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

# PhD Student: Eliana Cinotti

**Cycle: XXXIX**

## Training and Research Activities Report

**Academic year: 2024-25 - PhD Year: Second**

Eliana Cinotti

**Tutor: Prof. Paolo Bifulco** Paolo Bifulco

**Co-Tutor: Prof. Emilio Andreozzi**

**Date: October 31, 2025**

# Training and Research Activities Report

PhD in Information Technology and Electrical Engineering

**Cycle:** XXXIX **Author:** Eliana Cinotti

## 1. Information:

- **PhD student:** Eliana Cinotti **PhD Cycle:** XXXIX
- **DR number:** DR997207
- **Date of birth:** 18/04/1998
- **Master Science degree:** Biomedical Engineering **University:** University of Naples Federico II
- **Scholarship type:** PNRR-Partenariato Esteso PE14-"RESTART - RESearch and innovation on future Telecommunications systems and networks, to make Italy more smART"
- **Tutor:** Prof. Paolo Bifulco
- **Co-tutor:** Prof. Emilio Andreozzi
- **Period abroad:**
  - From 1st November 2024 to 30th November 2024, at Department of Mechanical, Biomedical and Design Engineering, Aston University, Birmingham B47 7ET, UK, under the supervision of Prof. Antonio Fratini.
  - From 5th October 2025 to 31st October 2025 at Department of Electronic Engineering and Communications, University of Zaragoza, María de Luna, 3, 50018, Zaragoza, Spain, under the supervision of Prof. Pablo Laguna.

## 2. Study and training activities:

| Activity | Type[1] | Hours | Credits | Dates | Organizer | Certificate[2] |
|---|---|---|---|---|---|---|
| Shaping robustly control loop: look into stability Margins & uncertainties 05 December 2024 | Seminar | 1 | 0.2 | 05/12/2024 | Prof. Ciro Visone | Y |
| Research activity abroad: development of a sensorised garment for vital signs monitoring | Research | | 5 | 01/11/2024 - 30/11/2024 | | |
| Vital signs monitoring via smartphone inertial sensors | Research | | 2 | 01/11/2024 - 31/12/2024 | | |
| Design methodologies for digital circuits and systems oriented to FPGA | Ad hoc course | 12 | 2.4 | 28/02/2025 | Dr. Gennaro Di Meo | Y |
| Can we Rely on AI? Reliability Issues in Artificial Neural Networks and Potential | Seminar | 1 | 0.2 | 16/01/2025 | Dr. Edoardo Giusto | Y |

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| Solutions for Autonomous Vehicles | | | | | | |
| The Good, the Bad, and the Ugly in Quantum Computing: Computational Power, Intrinsic Noise, and Transient Faults | Seminar | 1 | 0.2 | 17/01/2025 | Dr. Edoardo Giusto | Y |
| Optimisation-based Control of Flexible Resources in Sustainable Energy Network | Seminar | 1 | 0.2 | 05/02/2025 | Prof. Luigi Glielmo | Y |
| Emergent behaviors and collective decisions in cyber-physical-human systems | Seminar | 1 | 0.2 | 13/02/2025 | Dr. Alessandro Della Pia | Y |
| Review and publication of the journal paper: "Accuracy of the Instantaneous Breathing and Heart Rates Estimated by Smartphone Inertial Units" | Research | | 2 | 01/01/2025 - 28/02/2025 | | |
| Submission and review of the journal paper: "A New Flexible PVDF Sensor for Forcecardiography" | Research | | 3 | 01/01/2025 - 28/02/2025 | | |
| Study on the current state of the art regarding remote monitoring devices for patients with Arteriovenous Fistula (AVF) | Research | | 5 | 01/01/2025 - 28/02/2025 | | |
| Co-supervisor for the Thesis entitled: "Progetto e sviluppo di un sistema prototipale per il monitoraggio non invasivo dell'attività cardiaca elettro-meccanica" by the candidate Daniele Longobardo | Tutorship | | 0.3 | 01/01/2025 - 28/02/2025 | | |
| Staff member for: "Open Day: Porte | Tutorship | | 0.2 | 13/02/2025 | | |

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| Aperte Ingegneria 2025 - UNINA" | | | | | | |
| 5G & Digital Transformation: a view from an Unconventional perspective second edition | Seminar | 4 | 0.8 | 14/03/2025 | Prof.ssa Antonia Maria Tulino | Y |
| Study on different types of cardiac mechanical signals and their acquisition. | Research | | 2 | 01/03/2025 - 30/04/2025 | | |
| Auditor at the "Telecommunications of the Future – Solutions for Telecommunications & Telecommunications as a Solution" conference, promoted by CNIT (Consorzio Nazionale Interuniversitario per le Telecomunicazioni) and by RESTART Foundation | Research | | 1 | 08/04/2025 - 09/04/2025 | | |
| Development of a novel device for monitoring patients with AVF | Research | | 5 | 01/03/2025 - 30/04/2025 | | |
| Speaker/Tutor for PCTO program - "Percorsi per la Competenze Trasversali e l'Orientamento" | Tutorship | | 0.2 | 28/03/2025 | | |
| Staff member for: "Career Day" UNINA | Tutorship | | 0.1 | 03/04/2025 | | |
| Unveiling the faintest side of the Universe: discoveries, structure and open issues on ultra-diffuse galaxies | Seminar | 1 | 0.2 | 08/05/2025 | Dr. Francesco Bajardi | Y |
| The Strong Crystalline Field: or how to play with particle beams using tiny crystals | Seminar | 1 | 0.2 | 15/05/2025 | Dr. Francesco Bajardi | Y |
| Numerical analysis for the dynamics of delay equations | Seminar | 1 | 0.2 | 22/05/2025 | Dr. Alessandro Della Pia | Y |

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| Superconducting Radio Frequency Cavities for Quantum Computing and Communication | Seminar | 1 | 0.2 | 24/06/2025 | Prof. Edoardo Giusto | Y |
| Trusted Execution Environments for QPUs | Seminar | 1 | 0.2 | 27/06/2025 | Prof. Edoardo Giusto | Y |
| Development of a novel device for monitoring AVF patients | Research | | 4 | 01/05/2025 - 30/06/2025 | | |
| Attendance at the AIIC congress 2025 - Associazione Italiana Ingegneri Clinici and presentation of three posters | Research | | 3 | 14/06/2025 - 17/06/2025 | | |
| Strumentazione e ingegneria clinica | MSc course | 72 | 9 | 01/07/2025 | Prof. Paolo Bifulco | Y |
| Reconfigurable femtosecond-laser-written interferometers for quantum photonics | Seminar | 1 | 0.2 | 03/07/2025 | Prof. Andrea Crespi | Y |
| Affidabilità dell'AI: è possibile definire dei confini accettabili consapevolmente? | Seminar | 2 | 0.4 | 08/07/2025 | Prof. Leopoldo Angrisani, | Y |
| Acquisition and processing physiological signals from patients with AVF | Research | | 2 | 01/07/2025 - 31/08/2025 | | |
| Acquisition of Forcecardiography signals from patients with heart failure | Research | | 1 | 01/07/2025 - 31/08/2025 | | |
| Preparation and submission of the paper “A novel system to record pulses, thrills, and bruit sounds generated by arteriovenous fistulas” | Research | | 2 | 01/07/2025 - 31/08/2025 | | |
| Co-Supervision of a MSc thesis based on the development of a wearable which analyses ECG signals in real time using an artificial intelligence algorithm to detect | Tutorship | | 0.2 | 01/07/2025 - 31/08/2025 | | |

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| Atrial Fibrillation (AF) events | | | | | | |
| XLIV Annual School GNB "Unlocking the Mind and Emotions" | PhD School | | 3 | 15/09/2025 - 18/09/2025 | | Y |
| Acquisition and processing physiological signals from patients with AVF. | Research | | 1 | 01/09/2025 - 31/10/2025 | | |
| Acquisition of Forcecardiography signals from patients with heart failure | Research | | 1 | 01/09/2025 - 31/10/2025 | | |
| Revision of the paper "A novel system to record pulses, thrills, and bruit sounds generated by arteriovenous fistulas" | Research | | 1 | 01/09/2025 - 31/10/2025 | | |
| Submission of the conference paper: "Spectral Analysis of AVF Signals for Early Dysfunction Detection: Towards AI-Based Home Monitoring" | Research | | 1 | 01/09/2025 - 31/10/2025 | | |
| Study on the comparison between Electromyographic (EMG) and Forcemyographic (FMG) signals | Research | | 1 | 01/09/2025 - 31/10/2025 | | |
| Research activities abroad: study on cardio-mechanical signals from patients undergoing Cardiac Resynchronisation Therapy (CRT) and non-invasive blood pressure measurements via Forcecardiography | Research | | 3 | 05/10/2025 - 31/10/2025 | | |
| Co-Supervision of a MSc Thesis entitled: "Applicazione del Paradigma IoT 5.0 al Rilevamento in Tempo Reale della Fibrillazione | Tutorship | | 0.3 | 01/09/2025 - 30/09/2025 | | |

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| Atriale mediante Dispositivo Wearable Embedded" by the candidate Sara Balletta | | | | | | |
| 2025 Spring School on Transferable Skills | Course | 9 | 2 | 30-31/10/2025 | Department of Pharmacy University of Naples Federico II | Y |

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 | **0** | **0.2** | **7** | **0** | **7.2** |
| Bimonth 2 | **2.4** | **0.8** | **10** | **0.5** | **13.7** |
| Bimonth 3 | **0** | **0.8** | **8** | **0.3** | **9.1** |
| Bimonth 4 | **0** | **1** | **7** | **0** | **8** |
| Bimonth 5 | **9** | **0.6** | **5** | **0.2** | **14.8** |
| Bimonth 6 | **2** | **3** | **8** | **0.3** | **13.3** |
| **Total** | **13.4** | **6.4** | **45** | **1.3** | **66.1** |
| **Expected** | **10 - 20** | **5 - 10** | **30 - 45** | **0 – 1.6** | |

## 3. Research activity:

During my first second of Ph.D. course I carried out two research activities within my research field, namely "Monitoring of vital signs via personal devices" and "Novel devices based on IoT and Edge-AI for diagnosis of cardiac diseases".

- **Monitoring of vital signs via personal devices**

During the first part of the year, I investigated the use of inertial sensors integrated in personal devices, such as the smartphone, for monitoring vital signs. Cardiovascular diseases and their consequences still affect a considerable percentage of the population, so health monitoring would allow for continuous information gathering, enabling more timely recognition of acute conditions or developing diseases. This would enable the population to be more aware of their own health conditions and allow them to better manage their physical conditions, thus achieving a good degree of autonomy. The most widely used personal devices are smartphones, which have become essential elements of modern daily life. Their built-in electronic components can be leveraged to assess individuals' physiological status outside clinical settings.
Nowadays, accelerometers and gyroscopes are widely integrated into smart phones, thus increasing the potential of seismocardiography (SCG) and gyrocardiography (GCG) as cardiorespiratory monitoring tools. These two signals use lightweight, miniaturized accelerometers and gyroscopes to record, respectively, cardiac-induced linear accelerations and angular velocities of the chest wall.

In recent years, the use of smartphone inertial sensors for the acquisition of cardiomechanical signals has been investigated. However, a comparison between accelerometers and gyroscopes in terms of the estimation accuracy of both the heart rate and breathing rate has never been carried out. For this topic, experimental tests on a cohort of healthy subjects at rest in a supine position under quiet breathing conditions. Accelerometric and gyroscopic signals derived from smartphones were recorded using an open-source application. The performance of heartbeat and respiratory act detection, as well as the estimation of inter-beat intervals (IBIs) and inter-breath intervals (IBrIs), was assessed against reference techniques through statistical analyses.
The study demonstrated that instantaneous heart and breathing rates can be accurately estimated from accelerometric and gyroscopic signals acquired via inertial sensors embedded in a smartphone. Heartbeats were detected from these signals using an ECG-independent template matching approach. Respiratory acts were monitored by tracking thoracic movements, which reflect on accelerometric and gyroscopic signals as baseline wanderings.
Regarding the mechanical activity of the heart, I carried out a research activity abroad that focused on the acquisition of cardiomechanical signals using Forcecardiography (FCG) sensors applied to the chest. Since multiple sensors can be positioned simultaneously, it is possible to develop a sensor array capable of recording signals from different chest locations, thereby enabling a more comprehensive analysis of the relationship between the forces generated by the heart and the resulting cardiac movements. To this end, a sensorised garment was developed, with sensors carefully positioned at specific chest sites to capture the most relevant information about cardiac motion.

- **Novel devices based on IoT and Edge-AI for diagnosis of cardiac diseases**

During my second year I pursued the research I had begun the previous year about the detection of Atrial Fibrillation (AF) events. I carried out studies on existing devices and algorithm to better investigate the current state of the art about early detection of cardiac diseases. AF is considered a 21st century cardiovascular disease epidemic and is currently acknowledged as the most prevalence cardiac arrhythmia. AF episodes occur suddenly and short-lived, generally characterised by an irregular heartbeat, and are diagnosed using electrocardiography (ECG). To detect these episodes, long-term heart rate monitoring is important, which is better than intermittent monitoring. Currently, devices used for the detection of atrial fibrillation (AF) are Holter ECG monitors, which provide limited monitoring (up to 48 hours) and are often insufficient for capturing sporadic AF episodes. Implantable loop recorders allow for prolonged monitoring but require a surgical procedure for implantation. A prototype personal device has been developed for daily, continuous use. Furthermore, the integration of the Internet of Things (IoT), in particular narrowband IoT (NB-IoT), enables connection to the cloud for the analysis and sharing of physiological data with healthcare professionals. The software for recognising atrial fibrillation events runs on the cloud and generates alerts when it recognises such an arrhythmia. The prototype hardware device made is of a small size and has low power consumption.
Another focus of my research is the integration of artificial intelligence algorithms (AI) to improve AF detection, where the entire analysis is performed on the device, and cloud connectivity is used exclusively to alert the physician in the event of an AF episode. The AF detection algorithm, particularly the Lorenz algorithm, was implemented on the microcontroller, and a neural network was developed. This improves the accuracy of cardiac anomaly detection by excluding portions of the ECG signal that do not contain clear information. For example, segments may be corrupted by artifacts or be

clinically irrelevant. A neural network trained to recognize these events prevents them from being analysed by the AF detection algorithm, thereby enhancing overall reliability.
Another approach relies solely on an AI-based method, without using classical algorithms such as the Lorenz algorithm. An embedded neural network analyses only the inter-beat intervals to detect AF episodes. The device continuously records the ECG signal and processes it in real time to identify heartbeats and calculate inter-beat intervals. The resulting time series are sent to a microcontroller, where a convolutional neural network is implemented to detect AF episodes. A one-dimensional convolutional neural network (1D-CNN) was implemented for the classification of heart rhythms when the input data consists of a sequence of RR intervals (specifically, sequences of 25, 50, and 100 RR were analysed). The model's performance improved as the RR window increased. In fact, the model's accuracy increased from 0.951 (25RR) to 0.965 (50RR) and 0.978 (100RR). This approach lays the foundation for an alternative type of analysis that goes beyond the traditional method of cardiac monitoring based solely on ECG. By analysing only the intervals between beats, it becomes possible to incorporate a variety of physiological signals, which can then be processed by a neural network capable of detecting AF events solely from this small amount of data. This enables the development of wearable devices for AF detection with the advantage of reducing memory requirements.

- **Other research activities**

During my second year of PhD course, together with my research group, I also investigated the use of FCG sensors for monitoring patients with the arteriovenous fistula (AVF), which is the preferred vascular access for haemodialysis. AVF consists of an artificial connection between an artery and a vein. One of the possible complications of arteriovenous fistula (AVF) is stenosis, which, if not diagnosed in time, can cause dysfunction and discomfort for the patient.
The focus of this work was the design of a device capable of continuously monitoring the arteriovenous fistula (AVF) to reduce the number of in-person clinical visits, optimize the involvement of multiple healthcare professionals, and increase the likelihood of detecting the early onset of stenosis in a timely manner. The proposed system is based on a piezoelectric vibration sensor that simultaneously records the palpable and audible pulsations and vibrations of the arteriovenous fistula (AVF), like those analysed by doctors through manual palpation. It extracts multiple characteristics from these signals, which are then processed by an artificial intelligence algorithm for the diagnosis of stenosis.
Another research topic focused on the analysis of Forcecardiography (FCG) signals to investigate clinical information that can be extracted from them. To this aim, together with my research group, I developed a new device consisting of an array of FCG sensors positioned at different points on the patient's chest to study the mechanical activity of the heart. To compare FCG signals against reference techniques, a data acquisition campaign was conducted on healthy patients and patients with heart problems, involving the simultaneous acquisition of Forcecardiographic (FCG) signals, Elettrocardiographic (ECG) signals and Echocardiographic signals.
To investigate other potential fields of application of FCG sensors, another research topic involved the study of FCG signals acquired on patients undergoing Cardiac Resynchronization Therapy (CRT). The main objective was to extract information from FCG signals to optimize the setting of pacemaker parameters during implantation or during monitoring. This requires careful analysis and comparison of the data acquired from force signals positioned on the patient's chest and electrocardiographic signals acquired simultaneously.

A further research topic focused on the use of FCG sensors for continuous measurement of blood pressure via the calculation of pulse transit time over the aorta artery. Specifically, an increase in blood pressure is associated with increased aortic stiffness and a reduction in transit time.
Research has also been conducted on force signals, comparing Forcemyography (FMG) signals with Electromyography (EMG) signals to estimate instantaneous muscle force during isometric contractions.

## 4. Research products:

### a. Scientifics papers:

- Cinotti, E.; Centracchio, J.; Parlato, S.; Esposito, D.; Fratini, A.; Bifulco, P.; Andreozzi, E. Accuracy of the Instantaneous Breathing and Heart Rates Estimated by Smartphone Inertial Units. Sensors 2025, 25, 1094. https://doi.org/10.3390/s25041094;
- Parlato, S.; Centracchio, J.; Cinotti, E.; Gargiulo, G.D.; Esposito, D.; Bifulco, P.; Andreozzi, E. A Flexible PVDF Sensor for Forcecardiography. *Sensors* **2025**, *25*, 1608. https://doi.org/10.3390/s25051608;
- Parlato, S., Centracchio, J., Cinotti, E. et al. A Forcecardiography dataset with simultaneous SCG, Heart Sounds, ECG, and Respiratory signals. Sci Data 12, 1370 (2025). https://doi.org/10.1038/s41597-025-05694-2;
- Centracchio, J., Cinotti, E., Parlato, S., Bifulco, P., Zamboli, P., Liguori, R., Longo, G., Punzi, M., Liccardo, A., Buonavolontà, F., Capolongo, G., Andreozzi, E. A novel system to record pulses, thrills, and bruit sounds generated by arteriovenous fistulas, Sensors International, accepted;
- Cinotti, E., Gragnaniello, M., Parlato, S., Centracchio, J., Andreozzi, E., Bifulco, P., Riccio, M., Esposito, D. An Edge-AI approach for low-power, real-time atrial fibrillation detection on wearable devices based on heartbeat intervals, Sensors, submitted;
- Liguori, R., Longo, G., Di Benedetto, L., Licciardo, G.D., Centracchio, J., Parlato, S., Cinotti, E., Andreozzi, E., Buonavolontà, F., Liccardo, A., Zamboli, P., Punzi, M., Capolongo, G. Spectral Analysis of AVF Signals for Early Dysfunction Detection: Towards AI-Based Home Monitoring, IEEE BATS 2025**,** accepted conference paper;

## 5. Conferences and seminars attended

Attendance at the conference as an auditor "Telecommunications of the Future – Solutions for Telecommunications & Telecommunications as a Solution", promoted by CNIT (Consorzio Nazionale Interuniversitario per le Telecomunicazioni) and by RESTART Foundation, 8th and 9th April 2025.

Attendance at the AIIC congress 2025 - Associazione Italiana Ingegneri Clinici, from 14th to 17th June 2025 and presentation of three posters:

a. Cinotti, E.; Parlato, S.; Gragnaniello, M.; Centracchio, J. "Dispositivo indossabile per il riconoscimento di aritmie con tecniche Edge-AI";

b. Parlato, S.; Cinotti, E.; Centracchio, J.; "Bracciale sensorizzato per il monitoraggio continuo del ritmo cardiaco: un'alternativa allo smartwatch";
c. Centracchio, J.; Parlato, S.; Cinotti, E.; Andreozzi, E.; "Sistema di telemonitoraggio per la fistola arterovenosa".

Attendance at the XLIV Annual School GNB "Unlocking the Mind and Emotions" in Pisa from 15th to 18th September 2025.

## 6. Periods abroad and/or in international research institutions

Period and research activity abroad was spent from 1st November 2024 to 30th November 2024, at Department of Mechanical, Biomedical and Design Engineering, Aston University, Birmingham B47 7ET, UK, under the supervision of Prof. Antonio Fratini. I spent one month abroad, and during this period I focused on analysing mechanical activity and monitoring these signals by developing a prototype sensorised garment, positioning sensors at different points on the chest to better study the relationship between the forces generated by the heart and the resulting cardiac movements.

Period and research activity abroad was spent from 5th October 2025 to 31st October 2025 at Department of Electronic Engineering and Communications, University of Zaragoza, María de Luna, 3, 50018, Zaragoza, Spain, under the supervision of Prof. Pablo Laguna. During this period, I conducted research on cardiological diseases in Cardiac Resynchronization Therapy (CRT) patients, developing new software to analyse their biological signals. The main objective is to investigate FCG signals through the monitoring methodologies currently utilized in clinical practice. In addition, I conducted research on non-invasive blood pressure measurement systems and signal analysis via the calculation of the pulse transit time over the aorta artery.

During my second year I spent two months abroad.

## 7. Tutorship

Co-supervisor for the Thesis entitled: "Progetto e sviluppo di un sistema prototipale per il monitoraggio non invasivo dell'attività cardiaca elettro-meccanica" by the candidate Daniele Longobardo;

Staff member for: "Open Day: Porte Aperte Ingegneria 2025 - UNINA";

Speaker/Turor for PCTO program - "Percorsi per la Competenze Trasversali e l'Orientamento";

Staff member for: "Career Day" UNINA;

Co-Supervision of a MSc Thesis entitled: "Applicazione del Paradigma IoT 5.0 al Rilevamento in Tempo Reale della Fibrillazione Atriale mediante Dispositivo Wearable Embedded" by the candidate Sara Balletta. The Thesis topic is the development of a wearable which analyses ECG signals in real time using an artificial intelligence algorithm to detect Atrial Fibrillation (AF) events.

## 8. Plan for year three

Next year, I will mainly focus on techniques for detecting AF (atrial fibrillation) events and on the extraction of relevant clinical information from FCG signals. I plan to continue the research activity started during my PhD, aimed at developing new wearable devices for health monitoring and disease detection, which will be the topic of my PhD thesis.
The projects will also include a cloud connectivity component, allowing continuous monitoring of physiological parameters. This feature will enable physicians to remotely access patient data in real time, providing more accurate and timely assessments of the patient's health condition.

During the first month of the third year, I will continue my international research period in Zaragoza, Spain.