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

PhD Student: Nicola Albarella

Cycle: XXXV

Training and Research Activities Report

Academic year: 2020-21 - PhD Year: Second

Tutor: prof. Stefania Santini

Date: October 21, 2021

1. Information:

- **PhD student:** **Nicola Albarella** **PhD Cycle:XXXV**
- **DR number:** **DR993892**
- **Date of birth:** **20/07/1993**
- **Master Science degree:** **Automation Engineering** **University:** **Federico II**
- **Scholarship type: funded by Kineton s.r.l.**
- **Tutor: prof. Stefania Santini**
- **Co-tutor: -**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
L'esperienza del progetto di tele-riabilitazione NEUROREAB	Seminar	3	0.6	24/11/2020	Ing. D. Furno Ing. L. Romanelli	Y
Patent searching best practices with IEEE Xplore	Seminar	1	0.2	27/11/2020	ITEE	Y
GDPR basics for computer scientists	Seminar	1.5	0.3	10/12/2020	Prof. P. Bonatti	N
At the Nexus of Big Data, Machine Intelligence, and Human Cognition	Seminar	1	0.2	2/12/2020	Prof. Amato Prof. Longo	Y
Exploiting Deep Learning and Probabilistic Modeling for Behavior Analytics	Seminar	1	0.2	9/12/2020	Prof. Amato Prof. Longo	Y
Data Driven Transformation in WINDTRE through Managers voice	Seminar	2	0.4	16/12/2020	Prof. Amato Prof. Longo	Y

From Photometric Redshifts to Improved Weather Forecast an interdisciplinary view on machine learning	Seminar	1	0.2	13/01/2021	Prof. Amato Prof. Longo	Y
Cybercrime and electronic evidence, The international legal framework for an effective criminal justice response	Seminar	2	0.4	20/01/2021	Prof. Amato Prof. Longo	Y
Artificial Intelligence for notary's sector - a case study	Seminar	1	0.2	21/01/2021	Prof. Amato Prof. Longo	Y
The era of Industry 4.0: new frontiers in business model innovation	Seminar	1	0.2	03/02/2021	Prof. Amato Prof. Longo	Y
Machine Learning: causality lost in translation	Seminar	1.5	0.3	10/02/2021	Prof. Amato Prof. Longo	Y
Approaches to Graph Machine Learning	Seminar	1	0.2	17/02/2021	Prof. Amato Prof. Longo	Y
Dissecting human gliomas and their microenvironment by single-cell genomics	Seminar	1.5	0.3	21/01/2021	Prof. Ceccarelli	N
Classification and precision therapy of glioblastoma	Seminar	1	0.2	29/01/2021	Prof. Ceccarelli	N
Finding Drivers in Cancer: from Primary Cancers to Resistance	Seminar	2	0.4	08/02/2021	Prof. Ceccarelli	N

Supporting machine learning with biological knowledge to extract insight from omics data",	Seminar	2	0.4	26/02/2021	Prof. Ceccarelli	N
Control Systems for Autonomous Ground Vehicles	MSc Course	38	6	17/02/2021	Prof. Santini	Y
Visual Interaction and Communication in Data Science	Seminar	2	0.4	03/03/2021	Prof. Amato Prof. Longo	Y
Big Data and Computational Linguistics	Seminar	2	0.4	10/03/2021	Prof. Amato Prof. Longo	Y
Emotions in Reinforcement Learning Agents	Seminar	1	0.1	17/03/2021	Prof. Silvia Rossi	Y
The coming revolution of Data driven Discovery	Seminar	1.5	0.3	10/03/2021	Prof. Amato Prof. Longo	Y
Parameter Sensitivity in Time Delay System	Seminar	1	0.2	26/03/2021	Prof. Gabor Stepan	N
Elucidating and Targeting Mechanisms of Single Cell State Maintenance	Seminar	1.5	0.3	31/03/2021	Prof. Ceccarelli	N
Why do we cooperate? Understanding and Modelling Socioties using Reinforcement Learning	Seminar	1	0.2	01/04/2021	Scuola Superiore Meridionale	N
DoveAndiamoDomani - Deep Tech	Seminar	1.5	0.3	28/04/2021	Prof. Amato Prof. Longo	Y

L'avvincente storia degli acceleratori	Seminar	1.5	0.3	14/05/2021	Prof. R. Massa	N
Risk assessment in real life: experiences from the railway domain	Seminar	1.5	0.3	26/05/2021	Prof. V.Vittorini	N
Artificial Intelligence and 5G combined with holographic technology: a new perspective for remote health monitoring	Seminar	2	0.4	26/05/2021	Prof. Amato Prof. Longo	Y
Synchronization in complex networks, hypergraphs and simplicial complexes	Seminar	1	0.2	27/05/2021	Scuola Superiore Meridionale	N
5G: l'architettura le applicazioni e la rete di accesso radio	Seminar	2	0.4	08/06/2021	N. Pascquino	N
Strategic Orientation for STEM Research & Writing	Ad hoc Course	18	4	14/10/2021	ITEE	N

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**	**1.9**	**3.1**	**0**	**5**
Bimonth 2	**0**	**2.8**	**7.2**	**0**	**10**
Bimonth 3	**6**	**2.3**	**2.7**	**0**	**11**
Bimonth 4	**0**	**1.6**	**7.4**	**0**	**9**
Bimonth 5	**0**	**0**	**10**	**0**	**10**
Bimonth 6	**4**	**0**	**6**	**0**	**10**
Total	**10**	**8.6**	**36.4**	**0**	**55**
Expected	**30 - 70**	**10 - 30**	**80 - 140**	**0 – 4.8**	

3. Research activity:

- ***ADAS and Autonomous Vehicle (AV): analysis of the state of the art and state of the research.***

Carrying on the same line of research of my first Ph.D. year, I kept digging into the state of the art of

control architectures for Autonomous Ground Vehicles (AVs). Specifically, I studied advanced algorithms and architectures, such as planning strategies formulated as optimal problems, Simultaneous localization and mapping *(SLAM) techniques for localization and HD-mapping and, finally, Reinforcement Learning (RL) strategies, in order to train a vehicle in learning an optimal behavior through trial-and-error approaches. Despite their complexity, these algorithms are fundamental for the realization of AV, being the traditional ADAS architectures only limited to controlling longitudinal and lateral movements of the vehicle without a clear decision-making mechanism and basing their actions on classical model-based control strategies.*
Moreover, with the aim to extend the operation to the collaborative field and to exploit the capability of the Multi-Agent Systems (MASs) to obtain more information that are beyond the line of sight of classical on-board sensors and to overcome some issues typically of the centralized architectures (e.g. spatial distribution of actuators, limited sensing capability and short wireless communication ranges), many studies have been carried out in the last years in the field of Multi-Agent Reinforcement Learning (MARL), in which the environment is modeled as a Partially Observable Markov Decision Problem (POMDP) and the vehicle needs to consider the actions of all the agents to make a "correct" decision from the defined reward. This framework is more complex and brings further problems with respect to single-agent case, mainly related to a loss of stationarity of the environment, i.e., whatever is the vehicle choice, the new observed environment state will change depending on all the choices of all the agents. Since the classical RL approaches no longer be used, the community research is studying new algorithms able to deal with this more challenging framework. With the aim to bring this development to the automotive field, these new algorithms are currently the subject of my studies.

- ***Research on friction detection-based improvement on Anti-Lock braking systems.*** *The work carried out during my first Ph.D. year on tire-road interaction produced the work reported in [1]. Following that line of research, a similar scheme has been proposed for an improvement of Anti-Lock Braking systems (ABS) for vehicle performances maximization. The previously proposed architecture was designed to improve safety and comfort by minimizing acceleration commands, nonetheless, we noticed that with minimal changes and tuning of the Sliding Model Controller, it is possible to control wheel speed on peak adhesion, which is fundamental to minimize stopping distance, thus maximize race vehicles performances. The proposed scheme has been validated through simulation in Matlab/Simulink on a highly detailed set of ODEs, simulating both vehicle and wheels dynamics. Finally, the line of research produced the work reported in [3], in cooperation with the DII department.*

- ***Path planning and trajectory tracking for autonomous vehicle in urban scenarios.*** *Path planning and trajectory tracking are fundamental building blocks for both driving assistance and autonomous vehicle driving. This line of research involved the design and testing of a complete architecture for longitudinal and lateral control of ground vehicles in urban scenarios. First, the curvilinear reference system, known as Frenet coordinates has been considered. Here the lane central line is taken as the reference and all the information are parametrized with respect to its arc length, i.e., the curvilinear abscissa along the line. This setup is convenient because it allows a simple definition of paths and trajectories in road local coordinates, where the only needed info is the road curvature. Then a hierarchical architecture has been designed based on a double layer Nonlinear Model Predictive Controllers (NMPC). The high-level controller has the aim to replan the given reference to avoid obstacles, change lanes, smooth paths to improve comfort. The lower-level controller has the aim to*

control the vehicle in order to follow the reference obtained from the replanner. The main advantage of this hierarchical architecture lies in the fact the low-level controller can be designed considering the only ego vehicle dynamics, so it can be validated in a controlled environment. Conversely, the high-level NMPC controller has the aim to only generate a new path, so it can be designed on simpler models, such as kinematic models. Moreover, thanks to the Frenet coordinates, the replanner can use state-bound constraints instead of non-convex ones, with the advantage to avoid numerical problems and achieving higher total execution speed. To evaluate the efficiency of the proposed architecture, a simulation platform has been designed with MATLAB/Python/CARLA and Forces Pro has been used to solve the nonlinear optimization problems. Numerical simulations are carried out in order to prove how the proposed architecture is suitable for obstacle avoidance, lane following, lane changing and vehicle following, so can be considered as a legit generalization for both autonomous vehicle guidance and driving assistance with proper tuning of the parameters.

- ***Behaviour planning for highway driving through Reinforcement Learning.*** *State of art on highway driving mainly involves lane keeping and speed regulation. Still little addressed in the current literature is the study of a decision-making module able to choose when and how to perform a change lane to overtake a slower vehicle, to merge or leave the highway. Traditionally, most of the works proposed in the technical literature have been focused on model-based techniques, through a series of hand-written rules. Despite their simple design, it is not possible to list all possible scenarios and necessary rules. Therefore, recently, model-free approaches based on Deep Reinforcement Learning theory have attracted the research community, due to their capability to learn an optimal behavior from collected data and for higher performances. However, have not been yet defined a formal analysis which is mandatory for safety reasons. Furthermore, it is well-known that the main drawback of the model-free approaches lies in the large amount of data required for the training. This line of research has the focus of combining Reinforcement Learning schemes with model-based ones to combine the pros of both. We designed lower-level controllers based on hierarchical NMPC, in the same fashion as the previous line of research. Moreover, a DQN (Deep Q-Learning) algorithm has the only aim of choosing when to change the highway lane. By resorting to a simulation platform based on MATLAB and Sumo, the agent has been trained and results were comparable to the ones found in the literature. This hierarchical structure allows for faster training and improved safety performances, even though not enough for practical application. Moreover, results highlighted that algorithm based on the famous Q-learning might be not suitable for this application. Thus, investigations on different designs are being carried out and will be the focus of next year.*

4. Research products:

[1] Santini, S.; Albarella, N.; Arricale, V.M.; Brancati, R.; Sakhnevych, A. On-Board Road Friction Estimation Technique for Autonomous Driving Vehicle-Following Maneuvers. Appl. Sci. 2021, 11, 2197. https://doi.org/10.3390/app11052197 (published and indexed SCIE/Scopus)

[2] Albarella, N.; Masuccio, F.; Novella, L.; Tufo, M.; Fiengo, G. A Forward-Collision Warning System for Electric Vehicles: Experimental Validation in Virtual and Real Environment. Energies 2021, 14, 4872. https://doi.org/10.3390/en14164872 (published and indexed SCIE/Scopus)

[3] Albarella, N.; Arricale, V.M.; Maiorano, A.; Mosconi, L.; Napolitano Dell'Annunziata, G.; Rocca, E.; Improved Anti-Lock Braking System With Real-Time Friction Detection to Maximize Vehicle Performance, International Design Engineering Technical Conferences & Computers and Information in Engineering Conference 2021 (conference paper publication)

5. Conferences and seminars attended

6. Periods abroad and/or in international research institutions

7. Tutorship

8. Plan for year three

- ***AI based control for autonomous driving.*** *Following on the last line of research next year will be devote to design and test AI control techniques based on DRL and their testing by using a purposely design virtual testing platform. Indeed, according to the recent advancement in the literature, policy based RL seems to be a promising tool for the practical implementation of end-to-end driving for self-driving cars at SAE level 5. The idea is to compare a policy based RL solution to the value-based Q-learning, with the idea of solving the well-known signal-to-noise problem. Moreover, I plan to design the decision-making module on option graphs, in order to achieve higher safety. The overall architecture will be implemented and tested through virtual simulation at first in structured environments as highway, in different traffic conditions. Urban scenarios will be then investigated in a following stage, in order to understand the ability of the AI based control architecture in dealing with unstructured environments that are characterized by a wide range of different conditions depending on the presence of pedestrians, different traffic rules and a wide range of road geometries. With the final aim to address the very challenging problem of cooperative driving in unstructured environments, I will then focus on design and virtual testing of Multi-Agent Systems control leveraging MARL techniques in POMDP scenarios. This line of research will be the focus of the third year and will lead to the final thesis.*

- ***Abroad period.*** *The third year will comprise for few months (around 6 months) abroad. At the moment I am in contact with different research institutions.*