

Università Campus Bio-Medico di Roma

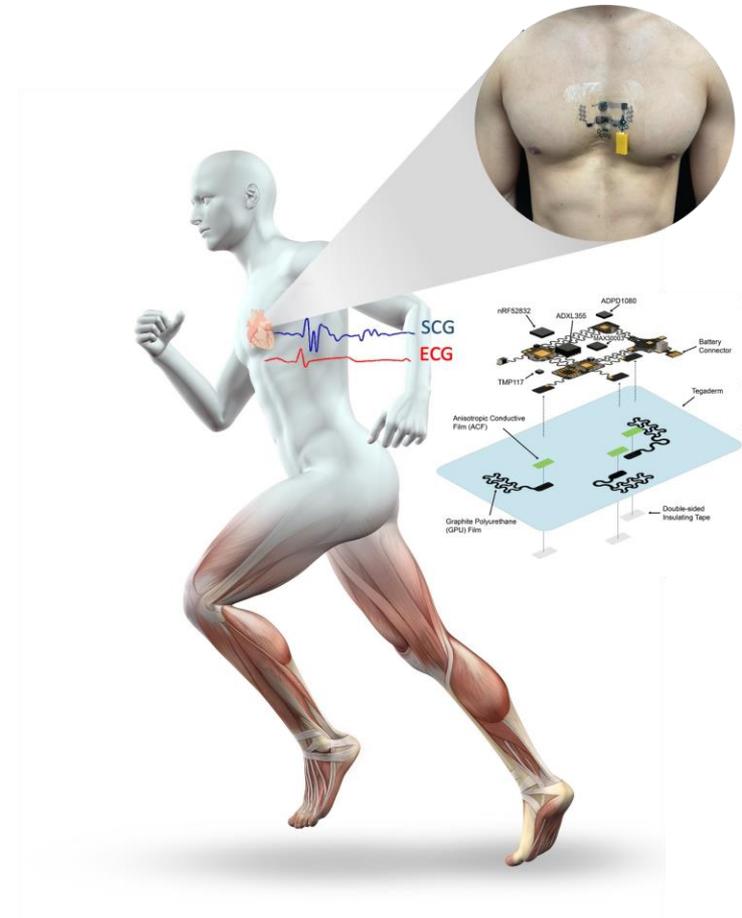


In collaborazione con

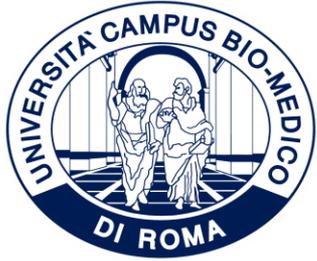
The University of Texas at Austin



«Exploring Wearable Systems for Seismocardiographic Information Extraction: Advancements in Utilization and Implementation»



Il gruppo di lavoro



Francesca Santucci
Postdoc



Roberto Setola
Professore Ordinario



Emiliano Schena
Professore Ordinario



Gabriele Oliva
Professore Associato



Daniela Lo Presti
Ricercatrice



Nanshu Lu
Assistant Professor



Sarnab Bhattacharya
Graduate Student



LU RESEARCH GROUP

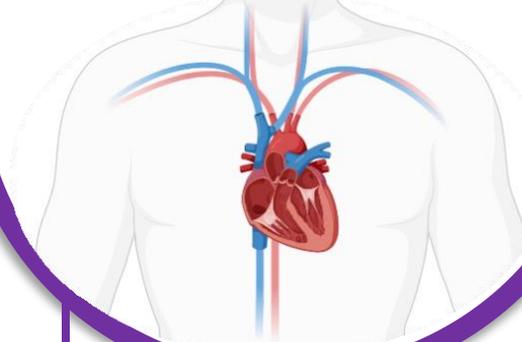
Mechanics and Materials of Bio-integrated Electronics

Obiettivi e destinatari del lavoro

17 MILIONI DI MORTI
ALL'ANNO NEL MONDO



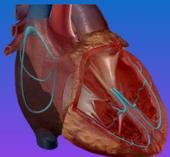
LE MALATTIE
CARDIOVASCOLARI SONO LA
PRIMA CAUSA DI MORTALITA'
A LIVELLO GLOBALE



MONITORAGGIO
CONTINUO E
CONFORTEVOLE PER
TEMPI PROLUNGATI



805,000 MORTI SOLO
NEGLI STATI UNITI PER
ATTACCO CARDIACO

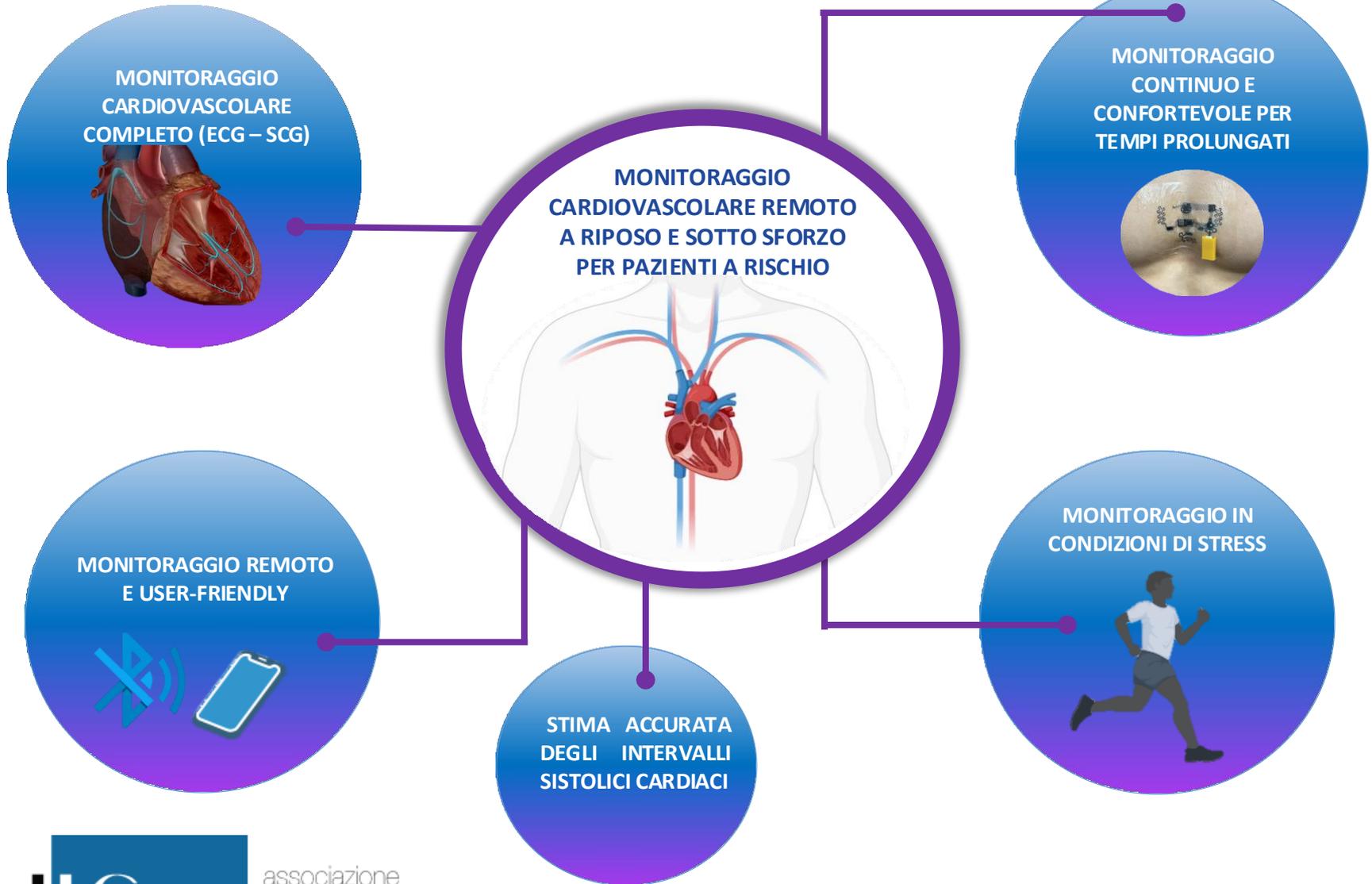


L'80% DELLE
MALATTIE
CARDIOVASCOLARI E'
PREVENIBILE

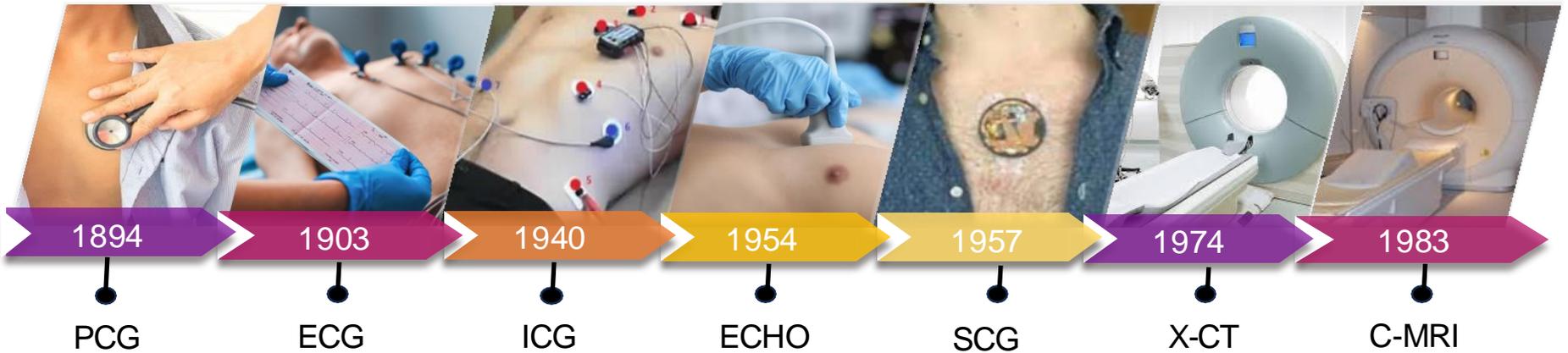
1 ATTCCO DI CUORE SU 5
E' SILENTE



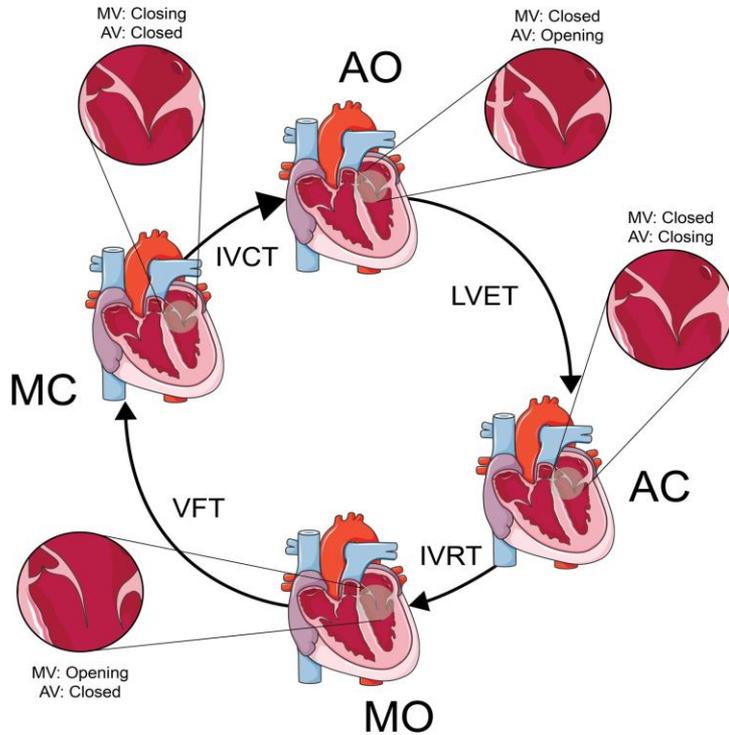
Obiettivi e destinatari del lavoro



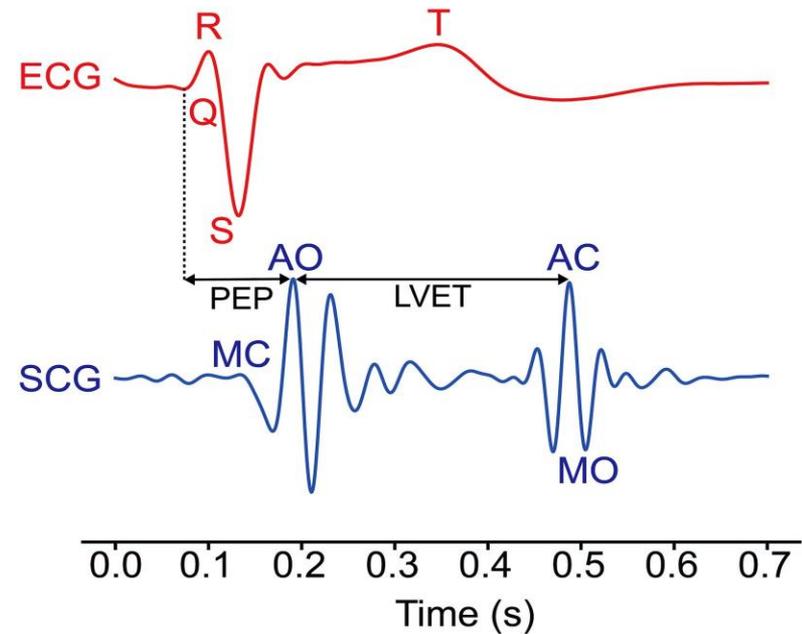
Sismocardiografia (SCG): rileva le vibrazioni meccaniche del torace causate dal battito cardiaco.



IL POTERE DIAGNOSTICO DEL SISMOCARDIOGRAMMA



- **Periodo di pre-eiezione (PEP):** tempo di pre-eiezione, durante il quale i ventricoli si contraggono ma il sangue non viene ancora espulso.
- **Tempo di eiezione ventricolare sinistro (LVET):** intervallo di tempo impiegato dal cuore per espellere il sangue nell'aorta.



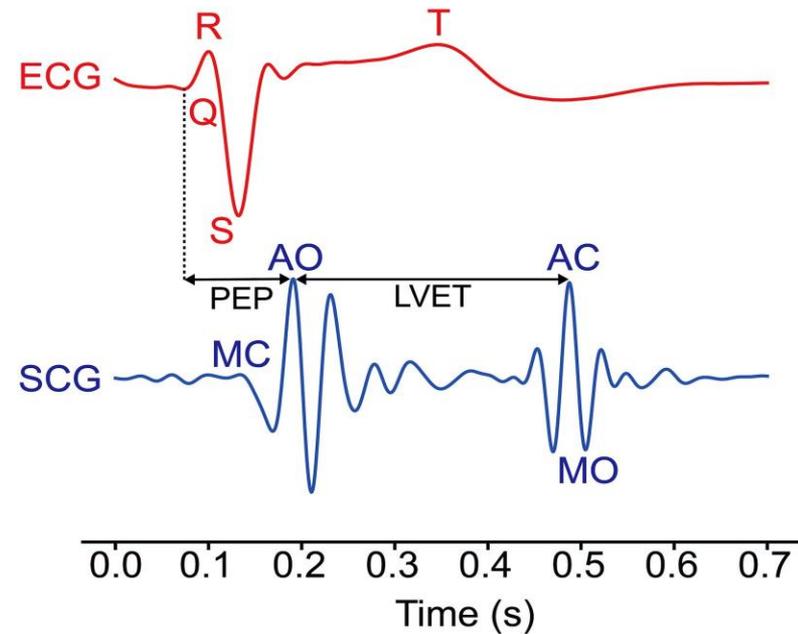
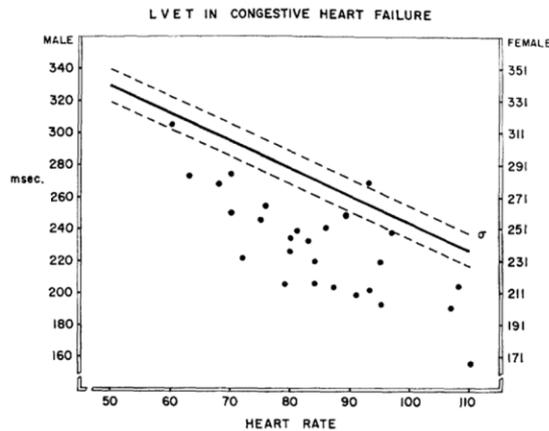
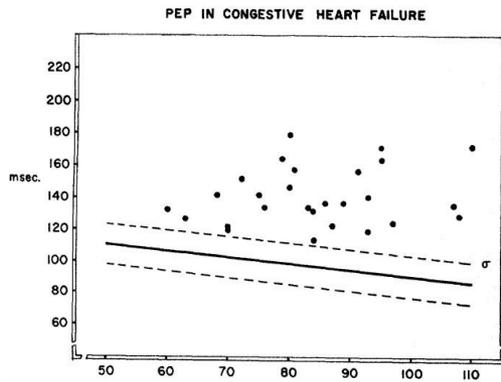
AO: Aortic valve Opening
AC: Aortic valve Closing

MO: Mitral valve Opening
MC: Mitral valve Closing

LVET: Left Ventricular Ejection Time
PEP: Pre-Ejection Period

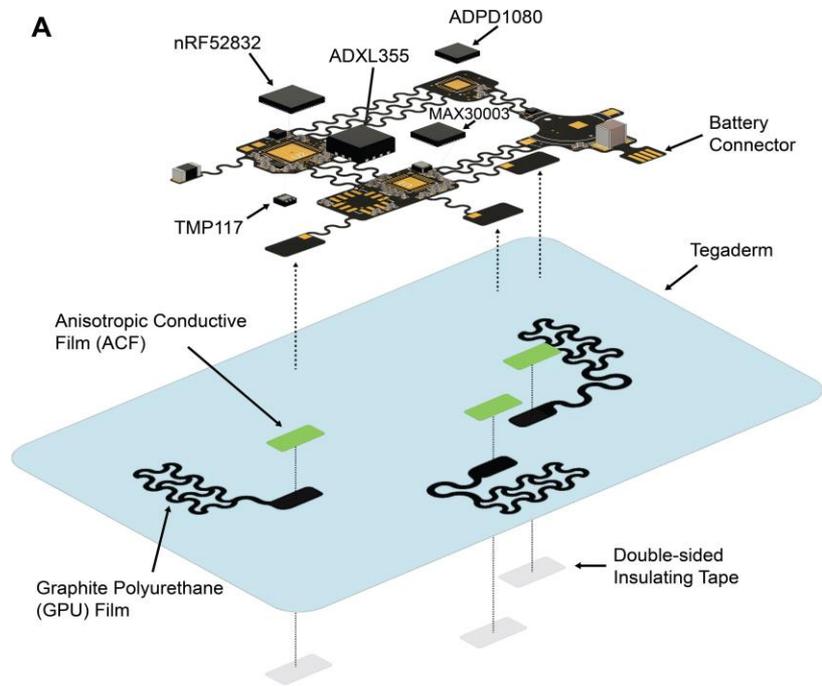
IL POTERE DIAGNOSTICO DEL SISMOCARDIOGRAMMA

- **Periodo di pre-eiezione (PEP):** tempo di pre-eiezione, durante il quale i ventricoli si contraggono ma il sangue non viene ancora espulso.
- **Tempo di eiezione ventricolare sinistro (LVET):** intervallo di tempo impiegato dal cuore per espellere il sangue nell'aorta.

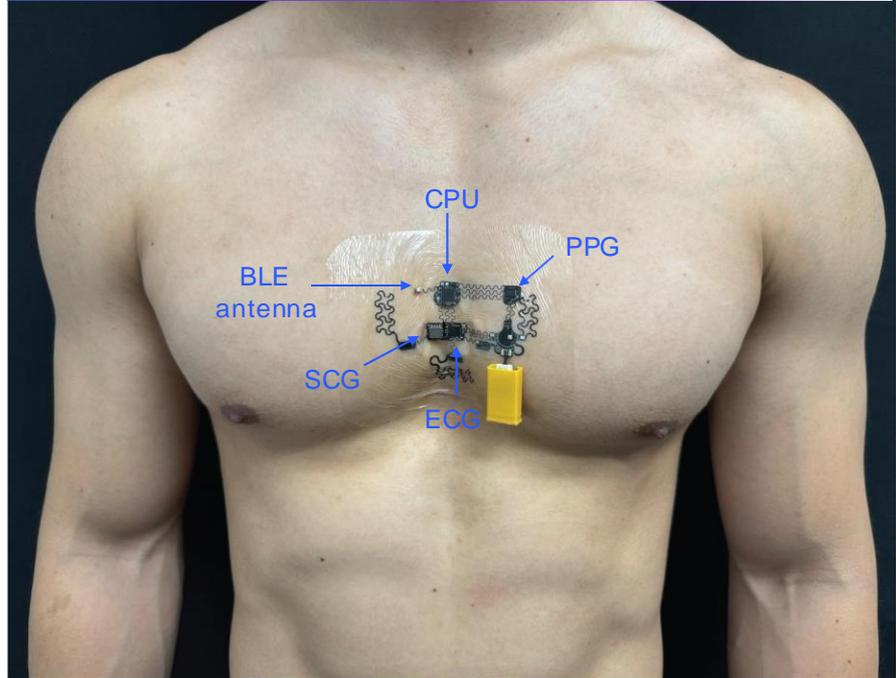


Weissler *et al.* *Circulation* 37:
149, 1968

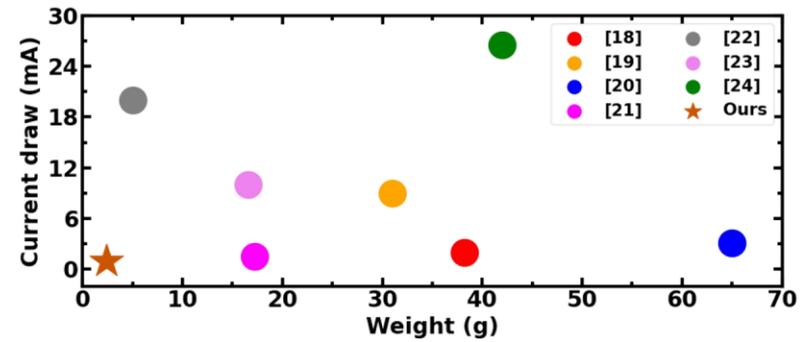
Descrizione

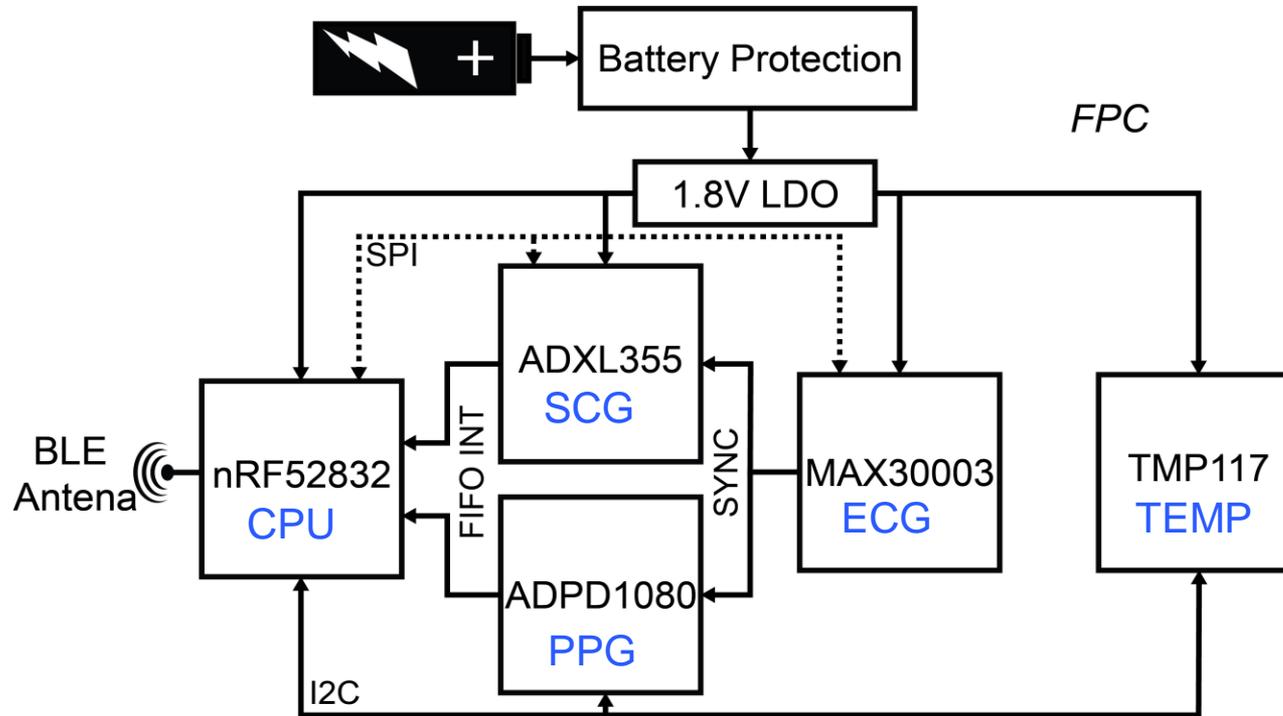


TATUAGGIO ELETTRONICO WIRELESS PER MONITORAGGIO BIMODALE CONTINUO



Caratteristiche dell'e-tattoo		
Spessore totale	Peso	Consumo energetico
200 μm	2.5 g	< 3 mW





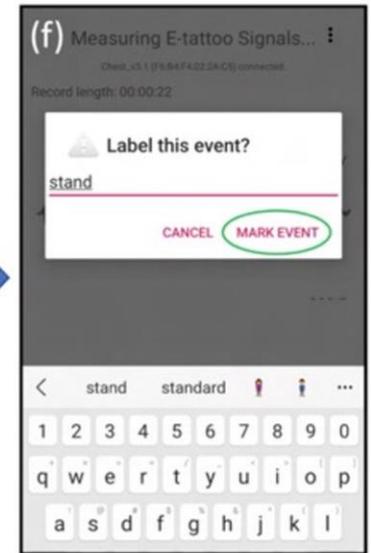
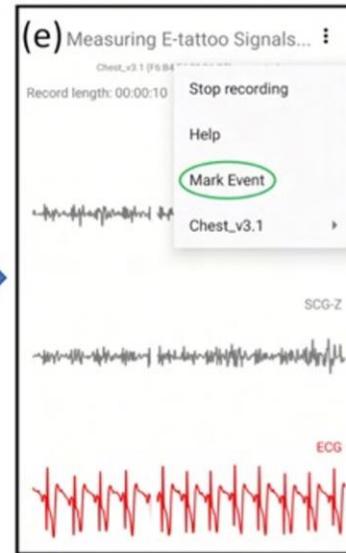
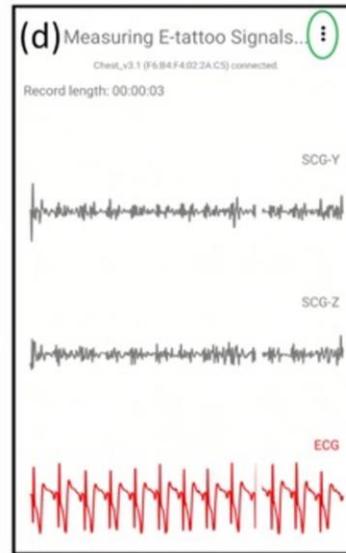
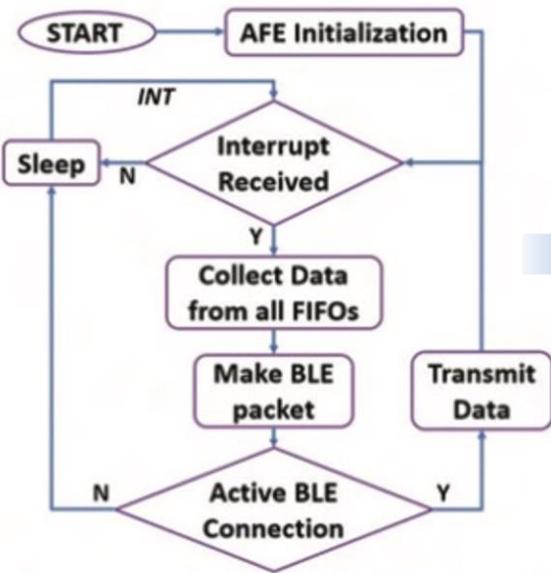


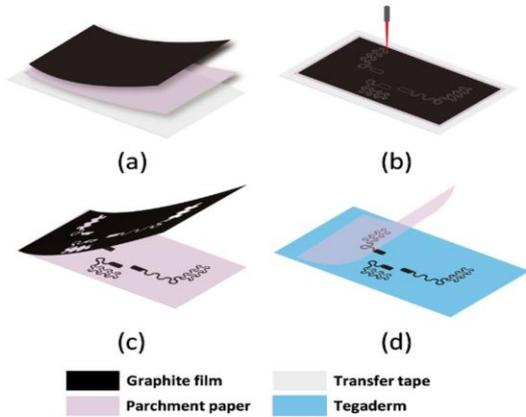
Diagramma del flusso del firmware per raccolta e trasmissione dei dati.

Descrizione

TATUAGGIO ELETTRONICO WIRELESS PER MONITORAGGIO BIMODALE CONTINUO

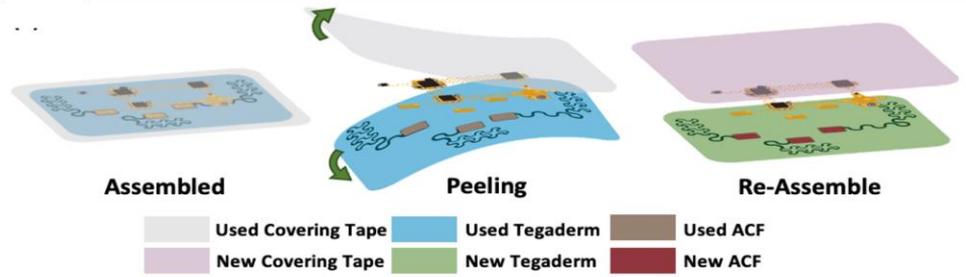
01

Fabrication Process



02

Recycling Process



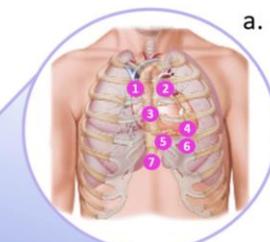
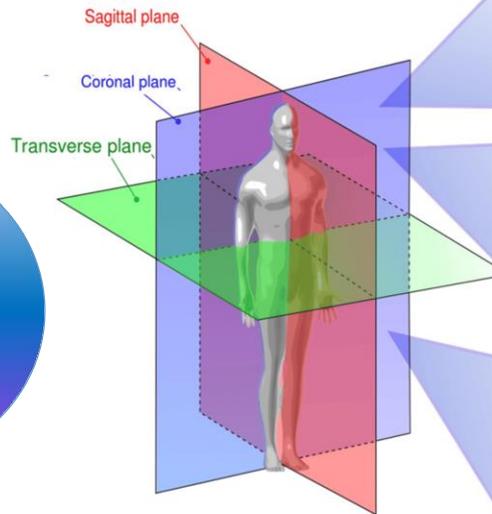
Descrizione

Posizionamento
del sensore

Rimozione
artefatti da
movimento

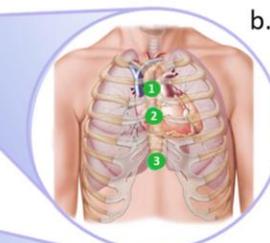
Integrazione
con altre
tecnologie

Analisi
automatizzata



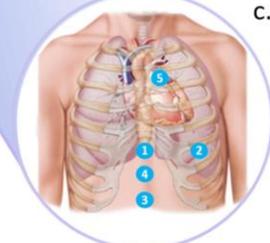
Accelerometri

- a.
- 1 Aortic valve auscultation site
 - 2 Pulmonic valve auscultation site
 - 3 Middle of the sternum
 - 4 Fourth intercostal space
 - 5 Tricuspid valve auscultation site
 - 6 Mitral valve auscultation site
 - 7 Xiphoid process



b. Giroscopi

- 1 Along the second and third rib
- 2 Middle of the sternum
- 3 Xiphoid process



c. Sensori ottici

- 1 Xiphoid process
- 2 Below the nipple
- 3 Above the umbilicus
- 4 Lower thorax
- 5 Pulmonic area near to the heart

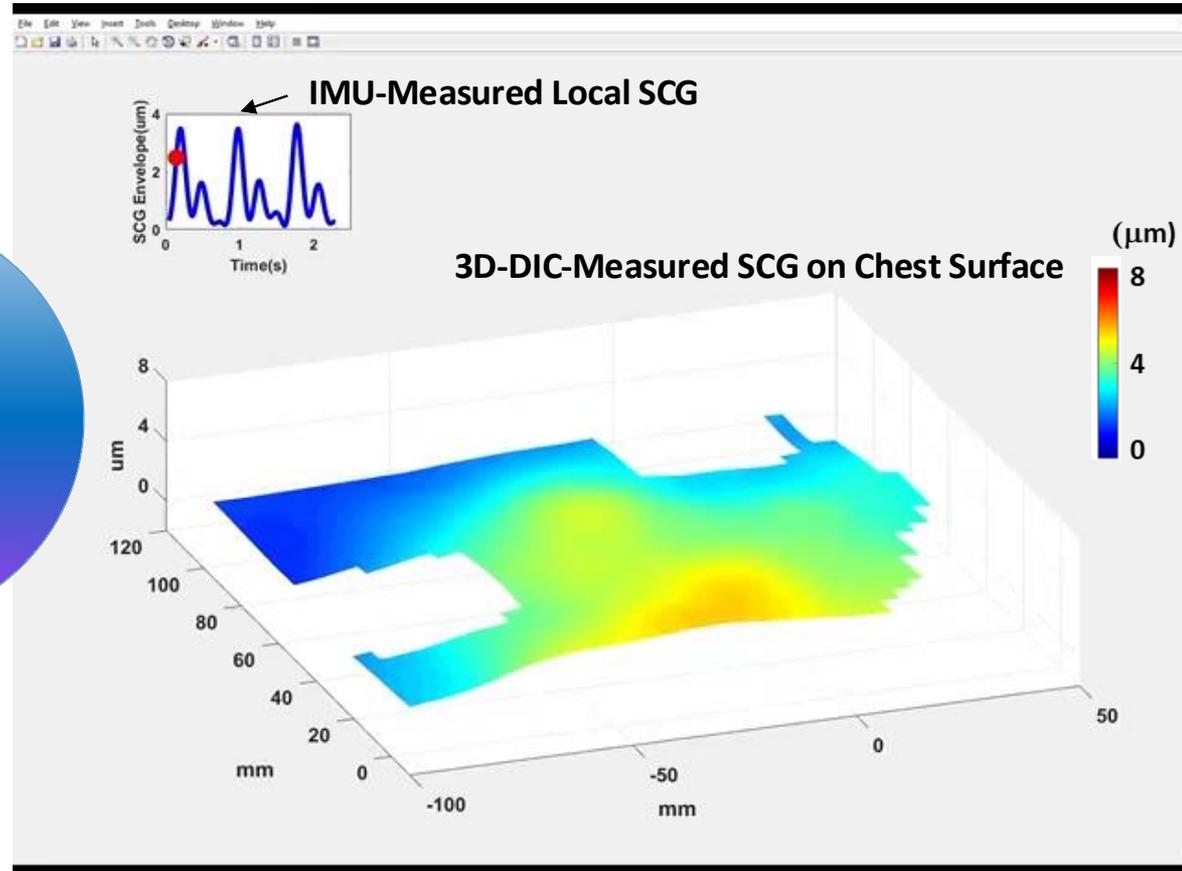
Descrizione

Posizionamento
del sensore

Rimozione
artefatti da
movimento

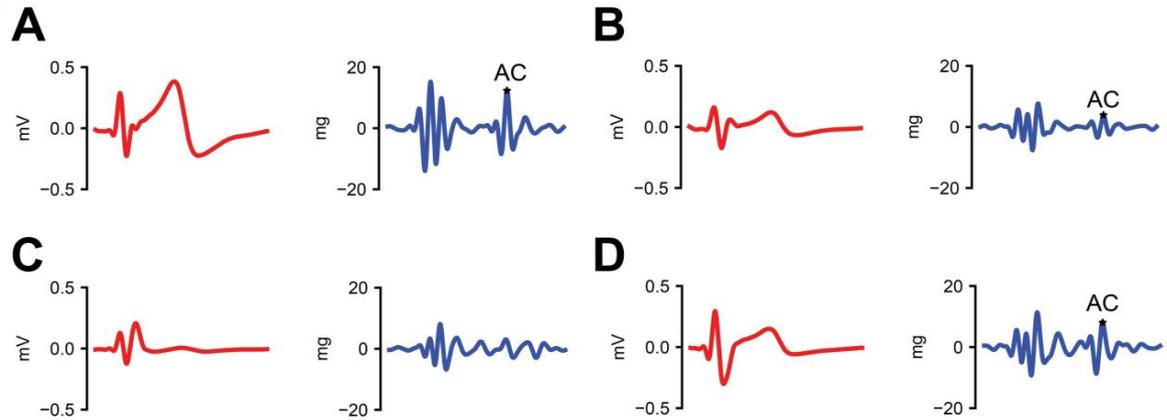
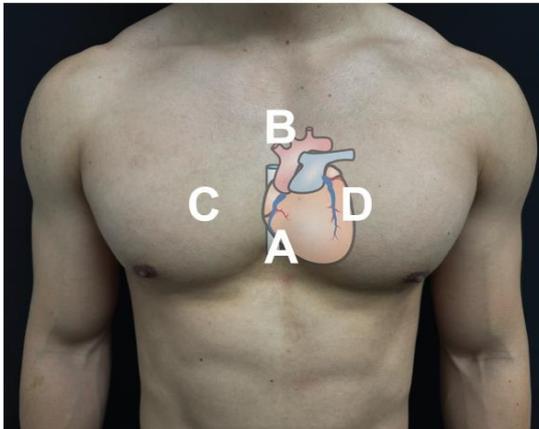
Integrazione
con altre
tecnologie

Analisi
automatizzata

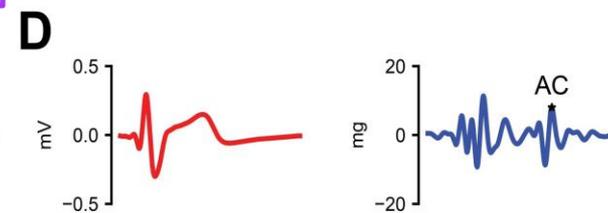
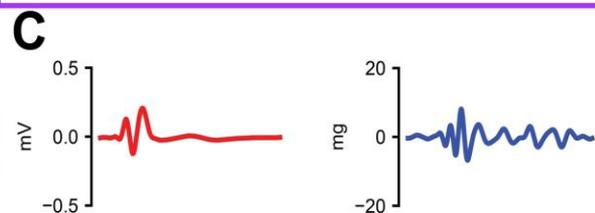
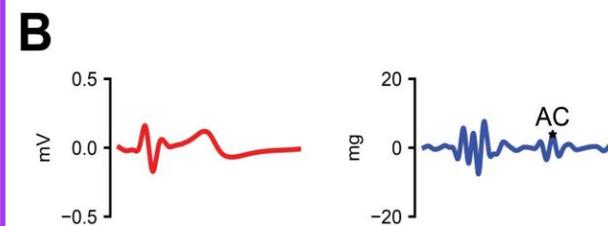
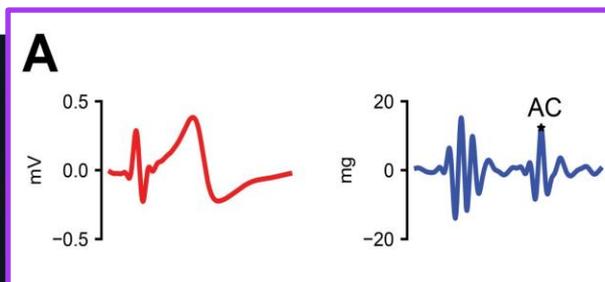
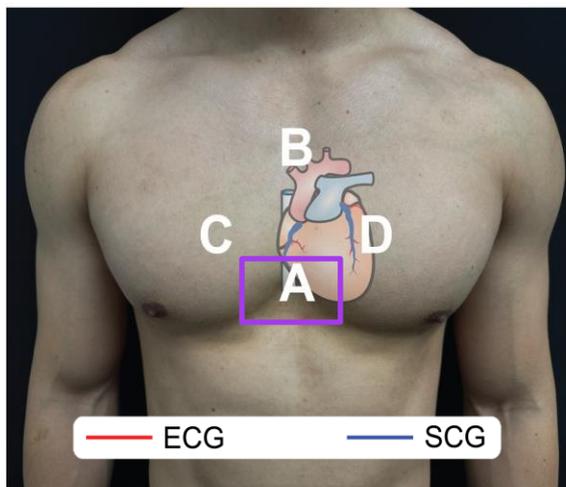


Huh H, Qiu Y, Duong J, Wang RL, Wang P, Tandon A, Sirohi J, Lu N. A Chest-Laminated Ultrathin and Stretchable E-Tat Seismocardiogram, and Cardiac Time Intervals. *Adv Sci (Weinh)*. 2019 May 21;6(14):1900290. doi: 10.1002/advs.20190

POSIZIONE OTTIMALE PER MISURA FORMA D'ONDA STANDARD

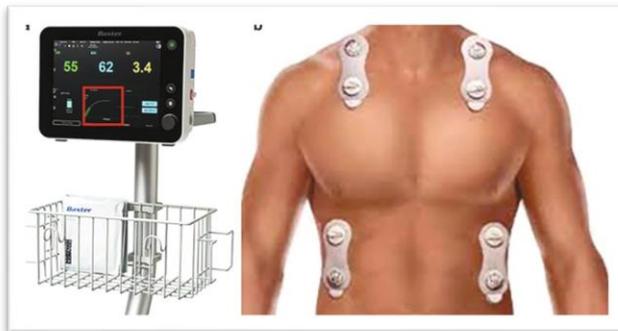
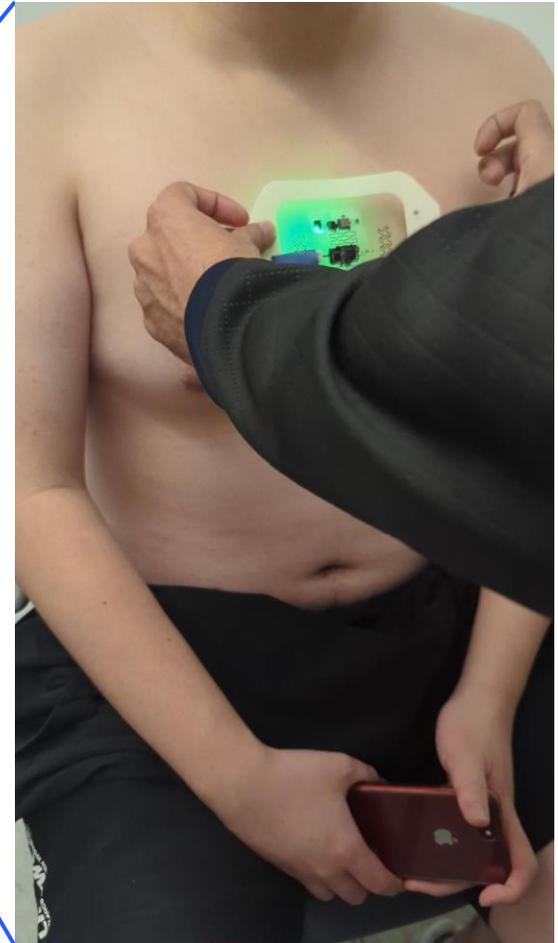
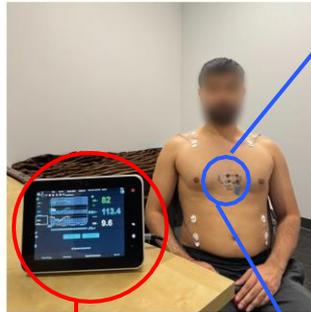
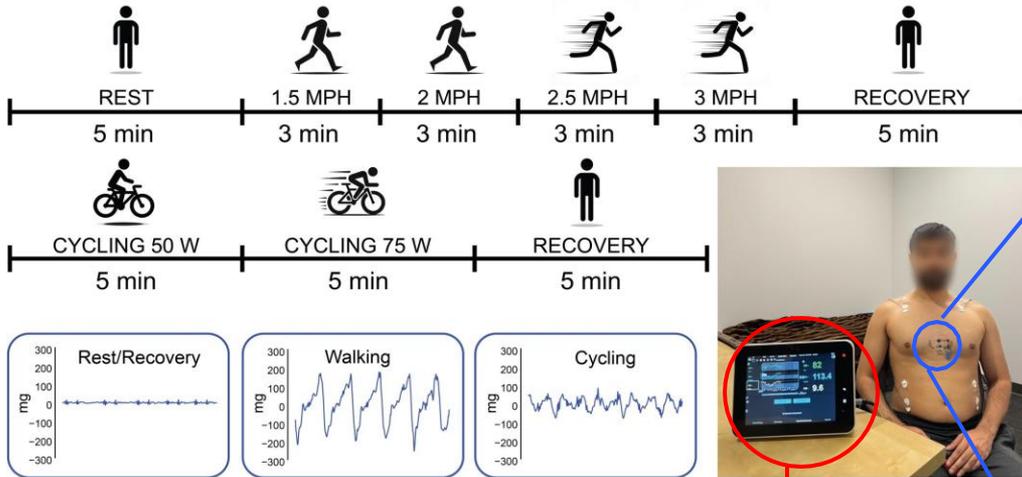


POSIZIONE OTTIMALE PER MISURA FORMA D'ONDA STANDARD



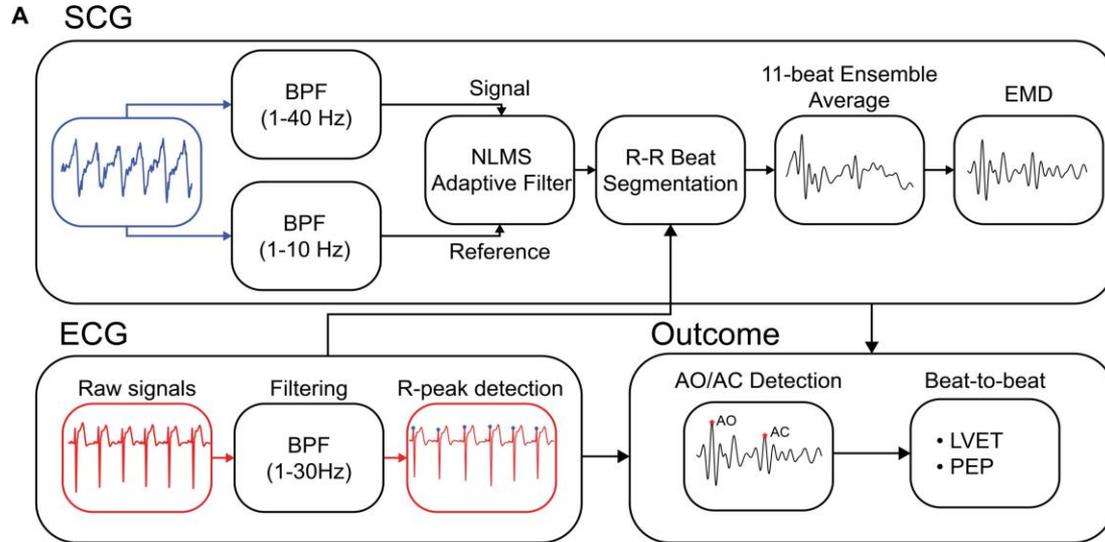
Descrizione

RIMOZIONE ARTEFATTI DA MOVIMENTO

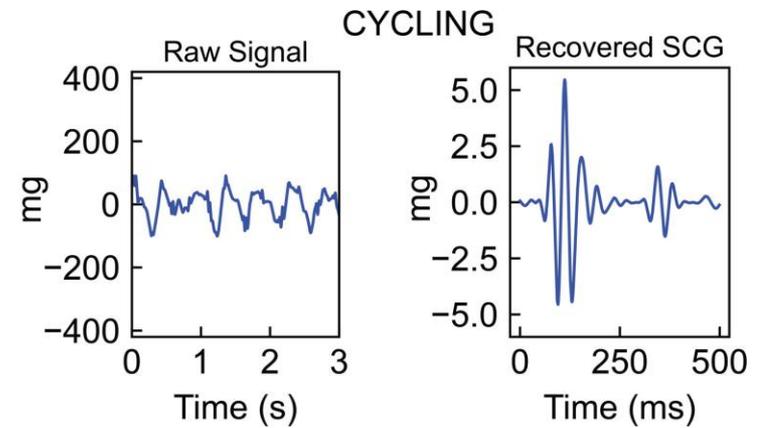
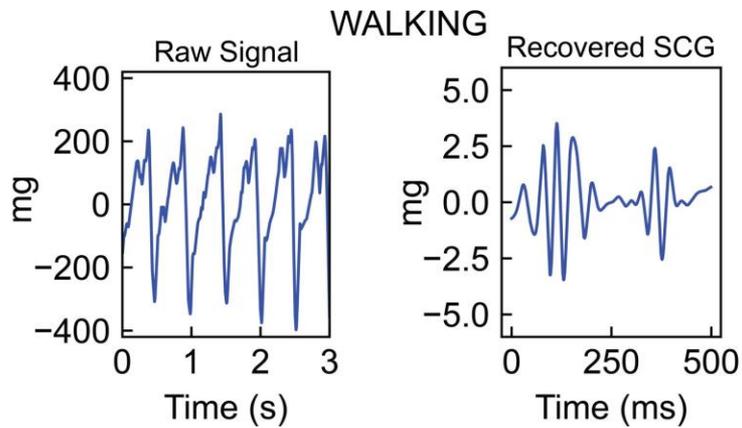


Descrizione

RIMOZIONE ARTEFATTI DA MOVIMENTO

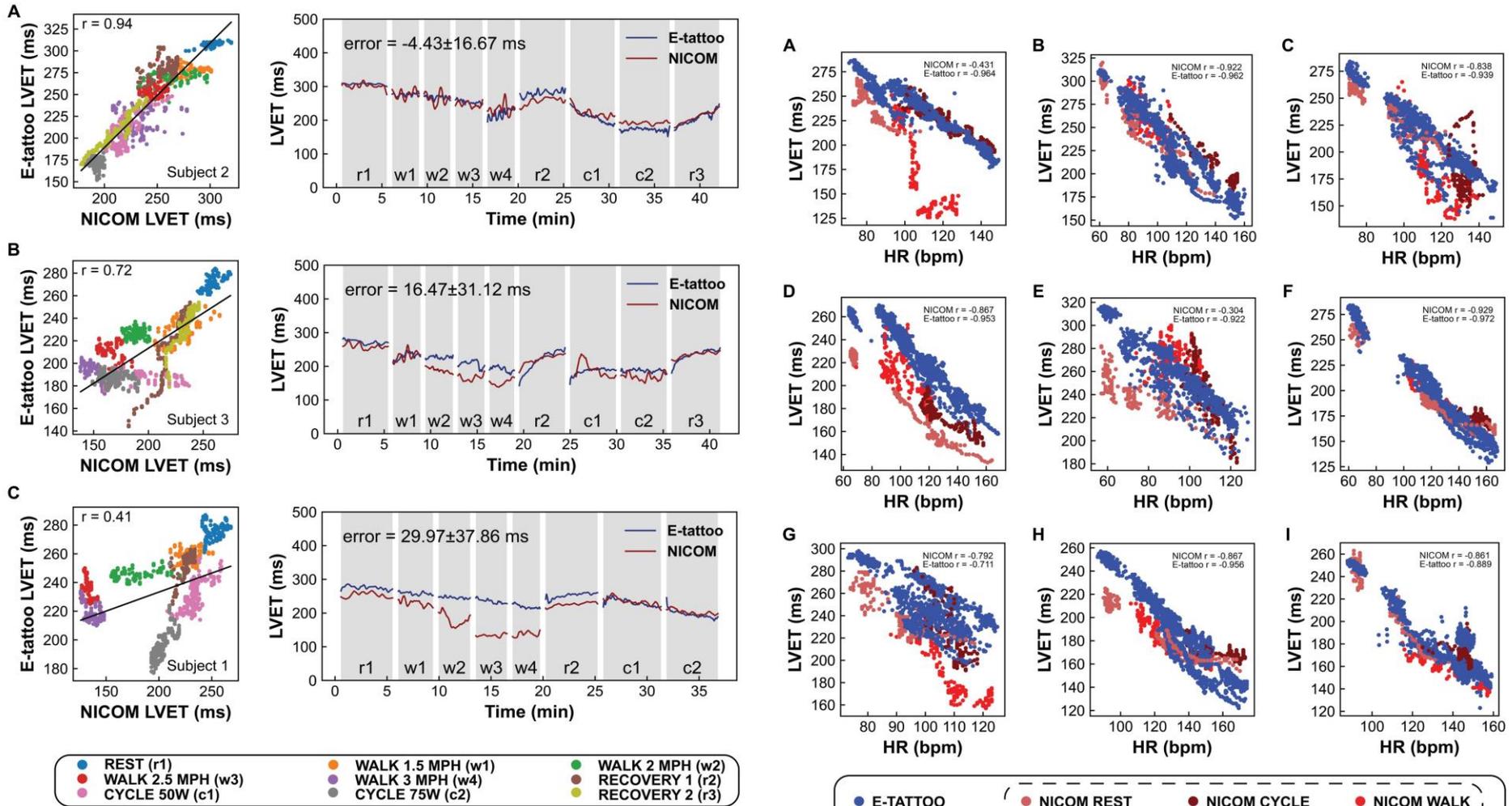


RIMOZIONE ARTEFATTI DA MOVIMENTO



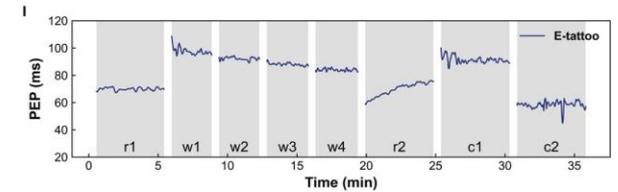
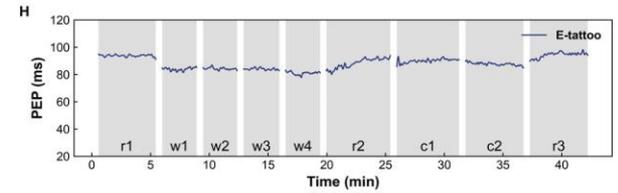
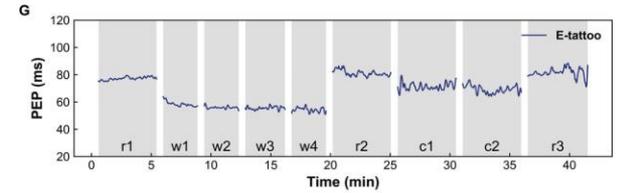
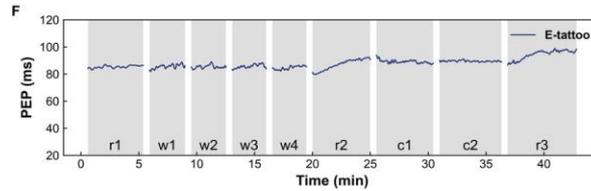
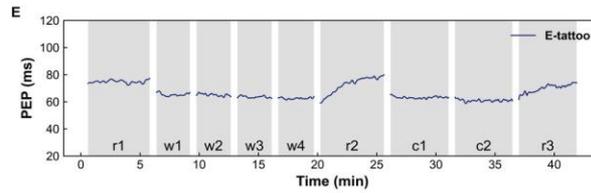
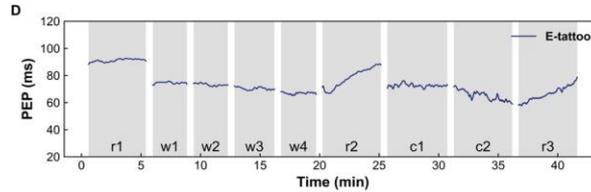
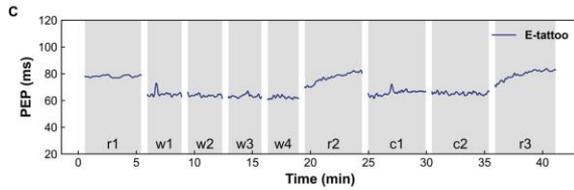
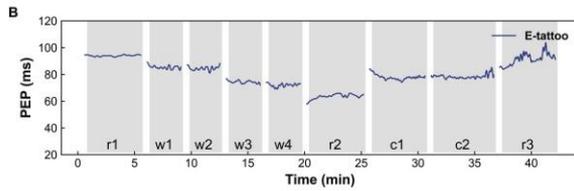
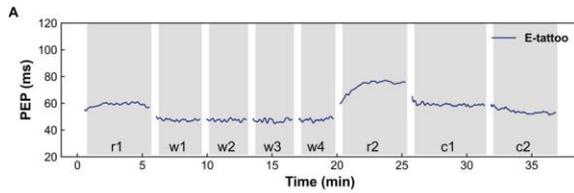
Risultati

VALIDAZIONE CON GOLD STANDARD PER STIMA DEGLI INTERVALLI CARDIACI



Risultati

VALIDAZIONE CON GOLD STANDARD PER STIMA DEGLI INTERVALLI CARDIACI



BREVETTO

1. "Chest e-tattoo for daily use and cardiac monitoring"

- **Descrizione del brevetto:** 8114 Lu. US63/454,195.
- **Stato del brevetto:** Patent Pending.
- **Data di deposito:** 23 marzo 2023.
- **Inventori coinvolti:** Nanshu Lu, Sarnab Bhattacharya, Philip Tan, Pulin Wang, Francesca Santucci.

A STACKED-DESIGN MULTI-MODE CONFORMABLE EPIDERMAL SENSOR

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and benefit of U.S. provisional patent application serial no. 63/454,195 filed March 23, 2023, which is fully incorporated by reference and made a part hereof.

GOVERNMENT SUPPORT

[0002] This invention was made with government support under Grant no. ECCS2133106 awarded by the National Science Foundation and Grant no. N00014-20-1-2112 awarded by the Office of Naval Research. The government has certain rights in the invention.



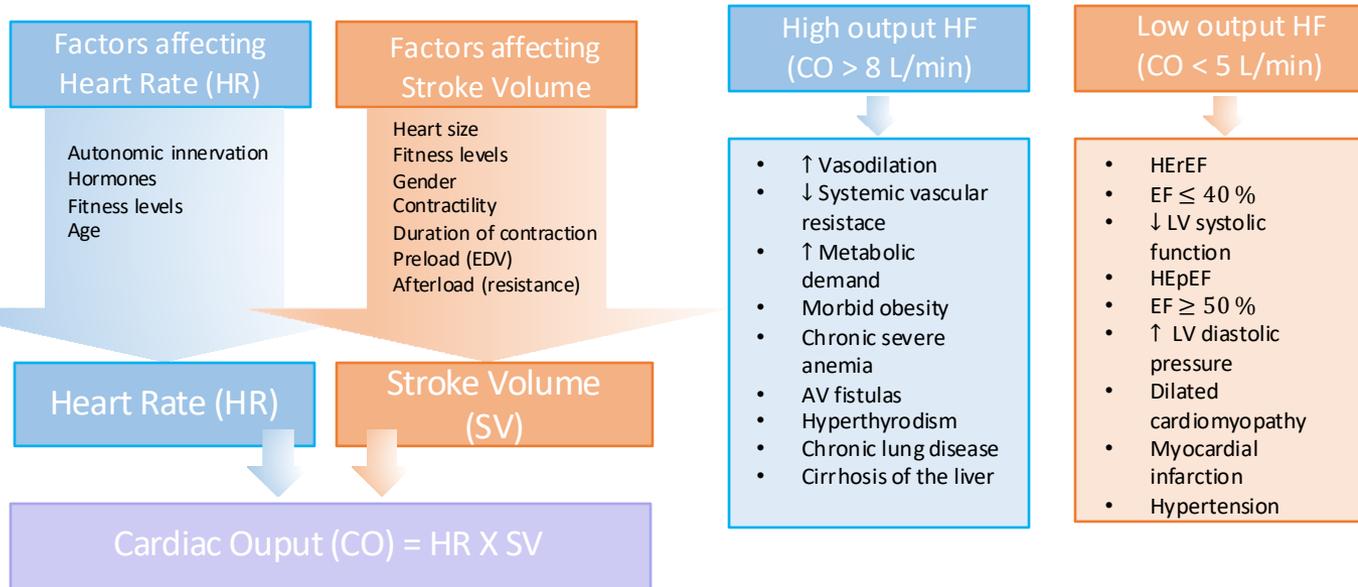
Attorney Docket No. 10046-518PV1
U.S. Application No.: 63/454,195

ASSIGNMENT

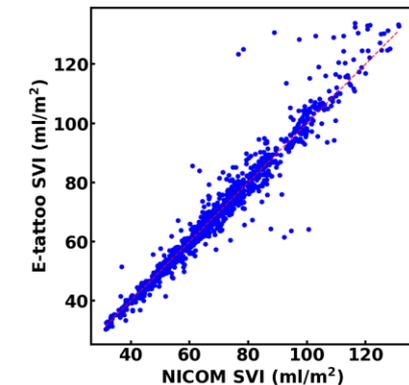
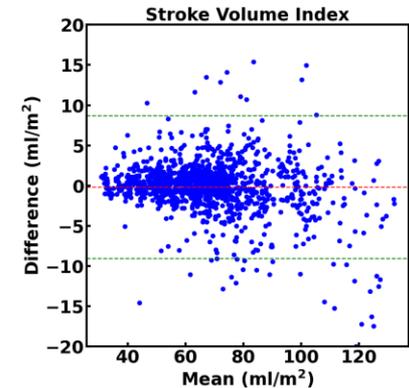
For good and valuable consideration, the receipt, sufficiency and adequacy of which are hereby acknowledged, we, **Nanshu Lu** of Austin, TX; **Sarnab Bhattacharya** of Austin, TX; **Philip Tan** of Austin, TX; **Pulin Wang** of Austin, TX; and **Francesca Santucci** of Austin, TX; hereby sell, assign and transfer to the **BOARD OF REGENTS, THE UNIVERSITY OF TEXAS SYSTEM**, a Texas institution of higher learning, having a place of business at 210 West 7th Street, Austin, TX 78701, and its successors and assigns (collectively hereinafter "the Assignee"), the entire right, title, and interest throughout the world in the inventions and improvements that are subject of an application for United States Patent, titled "A STACKED-DESIGN MULTI-MODE CONFORMABLE EPIDERMAL SENSOR," filed March 23, 2023, and assigned U.S. Patent Application No. 63/454,195, this assignment including said application, and all divisional, continuing, substitute, renewal, reissue and all other applications for patent that have been or shall be filed in the United States and all foreign countries on any such inventions or improvements; all original and reissued patents that have been or shall be issued in the United States and all foreign countries on such inventions or improvements; and specifically including the right to file foreign applications under the provisions of any convention or treaty and claim priority based on such application in the United States; and we authorize and request the issuing authority to issue any and all United States and foreign patents granted on such inventions or improvements to the Assignee; and we warrant and covenant that no assignment, grant, mortgage, license or other agreement affecting the rights and property herein conveyed has been or will be made to others by the undersigned, and that the full right to convey the same herein expresses is possessed by the undersigned.

RISULTATI - SVILUPPI FUTURI

- **Volume sistolico:** quantità di sangue espulso dal cuore in un singolo battito
- **Gittata cardiaca:** quantità di sangue che viene espulso dal cuore in un minuto



AV = arterial venous; CO = cardiac output; EF = Ejection fraction, HF = heart failure; HFpEF = heart failure with preserved ejection fraction; HFrEF = heart failure with reduced ejection fraction; LV = left ventricular.



AIIC 2024
AWARDS



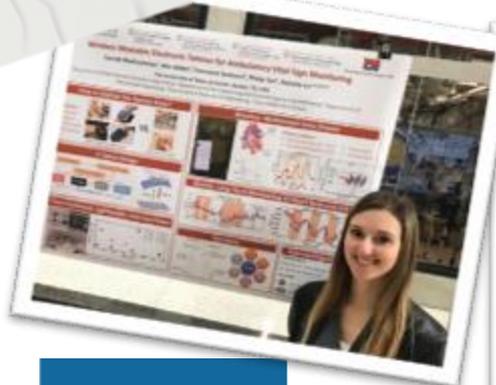
Francesca Santucci

f.santucci@unicampus.it

Postdoc presso Università Campus Bio-Medico di Roma

(Unità di Ricerca di Automatica,

Unità di Misure e Strumentazione Biomedica)



AIIC

associazione
italiana
ingegneri clinici

RISULTATI - SVILUPPI FUTURI

- **Volume sistolico:** quantità di sangue espulso dal cuore in un singolo battito
- **Gittata cardiaca:** quantità di sangue che viene espulso dal cuore in un minuto

Studio	Risultati predizione Volume Sistolico				
	Features combination	Corr. Coefficient (r-value)	MedAE (mL)	MAPE (%)	Bland Altman error (%)
Nostro	ECG	0.64	7.51	15.7	42.9
	SCG	0.75	6.41	14.5	37.6
	ECG + PPG _{e-tattoo}	0.92	1.79	5.89	21.6
	ECG + PPG _{somno}	0.94	1.79	5.59	19.
	SCG + PPG _{e-tattoo}	0.96	1.57	4.42	15.38
	SCG + PPG _{somno}	0.97	1.52	4.52	14.50
	ECG + SCG	0.97	1.24	3.29	11.7
	ECG + SCG + PPG _{somno}	0.99	1.06	2.71	9.42
	ECG + SCG + PPG _{e-tattoo}	0.98	1.15	2.91	10.7
	Studi Precedenti				
Semiz et al.	ECG + SCG _{x,y,z,total}	0.81	7.56		<30
Ganti et al.	ECG + SCG + BSA + Age	0.88			28

