Salvatore Parlato

Innovative devices and methods for heart monitoring

Tutor: Prof. Paolo Bifulco
Co-Tutor: Prof. Emilio Andreozzi

Cycle: XXXIX

Year: Second

BACKGROUND

EDUCATION

M.Sc. in Biomedical Engineering (University of Naples Federico II)

Heartbeats detection from Forcecardiography and Seismocardiography tracings

Ph.D. in Information Technology and Electrical Engineering (ITEE)

1st November 2023

UNINA scholarship

Biomedical Engineering Group

Healthcare Automation, Biomedical Instrumentation and Telemedicine Laboratory

MAIN STUDY ACTIVITIES

- Development of a fully automated method to localize heartbeats from cardio-mechanical signals;
- Development and test of a new flexible sensor for Focecardiography;
- Creation of FOSTER: The first public dataset of Forcecardiography;
- Development of innovative devices to record the mechanical vibrations and sounds generated by blood flow in patients with arterio-venous fistulas;
- Biomedical Design methodologies for digital circuits and systems oriented to FPGA – Ad hoc course;
- Strumentazione e Ingegneria Clinica– M.Sc. course;
- 2025 Spring School on Transferable Skills – Type C course;
- Study on the optimization of Cardiac Resynchronization Therapy (CRT) parameters via cardiomechanical signals. (research period at University of Zaragoza, Spain, ES from 5° October 2025 to 31° October 2025)
- Blood pressure estimation via the calculation of the pulse transit time (PPT) (research period at University of Zaragoza, Spain, ES from 5° October 2025 to 31° October 2025).

RESEARCH FIELD

Innovative devices and methods for cardio-mechanical monitoring

CARDIO-MECHANICAL MONITORING TECHNIQUES

Seismocardiography (SCG)

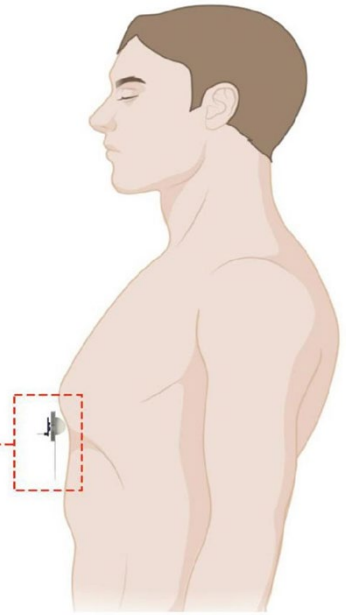
- Measures chest vibrations caused by heartbeats via **accelerometers**.

Gyrocardiography (GCG)

- Detects rotational heart movements via **gyroscopes.**

Forcecardiography (FCG)

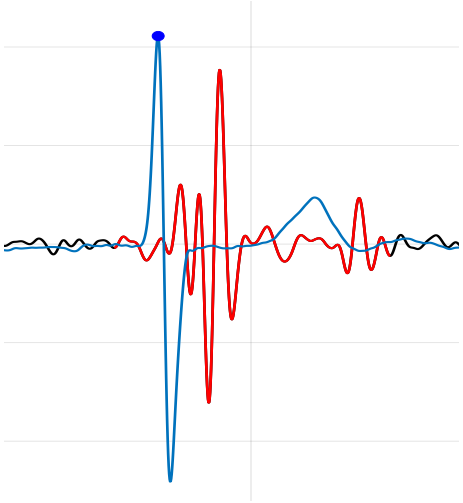
- Measures vibrations related to heart contractions via **broadband force sensors**



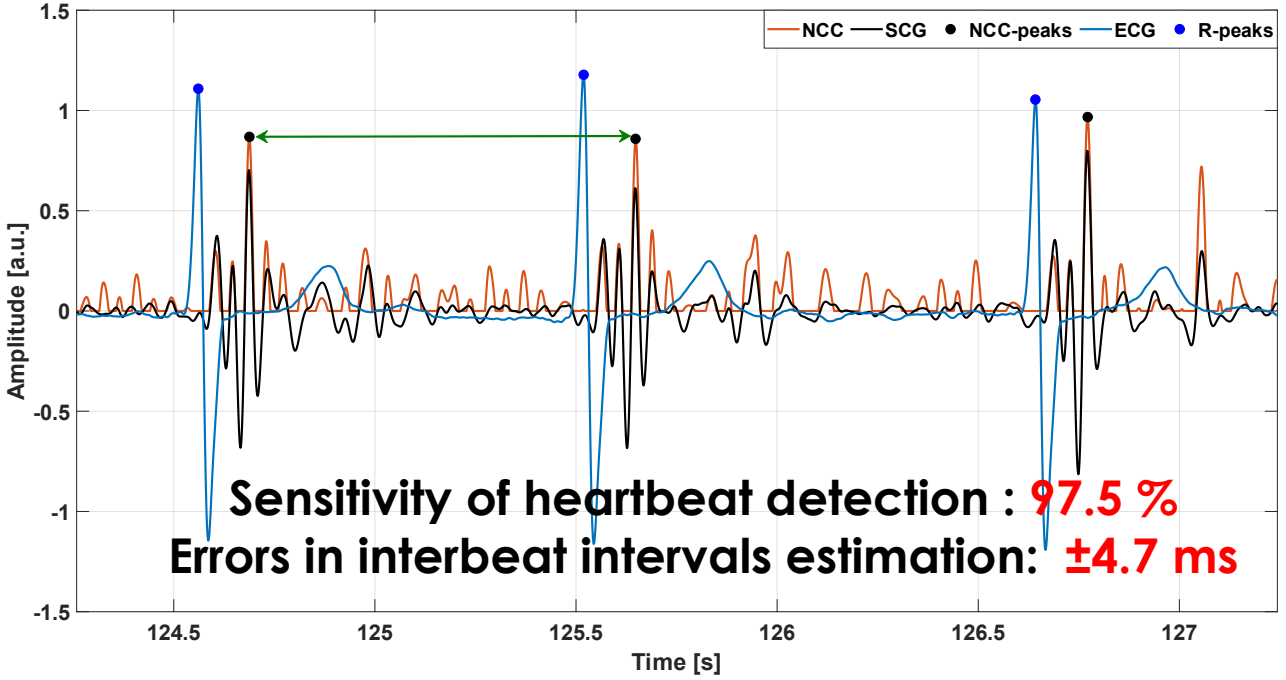
Non-invasive ECG-free methods to localize heartbeats from cardio-mechanical signals

METHODOLOGY AND RESULTS

A template matching approach, based on normalized cross-correlation function (NCC), was developed to localize heartbeats in cardiomechanical signals, such as SCG signals.

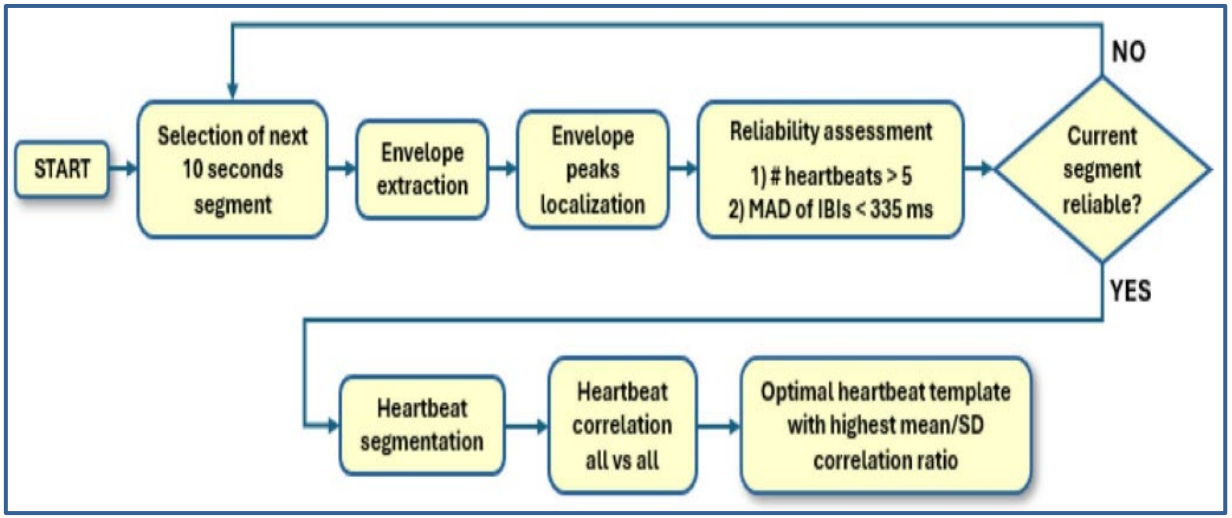


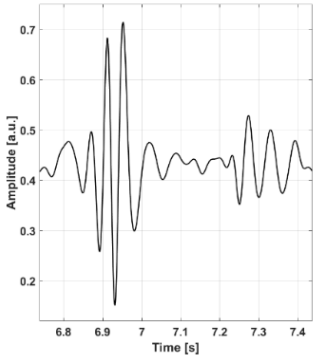
OPERATOR-DEPENDENT

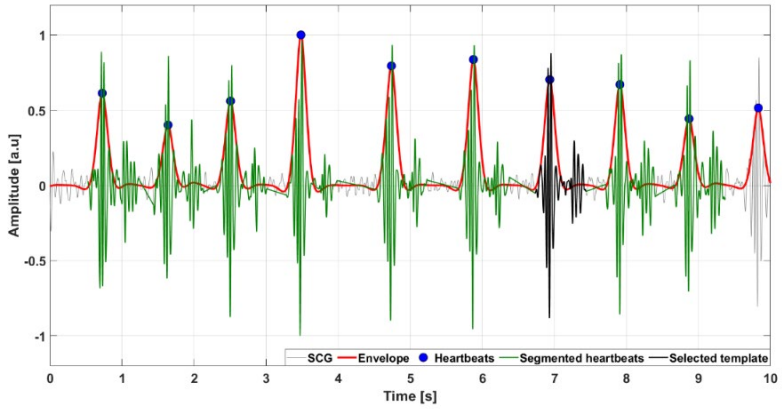


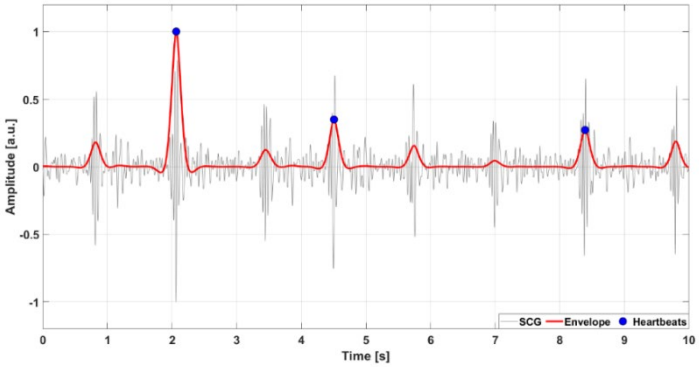
A fully automated method to localize heartbeats from cardio-mechanical signals

METHODS









A fully automated method to localize heartbeats from cardio-mechanical signals

RESULTS

HEALTH CONDITIONS	SIGNAL	$N_{SUBJECTS}$	$N_{HEARTBEATS}$	SENSITIVITY (%)	PPV (%)
Healthy	SCG	49	79937	97.8	96.7
	GCG	29	12259	96.2	94.6
	dHF-FCG	6	1434	99.2	99.3
Pathological	SCG	77	33265	85.2	95.1
	GCG	95	40527	85.2	94.9

Linear regression and correlation analyses

HEALTH CONDITIONS	SIGNAL	N_{IBI}	SLOPE	INTERCEPT (ms)	R^2
Healthy	SCG	77239	1.002	-1.5	0.9996
	GCG	11605	1.002	-1.4	0.9997
	dHF-FCG	1405	1.001	-0.8	0.9996
Pathological	SCG	25359	0.997	3.0	0.9989
	GCG	30765	0.997	3.0	0.9986

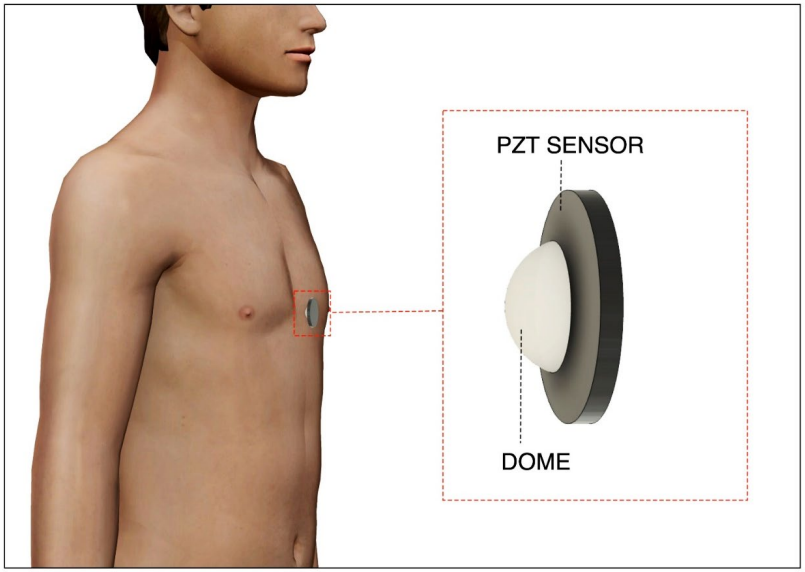
Bland-Altman analysis

HEALTH CONDITIONS	SIGNAL	N_{IBI}	BIAS (ms)	LoA (ms)
Healthy	SCG	77239	0.0	[-5.0; 5.4]
	GCG	11605	0.0	[-3.8; 5.0]
	dHF-FCG	1405	0.1	[-4.3; 4.2]
Pathological	SCG	25359	0.0	[-11.0; 11.0]
	GCG	30765	0.0	[-13.0; 13.0]

Development and test of a new flexible sensor for Forcecardiography;

WHERE DID THE IDEA COME FROM?

FORCECARDIOGRAPHY



lead-zirconate titanate (PZT)

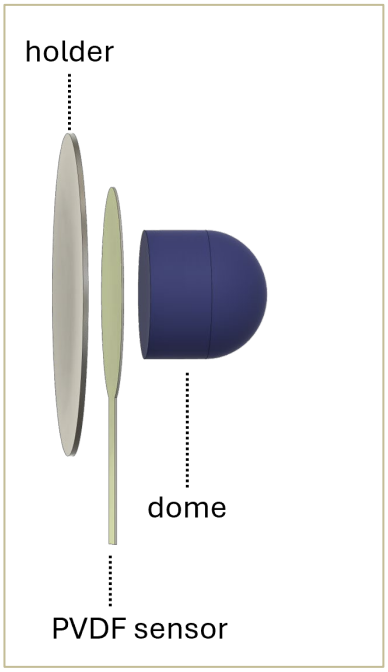
1. **Is not flexible and have a rigid structure**
2. **susceptible to thermal drift**
3. **contains up to 60% lead by weight**

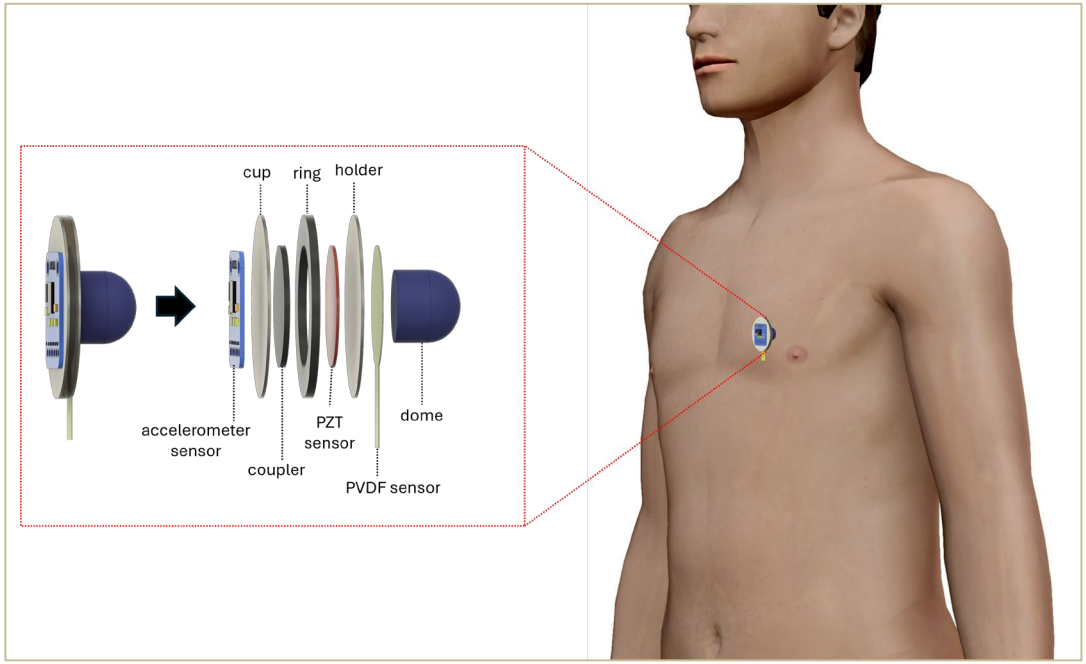
Flexible FCG sensor based on a piezoelectric polyvinylidene fluoride (PVDF) transducer.

Development and test of a new flexible sensor for Forcecardiography;

METHODS

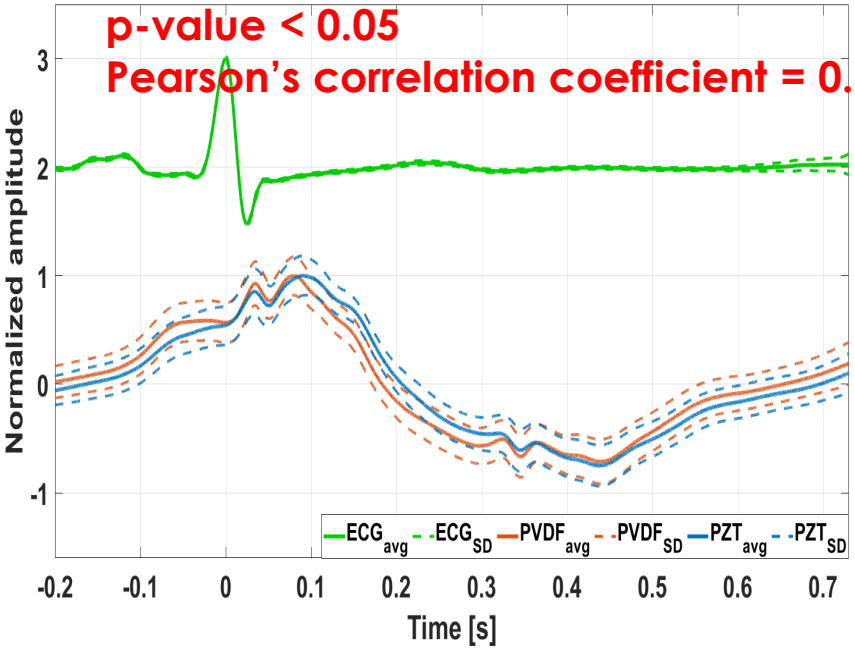
Flexible FCG sensor based on a piezoelectric PVDF transducer.





A fully automated method to localize heartbeats from cardio-mechanical signals

RESULTS



Linear regression and correlation analyses on IBIs vs ECG

Sensor	Signal	N_{IBIs}	R^2	slope	intercept (ms)
PVDF	dHF-FCG	13412	>0.99	1.001	-0.938
	HS-FCG	10023	>0.99	1.002	-1.273
PZT	dHF-FCG	13495	>0.99	1.002	-1.847
	HS-FCG	9519	>0.99	1.002	-1.743

Bland-Altman analysis on IBIs vs ECG

Sensor	Signal	bias (ms)	LoA (ms)
PVDF	dHF-FCG	0.00	[-5.300; 5.000]
	HS-FCG	0.00	[-4.200; 4.400]
PZT	dHF-FCG	0.00	[-6.100; 5.700]
	HS-FCG	0.00	[-4.800; 4.200]

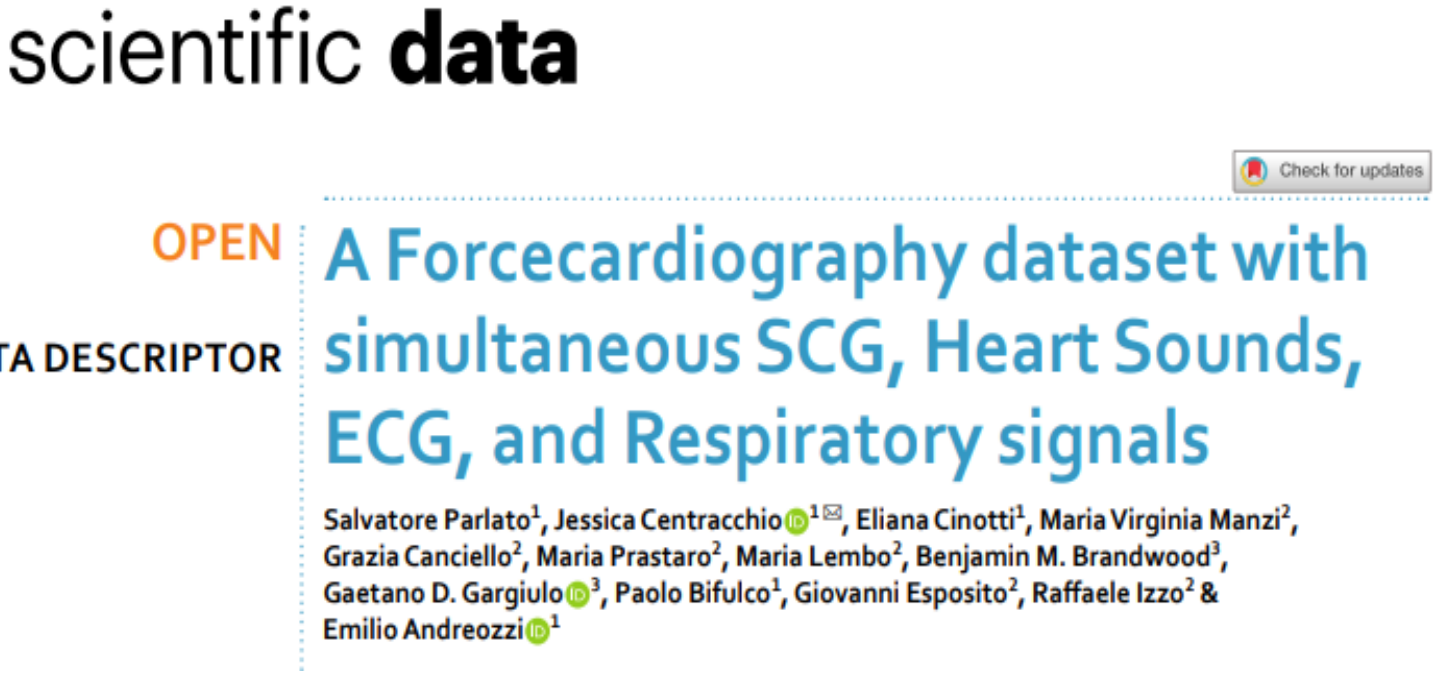
Linear regression and correlation analyses on IBrI

Signal	Sensor	N_{IBrIs}	R^2	slope	intercept (s)
FRG	PVDF	2752	0.967	0.994	0.019
	PZT	2720	0.963	0.993	0.020

Bland-Altman analysis on IBrIs

Signal	Sensor	bias (s)	LoA (s)	$CI_{LoA\ max}$(s)
FRG	PVDF	-0.003	[-0.505; 0.504]	[0.467; 0.590]
	PZT	-0.003	[-0.550; 0.557]	[0.490; 0.633]

FOSTER



scientific data

Check for updates

OPEN

DATA DESCRIPTOR

A Forcecardiography dataset with simultaneous SCG, Heart Sounds, ECG, and Respiratory signals

Salvatore Parlato[1], Jessica Centracchio[1]✉, Eliana Cinotti[1], Maria Virginia Manzi[2], Grazia Canciello[2], Maria Prastaro[2], Maria Lembo[2], Benjamin M. Brandwood[3], Gaetano D. Gargiulo[3], Paolo Bifulco[1], Giovanni Esposito[2], Raffaele Izzo[2] & Emilio Andreozzi[1]

SECOND YEAR PRODUCTION

JOURNAL PAPERS

1. 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

2. **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

3. **Parlato, S.**, Centracchio, J., Esposito, D. et al. Fully automated template matching method for ECG-free heartbeat detection in cardiomechanical signals of healthy and pathological subjects. Phys Eng Sci Med 48, 649–664 (2025). https://doi.org/10.1007/s13246-025-01531-3

4. **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

5. Centracchio, J., **Parlato, S.**, Schmidt, S.E. et al. Monitoring of respiration and cardiorespiratory interactions from multichannel seismocardiography signals. Phys Eng Sci Med (2025). https://doi.org/10.1007/s13246-025-01657-4

6. 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, 2025. https://doi.org/10.1016/j.sintl.2025.100356

7. 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. **Submitted** on Sensors-MDPI.

CONFERENCE PAPERS

1. Salucci, A., Simonetti, A., Piccirillo, S., Centracchio, J., Andreozzi, E., **Parlato, S.**, Pergola, V., Ammirati, G., Cocchiara, L., Visconti, P., Volpe, A., Faccenda, D., Parlato, E., Santoro, C., Strisciuglio, **T.**, Rapacciuolo, **A.** PO-07-024 A PRELIMINARY STUDY ON FORCECARDIOGRAPHY CAPABILITY TO PREDICT ECHOCARDIOGRAPHY PARAMETERS IN PATIENTS UNDERGOING CARDIAC RESYNCHRONIZATION THERAPY. *Heart Rhythm, Vol. 22, Issue 4, 2025, S741-S742.* *https://doi.org/10.1016/j.hrthm.2025.03.1784*

2. 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. **Accepted and presented** at 2025 International Workshop on Biomedical Applications, Technologies and Sensors (BATS).

SECOND YEAR CREDITS

PhD Student: Salvatore Parlato
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Tutor: prof. Paolo Bifulco
paolo.bifulco@unina.it
Co-TutoCor: prof. Emilio Andreozzi
emilio.andreozzi@unina.it

PhD Cycle: XXXIX

	Courses	Seminars	Research	Tutorship	Total
Bimonth 1	0	0.2	6	0.3	6.5
Bimonth 2	2.4	1.4	6	0.5	10.3
Bimonth 3	0	0.8	6	0	6.8
Bimonth 4	0	1.2	6	0.3	7.5
Bimonth 5	9	0.6	5	0	14.6
Bimonth 6	2	3.2	15	0.3	20.5
Total	13.4	7.4	44	1.4	66.2
Expected	10 - 20	5 - 10	30 - 45	0 – 1.6	

NEXT YEAR

Objectives for next year:

- on the topics covered during my period abroad (optimization of CRT parameters and Blood pressure estimation via FCG sensors).
- Forcecardiography, particularly its use in non-invasive cardiac output estimation;
- development of new sensors to record human body mechanical vibrations.

UNIVERSITÀ DEGLI STUDI DI NAPOLI
FEDERICO II

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electrical engineering

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THANK YOU
FOR YOUR KIND ATTENTION