Jessica Centracchio

Innovative bioengineering methods for diagnosis and monitoring

Tutor: Prof. Paolo Bifulco

Cycle: XXXV

Year: Second

BACKGROUND

EDUCATION

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

Development of a new method for ECoG electrodes localization in CT images

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

1st November 2019

UNINA scholarship

Biomedical Group

Healthcare Automation, Biomedical Instrumentation and Telemedicine Laboratory

RESEARCH FIELD

Innovative bioengineering methods for diagnosis and monitoring

Forcecardiography (FCG) is a novel, non-invasive technique to monitor cardiovascular and pulmonary mechanical activity via force sensors.

FCG can provide detailed information on relevant clinical parameters, such as heart rate and respiratory rate, thus standing as a promising wearable technique for continuous, long-term monitoring of cardio-respiratory function.

FCG could lead to an improvement in personal care, as well as a reduction in healthcare costs.

MAIN STUDY ACTIVITIES

- Study on non-invasive methods for heart and respiration monitoring;
- Study on cardiovascular and pulmonary mechanical activity;
- Study on biomedical applications of Force Sensitive Resistors;
- Study on Forcecardiography;
- Statistical Data Analysis for Science and Engineering Research – ad hoc course;
- Matrix Analysis for Signal Processing with Matlab Examples – ad hoc course;
- Data Science for Patient Records Analysis – ad hoc course;
- Study on biosignal-based Human-Machine Interfaces.

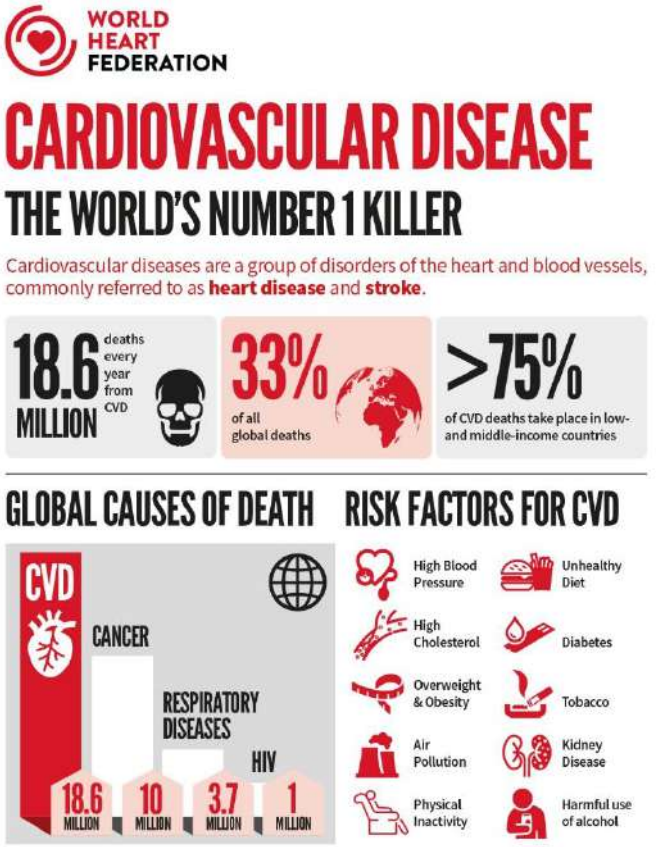
ANALYSIS AND MONITORING OF CARDIOVASCULAR AND PULMONARY MECHANICAL ACTIVITY

PROBLEM

Cardiovascular and respiratory diseases are among the leading causes of death worldwide.

Long-term monitoring of both cardiac and pulmonary function is fundamental in health condition assessment, e.g. follow-up of chronic patients and early detection of cardio-respiratory diseases.

Non-invasive techniques, as well as portable or even wearable instruments, are needed for monitoring in daily life environments.



ANALYSIS AND MONITORING OF CARDIOVASCULAR AND PULMONARY MECHANICAL ACTIVITY

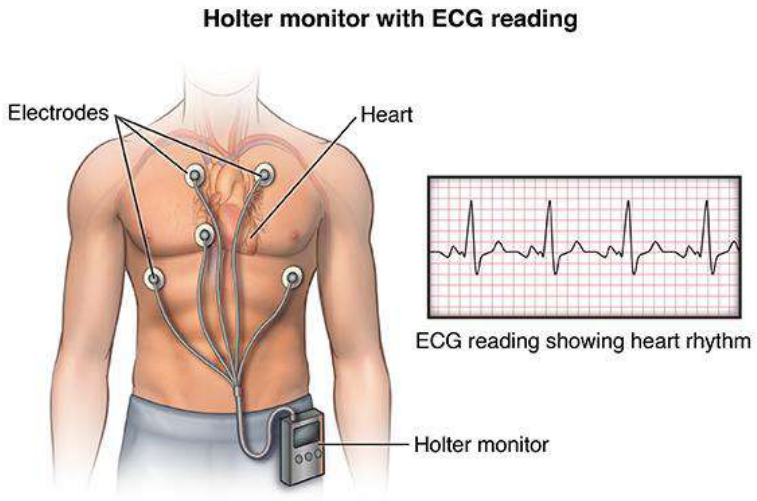
PROBLEM

Electrocardiography (ECG) is widely considered as a gold standard for non-invasive measurement of the heart electrical activity.

ECG is not well suited to long-term monitoring.

The well-known Holter device usually provides recordings up to 48-72 h.

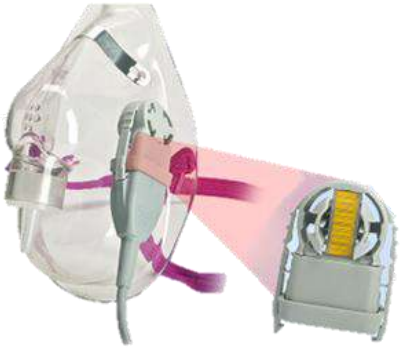
Despite its portability, the Holter device is uncomfortable for the subject.

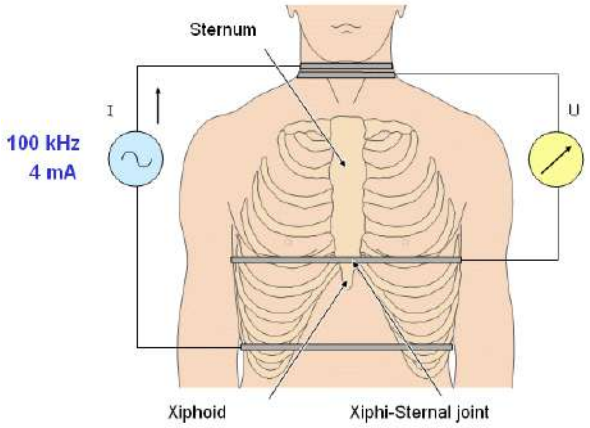


ANALYSIS AND MONITORING OF CARDIOVASCULAR AND PULMONARY MECHANICAL ACTIVITY

PROBLEM

Many different techniques are available for respiration monitoring. They are usually bound to obtrusive sensors (e.g. mounted on face masks or nasal cannulas) or cumbersome instrumentation (e.g. transthoracic impedance plethysmography), making them confined to research or clinical settings.



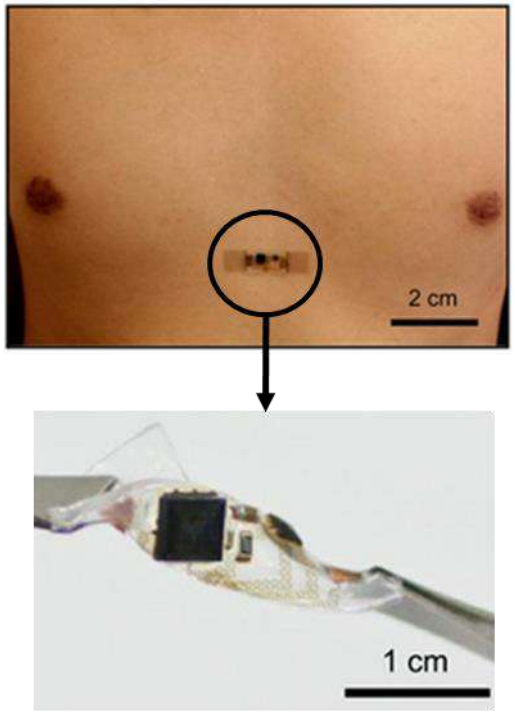


ANALYSIS AND MONITORING OF CARDIOVASCULAR AND PULMONARY MECHANICAL ACTIVITY

PROBLEM

Since 19th century, research has been directed towards the measurement of cardiac-induced mechanical vibrations at the chest surface.

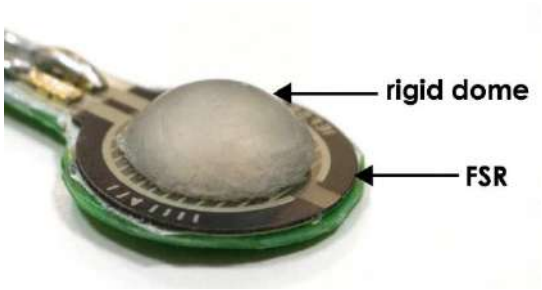
Nowadays, the most widespread technique to acquire such mechanical signals is Seismocardiography (SCG), which is usually based on MEMS accelerometers.



ANALYSIS AND MONITORING OF CARDIOVASCULAR AND PULMONARY MECHANICAL ACTIVITY

OBJECTIVE

Forcecardiography (FCG) is based on force sensors (e.g. FSRs). When placed onto the chest wall, they can measure the local mechanical vibrations induced by the beating heart and by the expansions and releases of the ribcage during the breathing acts.



ANALYSIS AND MONITORING OF CARDIOVASCULAR AND PULMONARY MECHANICAL ACTIVITY

OBJECTIVE

Extracting clinically relevant parameters of cardiorespiratory function:

- Identification of typical SCG fiducial points in FCG signals;
- Estimation of cardiac and respiratory rates;
- Extraction of cardiac time intervals;
- Evaluation of parameters of mechanical cardiac performance.

By considering the recent introduction of FCG, the primary goals are the analysis of accuracy and the optimization of performances, then moving towards a standardization, as in the case of other well-established techniques.

ANALYSIS AND MONITORING OF CARDIOVASCULAR AND PULMONARY MECHANICAL ACTIVITY

METHODOLOGY

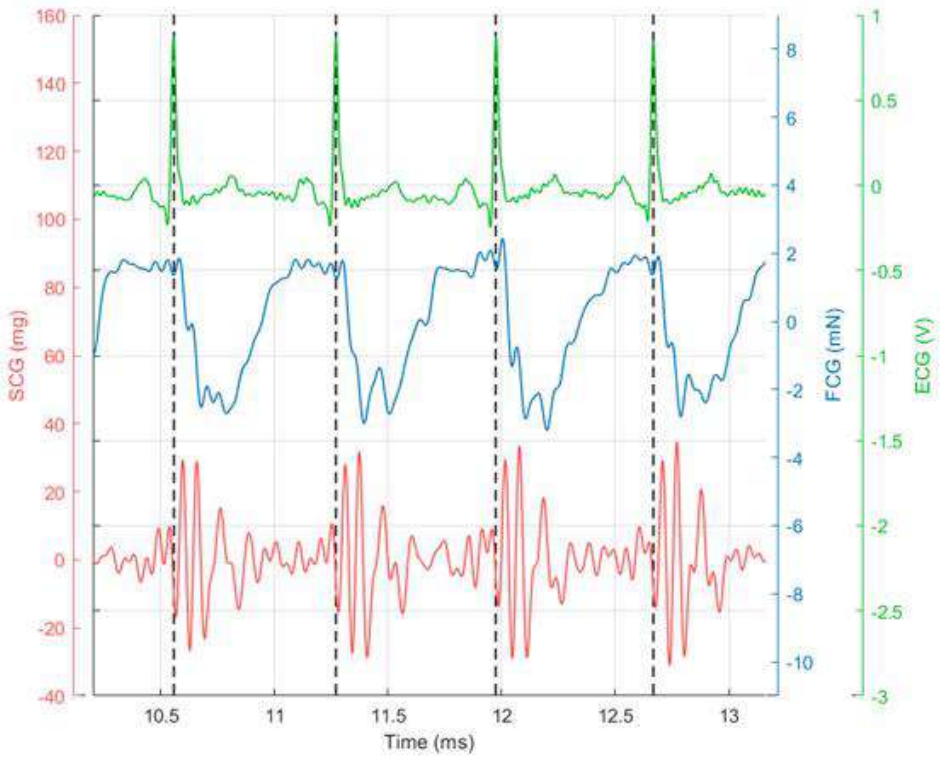
Experimental tests were carried out on 7 healthy volunteers at the Biomedical Instrumentation Laboratory.

Statistical performance analyses were performed by comparing FCG to reference methods, in order to assess its accuracy and reliability.

ANALYSIS AND MONITORING OF CARDIOVASCULAR AND PULMONARY MECHANICAL ACTIVITY

METHODOLOGY

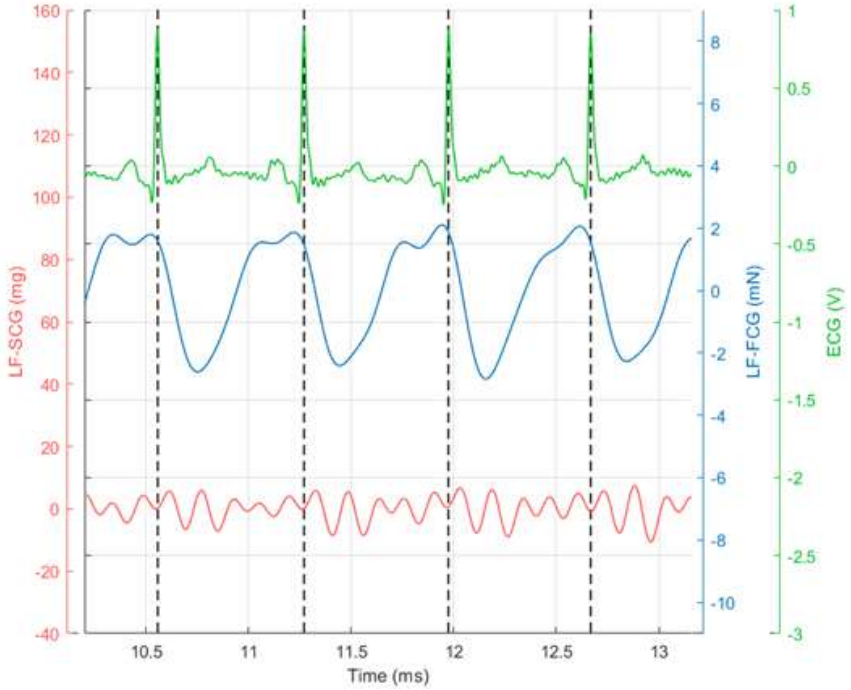
Regarding cardiac activity, FCG, SCG, ECG signals were acquired simultaneously on a subject while holding his breath.

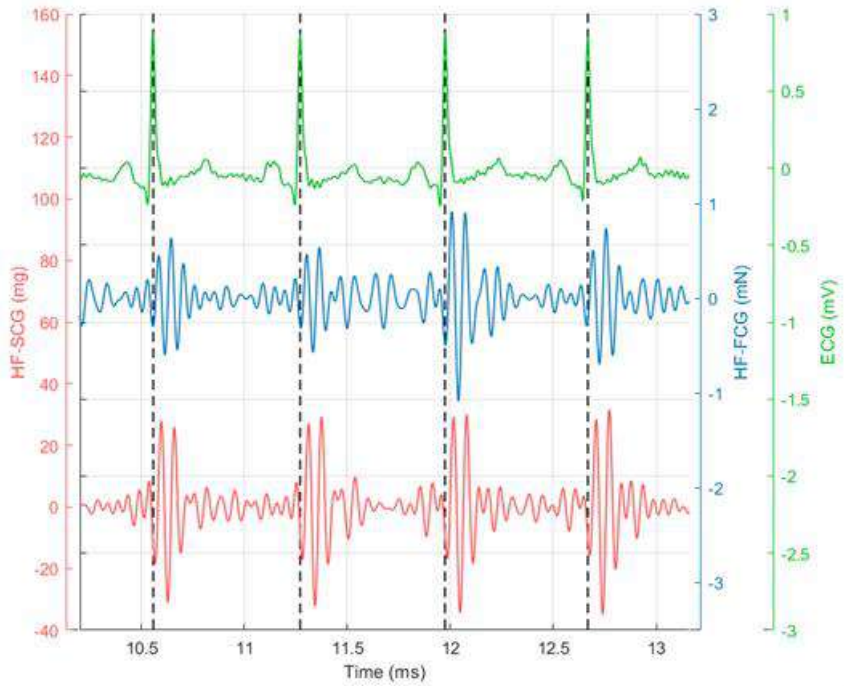


ANALYSIS AND MONITORING OF CARDIOVASCULAR AND PULMONARY MECHANICAL ACTIVITY

METHODOLOGY

Low-frequency (LF) and high-frequency (HF) components of FCG and SCG signals were extracted, and R-peaks were located on ECG signals in order to compute the inter-beat intervals.

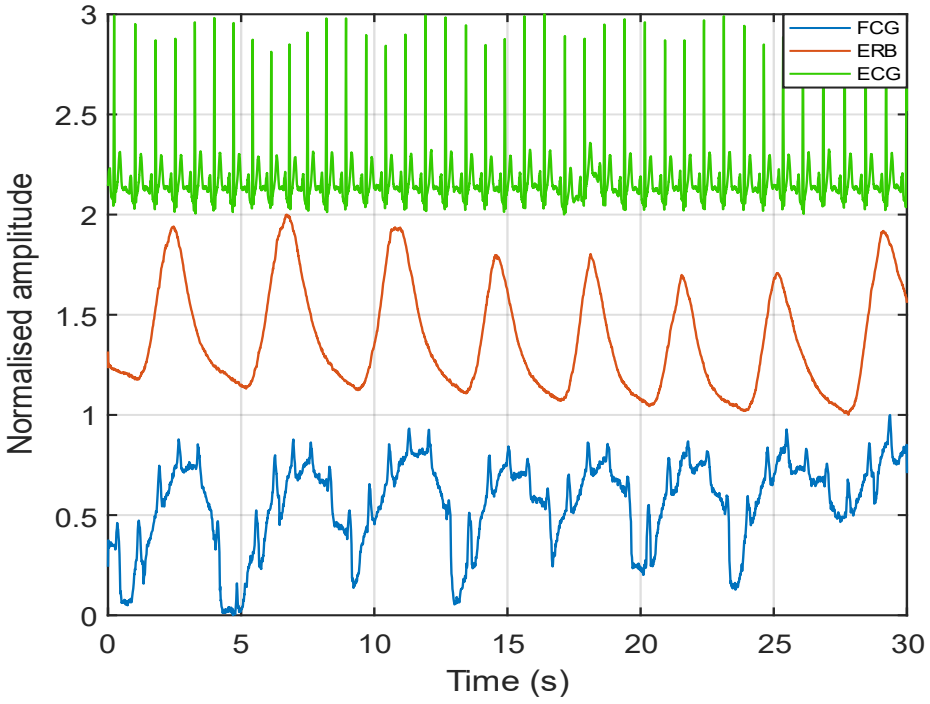




ANALYSIS AND MONITORING OF CARDIOVASCULAR AND PULMONARY MECHANICAL ACTIVITY

METHODOLOGY

Regarding respiratory activity, simultaneous recordings of FCG, ECG and Electroresistive respiration band (ERB) signals were obtained both during normal breathing and forced inhalation and exhalation phases.

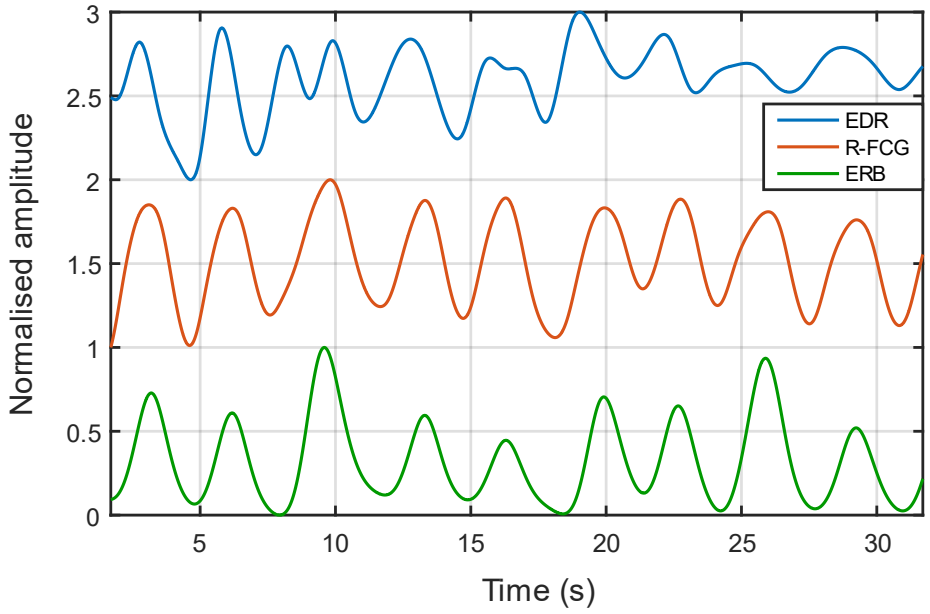


ANALYSIS AND MONITORING OF CARDIOVASCULAR AND PULMONARY MECHANICAL ACTIVITY

METHODOLOGY

ECG-derived respiration (EDR) signals were obtained from ECG and the respiratory component of FCG (R-FCG) was extracted via low-pass filtering.

The positive peaks related to the inspiratory acts were located on the signals in order to compute the inter-breath intervals.

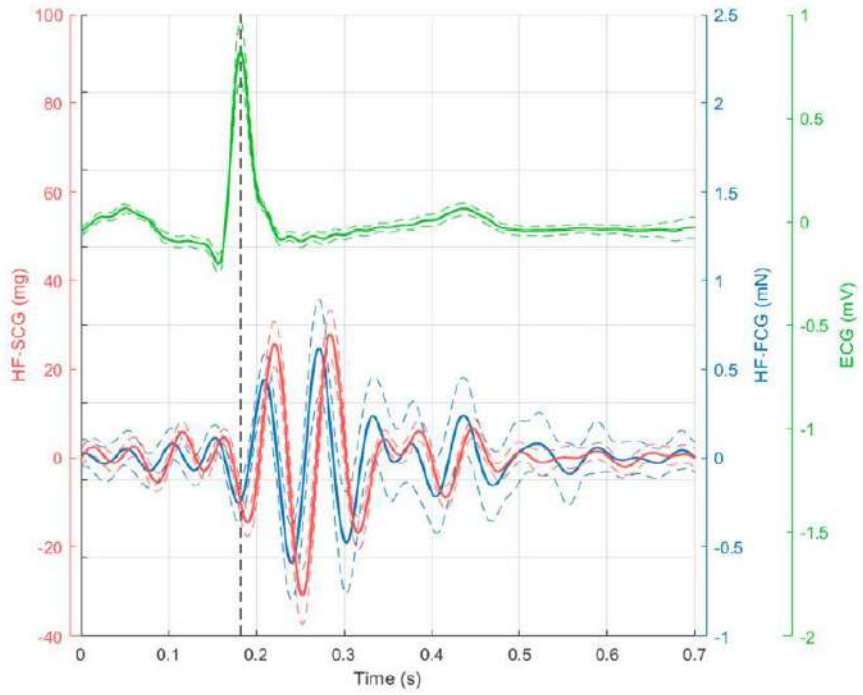


ANALYSIS AND MONITORING OF CARDIOVASCULAR AND PULMONARY MECHANICAL ACTIVITY

RESULTS

HF-FCG and HF-SCG turned out to be highly comparable (Pearson's correlation coefficient > 0.95) although lagged.

The lag was estimated in about tens of milliseconds.

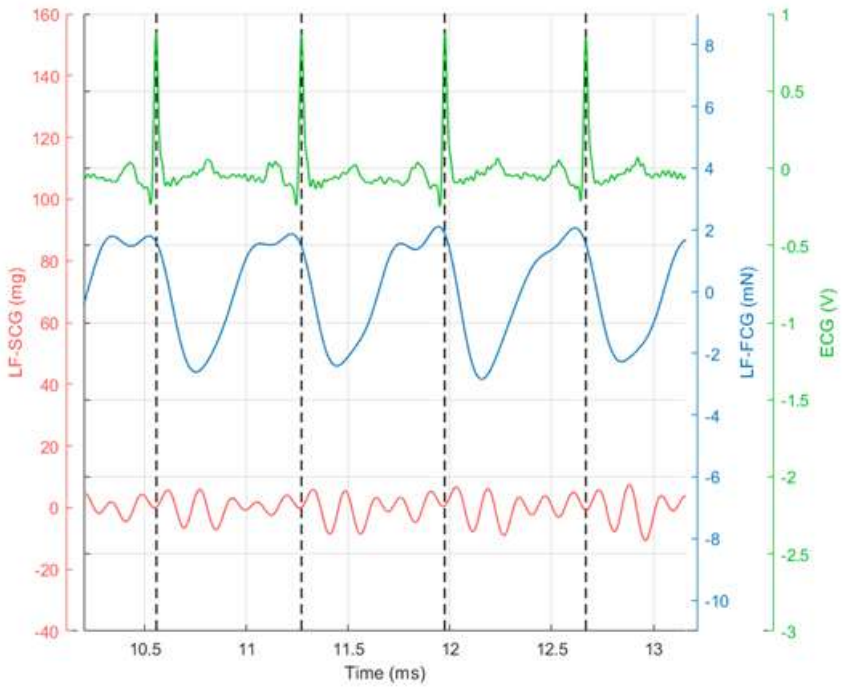


ANALYSIS AND MONITORING OF CARDIOVASCULAR AND PULMONARY MECHANICAL ACTIVITY

RESULTS

An additional, large, low-frequency component, associated with ventricular volume variations, was observed in FCG, while not being visible in SCG.

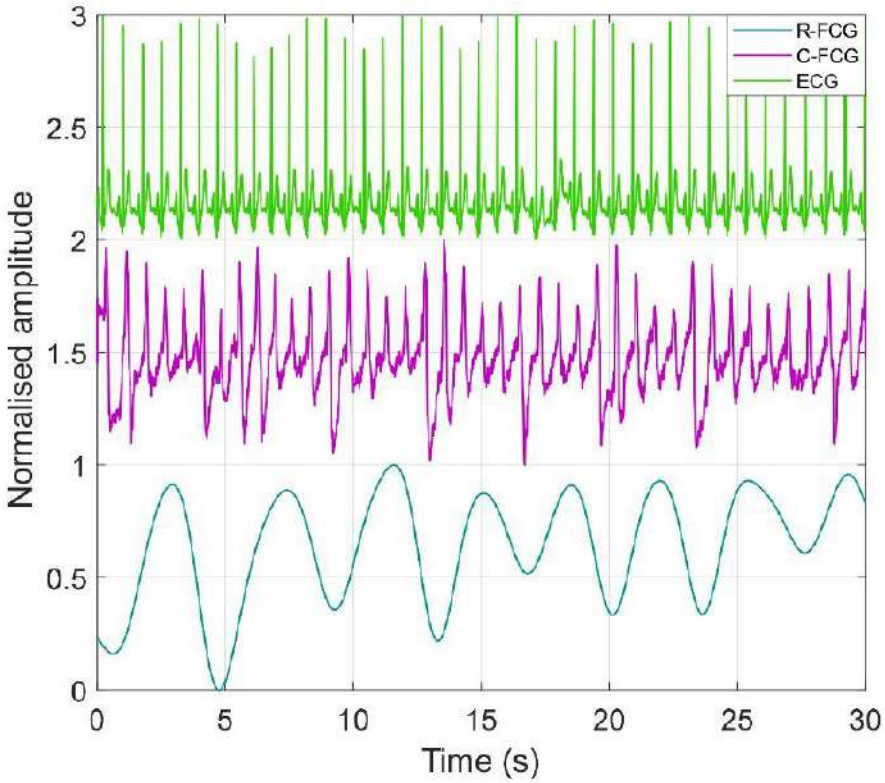
Analyses confirmed that both LF-FCG and HF-FCG are highly correlated with heart contractions.



ANALYSIS AND MONITORING OF CARDIOVASCULAR AND PULMONARY MECHANICAL ACTIVITY

RESULTS

In the raw FCG signal, the typical FCG components related to the cardiac activity appear as superimposed to a much larger and slower component, which is related to the respiration, namely R-FCG.



ANALYSIS AND MONITORING OF CARDIOVASCULAR AND PULMONARY MECHANICAL ACTIVITY

RESULTS

FCG sensors ensure a more sensitive and precise detection of respiratory acts than EDR:

sensitivity: **100%** **vs.** **95.8%** **positive predictive value**: **98.9%** **vs.** **92.5%**)

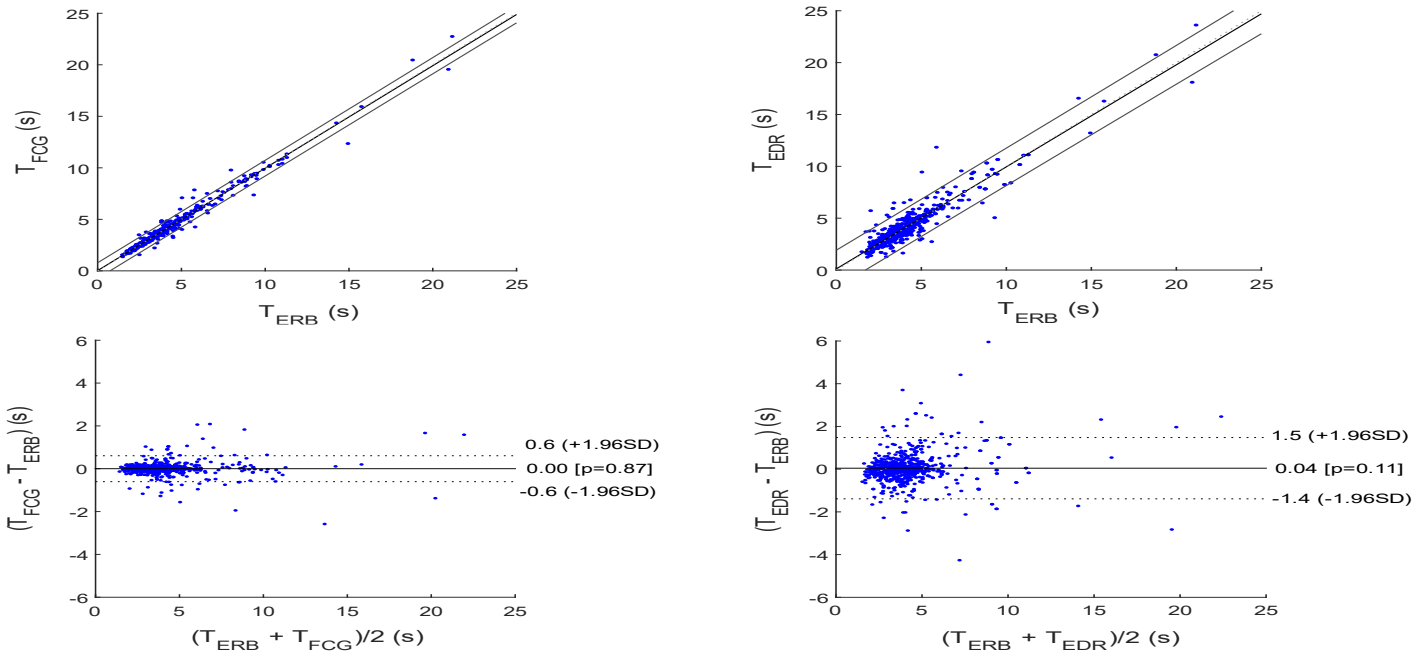
Subject	Respiration ACTS			Missed ACTS		Spurious ACTS	
	ERB	R-FCG	EDR	R-FCG	EDR	R-FCG	EDR
#1	90	93	95	0	0	3	5
#2	110	111	107	0	7	1	4
#3	177	180	178	0	6	3	7
#4	74	74	75	0	3	0	4
#5	86	87	95	0	3	1	12
#6	76	76	88	0	12	0	24
#7	130	130	132	0	0	0	2
Total	743	751	770	0	31	8	58

ANALYSIS AND MONITORING OF CARDIOVASCULAR AND PULMONARY MECHANICAL ACTIVITY

RESULTS

as well as a superior accuracy and precision in inter-breath interval measurement:

R^2 = 0.98 vs. 0.88 **Bland–Altman limits of agreement: ±0.61 s vs. ±1.5 s**



SECOND YEAR PRODUCTION

JOURNAL PAPERS

1. Centracchio, J.; Sarno, A.; Esposito, D.; Andreozzi, E.; Pavone, L.; Di Gennaro, G.; Bartolo, M.; Esposito, V.; Morace, R.; Casciato, S.; Bifulco, P. **Efficient Automated Localization of ECoG Electrodes in CT Images Via Shape Analysis**. Int J CARS, 2021, 16, 543-554, https://doi.org/10.1007/s11548-021-02325-0
2. Andreozzi, E.; Centracchio, J.; Punzo, V.; Esposito, D.; Polley, C.; Gargiulo, G.D.; Bifulco, P. **Respiration Monitoring via Forcecardiography Sensors**. Sensors 2021, 21, 3996, https://doi.org/10.3390/s21123996
3. Esposito, D.; Centracchio, J.; Andreozzi, E.; Gargiulo, G.D.; Naik, G.R.; Bifulco, P. **Biosignal-based Human-Machine Interfaces for Assistance and Rehabilitation: A Survey**. Sensors 2021, 21, 6863, https://doi.org/10.3390/s21206863
4. Polley, C.; Jayarathna, T.; Gunawardana, U.; Naik, G.R.; Hamilton, T.; Andreozzi, E.; Bifulco, P.; Esposito, D.; Centracchio, J.; Gargiulo, G.D. **Small silicone encased piezoelectric sensor for wearable Bluetooth triage healthcare monitoring**. Submitted to Sensors, Special Issue "Patient Triage & Telemedicine Post COVID19: Sensors and Solutions for Monitoring and Management in Hospital and at Home".

TUTORSHIP

- Assistant for the B.Sc. course of "Elaborazione dei Segnali e dei Dati Biomedici" (20 hours), held by Prof. Francesco Amato;
- Assistant for the M.Sc. course of "Strumentazione e Ingegneria Clinica" (10 hours), held by Prof. Paolo Bifulco;
- Assistant for the M.Sc. course of "Computer Interface for Biological Systems" (10 hours), held by Prof. Paolo Bifulco.

PhD Student: Jessica Centracchio jessica.centracchio@unina.it

Tutor: prof. Paolo Bifulco paolo.bifulco@unina.it

PhD Cycle: XXXV

	Credits year 2							
		1	**2**	**3**	**4**	**5**	**6**	
	Estimated	**Bimonth**	**Bimonth**	**Bimonth**	**Bimonth**	**Bimonth**	**Bimonth**	**Summary**
Courses	Min 10 – Max 20	3.2	0	6.5	2	0	0	11.7
Seminars	Min 5 – Max 10	3.8	0	0.7	1.2	0	0	5.7
Research	Min 30 – Max 45	7.5	7.5	7.5	7.5	7.5	7.5	45
	60	14.5	7.5	14.7	10.7	7.5	7.5	**62.4**

NEXT YEAR

Topic of Ph.D. thesis: Forcecardiography

Objectives for next year:

- More accurate study on the physiological origins of FCG signals;
- Deeper investigation on clinical information that can be extracted from FCG signals;
- Larger subjects cohort, possibly with pathologies;
- Possible comparison with Echocardiography.

THANK YOU
FOR YOUR KIND ATTENTION