# UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

## DOTTORATO DI RICERCA / PhD PROGRAM IN INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING

## Activities and Publications Report

# PhD Student: Carlo Motta

**Student ID: DR995143**

**PhD Cycle: XXXVI**
**PhD Cycle Chairman: Prof. Stefano Russo**

**PhD program student's start date: 01/11/2020**
**PhD program student's end date:31/01/2024**

**Supervisor: Prof. Gianmaria De Tommasi**

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**Co-supervisor: Prof. Stefania Santini**

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**PhD scholarship funding entity:**
Università Federico II

# General information

Carlo Motta received in year 2019 the Master Science degree in Automation Engineering from the University of Naples Federico II. He attended a curriculum in "Assessment and enforcement of resilience and security properties in control systems" within the PhD program in Information Technology and Electrical Engineering. He received a grant from University of Naples Federico II.

# Study activities

## Attended Courses

| Year | Course Title | Type | Credits | Lecturer | Organization |
|------|--------------|------|---------|----------|--------------|
| 1st | Digital Forensics | Ad hoc course | 3 | Prof. Cozzolino | ITEE |
| 1st | Stochastic Modeling | Ad hoc course | 6 | Prof. Giorgio | Scuola Superiore Meridionale |
| 1st | From observability to privacy and security in discrete event systems | Ad hoc course | 5 | Prof. De Tommasi | ITEE |
| 1st | Scientific Programming and Visualization with Python | Ad hoc course | 2 | Prof. Botta | ITEE |
| 1st | Corso di Imprenditorialità Accademica | Ad hoc course | 4 | Prof. Rippa | ITEE |
| 2nd | Matrix Analysis for Signal Processing with MATLAB | Ad hoc course | 2 | Prof Carotenuto | ITEE |
| 2nd | Big Data Architecture and Analytics | Ad hoc course | 5 | Prof. Sperlì | ITEE |
| 2nd | Operational Research: Mathematical Modelling, Methods and Software Tools for Optimization Problems | Ad hoc course | 4 | Prof. Masone | ITEE |

## Attended PhD Schools

| Year | School title | Location | Credits | Dates | Organization |
|------|--------------|----------|---------|-------|--------------|
| 1st | AIRO: Optimization and Data Science: Trends and Applications | Napoli, Italy | 3.6 | 08-12/02/2021 | Associazione Italiana di Ricerca Operativa |

## Attended Seminars

| Year | Seminar Title | Credits | Lecturer | Lecturer affiliation | Organization |
|------|---------------|---------|----------|----------------------|--------------|
| 1st | Robot Manipulation and Control | 0.5 | Prof. B. Siciliano | University of Naples Federico II | Information and Communication Technology for Health |
| 1st | Digital Project Management | 0.2 | Prof. D. Carotenuto | University of Naples Federico II | Picariello Lecture |
| 1st | Beyond Einstein Gravity: Dark Energy and Dark Matter as Curvature Effects | 0.3 | Prof. S. Capozziello | University of Naples Federico II | Scuola Superiore Meridionale |
| 1st | Science, Reality and Credibility | 0.3 | Prof. S. Perlmutter | University of California | Futuro Remoto |
| 1st | Images, Texts, Emojis & Geodata in a Sentiment Analysis Pipeline | 0.3 | Prof. S. Pelosi | University of Salerno | Picariello Lecture |
| 1st | The Ohta-Kawasaki model for diblock copolymers: stability and minimality of critical points | 0.3 | Prof. N. Fusco | University of Naples Federico II | Scuola Superiore Meridionale |
| 1st | Patent Searching Best Practice with IEEE Xplore | 0.2 | Dr. E. Lukacs | University of Gyòr | IEEE Xplore |
| 1st | At the Nexus of Big Data, Machine Intelligence and human cognition | 0.2 | Prof. G. S. Djorgovski | California Institute of Technology | Picariello Lecture |
| 1st | The Ohta-Kawasaki model for diblock copolymers: stability and minimality of critical points | 0.3 | Prof. G. S. Djorgovski | California Institute of Technology | Scuola Superiore Meridionale |
| 1st | Exploiting Deep Learning and Probabilistic Modeling for Behaviour Analytics | 0.2 | Prof. G. Manco | Università di Pisa | Picariello Lecture |
| 1st | Quasars as high Redshift Standard Candles | 0.3 | Prof. G. Risaliti | Università di Firenze | Scuola Superiore Meridionale |
| 1st | GDPR basics for computer scientists | 0.3 | Dr. R. Wenning | European Research Consortium for Informatics and Mathematics | ITEE |
| 1st | From Photometric Redshifts to Improved Weather Forecasts: an interdisciplinary view on machine learning | 0.2 | Prof. K. Polsterer | Heidelberg Institute of Theoretical Studies | Picariello Lecture |
| 1st | Synchronization: A Universal Concept in Nonlinear Sciences | 0.3 | Prof. J. Kurths | University of Postdam | Scuola Superiore Meridionale |
| 1st | Cybercrime and e-evidence: | 0.4 | Prof. M. | European Council | Picariello Lecture |

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| | the criminal justice response | | Lucchetti | | |
| 1st | State Estimation and Event Inference in DES: Implications to Detectability, Diagnosability and Opacity | 0.3 | Prof. C. Hadjicostis | University of Cyprus | IEEE-CSS |
| 1st | AI: Artificial Intelligence for notary's sector – a case study | 0.2 | Prof. S. Palange | Università Cattolica | Picariello Lecture |
| 1st | Quantum Simulators | 0.3 | Prof. R. Fazio | Institute of Quantum Technologies | Scuola Superiore Meridionale |
| 1st | Dynamical Systems Laboratory | 0.2 | Prof. M. Porfiri | New York University | Scuola Superiore Meridionale |
| 2nd | Complexity and the City: transitioning towards the smart cities of the future | 0.3 | Prof. L. Bettencourt | University of Chicago | Università di Milano |
| 2nd | Graphons: A Tool for the Analysis of Systems on Larger Networks | 0.3 | Prof. P. Frasca | Centre national de la recherche scientifique | Scuola Superiore Meridionale |
| 2nd | Data-Driven methods in engineering -Part I | 0.4 | Prof. R. Vinuesa | KTH - Royal Institute of Technology | Università Di Bologna |
| 2nd | Hyperuniform States of Matter and Their Novel Transport Properties | 0.3 | Prof. R. Torquato | Princeton Institute | Scuola Superiore Meridionale |
| 2nd | Data-Driven methods in engineering -Part II | 0.4 | Prof. R. Vinuesa | KTH - Royal Institute of Technology | Università Di Bologna |
| 2nd | Data-Driven methods in engineering -Part III | 0.4 | Prof. R. Vinuesa | KTH - Royal Institute of Technology | Università Di Bologna |
| 2nd | Advanced Controls Test Bed for Evaluation of Rule-Based, Model Predictive, and Reinforcement Learning Building Control | 0.3 | Prof. G. P. Henzea | University of Colorado Boulder | ITEE |
| 2nd | Structure Process and Dynamics of Networks with higher Order Interaction | 0.3 | Prof. S. Boccaletti | Institute for Complex Systems | Scuola Superiore Meridionale |
| 2nd | Data-Driven methods in engineering -Part IV | 0.4 | Prof. R. Vinuesa | KTH - Royal Institute of Technology | Università Di Bologna |
| 2nd | Social Network Dynamics Leading to Community Formation and Residential Segregation | 0.3 | Prof. M. Franceschetti | University of California | Scuola Superiore Meridionale |
| 2nd | Data-Driven methods in | 0.4 | Prof. R. | KTH - Royal Institute | Università Di Bologna |

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| | engineering -Part V | | Vinuesa | of Technology | |
| 2nd | Turbulent dynamics in viscous fluids: a complex phenomenon ubiquitous in nature | 0.3 | Prof. V. Carbone | University of Calabria | Scuola Superiore Meridionale |
| 2nd | Climate Meets Complexity: Exploring predictability of extreme climate events via complex network approach | 0.3 | Prof. J. Kurths | University of Potsdam | Scuola Superiore Meridionale |
| 2nd | The Challenge of Gravitational Wave Detectors of the 3rd Generation. Cultural and Technological Aspects | 0.3 | Prof. E. Majorana | Sapienza - Università di Roma | Scuola Superiore Meridionale |
| 2nd | Enlightening the Universe with High-Energy Cosmic Neutrinos | 0.3 | Prof. M. Chianese | University of Naples Federico II | Scuola Superiore Meridionale |
| 2nd | Using Delays for Control | 0.2 | Prof. E. Fridman | Tel Aviv University | ITEE |
| 2nd | Using Delays for Control | 0.2 | Prof. E. Fridman | Tel Aviv University | ITEE |

## Research activities

Carlo Motta participated in the research with the study of Cyber-Physical Systems (CPS) and related attacks in the context of Discrete Event Systems (DES). Threats to privacy and security resulting from information breaches and fraud in distributed systems require the search for control systems that are resilient against external attacks, both active and passive. The approach involved modeling Cyber-Physical Systems (CPS) as DES, with a focus on passive attacks through concepts such as opacity and non-interference. For active attacks, the theory for ensuring safety in Intelligent Transportation Systems (ITS) was applied, with a focus on autonomous vehicles at unsignalized intersections. A realistic model, implemented with MATLAB, was developed to identify resilient supervisors. In the context of connected and autonomous platoons, we tried to solve the Safety Of The Intended Functionality (SOTIF) problem with the aim of designing a robust and non-fragile control strategy in the presence of uncertainties and disturbances. A robust estimation method was proposed to evaluate the performance limitations, formulating the problem in terms of linear matrix inequalities (LMI). The analysis of stability, robustness and performance requirements under the proposed strategy was carried out using Lyapunov theory. Overall, the research integrated DES modeling, cybersecurity concepts, and control strategies to address emerging challenges in cyber-physical systems, with a specific focus on passive and active attacks in the vehicular domain.

## Tutoring and supplementary teaching activities

During his PhD, Carlo Motta gave several seminars about the assessment of privacy properties, such as opacity, in DES modelled as Petri nets. The seminars have been were included as part of the tutoring and teaching activities of the Discrete event systems and supervisory control course for the MSc in Automation Engineering & Robotics at University of Naples Federico II. The total duration of the seminars is about 8 hours.

## Credits summary

| PhD Year | Courses | Seminars | Research | Tutoring / Supplementary Teaching |
|----------|---------|----------|----------|-----------------------------------|
| 1st | 23.6 | 5.3 | 31 | 0 |
| 2nd | 11 | 5.4 | 43.6 | 0.96 |
| 3rd | 0 | 0 | 60 | 0 |

## Research periods in institutions abroad and/or in companies

| PhD Year | Institution / Company | Hosting tutor | Period | Activities |
|----------|-----------------------|---------------|--------|------------|
| 1st | Swinburne University of Technology, Melbourne, Australia | Prof. Xiaohua Ge | 18/10/2022-04/06/2023 | Research on joint scientific paper preparation. |

## PhD Thesis

In the PhD Thesis, Carlo Motta tackles cyber-attacks in cyber-physical systems. Today's technological society is characterized by the prevalence of complex systems comprising multiple intelligent elements and devices. The communication among these elements forms the so-called cyber-physical systems, examples of which are autonomous automated highway systems, avionics, and smart grids. The connectivity, needed to make the physical objects (or sensor devices) transmit information to the control system and receive data, renders the control system susceptible to cyber-attacks. The realm of discrete event systems offers promising avenues for addressing the challenges posed by cyber-attacks in cyber-physical systems, whether they constitute a threat to safety or privacy.

This dissertation aims to withdraw optimization-based approaches to assess both non-interference and opacity in discrete event systems modeled as Petri nets. Retrieving necessary and sufficient conditions to obtain non-interference requires the solution of integer feasibility problems with nonlinear constraints. Regarding opacity, necessary and sufficient conditions to check initial state opacity in discrete event systems modeled as bounded and live Petri nets are given. The proposed

approaches for these two cases rely on both the algebraic representation of Petri nets dynamic and their structural representation and exploits commonly used off-the-shelf optimization tools. The second aim is to ensure safety in a distributed dynamical system, modeled as a discrete events system, whose feedback control is compromised by either communication delays or by a malicious attacker hijacking the system communication channel. The focus is autonomous connected vehicle applications and the synthesis of a supervisor that is robust against large class attacks. The effectiveness of the proposed approaches is shown by means of several examples.

## Publications

Research results appear in 3 papers published in international journals, 0 papers published in national journals, 3 contributions to international conferences, 2 contributions to national conferences, 0 patents.

## List of scientific publications

### International journal papers

F. Basile, M. Boccia, G. De Tommasi, C. Motta, C. Sterle
An optimization-based approach to assess non-interference in labeled and bounded Petri net Systems; Nonlinear Analysis: Hybrid Systems,
vol. 44, pp. 101153, 2022, DOI: 10.1016/j.nahs.2022.101153.

F. Basile, G. De Tommasi, C. Motta, C. Sterle
Necessary and Sufficient Condition to Assess Initial-State-Opacity in Live Bounded and Reversible Discrete Event Systems.
IEEE Control System Letters,
vol. 6, pp. 2683-2688, 2022, DOI: 10.1109/LCSYS.2022.3174521.

A. Coppola, G. De Tommasi, C. Motta, A. Petrillo, S. Santini
Double-Layer Control Architecture for Motion and Torque Optimisation of Autonomous Electric Vehicles
Transportation Research Interdisciplinary Perspectives
vol. 21, pp. 100866, 2023, DOI: 10.1016/j.trip.2023.100866.

F. Basile, G. De Tommasi, C. Motta
Assessment of initial-state-opacity in live and bounded labeled Petri net systems via optimization techniques
Automatica
vol.152, pp 110911, 2023, DOI: 10.1016/j.automatica.2023.110911

## International conference papers

F. Basile, G. De Tommasi, C. Motta, A. Petrillo, S. Santini
Assessment of Initial-State-Opacity in Live Bounded and Reversible Discrete Event Systems via Integer Linear Programming
The 30th Mediterranean Conference on Control and Automation,
Athens, Greece, Jul. 2022, pp. 994-999, IEEE, DOI: 10.1109/MED54222.2022.9837143.

G. De Tommasi, C. Motta, A. Petrillo, S. Santini
Design of Resilient Supervisory Control for Autonomous Connected Vehicles Approaching Unsignalized Intersection in presence of Communication Delays
*IEEE International Conference on Networking, Sensing and Control (ICNSC)*,
Shanghai, China, Jan. 2023, pp. 1-6, IEEE, DOI: 10.1109/ICNSC55942.2022.10004176.

G. De Tommasi, C. Motta, A. Petrillo, S. Santini
Design of Resilient Supervisory Control for Autonomous Connected Vehicles Approaching Unsignalized Intersection in presence of Cyber-Attacks
*International Federation of Automatic Control (IFAC)*,
Yokohama, Japan, Sep. 2023, pp. 587-592, Elsevier, DOI: 10.1016/j.ifacol.2023.10.1631

## National conference papers

G. De Tommasi, C. Motta, A. Petrillo, S. Santini
Optimization-based assessment of Initial-State Opacity in Petri Nets,
Italian Association of Operations Research - Optimization and Decision Science, AIRO Conference
Naples, Italy, Aug. 2021, pp. 127-138, Springer, DOI: 10.1007 /978-3-030-86286-2_10.

R. Brancati, G. Di Massa, C. Motta, S. Pagano, A. Petrillo, S. Santini
A Test Rig for Experimental Investigation on a MRE Vibration Isolator,
*The International Conference of IFToMM ITALY*
Ischia, Italy, Sep. 2022, pp. 313-320, Springer, DOI: 10.1007/978-3-031-10776-4_37.

# Patents and/or spin offs

N/A

# Awards and Prizes

Third Best Paper Award - 30th Mediterranean Conference on Control and Automation (MED 2022).

Silver Best Application Paper Award – Fourth International Conference of IFToMM Italy (2022).

Best Emerging Technology Paper Award - IEEE Systems, Man, and Cybernetics Society – 19th IEEE International Conference on Networking, Sensing, and Control (IEEE ICNSC 2022).

**Date 15/01/2024**

**PhD student signature** _____

**Supervisor signature** _____