Optimization Theory in Advanced Radar Signal Processing

Instructors:

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Abstract:

The objective of this tutorial is to provide a systematic overview of innovative radar signal processing algorithms based on modern optimization theory according to a rigorous and academic style. Specifically, the theoretical basis to address constrained design problems is given, illustrating in the radar context some key/relevant results of modern optimization theory about convex and non-convex problems.

Intended Audience:

This course is suitable both for young students who are approaching optimization theory and innovative radar signal processing designs as well as for radar scientists, engineers and practitioners which need a rigorous and academic point of view on the fundamentals of several algorithms and their implementation that hopefully will be present in the modern radar systems.

Learning Outcomes:

After attending this tutorial attendees will become familiar with a rigorous approach to the design of advanced radar signal processing techniques based on modern optimization theory which provide the base to address more challenging radar constrained design problems.

Prerequisite:

Radar Systems Fundamentals, Basic Optimization Theory, Mathematical Analysis.

Detailed Description:

1. Introduction to convex optimization theory:
    - Historical notes on the use of optimization theory in Radar;
    - Preliminaries on the Constrained Optimization Problems;

- Convex Optimization;
- Convex sets and Radar Examples;
- Convex Functions and Radar Examples,
- Taxonomy of Convex Programming Problems.

2. Convex optimization problems in radar and their solution via CVX:
   - Linear Programming (mismatched filter for real observations);
   - Quadratic Problems (Capon filter, Knowledge-Based beamformer);
   - Second Order Cone Programming, SOCP (Lp-norm minimization filter, robust beamformer);
   - SemiDefinite Programming, SDP (MIMO Matrix Beamformer, MIMO Waveform Design in Tracking Applications);
   - Max-Det (constrained precision matrix maximum likelihood estimate).

3. Non-convex design problems in radar and the implementation of effective algorithms for their solution:
   - Hidden Convex Quadratic Problems based on Rank-One Decomposition (robust detection, waveform design with similarity constraint);
   - NP-hard Quadratic Problems based on Relaxation & Randomization (waveform design with phase/PAR constraint);
   - Fractional Quadratic Programming (robust detection, robust constrained Doppler filters).

Estimated Attendance Number:

many researchers are active in this field; however, an estimate is not easy: it depends also on the cost of the tutorial.

Prior Presentations:

part of the material has also been presented during the tutorial by the same main author (A. Aubry and A. De Maio) at the International Conference on Radar Systems in Belfast 2017.

Bio-sketches:

Augusto Aubry (M'12–SM'16) received the Dr.Eng. (Hons.) and Ph.D. degrees in information engineering from the University of Naples Federico II, Naples, Italy, in 2007 and 2011, respectively. From February to April 2012, he was a Visiting Researcher with the Hong Kong Baptist University, Hong Kong. He is currently under research agreement with the Department of Electrical and Information Technology Engineering, University of Naples Federico II. His research interests include statistical signal processing and optimization theory, with emphasis on MIMO communications and radar signal processing. He is also the corecipient of the 2013 best paper award (entitled to B. Carlton) of the IEEE TRANSACTIONS ON AEROSPACE AND ELECTRONIC SYSTEMS with the contribution "Knowledge-Aided (Potentially Cognitive) Transmit Signal and Receive Filter Design in Signal-Dependent Clutter".

Antonio De Maio (S'01-A'02-M'03-SM'07-F'13) was born in Sorrento, Italy, on June 20, 1974. He received the Dr.Eng. (Hons.) and Ph.D. degrees in information engineering from the University of Naples Federico II, Naples, Italy, in 1998 and 2002, respectively. From October to December 2004, he was a Visiting Researcher with the U.S. Air Force Research Laboratory, Rome, NY, USA. From November to December 2007, he was a Visiting Researcher with the Chinese University of Hong Kong, Hong Kong. He is currently a Professor with the University of Naples Federico II. His research interest lies in the field of statistical signal processing, with emphasis on radar detection, optimization theory applied to radar signal processing, and multiple-access communications. He is the recipient of the 2010 IEEE Fred Nathanson Memorial Award as the young (less than 40 years of age) AESS Radar Engineer 2010 whose performance is particularly noteworthy as evidenced by contributions to the radar art over a period of several years, with the following citation for "robust CFAR detection, knowledge-based radar signal processing, and waveform design and diversity." He is the corecipient of the 2013 best paper award (entitled to B. Carlton) of the IEEE TRANSACTIONS ON AEROSPACE AND ELECTRONIC SYSTEMS with the contribution "KnowledgeAided (Potentially Cognitive) Transmit Signal and Receive Filter Design in Signal-Dependent Clutter".