



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

PhD Student: Maria Gragnaniello

Cycle: XXXIX

Training and Research Activities Report

Academic year: 2024-25 - PhD Year: Second

student signature

Tutor: prof. Michele Riccio

tutor signature

Date: November 10, 2025

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Author: Maria Gragnaniello

1. Information:

- **PhD student:** Maria Gragnaniello **PhD Cycle:** XXXIX
- **DR number:** DR997196
- **Date of birth:** 20/04/1998
- **Master Science degree:** Biomedical Engineering
- **University:** University of Naples Federico II
- **Scholarship type:** PNRR *DM 118/2023*
- **Tutor:** Prof. Michele Riccio
- **Co-tutor:**
- **Period abroad:** six months *to be spent* at University of South Florida (USF), Tampa FL

2. Study and training activities:

Activity	Type ¹	Hours	Credits	Dates	Organizer	Certificate ²
FIT4MEDROB INTERNATIONAL SEASONAL SCHOOL – Robotics and allied technologies for rehabilitation	Seminar	24	3.2	18th-21st November 2024	CNR	Y
Miniaturisation of Optical Spectrometers	Seminar	1	0.2	14th November 2024	Prof. G. Breglio	N
IoT and Embedded Electronic Systems for Industrial and Mechanical Applications: From Sensing and Monitoring to Remote Control	Courses	12	3	31st March-10th April 2025	Prof. A. Borghese	Y
Fiber optic sensing and optoelectronic circuits: design and application.	Courses	15	4	07th to 17th April 2025	Prof V.R. Marrazzo	Y
5G & Digital transformation: a view from an unconventional perspective	Seminar	4	0.8	14 th March 2025	5G Academy	N
Supervised Autonomy: How to Shape Human–Robot Interaction	Doctoral School	28h 45min	6	17th to 21th June 2025	Prof F. Ficuciello	Y
MEMS AND AI Practical Workshop	Seminar	8	1.6	11 th June 2025	STMicroelectronics	Y

1) Courses, Seminar, Doctoral School, Research, Tutorship

2) Choose: Y or N

Training and Research Activities Report

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2.1. Study and training activities - credits earned

	Courses	Seminars	Research	Tutorship	Total
Bimonth 1	0	3.4	6	0	9.4
Bimonth 2	0	0	9	1.2	10.2
Bimonth 3	7	0.8	3	0.2	11
Bimonth 4	6	1.6	4	0	11.6
Bimonth 5	0	0	10	0	10
Bimonth 6	0	0	13	0.2	13.2
Total	13	5.8	45	1.6	65.4
Expected	30 - 70	10 - 30	80 - 140	0 - 4.8	

3. Research activity:

During the second year of my PhD, I consolidated and extended the knowledge and results achieved in the first year. While my previous work focused on implementing 1D convolutional neural networks (CNNs) for biosignal analysis on embedded devices, this phase of research was dedicated to advancing the Edge AI framework by developing and deploying 2D-CNNs architectures directly on microcontrollers. To achieve this, I dedicated significant effort to data preprocessing and signal transformation, ensuring that the input representations were compatible with the computational and memory constraints of low-power embedded platforms. In parallel, I systematically evaluated optimization techniques such as quantization, which allowed me to preserve model accuracy while enabling real-time inference and minimizing energy consumption.

Beyond the classical Edge AI approach, I also explored the concept of Deep Edge AI, assessing the feasibility of implementing simplified neural models directly on the sensing nodes. This distributed intelligence paradigm allows computation to occur at multiple levels, from the sensor to the microcontroller, enabling simultaneous and collaborative processing activities while reducing data transmission requirements.

A central part of my work involved the co-design of hardware, firmware, and AI algorithms, ensuring full integration of the processing pipeline on embedded systems. I contributed to the design of dedicated PCBs for the different biomedical case studies, supporting local signal acquisition and inference. During the validation phase, I used development boards to experimentally evaluate system performance, power consumption, and latency, confirming their suitability for wearable healthcare applications in terms of energy efficiency and responsiveness.

The developed methodology and hardware-software framework were validated through multiple biomedical case studies, each addressing a specific use case:

- Sleep Apnea Detection: development of a portable, non-invasive system based on tracheal signal analysis through embedded CNNs for real-time apnea detection;
- Atrial Fibrillation Detection: comparative evaluation of a cloud-based Lorenz statistical approach versus an embedded neural model, proving the superior efficiency of Edge AI in terms of accuracy, latency, and power;
- Optical Fiber Sensing: analysis of plethysmographic signals acquired via Fiber Bragg Grating (FBG) sensors for heart rate estimation and validation against traditional PPG;

Training and Research Activities Report

PhD in Information Technology and Electrical Engineering

Cycle: XXXIX

Author: Maria Gragnaniello

- Wearable Robotic Control: implementation of Deep Edge AI directly on sensing units for adaptive and intuitive control of a wearable robotic finger.

Overall, my research contributed to strengthening the methodological and technological foundations of embedded intelligence for biomedical systems, demonstrating how both Edge AI and Deep Edge AI can enable autonomous, low-power, and privacy-preserving health monitoring and control, through a multi-level distribution of intelligence, from sensors to microcontrollers, in an integrated and energy-efficient manner.

4. Research products:

Award

First place at the Hackathon organised by the National Research Council as part of the PNRR PNC Fit for Medical Robotics project.

Published Papers

1. Gragnaniello, M.; Marrazzo, V.R.; Borghese, A.; Maresca, L.; Breglio, G.; Riccio, M. Edge-AI Enabled Wearable Device for Non-Invasive Type 1 Diabetes Detection Using ECG Signals. *Bioengineering* 2025, 12, 4. <https://doi.org/10.3390/bioengineering12010004>
2. M. Gragnaniello, T. L. Baldi, E. Landi, G. Salvietti, G. Breglio and M. Riccio, "Deep Edge-AI for Prosthetic Control: Feasibility of ISPU-Based Solutions for a Robotic Extra Limb," 2025 IEEE Medical Measurements & Applications (MeMeA), Chania, Greece, 2025, pp. 1-5, doi: 10.1109/MeMeA65319.2025.11068047.
3. M. Gragnaniello et al., "A Feasibility Assessment on the Use of FBG Sensors for Pulse Wave Detection," 2025 IEEE Medical Measurements & Applications (MeMeA), Chania, Greece, 2025, pp. 1-5, doi: 10.1109/MeMeA65319.2025.11068062.

Accepted Papers

1. M. Cuomo, M. Gragnaniello, E. De Vita, V. Romano Marrazzo, G. Breglio, A. Iadicicco, M. Riccio, and S. Campopiano, "Pulse Wave Analysis Based on Fiber Bragg Gratings," presented at the 2025 INTERNATIONAL WORKSHOP on Biomedical Applications, Technologies and Sensors (BATS), 2025.
2. M. Gragnaniello, F. Mariani, A. Borghese, V. Romano Marrazzo, G. Breglio, A. Irace, and M. Riccio, "A Power Efficient Wearable Solution for Sleep Apnea Diagnosis Based on Tracheal Sounds and on-Device AI," presented at the 2025 INTERNATIONAL WORKSHOP on Biomedical Applications, Technologies and Sensors (BATS), 2025.
3. M. Gragnaniello, E. Andreozzi, D. Esposito, J. Centracchio, G. Breglio, A. Irace, and M. Riccio, "A Force Sensor-Based Approach for Continuous Blood Pressure Monitoring on Wearable Devices," presented at the 2025 INTERNATIONAL WORKSHOP on Biomedical Applications, Technologies and Sensors (BATS), 2025.

Submitted Papers

1. M. Cuomo, M. Gragnaniello, E. De Vita, V. Romano Marrazzo, G. Breglio, A. Iadicicco, M. Riccio, and S. Campopiano, "Pulse Wave Detection Using Fiber Optic Sensors: Comparison with Multiwavelength Photoplethysmography Devices," *IEEE Transactions on Instrumentation & Measurement*, 2025.

Training and Research Activities Report

PhD in Information Technology and Electrical Engineering

Cycle: XXXIX

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- E. Cinotti, M. Gragnaniello, S. Parlato, J. Centracchio, E. Andreozzi, P. Bifulco, M. Riccio, and D. Esposito, "An Edge-AI approach for low-power, real-time atrial fibrillation detection on wearable devices based on heartbeat intervals," *Sensors*, 2025.

5. Conferences and seminars attended

- FIT4MEDROB International Seasonal School – “Robotics and Allied Technologies for Rehabilitation”**

Organizer: National Research Council (CNR)

Place & Dates: 18th–21st November 2024

Description: Participated in the international seasonal school focused on robotic systems and assistive technologies for rehabilitation.

- Doctoral Course – “Supervised Autonomy: How to Shape Human–Robot Interaction”**

Organizer: Prof. Fanny Ficuciello

Place & Dates: 17th–21st June 2025

Description: Attended the 28-hour course on supervised autonomy and adaptive control in human–robot interaction.

- MEMS and AI Practical Workshop**

Organizer: STMicroelectronics

Place & Date: 11th June 2025

Description: Participated in the 8-hour workshop focused on the integration of AI with MEMS sensors and embedded platforms.

- IEEE International Symposium on Medical Measurements and Applications (MeMeA 2025)**

Place & Dates: Chania, Greece, 28th–30th May 2025

Presented Papers (oral presentation):

- “Deep Edge-AI for Prosthetic Control: Feasibility of ISPU-Based Solutions for a Robotic Extra Limb”

(M. Gragnaniello, T. L. Baldi, E. Landi, G. Salvietti, G. Breglio, and M. Riccio)

- “A Feasibility Assessment on the Use of FBG Sensors for Pulse Wave Detection”

(M. Gragnaniello et al.)

- 56th Annual Meeting of the Italian Electronics Society (SIE 2025)**

Place & Dates: Naples, Italy, 25th–27th June 2025

Presentation: Poster entitled “Low-Power Embedded AI for Wearable Robotic Finger Control via Inertial Sensing and ARM Cortex-M4 Microcontroller.”

6. Periods abroad and/or in international research institutions

A six-month research period will be spent at the University of South Florida (Tampa, FL), under the supervision of Prof. Dr. Stephen E. Sadow, from November 3rd, 2025, to May 3rd, 2026.

7. Tutorship

- Participation in the event “Porte Aperte Ingegneria 2025” (February 12th, 2025), providing 4 hours of assistance for student reception and orientation.

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- Co-supervision of MSc student Marianna Rullo, thesis entitled “Development of Edge AI Solutions Using IMU Sensors and STM32 Microcontrollers for the Control of an Artificial Sixth Finger.”
- Co-supervision of MSc student Federica Mariani, thesis entitled “Hardware Design of a Wearable Device and Development of a CNN for Sleep Apnea Monitoring through Edge AI Techniques.”
- Co-supervision of MSc student Sara Balletta, thesis entitled “Application of the IoT 5.0 Paradigm to Real-Time Atrial Fibrillation Detection Using an Embedded Wearable Device.”
- Co-supervision of MSc student Anna Cacciapuoti, thesis entitled “Firmware Development and Hardware Integration of a Wearable Device with Edge AI for Sleep Apnea Monitoring.”
- Co-supervision of MSc student Luisa Tesone, thesis entitled “Development and Experimental Validation of Integrated Circuits in Wearable Applications: Biopotential Monitoring Using ST-Qvar Technology.”
- Co-supervision of MSc student Elena Zennamo, thesis entitled “New Hardware Frontiers for Edge AI: The New STM32N6 MCU and the Case Study of Skin Lesion Assessment.”

8. Plan for year three

During the third year of my PhD, the research activity will focus on the development of a final integrated application that brings together all the results and methodologies achieved during the first two years.

The main goal is to design and implement a complete wearable system, capable of operating autonomously and efficiently, based on the Edge AI paradigm and able to perform the entire biosignal processing pipeline directly on the device. This activity will integrate the preprocessing, hardware design, and neural network optimization techniques for low-power operation previously developed, consolidating them into a single application framework. Within this context, I will investigate and implement advanced power optimization strategies, both at the firmware and hardware levels, to minimize current consumption and extend the operational lifetime of the device. Specifically, the work will explore dynamic power management, duty cycling, intelligent sleep/wake scheduling, and data path optimization, aiming to maximize system efficiency without compromising the performance of the embedded artificial intelligence. From an experimental research perspective, the system will be validated through a real biomedical case study, chosen for its clinical relevance and for the possibility of comparison with existing commercial or cloud-based solutions. Furthermore, national and international collaborations will be strengthened with research groups active in the fields of Edge AI and embedded systems for healthcare.

A research period abroad is also planned, at University of South Florida to exchange methodologies, validate the proposed solutions, and expand scientific collaboration networks.

In parallel, I will complete the writing of the PhD thesis, with the provisional title: “Energy-Efficient Electronic Systems for Edge-AI-Based Healthcare Monitoring”.