PhD in Information Technology and Electrical Engineering
Università degli Studi di Napoli Federico II

PhD Student: Marco Aruta

Cycle: XL

Training and Research Activities Report

Year: First

Tutor: prof. Aniello Murano

Co-Tutor: Vadim Malvone

Date: October 31, 2024

Training and Research Activities Report

PhD in Information Technology and Electrical Engineering

Cycle:XL **Author: Marco Aruta**

1. Information:

- **PhD student: Marco Aruta**
- **DR number: DR999872**
- **Date of birth: 27/05/1995**
- **Master Science degree:** **University: Università Federico II di Napoli**
- **Doctoral Cycle: XL**
- **Scholarship type: UNINA**
- **Tutor:Aniello Murano**
- **Co-tutor: Vadim Malvone**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Alternating Time Logic Meets Information Theory	Seminar	2	0.4	04/12/2024	Prof. Murano	Y
Complexity Measures for Reactive Systems at LAMAS & SR '24	Seminar	1	0.2	11/12/2024	Prof. Murano	Y
Computationally Feasible Strategies at LAMAS & SR '24	Seminar	1	0.2	11/12/2024	Prof. Murano	Y
How to Boost your PhD	Course	18	5	08-15-22-29/01/2025 05-12/02/2025	Prof. Marino	Y
Opportunità e Prospettive dell'Intelligenza Artificiale nel mondo del Lavoro e della Ricerca	Seminar	8 1/2	1	29/01/2025	Prof. Di Francia	Y (Uploaded lately in ArutaMarcoYr1Att4)
Using Deep Learning properly	Course	12	4	3-6-10-14-17-19/02/2025	Prof. Apicella	Y
How can we interpret distributed knowledge via Artemov and Protopopescu's intuitionistic epistemic logic?	Seminar	1	0.2	28/03/2025	Prof. Murano	Y
Medicina & I.A.: Oggi e Domani	Seminar	9	1	5/06/2025	Dott. Aruta, Prof. Murano	Y
What Is Theoretical Computer Science?	Seminar	4	0.8	20/06/2025	Prof. Murano	Y
Main Organizer and Participant - Medicina & I.A.: Oggi e Domani	Research	9	1	5/06/2025	Dott. Aruta, Prof. Murano	Y

Formal Modeling, Specification, and Verification of Multi-Agent Systems	Seminar	1	5	15/07/2025	Prof. Murano	Y
Complexity Study of Reasoning about Knowledge and Public Observations	Seminar	0.8	4	9/07/2025	Prof. Murano	Y
ESSAI Summer School: Formal verification of symbolic and connectionist AI: a way toward higher quality software; Explainable AI via Argumentation: Theory & Practice; Strategic AI: Bridging Game Theory and Multi-Agent Systems via Autoformalization; AI for Autonomous Robots: Bridging Theory and Practice	Courses	35	4	30/06/2025 – 04/07/2025	Prof. Drotàr, Prof. Groznik	Y
La Scienza moderna e il problema della disciplina giuridica dell'IA	Courses	22	6	17-19-24-26/06/2025 01-03-08-10-15-17/07/2025	Prof. Franzese	Y
AI Code Generation: Foundations, Evaluation, and Security	Courses	15	3	7-10-14-15-17-31/10/2025	Dott. Liguori	N (Will be uploaded lately in ArutaMarcoYr2Att1 as the final exam will be on 31st of October,2025)
Participation to 22nd European Conference on Multi-Agent Systems - EUMAS 2025	Seminar	20	1	3-4-5/09/2025	Prof. Sorici	Y
The Logic of Anonymous Public Announcements	Seminar	3	0.6	22/09/2025	Prof. Murano	Y
Real-Valued Logics for Markov Decision processes	Seminar	2	0.4	16/10/2025	Prof. Jamroga	Y
IEEE International Conference on E-health Networking, Application & Services 2025	Seminar	15	1	21-22-23/10/2025	Prof. Hadjileontiadis and Prof. Mao	N (Will be uploaded lately in ArutaMarcoYr2Att1)
Workshops and Conference at ECAI 2025	Seminar	35	1	25-26-27-28-29-30/10/2025	Prof. Dastani, Prof. Lynce, Prof Murano	N (Will be uploaded lately in ArutaMarcoYr2Att1)

1) Courses, Seminar, Doctoral School, Research, Tutorship
2) Choose: Y or N

2.1. Study and training activities - credits earned

	Courses	Seminars	Research	Tutorship	Total
Bimonth 1		- Alternating Time Logic Meets Information Theory - Complexity Measures for Reactive Systems - Computationally Feasible Strategies	- Study on application of natural strategies in strategy logic, application of formal methods for videogames verification, application of formal methods for medical care safety and AI methods in digital healthcare - Optimization techniques for natural strategies generation. - Preparation and revision of the conference paper for AAMAS'25 - Preparation of two conference papers for AAMAS'25 Demonstration tracks - Preparation of a journal paper for JAAMAS, preparation of the conference paper for DSN'25. - Participation to the Conference AIXIA '24 - Participation to the conference LAMAS & SR '24. - Presentation of the paper "Development of Natural Strategies in Strategic Logics" to the Conference AIxIA (SPIRIT Workshop). - Implementation of optimization algorithms for generation of natural strategies - Implementation of model checking algorithm for Natural Strategy Logic - Implementation of algorithms for optimization of dynamic videogames models.		**6,8**
Bimonth 2	- How to Boost your PhD - Using Deep Learning Properly	- Opportunità e Prospettive dell'Intelligenza Artificiale nel mondo del Lavoro e della Ricerca	- Studying new applications of natural strategies in neuroscience - creation of a novel tool for synthetize Human-like strategies - studying formal methods approaches for medical care safety and applying AI and Machine Learning methods in digital healthcare for Leukemia predictions. - Final revision of a journal paper for JAAMAS.		**16**

			- Preparation of a conference paper for IJCAI'25 - Preparation of a conference paper for KES-InMed '25. - Post-proceedings submission of accepted AAMAS 2025 conference demonstrator paper "FindMe: A Prototype Videogame AI based on CTL with an Optimized Synthesis Algorithm" - Implementation of optimization model checking algorithms for Natural Strategy Logic, implementation of AI algorithms for Leukemia predictions.		
Bimonth 3		- How can we interpret distributed knowledge via Artemov and Protopopescu's intuitionistic epistemic logic?	- Invited Speaker at at BrainJuice Rome-Neuroscience and AI union - Dissemination of new applications of natural strategies in neuroscience and of a novel tool for synthetize Human-like strategies. - Studying formal methods approaches for medical care safety and neuroscience. - Submission of a journal paper for JAAMAS. - Preparation and Submission of a conference paper for PAAMS'25. - Preparation of a two conference papers for KR'25. - Post-proceedings submission of accepted KES-InMed 2025 conference paper - Theory and Implementation of Natural Strategy Checking in Concurrent Games with Imperfect Information - Optimization of clustering techniques for unsupervised learning for Leukemia predictions. - Theory and Implementation of a new temporal logic: a quantitative extension of Natural Strategic Ability.		**6,2**
Bimonth 4		- What Is Theoretical Computer Science?	- Main Organizer and Participant at Medicina & I.A.: Oggi e Domani. (https://medicinaeiaoggiedomani.github.io) - Presented a paper at KES-InMed 2025		**8**

		- Medicina & I.A.: Oggi e Domani	conference - Departed to attend to ESSAI 2025 Summer School - Studying new formal methods approaches for medical care safety and neuroscience, as spatial logics, and new research pathways in strategy logic. - Acceptance and online presentation of a paper for PAAMS'25 conference. - Submission of a conference paper for KR'25. - Submission of a conference paper for IEEE Healthcom '25.		
Bimonth 5	- La Scienza moderna e il problema della disciplina giuridica dell'IA - ESSAI 2025 Summer School (35 certified hours of lectures about the following courses: Formal verification of symbolic and connectionist AI: a way toward higher quality software; Explainable AI via Argumentation: Theory & Practice; Strategic AI: Bridging Game Theory and Multi-Agent Systems via Autoformalization; AI for Autonomous Robots: Bridging Theory and Practice)	- KES International: Smart Digital Futures 2025 - Formal Modeling, Specification, and Verification of Multi-Agent Systems - Complexity Study of Reasoning about Knowledge and Public Observations	- Studied new formal methods approaches for high quality software safety - delved deeper new research pathways in strategy logic. - explored Explainable AI techniques via Argumentation. - Acceptance of paper for IEEE Healthcom '25 conference. - Acceptance of paper for EUMAS '25 conference. - Submission of 2 conference papers at AAAI'26. - Submission of camera ready versions of accepted papers for IEEE Healthcom '25 and EUMAS '25.		**17,8**
Bimonth 6	- AI Code Generation: Foundations, Evaluation, and Security	- The Logic of Anonymous Public Announcements	- Novel natural strategies approaches (neuroscience) - Novel LLM for natural strategies generation approach.		**10,6**

		- 22nd European Conference on Multi-Agent Systems - Real-Valued Logics for Markov Decision processes - IEEE International Conference on E-health Networking, Application & Services 2025 - Workshops and Conference at ECAI 2025	- First phase rebuttal for paper acceptance at AAAI '26 - Paper at EUMAS '25 - Paper at IEEE Healthcom '25 - Organization and Attendance at ECAI'25 - Submission of 2 papers at HealthInf'26 and ICAART'26.		
Total	**22**	**10**	**35**	**0**	**67**
Expected	**30 - 70**	**10 - 30**	**80 - 140**	**0 – 4.8**	

3. Research activity:

During the first year of my PhD in "New Application Frontiers in the Development of Formal Methods for Multi-Agent Systems", my research focused on extending and applying Formal Methods and Strategy Logic to new interdisciplinary domains, including videogame AI, medical care safety, and neuroscience.
The main goal was to explore how Natural Strategies can be formally defined, optimized, and applied to systems that require intelligent, interpretable, and safe decision-making.

*The central topic of my research concerns the **development of a novel Natural Strategy Logic**, designed to formalize and reason about human-like strategies in multi-agent systems.*
The objectives of the first year were:

- *to design formal models and optimization algorithms for the synthesis and verification of natural strategies;*
- *to investigate cross-domain applications in AI for videogames, digital healthcare, and neuroscience;*
- *to build software tools implementing these theories, and to validate them experimentally.*

My work combined theoretical formalization with computational implementation and empirical validation:

1. ***Formal Development:*** *I extended the theory of Natural Strategies by introducing a quantitative notion of Natural Strategic Ability, enabling reasoning about imperfect information and bounded rationality in concurrent games.*
2. ***Algorithmic Implementation:*** *I designed and implemented* ***model checking*** *and* ***optimization algorithms*** *for NatSL[1G], NatATL, Optimized NatlATL, HumanATL[F], Solution Concepts, as well as* ***clustering and machine learning techniques*** *to optimize dynamic models and predict outcomes in real-world systems (e.g., leukemia diagnosis, ADNF-Clustering).*
3. ***Tool Development:*** *I developed S4H - Synthesizing Human-like Strategies, a software prototype capable of generating human-like strategies through formal synthesis methods.*
4. ***Application Studies:***
    - *In* ***videogames****, I applied formal verification to AI agents, developing FindMe, a CTL-based prototype that demonstrates how formal synthesis can produce adaptive and explainable AI behaviors.*
    - *In* ***digital healthcare****, I applied formal methods and machine learning to the development of predictive models for leukemia detection (L-CNN and ADNF-Clustering).*
    - *In* ***neuroscience****, I began a collaboration with a PhD student in neurocognitive sciences to study how natural strategies can represent human decision processes and cognitive reasoning patterns to refine the logic from scratch.*

The first-year activities led to significant theoretical and practical outcomes:

- ***Scientific publications:*** *multiple papers were accepted or submitted to major international venues, including AIxIA 2024, EUMAS 2024, AAMAS 2025, KES-InMed 2025, PAAMS 2025, IEEE Healthcom 2025, EUMAS 2025, AAAI 2026, HealthInf 2026. A journal manuscript was also submitted to JAAMAS.*
- ***Software artifacts:*** *developed and released S4H (for strategy synthesis) and the FindMe demonstrator (videogame AI based on CTL).*
- ***Invited talks and events:*** *presented research results at the aforementioned conferences, acted as Invited Speaker at BrainJuice Rome - Neuroscience and AI Union, and organized the interdisciplinary congress "Medicina & I.A.: Oggi e Domani".*
- ***Training and courses:*** *attended the ESSAI 2025 European Summer School on Artificial Intelligence (35 hours certified), and completed ad hoc PhD courses that helped to increase my interdisciplinary knowledge.*

In the last months of the year, I started developing a Large Language Model (LLM)-based approach for natural strategy generation. This research direction, combined with ongoing collaborations in neuroscience, will represent the foundation of my second-year activities, oriented toward building hybrid Multi-Agent human-AI reasoning frameworks that integrate formal methods, learning, and cognition.

4. Research products:

M. Aruta, V.Malvone, A.Murano, V. Palma, S.Romano
FindMe: A Prototype Videogame AI based on CTL with an Optimized Synthesis Algorithm,
Proceedings of the 24th International Conference on Autonomous Agents and Multiagent Systems, *pp. 2997-2999, AAMAS 2025 (published)*

M. Aruta, F. Improta, V. Malvone, A. Murano
Theory and Practice of Natural Strategy Checking in Concurrent Games with Imperfect Information,
23rd International Conference on Practical applications of Agents and Multi-Agent Systems, PAAMS 2025, Lille, France, June 25-27, 2025 *(to be published in proceedings)*

M. Aruta, V. Malvone, A. Murano
S4H: A Tool for Synthesizing Human-Like Strategies,
Multi-Agent Systems: 22st European Conference, EUMAS 2025, Bucharesti, Romania, September 3–5, 2025 *(to be published in proceedings)*

M. Aruta, A. Murano, G. Murano, L. Tecchia
L-CNN: A Convolutional Neural Network for Leukemia predictions,
Innovation in medicine and healthcare systems, and multimedia, KES-InMed-25, Solin, Croatia, June 25-27, 2025 *(to be published in proceedings)*

M. Aruta, C.Listone, A. Murano, G. Murano
ADNF Clustering: An Adaptive and Dynamic NeuroFuzzy Clustering for Leukemia Prediction,
IEEE International Conference on E-health Networking, Application & Services, IEEE Healthcom 2025, Abu Dhabi, UAE, October 21-23, 2025 *(to be published in proceedings)*

M. Aruta, A. Murano, S. Romano
EUMAS 2024 Conference Paper - ATL for Dynamic Gaming Environments
Multi-Agent Systems: 21st European Conference, EUMAS 2024, Dublin, Ireland, August 26–28, 2024, Proceedings. Vol. 15685. Springer Nature, 2025 *(published)*

M. Aruta, V. Malvone, A. Murano
Development of Natural Strategies in Strategic Logics,
Proceedings of the International Workshop on Artificial Intelligence for Climate Change, Italian Workshop on Planning and Scheduling, RCRA Workshop on Experimental evaluation of algorithms for solving problems with combinatorial explosion, and SPIRIT Workshop on Strategies, Prediction, Interaction, and Reasoning in Italy (AI4CC-IPS-RCRA-SPIRIT 2024)
co-located with 23rd International Conference of the Italian Association for Artificial Intelligence AIxIA 2024, November 25-28th, Bolzano, Italy, 2024 *(published)*

M. Aruta, F.Improta, V.Malvone, A. Murano
AAAI 2026 Conference Paper
Fortieth AAAI Conference on Artificial Intelligence (AAAI-26), Singapore from January 20 to January 27, 2026 (submitted)

M. Aruta, F.Belardinelli, W. Jamroga, V. Malvone, M. Mittelmann, A. Murano, L. Perrussel
JAAMAS Journal
(submitted)

E.Ambrosino, M. Aruta, D.Asad, S.Ferrigno, C.Listone, A. Murano, S.Romano, M. Ruopolo
HealthInf 2026 conference paper
Marbella, Spain, March 2-3-4 2026 (submitted)

5. Conferences and seminars attended

I. Innovation in medicine and healthcare systems, and multimedia, ***KES-InMed 25****, Solin, Croatia, June 25-27, 2025 (attended and presented my paper)*
II. Multi-Agent Systems: 22st European Conference, ***EUMAS 2025****, Bucharesti, Romania, September 3–5, 2025 (attended and presented my paper)*
III. IEEE International Conference on E-health Networking, Application & Services, ***IEEE Healthcom 2025****, Abu Dhabi, UAE, October 21-23, 2025 (attended and presented my paper)*
III. 23rd International Conference on Practical applications of Agents and Multi-Agent Systems, ***PAAMS 2025****, Lille, France, June 25-27, 2025 (online paper presentation)*
IV. 28th European Conference on Artificial Intelligence, ***ECAI 2025****, October 25-30, 2025, Bologna, Italy (attended)*
V. 23rd International Conference of the Italian Association for Artificial Intelligence ***AIxIA 2024****, November 25-28th, Bolzano, Italy, 2024 (attended and presented my paper at* ***SPIRIT*** *Workshop)*
VI. Logical Aspects of Multi-Agent Systems & Strategic Reasoning Workshop 2024, LAMAS & SR '24, December 11, 2024, Naples, Italy (attended)
VIII. Five ACAI Tutorials at ESSAI 2025, 30/06/2025 – 04/07/2025, Bratislava, Slovakia (attended)

6. Activity abroad:

7. Activity in partner companies:

8. Tutorship