

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

Safe Reinforcement Learning for Decision and Control of Robots and Smart Embedded Devices

PhD candidate

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Cycle

XXXVII

Tutors

Prof. Luca De Cicco

Description of the research program

The research program described herein is rooted in the field of Deep Reinforcement Learning (DRL) for control applications. In particular, the proposed research plan focuses on studying the foundational problems for the application of DRL as a control solution for robots and Smart Embedded Devices, the latter typically characterized by limited (computational, data and energy storage) capacities.

DRL agents controlling robotic devices are required to incorporate constraints related to safety in order to be employed in industrial scenarios without harming human operators and the environment they interact with. DRL techniques specifically designed to guarantee Safety go under the name *Safe Reinforcement Learning* (SRL) systems.

Another particularly challenging aspect that this research program is going to address is the employment of DRL solutions on embedded devices. Such computing systems, characterized by limited performance, are receiving a great deal of attention in the AI field due to the peculiar challenges they offer. In particular, the very limited amount of memory (SRAM) and storage (Flash) embedded devices are equipped with make very difficult to deploy expressive neural networks on such devices. Such a challenge can be tackled by considering new techniques such as the Quantization Aware Training that allow to deeply quantize the NN to reduce the overall amount of storage and memory required to run such models on an embedded device. The first solutions available in the recent literature that go in this direction are set in the emerging research field that is often referred to as “Edge-AI”. Leveraging such techniques in the field of Reinforcement Learning is an open research issue as most of the proposed techniques in the Edge-AI field relate to Deep Neural Networks, whereas DRL and SRL applications are not sufficiently explored yet.

In order to pursue the goals of the research program described in this document we will actively cooperate with STMicroelectronics to allow identifying key real case scenarios and test the proposed solutions on industrially relevant use cases.

Note that the research plan integrates the cooperation with STMicroelectronics during the whole duration of the PhD program, as the point of view of a leading player in the field of embedded devices is considered instrumental to efficiently pursue the research goals of this program.

Schedule of the research activities

The research activity plans to carry out as a first step a thorough study of the state of art of the relevant literature related to DRL, SRL, Edge-AI fields. Based on a gap analysis, I will then study and design new techniques and solutions to tackle the identified criticalities. The research in the state of art will also focus on the general topic of Deep Learning, as many critic aspects are shared across in all fields of machine learning (such as overfitting, steepness of the loss function and so on).

Note that the research in the state of art is planned as an activity which will be carried on during all the period of research by actively monitoring and studying the most important international conferences and journals related to my research program.

The new techniques proposed will be tested in control scenarios and will be carefully analysed. The obtained results will be disseminated through publications in the proceedings of high impact international conferences and journals.

First academic year (planned)

	Description	Period	Activity abroad
Study the relevant literature	Research in the state of art for key improvements and approaches in the field of DRL, SRL and Edge-AI.	1 - 6	NO
Study and design of new SRL techniques	Design of new approaches in the field of SRL, study of its main problematics.	1 – 12	NO

Study and design of new Edge-AI techniques	Design of new approaches in the field of Edge-AI, study of its main problematics.	1 - 12	NO
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Second academic year (planned)

	Description	Period	Activity abroad
Design and implementation of new SRL techniques	Refinement of the solutions identified. Identification of useful scenarios in which the designed solutions will be tested.	1 - 12	NO
Design and implementation of new Edge-AI techniques	Refinement of the solutions identified. Identification of useful scenarios in which the designed solutions will be tested.	1 - 12	NO

Third academic year (planned)

	Description	Period	Activity abroad
Performance analysis	Design and implantation of the tools for the analysis of the techniques proposed.	1 - 12	NO
Cooperation with STMicroelectronics	Strict cooperation with STMicroelectronics in order to test the solutions proposed on real case scenarios.	1 - 12	NO. The activity will be carried out at the STM offices in Agrate.
Writing of the PhD Thesis	Writing of the PhD thesis	1 - 12	NO

Provisional training and research activities plan

Specify with the related CFU (ECTS) the training activities that you plan to carry out or have completed in the three years (e.g., courses to attend, conferences, seminars, etc.). Please refer to the Educational regulations of the Doctoral School of Politecnico di Bari:
<http://www.poliba.it/sites/default/files/dottorati/regscudopoliba.pdf>

Specify with the related CFU (ECTS) the research activities that you plan to carry out in the three years (e.g., individual research activity, supervision of students, integrative seminars to be given by the PhD student, activity of manuscript preparation for conferences or journals, activity of patents preparation, etc.).

First academic year (planned)

	Description	Period	Duration	CFU
PhD courses	Complex Networks: Big Data modelling and learning			2
	Time-Series databases for sensor data analysis			2
	Artificial Intelligence and Machine Learning (Uniba, Physics Department)			2
Master's degree courses				
Participation to seminars and international congresses or workshops	<i>Learning-Based Predictive Control</i> (Melanie N. Zeilinger, Lorenzo Fagiano, Lukas Hewing)	11/07/2022 15/07/2022		3
	Participation to at least two seminars/workshops according to availability.			6
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.	1 - 12		2
	TOTAL OF CFU FOR TRAINING ACTIVITIES			17
Individual research activity	Research activity in the topics of Deep Reinforcement Learning for Robots and Embedded Devices	1 - 12		18
Students' supervision	Supervision of Students under the guidance of the tutor	1 - 12		9
Integrative didactic activities	Integrative didactic activities to be carried out under the supervision of the tutor	1 - 12		7
Preparation of manuscripts for conferences or journals	Verbalization of the results obtained, in the form of a paper for a conference or a journal.	6 - 12		9
	TOTAL OF CFU FOR RESEARCH ACTIVITIES			43
	TOTAL OF CFU FOR YEAR I			60

Second academic year (planned)

	Description	Period	Duration	CFU
PhD courses	Fundamentals of information theory, 2 CFU, SSD: ING-INF/03			2
	One/two courses to be defined according to the syllabus regarding academic year 2022/23, that can eventually replace former ones.			2

Master's degree courses				
Participation to seminars and international congresses or workshops	Participation to at least three seminars/workshops according to availability.			9
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 CFU FOR TRAINING ACTIVITIES			17
Individual research activity	Research activity in the topics of Deep Reinforcement Learning for Robots and Embedded Devices	1 - 12		18
Students' supervision	Supervision of Students under the guidance of the tutor	1 - 12		8
Integrative didactic activities	Integrative didactic activities will be carried out under the supervision of the tutor	1 - 12		8
Preparation of manuscripts for conferences or journals	Verbalization of the results obtained, in the form of a paper for a conference or a journal.	6 - 12		9
	TOTAL OF CFU FOR RESEARCH ACTIVITIES			43
	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.			3
Presentation of research products at international	Presentation of the results obtained to two international congresses or workshops associated to a high impact factor.			4

congresses or workshops				
	TOTAL OF CFU FOR TRAINING ACTIVITIES			7
Individual research activity	Research activity in the topics of Deep Reinforcement Learning for Robots and Embedded Devices and writing of the PhD thesis.	1 - 12		23
Students' supervision	Supervision of Students under the guidance of the tutor	1 – 12		6
Integrative didactic activities	Integrative didactic activities will be carried out under the supervision of the tutor	1 – 12		10
Preparation of manuscripts for conferences or journals	Verbalization of the results obtained, in the form of a paper for a conference or a journal.	6 - 12		14
	TOTAL OF CFU FOR RESEARCH ACTIVITIES			53
	TOTAL OF CFU FOR YEAR III			60
	TOTAL OF CFU FOR THE WHOLE PHD COURSE			180