

Nicola Forti

CURRENT APPOINTMENT Scientist, Research Department – NATO Science & Technology Organization
Centre for Maritime Research and Experimentation
Viale San Bartolomeo, 400 – 19126 La Spezia, Italy

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RESEARCH INTERESTS Artificial intelligence, computational statistics, and machine learning, with special emphasis on deep learning, probabilistic modeling, statistical signal processing, and data fusion in multi-sensor systems.

WORK & RESEARCH EXPERIENCE **NATO Centre for Maritime Research and Experimentation**
Scientist, Research Department January 2018 – Present

MAIN RESEARCH ACTIVITIES:

- Deep learning and probabilistic methods (and the interplay between them) with application to prediction, uncertainty modeling, data mining, and automatic anomaly detection of marine vessels and autonomous systems.
- Signal processing, information fusion, and target tracking solutions using heterogeneous data for maritime and underwater surveillance.

MAIN RESEARCH PROJECTS:

- ACT* Data Knowledge and Operational Effectiveness
Maritime pattern learning and predictive analytics, maritime anomaly detection, target tracking, and data fusion.
**NATO Allied Command Transformation*
- EU H2020 PROMENADE - Improved Maritime Awareness by means of AI and BD Methods
Application of AI and Big Data technologies to improve vessel tracking, behaviour analysis and automatic anomaly detection solutions, and deliver an open, service-based toolkit with a high-performance computer platform.
- ACT EFT - Emerging and Future Technology
Learning-based dynamic underwater source localization, acoustic field estimation, finite-element sound propagation model, target detection and tracking.
- EU H2020 MARISA - Maritime Integrated Surveillance Awareness
Development of enhanced maritime surveillance knowledge and capabilities by fusing heterogeneous data (historical AIS, satellite, OSINT, ocean and meteo) for object assessment, behaviour analysis, prediction of future states, common situation awareness and sharing of data. Validated by trials in the North Sea, Iberian Sea, Aegean Sea, and Ionian Sea.

Università degli Studi di Firenze, Information Engineering

Postdoctoral Researcher – Firenze, Italy December 2016 – December 2017
Research project: *Towards a smart sensor network for air quality monitoring*
In collaboration with the Italian Institute of Biometeorology (IBIMET-CNR)

Carnegie Mellon University, Electrical and Computer Engineering

Postdoctoral Researcher – Pittsburgh, USA April 2017 – December 2017
Research project: *An interdisciplinary approach to integratable, composable and evolvable cybersecurity in energy delivery systems*, U.S. Department of Energy

Leonardo S.p.A.

Research Collaborator – Rome, Italy June 2014 – June 2015
Research project: *Machine learning techniques for land-cover classification and monitoring using GIS data and SAR images*

EDUCATION

Università degli Studi di Firenze Firenze, Italy
Ph.D. in Information Engineering November 2016
Advisors: Prof. Luigi Chisci, Prof. Giorgio Battistelli
Thesis: *Dynamic field estimation in complex environments*

Carnegie Mellon University Pittsburgh, USA
Visiting Ph.D. Research Fellow September 2015 – August 2016
Advisor: Prof. Bruno Sinopoli, Electrical and Computer Engineering

Università degli Studi di Firenze Firenze, Italy
M.S. in Electrical and Automation Engineering April 2013
Advisors: Prof. Luigi Chisci, Prof. Giorgio Battistelli
Thesis: *Distributed multi-target tracking over sensor networks*

University of Southern Denmark Odense, Denmark
Study abroad in Electrical and Automation Engineering February – July 2010

Università degli Studi di Firenze Firenze, Italy
B.S. in Mechanical Engineering December 2009
Advisor: Prof. Benedetto Allotta
Thesis: *Modeling and control of a Ball & Plate system*

**TEACHING &
LEADERSHIP
EXPERIENCE**

Supervisor of Ph.D. thesis: *Underwater acoustic source localization based on finite-element field estimation* of G. Manduzio, Ph.D. candidate in Smart Industry, University of Pisa, 2020-2023.

Supervisor of Visiting Research Fellows S. Capobianco and G. Manduzio in research activities of the DKOE group at NATO STO CMRE, 2020-2021.

Supervisor of Master's thesis: *Real-time air quality monitoring using smart sensor networks* of G. Manduzio, student of Electrical and Automation Engineering, Università degli Studi di Firenze, 2017.

Teaching assistant, *Analysis of environmental systems*. Graduate course, Department of Civil and Environmental Engineering, Università degli Studi di Firenze, 2016.

Supervisor of Master's thesis: *Source seeking with simple robots: Modeling and implementation* of L. Alessandrini, student of Electrical and Automation Engineering, Università degli Studi di Firenze and University of Liverpool, 2015.

Supervisor of Master's thesis: *Machine learning techniques for land-cover classification and monitoring using SAR images* of V. Salvo, student of Electrical and Automation Engineering, Università degli Studi di Firenze, 2015.

Supervisor of Master's thesis: *Finite element Kalman filtering for distributed monitoring via sensor networks* of G. Lucchesi, student of Electrical and Automation Engineering, Università degli Studi di Firenze, 2015.

Supervisor of Master's thesis: *Decentralized state estimation of spatially distributed systems via the finite element method* of S. Guidoni, student of Electrical and Automation Engineering, Università degli Studi di Firenze, 2014.

PUBLICATIONS

N. Forti, E. d'Afflisio, P. Braca, L. M. Millefiori, P. Willett, and S. Carniel, "Next-Gen Intelligent Situational Awareness Systems for Maritime Surveillance and Autonomous Navigation," *Proceedings of the IEEE*, accepted for publication.

S. Capobianco, **N. Forti**, L. M. Millefiori, P. Braca, and P. Willett, "Recurrent encoder-decoder networks for vessel trajectory prediction with uncertainty estimation," *IEEE Transactions on Aerospace and Electronic Systems*, under review.

N. Forti, L. Gao, G. Battistelli, and L. Chisci, "Unknown source in spatially distributed systems: identifiability analysis and estimation," *Automatica*, vol.136, 2022.

N. Forti, L. M. Millefiori, P. Braca, and P. Willett, "Bayesian filtering for dynamic anomaly detection and tracking," *IEEE Transactions on Aerospace and Electronic Systems*, vol. 58, no. 3, pp. 1528-1544, 2022.

N. Forti, E. d'Afflisio, P. Braca, L. M. Millefiori, P. Willett, and S. Carniel, "Maritime anomaly detection in a real-world scenario: *Ever Given* grounding in the Suez Canal," *IEEE Transactions on Intelligent Transportation Systems*, 2021.

G. Soldi, **N. Forti**, D. Gaglione, P. Braca, L. M. Millefiori, S. Marano, P. Willett, and K. Pattipati, "Quickest detection and forecast of pandemic outbreaks: Analysis of COVID-19 waves," *IEEE Communications Magazine*, vol.59, no.9, pp.16-22, 2021.

S. Capobianco, **N. Forti**, L. M. Millefiori, P. Braca, and P. Willett, "Uncertainty-aware recurrent encoder-decoder networks for vessel trajectory prediction," *24th Int. Conference on Information Fusion (FUSION)*, Sun City, South Africa, 2021.

S. Capobianco, L. M. Millefiori, **N. Forti**, P. Braca, and P. Willett, "Deep learning

methods for vessel trajectory prediction based on recurrent neural networks,” *IEEE Transactions on Aerospace and Electronic Systems*, vol.57, no.6, pp.4329–4346, 2021.

G. Manduzio, **N. Forti**, R. Sabatini, P. Braca, G. Battistelli, and L. Chisci “Dynamic source localization via finite-element underwater acoustic field estimation,” *Proc. 29th European Signal Processing Conference (EUSIPCO)*, Dublin, Ireland, 2021.

D. Gaglione, P. Braca, G. Soldi, **N. Forti**, L. M. Millefiori, S. Marano, P. Willett, and K. Pattipati, “Information processing methodologies to combat the COVID-19 pandemic,” *ISIF Perspectives on Information Fusion*, vol. 4, no. 1, pp. 15–20, 2021.

G. Soldi, D. Gaglione, **N. Forti**, A. Di Simone, F. Daffinà, G. Bottini, D. Quattrocchi, L. Millefiori, P. Braca, S. Carniel, P. Willett, A. Iodice, D. Riccio, A. Farina, “Space-based global maritime surveillance. Part II: Artificial intelligence and data fusion techniques,” *IEEE Aerospace and Electronic Systems Magazine*, vol. 36, no. 9, pp. 30–42, 2021.

G. Soldi, D. Gaglione, **N. Forti**, A. Di Simone, F. Daffinà, G. Bottini, D. Quattrocchi, L. Millefiori, P. Braca, S. Carniel, P. Willett, A. Iodice, D. Riccio, A. Farina, “Space-based global maritime surveillance. Part I: Satellite technologies,” *IEEE Aerospace and Electronic Systems Magazine*, vol. 36, no. 9, pp. 8–28, 2021.

N. Forti, L. M. Millefiori, P. Braca, and P. Willett “Random finite set tracking for anomaly detection in the presence of clutter,” *Proc. IEEE Radar Conference*, Florence, Italy, 2020.

N. Forti, L. M. Millefiori, P. Braca, and P. Willett “Prediction of vessel trajectories from AIS data via sequence-to-sequence recurrent neural networks,” *IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, pp. 8936–8940, Barcelona, Spain, 2020.

D. Gaglione, P. Braca, L. M. Millefiori, G. Soldi, **N. Forti**, S. Marano, P. Willett, K. Pattipati, “Adaptive Bayesian learning and forecasting of epidemic evolution – Data analysis of the COVID-19 outbreak,” *IEEE Access*, vol.8, pp.175244–175264, 2020.

N. Forti, L. M. Millefiori, P. Braca, and P. Willett “Anomaly detection and tracking based on mean-reverting processes with unknown parameters,” *IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, pp. 1178–1184, Brighton, UK, 2019.

N. Forti, G. Battistelli, L. Chisci, and B. Sinopoli, “Joint attack detection and secure state estimation of cyber-physical systems,” *International Journal of Robust and Nonlinear Control*, vol. 30, no. 11, pp. 4303–4330, 2019.

N. Forti, L. M. Millefiori, and P. Braca, “Unsupervised extraction of maritime patterns of life from Automatic Identification System data,” *Proc. MTS/IEEE OCEANS*, Marseille, France, 2019.

- G. Battistelli, L. Chisci, **N. Forti**, and S. Gherardini, “MAP moving horizon estimation for threshold measurements with application to field monitoring,” *International Journal of Adaptive Control and Signal Processing*, vol. 34, no. 6, pp. 796–811, 2019.
- N. Forti**, G. Battistelli, L. Chisci, S. Li, B. Wang, and B. Sinopoli, “Distributed joint attack detection and secure state estimation,” *IEEE Transactions on Signal and Information Processing over Networks*, vol. 4, no. 1, pp. 96–110, 2018.
- N. Forti**, L. M. Millefiori, and P. Braca, “Hybrid Bernoulli filtering for detection and tracking of anomalous path deviations,” *Proc. 21st Int. Conference on Information Fusion (FUSION)*, pp. 1178–1184, Cambridge, UK, 2018.
- G. Battistelli, L. Chisci, **N. Forti**, G. Pelosi, and S. Selleri, “Distributed finite-element Kalman filter for field estimation,” *IEEE Transactions on Automatic Control*, vol. 62, no. 7, pp. 3309–3322, 2017.
- E. Bou-Harb, W. Lucia, **N. Forti**, S. Weerakkody, N. Ghani, and B. Sinopoli, “Cyber meets control: A novel federated approach for resilient CPS leveraging real cyber threat intelligence,” *IEEE Communications Magazine*, vol. 55, no. 5, pp. 198–204, 2017.
- N. Forti**, G. Battistelli, L. Chisci, and B. Sinopoli, “Worst-case analysis of joint attack detection and resilient state estimation,” *Proc. 56th IEEE Conference on Decision and Control*, Melbourne, Australia, 2017.
- N. Forti**, G. Battistelli, L. Chisci, and B. Sinopoli, “Secure state estimation of cyber-physical systems under switching attacks,” *Proc. 20th World Congress of the International Federation of Automatic Control*, Toulouse, France, 2017.
- N. Forti**, G. Battistelli, L. Chisci, and B. Sinopoli, “A Bayesian approach for joint attack detection and resilient state estimation,” *Proc. 55th IEEE Conference on Decision and Control*, pp. 1192–1198, Las Vegas, NV, 2016.
- G. Battistelli, L. Chisci, **N. Forti**, and S. Gherardini, “MAP moving horizon state estimation with binary measurements,” *Proc. American Control Conference*, pp. 5413–5418, Boston, MA, 2016.
- G. Battistelli, L. Chisci, **N. Forti**, G. Pelosi, and S. Selleri, “Point source estimation via finite element multiple-model Kalman filtering,” *Proc. 54th IEEE Conference on Decision and Control*, pp. 4984–4989, Osaka, Japan, 2015.
- G. Battistelli, L. Chisci, **N. Forti**, G. Pelosi, and S. Selleri, “Distributed finite element Kalman filter,” *Proc. 14th European Control Conference*, pp. 3695–3700, Linz, Austria, 2015.
- G. Battistelli, L. Chisci, C. Fantacci, **N. Forti**, A. Farina and A. Graziano, “Distributed peer-to-peer multitarget tracking with association-based track fusion,” *Proc. 17th Int. Conference on Information Fusion (FUSION)*, Salamanca, Spain, 2014.

ADDITIONAL ACTIVITIES

Organizer, special session *Machine learning methods for the prediction and modelling of object dynamics*, 24th Int. Conference on Information Fusion, 2021, and special session *Multisensor multitarget tracking in surveillance applications*, IEEE Radar Conference, 2020.

Technical Program Board Member, *Maritime Situational Awareness Workshop*, Lerici (SP), Italy, 2019.

Invited talk, *Joint attack detection and secure state estimation of cyber-physical systems*, Concordia University, Montreal, Canada, 2017.

Reviewer, IEEE Transactions on Signal Processing, IEEE Transactions on Automatic Control, IEEE Transactions on Control of Network Systems, IEEE Transactions on Aerospace and Electronic Systems, Automatica, International Journal of Robust and Nonlinear Control, International Journal of Adaptive Control and Signal Processing, International Conference on Information Fusion, IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP).

TECHNICAL SKILLS

Programming languages: Python, MATLAB, C/C++.

AI experience: Supervised, unsupervised, and sequential learning, particularly focused on recurrent neural network-based architectures and sequence-to-sequence predictive models used in Natural Language Processing with applications to pattern recognition and prediction in the maritime domain; image segmentation, classification, and object detection methods in the context of Computer Vision. Probabilistic deep learning, uncertainty estimation for deep neural networks, recursive Bayesian estimation, physics-informed neural networks.

Software development processes and tools: Experience with Agile development methodologies, Continuous Integration/Continuous Deployment and code management.

Database and large datasets management: Experience with large datasets and big data management especially with real-world data for maritime surveillance in the context of EU and NATO projects.

HONORS & AWARDS

Recipient of the NATO STO Scientific Achievement Team Award in 2020 for “*Advances in Artificial Intelligence and Information Fusion for Maritime Situational Awareness*”.

Selected to participate in the NATO Early Career Scientist 2019 for research activity on “*AIS-based learning of maritime traffic patterns for long-term prediction and anomaly detection*”.

Ph.D. thesis awarded with highest honors (cum laude) by unanimous vote of the Committee Members for the exceptional scientific achievements.

Recipient of the Postdoctoral Research Fellowship, Information Engineering, Università degli Studi di Firenze, for the research project “*Towards a smart sensor network for air quality monitoring*” funded by Ente Cassa di Risparmio di Firenze.

Recipient of the annual “*Leonardo Tesi Thesis Award*” for the best thesis 2011/2012 in Automation Engineering – Università degli Studi di Firenze.