PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Angelo Coppola

XXXIV Cycle

Training and Research Activities Report – Second Year

Tutor: Stefania Santini

1. Information

   a. Angelo Coppola, MS degree in Hydraulic and Transportation Systems Engineering – University of Naples Federico II.

   b. XXXIV Cycle- ITEE – Università di Napoli Federico II.

   c. Fellowship type: “Borsa POR”.

   d. Tutor: Prof.ssa Stefania Santini.

   e. Co-Tutor: Luisa Andreone and Anita Fiorentino, FCA group

2. Study and Training activities

   a. Courses

      - “Intelligenza Artificiale” (6.0 CFU).
        Lecturer: Prof.ssa Flora Amato.
        1/04/2020-10/06/2020

   b. Ad Hoc Courses

      - “Intelligenza artificiale ed Etica: la ricerca in IA alla prova delle sfide etiche (workshop)” (1.6 CFU).
        Lecturer: Daniela Amoroso, Piero A. Bonatti, Josè M. Galvan, Riccardo Inverardi, Roberto Prevete, Luciano Serafini, Viola Schiaffonati.
        06/12/2019
      - “Safety Critical Systems for Railway Traffic Management” (3.3 CFU).
        Lecturer: Dr. Mario Barbareschi
        10/01/2020-13/01/2020-17/01/2020-20/01/2020-24/01/2020-27/01/2020.
      - “MATLAB Fundamentals” (2 CFU).
        Lecturer: Agostino De Marco and Stefano Marrone.
        16/03/2020-17/03/2020-18/03/2020-19/03/2020-20/03/2020-24/03/2020-25/03/2020-27/03/2020
      - “Innovative management, entrepreneurship and intellectual property” (5 CFU).
        Lecturer: Michele Simoni, Adele Parmentola, Francesco Izzo, Francesco Schiavone, Raffaele Fiorentino, Davide Dell’Anno, Domenico Ferrarese, Olga Capasso, Massimo Varrone, Alessandro Scaletti, Gianpiero Bruno;
        Organizer: Prof. Pierluigi Rippa (DII Unina), 05/05/2020-07/05/2020-08/05/2020-11/05/2020-21/05/2020-22/05/2020-05/06/2020-19/06/2020
      - “Model Predictive Control” (2 CFU).
        Lecturer: Prof. Alberto Bemporad
        Organizer: Prof. Alberto Bemporad, IMT School for Advanced Studies Lucca
        03/06/2020-04/06/2020-05/06/2020-08/06/2020-09/06/2020

c. Seminars

- "Lo spazio cibernetico come dominio bellico" (0.4 CFU).
  Lecturer: Dott. Gian Piero Siroli and Prof. Guglielmo Tamburrini
  15/11/2109
- "Introduction to CERN and wakefield measurements at CLEAR" (0.4 CFU).
  Lecturer: Ing. A. Gilardi and Prof. Pasquale Arpaia
  Organizer: Prof. Pasquale Arpaia, 18/11/2019
- "Deep Learning Onramp" (0.4 CFU).
  Lecturer: Ing. Stefano Marrone
  Organizer: Prof. Carlo Sansone, 21/11/2019
- "L'ingegnere nel business dell'energia" (1.0 CFU).
  Lecturer: Dott. Paolo Pietrogrande
  Organizer: Ing. Annamaria Buonomano, Dipartimento Ingegneria Industriale (DII), Università degli Studi di Napoli "Federico II", 28/11/2019
- "How to get published with the IEEE?" (0.4 CFU).
  Lecturer: Dr.ssa Eszter Lukacs
  Organizer Dr.ssa Alessandra Scippa 20/04/2020
- "Cooperation in Autonomous Vehicles" (0.2 CFU).
  IEEE online courses, 24/04/2020
- "Access the eLearning Library" (0.2 CFU).
  Lecturer: Dr.ssa Eszter Lukacs
  Organizer Dr.ssa Alessandra Scippa 04/05/2020

3. Research activity

a. Title: "C-ITS services and advanced vehicle control for complex traffic scenarios"

b. Study: Smart and autonomous system, connected vehicles, virtual vehicle simulation platform.

c. Research description

The transformation towards "Smart Roads" is underway in full harmony with the processes of governing and managing innovation in the sector in Europe, with reference to the European C-ITS Platform (Cooperative Intelligent Transport Systems; C-ITS), to the GEAR 2030 initiative and to the Smart Road Decree signed by the Italian Government in March 2018. The process involves the development and exploitation of key technologies for enabling innovative and automated driving functions and applications, as well as the design of demonstration scenarios in which automated driving functions are tested in various use cases. The main idea is to improve road safety and traffic flow, and to reduce congestion, fuel consumption and pollutant emissions.
New C-ITS (connected and fully automated) mobility services can also contribute to reducing overall traffic, making cities and human settlements safe, resilient, sustainable, and decrease the number of deaths and injuries caused by road accidents. An open challenge is related to the introduction of automated vehicles in existing traffic poses specific and new problems in terms of reliability and effectiveness, concerning interactions with other vehicles and/or other actors of the traffic scenario, such as pedestrians, public vehicles or cyclists. Furthermore, automated guidance systems must be appropriately designed to be resilient both to the uncertainties of V2X communication, to guarantee enough reliability and robustness in

every traffic situation in the real world.
In this framework, my study focuses on the develop of cooperative strategies for cooperative vehicles, based on both onboard sensors and V2X communication, and test them in complex traffic contexts with high interaction between vehicles.
To develop these strategies, methodologies for cooperative and distributed control of multi-agent systems, advanced techniques for the control of cyber-physical systems and algorithms of Sensor Fusion were widely used.
The development of such cooperative strategies needs for testing and validation, due to a wide range of driving situations in which vehicles can be in.

During the second year, the develop of a light-weighted and open Virtual Simulation Platform for mixed traffic (called MiTraS, i.e. Mixed Traffic Simulator), aiming to easily test and validate C-ITS strategies in mixed traffic, has been continued. The MiTraS platform is based on the integration of SUMO and Matlab/Simulink, so to have a realistic representation of Vehicle Dynamics and Surrounding Road Environment, and to quantify the impacts, benefits and costs of connected and automated vehicles driving systems in urban mixed traffic flow (connected human-driven and autonomous). Specifically, Matlab/Simulink allows to manage Vehicle Dynamics, Sensors and Control Logics, and to create a simplified 3D road environment, while SUMO is used to recreate realistic road traffic conditions. The main advantages of such a tool are: 1) light-weighted tool, so no powerful hardware is needed to perform simulations; 2) low cost because no commercial software is required; 3) easily adaptable to developer's needs.
The proposed virtual simulation platform has been used to numerically analyze the control strategies for each of the addressed road traffic issues.

1. One of the most safety-critical challenge for mixed-traffic scenarios in urban environment is non-signalized intersection due to: 1) stop&go phenomena and tight spacing affect road safety, increasing the probability of road accidents; 2) stops along trip increases travel time, fuel consumption and pollutant emissions. In this context, the problem of the safe crossing at unsignalized intersection in mixed traffic composed of both CAVs and CHVs without using centralized signaling system (e.g. classical TLS or virtual one communicating with via V2I) has been addressed. Although all vehicles within the traffic flow are connected, i.e. they are able to share their status data (speed, position and driving direction), only CAVs are equipped with on-board control algorithms adapting their motion w.r.t. the surrounding environment. A cooperative fully-distributed control strategy for CAVs that, leveraging on-board sensors and information shared by all the connected vehicles via V2V, guarantees a safe intersection crossing, manages unfavorable traffic situations to avoid both intersection dead-lock and slowing-down phenomena, and improves the intersection throughput has been proposed. The novel proposed cooperative control strategy augments the classical ACC (Adaptive Cruise Control) action with an additional networked control action that exploit the Time-to-Intersection information of all incoming vehicles within the communication range. This further action allows avoiding collisions at intersection w.r.t. the vehicles that are beyond the CAVs line of sight

2. Typically, technical literature considers linear dynamical system to describe the vehicle dynamics and do not consider for the model nonlinearities induced by vehicle powertrain system (e.g. engine, driveline, and aerodynamic drag). Vehicle dynamics parameters are also affected by uncertainties since there are a lot of mismatches between the real plant and the model, due to the environmental disturbances, parameter variations, and neglected dynamics. Another issue in the cooperative driving application are the platooning maneuvers (i.e. create merge and disengaged platoons) since vehicles must be able to join or leave a platoon at any time. Indeed, during such maneuvers, some communication links among the vehicles within the platoon can be created and/or disrupted. This implies a switching of the communication topology and the designed platoon control strategy has also to cope with such time-varying structure of the communication network. To overcome all the

issues, a novel robust distributed PI-based control strategy which ensures that all vehicles within the platoon track the leader behaviour while coping with both the time-varying structure of the communication network and the presence of unknown uncertainties acting on the their dynamics has been proposed. The control strategy weights the vehicle state information via proportional actions that are augmented with an additional integral action on the position state information so to improve the steady-state and robustness performances.

3. In real scenarios, the reference speed is provided to a platoon by a virtual leader (e.g. an infrastructure). Typically, the computed reference speed allows to harmonize the traffic flow and, thereby, deal with traffic congestion problem. Furthermore, these kinds of system can also improve the energy consumption of vehicle w.r.t. a defined controlled rod link. Among these systems, one of the most widely used is the so-called Variable Speed Limit (VSL). To test the effectiveness of such system in energy-saving, a simple rule based VSL system has been developed and tested on a real road network, i.e. a freeway road segment of the city of Naples. The control strategy leverages volume, occupancy, and average speed data, provided by loop detectors located along the road, for adapting dynamically the road speed limit.

d. Collaborations

- Research Group of Prof. Gennaro Nicola Bifulco (DICEA, Università di Napoli Federico II)
- Fiat Chrysler Automobiles group, FCA

4. Products

a. Publications

i. **Published:** "Intersection Crossing in Mixed Traffic Flow Environment leveraging V2X information", Angelo Coppola, Bianca Caiazzo, Gennaro Nicola Bifulco, Stefania Santini, in 8th *IEEE International Conference on Connected Vehicles and Expo (ICCVE),* Graz (Austria), November 2019
ii. **Published:** "Variable Speed Limits System: A Simulation-Based Case Study in the city of Naples". Di Costanzo, L., Coppola, A., Pariota, L., Petrillo, A., Santini, S., & Bifulco, G. N. (2020, June). In 2020 IEEE International Conference on Environment and Electrical Engineering and 2020 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe) (pp. 1-6). IEEE.
iii. **Published:** "Integrating tools for an effective testing of connected and automated vehicles technologies". Pariota, L., Coppola, A., Di Costanzo, L., Di Vico, A., Andolfi, A., D'Aniello, C., & Bifulco, G. N. (2020). Integrating tools for an effective testing of connected and automated vehicles technologies. IET Intelligent Transport Systems, 14(9), 1025-1033.

5. Conferences and Seminars

a. Details

- 8th IEEE International Conference on Connected Vehicles and Expo (ICCVE), Graz (Austria), November 2019

- 1 paper;

- 2020 IEEE International Conference on Environment and Electrical Engineering and 2020 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe)
  - 1 paper;

b. Presentations made

- 8th IEEE International Conference on Connected Vehicles and Expo (ICCVE), Graz (Austria), November 2019;
- 2020 IEEE International Conference on Environment and Electrical Engineering and 2020 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe).

6. Activity abroad

a. Details: study of cooperative control strategy for autonomous vehicle, able to share information via V2V, in complex road traffic scenarios.
b. Dates: 01/07/2020 – 30/09/2020;
c. Places: via telematic mode (smart working);
d. Partner: Mechanical and Materials Science and Engineering, Cyprus University of Technology (Dorothea Bldg 507, 45 Kitiou Kyprianou Str., Limassol 3041, Cyprus);
e. Contact: Prof. Savvas G. Loizou, Assistant Professor of Automatic Control, e-mail: savvas.loizou@cut.ac.cy.

7. Tutorship

Subsidiary teaching activity, for the exercise lessons, in the course “ANALISI DEI SISTEMI” (ING-INF/04), for a total of 18 hours.

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angelo.coppola@unina.it									stsantin@unina.it																	
	Credits year 1								Credits year 2								Credits year 3									
		1	2	3	4	5	6			1	2	3	4	5	6			1	2	3	4	5	6			
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Total	Check
Modules	17,8	2	3	3	0,8	6	3	**17,8**	9,2	1,6	3,3	2	7	6	0	**20**	0							**0**	**37,7**	30-70
Seminars	8	1,4	0,5	1	1,4	0	3,7	**8**	2	2,2	0	0,6	0,2	0	0	**3**	0							**0**	**11**	10-30
Research	34,2	6,6	6,5	6	7,8	4	3,3	**34,2**	48,8	6,2	6,7	7,4	2,8	4	10	**37**	60							**0**	**71,3**	80-140
	60	10	10	10	10	10	10	**60**	60	10	10	10	10	10	10	**60**	60	0	0	0	0	0	0	**0**	**120**	180