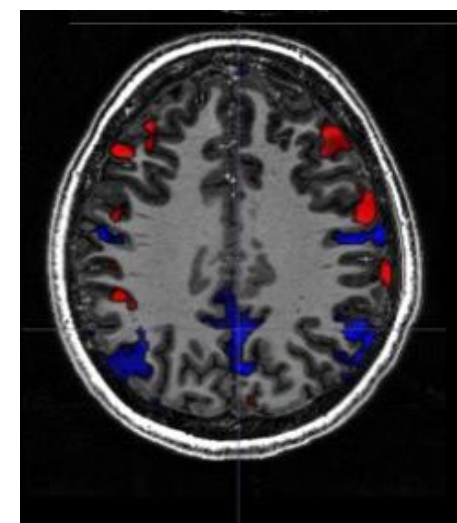




POLITECNICO
MILANO 1863

B³ Lab

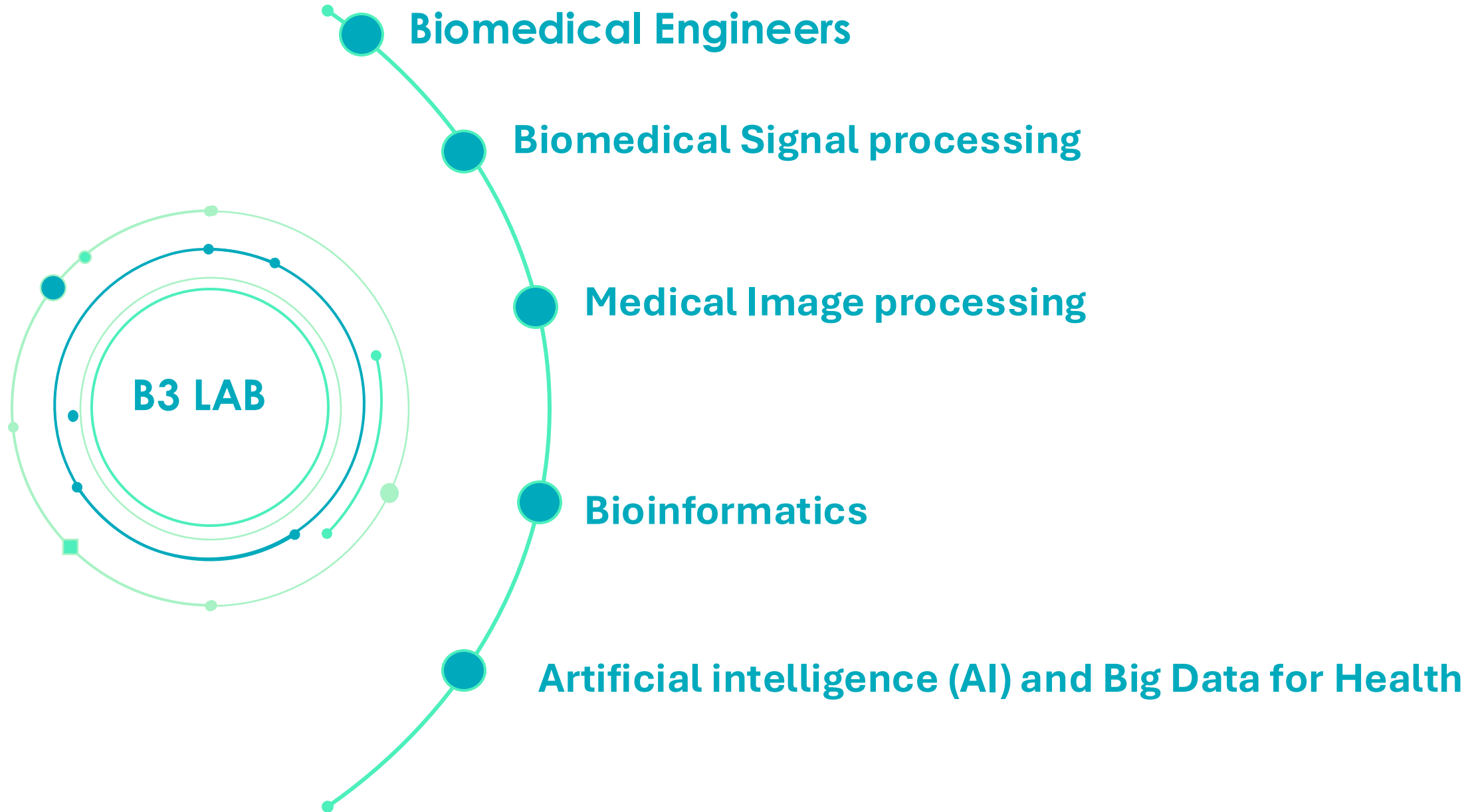
Biosignals
Bioimages
Bioinformatics

<https://www.b3lab.deib.polimi.it>



DIPARTIMENTO DI ELETTRONICA
INFORMAZIONE E BIOINGEGNERIA

B3 LAB @POLIMI



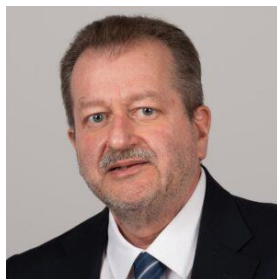
Application areas



People



Sergio Cerutti
(Prof. Emeritus
funder)



Giuseppe Baselli
(full professor)



Anna Maria Bianchi
(full professor)



Luca Mainardi
(full professor)



**Maria Gabriella
Signorini**
(full professor)



Riccardo Barbieri
(full professor)



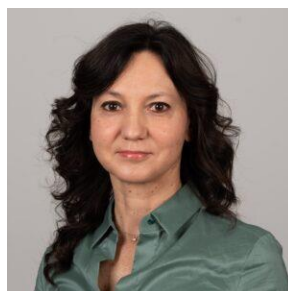
Valentina Corino
(Associate
professor)



Manuela Ferrario
(Associate
professor)



**Martin Osvaldo
Mendez Garcia**
(Associate
professor)



Linda Pattini
(Associate
professor)



Stefania Coelli
(Assistant
professor)



Anna Corti
(Assistant
professor)



Marta Carrara
(Assistant
professor)



Eleonora Maggioni
(Assistant
professor)

Cardiovascular Signal Processing and Modelling

Contacts:

Prof. Manuela Ferrario

Prof. Valentina Corino

Prof. Anna M. Bianchi

Prof. Maria Gabriella Signorini

Prof. Marta Carrara

Prof. Anna Corti

Prof. Stefania Coelli

Prof. Luca Mainardi

Prof. Riccardo Barbieri

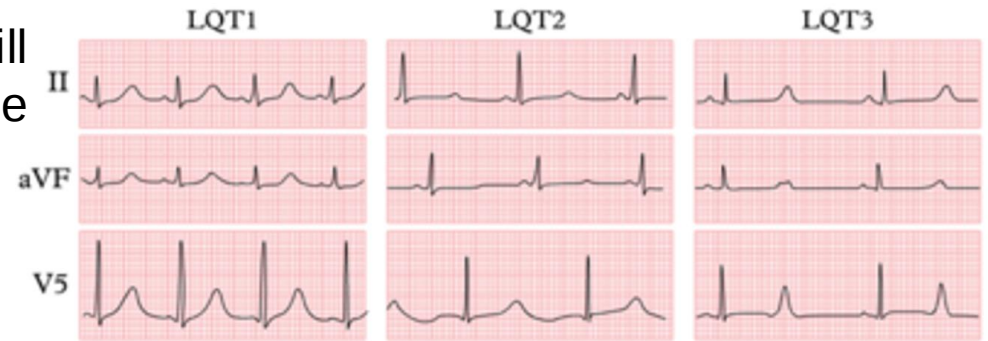
Prof. Martin O. Mendez



Heart signal analysis for diseases detection and monitoring

Pathology

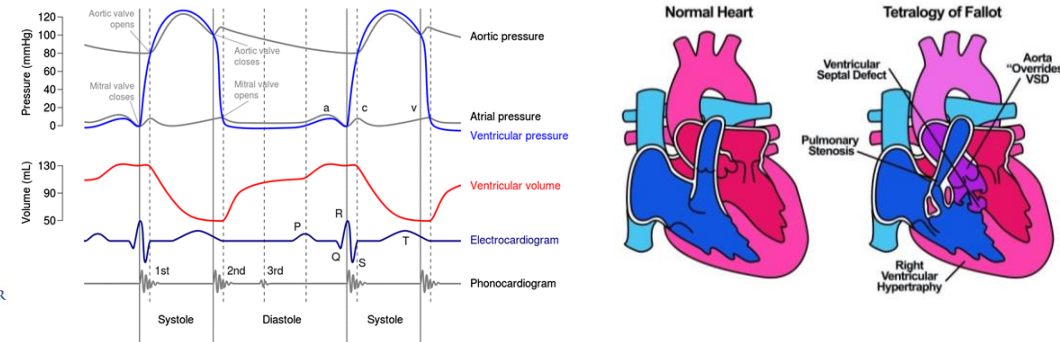
To develop an algorithm for identifying patients who will develop symptoms/endpoints, using two approaches "single ECG prediction" and "serial ECGs up until diagnosis date"



Contacts: valentina.corino@polimi.it

Newborns

Monitoring newborns in neonatal intensive care unit (NICU):
Tetralogy of Fallot (TOF) is a rare combination of four congenital heart defects, that required surgery immediately after baby delivery.
Post-operative period is critical and complex to manage.
Signal waveforms (ECG, ABP, CVP, etc.) were collected for the entire neonatal ICU stay.



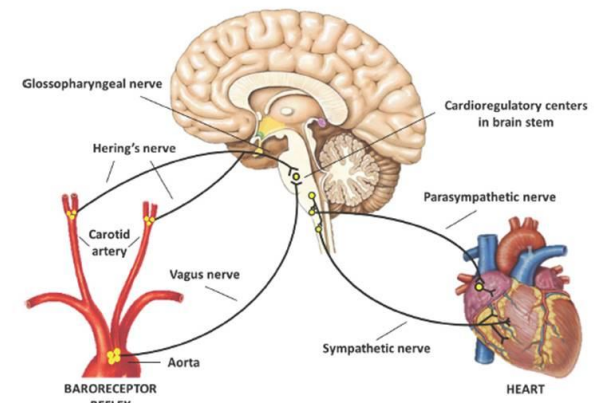
Contacts: manuela.ferrario@polimi.it , marta.carrara@polimi.it

Autoregulation

- Assessing cerebral autoregulation in clinical scenarios
- Assessing simultaneously peripheral vasomotion, cerebral autoregulation and baroreflex in healthy subjects
- Analysis of the within-burst and between-burst muscle sympathetic nerve activity dynamics in healthy and pathological subjects

Contacts:

riccardo.barbieri@polimi.it, edoardomaria.poli@polimi.it



Cardiovascular characterization of pathophysiological states in the ICU

- To develop **novel indices** able to improve clinical monitoring, drug delivery and patients risk stratification.
- To **model physiological cardiovascular mechanisms** during sepsis development and therapy administration
- To develop **machine/ deep learning techniques** to assist clinicians in the prompt identification and immediate, tailored assistance.



49M
cases/year



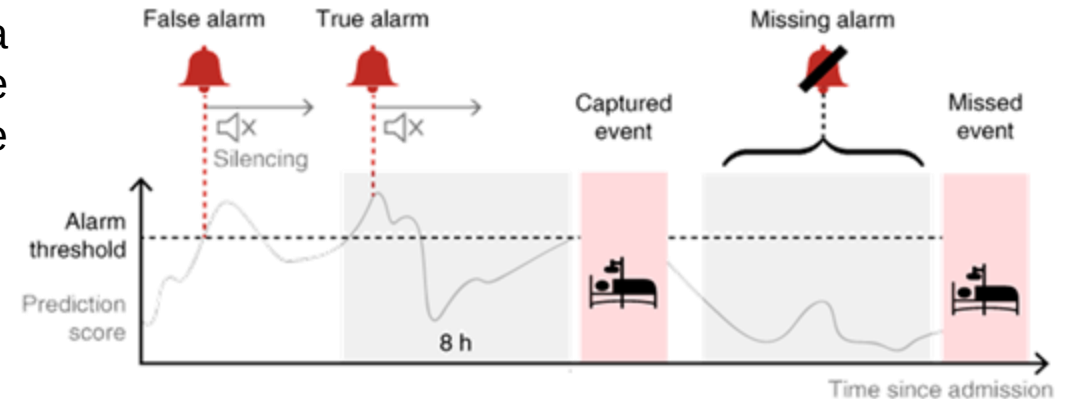
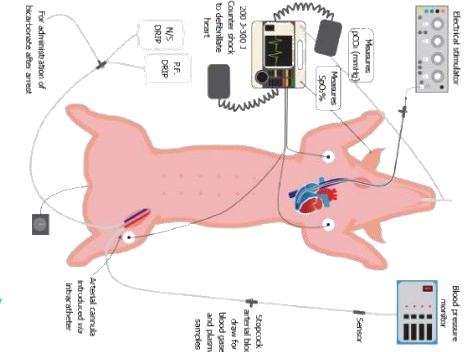
42%
ICU mortality

The world of critical care and acute illness is experiencing a fundamental data revolution and is fertile ground for the emergence of **artificial intelligence (AI)** aiming to improve personalized care and the evolution of data-augmented care

Contacts: manuela.ferrario@polimi.it , marta.carrara@polimi.it

- Characterization of the patients' response to different treatments and to predict the need and the optimal treatment strategies.
- Reinforcement algorithms for optimal treatment and intervention strategies
- Data sharing: anonymization techniques and privacy

Contacts: Riccardo Barbieri, Edoardo Polo

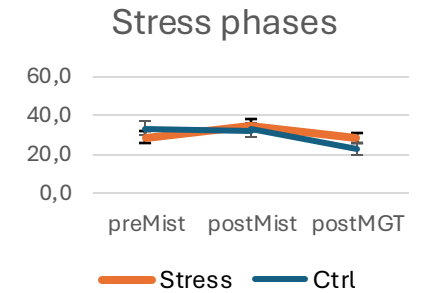
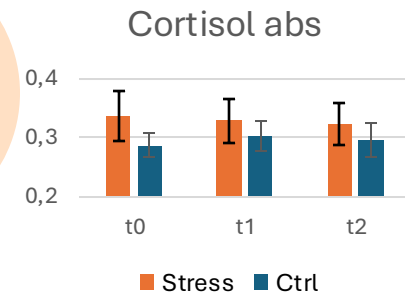
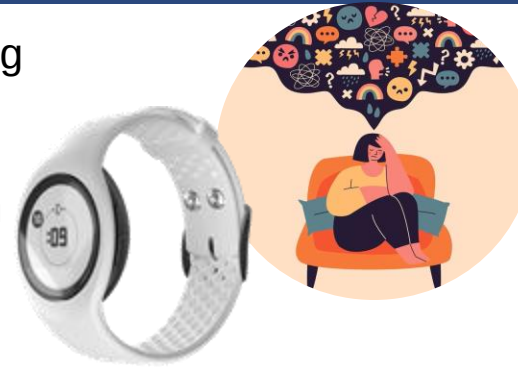


Smart physiological signals monitoring: Wearable devices

Stress

Acquisition of **stress-related** parameters: validating the reliability of wearable devices

- Identification of stress-related physiological response to acute stress and their classification
- Validation of wearable devices collecting physiological stress-related parameters



Contacts:

annamaria.bianchi@polimi.it , martin.mendez@polimi.it stefania.coelli@polimi.it , pierluigi.reali@polimi.it

From ECG to Emotion

Heart Rate Variability (HRV) provides valuable insights into the autonomic nervous system activity. However, the extraction and representation of meaningful HRV features become increasingly challenging in settings where **emotion-eliciting stimuli** and **physical activity** overlap, such as in motor rehabilitation, where the focus is in monitoring the patient's **engagement to the therapy**.



Contacts:

annamaria.bianchi@polimi.it , simone.costantini@polimi.it, riccardo.barbieri@polimi.it, edoardomaria.poli@polimi.it

Sport

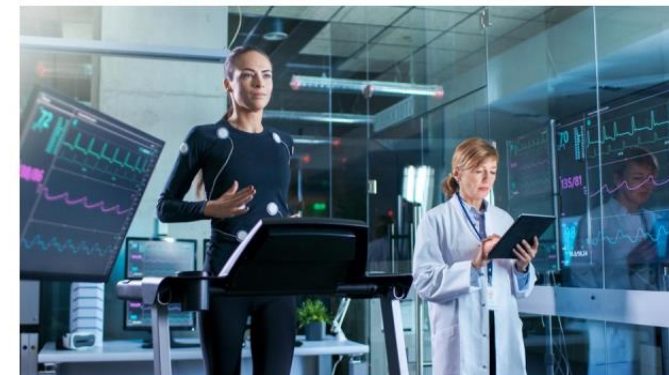
Collection and analysis of physiological signals, during the execution of **Sport** activities, for the validation of cardiac and respiratory variability measurements using wearable and/or clinical devices.

- performance evaluation and movement tracking

Contacts:

annamaria.bianchi@polimi.it , marta.carrara@polimi.it stefania.coelli@polimi.it , riccardo.barbieri@polimi.it, edoardomaria.poli@polimi.it

MOVLAB
Laboratorio di Analisi della Postura
e del Movimento "Luigi Divieti"



Smart physiological signals monitoring: Wearable devices

Mom
monitoring

The purpose is to lead the way in the clinical application and advancement of new ultrasound technologies, **wearables** and sensor technology to improve the health and well-being of pregnant women.



Contacts:

martin.mendez@polimi.it

Fetal monitoring

Monitoring of fetal well being with AI Methods:

- **Artificial Intelligence applications for electronic fetal monitoring**
- **Cardiotocography, fetal heart rate variability analysis during pregnancy and labour**
- **Study of fetal behavioral states**
- **Monitoring the emergence of pathologies in pregnancy via biosignals analysis**

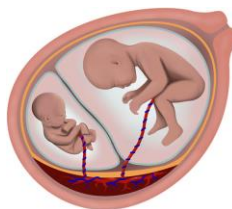
CTG dataset



NOTE FIELD

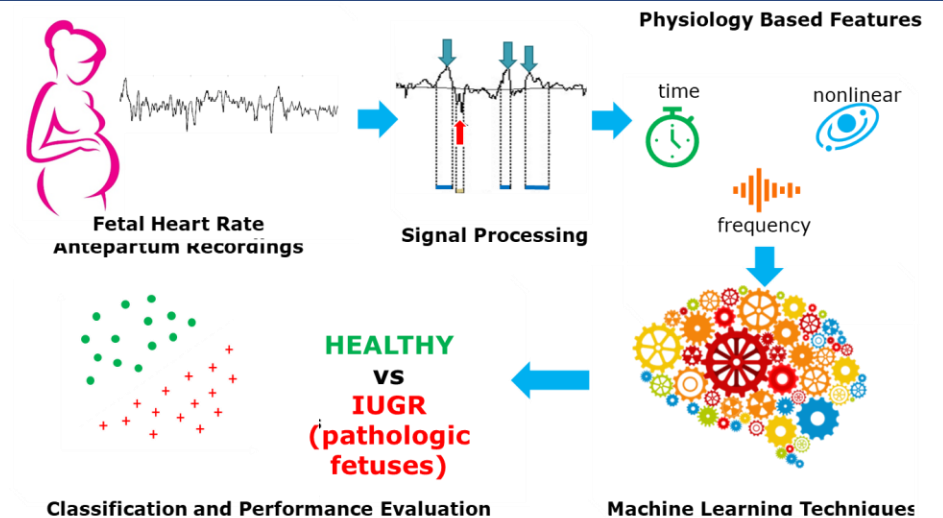
Fetus with a normal weight (2.5 kg). The mother is smoke addicted and makes regular assumption of lexotan

Weight: 2.5 kg
Drugs: benzodiazepines
Risk factors: smoke



Contacts:

giulio.steyde@polimi.it,
mariagabriella.signorini@polimi.it



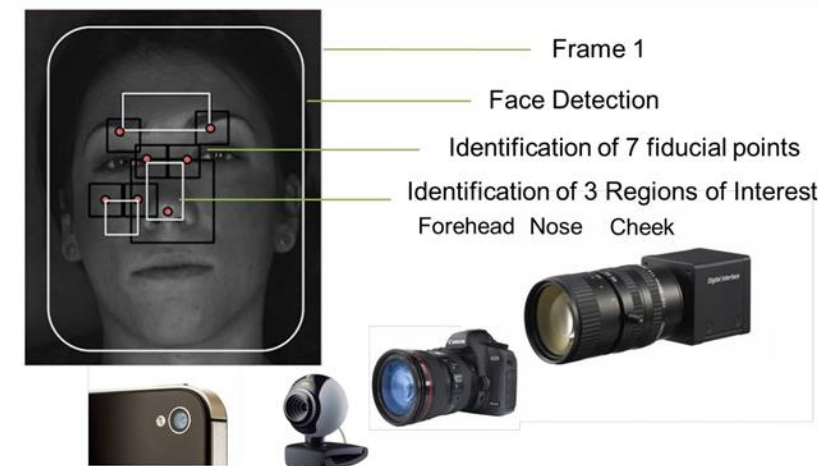
New Technologies and New Information

Contactless monitoring of cardiovascular signals through videophotoplethysmography (VPPG) is emerging as a new, powerful monitoring technique. The thesis aims at developing advanced algorithms to extract features associated with cardiovascular system dynamics from VPPG

deep learning tools

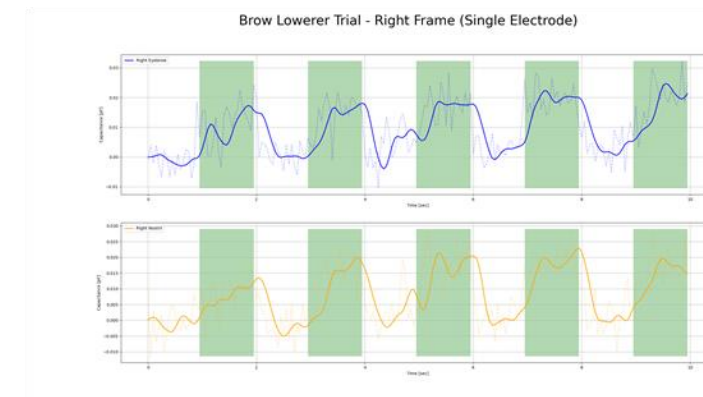
Contacts:

riccardo.barbieri@polimi.it, luca.mainardi@polimi.it



This research aims to explore the feasibility of using miniature sensor technologies, specifically optomyography and capacitive sensors, for real-time facial expression recognition (FER) in head-mounted setups. By defining a validation protocol and leveraging ML/DL algorithms, we seek to develop a robust and accurate FER system.

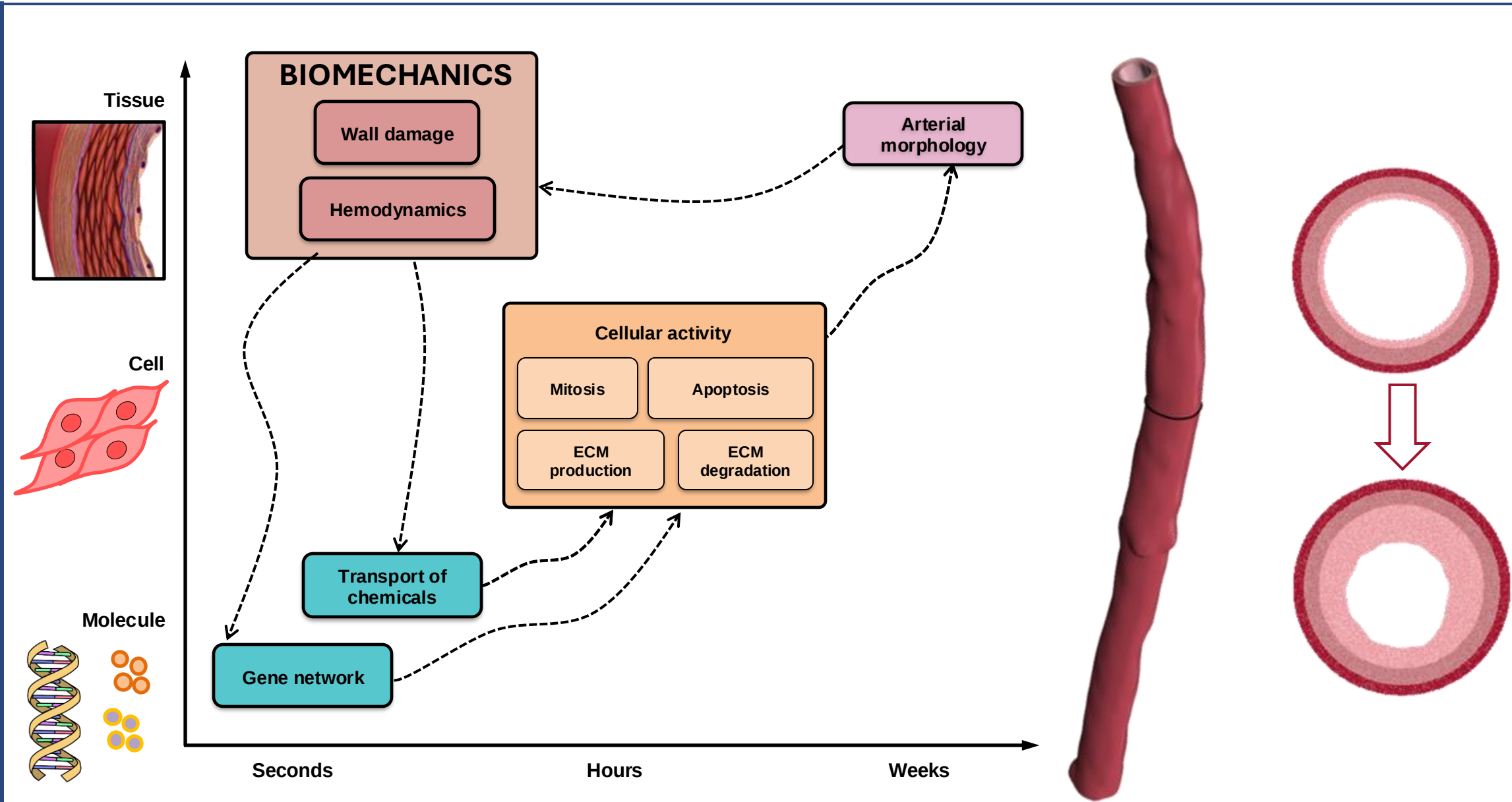
deep learning



Contacts:

luca.mainardi@polimi.it, pietro.cerveri@polimi.it

Multiscale modeling of vascular remodeling

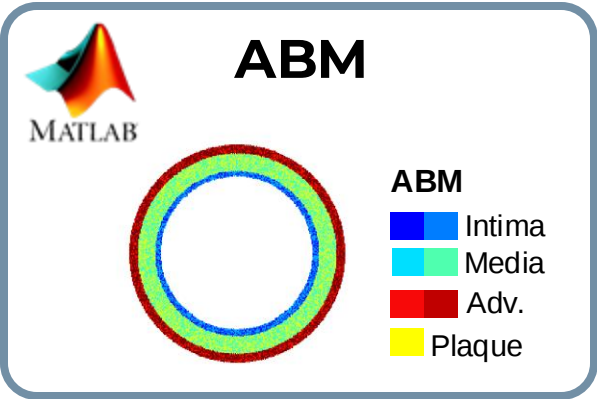
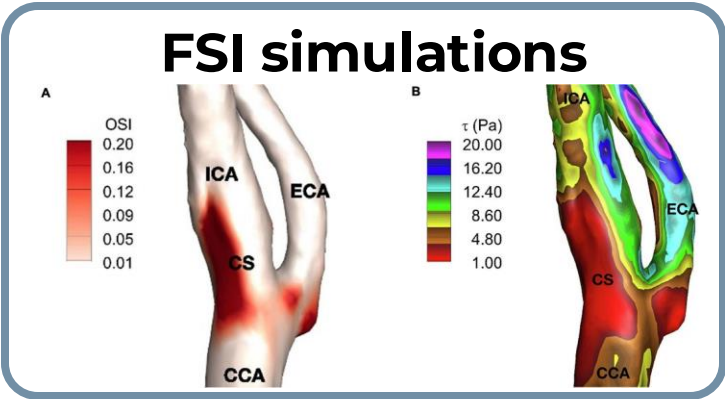


Multiscale modeling of vascular remodeling

Atherosclerosis

Multiscale model of **atherosclerosis** in carotid arteries to simulate the mechanobiological processes of plaque formation in response to **hemodynamic and biomechanical** stimuli

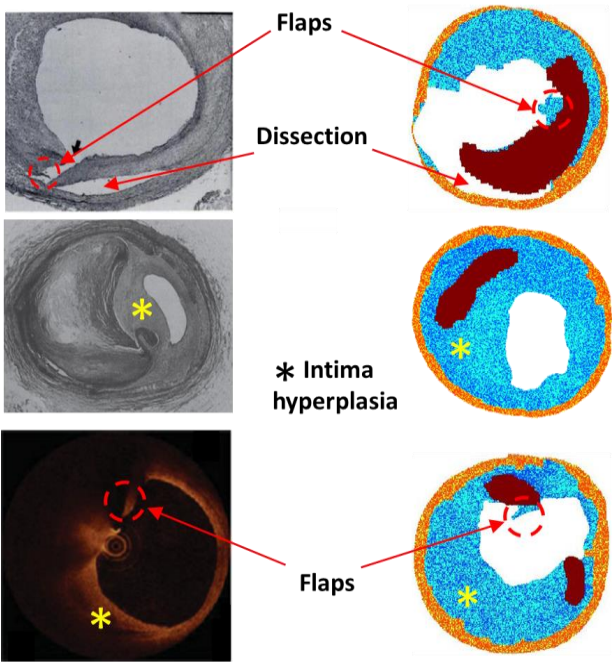
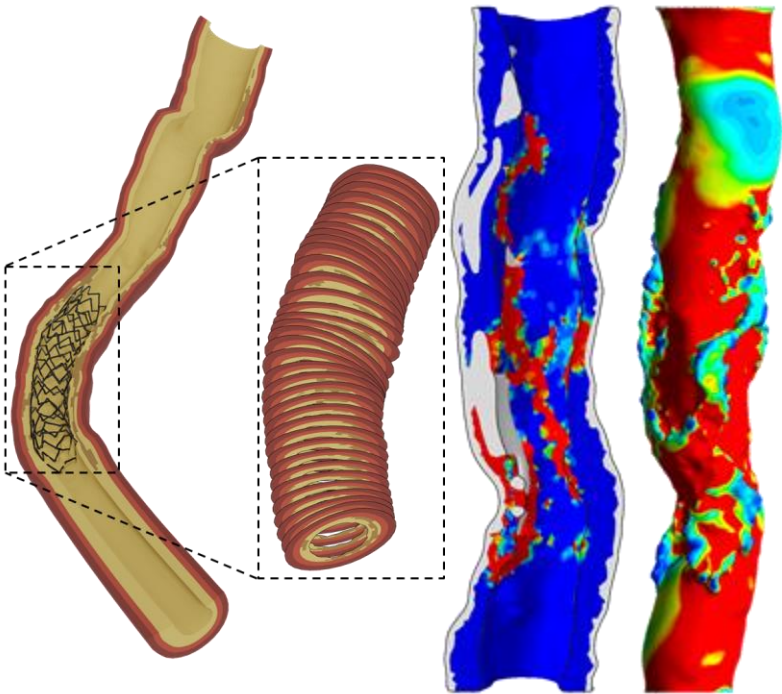
Contacts:
Anna Corti



Restenosis

multiscale model of **in-stent restenosis** in stented coronary arteries, by coupling the damage obtained from finite element simulation of the stenting intervention and an **agent-based model (ABM)** of vascular remodeling

Contacts:
Anna Corti



Medical Images analysis and interpretation & Radiomics

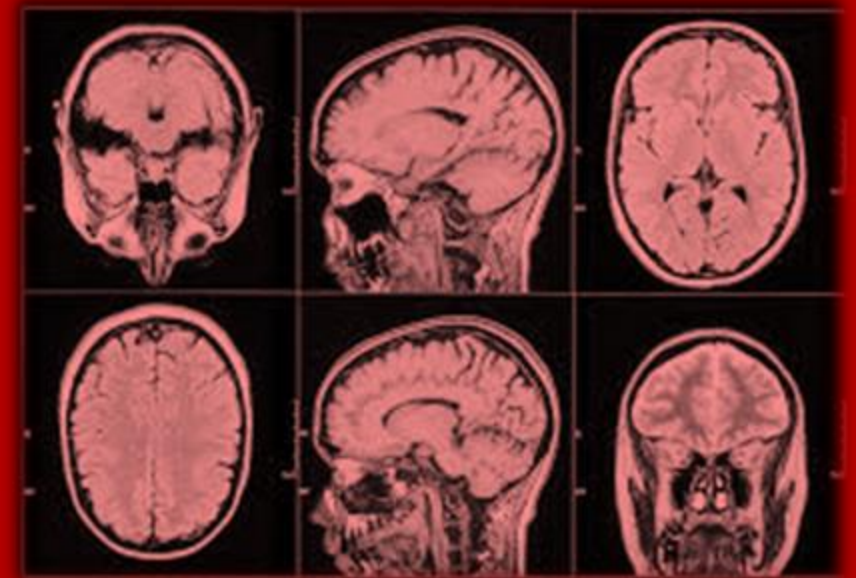
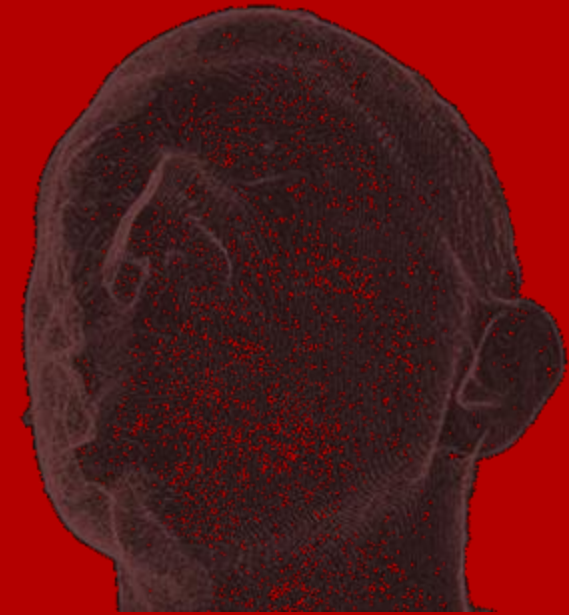
Contacts:

Prof. Valentina Corino

Prof. Anna Corti

Prof. Giuseppe Baselli

Prof. Luca Mainardi

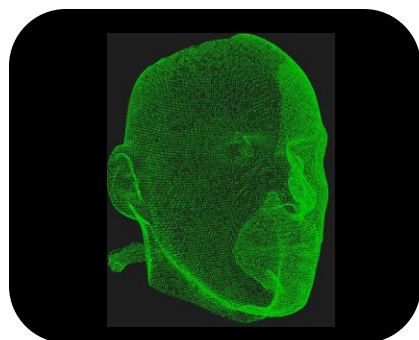


Use of Graph NN for medical imaging analysis

Focus: Head and face district

Graph Neural Networks (GNN) are transforming medical imaging analysis due to their ability to model complex relationships.

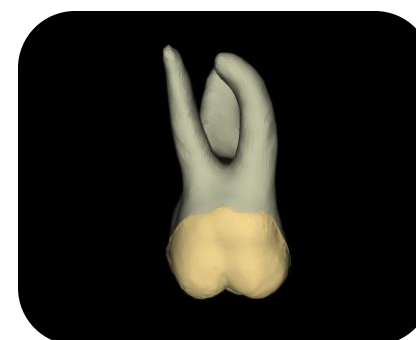
- Use of annotated medical datasets, image preprocessing, and training of Graph Neural Networks.
- Improve diagnostic accuracy in analyzing head and face imaging (**annotation, segmentation multimodal image fusion**, virtual head **model** creation) to support clinicians in diagnosis, treatment planning, and follow-up.
- Scalability to other types of images and datasets.



Annotation



Segmentation



Fusion



Virtualization

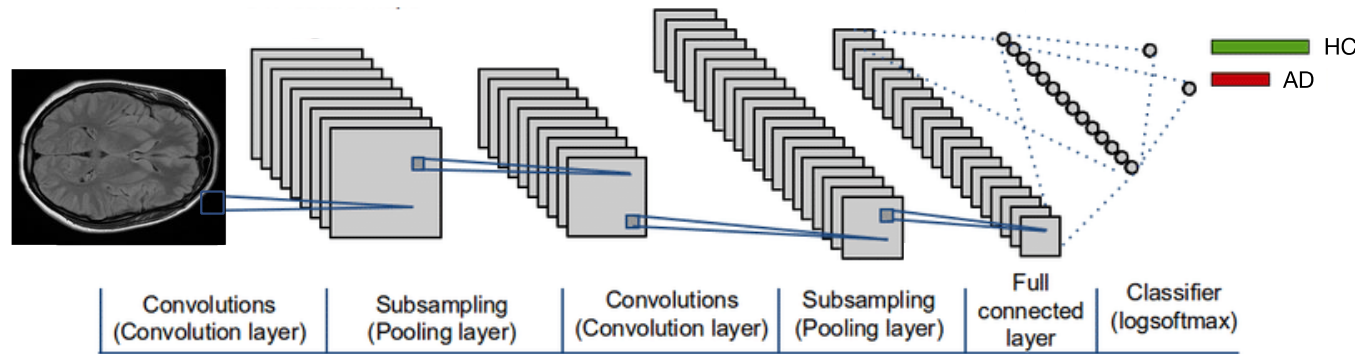
Contacts:

Prof Giuseppe Baselli giuseppe.baselli@polimi.it, Benedetta Baldini benedetta.baldini@polimi.it

Ali Shadman Yazdi ali.shadman@polimi.it

AI-based Methods to enhance information from MRI Images

→ Development of comprehensive **artificial intelligence (AI) approaches leveraging multi-modal MRI** for the early detection and prediction of neurodegenerative conditions, particularly Alzheimer's Disease (AD).



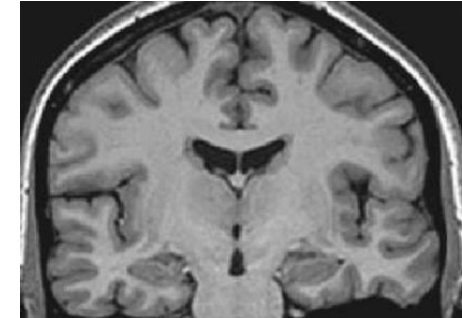
→ Use of **Explainable AI (XAI)** to validate model predictions against established imaging biomarkers across disease stages; potentially identifying novel biomarkers (e.g., of vascular damage).

Contacts:

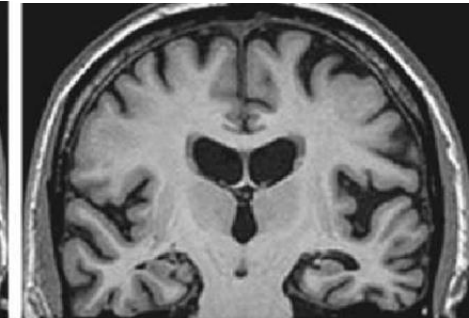
Prof. G. Baselli: giuseppe.baselli@polimi.it

valentina.bordin@polimi.it

MRI of a *healthy* subject



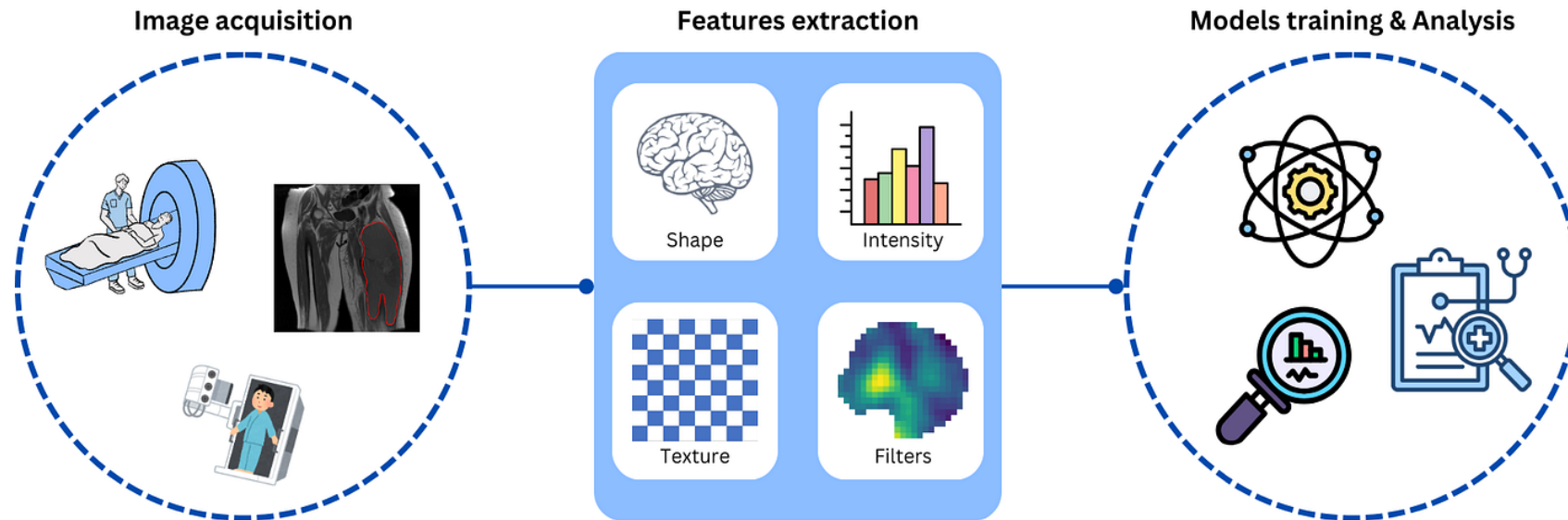
MRI of an *AD* subject



→ Focus on developing **clinically translatable solutions** by finding the optimal balance between *complex high-performance models* and *interpretable approaches*.



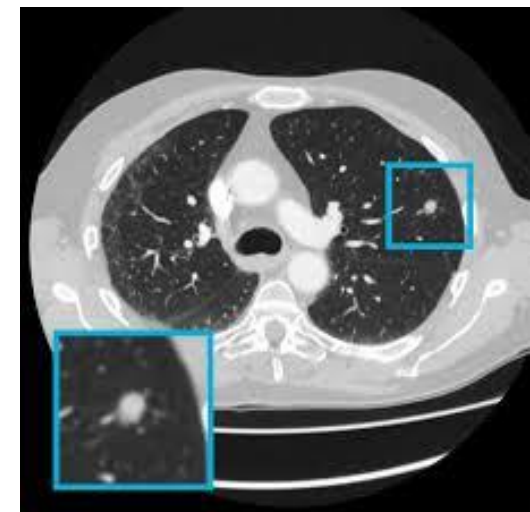
Radiomics to improve diagnosis and patient stratification



Development of artificial intelligence (AI) approach, based on the integration of radiomics and deep learning for nodule detection and identification of malignant nodules in lung cancer

Contacts:

luca.mainardi@polimi.it; valentina.corino@polimi.it;
anna.corti@polimi.it

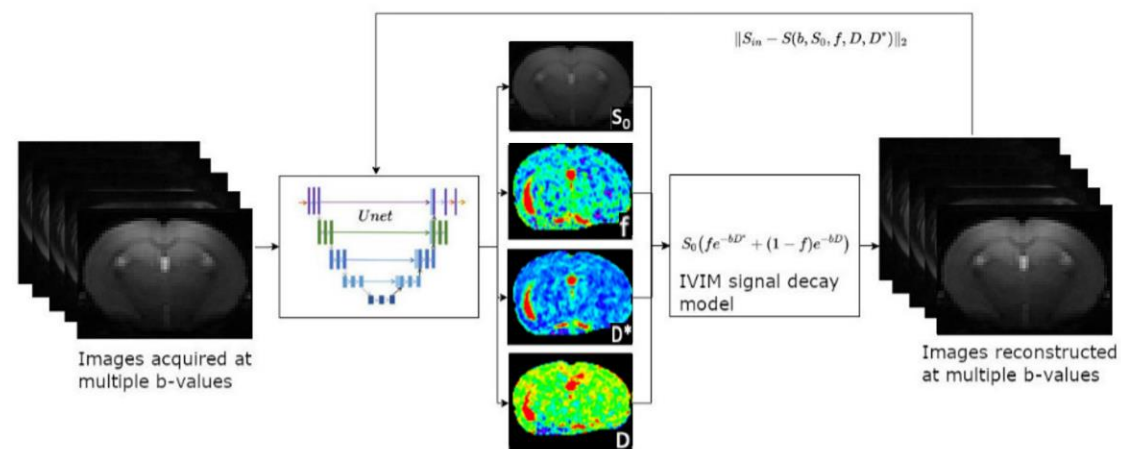


Deep Learning for Intravoxel Incoherent Motion parameter estimation in brain scans of Alzheimer's mice

- **Diffusion weighted Magnetic Resonance Imaging (DW-MRI)** enables an indirect estimate of the parameters that govern tissue microstructure.
- **Intravoxel Incoherent Motion (IVIM)** is a DWI technique that can provide separates estimates of diffusion of water molecules and the perfusion fraction.

- **Contacts: Prof. Giuseppe Baselli**
(giuseppe.baselli@polimi.it);
Dr. Alfonso Mastropietro
(alfonso.mastropietro@stiima.cnr.it)

- **Objective:** Develop Deep Learning methods for IVIM maps estimation and compare them to classical methods.
- Brain scans of Alzheimer's mice will be evaluated to compare diffusion and microvascular perfusion parameters with those of a control group. IVIM may provide new insight into cerebral small vessel health in an early Alzheimer disease stage



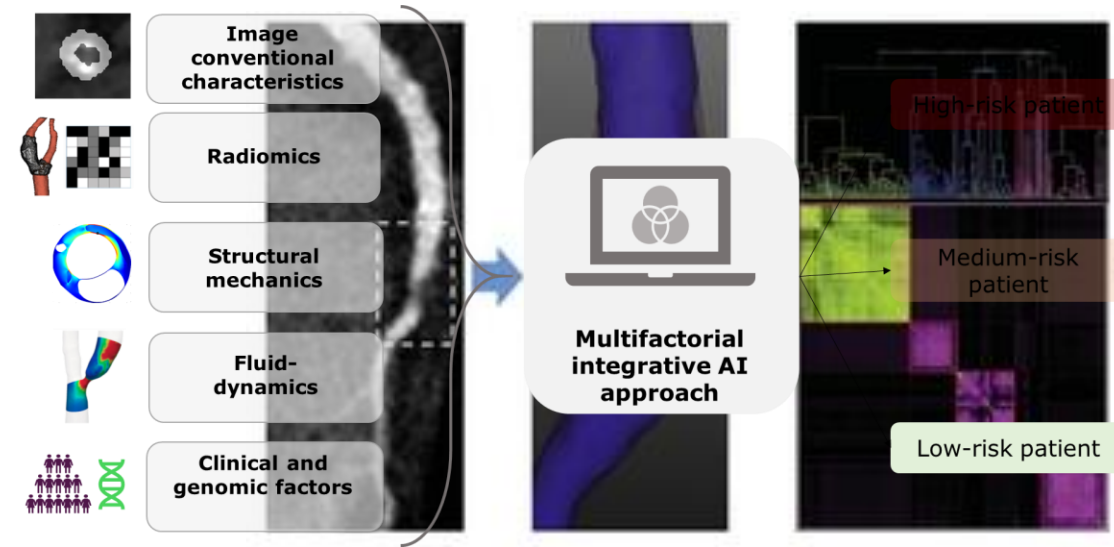
Radiomics to improve diagnosis and patient stratification

Atherosclerotic Plaque radiomics

- Identify vulnerable, rupture-prone plaques
- Identify plaque composition
- Characterize plaque biomechanics
- Develop integrative AI approaches

Contacts:

luca.mainardi@polimi.it; valentina.corino@polimi.it;
anna.corti@polimi.it



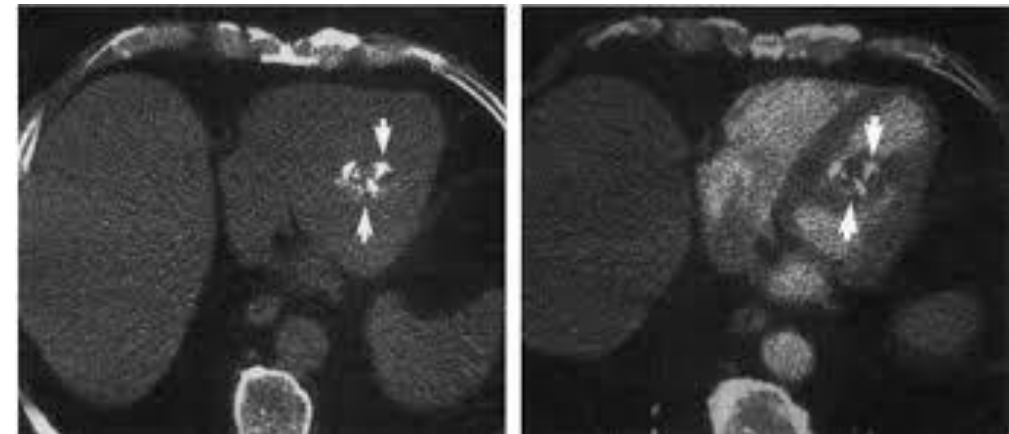
Cardiac radiomics

- characterize ventricular scar in respect to response to radiotherapy
- identify malignant mass from cardiac CT



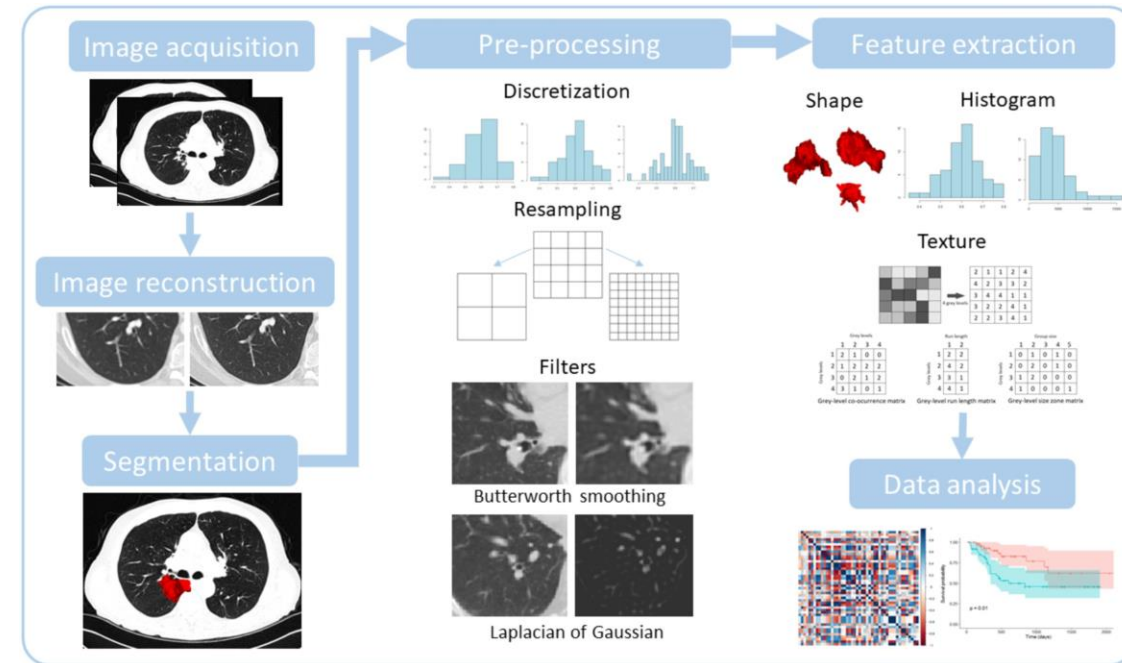
Contacts:

valentina.corino@polimi.it



Radiology and multimodal MRI Image Processing

- Development of accurate image segmentation of lumbar vertebrae from CT-scans for radiomic study.
- **Integration of imaging and cardiovascular signal** of critically-ill patients through machine learning and advanced statistical modelling approaches.
- Development of Deep-Learning neural network to automatically detect and segment **Crohn's disease** in the lower gastrointestinal tract from multimodal MRI acquisitions
- Application of graph neural network in patients with osteoporosis



In collaboration with:

HUMANITAS
RESEARCH HOSPITAL

Contacts:

riccardo.barbieri@polimi.it, edoardomaria.polo@polimi.it

Signal Analysis and Neuroimaging for Neuroscience



Contacts:

Prof. Anna M. Bianchi

Prof. Eleonora Maggioni

Prof. Stefania Coelli

Prof. Riccardo Barbieri

Prof. Giuseppe Baselli

Prof. Luca Mainardi

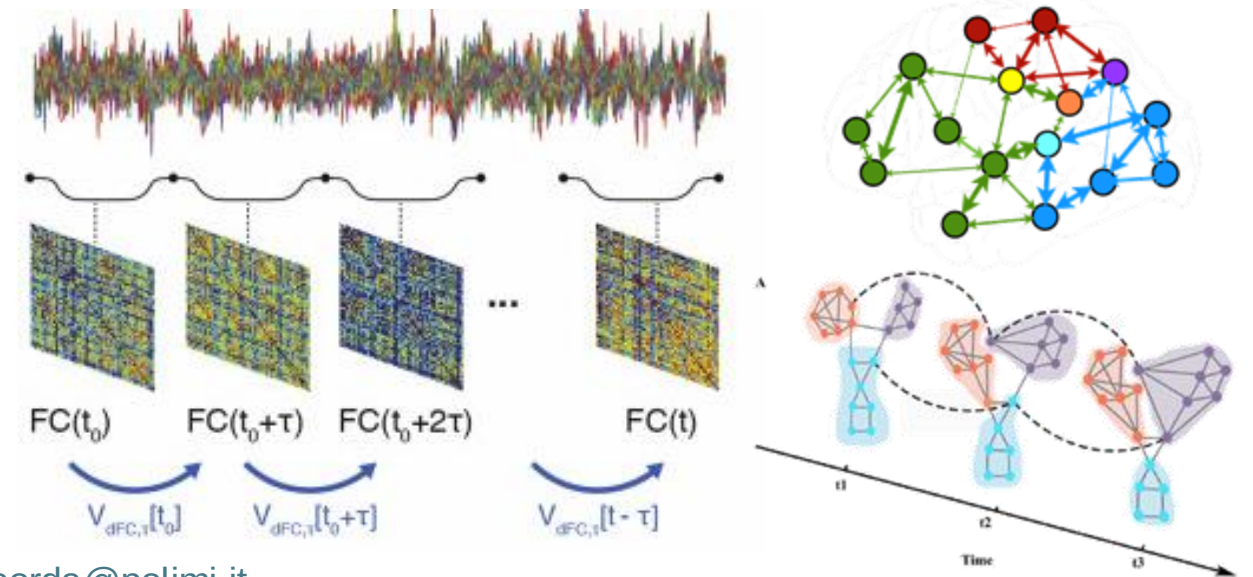
Advanced methods for Neurophysiological signals analysis

Dynamic functional connectivity (dFC): Brain functions are the results of continuous organized network reconfigurations among the functional cortical regions in response to external stimuli or internal commands.

-Explore, improve and develop innovative methods to track dynamic network reconfiguration using EEG signals to study Motor and Cognitive functions

Contacts:

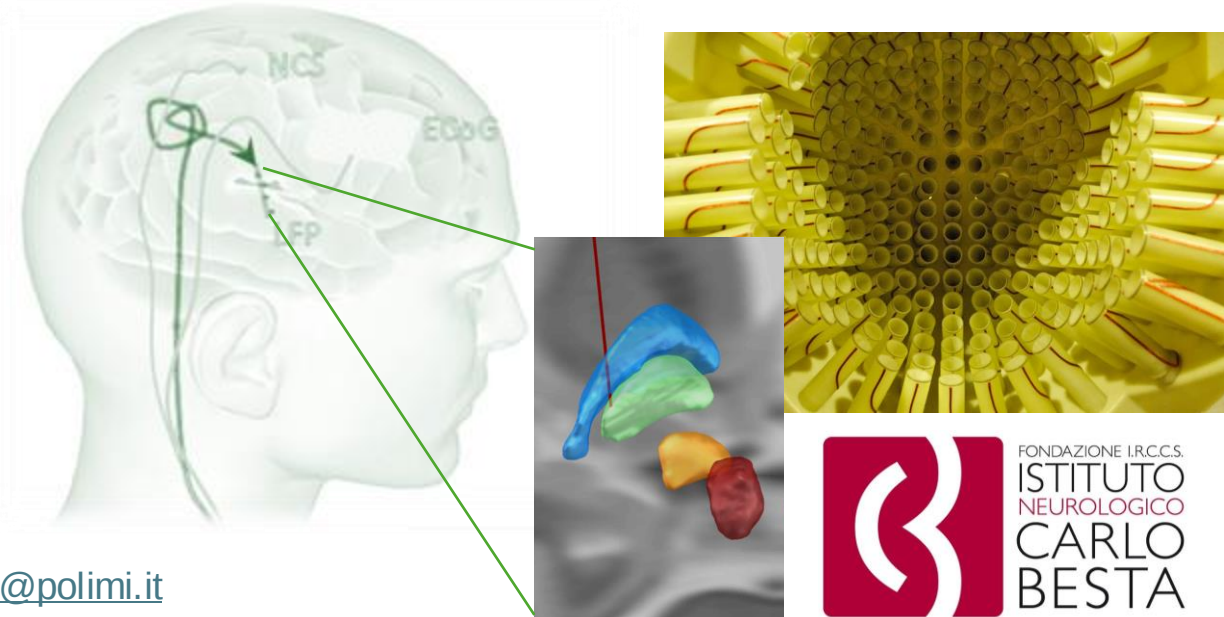
annamaria.bianchi@polimi.it, stefania.coelli@polimi.it, martina.corda@polimi.it



- Analysis and classification of microelectrode recordings for Deep Brain Stimulation surgery
- Assessment of resting-state electrophysiological network in dystonic patients by simultaneous LFPs-EEG/MEG
- Multiscale brain dynamics

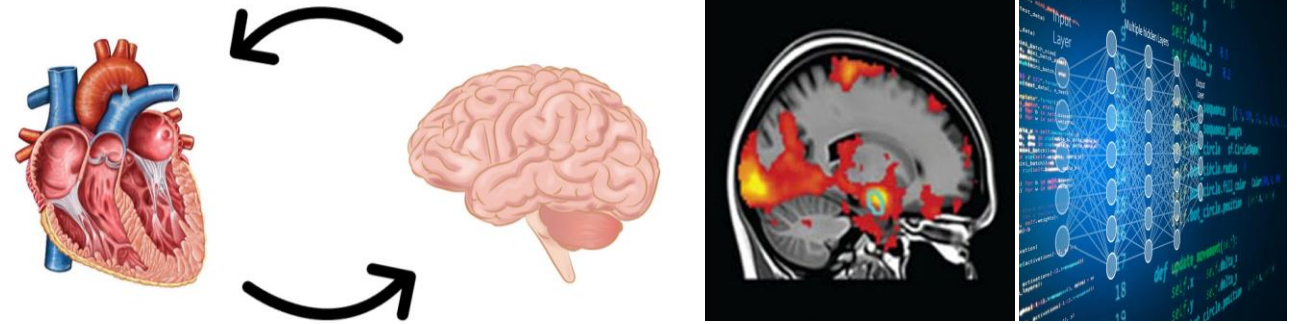
Contacts:

annamaria.bianchi@polimi.it, stefania.coelli@polimi.it, martina.corda@polimi.it



Multimodal neuroimaging and electrophysiological integration

Investigation of brain-heart interactions in psychiatric disorders through statistical and AI tools



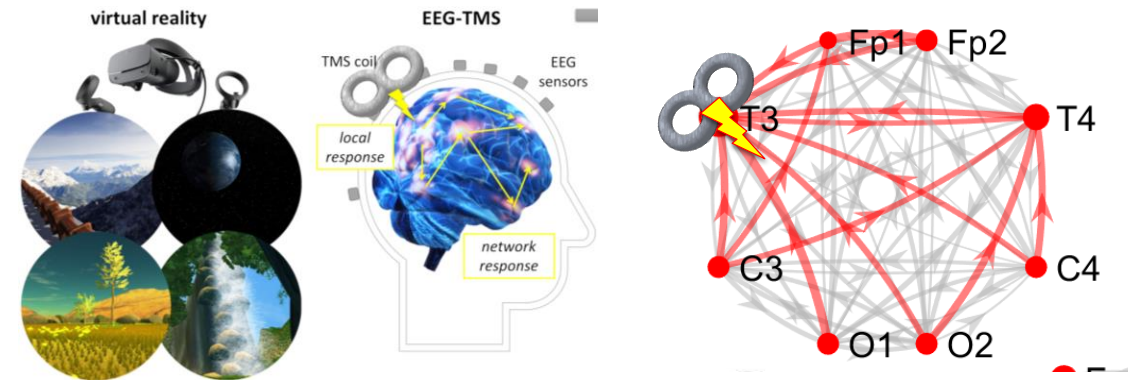
Contacts:

leonora.maggioni@polimi.it, federica.goffi@polimi.it

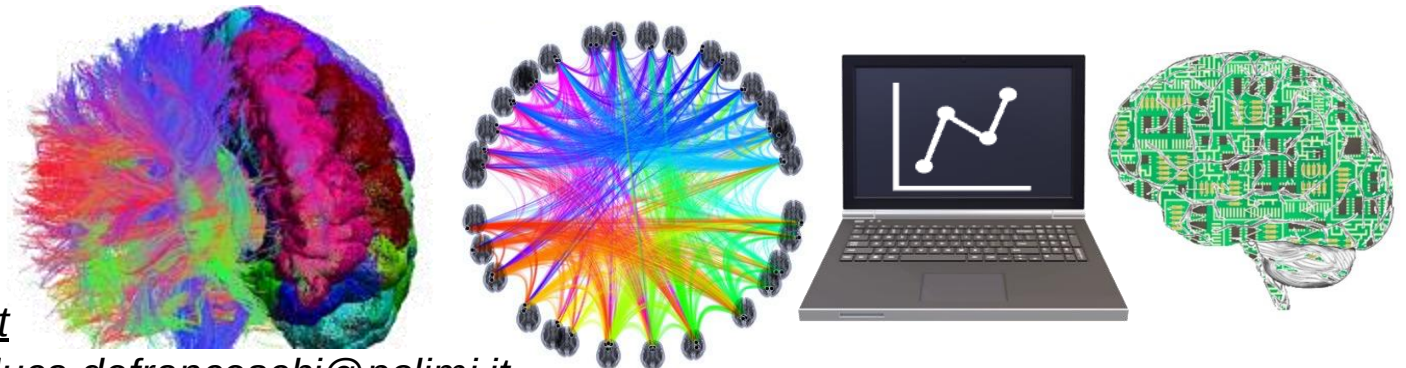
Investigation of brain networks responding to neural stimulation and to complex emotional experiences in virtual reality

Contacts:

leonora.maggioni@polimi.it, elena.bondi@polimi.it,
flavia.carbone@polimi.it



Advanced AI methods for multimodal electrophysiology and MRI data integration in psychiatric disorders



Contacts:

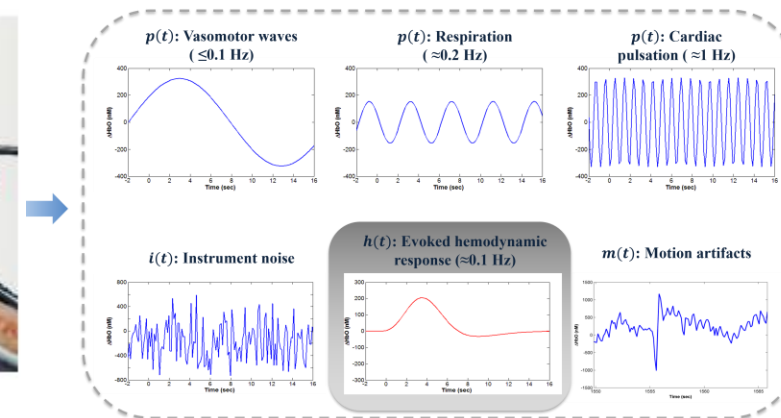
leonora.maggioni@polimi.it, emma.tassi@polimi.it,
stefano.vanoni@polimi.it, ines.won@polimi.it; gianluca.defranceschi@polimi.it

Functional Near-Infrared Spectroscopy (fNIRS)

- Assessment of Physiological Confounding Factors in fNIRS
- Assessment of posture changes on task-based cortical activity
- Protocols for fNIRS-EEG integration
- Applications for brain activity monitoring during daily life activities

Contacts:

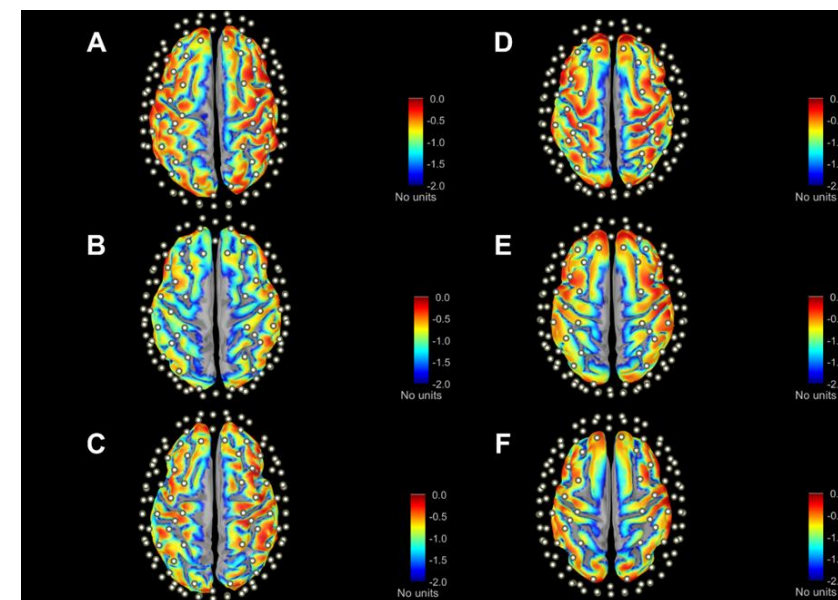
Prof. giuseppe.baselli@polimi.it
augusto.bonilauri@polimi.it



- Integration of optical properties and cortical mapping methods into sensor-based fNIRS analyses
- Promoting a systematic fNIRS mapping of cerebral activity according to optode's scalp location and age of the subject

Contacts:

Prof. giuseppe.baselli@polimi.it
augusto.bonilauri@polimi.it



EEG signals for Brain Computer Interfaces and affective computing and stimulations

- Develop Machine Learning and Deep Learning algorithm to classify Imagined Speech
- Asynchronous classification of ErrP events through Siamese Neural Network in BCI application.

Contacts: luca.mainardi@polimi.it , andrea.farabbi@polimi.it , francesco.iacomi@polimi.it riccardo.barbieri@polimi.it

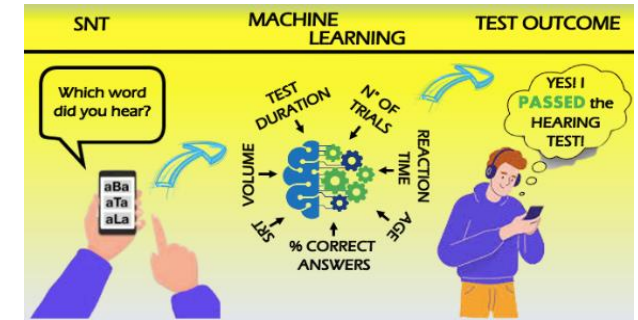


AI-driven tools for early detection of hearing and cognitive risk: development and validation of novel web-based tool for adult hearing screening that integrates a language-independent speech-in-noise test, multiple cognitive tests, and a survey of risk factors with AI-based models



Contacts:

riccardo.barbieri@polimi.it, edoardomaria.polo@polimi.it, Alessia Paglialonga



Characterization of emotional states through physiological signals



Contacts:

riccardo.barbieri@polimi.it, edoardomaria.polo@polimi.it, annamaria.bianchi@polimi.it, stefania.coelli@polimi.it

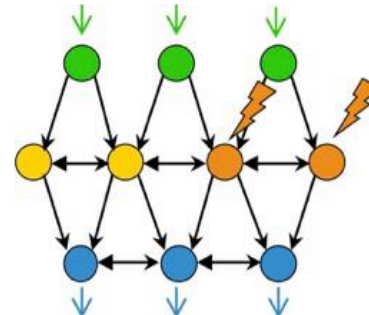
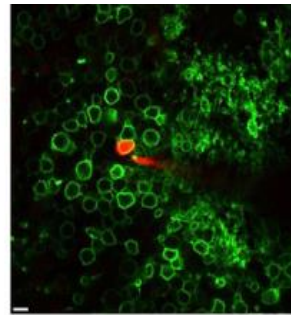
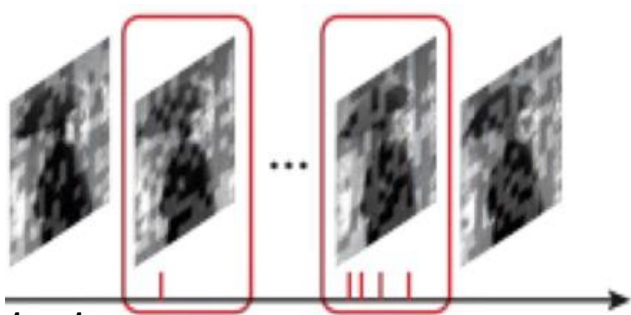


Neural Signal Analysis

The aim is to understand how ganglion cells, the retinal output, extract relevant information from complex, natural scenes before it is sent to the rest of the brain. For this we use a combination of experiments (e.g. large-scale recordings with multi-electrode arrays) and modeling (based on machine learning and theoretical physics). Recently we have developed a perturbative approach to characterize how ganglion cells process natural scenes. We want to expand this approach to characterize temporal processing in the retina. The purpose of this internship is to develop models and novel strategies to understand the non-linear processing performed by ganglion cells, in particular during natural motion. The intern will work in close connection with experimentalists. He/She will develop models to predict and understand how ganglion cells respond to natural scenes containing motion, and will also participate in the design of experiments to answer this question.

Duration of the internship: 6 months.

Indemnity: 500E / month, can be cumulated with an ERASMUS fellowship



Contacts:

riccardo.barbieri@polimi.it, edoardomaria.polo@polimi.it

Bioinformatics

Contacts:

Prof. Linda Pattini

Prof. Manuela Ferrario



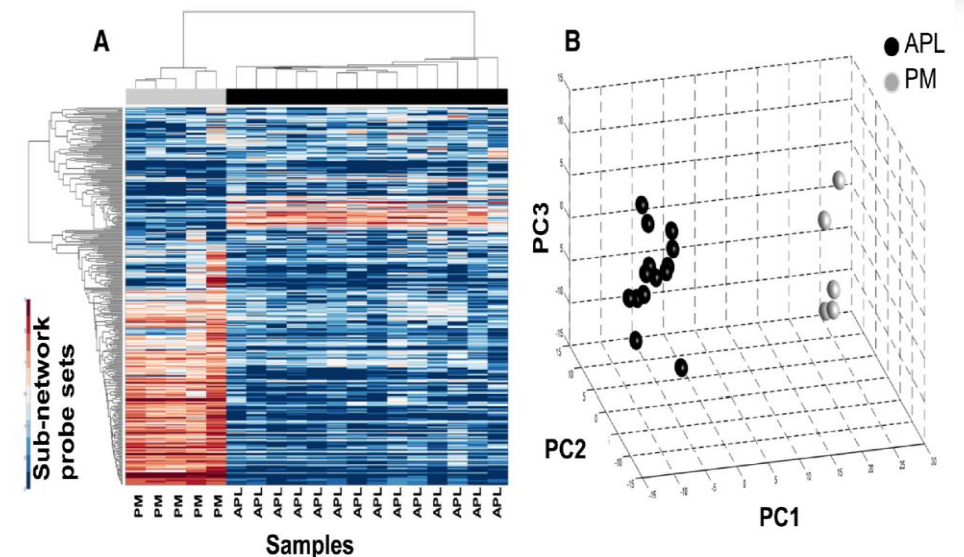
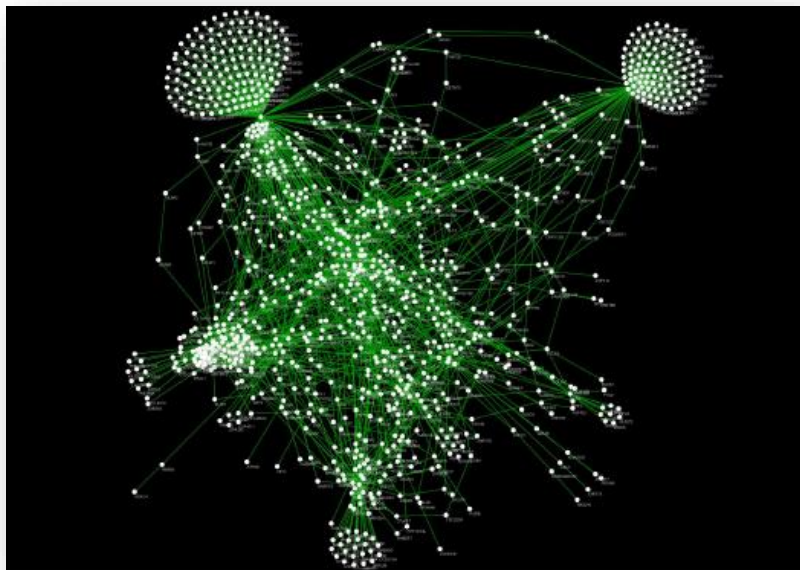
Information bioengineering for genome medicine

Next Generation Sequencing (NGS)- based experiments

- Data analytics and AI for **genetics, genomics and multi-omics data**
- **Systems biology and integrative bioinformatics**
- **Pharmacogenomics**: drug sensitivity and drug response characterization
- **Statistical genetics**

Contacts:

linda.pattini@polimi.it

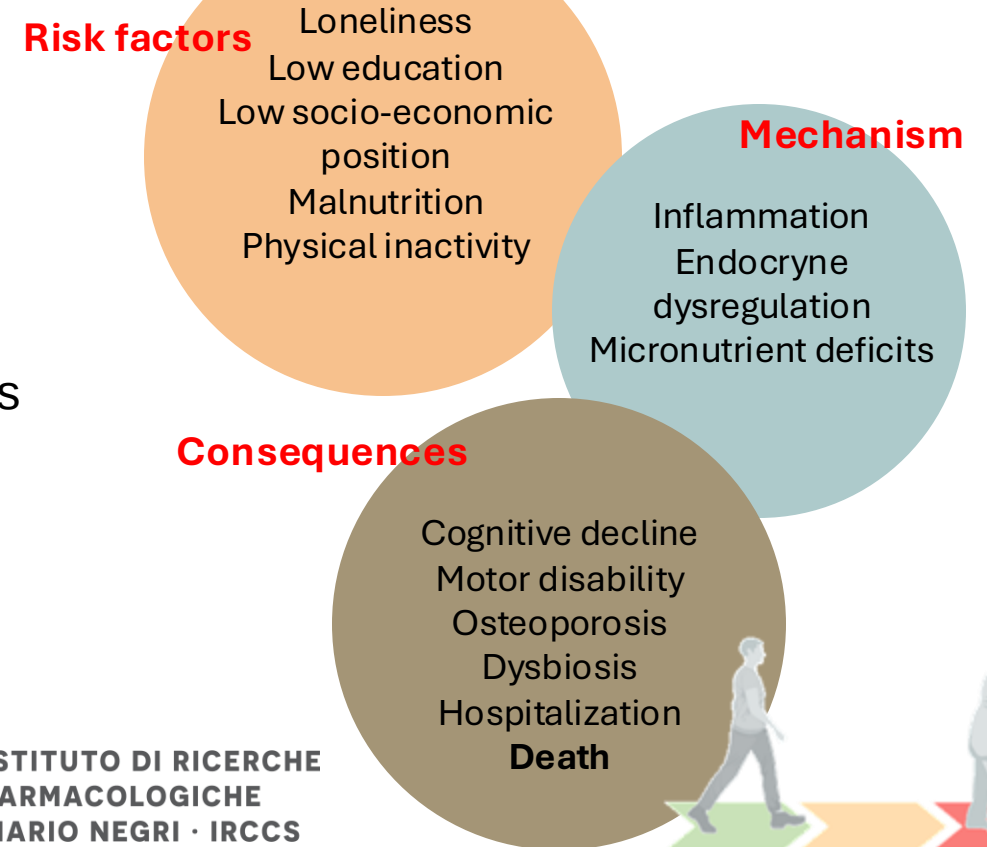


Information bioengineering for Metabolomics

Predicting frailty onset on a large cohort of older adults:

Ageing is a natural biological process that has emerged as a major global challenge. In this context, studying frailty and identifying factors that influence the ageing process are essential. Increasing evidence in literature highlights a healthy diet as a key factor for promoting healthy ageing. We have a dataset of nutrimetabolomics data collected from individuals at three or more time points, with an increasing percentage of these individuals becoming frail over time.

- Effective representation of longitudinal data with decomposition methods
- Data mining applications to identify food-related compounds which discriminate frailty from fit individuals
- Development of prediction models for frailty onset



Contacts: manuela.ferrario@polimi.it ,
aurelia.morabito@polimi.it



ISTITUTO DI RICERCHE
FARMACOLOGICHE
MARIO NEGRI · IRCCS

Medical Informatics and Big Data for Health



Contacts:

Prof. Maria Gabriella Signorini

Prof. Manuela Ferrario

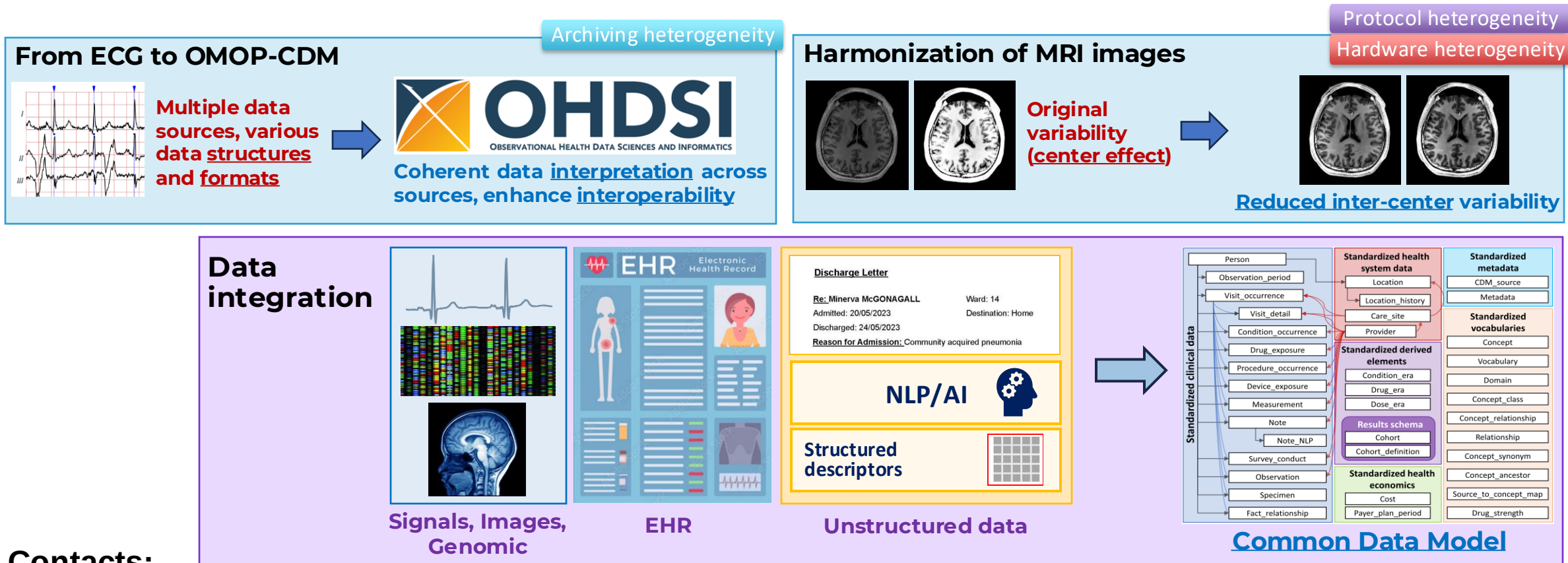
Prof. Riccardo Barbieri

Prof. Anna M. Bianchi

Prof. Luca Mainardi

Health Big Data

- Health data collected in hospitals increases every year, offering unprecedented opportunities to investigate complex pathophysiological mechanisms and improve patient care. However, **data heterogeneity** and **lack of integration** hinder the potential for **multicentric studies**
- The Health Big Data project aims to develop **standardization pipelines** to facilitate **data sharing** across hospitals, improve **trustworthiness**, and foster the **integration of multiple types of data**



Contacts:

mariagabriella.signorini@polimi.it , pierluigi.reali@polimi.it

Analysis of electronic medical records (EMR)

Hospital Management

- to develop a predictive model of future bed resources/hospitalization given the EMRs of the ambulatory visits (e.g. cardiovascular department)
- To develop a predictive model of possible bed occupancy given previous specific ambulatory visits

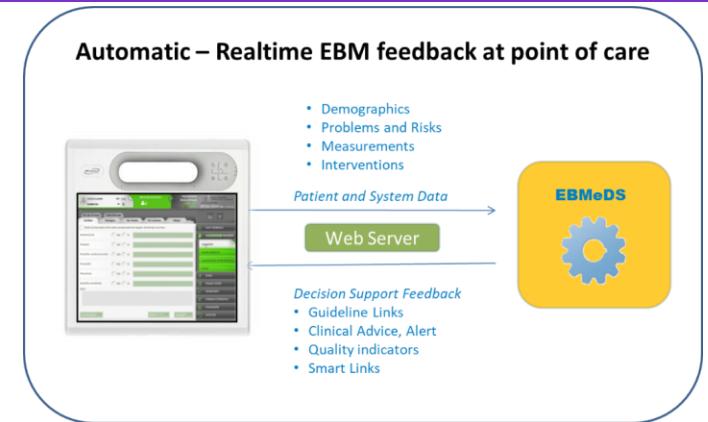
Contacts: manuela.ferrario@polimi.it , marta.carrara@polimi.it



Evidence-based Medicine (EBM)

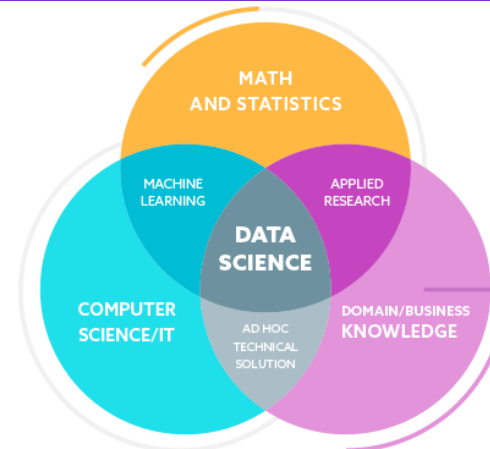
Design and implement predictive algorithms, built on the basis of available clinical data to predict the development of specific chronic disease, in terms of evolution of clinical parameters, prevention of clinical complications, patient re-hospitalization reduction;

Contacts:
annamaria.bianchi@polimi.it



Management of infections

Antibiotic Pharmacokinetics: development of pharmacokinetic models starting from data collected with MargheritaTre database , using nonlinear models with mixed random effect



Contacts:
riccardo.barbieri@polimi.it, edoardomaria.polo@polimi.it



Novel integration of digital information

The SMASH-HCM EU project is aimed at identifying Hypertrophic cardiomyopathy (HCM) at higher risk of sudden cardiac death (SCD) through hybrid Digital Twins (DT). Thesis aims:

- To develop new DT to detect and characterize at-risk patient using combination of multi-source data (clinical measurements, ECG records, MRI images) and computer simulations.

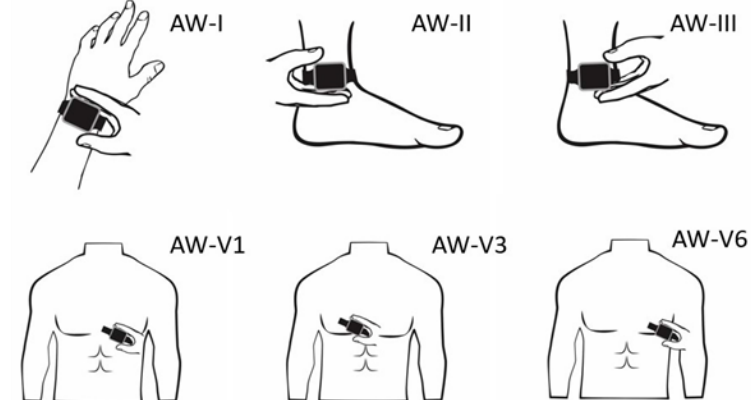
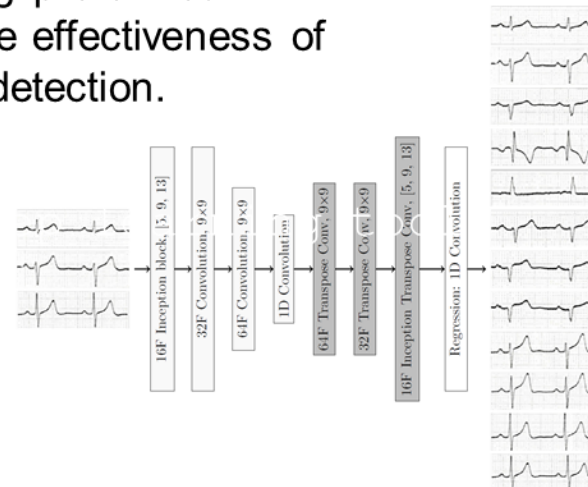
Options for thesis abroad available within the consortium partners

Contacts:

luca.mainardi@polimi.it, marionne.tacconne@polimi.it and <https://smash-hcm.eu/>



The thesis aims at reconstructing 12-Leads ECG from the recordings of few, asynchronous ECG recording preformed through smartwatches and at demonstrating the effectiveness of the new method for Myocardial Infarction (MI) detection.



Contacts:

luca.mainardi@polimi.it, sara.pagotto@polimi.it

