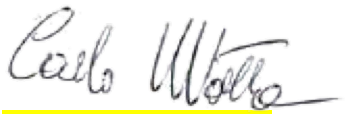
PhD in Information Technology and Electrical Engineering
Università degli Studi di Napoli Federico II

PhD Student: Carlo Motta

Cycle: XXXVI

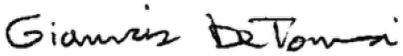
Training and Research Activities Report

Academic year: 2021-2022 - PhD Year: Second



student signature

Tutor: prof. Gianmaria De Tommasi



tutor signature

Co-Tutor: prof. Stefania Santini

Date: October 25, 2022

1. Information:

- **PhD student: Carlo Motta**
- **PhD Cycle:XXXVI**
- **DR number: DR995143**
- **Date of birth:25/03/1996**
- **Master Science degree: Automation Engineering**
- **University: University of Naples Federico II**
- **Scholarship type: UNINA**
- **Tutor: Prof. Gianmaria De Tommasi**
- **Co-tutor: Prof. Stefania Santini**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Complexity and the City: transitioning towards the smart cities of the future	Seminar	1.5	0.3	23/11/2021	Prof. Luis Bettncourt	N
Graphons: A Tool for the Analysis of Systems on Larger Networks	Seminar	1.5	0.3	25/11/2021	Prof. Paolo Frasca	Y
Data-Driven methods in engineering -Part I	Seminar	2	0.4	29/11/2021	Prof. Riccardo Vinuesa	Y
Hyperuniform States of Matter and Their Novel Transport Properties	Seminar	1.5	0.3	02/12/2021	Prof. Salvatore Torquato	Y
Data-Driven methods in engineering -Part II	Seminar	2	0.4	03/12/2021	Prof. Riccardo Vinuesa	Y
Data-Driven methods in engineering -Part III	Seminar	2	0.4	06/12/2021	Prof. Riccardo Vinuesa	Y

Advanced Controls Test Bed for Evaluation of Rule-Based, Model Predictive, and Reinforcement Learning Building Control	**Seminar**	**1.5**	**0.3**	**09/12/2021**	**Prof. Gregor P. Henze**	**Y**
Structure Process and Dynamics of Networks with higher Order Interaction	**Seminar**	**1.5**	**0.3**	**09/12/2021**	**Prof. Stefano Boccoletti**	**Y**
Data-Driven methods in engineering -Part IV	**Seminar**	**2**	**0.4**	**13/12/2021**	**Prof. Riccardo Vinuesa**	**Y**
Social Network Dynamics Leading to Community Formation and Residential Segregation	**Seminar**	**1.5**	**0.3**	**16/12/2021**	**Prof. Massimo Francesch etti**	**Y**
Data-Driven methods in engineering -Part V	**Seminar**	**2**	**0.4**	**17/12/2021**	**Prof. Riccardo Vinuesa**	**Y**
Turbulent dynamics in viscous fluids: a complex phenomenon ubiquitous in nature	**Seminar**	**1.5**	**0.3**	**18/11/2021**	**Prof. Vincenzo Carbone**	**Y**
Climate Meets Complexity: Exploring predictability of extreme climate events via complex network approach	**Seminar**	**1.5**	**0.3**	**13/01/2022**	**Prof. Jürgen Kurths**	**Y**
The Challenge of Gravitational Wave Detectors of the 3rd Generation. Cultural and Technological Aspects	**Seminar**	**1.5**	**0.3**	**20/01/2022**	**Prof. Ettore Majorana**	**Y**
Enlightening the Universe with High-	**Seminar**	**1.5**	**0.3**	**10/02/2022**	**Prof. Marco**	**Y**

Energy Cosmic Neutrinos					**Chianese**	
Matrix Analysis for Signal Processing with MATLAB	**Course**	**8**	**2**	**22-23/03/2022 5-7/04/2022**	**Prof. Vincenzo Carotenuto**	**Y**
Using Delays for Control	**Seminar**	**1**	**0.2**	**21/04/2022**	**Prof. Emilia Fridman**	**Y**
Using Delays for Control	**Seminar**	**1**	**0.2**	**28/04/2022**	**Prof. Emilia Fridman**	**Y**
Big Data Architecture and Analytics	**Course**	**16**	**5**	**6-29/04/2022 6-11/05/2022**	**Prof. Giancarlo Sperlì**	**Y**
Operational Research: Mathematical Modelling, Methods and Software Tools for Optimization Problems	**Course**	**10**	**4**	**14-28/09/2022 - 05-12/10/2022**	**Prof. Adriano Masone**	**Y**

1) Choose: Y or N

2.1. Study and training activities - credits earned

	Courses	Seminars	Research	Tutorship	Total
Bimonth 1	**0**	**4.1**	**5.9**	**0**	**10**
Bimonth 2	**0**	**0.9**	**9.1**	**0**	**10**
Bimonth 3	**2**	**0.4**	**7.6**	**0**	**10**
Bimonth 4	**0**	**0**	**8**	**0**	**8**
Bimonth 5	**5**	**0**	**7**	**0**	**12**
Bimonth 6	**4**	**0**	**6**	**0**	**10**
Total	**11**	**5.4**	**43.6**	**0**	**60**
Expected	**30 - 70**	**10 - 30**	**80 - 140**	**0 – 4.8**	

3. Research activity:

The focus for this year's research has been the study of cyber-physical systems and the related attacks in the framework of Discrete Event Systems (DES). Indeed, in a distributed system, information leaks and deceptions represent a threat to the privacy and security of the system itself, since they may enable external cyber attackers to infer information about the system state, and consequently, interact in a malicious way with safety-critical functions. The objective was finding resilient control systems able to make those cyber-physical systems robust to external attacks which can either be active or passive. When dealing with active attacks, the attacker can corrupt some parts of the systems such as actuators or sensors while trying to inflict damage on the system; on the other hand, passive attacks tend to violate the privacy or confidentiality by learning secrets about the system. We decided to approach those attacks on a high level, the so-called supervisory level, in

which the whole Cyber-Physical System (CPS) is modeled as a DES.
To this aim we started dealing with passive attacks by studying two main information-flow concepts which have already been widely used to characterize privacy when the CPSs are modelled at the DES level: opacity[2] and non-interference[3] security properties. In an opaque system, a user with full knowledge of the model, but with partial capabilities about the observation of the event occurrences cannot infer any secret, no matter for how long the system dynamic is partially observed. Supervisory control can be used to enforce opacity by restricting the closed-loop behavior in presence of controllable events[4]. We dealt with Initial State Opaque (ISO) in DESs. A DES is said to be ISO if, for every trajectory originating from a secret state, there exists another trajectory originated from a non-secret state, such that both are equivalent from an external, potentially malicious, observer's point of view. We introduced a sufficient condition to conclude if a DES modeled as a Petri Net system is not ISO. Such a condition is based on the solution of optimization problems in the form of Integer Linear Programming (ILP) problems. A system can be designed so that it fulfills the opacity property; therefore, at design-time, it is possible to check the opacity property and enforce it if not fulfilled.
As for non-interference, the users that can interact with the system belongs to different domains. The simplest notions of non-interference refer just to two domains: high-level and low-level[5]. It is assumed that both high-level and low-level users know the system model, but they interact with it with two different views. A leak of information occurs when a low-level user, which is the intruder, obtains information meant to be visible only to the high-level ones.
We dealt with two specific non-interference concepts, namely Strong Non-Deterministic Non-Interference (SNNI) and Bisimulation SNNI (BSNNI); when talking about SNNI, we refer to the net's property of preventing an intruder from infer the occurrence of any secret modeled as highlevel
event, which cannot be directly observed by the intruder; when talking about BSNNI, the objective extends to avoiding the detection of the disabling of the high-level events. Similarly to what has been done for opacity, we proposed some conditions based on the solution of ILP problems to check both SNNI and BSNNI. In the case of non-interference, the proposed conditions turn out to be necessary and sufficient. Moreover, also in this case, the proposed results can be exploited offline during the system design phase.

As for the active attacks we have applied some pre-existing theory to guarantee safety when it comes to Intelligent Transportation Systems (ITS), more specifically we have been focusing on multiple autonomous vehicles crossing an unsignalized intersection. The first step for this topic has been finding and editing a realistic model for the plant and the attacker and building up a software, through the usage of Matlab, able to imitate their behavior in different scenarios. Next in progress we are conducting tests to find resilient supervisors, confront them and expose their flaws. Apart from cyber-attacks the system could be subject to delays (both communication and actuation), therefore we wanted to make sure that regardless their presence, the supervisor is always able to direct the plant in a safe manner.

Last but not least we have been studying the with Safety Of The Intended Functionality (SOTIF) when it comes to platoons of autonomous vehicles. The general idea is to design a robust non-fragile fault tolerant control (RNFTC) strategy reduction method for ensuring SOTIF of CACC with

system uncertainty, multisource disturbances, and controller perturbations. To do so an intermediate based robust estimation method is proposed to estimate the performance limitations of perception and actuation, system states, and matched disturbances, simultaneously. Then we can withdraw the problem in terms of linear matrix inequalities (LMIs). The requirements for CACC system stability, robustness, nonfragile and H_ performances under the proposed RNFTC are analyzed using Lyapunov theory.

4. Research products:

Francesco Basile; Gianmaria. De Tommasi; Carlo Motta; Alberto Petrillo; Stefania Santini
30th Mediterranean Conference on Control and Automation (MED)
"Assessment of Initial-State-Opacity in Live Bounded and Reversible Discrete Event Systems via Integer Linear Programming"
3rd place as "Best Paper Award" at MED conference
Publish date: 28/06/2022

Francesco Basile; Gianmaria. De Tommasi; Carlo Motta; Claudio Sterle
IEEE Control System Letters
"Necessary and Sufficient Condition to Assess Initial-State-Opacity in Live Bounded and Reversible Discrete Event Systems"
Publish date: 05/11/2022.

Renato Brancati; Giandomenico Di Massa; Carlo Motta; Stefano Pagano; Alberto Petrillo; Stefania Santini
The International Conference of IFToMM ITALY
"A Test Rig for Experimental Investigation on a MRE Vibration Isolator"
2nd place as Best Application Paper Award
Publish date: 2022.

Gianmaria. De Tommasi; Carlo Motta; Alberto Petrillo; Stefania Santini
IEEE International Conference on Networking, Sensing and Control (ICNSC) 2022
"Design of Resilient Supervisory Control for Autonomous Connected Vehicles Approaching Unsignalized Intersection in presence of Communication Delays"
Accepted for publication

Angelo Coppole; Gianmaria. De Tommasi; Carlo Motta; Alberto Petrillo; Stefania Santini
Yet to be accepted
"Double-Layer Control Architecture for Motion and Torque Optimisation of Autonomous Electric Vehicles"

5. Conferences and seminars attended

***MED** - THE 30TH MEDITERRANEAN CONFERENCE ON CONTROL AND AUTOMATION*
Athens (Greece) 28/06/2022-01/07/2022
***Presented Paper:** "Assessment of Initial-State-Opacity in Live Bounded and Reversible Discrete Event Systems via Integer Linear Programming"*

6. Periods abroad and/or in international research institutions

18/10/2022-18/06/2022 at Swinburne University of Technology (SUT) with Prof. Xiaohua Ge

I am dealing with Safety Of The Intended Functionality (SOTIF) when it comes to platoons of connected autonomous vehicles.

7. Tutorship

8. Plan for year three

While the majority of the third year will be spent abroad (18/10/2022—18/06/2023) dealing with Safety Of The Intended Functionality (SOTIF) problems when it comes to platoons of vehicles subject to multiple kinds of uncertainties and disturbances (such as performance limitation of the radar sensor, system uncertainty, actuation uncertainty), I will still be conducting research on passive cyber-attacks in a discrete event systems fashion. Multiple articles on case studies will be presented in the upcoming months showing how to design supervisors to cyber physical that are resilient to cyber-attacks and delays in communication and actuation. On the other hand, we intend to formulate some theorems to demonstrate the resilience of systems, presented as Petri Nets, to passive cyber-attacks. Studies on that topic are about to be concluded as this will be the main topic for my thesis work. Regarding the SOTIF theory our intent is to produce an output research paper by the end of the year in collaboration with professor Xiaohua Ge from Swinburne University of Technology (SUT), and progressively stress the problem and enforce the withdrawn solution.