Fusion 2023 Tutorial Proposal

Model-based Systems Engineering Foundations for Information Fusion System Design and Performance Evaluation via Machine Learning

Description:

Information fusion (IF) systems find their application in multiple domains from defense applications such as command and control systems to self-driving cars, and autonomous systems. Irrespective of the application domain, an IF system's objective is to produce optimal state/situation estimates from various sources that are supportive of typically mixed-initiative decision-making which leads to an action. These three processes of fusion, sensemaking, and decision-making have critical interdependencies that are often overlooked in an IF system design. Engineering the IF system requires a holistic, systemic perspective that includes evaluation of a multitude of interacting design variables which span the fusion, sensemaking and decision-making aspects. This tutorial addresses this problem from a Systems Engineering approach and evaluation methodology.

In this tutorial, first the interdependencies between fusion, sensemaking, and decision-making are introduced, followed by a development of a domain-agnostic framework which provides holistic design and performance evaluation of an IF system. A system development framework is presented that leverages Systems Engineering principles and Model-based Systems Engineering (MBSE) techniques for practical system development. On the evaluation side, this tutorial pairs the MBSE approach with statistical methods and machine learning to provide a holistic and integrated evaluation of fusion, sensemaking, and decision-making. Theoretical foundations for performing design and analysis of experiments, followed by a hands-on IF system application example is presented. A refresher on Monte-Carlo simulations and hypothesis testing will also be provided. At the conclusion of the tutorial, the participants will be able to:

1) Identify and discuss the nature of interdependencies in fusion, sensemaking, and decision-making processes and derive the implications for IF system design
2) Appreciate the value Systems Engineering and MBSE provide for a systemic design methodology for IF system and decompose the IF system into a set of inter-dependent design variables
3) Formulate an 'experimental design' for the IF system design and performance evaluation
4) Employ hypothesis testing for comparing uncertain data and perform analysis of variance (ANOVA) to establish statistical significance of design variables and interactions
5) Perform multiple comparison statistical range tests to quantify the impact of variation and obtain sensitivity analysis amidst interacting design variables

Tutorial Session Overview

- **Tutorial Sections**
    - Section 1: Perspectives on Information Fusion—Decision Making Inter-dependencies
    - Section 2: Introduction to Systems Engineering, Model-based Systems Engineering and Integrated Design of Information Fusion System
    - Section 3: Statistical Concepts Review and Application to Information Fusion System
    - Section 4: Design of Experiments/Machine Learning for Information Fusion System Performance Evaluation
- **Tutorial Duration:**
    - Half-day tutorial (~3 hours)
    - Questions and discussion encouraged throughout the tutorial
- **Intended Audience:**

  Graduate students, industry practitioner, and fusion researchers who are faced with integrated design and evaluation of fusion system.
- **Pre-requisites:**

  Basic knowledge of tracking and fusion concepts. Basic knowledge of probability, statistics and linear algebra (relevant statistical concepts will be briefly reviewed during the tutorial).
- **Previous tutorial experience:**

  Earlier versions of this tutorial were previously offered at Fusion 2018 and Fusion 2019 and IEEE SMC Conference in 2018 and 2019. Participants at both conferences provided very positive feedback on this tutorial. Moreover, the latest extended revision of the content was offered as a continuing education short course by the American Institute of Aeronautics and Astronautics (AIAA) in Spring 2021. This short course was attended by ~20 paid participants during live course streaming. (http://aiaa.mycrowdwisdom.com/diweb/catalog/item/id/6183262)

- **Presenters:**

Dr. Ali Raz is an Assistant Professor at George Mason University Systems Engineering and Operations Research department and an Assistant Director of Intelligent Systems and Integration at the C4I and Cyber Center. Dr. Raz research and teaching interests are in understanding collaborative autonomy and developing systems engineering methodologies for integrating autonomous systems. Raz's research brings a Systems Engineering perspective, particularly inspired by complex adaptive systems, to information fusion and artificial intelligence/machine learning technologies that form the foundations of collaborative and integrated autonomous systems. Prior to joining Mason, he was a Visiting Assistant Professor at Purdue University School of Aeronautics and Astronautics where he taught courses in aerospace systems design. He holds a visiting faculty appointment with the U.S. Navy Naval Surface Warfare Center at Crane, Indiana and has worked with Naval Postgraduate School, John Hopkins University Applied Physics Laboratory (JHU-APL), the United States Missile Defense Agency, and Honeywell Aerospace. He holds a BSc. and MSc. in Electrical Engineering from Iowa State University, and a Ph.D. in Aeronautics and Astronautics from Purdue University. He is a co-chair of International Council of Systems Engineering (INCOSE) Complex Systems Working Group, Artificial Intelligence Working Group, and a Certified Systems Engineering Professional (CSEP). He is also a senior member of the American Institute for Aeronautics and Astronautics (AIAA) and Institute of Electrical and Electronics Engineers (IEEE).

Dr. James Llinas brings over 35 years of experience in multisource information processing and data fusion technology to his research, teaching, and business development activities. He is an internationally-recognized expert in sensor, data, and information fusion, co-authored the first integrated book on Multisensor Data Fusion, and has lectured internationally for over 20 years on this topic. His experience in applying this technology to different problem areas ranges from defense applications to non-defense applications to include intelligent transportation systems, medical diagnostics, and condition-based maintenance, among others. Current research activities related to the field of Information Fusion include funded programs in Space Situational Awareness, Machine Understanding, Autonomy/Autonomous Operations, and Missile Defense. He has been a Consultant to many U.S. and International defense organizations to include the Air Force Research Laboratory, DARPA, NSA, and the NRO. Dr. Llinas created the concept for and is now Director for the "Center for Multisource Information Fusion" located at the State University of New York at Buffalo. This first-of-its-kind, University-based research center has been conducting basic research in Data and Information Fusion over some 20+ years.