



NATIONAL PH.D. PROGRAM IN AUTONOMOUS SYSTEMS

Multi-agent Systems Methodologies and Frameworks for Edge-AI in Smart Environments

Ph.D. candidate

Bouleanu Daniel-Costel

Cycle

XXXIX

Tutors

Professor Giancarlo Fortino, University of Calabria

Professor Dr. Ing. Costin Badica, University of Craiova

1. Description of the research program

With the rising of Internet of Things (IoT) during the past few years, the amount of data collected, transmitted, and processed by computer systems is growing enormously. This drives the need to process huge amount of data as close as possible to the source, to simultaneously enable system's smartness while improving performances. The aim of the proposed research is to design, implement and test innovative techniques and models based on Multi-Agent Systems (MAS) within the IoT-Edge-Cloud continuum for enhancing intelligence at the edge of the network by exploiting the availability of Massively Decentralized Data Sources. The aim of the proposed research is to focus on innovative MAS-based techniques for bringing intelligence closer to end users, i.e., at the edge of IoT architectures. The main idea is to develop IoT systems made of a single network with flexible and adaptable sensors, i.e., able to measure basic phenomena from the environment and, by using AI algorithms, either to predict specific behaviour or to act to optimize the surroundings. More specifically, the research objectives are:

1. Deliver an open AI-ready MAS framework for holistic, trustworthy, scalable, and adaptive system operation across the IoT-Edge-Cloud continuum.
2. Develop an agent-based AI architecture supporting re-trainable ML models for end-to-end autonomic system operation.
3. Enable efficient isolated agent execution across the heterogeneous continuum.
4. Support MAS-based resource orchestration for efficient and trustworthy system operation, while satisfying application quality requirements.
5. Perform realistic experimental evaluation of the proposed framework.

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
Systematic Survey of the State of the Art	Survey of the State of the Art in the fields of the proposed research topic (Multi-Agent Systems, Edge-AI, Smart Environments) using Prisma Systematic Literature Review Methodology.	First Year	NO
Publish Results	Publish Results Paper on Journals/Conferences.	First Year	NO

Second academic year planned

	Description	Period	Activity abroad
Definition of the System	Definition of the Multi Agent System Architecture for Edge-AI in Smart Environments	First Semester	YES(University of Craiova, Romania)
Study of AI Algorithms	Study of AI Algorithms that can be Embedded in the Architecture.	Second Semester	YES(University of Craiova, Romania)

Publications	Publish Results Paper on Journals/Conferences.	End of Year	YES(University of Craiova, Romania)
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Third academic year planned

	Description	Period	Activity abroad
Integration	Integration of the algorithms and Development of Case Studies.	First Semester	NO
Implementation	Implementation of the architecture and Development of Case Studies.	Second Semester	NO
Publications	Publish Results Paper on Journals/Conferences.	End of Year	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. Didactic activities are divided into:

- 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.).
- 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.
- Soft skills:** maximum 12 ECTS can be obtained by courses classified as "soft skills" after the authorization of the Academic Board.
- Participation to seminars:** participation to seminars related to the research program is considered as a didactic activity (5 hours of seminar = 1.5 ECTS).
- 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).
- 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:

- Individual research activity.**
- 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	Advanced Edge/Cloud – University of Calabria	2023/24	Yes	2
	Approximate Computing & digital systems – University of Calabria	2023/24	Yes	2
	Mathematical Optimization for Machine Learning – University of Calabria	2023/24	Yes	2
	Digital technologies and artificial intelligence law – University of Calabria	2023/24	Yes	2
	Emerging networking paradigms for 5G/6G Systems – University of Calabria	2023/24	Yes	2
	Advanced Cyber Security – University of Calabria	2023/24	Yes	2
	A Primer on Resilient Control Methodologies for Cyber-Physical Systems	2023/24	Yes	2
	Ethics and academic integrity – University of Craiova – Online	2023/24 Nov-Feb	Yes	3
B. Master's degree courses				
C. Soft skill courses	Italian Courses – University of Calabria	2023/24	Yes	2
D. Participation to seminars				
E. Participation to international congresses or workshops	Participation in one conference		No	1
F. Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			20
G. Individual research activity	Research Activity at the University of Calabria, Italy	2023/24	No	35
H. Supervision of students				
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	Preparation of one manuscript	2023/24	No	5
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			40
	TOTAL OF ECTS			60

Second 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 two seminars (or the equivalent of 10 hours)		No	3
E. Participation to international congresses or workshops	Participation in one conference		No	1
F. Presentation of research products at international congresses or workshops	Presentation of one research paper in a conference		No	2
TOTAL OF ECTS FOR TRAINING ACTIVITIES				6
G. Individual research activity	Research Activity at the University of Craiova, Romania			45
H. Supervision of students				
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	Preparation of one manuscript		No	9
TOTAL OF ECTS FOR RESEARCH ACTIVITIES				54
TOTAL OF ECTS				60

Third academic year planned

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Advanced Big Data – University of Calabria		Yes	2
	Deep Generative Models – University of Calabria		Yes	2
	Computational issues in game theory – University of Calabria		Yes	2
	Sensor-based Wearable Computing Systems – University of Calabria		Yes	2
	Advanced Measurement and Data Acquisition Systems – University of Calabria		Yes	2
	Microwaves for Sensing: Circuits and Methods for Biomedical Data Analysis – University of Calabria		Yes	2
B. Master's degree courses				
C. Soft skill courses				
D. Participation to seminars				
E. Participation to international congresses or workshops	Participation in two conferences		No	2
F. Presentation of research products at international congresses or workshops	Presentation of one research paper in a conference			2
TOTAL OF ECTS FOR TRAINING ACTIVITIES				16

G. Individual research activity	Research Activity at the University of Calabria, Italy		No	34
H. Supervision of students				
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	Preparation of two manuscripts		No	10
TOTAL OF ECTS FOR RESEARCH ACTIVITIES				44
TOTAL OF ECTS				60

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

Daniel-Costel Bouleanu

Professor Giancarlo Fortino

Professor Dr. Ing. Costin Bădică