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UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

**DOTTORATO DI RICERCA / PhD PROGRAM IN  
INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING**

## **Activities and Publications Report**

# PhD Student: **Jessica Centracchio**

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**Student ID: DR993886**

**PhD Cycle: XXXV**

**PhD Cycle Chairman: Prof. Stefano Russo**

**PhD program student's start date: November 1, 2019**

**PhD program student's end date: January 31, 2023**

**Supervisor: Prof. Paolo Bifulco**

**e-mail: [paolo.bifulco@unina.it](mailto:paolo.bifulco@unina.it)**

**PhD scholarship funding entity:**

*University of Naples "Federico II"*

### General information

Jessica Centracchio received in year 2019 the Master Science degree in Biomedical Engineering from the University of Naples “Federico II”. She attended a curriculum in Biomedical Engineering within the PhD program in Information Technology and Electrical Engineering. She received a grant from University of Naples “Federico II”

### Study activities

#### Attended Courses

Year	Course Title	Type	Credits	Lecturer	Organization
1 <sup>st</sup>	“Intelligenza Artificiale ed Etica: la ricerca in IA alla prova delle sfide etiche”	Ad hoc course	1.2	Prof. Daniele Amoroso, Dipartimento di Giurisprudenza, Università di Cagliari; Prof. Piero A. Bonatti, DIETI, Università di Napoli Federico II; Prof. José M. Galvan, Dipartimento di Teologia Morale, Pontificia Università della Santa Croce, Roma; Dr. Riccardo Guidotti, KDD-Lab – ISTI-CNR, Pisa; Prof. Paola Inverardi, DISIM, Università degli Studi dell’Aquila; Prof. Roberto Prevete; Dr. Luciano Serafini, ICT, Fondazione Bruno Kessler, Trento; Prof. Viola Schiaffonati, Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano	DIETI
1 <sup>st</sup>	“Scientific Programming and Visualization with Python”	Ad hoc course	2	Prof. Alessio Botta	DIETI
1 <sup>st</sup>	“Innovation Management,	Ad hoc	5	Prof. Pierluigi Ripa	UNINA – StartCup

## Activities and Publications – Final Report

UNINA PhD in Information Technology and Electrical Engineering – XXXV Cycle

PhD candidate: Jessica Centracchio

	entrepreneurship and intellectual property”	and course	Dipartimento di Ingegneria Industriale, Università degli Studi di Napoli “Federico II”; Prof. Michele Simoni, Dipartimento di Studi Aziendali e Quantitativi, Università degli Studi di Napoli “Parthenope”; Prof. Adele Parmentola, Dipartimento di Studi Aziendali e Quantitativi, Università degli Studi di Napoli “Parthenope”; Prof. Francesco Izzo, Dipartimento di Economia, Università degli Studi della Campania Luigi Vanvitelli; Prof. Francesco Schiavone, Dipartimento di Studi Aziendali e Quantitativi, Università degli Studi di Napoli “Parthenope”; Prof. Raffaele Fiorentino, Dipartimento di Studi Aziendali ed Economici, Università degli Studi della Campania Luigi Vanvitelli; Prof. Davide Dell’Anno, Dipartimento di Economia, Università degli Studi della Campania Luigi Vanvitelli; Domenico Ferrara, Università degli Studi della	Campania 2020
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## Activities and Publications – Final Report

UNINA PhD in Information Technology and Electrical Engineering – XXXV Cycle

PhD candidate: Jessica Centracchio

				Campania Luigi Vanvitelli; Olga Capasso, De Simone & Partners – Intellectual Property Attorneys; Massimo Varrone, Head of Incubator at Campania Newsteel; Prof. Alessandro Scaletti, Dipartimento di Studi Aziendali e Quantitativi, Università degli Studi di Napoli “Parthenope”; Gianpiero Bruno, Incubatore Centro Servizi Napoli Est;	
1 <sup>st</sup>	“Strategic Orientation for STEM Research & Writing”	Ad hoc course	3.6	Dr. Chie Shin Fraser	ITEE
1 <sup>st</sup>	“Machine Learning”	Ad hoc course	4	Dr. Marco Aiello, Istituto di Ricerca IRCCS SDN, Napoli, Prof. Anna Corazza; Prof. Diego Gagnaniello; Prof. Francesco Isgrò; Prof. Roberto Prevete; Prof. Francesco Raimondi, Dipartimento di Scienze mediche traslazionali, Università degli Studi di Napoli “Federico II”; Prof. Carlo Sansone	ITEE-ICTH
1 <sup>st</sup>	“Computer Interface for Biological Systems”	MSc course	6	Prof. Paolo Bifulco	UNINA Polytechnic and Fundamental Sciences School
2 <sup>nd</sup>	“Professional skills in clinical environment for biomedical engineering”	Ad hoc course	2	Prof. Giovanni D’Addio	DIETI
2 <sup>nd</sup>	“Sistemi per ricostruzione delle immagini TC”	Ad hoc course	1.2	Dr. Maurizio Centonze, UO	Scuola Medica Ospedaliera della

## Activities and Publications – Final Report

UNINA PhD in Information Technology and Electrical Engineering – XXXV Cycle

PhD candidate: Jessica Centracchio

				<p>Diagnostica per immagini APSS Trento; Dr. Davide Ippolito, UOC Radiodiagnostica Ospedale San Gerardo; Dr. Fabio Falzea, Resp. Cardiologia in Ecrad, Is. IC. De Blasi, Sirio, Villa Serena, Biocontrol; Dr. Carlo Liguori, UOC Diagnostica per immagini ASL Napoli 1; Eng. Giovanni Guizzetti, UOC Ingegneria Clinica ASST Pavia; Fabiano Caprotti, GE; Ilaria Crippa, SIEMENS; Alfredo Sanguinetti, PHILIPS; Silvia Magnani, CANON</p>	Campania
2 <sup>nd</sup>	“Data Science for Patient Records Analysis”	Ad hoc course	2.5	<p>Prof. Marcello Cinque; Prof. Carmela Bravaccio, Dipartimento di Scienze mediche traslazionali, Università degli Studi di Napoli “Federico II”</p>	ITEE-ICTH
2 <sup>nd</sup>	“Statistical Data Analysis for Science and Engineering Research”	Ad hoc course	4	<p>Prof. Roberto Pietrantuono</p>	DIETI
2 <sup>nd</sup>	“Matrix Analysis for Signal Processing with Matlab Examples”	Ad hoc course	2	<p>Prof. Antonio De Maio, Prof. Augusto Aubry, Dr. Vincenzo Carotenuto</p>	ITEE-DIETI
3 <sup>rd</sup>	“Biosignals Measurement and Analysis”	Ad hoc course	4	<p>Dr. Emilio Andreozzi</p>	DIETI
3 <sup>rd</sup>	“Muscle-based Human Machine Interfaces”	Ad hoc course	2.6	<p>Dr. Daniele Esposito; Prof. Gaetano D. Gargiulo, School of Engineering, Design</p>	DIETI

## Activities and Publications – Final Report

UNINA PhD in Information Technology and Electrical Engineering – XXXV Cycle

PhD candidate: Jessica Centracchio

				and Built Environment, Western Sydney University	
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### Attended Seminars

Year	Seminar Title	Credits	Lecturer	Lecturer affiliation	Organization
1 <sup>st</sup>	“Marked point processes for object detection and tracking in high resolution images: application to remote sensing data”	0.2	Prof. Josiane Zerubia	INRIA Sophia Antipolis Méditerranée	DIETI
1 <sup>st</sup>	“Computational Biology: Large scale data analysis to understand the molecular bases of human diseases”	0.2	Prof. Michele Ceccarelli	DIETI	DIETI
1 <sup>st</sup>	“Elettromagnetismo e Salute”	0.2	Prof. Rita Massa	Dipartimento di Fisica "Ettore Pancini", Università degli Studi di Napoli “Federico II”	DIETI – Dipartimento di Fisica “Ettore Pancini”
1 <sup>st</sup>	BCI & NEUROTECHNOLOGY SPRING SCHOOL 2020 <a href="https://www.gtec.at/spring-school-2020/">https://www.gtec.at/spring-school-2020/</a>	6	Dr. Christoph Guger	g.tec medical engineering GmbH (AT)	g.tec medical engineering GmbH (AT)
1 <sup>st</sup>	“La programmazione europea e la ricerca. Nuovi scenari della programmazione europea dopo il 2020. La gestione di un progetto di ricerca”	0.4	Prof. Filippo Ammirati	Project Manager & Innovation Management Consultant, Tec Up, San Giuseppe Vesuviano, Campania, Italy	Innovation Village 2020
1 <sup>st</sup>	“Noninvasive Mapping of Electrical Properties using MRI”	0.3	Prof. Riccardo Lattanzi	Grossman School of Medicine, Department of Radiology, New York University, USA	DIETI – Dipartimento di Fisica “Ettore Pancini”
2 <sup>nd</sup>	“Telemedicina in Italia: i casi di successo”	0.3	Dr. Maurizio Nardi	HTN s.r.l.	DIETI
2 <sup>nd</sup>	“Robot manipulation and control”	0.5	Prof. Bruno Siciliano	DIETI	DIETI
2 <sup>nd</sup>	“Digital Project Management: prassi, processi, tecniche,”	0.2	Prof. Dario Carotenuto	Project Management Institute	DIETI – Dipartimento di Fisica “Ettore Pancini”

## Activities and Publications – Final Report

UNINA PhD in Information Technology and Electrical Engineering – XXXV Cycle

PhD candidate: Jessica Centracchio

	strumenti e approccio scientifico”				
2 <sup>nd</sup>	“L’esperienza del progetto di teleriabilitazione NEUROREAB”	0.3	Eng. D. Furno, Eng. M. Romanelli	Università degli Studi di Salerno; Riatlas Healthcare s.r.l.	DIETI
2 <sup>nd</sup>	“Telemedicina, e-health e «mobile health» si può davvero usare il digitale nel percorso assistenziale”	0.3	Dr. Simonetta Scalvini	ICS IRCCS Maugeri s.p.a. SB, Pavia, Italy	DIETI
2 <sup>nd</sup>	“Patent Searching best practices with IEEE Xplore”	0.2	Dr. Eszter Lukacs	IEEE	IEEE
2 <sup>nd</sup>	"How to Get Published with IEEE"	0.3	Dr. Paul Henriques	IEEE	IEEE
2 <sup>nd</sup>	"At the Nexus of Big Data, Machine Intelligence, and Human Cognition"	0.2	Prof. George S. Djorgovski	Center for Data Driven Discovery - California Institute of Technology	DIETI – Dipartimento di Fisica “Ettore Pancini”
2 <sup>nd</sup>	“CRISPR-cas9 screens and multi-omic data integration for identifying and prioritising anticancer therapeutic targets”	0.2	Dr. Francesco Iorio	Human Technopole, Milan, Italy	DIETI
2 <sup>nd</sup>	"Exploiting medical imaging in the era of Big Data"	0.4	Dr. Marco Aiello	Istituto di Ricerca IRCCS SDN, Napoli, Italy	DIETI
2 <sup>nd</sup>	"GDPR basics for computer scientist"	0.3	Dr. Rigo Wenning	European Research Consortium for Informatics and Mathematics	DIETI
2 <sup>nd</sup>	"Subclonal reconstruction of tumour architectures by using machine learning and population genetics"	0.2	Dr. Giulio Caravagna	Cancer Data Science Laboratory, Dipartimento di Matematica e Geoscienze, Università degli Studi di Trieste	DIETI
2 <sup>nd</sup>	"Synthetic MRI: physical principles and applications"	0.2	Prof. Angelo Galante	Università degli Studi de L’Aquila	DIETI – Dipartimento di Fisica “Ettore Pancini”
2 <sup>nd</sup>	"Static magnetic field exposure monitoring of MRI workers: methods and practical implementations"	0.2	Prof. Angelo Galante	Università degli Studi de L’Aquila	DIETI – Dipartimento di Fisica “Ettore Pancini”
2 <sup>nd</sup>	“IEEE Authorship and Open Access Symposium: Best Practices to Get Published	0.4	Dr. Eszter Lukacs	IEEE	IEEE

	to Increase the Exposure and the Impact of your Research”				
2 <sup>nd</sup>	“Artificial Intelligence and 5G combined with holographic technology: a new perspective for remote health monitoring”	0.3	Dr. Pietro Ferraro, Dr. Pasquale Memmolo	Istituto di Scienze Applicate e Sistemi Intelligenti Eduardo Caianiello”, Consiglio Nazionale delle Ricerche, Napoli, Italy	5G Academy - DIETI
2 <sup>nd</sup>	“Short and ultrashort, high voltage electric pulses for biological and medical applications”	0.3	Dr. Stefania Romeo	CNR – Institute for Electromagnetic Sensing of the Environment (IREA), Bioelectromagnetics Lab	DIETI – Dipartimento di Fisica “Ettore Pancini”
2 <sup>nd</sup>	“L’avvincente storia degli acceleratori”	0.3	Prof. Vittorio Giorgio Vaccaro	INFN	DIETI – Dipartimento di Fisica “Ettore Pancini”
2 <sup>nd</sup>	“The new paradigms of soft tissues assessment: medical imaging, machine learning and 3D printing”	0.3	Prof. Paolo Gargiulo	Medical Technology Center - Reykjavik University /University Hospital Landspítali	DIETI
2 <sup>nd</sup>	“Introduzione alle applicazioni della RM in medicina”	0.3	Prof. Arturo Brunetti	Dipartimento di Scienze biomediche avanzate, Università degli Studi di Napoli “Federico II”	DIETI – Dipartimento di Fisica “Ettore Pancini”

### Research activities

Jessica Centracchio participated in the development of a new, automated method, based on shape analysis, for intracranial electrodes localization in CT volumes, also thanks to the collaboration with IRCCS Neuromed. Moreover, she participated in the research on Forcecardiography (FCG), getting involved in signals acquisition and analysis, as well as in the preparation and/or revision of scientific papers, also collaborating with Prof. Gaetano D. Gargiulo from Western Sydney University. Specifically, she participated in the experimental activities aimed at assessing the performance of FCG sensors for respiration monitoring. Furthermore, she investigated the localization of cardiac cycle events and the estimation of cardiac time intervals in FCG signals. She also analyzed the effect of respiration on the cardiac components of FCG signals. In addition, she was involved in the investigation about the extraction of heart walls motion information from Seismocardiography signals. She also participated in the experimental activities aimed at investigating the feasibility of a multimodal finger pulse wave sensor and evaluated the performance of a new Forcemyography (FMG) sensor for muscle activity monitoring. Finally, she



reviewed the scientific literature about the topic of biosignal-based Human-Machine Interfaces for assistance and rehabilitation and participated in the investigation on an FMG-controlled hand exoskeleton and an electromechanical system to test dynamic performance of force sensors.

### Tutoring and supplementary teaching activities

- Assistant for the BSc course of “Elaborazione dei segnali e dei dati biomedici”, held by Prof. Francesco Amato.
- Assistant for the MSc course of “Strumentazione e Ingegneria Clinica”, held by Prof. Paolo Bifulco.
- Assistant for the MSc course of “Computer Interface for Biological Systems”, held by Prof. Paolo Bifulco.
- Co-supervisor of the MSc thesis entitled “Comparison between Electromyography and Force myography to monitor muscle activity”, in “Computer Interface for Biological Systems”, of the student Alessia Arena, who graduated in Industrial Bioengineering on 28<sup>th</sup> October 2022 (supervised by Prof. P. Bifulco).
- Co-supervisor of the MSc thesis entitled “Rilevazione dei battiti cardiaci da tracciati di Forcecardiography e Seismocardiography”, in “Strumentazione e Ingegneria Clinica” of the student Salvatore Parlato, who graduated in Biomedical Engineering on 20<sup>th</sup> December 2022 (supervised by Prof. P. Bifulco).
- Co-supervisor of the laboratory activities of the students Pasquale Del Prete and Filomena Fezza for their pre-graduation internships in “Strumentazione e Ingegneria Clinica” and “Computer Interface for Biological Systems”, respectively (supervised by Prof. P. Bifulco).

### Credits summary

PhD Year	Courses	Seminars	Research	Tutoring / Supplementary Teaching
1 <sup>st</sup>	21.8	7.3	33	1.6
2 <sup>nd</sup>	11.7	5.7	45	1.6
3 <sup>rd</sup>	6.6	0	60	1.6
<b>Total</b>	<b>40.1</b>	<b>13</b>	<b>138</b>	<b>4.8</b>

## Research periods in institutions abroad and/or in companies

PhD Year	Institution / Company	Hosting tutor	Period	Activities
2 <sup>nd</sup>	School of Engineering, Design and Built Environment, Western Sydney University, Penrith, NSW 2751, Australia	Prof. Gaetano Dario Gargiulo	1 <sup>st</sup> June 2021 – 31 <sup>st</sup> August 2021	Research on heart activity monitoring sensors.

## PhD Thesis

In the PhD Thesis, Jessica Centracchio carried out an in-depth investigation of Forcecardiography (FCG), a novel technique that records the local forces induced onto the chest wall by the mechanical activity of the beating heart via broadband force sensors. In particular, she focused on the clinically relevant information that can be extracted from FCG signals and the analysis of performance as compared to well-established techniques. To this aim, FCG recordings were acquired simultaneously with reference signals on a cohort of healthy volunteers under different experimental conditions. First, she demonstrated the suitability of FCG sensors for accurate, continuous and unobtrusive respiration monitoring, thus proving that the raw FCG sensor signal consists of a large, very low-frequency component associated with respiration, referred to as the Forcerespirogram, and a much smaller, superimposed component, i.e., the actual Forcecardiogram, which carries information about the cardiac activity. The latter can be further divided into two infrasonic components, the low-frequency FCG (LF-FCG) and high-frequency FCG (HF-FCG), which reflect the forces impressed by the emptying and filling actions of heart chambers and cardiac cycle events, respectively, and a sonic component that captures heart sounds (HS-FCG). Moreover, she analysed the effect of respiration on the cardiac components of FCG signals, showing that the amplitude modulation of both LF-FCG and HF-FCG components, as well as the respiratory-induced variation of two parameters of heartbeat morphology provide accurate detection of respiratory acts and estimation of inter-breath intervals. Furthermore, she demonstrated that the first derivatives of HF-FCG signals have the highest similarity to accelerometric Seismocardiography (SCG) signals and allow precise localization of aortic valve opening and closures events and accurate estimation of pre-ejection periods and left ventricular ejection times. She also proposed a method, based on template matching, for heartbeats localization and inter-beat intervals estimation in FCG signals without the need for simultaneous electrocardiographic recordings, suggesting that FCG can also be used for strictly cardio-mechanical monitoring. In addition, she presented a numerical procedure, based on double integration, to recover information on heart walls motion from SCG signals, thus obtaining a new displacement signal that features a low-frequency component, namely LF-DSCG, which has been shown to share a very high similarity with the LF-FCG. However, the LF-FCG exhibited a greater

consistency within the cardiac cycle with respect to LF-DSCG. Finally, for the first time in the literature, she evaluated the performance of a true multimodal finger pulse wave sensor, obtained by integrating a Photoplethysmography sensor and a piezoelectric FCG sensor.

### Publications

Research results appear in 11 papers published in international journals and 2 contributions to international conferences.

#### List of scientific publications

##### International journal papers

J. Centracchio, A. Sarno, D. Esposito, E. Andreozzi, L. Pavone, G. Di Gennaro, M. Bartolo, V. Esposito, R. Morace, S. Casciato, P. Bifulco,  
Efficient automated localization of ECoG electrodes in CT images via shape analysis,  
*International Journal of Computer Assisted Radiology and Surgery*,  
vol. 16, pp. 543–554, 2021, DOI: 10.1007/s11548-021-02325-0.

E. Andreozzi, J. Centracchio, V. Punzo, D. Esposito, C. Polley, G.D. Gargiulo, P. Bifulco,  
Respiration Monitoring via Forcecardiography Sensors,  
*Sensors*,  
vol. 21(12), 3996, 2021, DOI: 10.3390/s21123996.

D. Esposito, J. Centracchio, A. Andreozzi, G.D. Gargiulo, G.R. Naik, P. Bifulco,  
Biosignal-based Human-Machine Interfaces for Assistance and Rehabilitation: A Survey,  
*Sensors*,  
vol. 21(20), 6863, 2021, DOI: 10.3390/s21206863.

C. Polley, T. Jayarathna, U. Gunawardana, G.R. Naik, T. Hamilton, E. Andreozzi, P. Bifulco, D. Esposito, J. Centracchio, G.D. Gargiulo,  
Wearable Bluetooth Triage Healthcare Monitoring System,  
*Sensors*,  
vol. 21(22), 7586, 2021, DOI: 10.3390/s21227586.

D. Esposito, J. Centracchio, E. Andreozzi, S. Savino, G.D. Gargiulo, G.R. Naik, P. Bifulco,  
Design of a 3D-Printed Hand Exoskeleton Based on Force-Myography Control for Assistance and Rehabilitation,  
*Machines*,  
vol. 10(1), 57, 2022, DOI: 10.3390/machines10010057.

J. Centracchio, E. Andreozzi, D. Esposito, G.D. Gargiulo, P. Bifulco,  
Detection of Aortic Valve Opening and Estimation of Pre-Ejection Period in Forcecardiography Recordings,  
*Bioengineering*,  
vol. 9(3), 89, 2022, DOI: 10.3390/bioengineering9030089.

E. Andreozzi, J. Centracchio, D. Esposito, P. Bifulco,  
A comparison of heart pulsations provided by Forcecardiography and Double Integration of  
Seismocardiogram,  
*Bioengineering*,  
vol. 9(4), 167, 2022, DOI: 10.3390/bioengineering9040167.

J. Centracchio, E. Andreozzi, D. Esposito, G.D. Gargiulo,  
Respiratory-induced amplitude modulation of Forcecardiography signals,  
*Bioengineering*,  
vol. 9(9), 444, 2022, DOI: 10.3390/bioengineering9090444.

E. Andreozzi, R. Sabbadini, J. Centracchio, P. Bifulco, A. Irace, G. Breglio, M. Riccio,  
Multimodal Finger Pulse Wave Sensing: Comparison of Forcecardiography and Photoplethysmography  
Sensors,  
*Sensors*,  
vol. 22(19), 7566, 2022, DOI: 10.3390/s22197566.

D. Esposito, J. Centracchio, E. Andreozzi, P. Bifulco, G.D. Gargiulo,  
Design and Evaluation of a Low-Cost Electromechanical System to Test Dynamic Performance of Force  
Sensors at Low Frequencies,  
*Machines*,  
vol. 10(11), 1017, 2022, DOI: 10.3390/machines10111017.

J. Centracchio, D. Esposito, G.D. Gargiulo, E. Andreozzi,  
Changes in Forcecardiography Heartbeat Morphology Induced by Cardio-Respiratory Interactions,  
*Sensors*,  
vol. 22(23), 9339, 2022, DOI: 10.3390/s22239339.

### International conference papers

J. Centracchio, V. Muto,  
Heartbeats Localization in Forcecardiography Signals via Template Matching,  
*International Conference on E-Health and Bioengineering (EHB) 2022*,  
Iasi, Romania, 17-18 Nov. 2022, pp. 1–4, IEEE Publisher, DOI: 10.1109/EHB55594.2022.9991505.

J. Centracchio,  
A new piezoelectric sensor for Forcemycography application,  
*International Conference on E-Health and Bioengineering (EHB) 2022*,  
Iasi, Romania, 17-18 Nov. 2022, pp. 1–4, IEEE Publisher, DOI: 10.1109/EHB55594.2022.9991364.

### Patents and/or spin offs

None.

### Awards and Prizes

None.

## Activities and Publications – Final Report

UNINA PhD in Information Technology and Electrical Engineering – XXXV Cycle

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Date 12/01/23

PhD student signature

Jessica Centracchio

Supervisor signature

Paolo Bifulco