MFI 2015 Workshop

Search this site

Navigation

Large-Scale Bayesian Data Fusion and Consensus

Important Dates

Abstract Submission: August 22, 2015
Author/Decision Notification: August 29, 2015
Workshop Date: September 14, 2015 (at MFI 2015, San Diego State University, San Diego, CA)

Submission Guidlines

We invite participants to submit extended 2-3 page abstracts describing new/ongoing work. Submissions should be in .pdf format using the standard IEEE conference paper template (LaTeX or Word). The best submissions will be selected for presentation during the workshop via single-blind review (so please include all author names and affiliations). Selected submissions will also be invited to submit their work to a future special book collection (to be arranged by the workshop organizers). Submissions should be submitted to mfi2015consensusworkshop@gmail.com by August 22, 2015

Abstract

Intelligent dependable sensor networks and dynamic distributed information processing systems have drawn considerable interest for applications such as environmental monitoring, surveillance, search and rescue, and scientific exploration. To operate autonomously in the face of real world uncertainties, individual sensor platforms in such networks typically rely on perception and planning algorithms that combine local and network-wide reasoning. This type of system architecture not only permits intelligent local decision-making amid noisy data and complex dynamics, but also enables efficient information-sharing and gathering, which greatly improves perceptual robustness and task performance. As computing power and hardware continue to improve, demand will also grow for these systems to process more diverse kinds of information for increasingly complex dynamical processes and to communicate within larger networks at very high rates for real-time/online decision-making.

This workshop will explore theoretical connections and novel large-scale applications of two frameworks popular in the robotics and controls communities for meeting these challenges: Bayesian distributed data fusion (DDF) and network-based consensus. Bayesian DDF provides a particularly strong foundation for fully decentralized information sharing and autonomous perception. In theory, DDF is mathematically equivalent to an idealized centralized Bayesian data fusion strategy (in which all raw sensor data is sent to a single location for maximum information extraction), but is far more computationally efficient, scalable, and robust to network node failures through the use of recursive peer-to-peer message passing of local statistical beliefs. The network-based consensus framework provides another formal framework for conservatively combining local state estimation information in large scale

dynamic networks in a decentralized manner via iterated averaging. Consensus is of particular interest to control theorists because it provides attractive convergence and stability guarantees for closed-loop multi-agent control, planning and coordination. Recent developments in the consensus literature, e.g. the emergence of “information weighted” consensus techniques, suggest potentially deeper connections to Bayesian DDF that have not yet been explored. Such connections could provide valuable insight for developing robust tightly integrated decentralized decision-making and information processing algorithms for dependable networks of intelligent heterogeneous sensing agents in large-scale problem spaces (as characterized by high data volume, high-dimensional processes, and/or large numbers of sensors or agents).

We invite participants to contribute abstracts for short talks describing new/ongoing work in any of the following topic areas (which will be the focus of the workshop sessions):

I. Fundamental connections between DDF and consensus techniques: Consensus and Bayesian DDF algorithms have evolved separately over the last 2 decades in different but related communities (control systems and robotics, respectively). Researchers in these fields have been working on fundamentally similar applications with different requirements for distributed estimation and sensor fusion. Perhaps unsurprisingly, a close inspection of both methodologies reveals some interesting similarities as well as some notable differences. Some particular issues of interest in the context of DDF and consensus algorithms for general applications include (but are not limited to):

- what are the formal theoretical links between consensus and Bayesian DDF? What analysis tools, algorithms and ideas can be brought together to unify these approaches in theory and in practice?

- what convergence guarantees can be made for DDF algorithms, especially with arbitrary network topologies or non-Gaussian probability distributions?

- how can consensus algorithms be enhanced to work with arbitrarily complex probability distributions, especially for real-time/online fusion in the presence of corrupted or inconsistent information?

- how can tasks/actions that sensor platforms need to perform be more tightly integrated to optimal or conservative information fusion processes? How can concepts from statistical decision theory (e.g. value of information) be leveraged in a tractable way?

- what can be done to make networks robust to time delays or inaccurate process/sensor models??

II. Fusion in high-dimensional and functional spaces: Although both consensus and DDF methods have been fairly well-studied, the question arises: how does either approach deal with high dimensional parameterizations? A particularly important application in this regard is estimation and information fusion via empirical sampling techniques, e.g. Monte Carlo particle filters, which are very useful for overcoming the curse of dimensionality when dealing with complex dynamical processes. Typical approaches for combining probability densities under, say, Bayesian DDF are technically not directly applicable to sampled representations, since operations such as probability density multiplication and division become undefined. Recent work in the areas of functional analysis and information geometry suggests that more alternative formulations of the fusion problem can address these limitations in elegant and general ways. Some particular issues of interest include:

- what parameterizations permit fusion of highly dimensional state spaces in a computationally efficient and scalable manner?

- what novel ways can be formulated for combining information from stochastic processes (e.g. Gaussian process models for learning) or sampled/particle representations of systems in very high-dimensions across multiple platforms? For instance, what insights from functional analysis or information geometry can be brought to bear on the problem of fusing empirically sampled densities?

- what lessons learned from other large-scale/real-time data fusion strategies, e.g. ensemble filtering or event-triggered estimation, can be employed?

Organizers

Nisar Ahmed (University of Colorado at Boulder, Nisar.Ahmed@colorado.edu)
David Casbeer (Air Force Research Lab, david.casbeer@us.af.mil)
Tansel Yucelen (Missouri University of Science and Technology, yucelent@mst.edu)
William Whitacre (Draper Laboratory, wwhitacre@draper.com)
Daniel Clarke (Cranfield University, d.s.clarke@cranfield.ac.uk)

Invited Speakers

Dr. Ronald Mahler (invited speaker #1, confirmed) is Founder and President of Random Sets, LLC, an independent consultancy established in 2015. He received the B.A. degree in mathematics from the University of Chicago, the Ph.D. in mathematics from Brandeis University, and the B.E.E in electrical engineering from University of Minnesota. His research interests include information fusion, expert systems theory, multitarget tracking, and sensor management. He is author, coauthor, or coeditor of over 70 publications. He received the 2004 and 2008 Author of the Year Awards from Lockheed Martin MS2, the 2007 Mignongna Data Fusion Award, and the 2005 IEEE AESS Harry Rowe Minmo Award, as well as the 2007 IEEE AESS Barry Carlton Award.

Dr. Simon Julier (invited speaker #2, confirmed) is a Senior Lecturer in the Department of Computer Science, University College London and holds a DPhil from the Robotics Research Group at the University of Oxford, UK. During his DPhil he assisted Jeff Uhlmann in the development of both the Unscented Kalman Filter and Covariance Intersection fusion algorithms. Between 1997 and 2006, he worked at the Naval Research Laboratory, Washington DC, where he led a team to develop mobile augmented reality systems. Since 2006 he has been working at UCL where he has been developing algorithms for simultaneous localisation mapping, augmented reality, and distributed data fusion.

Invited Panelists

Dr. Frederica Darema: Program Manager at the Air Force Office of Scientific Research (AFOSR) and founder of its Dynamic Data Driven Application Systems (DDDAS) program.

Dr. Michael Ouimet: Engineer at the Space and Naval Warfare Command (SPAWAR), specializing in dynamical systems and control theory for robotic applications.

Workshop Schedule

9:00 am	**Welcome, overview, opening remarks**
Session 1: Fundamental Connections between DDF and Consensus	
9:20 am	**Invited Speaker #1: Ronald Mahler (Random Sets, LLC) (confirmed)** **"Unified multi-target track-to-track fusion via Kullback-Leibler consensus"**
10:00 am	Q&A with audience
10:10 am	**Coffee Break**
10:30 am	Contributed Talks (3 talks, 10 mins each)
	"An Overview of Active-Passive Dynamic Consensus Filters for Situational Awareness", D. Peterson and T. Yucelen (Missouri University of Science and Technology)
	"Distributed Non-Bayesian Learning: Network/Node

	Independent and Accelerated Convergence Rates", A. Nedic, A. Olshevsky, C. Uribe (Univ. Illinois at Urbana-Champaign)
	"Developing a Hybrid Distributed Kalman Filter", He Bai (Oklahoma State University)
11:00 am	Session recap/group discussion ("public whiteboard time")
12:00 pm	**Lunch Break**

Session 2: Fusion in High-dimensional and Functional Spaces

1:30 pm	**Invited Speaker #2: Simon Julier (University College of London) (confirmed)**
2:10 pm	Q&A with audience
2:20 pm	Contributed Talks (3 talks, 10 mins each)
	"Robust Multi-target Localisation for Measurements with Unknown Correlation", Daniel Clarke (Cranfield University)
	"Event-Based Control and Estimation in Multi-agent Systems", David Casbeer and Eloy Garcia (Air Force Research Laboratory)
	"Fusion of Unequal State Vectors for Large-scale Systems", Benjamin Noack (Karlsruhe Institute of Technology)
2:50 pm	Session recap/group discussion ("public whiteboard time")
3:40 pm	**Coffee Break**

Session 3: Future Steps and Challenges for Large-scale Data Fusion

4:00 pm	**Panel discussion with government/defense experts**
	Dr. Frederica Darema (AFOSR), Dr. Michael Ouimet (SPAWAR)
5:00 pm	Closing thoughts, next steps
5:30 pm	**Adjourn**

Organizer Bios (in alphabetical order)

Dr. Nisar Ahmed is an assistant professor of Aerospace Engineering Sciences at the University of Colorado Boulder. He obtained his Ph.D. in Mechanical Engineering in 2012 from Cornell University in 2012, where he was also a postdoctoral researcher from 2012-2014. He is also an associate member of the AIAA Technical Committee on Intelligent Systems and a member of the Research and Engineering Center for Unmanned Vehicles (RECUV) at Colorado. Dr. Ahmed's research interests are in modeling, estimation and control of intelligent dynamical systems, especially for applications involving human-robot interaction, distributed autonomous sensor networks and decentralized information fusion. He received the Best Paper Award at the 2011 AIAA Guidance, Navigation and Control Conference, Best Poster Award at the 2012 Distributed Autonomous Robotic Systems Conference, and 2014 ASEE Air Force Summer Faculty Fellowship.

Dr. David Casbeer is a Research Engineer with the Aerospace Systems Directorate, Air Force Research Laboratory, where he carries out and leads basic research involving the control of autonomous UAVs with a particular emphasis on high-level decision making and planning under uncertainty. He received B.S. and Ph.D. degrees in Electrical Engineering from Brigham Young University in 2003 and 2009, respectively. He currently serves as the

conference planning subcommittee chair in the AIAA Intelligent Systems Technical Committee and an Associate Editor for the Journal of Intelligent and Robotic Systems.

Dr. Daniel Clarke is a lecturer in Communications and Electronic Warfare at Cranfield University, based at the Defence Academy of the United Kingdom. His main research
interests are the sensor signal processing and multi-sensor data fusion techniques which enable the detection, identification and localisation of targets of interest within defence and security and autonomous systems applications. He completed his PhD in Astrophysics at the University of Innsbruck in 2009 and was appointed a Research Scientist for the UK MOD's Defence Science and Technology Laboratory. In 2012-13 he deployed to Afghanistan as the Scientific Advisor to Task Force Helmand where he was awarded a commendation by the Commander of Joint Force Support (Afghanistan) for outstanding scientific contribution towards military operations.

Dr. William Whitacre is a Senior Member of the Technical Staff in the strategic navigation group at Draper Laboratory. He is currently leading research efforts across a wide variety of programs ranging from strategic navigation and ballistic missile defense to X-ray computed tomography reconstruction of composite materials. Before joining Draper Laboratory, Dr. Whitacre was an Engineering Systems Architect in the Advanced Concepts and Technologies Division of Northrop Grumman Electronic Systems. While at Northrop Grumman he led a multi-year internally funded research and development project to create new sensor optimization and resource management approaches for distributed intelligence, surveillance, and reconnaissance applications; developed state-of-the-art multi-sensor, multi-target tracking algorithms to fuse data from networked radar sensors, infrared sensors, and electronic warfare sensors. He earned a PhD from Cornell University with his research on cooperative geolocation using UAVs with gimballing camera sensors. During his Ph.D. research, Dr. Whitacre worked with Insitu Inc. to implement a square root sigma point information filter for cooperative vision based geolocation of a moving ground target using the ScanEagle UAV. William is a member of the American Institute of Aeronautics and Astronautics and serves on the Guidance Navigation and Control Technical Committee.

Dr. Tansel Yucelen is an Assistant Professor of Mechanical and Aerospace Engineering Department and the Director of Advanced Systems Research Laboratory at the Missouri University of Science and Technology since August 2013. He received the Ph.D. degree in Aerospace Engineering from Georgia Institute of Technology in May 2012. Prior to joining Missouri University of Science and Technology, he was a Research Faculty in the School of Aerospace Engineering (from December 2011 to February 2013) and the School of Electrical and Computer Engineering (from February 2013 to August 2013) both at the Georgia Institute of Technology. He was a Summer Faculty Research Fellow at the Air Force Research Laboratory at the Wright-Patterson Air Force Base in Ohio in 2014 and at the Eglin Air Force Base in Florida in 2015. Dr. Yucelen's research places a strong emphasis on not only theoretic research but also experimentation to validate the developed theory, to collect relevant data, and to motivate for new areas of research. In particular, his research falls into systems and controls with research specializations in robust and adaptive control of safety-critical systems, resilient autonomous vehicles and robotics, distributed estimation and control of large-scale systems, collective motion and networked multiagent systems, biologically-inspired control and learning, and smart modular systems. He has authored more than 120 archival journal and conference publications in these areas and his control architectures were implemented on various platforms including NASA Langley Research Center's AirSTAR. He is a recipient of the 2015 Ralph E. Powe Junior Faculty Enhancement Award by the Oak Ridge Associated Universities, where this award represents public recognition of the quality and promise of research.