



PhD in Information Technology and Electrical Engineering
Università degli Studi di Napoli Federico II

PhD Student: Massimo Marrazzo

Cycle: XL

Training and Research Activities Report

PhD Year: First

Tutor: Prof. Antonio De Maio

Antonio De Maio

Co-Tutor: Prof. Vincenzo Carotenuto

Vincenzo Carotenuto

Massimo Marrazzo

Date: October 31, 2025

Training and Research Activities Report

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Author: Massimo Marrazzo

1. Information:

- **PhD student:** Massimo Marrazzo
- **DR number:** 999877
- **Date of birth:** 25/04/1974
- **Master Science degree:** Electronic Engineering
- **University:** University of Cagliari
- **Doctoral Cycle:** XL
- **Scholarship type:** //
- **Current position:** Lieutenant of the Italian Coast Guard Headquarters, ICT and Vessel Traffic Monitoring Department, Radiocommunication and Electronic Office, Automatic Identification System Head Unit
- **Tutor:** Prof. Antonio De Maio
- **Co-tutor:** Prof. Vincenzo Carotenuto

2. Study and training activities:

Activity	Type ¹	Hours	Credits	Dates	Organizer	Certificate ²
Corso di Fondamenti di Project Management applicato alle funzioni di Guardia Costiera	Courses	72	//	02/12/2024 - 13/12/2024	Italian Coast Guard Headquarters. Dott. Ing. F. Alessandro	Y
Bibliographic research and literature review on passive localization methods using TOA and TDOA techniques. Laboratory activity about CESMA, RADAR-SA-LAB (Radar and RF Signal Analysis Laboratory del Centro Servizi Metrologici e Tecnologici Avanzati) of University of Naples "Federico II".	Research		//	01/11/2024 - 31/12/2024		

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Title: Can we Rely on AI? Reliability Issues in Artificial Neural Networks and Potential Solutions for Autonomous Vehicles	Seminar	1	0.2	16/01/2025	Organised by DIETI-UNINA. Prof. Paolo Rech – University of Trento	Y
Partecipation of international meetings: • 21 st MAREΣ AIS Expert Working Group meeting • 9 th EMSA/Italy/Norway meeting on regional AIS servers	Research		1	11/02/2025 and 12/02/2025	Organised by the Italian Coast Guard, as MAREΣ hosting authority, in coordination with EMSA (European Maritime Safety Agency)	Y
Bibliographic research and literature review on passive localization methods using TOA and TDOA techniques. Study of the following software: • MATLAB to implement and deploy codes for processing AIS sentences to obtain TOA and TDOA measurements. Study of the following documents: • ITU-R Recommendation M.1371-5, Technical characteristics for an automatic system using time division multiple access in the VHF maritime mobile frequency band	Research		7	01/01/2025 - 28/02/2025		
Tutorials on Telecommunications: Waveform Design for Coexistence between	Seminar	2		21/03/2025		

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Radar and Communication Systems: from Theory to Experimental validation						
<p>Bibliographic research and literature review on passive localization methods using TOA and TDOA techniques.</p> <p>Writing of the paper “TOA and TDOA-Based Passive Localization Using AIS Signals for Maritime Surveillance” and simulations with MATLAB application software.</p> <p>Study and simulation of the following software applications:</p> <ul style="list-style-type: none">• PostgreSQL to implement and deploy codes to obtain extraction and elaboration of AIS sentences (raw data)• MATLAB to implement and deploy codes for processing AIS sentences to obtain TOA and TDOA measurements. <p>Study of the following documents:</p> <ul style="list-style-type: none">• ITU-R Recommendation M.1371-5, Technical characteristics for an automatic system using time division multiple access in the VHF maritime mobile frequency band.	Research			01/03/2025 - 30/04/2025		

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<ul style="list-style-type: none">• IEC_61162-1_ed4-0, Maritime navigation and radiocommunication equipment ad system – Digital interfaces. Part 1: Single talker and multiple listeners.						
Mega Satellite Constellations for Communication: Stochastic Geometry Approaches for Modeling and Performance Analysis	Seminar	1	0.2	26/06/2025	IEEE-AESS, Lecturer: Prof. Akram Al-Hourani – RMIT University, Melbourne, Australia	Y
Partecipazione of international meetings: <ul style="list-style-type: none">• 11st NSATL (North Sea and Atlantic) AIS Expert Working Group meeting	Research		1	05/06/2025 and 06/06/2025	Organised by the Norwegian Coastal Administration, as the NSATL hosting authority, in coordination with EMSA (European Maritime Safety Agency)	Y
Bibliographic research and literature review on passive localization methods using TOA and TDOA techniques. Writing of the paper “TOA and TDOA-Based Passive Localization Using AIS Signals for Maritime Surveillance” and simulations with MATLAB application software. Study and simulation of the following software applications:	Research		7	01/05/2025 - 30/06/2025		

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<ul style="list-style-type: none">• PostgreSQL to implement and deploy codes to obtain extraction and elaboration of AIS sentences (raw data)• MATLAB to implement and deploy codes for processing AIS sentences to obtain TOA and TDOA measurements. <p>Study of the following documents:</p> <ul style="list-style-type: none">• ITU-R Recommendation M.1371-5, Technical characteristics for an automatic system using time division multiple access in the VHF maritime mobile frequency band.• IEC_61162-1_ed4-0, Maritime navigation and radiocommunication equipment ad system – Digital interfaces. Part 1: Single talker and multiple listeners. <p>Laboratory activity about CESMA, RADAR-SA-LAB (Radar and RF Signal Analysis Laboratory del Centro Servizi Metrologici e Tecnologici Avanzati) of University of Naples “Federico II”</p> <p>Study of the following research papers and documents:</p> <ul style="list-style-type: none">• An approach to detect identity spoofing in AIS						
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<p>messages, M. Louart, J.J. Szkolnik, A.O. Boudraa, J-C. Le Lann, F. Le Roy, ELSEVIER – Expert Systems with Applications, 2024</p> <ul style="list-style-type: none">• Uses and Misuses of the Automatic Identification System, C. Iphar, C. Ray, A. Napoli, OCEANS 2019 – Marsiglia, Jun 2019• Anomaly Detection in Maritime AIS Tracks: A Review of Recent Approaches, K. Wolsing, L. Roepert, J. Bauer and K. Wehrle, Journal of Marine Science and Engineering, 14 Jan. 2022• Dissecting uncertainty-based fusion techniques for maritime anomaly detection, A.L. Joussetme, G. Pallotta, 18th International Conference on Information Fusion, Washington, DC – July 6-9, 2015• A novel anomaly detection approach to identify intentional AIS on-off switching, F. Mazarella, M. Vespe, A. Alessandrini, D. Tarchi, G. Aulicino, A. Vollero, ELSEVIER – Expert Systems with Applications, 2017• Detection of AIS messages falsifications and spoofing by checking messages						
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compliance with TDMA protocol, M. Louart, J.J. Szkolnik, A.O. Boudraa, J-C. Le Lann, F. Le Roy, ELSEVIER – Expert Systems with Applications, 2023.						
Electronic Scan Antennas for Radar Signal Processing Applications	Courses	10	2	25/03/2025 - 07/07/2025	Dr. Enzo Carpentieri, Dr. Massimo Rosamilia DIETI-UNINA	Y
Matrix Analysis for Signal Processing with MATLAB Examples	Courses	14	3	06/05/2025 - 07/07/2025	Dr. Massimo Rosamilia DIETI-UNINA	Y
Cooperative and Non Cooperative Localization Systems	Courses	14	3	09/06/2025 - 07/07/2025	Dr. Massimo Rosamilia DIETI-UNINA	Y
Cognitive Electronic Warfare: Data and In-Mission Learning	Seminar	1	0.2	09/07/2025	IEEE-AESS, Lecturer: Dr. Karen Ziat Haigh	Y
Submitted the following paper to the IEEE International Workshop on Technologies for Defense and Security 2025: “TOA and TDOA-Based Passive Localization Using AIS Signals for Maritime Surveillance”, M. Marrazzo, V. Carotenuto, A. De Maio, L. Pallotta, Tech Defense, Rome, November 5-7, 2025. Study and simulation of the following software applications: <ul style="list-style-type: none">• PostgreSQL to implement and deploy	Research		7	01/07/2025 - 31/08/2025		

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<p>codes to obtain extraction and elaboration of AIS sentences (raw data)</p> <ul style="list-style-type: none">• MATLAB to implement and deploy codes for processing AIS sentences to obtain TOA and TDOA measurements. <p>Study of the following research papers and documents:</p> <ul style="list-style-type: none">• B. Friedlander, "A Passive Localization Algorithm and its Accuracy Analysis," IEEE Journal of Oceanic Engineering, vol. 12, no. 1, pp. 234-245, January 1987.• Y.T.Chan and K.C.Ho, "A Simple and Efficient Estimator for Hyperbolic Location," IEEE Transactions on Signal Processing, vol. 42, no.8, pp.1905-1915, August 1994.• K.C.Ho and W.Xu, "An Accurate Algebraic Solution for Moving Source Location using TDOA and FDOA Measurements", IEEE Transactions on Signal Processing, vol. 52, no. 9, pp. 2453-2463, September 2004.• A.Beck, P.Stoica, and J. Li, "Exact and Approximate Solutions of Source Localization Problems", IEEE Transactions on Signal						
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<p>Processing, vol. 56, no. 5, pp. 1770-1778, May 2008.</p> <ul style="list-style-type: none">• J. Shen, A. Molisch, and J. Salmi, "Accurate Passive Location Estimation Using TOA Measurements", IEEE Transactions on Wireless Communications, vol. 11, no. 6, pp. 2182-2192, June 2012.• A. Aubry, V. Carotenuto, A. De Maio, and L. Pallotta, "Joint Exploitation of TDOA and PCL Techniques for Two-Dimensional Target Localization", IEEE Transactions on Aerospace and Electronic Systems, vol. 56, no. 1, pp. 597-609, 2020.• "Localization in 2D PBR With Multiple Transmitters of Opportunity: A Constrained Least Squares Approach", IEEE Transactions on Signal Processing, vol. 68, pp. 634-646, 2020.• L. Pallotta and G. Giunta, "Accurate Delay Estimation for Multisensor Passive Locating Systems Exploiting the Cross-Correlation Between Signals Cross-Correlations", IEEE Transactions on Aerospace and						
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<p>Electronic Systems, vol. 58, no. 3, pp. 2568-2576, 2022.</p> <ul style="list-style-type: none">• A. Aubry, P. Babu, A. De Maio, G. Fatima, and N. Sahu, "A Robust Framework to Design Optimal Sensor Locations for TOA or RSS Source Localization Techniques", IEEE Transactions on Signal Processing, vol. 71, pp. 1293-1306, 2023.• F. Papi, D. Tarchi, M. Vespe, F. Oliveri, F. Borghese, G. Aulicino, and A. Vollero, "Radiolocation and Tracking of Automatic Identification System Signals for Maritime Situational Awareness", IET Radar, Sonar & Navigation, vol. 9, no. 5, pp. 568-580, 2015.• S. Ma, J. Wang, X. Meng, and J. Wang, "A Vessel Positioning Algorithm Based on Satellite Automatic Identification System", Journal of Electrical and Computer Engineering, vol. 2017, no. 1, p. 8097187, 2017.• C. Gioia, F. Sermi, and D. Tarchi, "Multi-Network Asynchronous TDOA Algorithm Test in a Simulated Maritime Scenario", Sensors, vol. 20, no. 7, 2020. [Online]. Available:						
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<p>https://www.mdpi.com/1424-8220/20/7/1842.</p> <ul style="list-style-type: none">• M. Delcourt and J.-Y. Le Boudec, “TDOA Source-Localization Technique Robust to Time-Synchronization Attacks”, IEEE Transactions on Information Forensics and Security, vol. 16, pp. 4249-4264, 2021.• L. A. Romero and J. Mason, “Evaluation of Direct and Iterative Methods for Overdetermined Systems of TOA Geolocation Equations”, IEEE Transactions on Aerospace and Electronic Systems, vol. 47, no. 2, pp. 1213-1229, 2011.• ITU-R Recommendation M.1371-5, Technical characteristics for an automatic system using time division multiple access in the VHF maritime mobile frequency band• IEC_61162-1_ed4-0, Maritime navigation and radiocommunication equipment ad system – Digital interfaces. Part 1: Single talker and multiple listeners <p>Laboratory activity about CESMA, RADAR-SA-LAB (Radar and RF Signal Analysis Laboratory del Centro Servizi</p>						
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Metrologici e Tecnologici Avanzati) of University of Naples "Federico II"						
English course. Level B1plus	Courses	50	//	13/05/2025 - 15/09/2025	Italian Coast Guard HeadQuarters and Istituto Orion	Y
VLO Target Track Extractor for Radar and for Camera	Seminar	1	0.2	14/10/2025	IEEE-AESS, Lecturer: Prof. Yaakov Bar-Shalom, University of Connecticut	Y
Cognitive Radar	Seminar	1	0.2	16/10/2025	IEEE-AESS, Lecturer: Dr. Marina Sabrina Greco	Y
Accepted the following paper to the 2025 IEEE International Workshop on Technologies for Defense and Security: "TOA and TDOA-Based Passive Localization Using AIS Signals for Maritime Surveillance", M. Marrazzo, V. Carotenuto, A. De Maio, L. Pallotta, Tech Defense, Rome, November 5-7, 2025 Study of the following application and software: • MATLAB: implementation and deployments of codes for processing AIS sentences to obtain TOA	Research		7	01/09/2025 - 31/10/2025		

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<p>and TDOA measurements.</p> <p>Study of the following documents:</p> <ul style="list-style-type: none">• ITU-R Recommendation M.1371-5, Technical characteristics for an automatic system using time division multiple access in the VHF maritime mobile frequency band.• IEC_61162-1_ed4-0, Maritime navigation and radiocommunication equipment ad system – Digital interfaces. Part 1: Single talker and multiple listeners.						
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- 1) Courses, Seminar, Doctoral School, Research, Tutorship
- 2) Choose: Y or N

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2.1. Study and training activities - credits earned

	Courses	Seminars	Research	Tutorship	Total
Bimonth 1	0	0	0	0	0
Bimonth 2	0	0.2	8	0	8.2
Bimonth 3	0	0	0	0	0
Bimonth 4	0	0.2	8	0	8.2
Bimonth 5	8	0.2	7	0	15.2
Bimonth 6	0	0.4	7	0	7.4
Total	8	1	30	0	39
Expected	30 - 70	10 - 30	80 - 140	0 - 4.8	

3. Research activity:

The research activity is focused on the: Localization of maritime traffic with the Automatic Identification System (AIS)

TOPIC

The Automatic Identification System (AIS), initially developed as a ship reporting tool for collision avoidance, has evolved into a fundamental component of maritime situational awareness. The increase of terrestrial networks and satellite constellations of AIS receivers provide global tracking data that enables a wide spectrum of applications beyond collision avoidance.

AIS, originally conceived for collision avoidance, is a system whereby ships broadcast their presence, identification and location.

Differently to other operational coastal active systems for maritime surveillance, AIS is characterized by considerable coverage (very high frequency (VHF) propagation) together with a relatively accurate positioning (global navigation satellite system (GNSS)) performance. Nevertheless, the cooperative nature of AIS and the lack of intrinsic security make it vulnerable to false or missing declarations.

Ships of 300 gross tons and upwards in international voyages, 500 tons and upwards for cargoes not in international waters and passenger vessels are obliged to be fitted with AIS equipment as regulated by the International Maritime Organisation (IMO) Safety of Life and Sea (SOLAS). Furthermore, all EU fishing vessels of overall length exceeding 15 m are also required to be fitted with AIS from May 2014.

AIS reports encode state vector information such as latitude, longitude, speed over ground (SOG), course over ground (COG) as derived by the on-board GNSS receiver. Such information is broadcasted at a variable transmission rate depending on the vessel motion: as an example, the rate is increased up to a message every 2 sec when the vessel is sailing at high speed or manoeuvring. In addition, every 6 min, vessels transmit their identification (IMO and maritime mobile service identity (MMSI) number, ship name and call sign), static (size, type of vessel, type of cargo etc.) and voyage related information (e.g. estimated time of arrival (ToA) and destination). Such information is manually set and therefore not fully reliable since more subject to errors if compared with positioning data.

With the advent of networked regional base stations (BSs) (e.g. the European SafeSeaNet or the Mediterranean AIS Regional Exchange System – MAREΣ), and satellite receiver constellations the

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system progressively proved effective for maritime surveillance and traffic monitoring, enabling far-reaching applications such as traffic knowledge discovery, route prediction and anomaly detection. The latter can target particular low-likelihood motion trajectories, alerts such as sailing in restricted areas, abrupt changes of direction or anomalies related to wrong AIS message information either unintentional or deliberate such as ‘spoofing’.

This PhD research topic addresses the study of the passive localization techniques that enable the estimation of vessel positions using physical-layer measurements, such as Time of Arrival (TOA) and Time Difference of Arrival (TDOA) extracted from AIS signals collected at multiple receiving nodes.

METHODOLOGY

The main objective of this research is to study and compare the effectiveness of three passive localization algorithms fed with real TOA measurements provided by the Italian Coast Guard AIS network. Specifically, two techniques rely on the classical Least Squares (LS) estimation technique using TOA (method uses the transit time between transmitter and receiver directly to find distance) and TDOA (method calculates location from the differences of the arrival times measured on pairs of transmission paths between the target and fixed terminals.) measurements. The third is the Constrained Least Squares (CLS) TDOA algorithm, which introduces two constraints into the estimation problem to improve localization accuracy.

In the methodology investigated during this year of research activity, the performance of these algorithms is experimentally assessed in terms of positioning accuracy using measured data, provided by the Italian AIS network.

The performance has been assessed in a real-world scenario by considering an AIS-based passive localization system composed of four Base Stations (BSs). Specifically, the BSs are located in southern Italy at Monte Redentore (40.6561° N, 17.2889° E), Monte San Michele (39.2861° N, 16.9794° E), Salento Turrisi (40.0621° N, 18.1424° E), and Stigliano (40.3955° N, 16.2321° E).

The analysis is aimed at studying: the localization performance of the LS-TOA, LS-TDOA, and CLS-TDOA methods and the impact of the sensor geometry on the achievable localization accuracy. For both assessments, performance is quantified by the Root Mean Square Error (RMSE).

RESULTS

The results have highlighted that the CLS-TDOA outperforms the classical LS-based approaches in terms of positioning accuracy, demonstrating improved robustness and precision under real-world conditions.

Visual inspection of the topographic maps has revealed that the CLS-TDOA algorithm yields position estimates that are almost always closer to the true vessel locations than those produced by the LS-TOA and LS-TDOA methods. In particular, the LS-TOA algorithm has demonstrated the lowest performance, primarily due to its reliance on absolute time of-arrival measurements, which makes it highly sensitive to clock synchronization errors and measurement noise.

Finally, the impact of the sensor arrangement on localization performance has also been investigated, showing that sensor geometry not only governs the theoretical estimation accuracy but also plays a crucial role in determining the robustness of practical estimators.

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4. Research products:

M. Marrazzo, V. Carotenuto, A. De Maio, L. Pallotta “TOA and TDOA-Based Passive Localization Using AIS Signals for Maritime Surveillance”, IEEE International Workshop on Technologies for Defense and Security 2025, Rome, November 5-7. (**speaker**)

5. Conferences and seminars attended

21st MAREΣ AIS Expert Working Group meeting, organised by the Italian Coast Guard, as the MAREΣ hosting authority, in coordination with EMSA (European Maritime Safety Agency), Rome, 11.02.2025

9th EMSA/Italy/Norway meeting on regional AIS servers, Rome, 12.02.2025

11st NSATL (North Sea and Atlantic) AIS Expert Working Group meeting, organised by the Norwegian Coastal Administration, as the NSATL hosting authority, in coordination with EMSA (European Maritime Safety Agency), Paris 05-06.06.2025

Seminar: “Can we Rely on AI? Reliability Issues in Artificial Neural Networks and Potential Solutions for Autonomous Vehicles”, DIETI-UNINA, Lecturer: Prof. Paolo Rech – University of Trento, Date: 16.01.2025

Tutorials on Telecommunications: “Waveform Design for Coexistence between Radar and Communication Systems: from Theory to Experimental validation”, Date: 21.03.2025

Seminar: “Mega Satellite Constellations for Communication: Stochastic Geometry Approaches for Modeling and Performance Analysis”, IEEE-AESS, Lecturer: Prof. Akram Al-Hourani – RMIT University, Melbourne, Australia, Date: 26.06.2025

Seminar: “Cognitive Electronic Warfare: Data and In-Mission Learning”, IEEE-AESS, Lecturer: Dr. Karen Ziat Haigh, Date: 09.07.2025

Seminar: “VLO Target Track Extractor for Radar and for Camera”, IEEE-AESS, Lecturer: Prof. Yaakov Bar-Shalom – University of Connecticut, Date: 14.10.2025

Seminar: “Cognitive Radar”, IEEE-AESS, Lecturer: Dr. Marina Sabrina Greco, Date: 16.10.2025

6. Activity abroad:

None

7. Activity in partner companies:

No period in the company

8. Tutorship

None