Exploiting Predictive capabilities in motion control for autonomous vehicles operating in crowded environments

Ph.D. candidate

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Cycle

XXXVIII Cycle

Tutors

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1. Description of the research program

In daily life, people are called upon to make decisions, which can influence others. This can be modelled as a very complex network of interactions, which may be hard to interpretate and study. A system of generic interactions between agents can be observed in different scenarios, such as traffic, power grids but also biological systems.

I.e., in the traffic scenario, the agents are the road users (RUs), which are required to decide their move, also considering the behavior of the other agents. In this sense, a single decision can influence the others' moves. However, the final decision of a RU is not just influenced by the others', but it should also consider other constraints, such as the road rules, road signs, the RU's personal purpose and the attitude of the RU (i.e.: a cyclist can be more stubborn than a pedestrian).

All these aspects rule the decision process, and the aim of the research project is to find single (or multiple) framework that can easily describe and catch the behaviors and the interactions between agents. Ideally, this framework should be versatile, namely it can be applied to several scenarios, just by considering the different constraints and/or issues. In the traffic scenario, for example, this framework should be able to highlight the effect of the road signs on the agents, other than the road rules. For this purpose, actual data must be integrated to derive the models. Once the framework has been derived, it can be used to analyze and predict the behaviors of a network of interacting agents.

So far, the system of interactions between agents has been modelled both as linear combination of neighbors' opinions [1], which is a deterministic approach, and Markov chain [2], which is stochastic. This latter method can be either in continuous (CTMC) [3] or discrete time (DTMC) [4]. The latest model [5] that has been proposed for a traffic scenario is based on a CTMC, which is an extension of the framework in [2],[6],[7]. While these frameworks just consider that agents are only attracted to others' decision states with an influence that depends on how many other agents share the same decision state, the novel framework also introduces a repulsive action through rate modulation. This addition is suitable for the characterization of the chosen scenario since it aims at considering its issues and constraints.

To sum up, the project aims at the development of learning-based (from actual data), predictive framework. This can be based on the work in [5], but it must be integrated with dataset, for example the *InD* intersection dataset [8].

[1] M. H. Degroot, "Reaching a consensus", *Journal of the American Statistical Association*, vol. 69, no. 345, pp. 118-121, 1974.

[2] P. Bolzern, P. Colaneri, G. De Nicolao, "Opinion influence and evolution in social networks: A Markovian agents model"*, Automatica*, vol. 100, pp. 219-230, 2019.

[3] P. Van Mieghem, "The n.intertwined sis epidemic network model", *Computing,* vol. 93, no. 2-4, pp. 147-169,2011.

[4] C. Asavathiratham, S. Roy, B. Lesieutre, and G. Verghese, "The influence model," *IEEE Control Systems Magazine*, vol. 21, no. 6, pp. 52–64, 2001.

[5] C. Heiker, P. Falcone, "Decision Modeling in Markovian Multi-Agent Systems".

[6] P. Bolzern, P. Colaneri, and G. De Nicolao, "Opinion dynamics in social networks with heterogeneous markovian agents," in 2018 *IEEE Conference on Decision and Control (CDC)*, Miami, USA, Dec. 2018, pp. 6180–6185.

[7] P. Bolzern, P. Colaneri, and G. De Nicolao, "Opinion dynamics in social networks: The effect of centralized interaction tuning on emerging behaviors," *IEEE Transactions on Computational Social Systems*, vol. 7, no. 2, pp. 362–372, 2020.

[8] J. Bock, R. Krajewski, T. Moers, S. Runde, L. Vater, and L. Eckstein, "The inD Dataset: A Drone Dataset of Naturalistic Road User Trajectories at German Intersections," in 2020 *IEEE Intelligent Vehicles Symposium (IV)*, 2020, pp. 1929–1934.

2. Schedule of the research activities

Insert the research activities that you plan, or you have completed for the three years, including any period abroad.

First academic year (planned)

	Description	Period	Activity abroad
Introductory part	Study of State of the Art of the research project.	November 2022 – March 2023	NO
Model the interactions of RUs (I)	Develop of frameworks for the modeling of interactions between agents (part I).	April 2023 – September 2023	NO

Second academic year (planned)

	Description	Period	Activity abroad
Model the interactions of RUs (II)	Develop of frameworks for the modeling of interactions between agents (part II).	October 2023 – February 2024	NO
Learning algorithms	Research activity at Chalmers University of Technology. It aims at designing algorithms that can estimate parameters starting from actual data.	March 2024 – October 2024	YES Chalmers University of Technology

Third academic year (planned)

	Description	Period	Activity abroad
Final tests	Final tests of the predictive and learning tools.	November 2024 – February 2025	NO
Thesis	Thesis	March 2025 – October 2025	NO

3. Training and research activities plan

Ph.D. students are required to carry out activities for an amount of 60 ECTS (CFU) per year, for a total of 180 ECTS throughout the academic course. The activities carried out by Ph.D. students are divided into:

- **Didactic activities:** min 36 – max 60 ECTS (of the total 180 ECTS), preferably in the first two years of the course.
- **Research activities:** min 120 – max 144 ECTS (of the 180 total ECTS)

The ECTS related to the **didactic activity** can be obtained, for instance, by attending courses and seminars from graduate schools or master's degree programs. The DAUSY teaching-course catalogue (http://dausy.poliba.it/Ph.D./teaching-course-catalogue/) comprehends a list of didactic activities that can be included in this plan. Didactive activities are divided into:

A. **Ph.D. courses:** these are courses offered at the Ph.D. level usually by doctoral schools (e.g., DAUSY Courses, Poliba ScuDo Courses, SIDRA Summer School Courses, EECI IGSC Courses, Partner Universities Ph.D. Courses, etc.).
B. **Master's degree courses**: maximum 18 ECTS can be obtained by master's degree courses or single-cycle degree courses if these have not been attended by the Ph.D. student during his/her second level education.
C. **Soft skills:** maximum 12 ECTS can be obtained by courses classified as "soft skills" after the authorization of the Academic Board.
D. **Participation to seminars**: participation to seminars related to the research program is considered as a didactic activity (5 hours of seminar = 1.5 ECTS).
E. **Participation to international congresses or workshops**: participation at international congresses and workshops is considered as a didactic activity (1 international congress/workshop day = 1 ECTS).

F. **Presentation of research products at international congresses or workshops:** presentation of a research product at international congresses and workshops is considered as a didactic activity (1 presentation = 2 ECTS).

Note that:

- **At least 18 ECTS (of the total 180 ECTS) of didactic activities (A) and (B) must be obtained by completing a final exam**.
- For all courses (A) and (B) the 50% of the total course ECTS is recognized in case the final exam is not completed.
- Didactic activities must be confirmed with attendance certificates.

Examples:

- A 6-ECTS course, given in a master's degree course, can be attended by the Ph.D. student who can receive 3 ECTS if he/she does not complete the final exam (in this case the attendance must be certified).
- If a Ph.D. student attends a 5-day conference presenting a scientific contribution, he/she will obtain 5 ECTS for the participation and additional 2 ECTS for the conference contribution (the certification is required for both the attendance and the presentation).

Please refer to the *"Educational regulations of the Doctoral School of Politecnico di Bari"* for more details
http://www.poliba.it/sites/default/files/dottorati/regscudopoliba.pdf

The ECTS related to the **research activities** are divided into:

G. **Individual research activity.**
H. **Supervision of students:** tutoring activities for students in undergraduate and master's degree programs.
I. **Integrative teaching activities:** supplementary teaching activity (e.g., seminars, courses, practical exercises, etc.) for students in undergraduate and master's degree programs within the limit of 40 hours per academic year.
J. **Preparation of manuscripts for conferences or journals.**

Note that each ECTS usually corresponds to 25 hours of research activity.

First academic year (planned)

		Description	Period	Final Exam	ECTS
A.	**Ph.D. courses**	*Numerical Methods for Big Data* (ScuDo courses)		Yes	2
		Multi-agent optimization and learning: resilient and adaptive solutions (EECI Courses)	February 2023	Yes	3
		SIDRA Summer School Courses	July 2023	Yes	10
B.	**Master's degree courses**	*Stochastic Processes* (Unipd)	March – June 2023	Yes	6
C.	**Soft skill courses**				
D.	**Participation to seminars**	*Opinion Dynamics* (DAUSY Seminars)	Feb/Jul/Sep 2023		1.5
		Learning influences in large scale dynamical social networks – a system and control approach (DAUSY Seminars)	March-July 2023		1.5
		Network dynamics and control (DAUSY Seminars)	Jan-Feb or Jun 2023		3
		Complex Systems Modeling (DAUSY Seminars)			1.5
E.	**Participation to international congresses or workshops**				
F.	**Presentation of research products at international congresses or workshops**				
		TOTAL OF ECTS FOR TRAINING ACTIVITIES			28.5
G.	**Individual research activity**	Analysis of the State of the Art and modeling of frameworks for the interactions between RUs.			22.5

		Description	Period	Final Exam	ECTS
H.	Supervision of students				
I.	Integrative teaching activities				
J.	Preparation of manuscripts for conferences or journals	Verbalization of the results obtained, in the form of a paper for a conference or a journal.			9
		TOTAL OF ECTS FOR RESEARCH ACTIVITIES			31.5
		TOTAL OF ECTS			**60**

Second academic year (planned)

		Description	Period	Final Exam	ECTS
A.	**Ph.D. courses**	One/two courses to be defined according to the syllabus		Yes	3
B.	**Master's degree courses**	*Reinforcement Learning* (Unipd)	Oct 2023 – Jan 2024	Yes	6
		Advanced probability and statistical methods for engineering (Unimore)	Oct 2023 – Jan 2024	Yes	6
C.	**Soft skill courses**				
D.	**Participation to seminars**	Participation to at least one seminar according to availability			1.5
E.	**Participation to international congresses or workshops**				
F.	**Presentation of research products at international congresses or workshops**	Presentation of the results obtained to one international congresses or workshops associated to a high impact factor			2
		TOTAL OF ECTS FOR TRAINING ACTIVITIES			18.5
G.	**Individual research activity**	Modeling of frameworks for the interactions between RUs and designing algorithms that can estimate parameters starting from actual data.			32.5
H.	**Supervision of students**				
I.	**Integrative teaching activities**				
J.	**Preparation of manuscripts for conferences or journals**	Verbalization of the results obtained, in the form of a paper for a conference or a journal.			9
		TOTAL OF ECTS FOR RESEARCH ACTIVITIES			41.5
		TOTAL OF ECTS			**60**

Third academic year (planned)

		Description	Period	Final Exam	ECTS
A.	**Ph.D. courses**				

B.	Master's degree courses				
C.	Soft skill courses				
D.	Participation to seminars	Participation to at least one seminar according to availability			1.5
E.	Participation to international congresses or workshops	Participation to at least one international congress/workshop according to availability			1
F.	Presentation of research products at international congresses or workshops	Presentation of the results obtained to two international congresses or workshops associated to a high impact factor			4
		TOTAL OF ECTS FOR TRAINING ACTIVITIES			6.5
G.	Individual research activity	Final tests and Thesis			44.5
H.	Supervision of students				
I.	Integrative teaching activities				
J.	Preparation of manuscripts for conferences or journals	Verbalization of the results obtained, in the form of a paper for a conference or a journal.			9
		TOTAL OF ECTS FOR RESEARCH ACTIVITIES			53.5
		TOTAL OF ECTS			**60**

4. List of the publications written by the candidate in the triennium

Insert the list of papers written during the Ph.D. program. If the paper is still not published indicate its status (e.g., submitted, under review, under 2nd review round, accepted to appear, etc.).

International Journal Articles

International Conference Proceedings