

INTERUNIVERSITY PH.D. PROGRAM BETWEEN
POLITECNICO DI BARI AND UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO
IN INDUSTRY 4.0

Autonomous Mobile Robots

PhD candidate

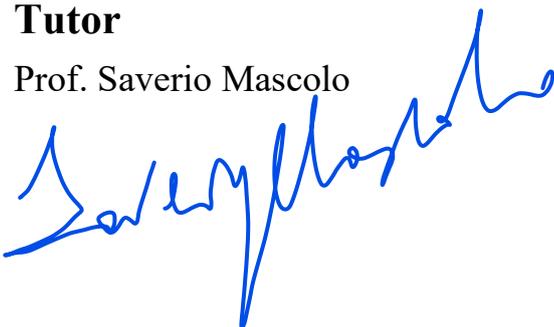
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Cycle

XXXVII

Tutor

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Description of the research program

The research program will focus on the design of control algorithms for autonomous or for assisted navigation of mobile robots in unstructured irregular environments. The control system will build upon the following fields: sensors acquisition and filtering, reconstruction and interpretation of environments, generalization of "path-planning" planners, localization and automatic mapping. Different control techniques will be explored with a particular focus on Model Predictive Control, Reinforcement Learning and Safe Controller Optimization.

The first part of the research will concern the management of the controller's intervention policies, sensors data interpretation and task-planning. When an Autonomous Guided Vehicle (AGV) moves within a fully known environment, the planning and execution of the task are relatively simple. The problem becomes complex when the AGV moves within a partially known or completely unknown environment in which the security policies and the task execution requests go into conflict, creating deadlock situations. Control policies in these context will be approached using Model Predictive Controllers. These type of controllers permit to work in the optimality region (at least locally) by taking into account functional and safety constraints that may exists. Furthermore, due to the way the cost function is modelled, it is possible to adjust the behaviour of the system by acting on its weights. A critical issue that will be considered is the execution time of the controller since, in the case of complex problems, the computation time may exceed the operating time of the system, thus causing unstable systems.

The second part of the research activity will aim at generalizing the control policies proposed in the first part. Indeed, a system with an MPC-type controller has a good degree of accuracy, as the model is available to the controller of the system. This is not always the case due to model uncertainty (eg systems with strong non-linearities, unmodeled dynamics)

To tackle this problem, an approach based on Reinforcement Learning (RL) will be investigated to model the system. This approach is called "*Data Driven MPC*" or "*RLMPC*". This is an approach that looks promising even though still not fully explored.

The application scenarios will be those of autonomous robots for "*Industria 4.0*" such as, in particular, automatic manufacturing system and warehouse system with the goal of increasing productivity and safety. In order to allow the developed techniques to permeate the industrial field, Safe Reinforcement Learning (SRL) and Safe Controller Optimization (SCO) solutions will be adopted to directly integrate the constraints of safety which are of importance in real case scenarios.

This will allow the employment of such technique in real world applications, leveraging the strengths of this approach, without exposing to any risk of damage the environment and equipment involved in the experiments.

Schedule of the research activities

The research activity will start by looking at the state of the art in the field of Autonomous Navigation and Mobile Robotics

Research results will be published on leading international journal and conference. A particular attention will be devoted to testing of proposed results at laboratory level.

First academic year (planned)

	Description	Period	Activity abroad
Research in the state of art	Recognition of the state of the art in the autonomous navigation sector for unstructured environments, SLAM algorithms and path planning through bibliographic research and study of international projects.	Nov 2021 – Apr 2022	NO
Study and design of new techniques of Mobile Robots Navigation	Design of new approaches in the field of Mobile Robots navigation for industrial environment, study of its main problematics.	Nov 2021 – Oct 2022	NO

Second academic year (planned)

	Description	Period	Activity abroad
Design and implementation of new autonomous driving techniques and their applications	Analysis of innovative scenarios and development of applications and solutions designed using mathematical models, simulation software and real testbeds.	Nov 2022 – Oct 2023	NO
Design and implementation of new assisted driving techniques and their applications	Refinement of the solutions identified. Identification of useful scenarios in which the designed solutions will be tested.	Nov 2022 – Oct 2023	NO

Third academic year (planned)

	Description	Period	Activity abroad
Performance analysis	Design and implementation of the tools for the analysis of the techniques proposed.	Nov 2023 – Oct 2024	NO
Cooperation with a foreign company or university	A collaboration with a foreign university or company will make possible to analyze the research problem addressed from a different perspective.	1 st semester third year	YES
Writing of the PhD Thesis	Writing of the PhD thesis	Nov 2023 – Oct 2024	NO

Provisional training and research activities plan

First academic year (planned)

	Description	Period	Duration	CFU
PhD courses	“Non-Integer Order Systems and Controllers” Prof. Guido Maione - SSD: ING-INF/04	16/05/2022 27/05/2022	20h	2
	“Complex Networks: Big Data modelling and learning” - Prof. Nicola Amoroso – SSD: FIS/07	06/06/2022 24/06/2022	20h	2
	“Time-series databases for sensor data analysis” Prof. Giuseppe Loseto – SSD: ING-INF/05	18/01/2022 11/02/2022	20h	2
	“Smart Building and Smart Mobility systems” Prof. Roccotelli – SSD: ING-INF/04	12/09/2022 28/09/2022	20h	2
Master’s degree courses				
Participation to seminars and international congresses or workshops	5 th SPRING SCHOOL on Data-Driven Model Learning of Dynamic Systems – Virtual Proff: Xavier Bombois, Håkan Hjalmarsson	04/04/2022 08/04/2022	20h	3
	2022 International Graduate School on Control – Module on “Learning-Based Predictive Control” – Zurich Proff: Melanie Zeilinger, Lorenzo Fagiano, Lukas Hewing	11/07/2022 15/07/2022	20h	3
Presentation of research products at international congresses or workshops	Presentation of the results obtained to at least one international congresses or workshops associated to a high impact factor.	Nov 2021 – Oct 2022		2
TOTAL OF CFU FOR TRAINING ACTIVITIES				20
Individual research activity	Research activity in the topics of safe Autonomous driving and assisted driving in industrial environment.	Nov 2021 – Oct 2022	525h	21
Students’ supervision	Supervision of Students under the guidance of the tutor	Nov 2021 – Oct 2022	75h	3
Integrative didactic activities	Integrative didactic activities will be carried out under the supervision of the tutor	Nov 2021 – Oct 2022	150h	6
Preparation of manuscripts for conferences or journals	Verbalization of the results obtained, in the form of a paper for a conference or a journal.	May 2021 – Oct 2022	250h	10
TOTAL OF CFU FOR RESEARCH ACTIVITIES				40
TOTAL OF CFU FOR YEAR I				60

Second academic year (planned)

	Description	Period	Duration	CFU
PhD courses	One/two courses to be defined according to the syllabus regarding academic year 2022/23, that can eventually replace former ones.	Nov 2022 – Oct 2023	40h	4
Master's degree courses				
Participation to seminars and international congresses or workshops	Participation to at least two seminars/workshops according to availability.	Nov 2022 – Oct 2023		6
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.	Nov 2022 – Oct 2023		4
	TOTAL OF CFU FOR TRAINING ACTIVITIES			14
Individual research activity	Research activity in the topics of safe Autonomous driving and assisted driving in industrial environment. Writing of PhD Thesis	Nov 2022 – Oct 2023	675h	27
Students' supervision	Supervision of Students under the guidance of the tutor	Nov 2022 – Oct 2023	75h	3
Integrative didactic activities	Integrative didactic activities will be carried out under the supervision of the tutor	Nov 2022 – Oct 2023	150h	6
Preparation of manuscripts for conferences or journals	Verbalization of the results obtained, in the form of a paper for a conference or a journal.	Nov 2022 – Oct 2023	250h	10
	TOTAL OF CFU FOR RESEARCH ACTIVITIES			46
	TOTAL OF CFU FOR YEAR II			60

Third academic year (planned)

	Description	Period	Duration	CFU
PhD courses				
Master's degree courses				
Participation to seminars and international congresses or workshops	Participation to at least one seminar/workshop according to availability.	Nov 2023 – Oct 2024		3
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.	Nov 2023 – Oct 2024		4
	TOTAL OF CFU FOR TRAINING ACTIVITIES			7
Individual research activity	Research activity in the topics of safe Autonomous driving and assisted driving in industrial environment. Writing of PhD Thesis	Nov 2023 – Oct 2024	800h	32
Students' supervision	Supervision of Students under the guidance of the tutor	Nov 2023 – Oct 2024	75h	3
Integrative didactic activities	Integrative didactic activities will be carried out under the supervision of the tutor	Nov 2023 – Oct 2024	150h	6
Preparation of manuscripts for conferences or journals	Verbalization of the results obtained, in the form of a paper for a conference or a journal.	Nov 2023 – Oct 2024	300h	12
	TOTAL OF CFU FOR RESEARCH ACTIVITIES			53
	TOTAL OF CFU FOR YEAR III			60
	TOTAL OF CFU FOR THE WHOLE PHD COURSE			180