

Dr. Nicola Forti

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

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RESEARCH INTERESTS My main research interests include state estimation and systems theory, statistical signal processing, artificial intelligence and machine learning, sensor networks and information fusion, with special emphasis on inference and learning from big data, multisensor multitarget tracking, monitoring/control of networked control systems, distributed parameter systems, and secure cyber-physical systems.

RESEARCH EXPERIENCE **NATO Science & Technology Organization** January 2018 – Present
Centre for Maritime Research and Experimentation – La Spezia, Italy
Scientist

Involved in several scientific projects in the field of Artificial Intelligence for Maritime Situational Awareness, including EU projects. Active involvement in the NATO/USA bilateral collaboration with the University of Connecticut in response to the COVID-19 pandemic focused on the development of adaptive learning and forecasting tools. Research activities mainly focus on the development of deep learning and stochastic model-based methods for prediction, data mining, knowledge discovery, and automatic anomaly detection of maritime traffic patterns using data from available tracking systems such as Automatic Identification System (AIS) and radar. Further activities include the development of signal processing, information fusion, and target tracking solutions using heterogeneous data for maritime and underwater surveillance.

Università degli Studi di Firenze December 2016 – December 2017
Department of Information Engineering, Systems and Control Lab – Firenze, Italy
Postdoctoral Researcher

Research project: *Towards a smart sensor network for air quality monitoring*, Ente Cassa di Risparmio di Firenze
Development of a high-resolution monitoring system of urban atmospheric pollution assimilating data gathered from new collection activities using a smart sensor network of low-cost stationary and mobile measurement devices. This project was in collaboration with the Italian Institute of Biometeorology (IBIMET-CNR).

Carnegie Mellon University April 2017 – December 2017
Department of Electrical and Computer Engineering – Pittsburgh, PA, USA
Visiting Postdoctoral Researcher

Research project: *An interdisciplinary approach to integratable, composable and evolvable cybersecurity in energy delivery systems*, U.S. Department of Energy
Research and development of secure technologies, tools, software, and methodologies for energy delivery systems against cyber-physical attacks which can corrupt sensor measurements and control inputs.

Leonardo S.p.A. June 2014 – June 2015
Rome, Italy

Research project: *Fusion of GIS data and SAR images*
Development of an automatic classification system of SAR images based on support-vector machines to update Geographic Information System data for automatic mapping and change detection tasks in surveillance intelligence.

Università degli Studi di Firenze September 2013 – October 2013
Department of Information Engineering – Firenze, Italy

Research project: Development of methodologies, algorithms, and software components for distributed multi-target tracking over sensor networks.

EDUCATION

Università degli Studi di Firenze November 2013 – November 2016
Ph.D. in Information Engineering – Firenze, Italy
Curriculum: Automatic Control, Optimization and Electrical Systems
Advisors: Prof. Luigi Chisci, Prof. Giorgio Battistelli

Thesis: *Dynamic field estimation in complex environments*
Addressed key challenges of estimating spatially-distributed time-varying systems governed by partial differential equations: decentralized data fusion for scalable state estimation of spatially-distributed systems; robustness of field estimators in the presence of unknown sources; field estimation with networks of binary sensors; security of next-generation field monitoring systems in the presence of cyber-physical attacks.

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

Development of methodologies and software components to address the analysis and design of secure cyber-physical systems, with special focus on detection and resilient state estimation in the presence of data integrity attacks.

Università degli Studi di Firenze January 2010 – April 2013
M.S. in Electrical and Automation Engineering – Firenze, Italy
Advisors: Prof. Luigi Chisci, Prof. Giorgio Battistelli
Graduated cum laude

Thesis: *Distributed multi-target tracking over sensor networks*

Addressed distributed multi-target tracking using consensus over a peer-to-peer network of TOA, DOA sensors with local Joint Probabilistic Data Association, and Unscented Kalman filters for recursive target state estimation.

University of Southern Denmark

February 2010 – July 2010

Study abroad in Electrical and Automation Engineering – Odense, Denmark

Completed electrical engineering courses in Power System Calculation and Protection, Transmission and Distribution of Electrical Power, Advanced Electronics, and the Automatic Control project (*Transformation of a quad: from gasoline to electricity*).

Università degli Studi di Firenze

December 2009

B.S. in Mechanical Engineering – Firenze, Italy

Specialization in Robotics and Mechatronics

Advisor: Prof. Benedetto Allotta

Thesis: *Modeling and control of a Ball & Plate system*

Development of mathematical models and software components for digital control and hardware in the loop data analysis of a “Ball & Plate” system.

PUBLICATIONS

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. Early access.

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*, 2021. Early access.

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,” *Proc. 24th Int. Conference on Information Fusion (FUSION)*, Sun City, South Africa, 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.

- 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.
- N. Forti**, L. Gao, G. Battistelli, and L. Chisci, “Unknown source in spatially distributed systems: identifiability analysis and estimation,” *Automatica*, 2021. To be published.
- 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.
- D. Gaglione, P. Braca, L. M. Millefiori, G. Soldi, **N. Forti**, S. Marano, P. Willett, and 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 “[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](#),” *Proc. IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, pp. 8936–8940, Barcelona, Spain, 2020.
- 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**, L. M. Millefiori, P. Braca, and P. Willett “[Anomaly detection and tracking based on mean-reverting processes with unknown parameters](#),” *Proc. IEEE*

International Conference on Acoustics, Speech and Signal Processing (ICASSP), pp. 1178–1184, Brighton, UK, 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)*, pp. 1–7, Salamanca, Spain, 2014.

WORKSHOPS &
TECHNICAL
REPORTS

N. Forti, G. Battistelli, L. Chisci, and B. Sinopoli “A Bayesian approach to secure state estimation of cyber-physical systems,” in *Convegno della Società Italiana Docenti e Ricercatori in Automatica*, Milano, Italy, 2017.

G. Battistelli, L. Chisci, **N. Forti**, G. Pelosi, and S. Selleri, “Localized diffusive source estimation via an hybrid finite element/Kalman filtering approach,” in *International Workshop on Finite Elements for Microwave Engineering*, Florence, Italy, 2016.

G. Battistelli, L. Chisci, and **N. Forti**, “Dynamic field estimation in complex environments,” in *Convegno della Società Italiana Docenti e Ricercatori in Automatica*, Rome, Italy, 2016.

G. Battistelli, L. Chisci, **N. Forti**, G. Pelosi, and S. Selleri, “A finite-element based field estimation via a Kalman filtering approach,” in *Riunione Nazionale di Elettromagnetismo*, Parma, Italy, 2016.

G. Battistelli, L. Chisci, **N. Forti**, V. Salvo, A. Graziano, F. Ciaramaglia, G. Golino, A. Liburdi, and W. Mellano, “Fusion of GIS data and SAR images,” Tech. Rep., 2015.

TEACHING
EXPERIENCE &
LEADERSHIP

Research manager: recruited and supervised Visiting Research Fellows S. Capobianco and G. Manduzio, in research activities of the DKOE group at NATO CMRE, 2020.

Ph.D. thesis: *Monitoring of spatially distributed systems* of G. Manduzio, Ph.D. candidate in Smart Industry, University of Pisa, 2020.

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.

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.

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.

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.

Master’s thesis: *Decentralized state estimation of spatially distributed systems via the finite element method* of S. Guidoni, student of Electrical and Automation Engineering,

ing, Università degli Studi di Firenze, 2014.

ATTENDED
CONFERENCES
& WORKSHOPS

Organizer, special session *Machine learning methods for the prediction and modelling of object dynamics*, 24th Int. Conference on Information Fusion, 2021.

Organizer, special session *Multisensor multitarget tracking in surveillance applications*, 2020 IEEE Radar Conference.

Participation in *Maritime Situational Awareness* course, NATO Maritime Security Centre of Excellence (MARSEC COE), virtual, 2020.

Presentation, *Random finite set tracking for anomaly detection in the presence of clutter*, IEEE Radar Conference, virtual, 2020.

Presentation, *Prediction of vessel trajectories from AIS data via sequence-to-sequence recurrent neural networks*, IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), virtual, 2020.

Presentation, *Unsupervised extraction of maritime patterns of life from Automatic Identification System data*, MTS/IEEE OCEANS, Marseille, France, 2019.

Presentation, *Anomaly detection and tracking based on mean-reverting processes with unknown parameters*, IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), Brighton, UK, 2019.

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

Presentation, *Hybrid Bernoulli filtering for detection and tracking of anomalous path deviations*, 21st Int. Conference on Information Fusion, Cambridge, UK, 2018.

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

Presentation, *Secure state estimation of cyber-physical systems under switching attacks*, 20th World Congress of the International Federation of Automatic Control, Toulouse, France, 2017.

Presentation, *A Bayesian approach to secure state estimation of cyber-physical systems*, Convegno della Società Italiana Docenti e Ricercatori in Automatica, Milano, Italy, 2017.

Participation at CPS Week, Pittsburgh, PA, USA, 2017.

Presentation, *A Bayesian approach for joint attack detection and resilient state estimation*, 55th IEEE Conference on Decision and Control, Las Vegas, NV, 2016.

Presentation, *MAP moving horizon state estimation with binary measurements*, American Control Conference, Boston, MA, 2016.

Presentation, *Dynamic field estimation in complex environments*, Convegno della Società Italiana Docenti e Ricercatori in Automatica, Rome, Italy, 2016.

Presentation, *Distributed finite element Kalman filter*, European Control Conference, Linz, Austria, 2015.

Participation at SIDRA Summer School on Control of Nonlinear Systems and Unmanned Aerial Vehicles, Bertinoro, Italy, 2014.

Participation at IEEE International Conference on Acoustics, Speech, and Signal Processing, Florence, Italy, 2014.

Participation at IEEE Conference on Decision and Control, Florence, Italy, 2013.

HONORS & AWARDS

Recipient of the NATO STO Scientific Achievement Team Award in 2020, as a member of the Data Knowledge and Operational Effectiveness Research Group for “*Advances in Artificial Intelligence and Information Fusion for Maritime Situational Awareness*”.

Selected to participate in the NATO Early Career Scientist 2019 event in Bucharest, Romania, for the 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, Department of Information Engineering, Università degli Studi di Firenze, for the research project “*Towards a smart sensor network for air quality monitoring*”.

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

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, ISIF Journal of Advances in Information Fusion, Engineering Applications of Artificial Intelligence, Frontiers in Signal Processing, IEEE International Conference on Acoustics, Speech and Signal Processing, IEEE Conference on Decision and Control, IEEE Radar Conference, International Conference on Information Fusion.

LANGUAGES

Native speaker in Italian, fluent in English (**ESOL Certificate in Advanced English, Level C1 – University of Cambridge**), basic knowledge of French and Spanish.