conflict. The related and often associated notion of distance will be also presented, highlighting links, similarities and differences with conflict. Each theoretical concept will be illustrated on examples from several applications mainly from the maritime domain.

T4. Algorithms for Estimation of Noise Parameters in State Space Models

Speaker(s): Ondřej Straka and Jindřich Duník
Duration: 3 hours
Abstract: Knowledge of a system model is a key prerequisite for many state estimation, signal processing, fault detection, and optimal control problems. The model is often designed to be consistent with 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 in a failure of the underlying algorithms. The tutorial introduces a more than six decades-long history as well as recent advances and the state-of-the-art of the methods for estimation of the properties of the stochastic part of the model. In particular, the estimation of state-space model noise means, covariance matrices, and other parameters is treated. The tutorial covers all major groups of the noise statistics estimation methods, including the 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. Performance of the methods will also be compared using a numerical illustration. The attendees will be provided with course notes and sample implementations of the selected methods.

T5. Multisensor Data Fusion for Industry 4.0

Speaker(s): Claudio M. de Farias and Jose F. B. Brancalion
Duration: 3 hours
Abstract: The Internet of Things (IoT) is a novel paradigm that is grounded on Information and Communication Technologies (ICT). Recently, the use of IoT has been gaining attraction in areas such as logistics, manufacturing, retailing, and pharmaceutics, transforming the typical industrial spaces into Smart Spaces. This leads to a novel paradigm called Industry 4.0. Since IoT data is usually dynamic and heterogeneous, it becomes important to investigate techniques for understanding and resolving issues about data fusion in Industry 4.0. Employment of Data fusion algorithms are useful to reveal trends in the sampled data, uncover new patterns of monitored variables, make predictions, thus improving decision making process, reducing decisions response times, and enabling more intelligent and immediate situation awareness. This tutorial aims to show the multisensor data fusion techniques used in the Industry 4.0 scenario as well as case studies.

T6. Context-enhanced Information Fusion

Speaker(s): Lauro Snidaro and Erik Blasch
Duration: 3 hours
Abstract: Contextual Information (CI) can be understood as the information that "surrounds" an observable of interest. Even if not directly part of the problem variables being estimated by the system, CI can influence their state or even the sensing and estimation processes themselves. Therefore, understanding and exploiting CI can be a key element for improving the performance of Information Fusion algorithms and automatic systems in general that have to deal with varying operating conditions. There is a growing interest for this promising research topic that should be considered for developing next-generation Information Fusion systems. Context can have static or dynamic structure, and be represented in many different ways such as maps, knowledge-bases, ontologies, etc. It can constitute a powerful tool to favour adaptability and boost system performance. Application examples include: context-aided surveillance systems (security/defence), traffic control, autonomous navigation, cyber security, ambient intelligence, ambient assistance, etc. The purpose of this tutorial is to survey existing approaches for context-enhanced information fusion, covering the design and development of information fusion solutions integrating sensory data with contextual knowledge. After discussing CI in other domains, the tutorial will focus on context representation and exploitation aspects for Information Fusion systems. The applicability of the presented approaches will be illustrated with real-world context-aware Information Fusion applications. L. Snidaro, J. Garcia Herrero, J. Llinas, E. Blasch (eds.), Context-Enhanced Information Fusion: Boosting Real-World Performance with Domain Knowledge, Springer, 2016.

T7. Stone Soup: an open source tracking and state estimation framework; principles, use and applications

Speaker(s): Lyudmil Vladimirov, David Kirkland, Jordi Barr, and Steven Hiscocks
Duration: 6 hours (two sessions)
Abstract: It is currently difficult and time consuming for academic researchers to recreate state-of-the-art tracking and state estimation algorithms to benchmark their work. Comparison of new algorithms with existing solutions involves recoding algorithms from the literature. Industrial users also find it difficult to assess which algorithms meet their, often quite varied, requirements. The Stone Soup framework is designed to provide a flexible and unified software platform for researchers and engineers to develop, test and benchmark a variety of existing multi-sensor and multi-object estimation algorithms. It is also designed to allow rapid prototyping of new algorithms in high-level languages, both open and proprietary (e.g. Python, Matlab), as well as development in compiled languages (e.g. C++), by providing a set of libraries which implement the necessary functions for tracking and state estimation. It profits from the object-oriented principles of abstraction, encapsulation and modularity, allowing users (beginners, practitioners or experts) to focus only on the most critical aspects of their problem. Stone Soup is endorsed by ISIF's working group on Open Source Tracking and Estimation (OSTEWG). These tutorials will introduce participants to Stone Soup's basic components and how they fit together. They are delivered by way of demonstrations, set tasks and interactive sessions where participants will be encouraged to write and modify algorithms. These tasks will be written up in the form of interactive browser-based applications which combine the ability to run code with a presentation environment suitable for instruction. The first tutorial will begin with basic examples using linear transition models, abstract range-bearing sensors and single-targets using the extended and unscented Kalman and particle filters. Multiple targets, clutter and methods of data association will be introduced. The second tutorial session is an interactive grouped activity, applying Stone Soup to several scenarios involving simulated and real-world data. The outputs of these tutorials are likely to be highly relevant to the Open Source Tracking and Estimation Working Group, whose annual meeting will take place during the Fusion conference.

T8. Overview of High-Level Information Fusion Theory, Models, and Representations

Speaker(s): Erik Blasch
Duration: 3 hours
Abstract: Over the past decade, the ISIF community has put together special sessions, panel discussions, and concept papers to capture the methodologies, directions, needs, and grand challenges of high-level information fusion (HLIF) in practical system designs. This tutorial brings together the contemporary concepts, models, and definitions to give the attendee a summary of the state-of-the-art in HLIF. Analogies from low-level information fusion (LLIF) of object tracking and identification are extended to the HLIF concepts of situation/impact assessment and process/user refinement. HLIF theories (operational, functional, formal, cognitive) are mapped to representations (semantics, ontologies, axiomatics, and agents) with contemporary issues of modelling, testbeds,

evaluation, and human-machine interfaces. Discussions with examples of search and rescue, cyber analysis, and battlefield awareness are presented. The attendee will gain an appreciation of HLIF through the topic organization from the perspectives of numerous authors, practitioners, and developers of information fusion systems. The tutorial is organized as per the recent text: E. P. Blasch, E. Bosse, and D. A. Lambert, High-Level Information Fusion Management and Systems Design, Artech House, April 2012.

T9. An Introduction to Track-to-Track Fusion and the Distributed Kalman Filter

Speaker(s): Felix Govaers
Duration: 3 hours
Abstract: The increasing trend towards connected sensors ("internet of things" and "ubiquitous computing") derive a demand for powerful distributed estimation methodologies. In tracking applications, the "Distributed Kalman Filter" (DKF) provides an optimal solution under certain conditions. The optimal solution in terms of the estimation accuracy is also achieved by a centralized fusion algorithm which receives either all associated measurements or so-called "tracklets". However, this scheme needs the result of each update step for the optimal solution whereas the DKF works at arbitrary communication rates since the calculation is completely distributed. Two more recent methodologies are based on the "Accumulated State Densities" (ASD) which augment the states from multiple time instants. In practical applications, tracklet fusion based on the equivalent measurement often achieves reliable results even if full communication is not available. The limitations and robustness of the tracklet fusion will be discussed. At first, the tutorial will explain the origin of the challenges in distributed tracking. Then, possible solutions to them are derived and illuminated. In particular, algorithms will be provided for each presented solution. The list of topics includes: Short introduction to target tracking, Tracklet Fusion, Exact Fusion with cross-covariances, Naive Fusion, Federated Fusion, Decentralized Fusion (Consensus Kalman Filter), Distributed Kalman Filter (DKF), Debiasing for the DKF, Distributed ASD Fusion, Augmented State Tracklet Fusion.

T10. Poisson multi-Bernoulli mixtures for multiple target tracking

Speaker(s): Ángel F. García-Fernández and Yuxuan Xia
Duration: 3 hours
Abstract: In this tutorial, the attendant will learn the foundations of the Poisson multi-Bernoulli mixture (PMBM) filter, a state-of-the-art multiple target tracking (MTT) algorithm that has been applied to data from lidars, radars, cameras and integrated search-and-track sensor management. In addition, the attendant will learn the relations of the PMBM filter with other MTT algorithms such as multi-Bernoulli mixture (MBM) filter, probability hypothesis density (PHD) filter, Poisson multi-Bernoulli (PMB) filter, delta-generalised labelled multi-Bernoulli (GLMB) filter, multiple hypothesis tracking (MHT), and joint integrated probabilistic data association (JIPDA) filter. Finally, this tutorial will cover the extension of the PMBM filter to sets of trajectories to include full trajectory information.

T11. Multi Sensor Data Fusion for Vehicular Automation and Autonomous Driving: Concepts, Implementations and Evaluation Techniques

Speaker(s): Bharanidhar Duraisamy, Ting Yuan, Tilo Schwarz, and Martin Fritzsche
Duration: 3 hours
Abstract: This tutorial is focussed towards the stringent requirements, foundations, development and testing of sensor fusion algorithms meant for advanced driver assistance functions (Partial - Conditional Automated), self-driving car applications (Conditional - Highly - Fully Automated) in automotive vehicle systems and vehicular infrastructure oriented sensor fusion applications under the realm of Internet of Things and Industry 4.0. The audience would be provided with the tutorial materials in PDF format through the conference content management system. The complex sensor world of autonomous vehicles is discussed in detail and different aspects of sensor fusion problem related to this area is taken as one of the core subject of this tutorial. In addition: a special discussion section on a sensor fusion system that is designed to work on data obtained from environment perception sensors placed in an infrastructure such as a parking house, is presented. The interesting part of the tutorial is covered on different challenging and important real world implementation problems including practical aspects such as fusion with incomplete information, data association, sensor communication latency, real world testing, real-life like simulation etc. related to fusion and target tracking in automotive domain. Challenges in automated driving in highway and urban setting are discussed in detail during every section of this tutorial. Interesting research and application based discussion on centralized, decentralized and hybrid-distributed sensor fusion designs in particular to autonomous driving is discussed in depth using the results obtained using several real world data sets that contains various static and dynamic targets would be presented in this tutorial. Fusion and management of the different extended target and static object representations from heterogeneous information sources with different resolution is presented with examples.

T12. Analytic Combinatorics for Multi-Object Tracking

Speaker(s): Roy Streit, R. Blair Angle, and Murat Efe
Duration: 3 hours
Abstract: Exact solutions of many problems in tracking have high computational complexity and are impractical for all but the smallest of problems. Practical implementations entail approximation. There is a bewildering variety of established trackers available and practicing engineers and/or researchers often study them almost in isolation of each other without fully understanding what these trackers are about and how they are inter-related. One reason for this is that these filters have different combinatorial problems which are approached by explicitly enumerating the feasible solutions. The enumeration is usually a highly detailed, hard to understand accounting scheme specific to the filter and the details cloud understanding the filter and make it hard to compare different filters. On the other hand, the analytic combinatoric approach presented in this tutorial avoids the heavy accounting burden and provides a solid tool to work with. This tool is the derivative of multivariate calculus, which all engineers easily understand. This tutorial is designed to facilitate understanding of the classical theory of Analytic Combinatorics (AC) and how to apply it to problems

in multi-object tracking. AC is an economical technique for encoding combinatorial problems—without information loss—into the derivatives of a generating function (GF). Exact Bayesian filters derived from the GF avoid the heavy accounting burden required by traditional enumeration methods. Although AC is an established mathematical field, it is not widely known in either the academic engineering community or the practicing data fusion/tracking community. This tutorial lays the groundwork for understanding the methods of AC, starting with the GF for the classical Bayes-Markov filter. From this cornerstone, we derive many established filters (e.g., PDA, JPDA, JIPDA, PHD, CPHD, MultiBernoulli, MHT) with simplicity, economy, and insight. We also show how to use the saddle point method (method of stationary phase) to find low complexity approximations of probability distributions and summary statistics.