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

PhD Student: Emanuele Carella

Cycle: XXXIX

Training and Research Activities Report

Academic year: 2024-25 - PhD Year: Second

Student signature:

Tutor: Prof.ssa Stefania Santini

Date: October 30, 2025

1. Information:

- **PhD student: Emanuele Carella** **PhD Cycle: XXXIX**
- **DR number: DR997208**
- **Date of birth: 23/01/1996**
- **Master Science degree: Mechatronics Engineering**
  University: Politecnico di Torino
- **Scholarship type: no scholarship**
- **Tutor: Stefania Santini ➢ Co-tutor:**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
How to boost your PhD	Courses	15	5	19/02/2025	Dr. Antigone Marino	Y
Embedded Systems	Courses	48	6	07/04/2025	Prof. Alessandro Cilardo	Y
Testing and validation of automated road vehicles	Courses	60	9	14/05/2025	Prof. Angelo Coppola	Y
Security Summit Napoli 2025	Seminar	2	0.4	23/09/2025	Clusit	Y
Guardians of Threats? AI at the Frontlines of Cybersecurity	Seminar	4	0.8	17/10/2025	5G Academy	Y
Solid State Transformers: Fundamentals, Insights and New Trends	Seminar	2	0.4	20/12/2024	Luigi Pio Di Noia	Y
Strutture basate su regole e strutture basate su approssimazioni	Seminar	1	0.2	10/12/2024	PRISCA Lab	Y
AI and Enabling Technologies for Social Robots	Seminar	1.5	0.3	03/12/2024	PRISCA Lab0	Y

Optimisation-based Control of Flexible Resources in Sustainable Energy Networks	Seminar	1	0.2	05/02/2025	Prof Luigi Glielmo	Y
The power of inhibition for collective decision making in minimalistic robot swarms	Seminar	1	0.2	14/11/2024	Scuola Superiore Meridionale	Y
Dynamic Risk Assessment in Industrial Applications: Leveraging Bayesian Inference for Enhanced Decision-Making	Seminar	1	0.2	04/03/2025	Dr. Simone Guarino	Y
Safety Assessment for Autonomous vehicles: Approaches and Challenges	Seminar	1.5	0.3	24/03/2025	Università degli Studi di Napoli “Federico II” Prof. S. Russo	Y
Robot Autonomy among Decision-Making Agents	Seminar	1	0.2	15/04/2025	Fabio Ruggiero	Y
Trusted Execution Environments for QPUs	Seminar	1	0.2	27/06/2025	Prof. Edoardo Giusti	Y
IEE ITSS Italian Chapter Annual Meeting and PhD Award 2025	Seminar	5	1	10/07/2025	IEEE ITSS Italian Chapter	Y
Optimization in Transportation and Logistics	Seminar	1	0.2	16/10/2025	Prof. Maurizio Boccia	Y
Local Explainability in Machine Learning: A collective framework	Seminar	1	0.2	16/10/2025	Prof. Maurizio Boccia	Y
Quality of services	Seminar	4	0.8	28/10/2025	5G Academy	Y

1) Courses, Seminar, Doctoral School, Research, Tutorship
2) Choose: Y or N

2.1. Study and training activities - credits earned

	Courses	Seminars	Research	Tutorship	Total
Bimonth 1	0	1.1	8.9	0	10
Bimonth 2	5	0.4	4.6	0	10
Bimonth 3	6	0.9	3.1	0	10
Bimonth 4	9	1.1	0	0	10.1
Bimonth 5	0	1	9	0	10
Bimonth 6	0	2.4	7.4	0	10
Total	20	6.9	39.9	0	
Expected	30 - 70	10 - 30	80 - 140	0 – 4.8	

3. Research activity:

Some of the most significant technological breakthroughs in vehicle transportation are represented by the development of advanced driver assistance systems (ADAS) and Vehicle-to-Everything (V2X) communication.

One of the most widely adopted ADAS services is Adaptive Cruise Control (ACC), which enables a vehicle to follow a leading vehicle at a predetermined distance by exploiting onboard sensors such as radar and LiDAR. ACC is a mature technology, so that is classified as level 2 of the SAE's LOAD (Levels of Automation).

Despite its maturity, ACC faces limitations in maintaining consistent time headway while avoiding rear-end collisions during sudden traffic fluctuations, known as the shockwave effect (1). Indeed, sudden braking by one vehicle propagates through the traffic flow, often leading to abrupt speed adjustments and potential string instability. Moreover, traffic with medium-to-high ACC penetration is more susceptible to self-organized phantom traffic jams.

To address these issues, Cooperative Adaptive Cruise Control (CACC) has been introduced. It exploits V2X communication, by which vehicles share information on position, speed, and acceleration, that are combined with local sensor data in order to optimize longitudinal control. CACC has demonstrated significant benefits in terms of shockwave attenuation (2), platooning stability (3), and congestion mitigation (4).

My research focuses on the microscopic level of traffic dynamics, where the behaviour of individual vehicles is explicitly modelled and controlled, and mesoscopic level, where the relationship between the CAV is handled to mitigate the actual congestion (5). In this context, congestion awareness is incorporated directly into the vehicle's local control algorithm, enabling each unit to recognize and react to emerging traffic disturbances in real time. This approach requires fast and precise computation of control actions to optimize longitudinal behaviour under system constraints, in parallel observing and detecting traffic congestion.

From a control perspective, implementing CACC with Model Predictive Control (MPC) introduces substantial computational challenges. MPC optimizes control actions under system constraints and multi-vehicle interactions, balancing safety, comfort, and efficiency. However, its computational complexity grows with the number of vehicles, prediction horizon, and system nonlinearities, posing a significant challenge for real-time implementation (6).

To overcome this limitation, this work proposes a hardware-accelerated control framework, where the most computationally intensive components of the MPC algorithm are offloaded to dedicated hardware (7). This approach significantly reduces execution time while preserving accuracy and robustness, enabling real-time operation even in complex multi-vehicle scenarios.

Finally, this framework also provides a foundation for extending MPC to nonlinear formulations, which are necessary to capture full vehicle dynamics under extreme or safety-critical conditions. Hardware acceleration is essential to ensure real-time feasibility, enabling the deployment of advanced predictive controllers in next-generation automated driving systems where both performance and safety are paramount.

Reference

1. *Impact of Intelligent Cruise Control on Motorway Capacity.* **Bovy, Michiel M. Minderhoud and Piet H. L.** 1999, Transportation Research Record.

2. *Cooperative Shock Waves Mitigation in Mixed Traffic Flow Environment.* **Di Vaio, Marco and Fiengo, Giovanni and Petrillo, Alberto and Salvi, Alessandro and Santini, Stefania and Tufo, Manuela.** 12, 2019, Vol. 20.

3. *Distributed Model Predictive Control Algorithm with Time-Varying Communication Delays for a CACC Vehicle Platoon.* **Maxim, Anca and Pauca, Ovidiu and Caruntu, Constantin F. and Lazar, Corneliu.** 2020. {2020 24th International Conference on System Theory, Control and Computing (ICSTCC).

4. *Mitigation of self-organized traffic jams using cooperative adaptive cruise control.* **Kim, Taehooie and Jerath, Kshitij.** 2016 International Conference on Connected Vehicles and Expo (ICCVE).

5. **Martin Treiber, Arne Kesting.** *Traffic flow dynamics.* s.l. : Springer, 2013.

6. *A Review of Model Predictive Controls Applied to Advanced Driver-Assistance Systems.* **{Musa, Alessia and Pipicelli, Michele and Spano, Matteo and Tufano, Francesco and De Nola, Francesco and Di Blasio, Gabriele and Gimelli, Alfredo and Misul, Daniela Anna and Toscano, Gianluca.** 2021, Energies.

7. *Fast Constrained Generalized Predictive Control with ADMM Embedded in an FPGA.* **Peccin, Vinícius Berndsen and Lima, Daniel Martins and Flesch, Rodolfo César Costa and Normey-Rico, Julio Elias.** 2020, IEEE Latin America Transactions.

4. Research products:

5. Conferences and seminars attended

6. Periods abroad and/or in international research institutions

7. Tutorship

8. Plan for year three

- Extension to nonlinear/adaptive MPC formulations and Scalable Cooperative Control Architectures as distributed/hierarchical multi-agent control
- Modeling and incorporation of Communication Uncertainty like communication delays, packet losses, and asynchronous updates within the control framework.
- Explore the integration of neural networks/machine learning models to complement the predictive control framework.