Angela Marino

Advanced Target Localization Strategies for Multiplatform Radar Systems via Constrained Optimization

Tutor: Prof. Augusto Aubry

co-Tutor: Dr. Paolo Braca

Cycle:XXXV

Year:2021-2022

Background information

- **Master Science degree:** Telecommunication Engineering at the University of Naples, “Federico II”
- **Research group/laboratory:** Radar Signal Processing and Electronic Defense Research Group (RSPRG)
- **PhD start date:** 01/11/2019
- **Scholarship type:** funded by NATO Science and Technology Organization - Centre for Maritime Research and Experimentation
- **Periods abroad:** Centre for Maritime Research & Experimentation NATO, La Spezia, 01.07.2021 - 17.12.2021. Supervisor: Dr. Paolo Braca

Summary of study activities

Study activities

- Advanced Radar Techniques
- Detection and Localization Theory
- Optimization Theory
- Statistical signal processing
- Radar Tracking Algorithms
- Statistical filtering techniques

Ad hoc PhD courses / schools

- Intelligenza Artificiale ed Etica: La ricercar in IA alla prova delle sfide etiche
- Deep Learning for Computer Vision: Classification, Segmentation, and Recognition
- Scientific Programming and Visualization with Python
- Matlab Fundamentals
- Innovation management, entrepreneurship and intellectual property
- Machine Learning
- Strategic Orientation for STEM Research & Writing
- Cooperative and Non Cooperative Localization Systems
- Matrix Analysis for Signal Processing with MATLAB

Summary of study activities

Courses attended borrowed from MSc curricula:

- Tecniche Di Elaborazione Dei Segnali Per la Bioingegneria
- Radiolocalizzazione Terrestre e Satellitare
- Teoria dell'Informazione

Conferences / events attended

- 2020 IEEE Radar Conference (Florence, Italy), 21-25 September 2020. 1 paper presented.
- Student Contest of the 1st International Virtual School on Radar Signal Processing University of Electronic Science and Technology of China (UESTC), 22-23 December 2020. 1 paper presented. Ranked Third to the Student Contest.
- Signal Processing Symposium (SPSympo) 2021, 21-23 September 2020, Lodz, Poland. 1 paper presented. Received the Young Scientist Contest Award (First Prize).
- *SET-284 Specialists' Meeting on Enhanced Situation Awareness using Active-Passive Radar Systems in Military Scenarios*, Gdynia, Poland, 15-16 September 2022. 1 paper presented.

Summary of study activities

	Courses	Seminars	Research	Tutorship	Total
Year 1	27.5	8.4	34	0	69.9
Year 2	20	7	42	0	69
Year 3	0	0.6	51	0	50.6
Total	**47.5**	**16**	**127**	**0**	**189.5**
Expected	30 - 70	10-30	80-140	0 – 4.8	

Research area(s)

Optimization Theory Applied to Radar Signal Processing

- Passive Bistatic Radar (PBR)
  - Target localization via passive and active radars
- FDA-MIMO Radar
  - Adaptive target detection
- Multiplatform Radar
  - 3D Target localization via Deployable Radar Nodes
  - Multitarget Tracking (MTT)

Research results

1. Advanced receivers to reliably detect targets in Frequency Diverse Array Multiple-Input Multiple-Output (FDA-MIMO) radars.
   - Development of an algorithm to determine the ML estimates of all unknown parameters (under both the hypothesis) as well as the devising of some low complexity sub-optimal counterparts.

2. Advanced target position estimate algorithm, jointly accounting for PBR and active radar information.
   - Formalization of ad-hoc constraints accounting for PBR receive antenna main-beam size and active radar data.
   - Design of an efficient algorithm which provides a closed-form solution to the non-convex optimization.

Research results

3. Advanced 3D target position estimate algorithm, accounting for angular constraints that capitalize the information embedded into the characteristics of the monostatic radiation pattern.
   - Formalization of ad-hoc constraints accounting for characteristics of the monostatic radiation pattern.
   - Design of an efficient algorithm, based on a smart rooting method, which provides a quasi-closed-form solution to the non-convex optimization.

4. Advanced Multitarget Tracking (MTT) technique based on combination of bespoke single-snapshot localization algorithm and Sum-Product Algorithm (SPA)-based MTT.
   - Introduction of a particles enrichment process using single-snapshot localization estimate.

Research products

[J1]	In preparation: Angela Marino, Giovanni Soldi, Domenico Gaglione, Augusto Aubry, Paolo Braca, Antonio De Maio, Peter Willett, *Localization and Tracking Methods for Multi-Platform Radar Networks*
[J2]	A. Aubry, P. Braca, A. De Maio, A. Marino, *Enhanced Target Localization with Deployable Multiplatform Radar Nodes Based on Non-Convex Constrained Least Squares Optimization*, **IEEE Transactions on Signal Processing,** vol. 70, pp. 1282-1294, 2022, DOI: 10.1109/TSP.2022.3147037
[J3]	A. Aubry, P. Braca, A. De Maio, A. Marino, *2-D PBR Localization Complying With Constraints Forced by Active Radar Measurements*, **IEEE Transactions on Aerospace and Electronic Systems,** vol. 57, pp. 2647-2660, 2021, DOI: 10.1109/TAES.2021.3067612
[J4]	L. Lan, A. Marino, A. Aubry, A. De Maio, G. Liao, J. Xu, and Y. Zhang, *GLRT-Based Adaptive Target Detection in FDA-MIMO Radar*, **IEEE Transactions on Aerospace and Electronic Systems,** vol. 57, pp. 597-613, 2021, DOI: 10.1109/TAES.2020.3028485
[C1]	A. Marino, A. Aubry, A. De Maio, P. Braca, *2D Constrained PBR Localization Exploiting Active Radar Measurements*, **SET-284 Specialists' Meeting on Enhanced Situation Awareness using Active-Passive Radar Systems in Military Scenarios**, Gdynia, Poland, 15-16 September 2022.

Research products

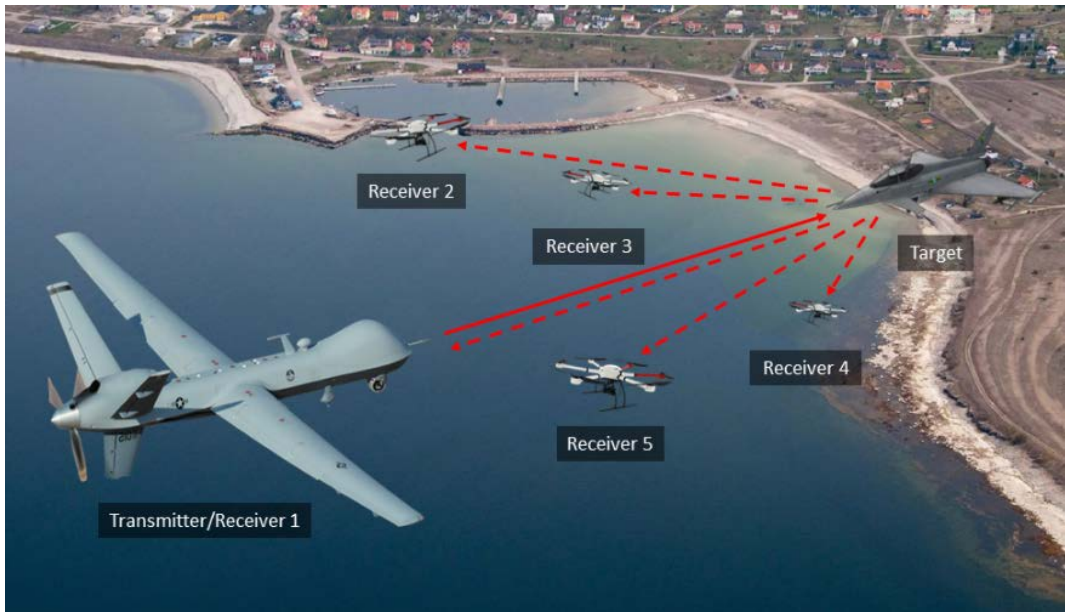
[C2]	A. Marino, A. Aubry, A. De Maio, P. Braca, D. Gaglione and P. Willett, *Constrained Target Localization for Multiplatform Radar Systems*, **MILCOM 2021-2021 IEEE Military Communications Conference (MILCOM)**, San Diego, CA, USA, 29 Nov.-2 Dec. 2021, pp. 635-640, IEEE, DOI: 10.1109/MILCOM52596.2021.9653089.
[C3]	A. Marino, A. Aubry, A. De Maio and P. Braca, *3D Localization for Multiplatform Radar Networks with Deployable Nodes*, **2021 Signal Processing Symposium (SPSympo)**, Lodz, Polland, 20-23 Sept. 2021, pp. 183-188, IEEE, DOI: 10.1109/SPSympo51155.2020.959353.
[C4]	A. Marino, A. Aubry, A. De Maio and P. Braca, *2D Constrained PBR Localization Via Active Radar Designation*, **2020 IEEE Radar Conference (RadarConf20)**, Florence, Italy, 21-25 Sept. 2020, pp. 1-6, IEEE, DOI: 10.1109/RadarConf2043947.2020.9266695.
[C5]	L. Lan, A. Marino, A. Aubry, A. De Maio, G. Liao and J. Xu, *Design of GLR-Based Detectors for FDA-MIMO radar*, **2020 IEEE 7th International Workshop on Metrology for AeroSpace (MetroAeroSpace)**, Pisa, Italy, 22-24 June 2020, pp. 17-21, IEEE, DOI: 10.1109/MetroAeroSpace48742.2020.9160020.
[C6]	L. Lan, A. Marino, A. Aubry, A. De Maio, G. Liao and J. Xu, *Design of adaptive detectors for FDA-MIMO radar*, **2020 IEEE 11th Sensor Array and Multichannel Signal Processing Workshop (SAM)**, Hangzhou, China, 8-11 June 2020, pp. 1-5, IEEE, DOI: 10.1109/SAM48682.2020.9104289.

PhD thesis overview

- **Problem statement**

  In the last decades, the requirements in terms of target positioning accuracy have become increasingly severe.

  To achieve this performance enhancement, Multiplatform Radar Network (MPRN) configuration is of tactical advantage.



PhD thesis overview

- **Objective**

  Development of advances localization algorithms capitalizing side-information.

- **Methodology**
  - *Ad hoc* constraints are defined to capitalize the available side-information.
  - The constrained LS framework is resorted to formulate the estimation problem.
  - Advanced optimization tools are leveraged to design an efficient localization algorithm.

PhD thesis

Three novel localization algorithms for multiplatform systems have been devised:

1. Angular and Active Constrained Least Square (AACLS):
   - Formalization of ad-hoc constraints for the localization process accounting for PBR receive antenna main-beam size and active radar data.
   - Definition of the position estimation problem resorting to the constrained LS estimation paradigm.
   - Design of an efficient optimization algorithm (via KKT condition exploitation) to globally solve the formulated non-convex optimization problem and determine the location estimate in closed-form.
   - Improvement of the position estimate quality with respect to some localization algorithms counterparts, for both static and dynamic scenario, proved by Monte Carlo simulations.

PhD thesis

2. Angular and Range Constrained Estimator (ARCE):
   - Restriction of the angular location of any illuminated target for capitalizing monostatic radiation pattern features.
   - Formalization of the localization as a non-convex optimization problem.
   - Design of an advanced estimation algorithm exploiting KKT conditions and determining the location estimate in quasi-closed-form among at most twenty-six candidates.
   - Development of a smart rooting method to solve the sixth- and fourth-order equations involved in the evaluation of the candidate optimal solutions.
   - Enhancement of the position estimate accuracy in comparison with some counterparts, especially for weak target returns, proved by Monte Carlo simulations.

PhD thesis

3. SPA based MTT technique exploiting single-snapshot localization:
   - Introduction of a particles enrichment process within the SPA-based MTT that uses the ARCE estimate.
   - Formalization of ad-hoc constraints for the localization process accounting for both the antenna beamwidth of the transmitter and the virtual beamwidth obtained from the target predicted uncertainty.
   - Generation of a new set of particles drawn from a distribution whose parameters depend on the ARCE location estimate.
   - Boost of performance compared to the baseline SPA-based MTT, proved by Monte Carlo simulations.