# Controlled Sensing in Multi-Sensor Systems

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## I. Abstract

This tutorial will focus on the recent state-of-the art theories and algorithms for inference driven controlled sensing in networked systems, such as radar systems and sensor networks. In the first half of the talk, theoretical foundations for controlled sensing for target detection and tracking will be presented. First, controlled sensing for sequential detection based on Kullback-Leibler divergence (KLD) or Chernoff information will be introduced. Controlled sensing for sequential estimation and nonlinear tracking based on mutual information, Rényi divergence, and conditional posterior Cramér-Rao lower bound (C-PCRLB), will be discussed. Greedy search for submodular problems will also be discussed.

The second part presents advanced optimization techniques that are particularly suitable for controlled sensing in large and/or complex network systems, such as convex relaxation for combinatorial problems, dynamic programming (DP) or approximate DP for sensor selection, dynamic bit allocation, sparsity aware sensor management, and multi-objective optimization for desirable tradeoff between the inference performance and resource efficiency. Several practical controlled sensing examples will also be presented, which include sensor selection and resource management in sensor networks.

## II. Objectives

Inference driven controlled sensing can significantly improve the system inference performance, while at the same time conserve system resources. This tutorial will give a thorough introduction to various aspects of recent advances in controlled sensing. Any researchers, engineers, and graduate students who are interested in multi-sensor information fusion for statistical inference can benefit from this tutorial. After taking this tutorial, they are expected to understand the principles behind controlled sensing, learn advanced optimization techniques to solve controlled sensing problems, and get insights on controlled sensing through practical examples. This tutorial will lay a foundation for the students to solve real-world problems later.

## III. List of Topics

- Introduction to controlled sensing in sensor networks
- Theoretical foundations for controlled sensing
  - Brief introduction to multi-sensor information fusion for detection, estimation, and tracking
  - Controlled sensing for sequential detection based on KLD or Chernoff information
  - Controlled sensing for nonlinear tracking based on mutual information, Rényi divergence, and C-PCRLB
  - Greedy search for submodular problems
- Advanced optimization techniques for controlled sensing
  - Convex relaxation for combinatorial problems
  - DP or approximate DP for sensor selection, dynamic bit allocation, and sparsity aware sensor management
  - Multi-objective optimization for tradeoff between inference performance and resource efficiency
- Controlled sensing examples
- Conclusion and future challenges

## IV. Intended Audience

Potential students include researchers, engineers, and graduate students who are interested in multi-sensor information fusion for statistical inference. These include practitioners and graduate students in both industry and academia, in a wide range of areas, such as defense, surveillance for security, and sensor networks. It is preferable that the students have taken courses in statistical signal processing (detection, estimation, and tracking) and optimization.

## V. Biographies of Instructors

Ruixin Niu received the Ph.D. degree in Electrical Engineering (EE) from the University of Connecticut, Storrs, in 2001. He is currently an Assistant Professor with the Department of Electrical and Computer Engineering, Virginia Commonwealth University (VCU), Richmond. Before joining VCU, he was a Research Assistant Professor with Syracuse University (SU), Syracuse, NY. His research interests are in the areas of statistical signal processing and its applications, including detection, estimation, tracking, information fusion, sensor networks, MIMO radar, and sensor management. He has nearly 100 publications in the above mentioned areas. Dr. Niu received the Best Paper Award at the 2004 International Conference on Information Fusion (Fusion'04). He is a coauthor of the paper that won the Best Student Paper Award at Fusion'10. He is an Associate Editor of the IEEE Transactions on Signal Processing and the Associate Administrative Editor of the Journal of Advances in Information Fusion. He was an Associate Editor of the International Journal of Distributed Sensor Networks between 2010 and 2012.

Engin Masazade got his B.S. degree from Electronics and Communications Engineering Department from Istanbul Technical University in 2003. He then obtained his M.S. and Ph.D. degrees from Sabanci University, Electronics Engineering Program, Istanbul, Turkey in 2006 and 2010 respectively. He is currently an Assistant Professor with the Department of Electrical and Electronics Engineering, Yeditepe University, Istanbul, Turkey. Before joining Yeditepe University, he was a Postdoctoral Research Associate with the Department of Electrical Engineering and Computer Science, Syracuse University, Syracuse, NY, USA. His research interests include distributed detection, localization, and tracking for wireless sensor networks, dynamic resource management in sensor/communication networks.

## VI. Instructors' Experience

Since Fall 2007, first at SU and then at VCU, Dr. Ruixin Niu has had totally eight years of experience of teaching both undergraduate and graduate courses in EE, which include courses in communications (EGRE336 Introduction to Communication Systems, EGRE444 Communication Systems, ELE651 Digital Communications, and ELE751 Wireless Communications), in estimation and tracking (ELE 852 Kalman Filters), and in digital signal processing (EGRE 535 DSP).

Dr. Masazade has been teaching courses in Yeditepe University at both undergraduate and graduate levels in the areas of probability, stochastic processes and communications (undergraduate level EE254 Applied Probability, graduate level EE664 Random Signal Processing, undergraduate level EE354 Communication Systems, upper undergraduate level EE456 Introduction to Coding and Information Theory, and upper undergraduate level EE458 Wireless Communications).

Drs. Niu and Masazade jointly developed a tutorial on adaptive sensor management, and presented it at the 16th International Conference on Information Fusion, in Istanbul, Turkey, July 2013.