UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

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

Activities and Publications Report

PhD Student: Giacomo Basile

Student DR number: DR995857

PhD Cycle: XXXVII
PhD Cycle Chairman: Prof. Stefano Russo

PhD program student's start date: 01/11/2021
PhD program student's end date: 31/10/2024

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PhD scholarship funding entity: INAF

General information

Giacomo Basile received the M.S. Degree in Automation Engineering from the University of Naples Federico II in 2020 with a thesis based on the development of AI controller to stabilize a ultrasonic missile. He is now a PhD Student in Information Technology and Electrical Engineering, Cycle: XXXVII. His research interests include Artificial Intelligence controller in autonomous drive field and adaptive optics system along with tracking control system for Very Large Telescope (VLT), Extremely Large Telescope (ELT) and Telescopio Nazionale Galileo (TNG) in collaboration with observatory of Naples Capodimonte.

Study activities

Attended Courses

Year	Course Title	Type	Credits	Lecturer	Organization
1st	Big Data Architecture and Analytics	PhD Course	20	Prof. Giancarlo Sperlì	Unina
1st	Operational Research: Mathematical Modelling, Methods and Software Tools for Optimization Problems	PhD Course	10	Prof. Adriano Masone	Unina
1nd	Sustainable Ship For Tue Energy Transitions of Maritime Transport	PhD Course	10	Prof. Ing. Tommaso Coppola	Unina
1rd	Machine Learning for Science and Engineering Research	PhD Course	20	Proff. A. Corazza, F. Isgrò, R. Prevete, C. Sansone, G. Pezzulo	Unina
1st	Matrix Analysis for Signal Processing with Matlab	PhD Course	8	Proff. Antonio De Maio, Augusto Aubry, Dr. Vincenzo Carotenuto	Unina
2st	Academic Entreprenuership	Phd Course	18	Prof. Pierluigi Rippa	Unina
2nd	Information systems and business intelligence	Phd Course	40	Prof. Flora Amato	Unina

Attended PhD Schools

Year	School title	Location	Credits	Dates	Organization
2st	EECI: "Nonlinear and data-driven model predictive control".	Parigi	4	06-10/03/2023	EECI

Attended Seminars

Year	Seminar Title	Credits	Lecturer	Lecturer affiliation	Organization
1st	Complexity and the City: transitioning towards the smart cities of the future	0.3	Prof. Luis Bettencourt	University of Chicago	23/11/2021
1st	Graphos: a tool for the analysis of system on large networks	0.3	Prof. Paolo Fransca		24/11/2021
1st	Data-Driven methods in engineering - Part I	0.4	Prof. Alessandro Talamelli	Unibo	29/11/2021
1st	Hyperunifrom States of Matter and Their Novel Transport Properties	0.3	Prof. Salvatore Torquato	Princeton University	02/12/2021
1st	Data-Driven methods in engineering - Part II	0.4	Prof. Alessandro Talamelli	Unibo	03/12/2021
1st	Advanced Controls Test bed for evaluation of rule-based, model predictive, and reinforcement learning building control	0.3	Prof. Gregor P.Henze	University of Colorado Boulder	09/12/2021
1st	Structure Process and Dynamics of Networks with higher Order Interaction	0.3	Prof. Stefano Boccaletti	CNR	09/12/2021
1st	Data-Driven methods for engineering – Part III	0.4	Prof. Alessandro Talamelli	Unibo	06/12/2021
1st	Data-Driven methods for engineering – Part IV	0.4	Prof. Alessandro Talamelli	Unibo	13/12/2021
1st	Social Network Dynamics leading to community formation and residential segregation	0.3	Prof. Massimo Franceschetti	Unibo	16/12/2021
1st	Data-Driven methods for engineering – Part V	0.4	Prof. Alessandro Talamelli	Unibo	17/12/2021
1st	Turbulent dynamics in viscous fluids: a complex phenomenon ubiquitous in nature	0.3	Prof. Vincenzo Carbone	Unical	18/11/2021
1st	Climate meets complexity: exploring predictability of extreme climate events via complex	0.3	Prof. Jürgen Kurths	Humboldt University	13/01/2022
1st	The Challenge of gravitational wave detectors of the 3rd generation.	0.3	Prof. Ettore Majorana	Sapienza	20/01/2022

	Cultural and technological aspects				
1st	The Quest of Quantum advantage a photonics platform	0.3	Prof. Fabio Sciarrino	Sapienza	03/02/2022
1st	Using Delay for Control – Part I	0.2	Prof. Emilia Fridman	Tel Aviv University	
1st	Using Delay for Control – Part II	0.2	Prof. Emilia Fridman	Tel Aviv University	
2st	Complex Networks Systems: Introduction and open challenges	0.3	Prof. Pietro De Lellis	Unina	17/11/2022
2st	Durability of Fuel Cell Systems	0.3	Doc. Elodie Pahon	FEMTO-ST	30/11/2022
2st	Ginger, Gyroscpoes in general relativity	0.3	Prof. Angeladi Virgilio	INFN	01/12/2022
2st	Back and forth between the infinite and the finite: a numerical view of time delay systems	0.3	Prof. Dimitri Breda	University of Udine	01/12/2022
2st	Progettazione di strategie di controllo in ambiente Simulink	0.6	Ing. Gianfranco Fiore	Matworks	03/12/2022
2st	Digital Forensics	0.4	Prof. Vladimir Kurdin		06/12/2022
2st	Threat Hunting & Incident Response	0.4	Prof. Vladimir Kurdin		13/12/2022
2st	From Cyber Situational Awareness to adaptive cyber defense: levelling the cyber playing filed	0.4	Prof. M. Albanese	INGM	13/12/2022
2st	Entangled Relativity	0.4	Prof. Oliver Minazzoli	Observatoire de la Côte d'Azur	15/12/2022
2st	Industry 4.0 Fundamental in Bosh Applications.	2	Ing. Bruni Martino	Bosh	23-26/01/2023
2st	Some free boundary problems in thermal insulation.	0.3	Prof. Carlo Nitsh	Unina	26/01/2023
2st	Multi-robot Control of Heterogeneous Herds	0.3	Prof. Eduardo Montijano	Universidad de Zaragoza	16/02/2023
2st	Discrete De Giorgi Theory: Analysis and Applications	0.3	Prof. Endre Suli	University of Oxford	24/02/2023

2st	Analysis and control of functional brain networks	0.3	Prof. Fabio Pasqualetti	UC Riverside	09/03/2023
2st	Quantum gravity or shaking the foundations of physics and cosmology	0.3	Prof. Daniele Oriti	Universidad Complutense de Madrid	23/03/2023
2st	Phenomenology of Planck-scale Physics	0.3	Prof. Giulia Gubitosi	Unina	30/03/2023
2st	Some advances in isogeometric analysis of coupled and complex problems	0.3	Prof. Alessandro Reali	University of Pavia	13/04/2023
2st	Atomistic and Mesoscopic Modeling of Structure - Property Relations in Polymers	0.3	Prof. Doros N. Theodorou	National Technical University of Athens	20/04/2023
2st	When quantum systems source gravity: how can we do physics without spacetime?	0.3	Doc. Flaminia Giacomini	ETH Zurich	27/04/2023
2st	Asymptotic Stability and Gamma-Stability of Linear Time Invariant Time Delays Systems (LTI-TDS) - Leveraging algebraic tools for analytical results.	0.3	Prof. Rifat Sipahi	Northeastern University	26/05/2023

Research activities

During my first years the following activity have been carried out:

- ELT project: during the first year, through the INAF, I attended to the ELT program, which aims to design and deploy a new extremely large telescope with the main mirror of almost 40m of diameter. In detail, my main role was the development of the Telemetry module and skeleton program of the adaptive optics control loops of the instrument called MAORY. Within this framework, I focus my study on the confidential technical report which have been reported in the following article [1], [2], [3]. During the study of the technical report I could learn how an adaptive optics control system works and is implemented in a scientific instrument.
- Reinforcement Learning: during my first year I focused my sturdies on the acquisition of the knowledge and skills regarding the new Reinforcement and Deep Reinforcement learning (RL/DRL)-based control strategy. In detail, I spent the first months in study the following article [4], [5], [6], [7], where I learned the difference between the different Reinforcement learning algorithms are adopted. Hence, I used this knowledge to design advanced RL-based control strategies for solving automotive control problem such as the cooperative adaptive cruise control for the virtual coupling control problem considering heterogenous high-speed train [8]. Another products carried out by this studied is reported in [9], where, the

Reinforcement learning has been adopted to deal the fault sensor measurement for an autonomous vehicle driving on a race track.

Besides, during my second years the following activity have been carried out:

- TNG project: Nowadays, INAF, with the ESO research group, not only design and deploy new advanced telescopes such as the one in commissioning with the project ELT, but it requests the update of the old telescopes in oreder to improve their performance. Within this framework, I attended to the update project of the *"Telescopio Nazionale Galileo"* (TNG) located in las Palmas, Gran Canarias. The project aims to improve the axes motion control performance allowing the tracking, hence, to study of other celestial bodies which are used to studied by leveraging more sophisticate ESO's telescope such as the VLTs. The last update of the TNG has been implemented and reported in the 2000 [10]. To this end, by studying the current axes control loop and based advanced control strategy reported in the following books [11], [12], several new control algorithms for the axes control have been investigated. Specifically, before the investigation, designing of the new advanced control strategy, the identification of the telescope's dynamical behavior is carried out on real measurements by exploiting the identification strategy reported in [11]. Then, based on the control strategy reported in [12], i.e. an optimal double control loop, an Linear Quadratic Gaussian with Proportional and Integral action is designed in order to improve the tracking performance. The results obtained are still in proceeding to be published. Otherwise, more advanced control strategy, such as Model Predictive Controller and Deep Reinforcement Learning (DRL) based control strategies, will be investigated during the next year in order to deal with exogenous factor (wind disturbance) and model uncertainties [13].
- ELT project: during the first year, the preparation of the control loop for the adaptive optics system for the ELT program, especially, the Telemetry module has been deployed and test. During the second years, the focus has been the well manage of the measurement, rejecting as much as possible the measurement noise, while, on the other hand, the elaboration of the measurement data, preparing it for the control loop, has been deployed.
- Hybrid control strategy study: while during my first year I focused my sturdies to acquire knowledge and skills regarding the new DRL-based control strategy. During the second year, my focus was to study and understand the main challenges of the optimal control algorithm such as the MPC to combining the DRL approaches with this latter. Within this framework, I attended the ITEE EECI Phd school on the nonlinear and data driven MPC, where I could study and acquired the skills for the design and implementation of the optimal controller reported in [13], [14], [15].

Finally, during my third year the following research activities have been carried out:

- TNG project: By spending my period abroad at the research center of the TNG, i.e. Fundacion Galileo Galilei, I could test and validate the results carried out during the previous year. Specifically, firstly we have deeply validated the identified predictor model exploited for the designing of the Model-based optimal control architecture in [16] and the MPC-based control architecture in [17].

- Hydrid control strategy: based on the skills obtained during my second year, I could designed an hydrid MPC control which combine the advantages of the MPC combined with a neural network based predictor model, i.e. LSTM [18].
- Sustainable control for AEV: I could apply the DRL approaches studied during the last two years. Specifically, I could demonstrate, via an advanced Matlab&Simulink simulation platform, the advantages of the DDPG control approach, studied during the last year, in solving the tracking control problem for autonomous electric vehicle (AEV) in a sustainable manner [19].

References:

[1] Ciliegi, P., Agapito, G., Aliverti, M., Annibali, F., Arcidiacono, C., Azzaroli, N., ... & Xompero, M. (2022). MAORY/MORFEO at ELT: general overview up to the preliminary design and a look towards the final design. *Adaptive Optics Systems VIII*, *12185*, 325-334.

[2] Rigaut, F., McDermid, R., Cresci, G., Agapito, G., Aliverti, M., Antoniucci, S., ... & Arsenault, R. (2021). MAVIS on the VLT: A Powerful, Synergistic ELT Complement in the Visible. *The Messenger*, *185*, 7-11.

[3] Baruffolo, A., Baronchelli, I., Savarese, S., Lampitelli, S., Foppiani, I., Capasso, G., ... & Ciliegi, P. (2022, August). MORFEO at ELT: preliminary design of the real-time computer. In *Adaptive Optics Systems VIII* (Vol. 12185, pp. 1719-1727). SPIE.

[4] Sutton, R. S., & Barto, A. G. (2018). *Reinforcement learning: An introduction*. MIT press.

[5] Lillicrap, T. P., Hunt, J. J., Pritzel, A., Heess, N., Erez, T., Tassa, Y., ... & Wierstra, D. (2015). Continuous control with deep reinforcement learning. *arXiv preprint arXiv:1509.02971*.

[6] Iqbal, S., & Sha, F. (2019, May). Actor-attention-critic for multi-agent reinforcement learning. In *International conference on machine learning* (pp. 2961-2970). PMLR.

[7] Kiran, B. R., Sobh, I., Talpaert, V., Mannion, P., Al Sallab, A. A., Yogamani, S., & Pérez, P. (2021). Deep reinforcement learning for autonomous driving: A survey. *IEEE Transactions on Intelligent Transportation Systems*, *23*(6), 4909-4926.

[8] Basile, G., Lui, D. G., Petrillo, A., & Santini, S. (2022, December). Deep deterministic policy gradient-based virtual coupling control for high-speed train convoys. In 2022 IEEE International Conference on Networking, Sensing and Control (ICNSC) (pp. 1-6). IEEE.

[9] Basile, G., Petrillo, A., & Santini, S. (2022, October). Ddpg based end-to-end driving enhanced with safe anomaly detection functionality for autonomous vehicles. In 2022 IEEE International Conference on Metrology for Extended Reality, Artificial Intelligence and Neural Engineering (MetroXRAINE) (pp. 248-253). IEEE.

[10] Mancini, D., & Schipani, P. (2000, June). Tracking performance of the TNG Telescope. In Advanced Telescope and Instrumentation Control Software (Vol. 4009, pp. 355-365). SPIE.

[11] Gawronski, W. K. (Ed.). (2004). Advanced structural dynamics and active control of structures. New York, NY: Springer New York.

[12] Gawronski, W. K. (2008). Modeling and control of antennas and telescopes (p. 43). Berlin, Germany: Springer.

[13] Allgöwer, F., & Zheng, A. (Eds.). (2012). Nonlinear model predictive control (Vol. 26). Birkhäuser.

[14] Chen, H., & Allgöwer, F. (1998). A quasi-infinite horizon nonlinear model predictive control scheme with guaranteed stability. Automatica, 34(10), 1205-1217.

[15] Berberich, J., Köhler, J., Müller, M. A., & Allgöwer, F. (2022, December). Stability in data-driven MPC: an inherent robustness perspective. In 2022 IEEE 61st Conference on Decision and Control (CDC) (pp. 1105-1110). IEEE.

[16] Basile, G., Gonzalez, M., Petrillo, A., Santini, S., Savarese, S., & Schipani, P. (2024, August). Model-based optimal tracking control architecture for ground-based telescopes. In *Ground-based and Airborne Telescopes X* (Vol. 13094, pp. 1432-1443). SPIE.

[17] Basile, G., Gonzalez, M., Petrillo, A., Santini, S., Savarese, S., & Schipani, P. (2024, August). Model Predictive Star Tracking Control for Ground-Based Telescopes: the Telescopio Nazionale Galileo Case. Journal of Astronomical Telescope, Instruments, and Systems. SPIE. **(under review).**

[18] Basile, G., Lui, D.G., Napoletano, E., Petrillo, A., &Santini, S. (2024, August). LSTM-based predictive control for cooperative driving of connected vehicles. Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles (ESARS) and International Transportation Electrification Conference (ITEC). IEEE. **(accepted)**

[19] Basile, G., Leccese, S., Petrillo, A., Rizzo, R., & Santini, S. (2024). Sustainable DDPG-based Path Tracking For Connected Autonomous Electric Vehicles in extra-urban scenarios. *IEEE Transactions on Industry Applications*.

Tutoring and supplementary teaching activities
N/A

Research periods in institutions abroad and/or in companies

PhD Year	Institution / Company	Hosting tutor	Period	Activities
3rd	INAF - FGG	Manuel Gonzalez	22-Feb./20-Aug.	On-field experiment on the Telescopio Nazionale Galileo

PhD Thesis

In the PhD Thesis, Giacomo Basile face the tracking control problem for ground-based telescope. Specifically, in the thesis he presents the methodology, the designing and the results obtained via the proposed solution in [1] and [2]. Then, since the proposed solution are tailored fo the Telescopio Nazionale Galielo (TNG), finally, it describes the started iter for the testing and validation of the solutions on the TNG.

Reference:

1. Basile, G., Gonzalez, M., Petrillo, A., Santini, S., Savarese, S., & Schipani, P. (2024, August). Model-based optimal tracking control architecture for ground-based telescopes. In *Ground-based and Airborne Telescopes X* (Vol. 13094, pp. 1432-1443). SPIE.

2. Basile, G., Gonzalez, M., Petrillo, A., Santini, S., Savarese, S., & Schipani, P. (2024, August). Model Predictive Star Tracking Control for Ground-Based Telescopes: the Telescopio Nazionale Galileo Case. Journal of Astronomical Telescope, Instruments, and Systems. SPIE. **(submitted).**

Research products

List of scientific publications

International journal papers

G. Basile, M. Gonzalez, A. Petrillo, S. Santini, S. Savarese, P. Schipani,

Model Predictive Star Tracking Control for Ground-Based Telescopes: the Telescopio Nazionale Galileo Case, Journal of Astronomical Telescopes, Instruments, and Systems,

SPIE. **(under-review 2024).**

G. Basile, D. G. Lui, A. Petrillo, S. Santini,

Deep Deterministic Policy Gradient Virtual Coupling control for the coordination and manoeuvring of heterogeneous uncertain nonlinear High-Speed Trains,

Engineering Applications of Artificial Intelligence,

Vol. 133, 2024, 108120, DOI: 10.1016/j.engappai.2024.108120.

G. Basile, S. Leccese, A. Petrillo, R. Rizzo, S. Santini,

Sustainable DDPG-based Path Tracking For Connected Autonomous Electric Vehicles in extra-urban scenarios,

IEEE Transactions on Industry Applications,

pp. 1-13, 2024, DOI: 10.1109/TIA.2024.3444733.

G. Basile, E. Napoletano, A. Petrillo, S. Santini,

Roadmap and challenges for reinforcement learning control in railway virtual coupling,

Discover Artificial Intelligence,

2(1), 27, 2022, DOI: 10.1007/s44163-022-00042-4.

International conference papers

G. Basile, D.G. Lui, E., Napoletano, A. Petrillo, S. Santini,

LSTM-based predictive control for cooperative driving of connected vehicles,

Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles (ESARS) and International

Transportation Electrification Conference (ITEC),

August 2024, IEEE. **(accepted).**

G. Basile, M. Gonzalez, A. Petrillo, S. Santini, S. Savarese, P. Schipani,

Model-based optimal tracking control architecture for ground-based telescopes,

In Ground-based and Airborne Telescopes X,

Yokohama, Japan, August 2024, Vol. 13094, pp. 1432-1443, SPIE. DOI: 10.1117/12.3020102.

G. Basile, D: G. Lui, A. Petrillo, S. Santini,

Adaptive Distributed PI-like Control Protocol for the Virtual Coupling of Connected Heterogeneous Uncertain Nonlinear High-Speed Trains,
31st Mediterranean Conference on Control and Automation (MED),
Limassol, Cyprus, June 2023, pp. 674-679, IEEE. DOI: 10.1109/MED59994.2023.10185892.

G. Basile, S. Leccese, A. Petrillo, R. Rizzo, S. Santini,
Sustainable DDPG-based Path Tracking For Connected Autonomous Electric Vehicles in extra-urban scenarios,
In *2023 IEEE IAS Global Conference on Renewable Energy and Hydrogen Technologies, GlobConHT 2023*,
Maldives, March 2023, pp. 1-7. IEEE. DOI: 10.1109/GlobConHT56829.2023.10087542.

G. Basile, D. G. Lui, A. Petrillo, S. Santini,
Deep deterministic policy gradient-based virtual coupling control for high-speed train convoys,
In 2022 IEEE International Conference on Networking, Sensing and Control (ICNSC),
Shanghai, China, December 2022, pp. 1-6, IEEE, DOI: 10.1109/ICNSC55942.2022.10004067.

G. Basile, A. Petrillo, S. Santini,
Ddpg based end-to-end driving enhanced with safe anomaly detection functionality for autonomous vehicles,
In 2022 IEEE International Conference on Metrology for Extended Reality, Artificial Intelligence and Neural Engineering (MetroXRAINE),
Rome, Italy, October 2022, pp. 248-253, IEEE, DOI: 10.1109/MetroXRAINE54828.2022.9967647.

S. Savarese, P. Schipani, G. Fiorentino, L. Schreiber, G. Basile, G. Capasso, M. Colapietro, S. D'Orsi, L. Marty, F. Perrotta,
Modeling wide-field telescopes in presence of misalignments: an application to the Vera C. Rubin Observatory,
In Modeling, Systems Engineering, and Project Management for Astronomy X
Montréal, Canada, 2022, Vol. 12187, pp. 594-602, SPIE, DOI: 10.1117/12.2630248

Basile, G., Lui, D. G., Petrillo, A., & Santini, S,
Acc fuzzy-based control architecture for multi-body high-speed trains with active inter-cars couplers.
In European Dependable Computing Conference,
Zaragozza, Spain, September 2022, pp. 126-138, Cham: Springer International Publishing, DOI: 10.1007/978-3-031-16245-9_10

S. Savarese, P. Schipani, G. Capasso, M. Colapietro, S. D'Orsi, S., M. Iuzzolino, G. Basile,
Software solutions for numerical modeling of wide-field telescopes.
arXiv preprint arXiv:2112.06857. DOI: 10.58550/arXiv.2112.06857

Patents and/or spin offs

- *DAS2: Distributed Automation System Solutions (DAS2), approved by Ufficio Terza Missione e Trasferimento Tecnologico board from University of Napoli Federico II with rector decree n.200 in 2.03.2023. The business idea aims at promoting the emerging paradigms of Mobility As A Service (MAAS) and Smart and Sustainable Mobility by developing and supplying integrated validation and simulation platforms for the virtual testing of MAAS and/or driver assistance systems, as well as infrastructure control and management systems from a Smart Roads perspective.*

Awards and Prizes

N/A

Date ___11/10/2024_____

PhD student signature _____

Supervisor signature _____