Master Thesis proposals
Biosignals, Bioimages and Bioinformatics

POLITECNICO MILANO 1863

B³ Lab

Biosignals
Bioimages
Bioinformatics

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PHEEL

PHYSIOLOGY.EMOTION.EXPERIENCE.LAB

e-health Lab

SPiN LABS

Who we are

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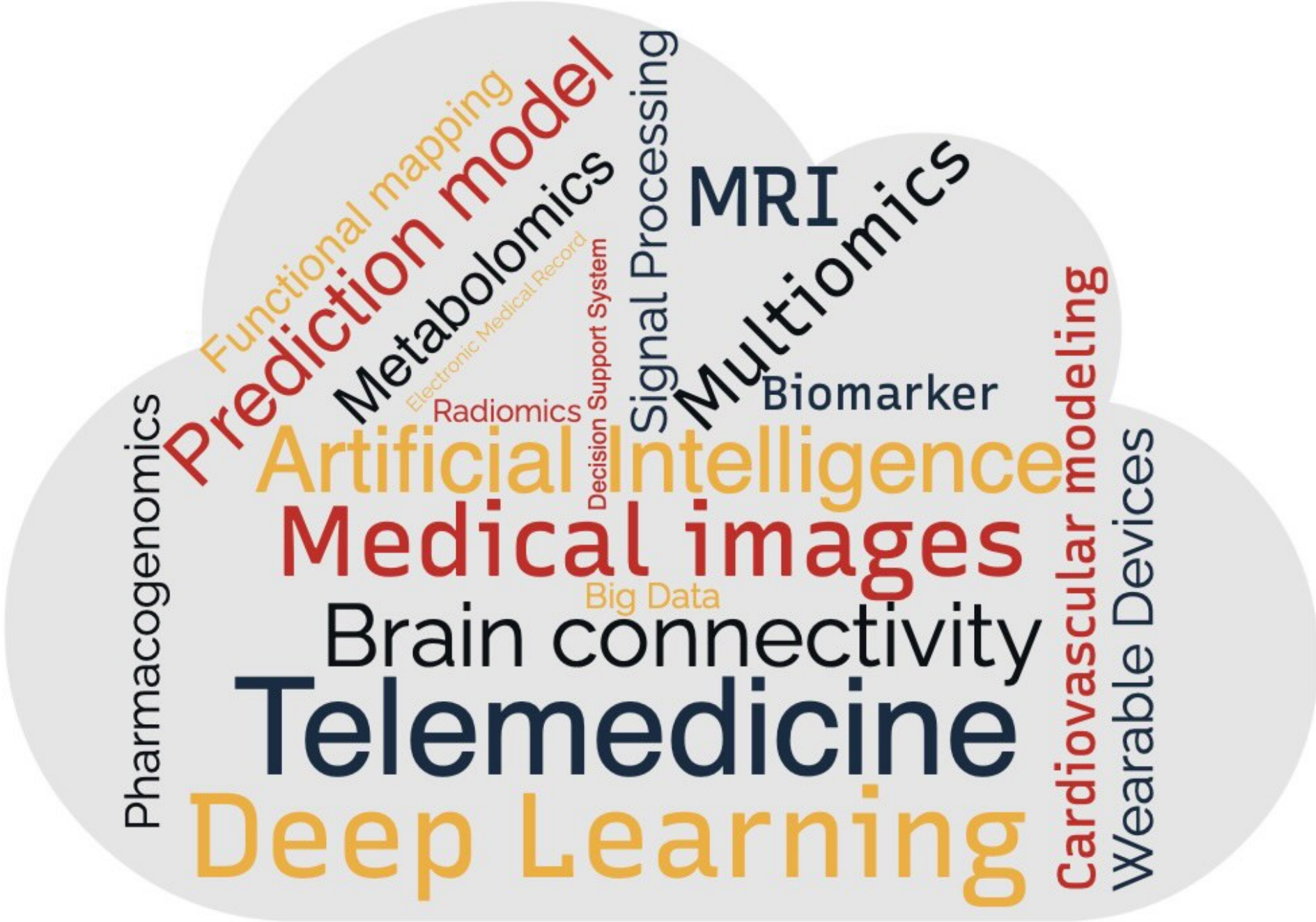
https://www.b3lab.deib.polimi.it

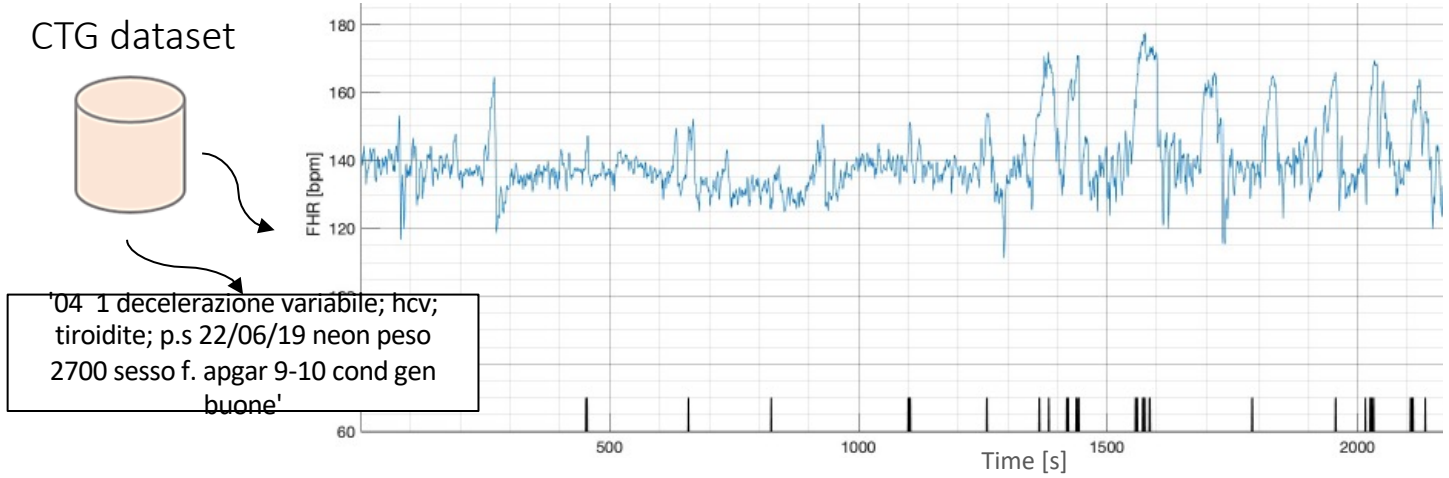

Functional mapping
Prediction model
Metabolomics
Electronic Medical Record
Decision Support System
Signal Processing
MRI
Multiomics
Pharmacogenomics
Radiomics
Biomarker
Artificial Intelligence
Medical images
Big Data
Brain connectivity
Telemedicine
Deep Learning
Cardiovascular modeling
Wearable Devices

Data Science in Cardiotocography

One of the most common exams to assess fetal well-being is **cardiotocography**: the continuous measures of fetal heart rate (FHR) along with uterine contractions and fetal movements.

For this thesis you will be provided with a very big dataset of **cardiotocographic recordings** (over **30000** entries) along with clinical information about maternal and fetal well-being written in natural language (Italian).

Your goal will be to apply **data-mining** techniques (DL, ML, Natural Language Processing) to monitor fetal maturation, relating clinical information to the CTG recordings.



Required skills:

- Basic knowledge of MATLAB and Python
- Knowledge in biomedical signal processing/time series analysis or natural language processing

Start date:

From November 2023

Contacts:

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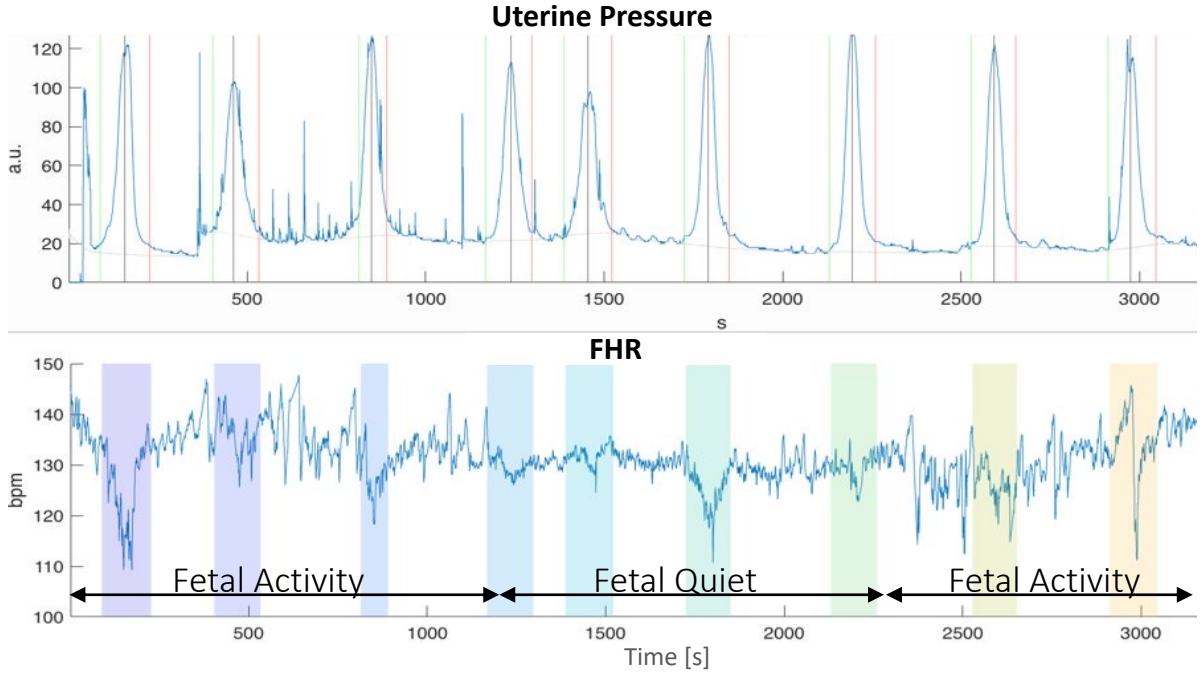
Characterization of FHR patterns: DECELERATIONS – QUIET to ACTIVITY

The heart rate is modulated by the **autonomous nervous system** (ANS). Thus, the **heart rate variability** (HRV) signal carries information on the ANS. In the fetal case, continuous measures of fetal heart rate (FHR) are routinely performed in clinic to assess **fetal well-being**.

DECELERATIONS and **CYCLES OF QUIET AND ACTIVITY** are typical patterns of the FHR which, depending also on their relationship with uterine contractions, may be physiological or a consequence of fetal hypoxia.



Your **goal** will be to develop algorithms able to
- robustly identify patterns in the FHR signal
- classify them as physiological or abnormal

Required skills:

- Basic knowledge of MATLAB and/or Python
- Knowledge in biomedical signal processing

Start date:
From November 2023

Contact:
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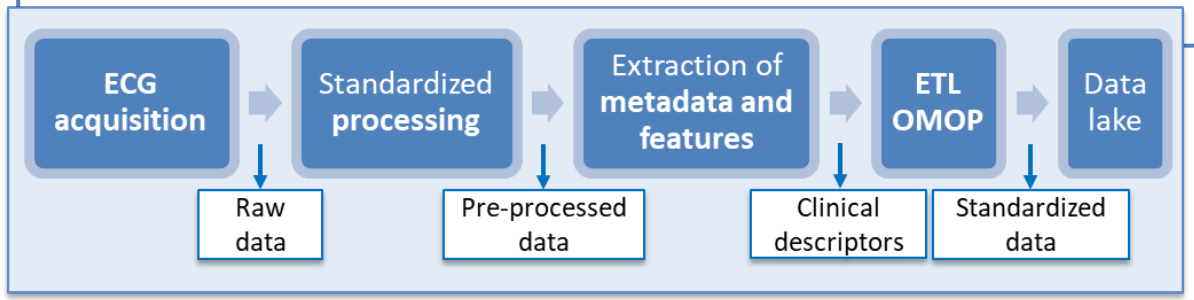
mariagabriella.signorini@polimi.it

Development of data standardization pipelines for multicentric studies

The amount of health data collected in hospitals increases every year, offering unprecedented opportunities to investigate intricate pathophysiological mechanisms and improve patient care. However, the **lack of standardization** hinders the potential of **multicentric studies**.

Data standardization pipelines are needed and are sought by the **Health Big Data (HBD) project** to facilitate data sharing across the IRCCSs.
We offer the opportunity to develop a Master's thesis inside the HBD project, with **one of the following goals**:

- Increase the exploitability of **ECG signals from different data sources in multicentric studies** by addressing the feature-extraction process and their inclusion in the OMOP standard
- Facilitate the **retrieval of gene sequence variations from huge databases** through proper standardization, exploring the opportunities offered by OMOP, HL7-FHIR, and other standard data structures



OMOP CONCEPT
concept_id: 3036449
concept_name: 'Gene mutation'
vocabulary_id: 'LOINC'
concept_code: '36908-2'
primary_domain: Measurement
standard_concept: Y

You will gain **hands-on experience with databases and several programming languages** (Matlab, Python, SQL) and connect with **renowned researchers and clinicians** from the HBD hospitals.

Required skills:

- Basic knowledge of MATLAB or Python
- Knowledge in signal processing or bioinformatics

Start date:
November 2023

Contacts:
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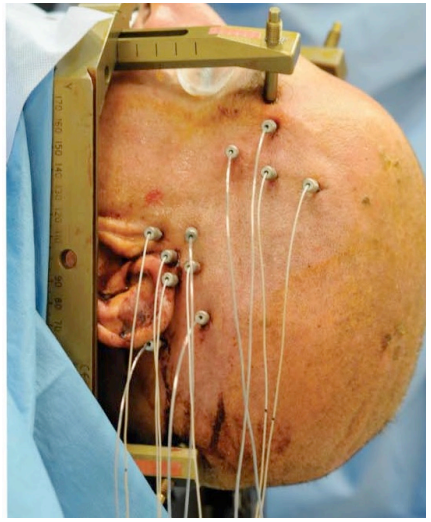
TOPIC: Neural Engineering and Investigation of the Central Nervous System

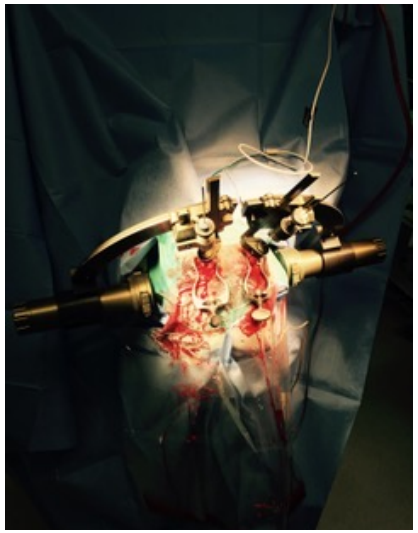
EEG

MEG

Stereo-EEG



LFP/MER



Advanced and innovative signal processing methods

Functional brain connectivity

Signal classification for Clinical applications

Sources reconstruction

Co-registration

Advancing the research in physiology and pathology

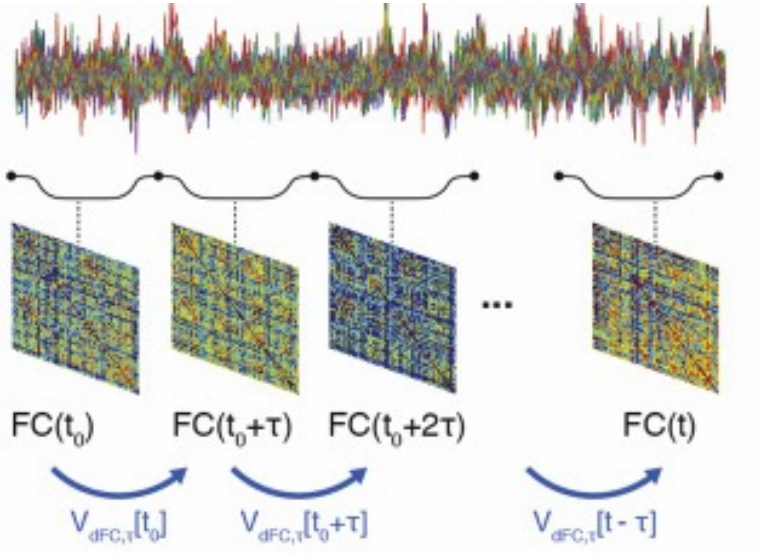
Ref: Prof. Anna Maria Bianchi

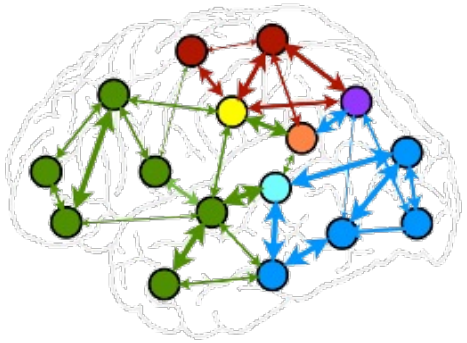
Stefania Coelli RTDa

Advanced methods for the analysis of brain dynamics

Dynamic functional connectivity (dFC): application to 1) action observation and motor imagery; 2) complex cognitive tasks; 3) stress conditions; 4) Pathologies

This methodological project aims at developing, implementing and comparing methods to study the **dynamic of brain networks** using different dataset as a bench-marking framework





- Motor planning and execution
- Learning new motor schemas
- Attention level
- Logical reasoning
- Stress and/or Flow conditions
- Epylepsia

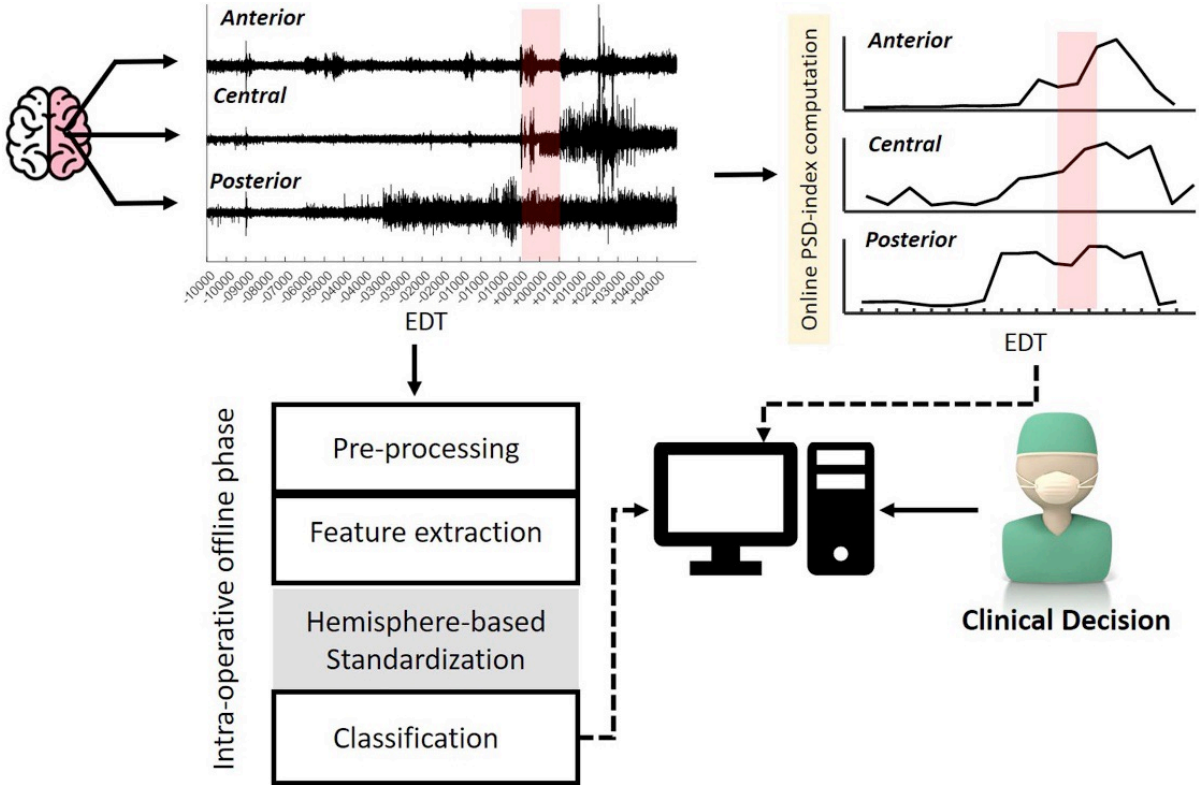
Pre-requisite abilities/skills:

- MATLAB programming
- Signal processing and interest in advanced methods
- Basic of Statistics
- Interest in neuroscientific and neuroengineering approaches

For more infos: stefania.coelli@polimi.it;
alessandra.calcagno@polimi.it
annamaria.bianchi@polimi.it

Fondazione I.R.C.C.S. Istituto Neurologico Carlo Besta
Sistema Socio Sanitario Regione Lombardia ASST Santi Paolo e Carlo
Università degli Studi di Milano
EBRAINS Italy
IRCCS Humanitas Research Hospital
Università degli Studi di Milano Bicocca

Analysis and classification of microelectrode recordings for Deep Brain Stimulation surgery improvement



The aim of the project is to provide methods for the characterization of MER Signals for the Subthalamic Nucleus identification in Parkinson's disease and the development of automatic classification tools to help and assist the neurosurgeon's evaluation process (ML and AI methodologies)

Collaboration: IRCCS istituto neurologico Carlo Besta, Milano

General Requirements

- Programming skills with MATLAB or Python
- Basic knowledge of signal processing and machine learning /deep learning methods
- Basic knowledge of / interest in learning Neuro-Electrophysiology principles and mechanisms

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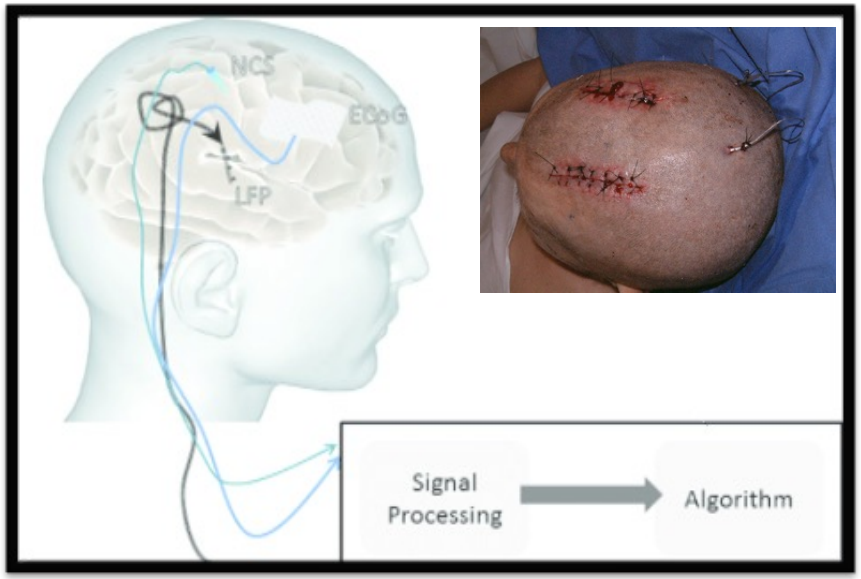
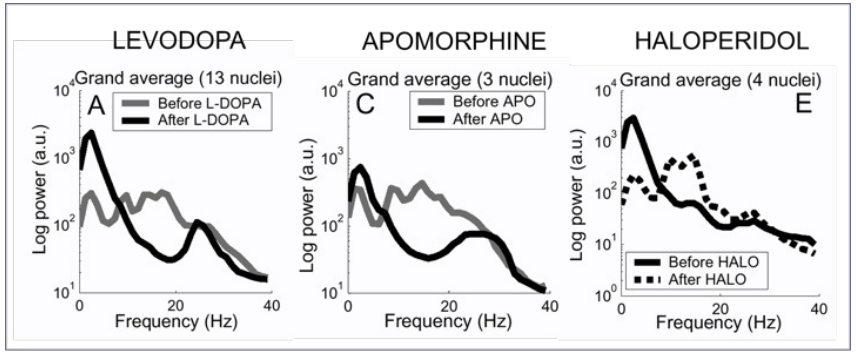
FONDAZIONE I.R.C.C.S. ISTITUTO NEUROLOGICO CARLO BESTA

Studying the electrical activity of the subthalamic nucleus in patients with Parkinson's disease and other movement disorders

Advanced analysis of Subthalamic Local Field Potentials (LFP) in Parkinson's Disease under different anesthesia levels (the effect of curare), different drugs, different movement conditions





[Priori et al., 2004]

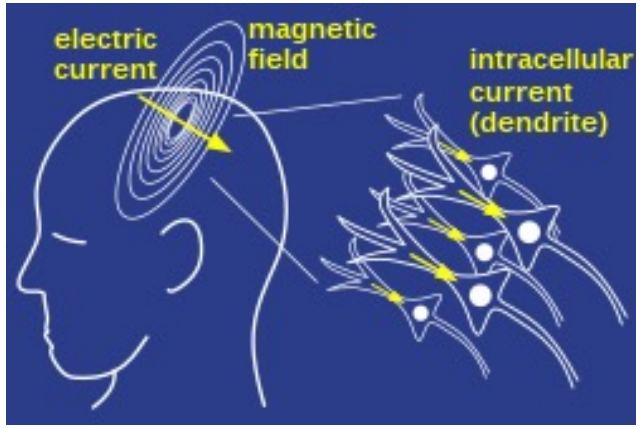
Collaboration: IRCCS istituto neurologico Carlo Besta, Milano and ASST Santi Paolo e Carlo, Presidio Ospedaliero San Paolo

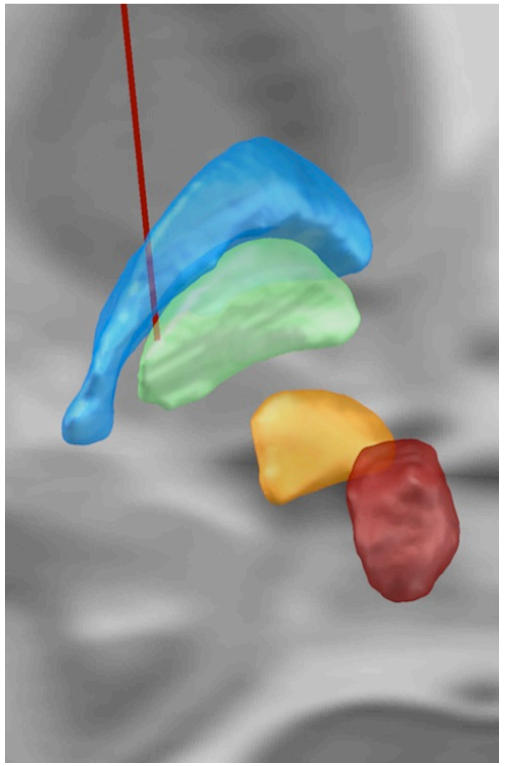
Pre-requisite abilities/skills:

- MATLAB programming
- Signal processing and Statistics
- Good English
- Attitude to experimental work
- interest in advanced methods
- Interest in neuroscientific and neuroengineering approaches

For more infos: annamaria.bianchi@polimi.it
stefania.coelli@polimi.it

Multimodal investigation of cortico-basal ganglia-thalamo-cortical (CBGTC) network dynamics in dystonic patients with Deep Brain Stimulation (DBS).





Assessment of resting-state CBGTC electrophysiological network in dystonic patients by simultaneous GPi LFPs-EEG/MEG and GPi LFPs-fMRI recordings.

Collaboration: IRCCS istituto neurologico Carlo Besta, Milano

General Requirements

- Programming skills with MATLAB or Python
- Basic knowledge of signal processing and machine learning /deep learning methods
- Basic knowledge of / interest in learning Neuro-Electrophysiology principles and mechanisms

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annamaria.bianchi@polimi.it

Topic: Development of technologies and customizable tools for continuous monitoring, wellbeing and health

MUSA

Multilayered Urban Sustainability Action

Study of work-related stress assessment and solutions

Sport and well-being

Screening for cardiovascular diseases prevention

For more infos: stefania.coelli@polimi.it; pierluigi.reali@polimi.it
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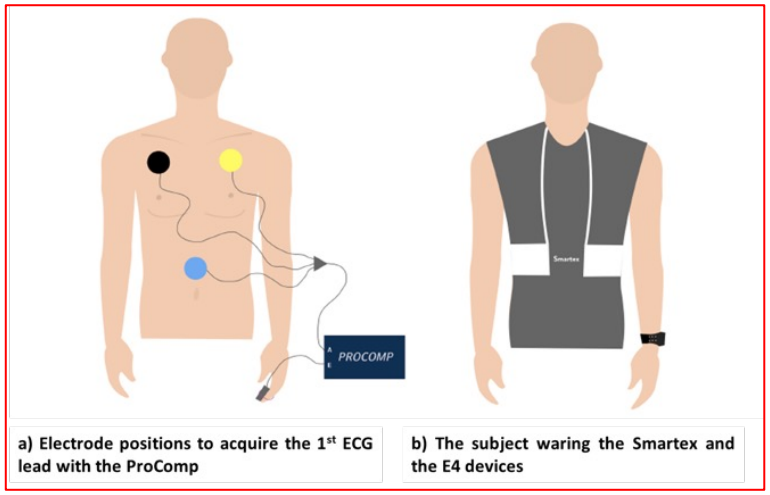
Methodologies

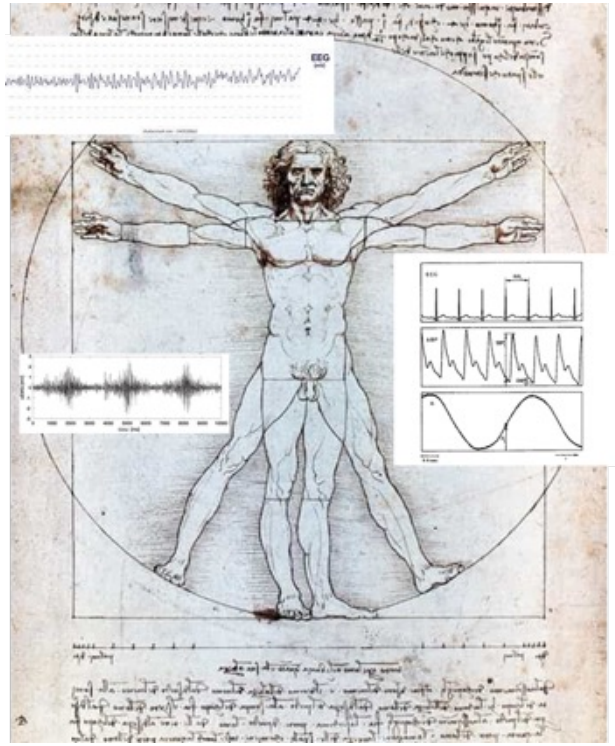
Use of wearable devices and acquisition of physiological parameters



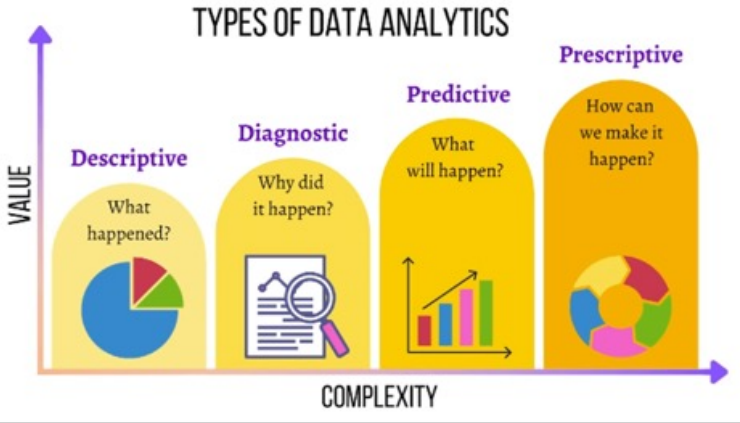
a) Electrode positions to acquire the 1st ECG lead with the ProComp

b) The subject waring the Smartex and the E4 devices

Data analysis, feature extraction and physiological modelling



Data analytics for stratification, prevention, prediction



Pre-requisite abilities/skills:

- MATLAB programming
- Signal processing and Statistics
- Good English
- Attitude to experimental work

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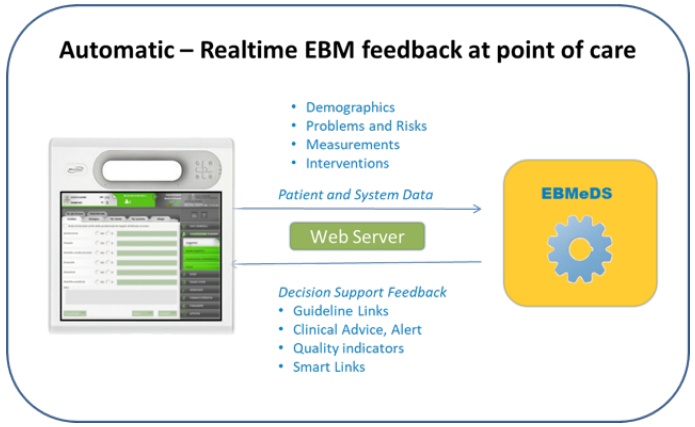
annamaria.bianchi@polimi.it

Topic: Regional Electronic Medical Record

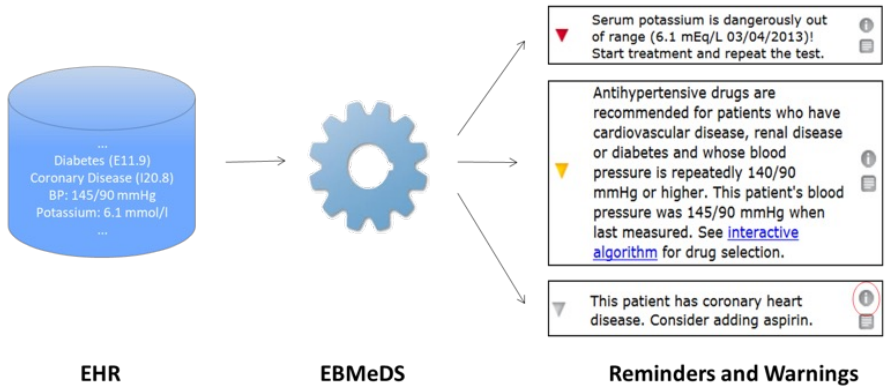
Regione Lombardia

Evidence-based Medicine (EBM)



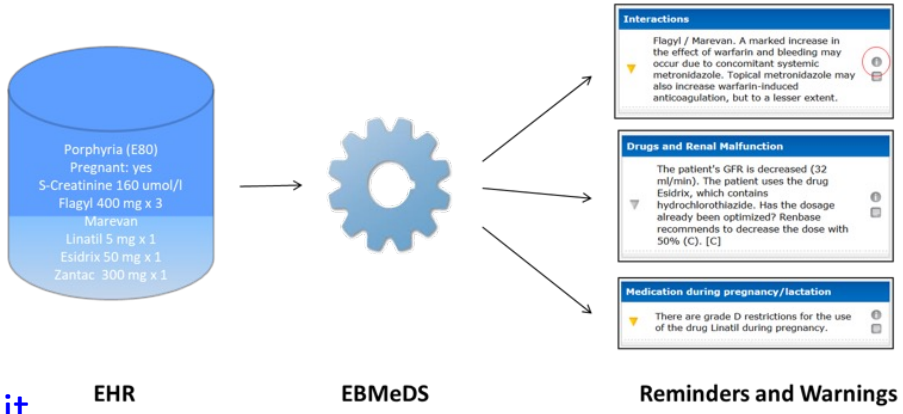
Rule Assistant

> 1 000 customized evidence-based reminders and warnings

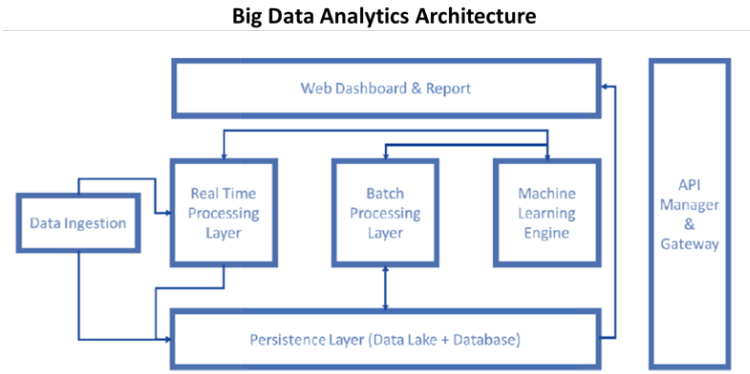


Drug Assistant

> 25 000 reminders and warnings concerning drug treatment



Taking advantage from data: new knowledge



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;

Design and implement a predictive model to outline the evolutionary scenario of chronic diseases, based on the different treatment and innovative healthcare organization models (planning forecast)

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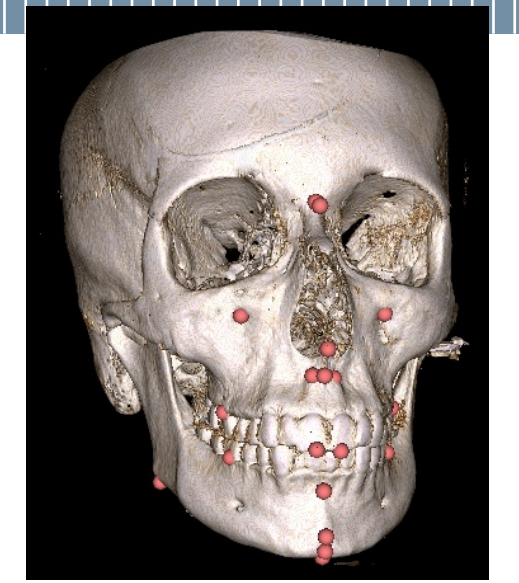
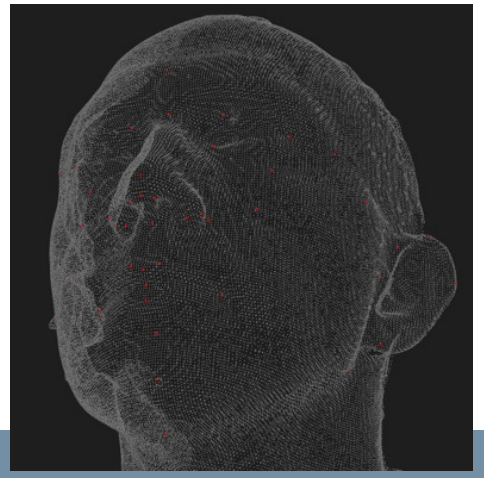
AI-based detection of Facial, Dental, and Skull Landmarks for Orthodontic and Maxillo-Facial Surgery





BACKGROUND

Orthodontic and maxillofacial treatments encompass the analysis of both soft and hard tissues, specifically through 3D cephalometry and 3D morphometric analysis. These procedures require the manual landmarking of anatomical points on radiographic images and facial scans, respectively, resulting in time consuming and operator dependent tasks.

AIMS

- Develop an AI-based algorithm to automatically detect landmarks on two types of imaging modalities: **CBCT** (Cone Beam Computed Tomography) and **facial scans**.
- Explore relationship between the two sets of landmarks.

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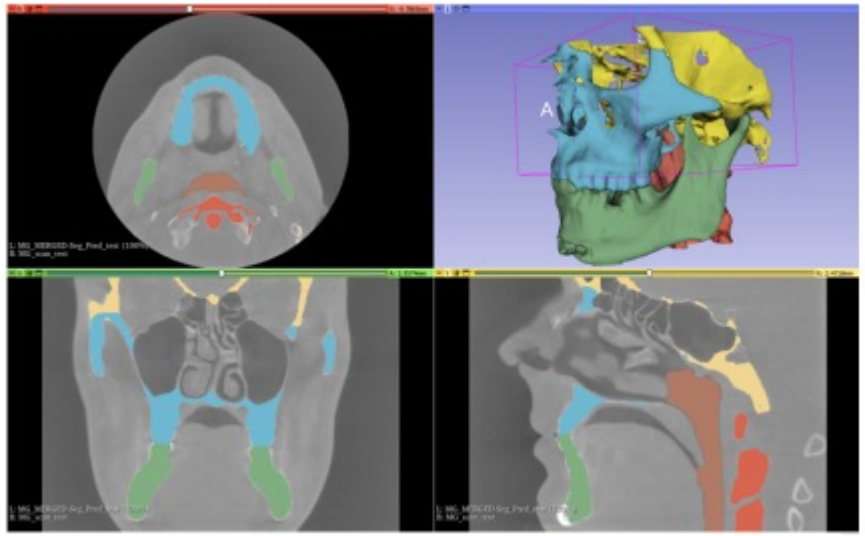
UNIVERSITÀ DEGLI STUDI DI MILANO

Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico

AI-based segmentation of bony tissue in full-cranium CBCT: Identification of the mandible and integration with other craniofacial structures.

BACKGROUND

Automated segmentation of various structures at the same time could offer significant benefits in clinical orthodontics, implant rehabilitation, and oral or maxillofacial surgical procedures. Moreover, visualizing structures and interactions between them is crucial for generating accurate 3D patient-specific models.



AIMS

- Automate the segmentation procedure by the application of AI techniques to eliminate constraints related to time and operator dependency.
- Integrate various structures to build a comprehensive virtual model of the patient's head.

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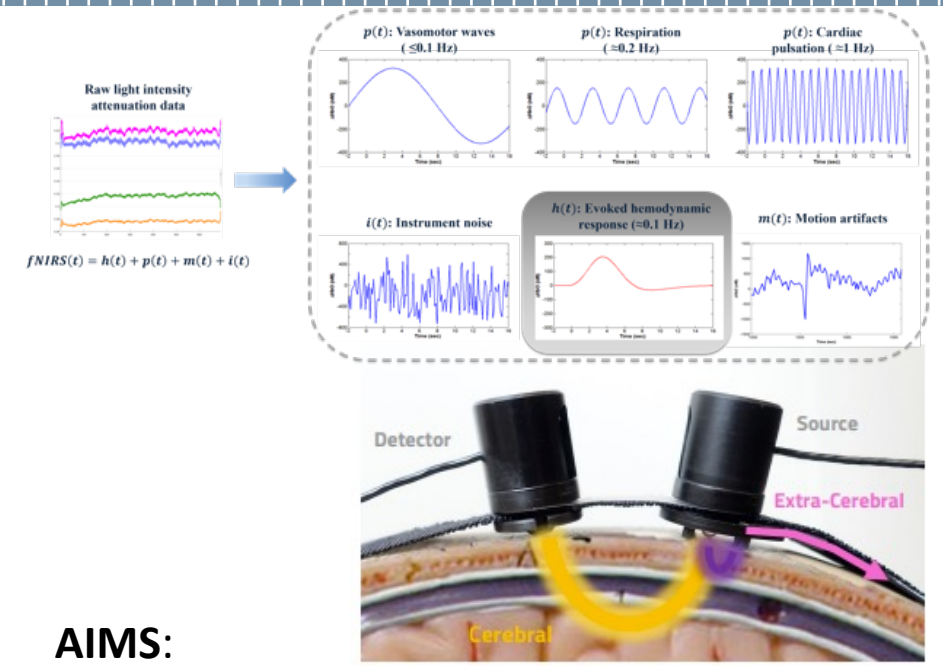
UNIVERSITÀ DEGLI STUDI DI MILANO

Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico

Assessment of Physiological Confoundig Factors in Functional Near Infrared Spectroscopy (fNIRS)



BACKGROUND:

- The fNIRS is an emerging optical technique for monitoring **brain activity** in open environment. However, the measured hemodynamic response is affected by **physiological confounding factors**, since the sensitivity of fNIRS measurements is limited to **cortical surface**

- **Short-separation channels** (SSC) are actually employed fNIRS statistical analysis to regress physiological confounding factors. Nevertheless, it is not clear how SSC spectral content is influenced by different experimental conditions

AIMS:

- Quantify the spectral content and effect of SSC regression in different experimental conditions during resting-state, motor and cognitive paradigms

- Integration of fNIRS resting-state measurements with **laser doppler flowmetry** for additional characterization of vasomotion effects

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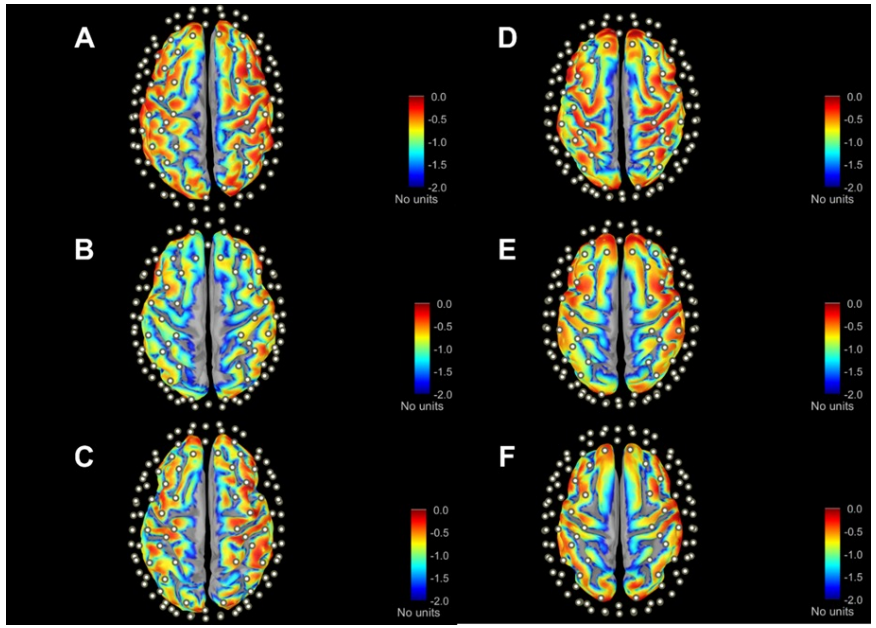
Assessment of Optical Properties Mapping over the Analysis of functional Near-Infrared Spectroscopy (fNIRS) Data



BACKGROUND:

- Current **continous-wave** (CW) fNIRS applications often employ heterogeneous NIR-light **optical properties** of head tissues. This aspect affects the analysis and interpretation of measured hemodynamic responses, since optical properties depend on **optode's scalp location** and **age** of the subject

- **Time-domain** (TD) fNIRS provides a quantification of NIR-light optical properties of head tissues, but it is generally more expensive than CW-fNIRS systems

AIMS:

- Integration of optical properties derived from TD-fNIRS measurements into CW-fNIRS analyses

- Promoting a **systematic fNIRS mapping** of cerebral activity according to optode's scalp location and age of the subject

This work is held in collaboration with BrainLab (Department of Physics DFIS, Politecnico di Milano).

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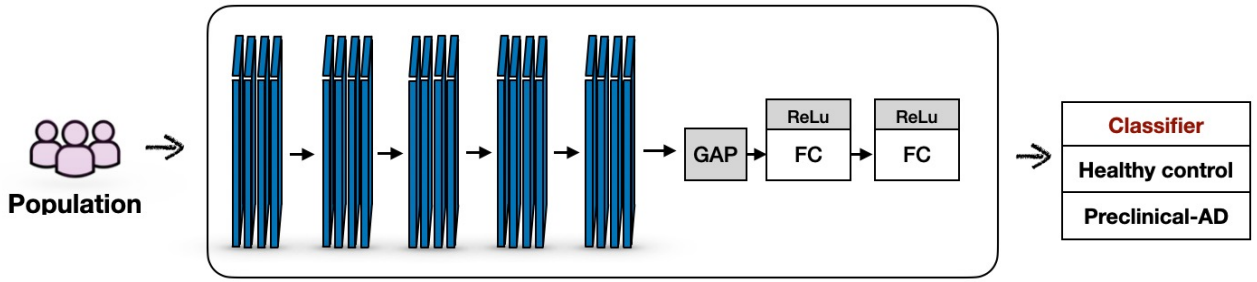
Dr. Augusto Bonilauri: augusto.bonilauri@polimi.it

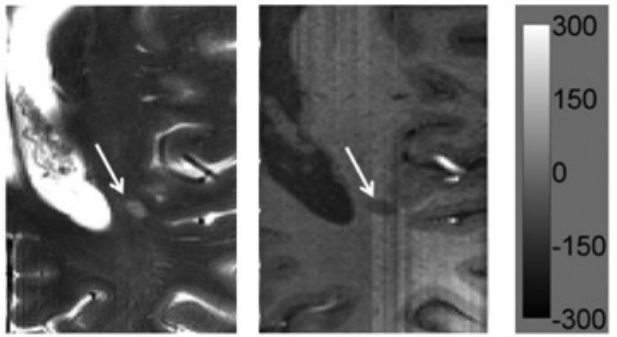
Early Neurodegeneration Prediction by AI and White Matter Hyperintensities

BACKGROUND: The aggregation of amyloid-beta (Aβ) proteins into brain plaques is among the early signs of Alzheimer's disease (AD), occurring far before the onset of clinical symptoms. The ability to detect AD at the pre-clinical stage is receiving increasing attention, especially due the limited availability of effective disease-modifying treatments. However, since direct measurements of Aβ are currently performed through costly or time-consuming techniques (i.e., positron emission tomography or a lumbar puncture) – inappropriate for cognitively normal individuals – establishing imaging biomarkers of pre-clinical AD would be of great help to design early prevention strategies.

AIMS: Development of artificial intelligence (AI) approaches for the prediction of pre-clinical AD; use of Explainable AI (XAI) to investigate if the model is leveraging White Matter Hyperintensities – an imaging biomarker of cognitive deterioration – to perform the final classification.



WMHs appearence on magnetic resonance imaging (MRI):



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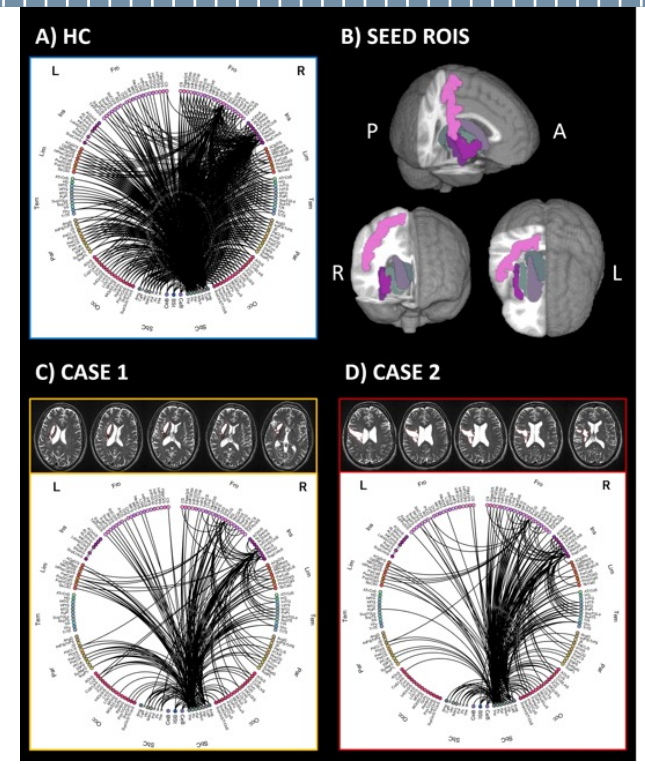
Keywords: Artificial Intelligence, Explainable Artificial Intelligence, White Matter Hyperintensities, Image Processing

Uncertainty Assessment of Brain Connectivity Biomarkers



BACKGROUND

- The brain can be depicted as a **complex network** with gray matter regions as nodes and white matter (**structural connectivity**) or BOLD signal activation (**functional connectivity**) measures as edges.

- This network can be analyzed at different scales using **graph theory**. Various studies identified abnormalities related to different pathologies, making this analysis useful for understanding their causes and effects, supporting diagnoses, and customizing rehabilitative treatments.

- However, the methods for quantifying and assessing connectivity lack standardized approaches, leading to **uncertainty** and noisy data, which can result in unreliable findings.

AIMS

- Analysis of the uncertainty of brain connectivity networks through the use of graph theory and robustness investigation of the topological changes and possible abnormalities.

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Dr. Davide Coluzzi: davide.coluzzi@unimi.it

Keywords: Structural Connectivity, Functional Connectivity, Graph Theory

Monitoring acutely ill patients in intensive care unit (ICU)

Prof. Manuela Ferrario, Prof. Marta Carrara

Sepsis is a complex syndrome that arises when the body's response to an infection injures its own tissues and organs, possibly leading to multi organ failure and death. Sepsis is a **major cause of death of COVID-19**.

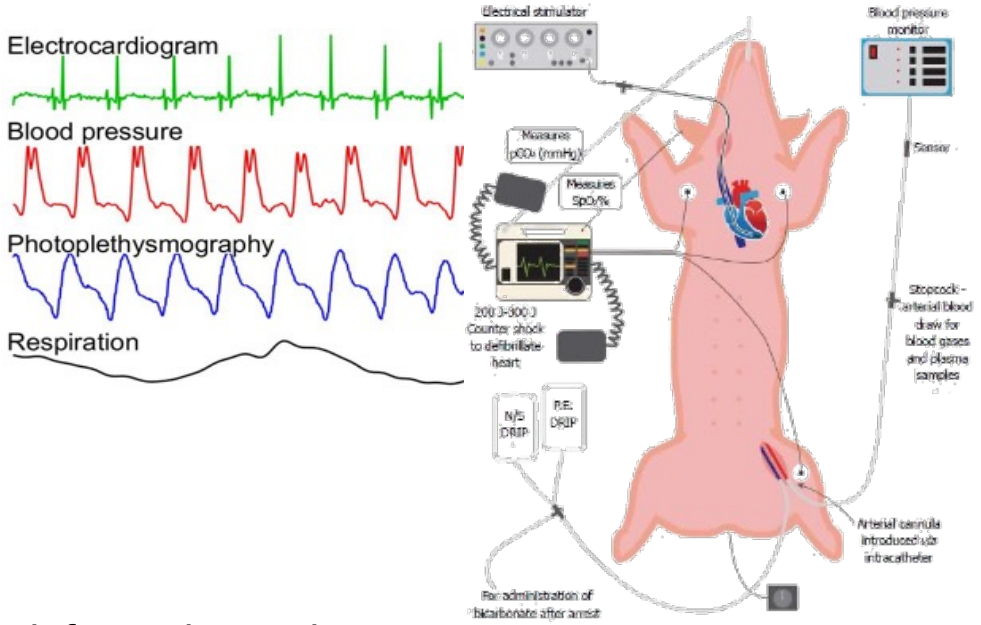
Clinical impact: high incidence (20-30% of ICU admissions), mortality (~40%), and long term physical and cognitive impairment in survivors (5-year mortality rate of 75%).

We have a **large database of biomedical signals** collected from different **animal experiments** of sepsis and resuscitation performed in Brussels (Belgium) and Bern (Switzerland)

Aim: **develop of data processing techniques to investigate novel indices able to improve clinical monitoring, drug delivery and patients risk stratification**.

Possible topics:

- To identify patterns associated to long term comorbidities, e.g. **cognitive impairment**, by the analysis of the **cerebral perfusion pressure signal** (ICP: intracranial pressure)
- To **model physiological cardiovascular mechanisms** during sepsis development and therapy administration by the analysis of **arterial blood pressure waveforms**



In collaboration with

Hôpital Erasme | ULB

INSELSPITAL
UNIVERSITÄTSSPITAL BERN
HÔPITAL UNIVERSITAIRE DE BERNE

For further information, write to
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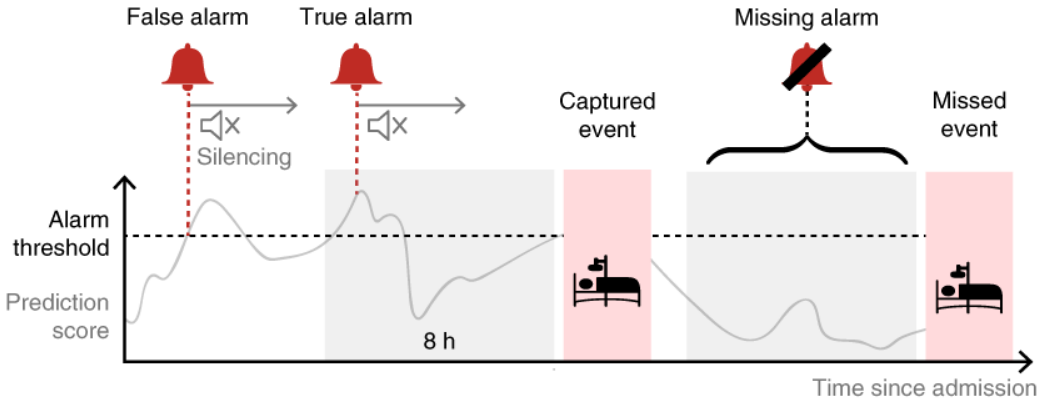
Monitoring acutely ill patients in intensive care unit (ICU)

Prof. Manuela Ferrario, Prof. Marta Carrara

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.**

Topics (but not limited to):

- **Classification of patient therapy responsiveness** from thousands of patient data consisting in lab data, vital signs, drug therapy, organ support therapy,…
- **Prediction of patient deteriorations** (e.g. hypotension, shock development)
- Patient classification by a **federated learning approach** (how to build a general model by sharing models instead of data from different hospitals?)



In collaboration with INSELSPITAL UNIVERSITÄTSSPITAL BERN HÔPITAL UNIVERSITAIRE DE BERNE

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Analysis of electronical medical records (EMR) for real time demand management hospital

Prof. Manuela Ferrario, Prof. Marta Carrara

The **management of beds/resources** is important for **improving patient flow**: admissions, discharges, and transfers within the hospital.

The hospital records every year **thousands of information** from lab visits, surgical procedures, etc.

These data could be used to **improve the planning of the medical activities and the agenda of the visits**.

Possible projects

- 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

In collaboration with

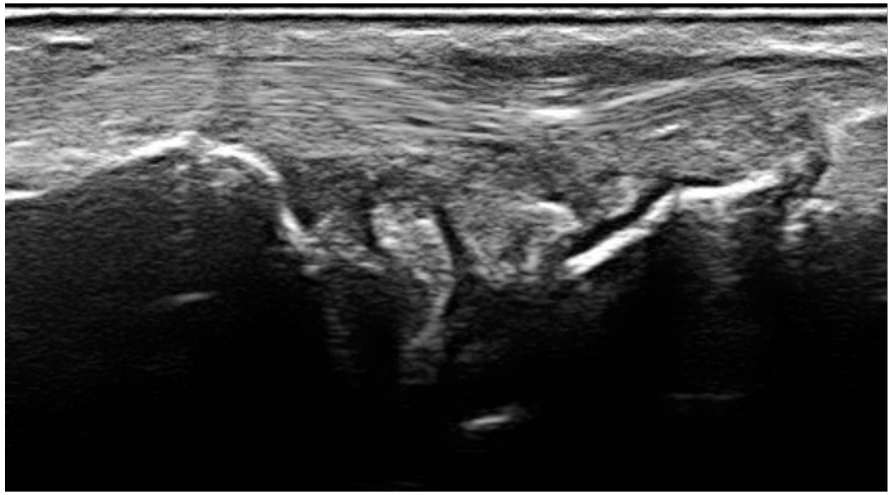
I.R.C.C.S. Ospedale San Raffaele
Gruppo San Donato

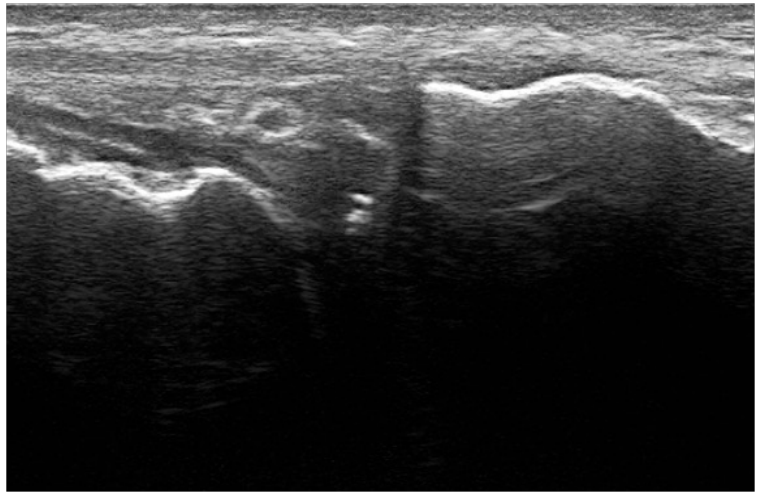
Required skills:
basic knowledge of python

For further information, write to
manuela.ferrario@polimi.it
marta.carrara@polimi.it

Multiclass automated classification of arthritis – Prof. Valentina Corino

AIM: ~ 1000 patients
AIM: to automatically classify echo images of arthritis according a clinical score (ranging from 0 to 3)





in collaboration with IRCCS Istituto Ortopedico Galeazzi

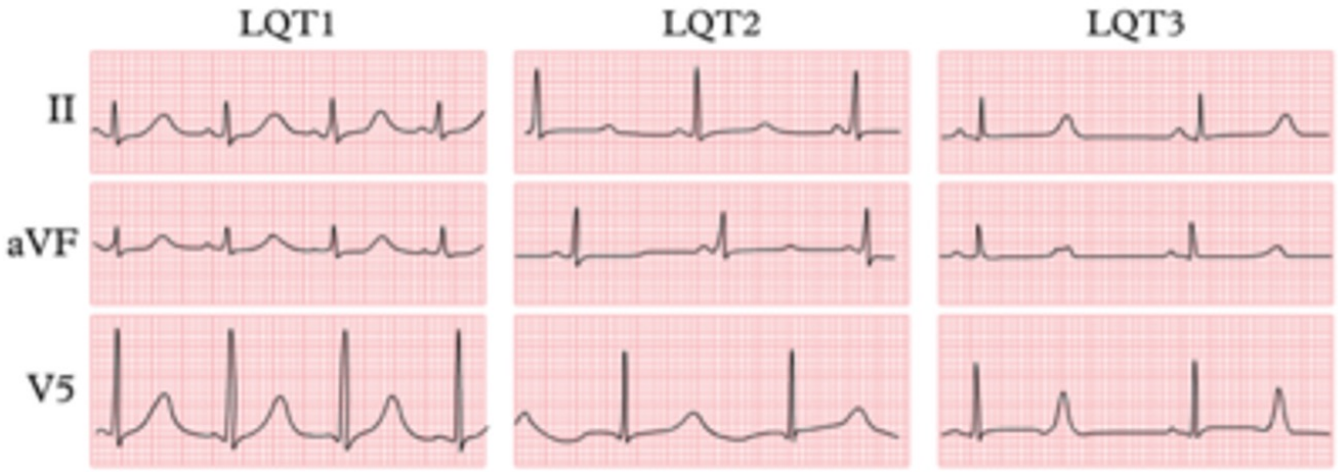
Required skills: Signal processing techniques (Matlab Python)

For further information write to valentina.corino@polimi.it

Keywords: artificial intellingence, classification

Long QT Syndrome – Prof. Valentina Corino

AIM: 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"
~ 400 patients



In collaboration with Lund University (possible in Sweden)

Required skills: Signal processing techniques (Matlab Python)

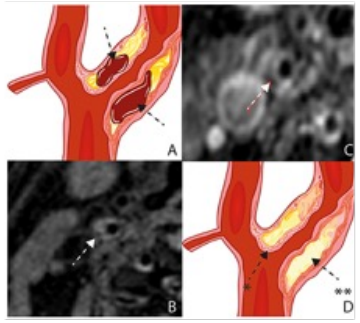
For further information write to
valentina.corino@polimi.it

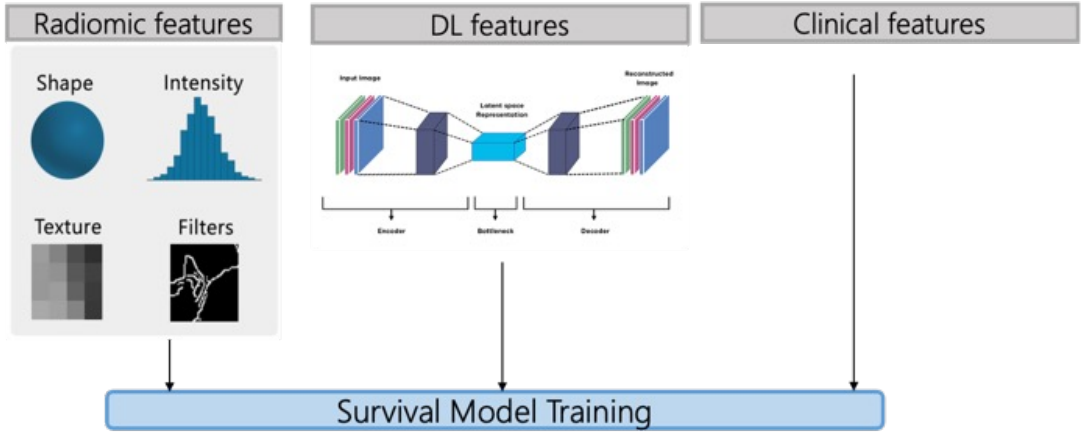
Keywords: Long QT Syndrome, electrocardiograms

Deep learning & Radiomics in carotid plaques – Prof. Valentina Corino

Radiomics: extraction of quantitative metrics — the so-called radiomic features — within medical images, used to capture tissue properties such as shape and heterogeneity and, on serial imaging, their changes over time, such as during treatment or surveillance

AIM: to develop a deep learning model of carotid plaques to predict symptomatic patients with carotid plaques & compare with radiomics analysis (~140 patients)





In collaboration with Policlinico di Milano

Required skills: Signal processing techniques (Matlab Python)

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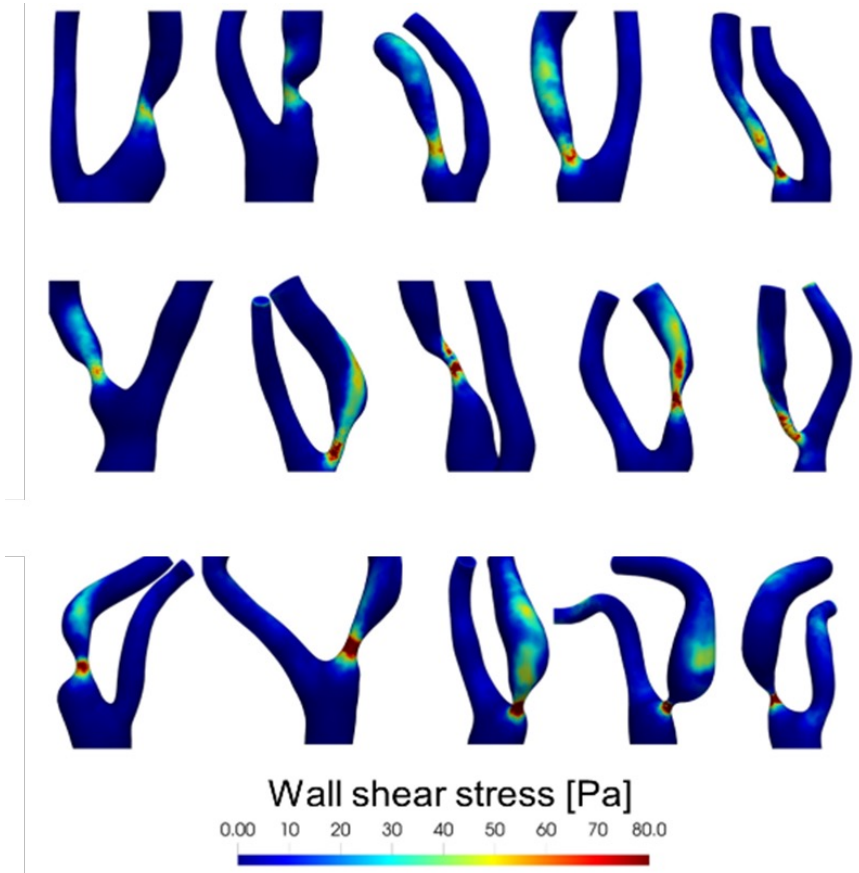
valentina.corino@polimi.it
anna.corti@polimi.it

Keywords: radiomics, cardiac imaging

CFD analysis of carotid artery plaques hemodynamics – Anna Corti



AIM:

1. To analyze hemodynamics in carotid arteries of symptomatic and asymptomatic patients through CFD simulations (140 patients)
2. To create synthetic data and develop a deep learning approach to predict hemodynamics

Required skills: AIM 1: CFD, Ansys. AIM 2: deep learning

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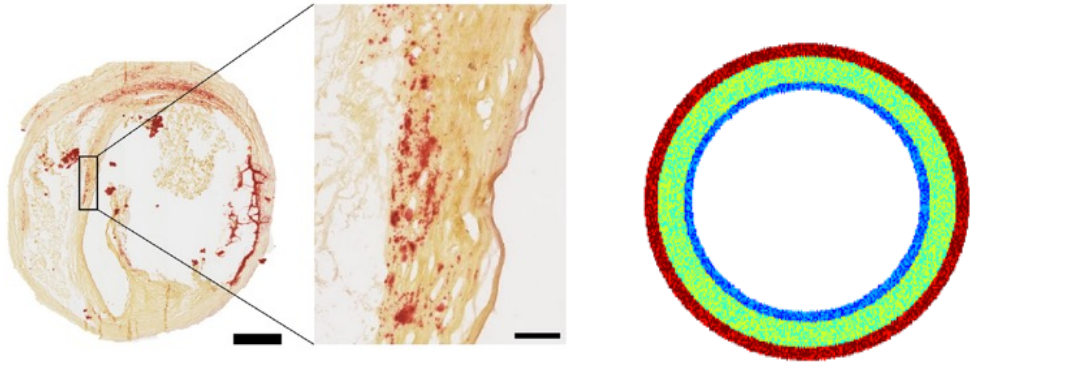
anna.corti@polimi.it

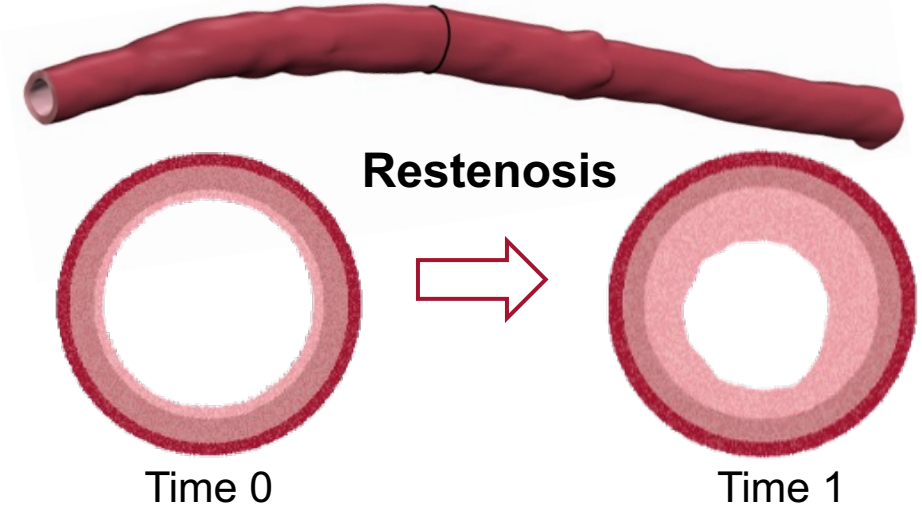
Agent-based modeling of vascular adaptation – Anna Corti

Example 1: to develop an agent-based model simulating the mechanisms of formation of vascular calcification



ABM of artery cross-section

Example 2: to develop an agent-based model of restenosis



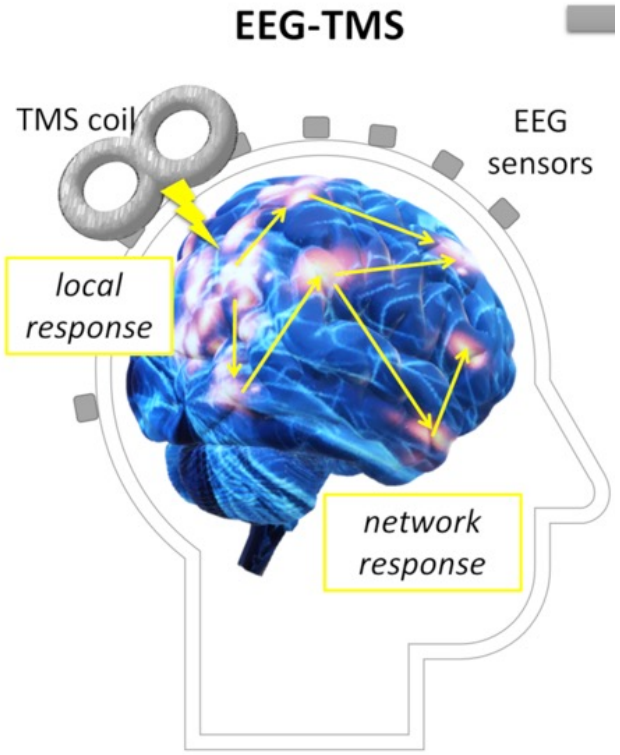
Required skills: Matlab

For further information write to
anna.corti@polimi.it

Investigation of functional brain network complexity during the sublime experience in virtual reality.

The **«sublime»** is one of the most fascinating emotions described so far. Virtual reality (VR) enables the generation of the sublime emotion in the lab.

The thesis deals with the analysis of **EEG** data collected during **sublime-inducing VR** from healthy controls. **Dynamic brain network features** will be extracted using linear and nonlinear EEG metrics. **Machine learning tools** will be used to **predict emotions from EEG features**.



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Flavia Carbone, flavia.carbone@polimi.it

Collaborations: *Prof. Paolo Brambilla, Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, Milan, Italy.*

Keywords: virtual reality; EEG; emotions; brain network complexity; machine learning.

TMS-EEG exploration of brain network changes induced by the sublime experience in virtual reality.

The **repetitive TMS stimulation** over a specific area can lead to unveil **brain network differences** induced by the complex sublime emotion.

The thesis deals with the **analysis of TMS-EEG data** collected from healthy controls after their navigation in sublime-inducing VR. **Connectivity** and **brain source analyses** will be performed on the TMS-EEG data to evaluate the differences among scenarios.

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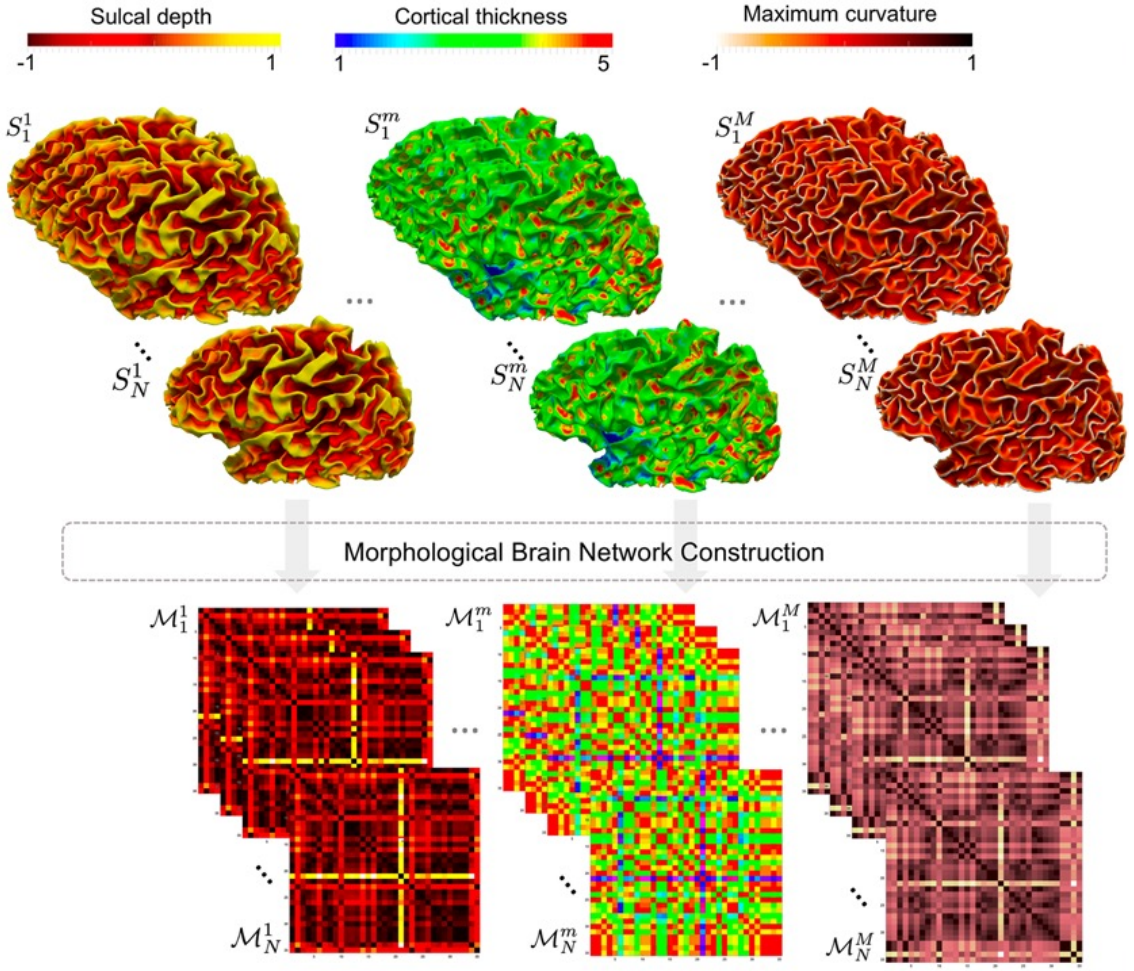
Collaborations: *Prof. Paolo Brambilla, Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, Milan, Italy.*

Keywords: virtual reality; TMS-EEG; emotions; brain network complexity; machine learning.

Development of diagnostic tools for affective disorders based on morphological brain network markers.

Structural similarity networks have recently emerged as a promising tool in the search for diagnostic brain markers in psychiatry.

The thesis goal is to use **multi-view morphological brain network features**, as compared to standard morphological features, to **discriminate subjects with depressive disorders** from controls through **supervised machine learning** and unsupervised data-driven methods such as the **sparse clustering approach**.



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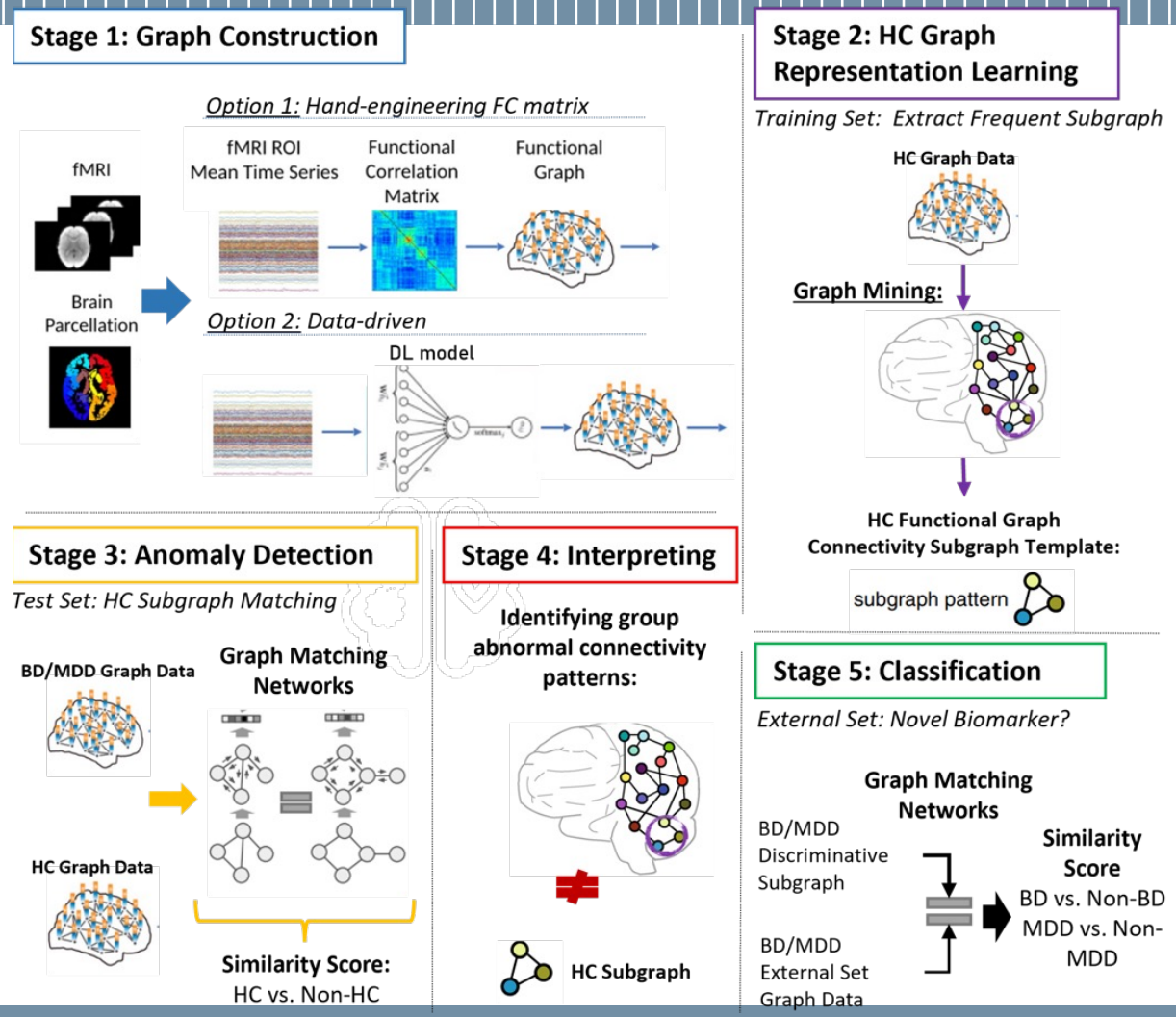
Keywords: brain connectivity, MRI, ML, sparse clustering.

Development of diagnostic tools for affective disorders based on morphological brain network markers.

Graph Neural Networks provide a natural representation of graphs, including the complex brain networks.

This thesis proposes the development of brain **GNN models to predict clinical outcomes** in individuals with different psychiatric disorders.

GNNs will be trained on brain connectivity matrices extracted from multi-site and multimodal, and multi-group MRI data.



Proposer: *Eleonora Maggioni,* eleonora.maggioni@polimi.it, *Inês W. Sampaio,* ines.won@polimi.it

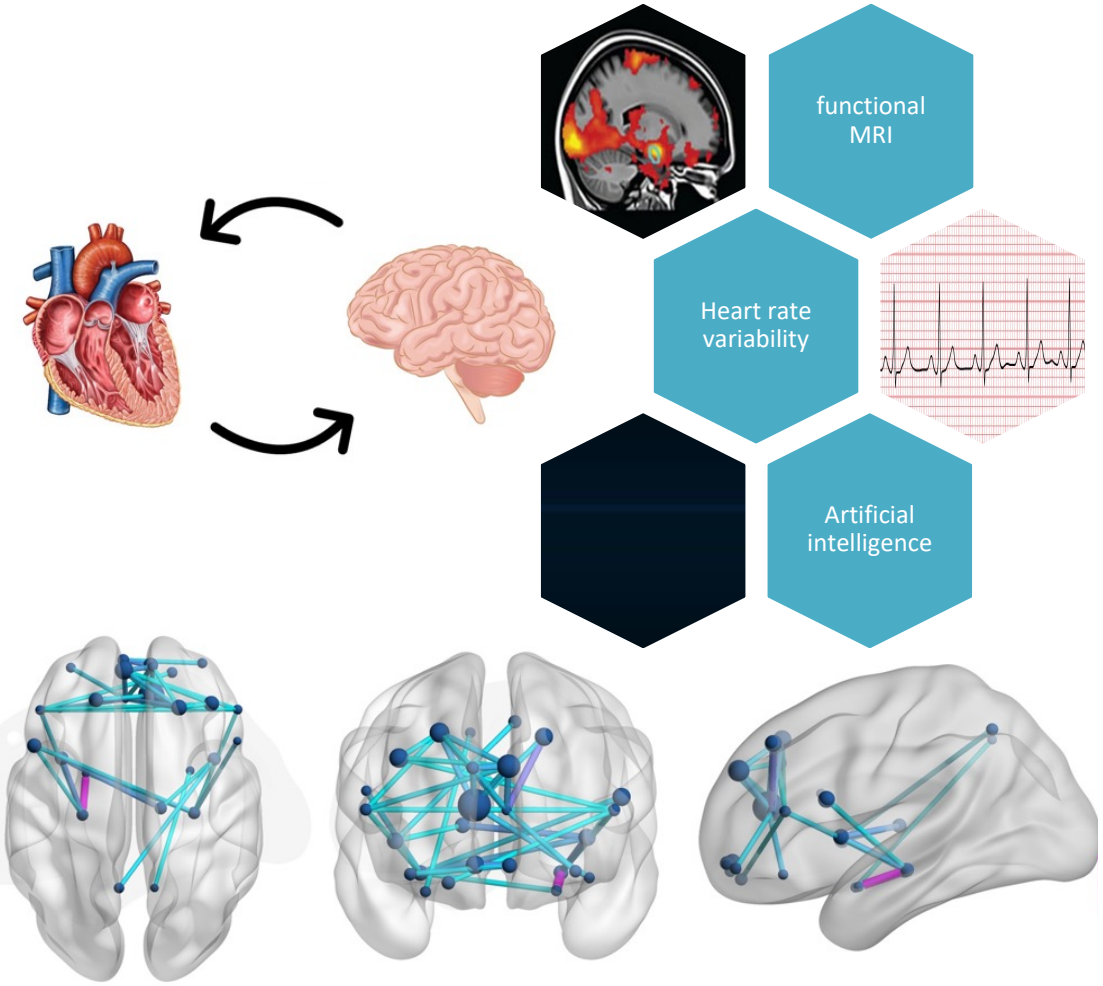
Collaborations: *Prof. Paolo Brambilla, Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, Milan, Italy.*

Keywords: graph neural networks, multimodal MRI, psychiatry

Investigation of brain connectivity on brain-heart interactions through machine and deep learning tools

Although **the connection between the brain and the heart** is well-established phenomenon, their complex relationship is still largely unexplored both in physiology and in **psychopathology**.

The thesis objective is to **develop machine or deep learning tools** on **heart rate variability** (HRV) and **functional MRI** information to explore their relationship and the corresponding **brain connectivity** patterns.



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Collaborations: *Prof. Paolo Brambilla*
Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, Milan, Italy.

Keywords: brain connectivity, HRV, fMRI, multimodal neuroimaging, machine learning, deep learning.

Identification of genetic and environmental determinants of psychopatological risk dimensions during neurodevelopment

The **investigation** of **neural bases** of **psychopathological risk traits** is at the beginning, and even lesser is known on how **genes** and **environment** interact in **shaping early-onset risk traits**.

The thesis aims to implement a **methodological approach** for the **extraction of multivariate associations** among psychopathological risk traits and brain anatomy and function. As follow, **statistical twin models** will be applied to **quantify genetic** and **environmental** effects on the associations found.

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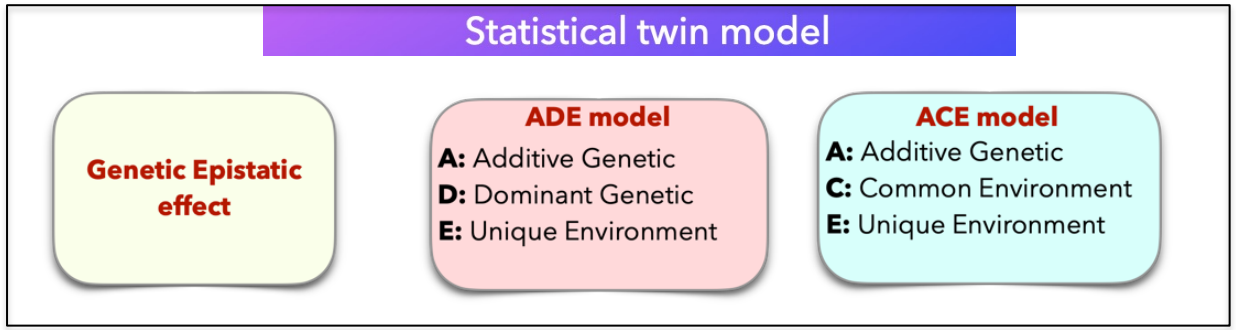
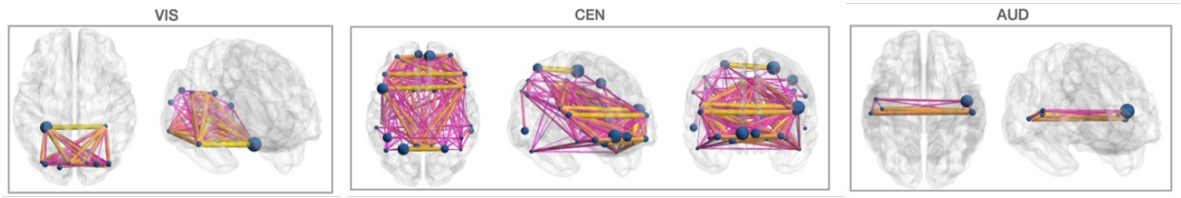
Collaborations: *Prof. Paolo Brambilla, Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, Milan, Italy.*

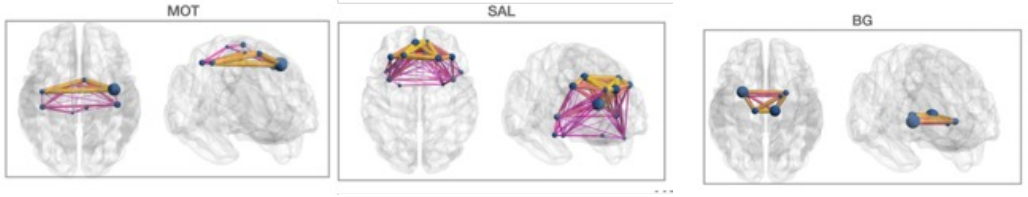
Keywords: gene-environment, neuroimaging, twin design.



Visual, Auditory and Central executive networks influenced by the effects created by **ACE model**



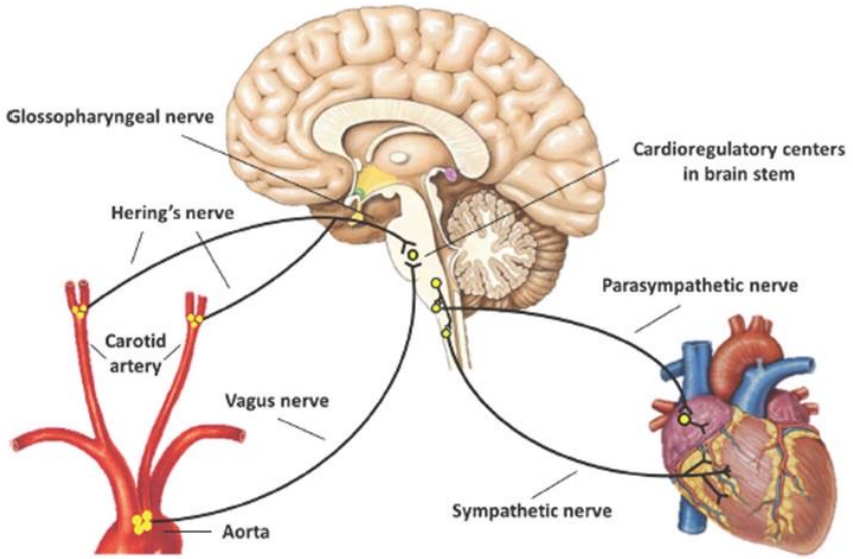
Basal ganglia, Motor and Salience networks resulted under **a strong genetic control** (**Epistatic Effect** and **ADE model**)



Cardiovascular Signal Processing and Modeling
Prof. Riccardo Barbieri

Thesis projects:

- Contactless monitoring of cardiovascular signals through video-photopletismography (VPPG) (**SpinLabS**, Milan, Prof. Barbieri & Prof. Mainardi)
- Characterization of emotional states during emotion elicitation protocols in normal and virtual reality environments (**SpinLabS**, Milan, Prof. Barbieri & Prof. Mainardi)
- Characterization of hypertensive patients during vagal nerve stimulation (**Massachusetts General Hospital,** Boston)
- Characterization of patients with fibromyalgia during pain elicitation protocols (**Spaulding Rehabilitation Hospital**, Boston)
- Assessing cerebral autoregulation in clinical scenarios (**Ospedale San Donato**, Milan)
- Assessing simultaneously peripheral vasomotion, cerebral autoregulation and baroreflex in healthy subjects (**Ospedale San Donato**, Milan)
- Analysis of the within-burst and between-burst muscle sympathetic nerve activity dynamics in healthy and pathological subjects (**Ospedale San Donato**, Milan)
- Cardiovascular characterization of pathophysiological states in the ICU (**Massachusetts Institute of Technology**, Boston)



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SPiN LABS

Biosignals Bioimages Bioinformatics

POLITECNICO MILANO 1863

AI-based monitoring system in Intensive Care Unit
Prof. Riccardo Barbieri

The Intensive Care Unit collects patients in very critical conditions and usually subjected to the administration of several drugs and fluids which have a great impact on the cardiovascular system. Several information are stored into the Electronic Health Records and as continuously recorded vital signs like ECG and Blood Pressure. The availability of such large amount of data and allows for the development of monitoring tools that can help clinicians in their decision making processess.
Our theses consist of:

- 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

Massachusetts Institute of Technology

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Management of infections
Prof. Riccardo Barbieri

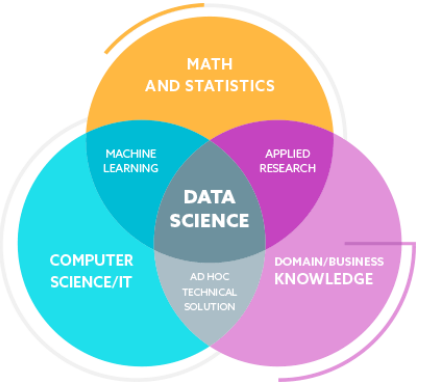
Clinical conditions of patients admitted to Intensive Care Units are critical and rapidly evolving in time. For this reason, it is necessary to personalize and adapt drug administrations strategies to optimize their therapeutic efficacy. In particular, it is important to choose the most appropriate dosage regimen for antibiotics. If their plasma concentration is too low, the drug is ineffective and drug-resistance bacterial strains may be selected. Conversely, high drug concentration may be toxic.

Antibiotic Pharmacokinetics

The candidate will participate in the development of pharmacokinetic models starting from data collected with MargheritaTre, using nonlinear models with mixed random effect

Antibiotic utilization in COVID patients

The candidate will contribute to identify the risk factors for developing healthcare associated infections, in particular sustained by multidrug-resistant bacteria.



AbioKin GiViTI

In collaboration with:

Antimicrobial Stewardship GiViTI

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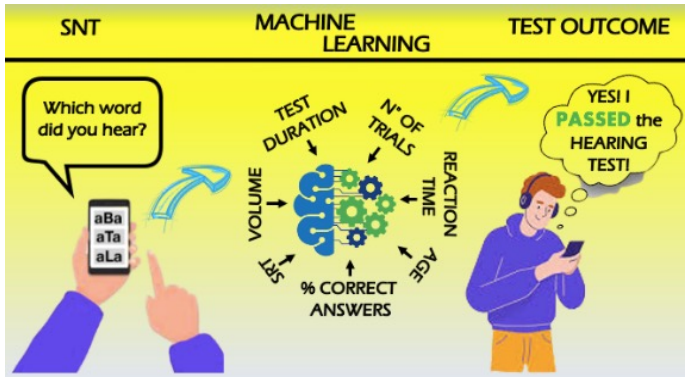
maximiliano.mollura@polimi.it

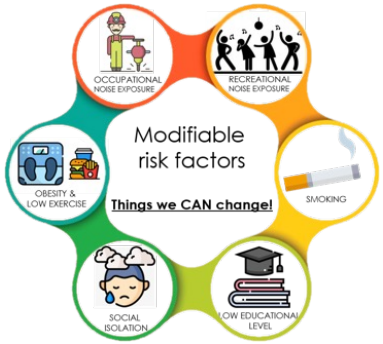
Keywords: Intensive Care Unit, Antibiotics, Pharmacokinetics, COVID

AI-driven tools for early detection of hearing and cognitive risk

Hearing loss (HL) is among the top leading causes of moderate-to-severe disability in older adults and its consequences can lead to a significant decline in quality of life (cognitive impairment, reduced social participation, depression…).Therefore, it is crucial to promote timely intervention through online screening tests, which can be performed by the user himself, directly from home.

The proposed project consists in the 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 (lifestyle, education, patient health status, and family history) with AI-based models able to identify early signs of hearing loss and cognitive decline with the final goal of characterizing individual risk and providing prevention strategies.





In collaboration with:

Consiglio Nazionale delle Ricerche
Istituto di Elettronica e di Ingegneria dell'Informazione e delle Telecomunicazioni

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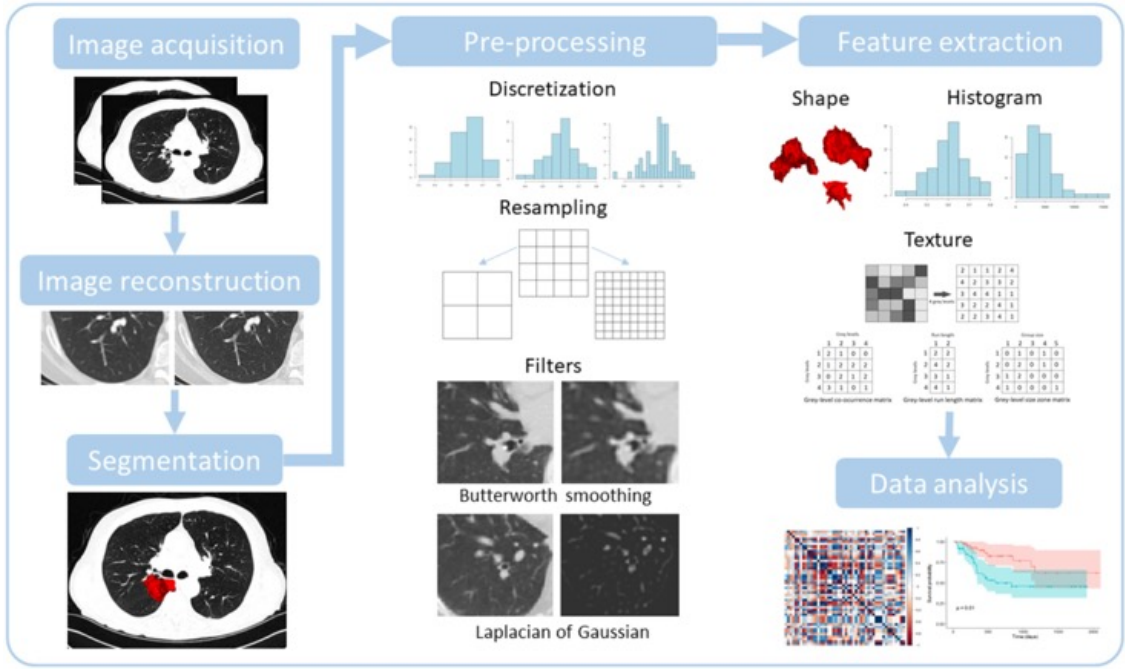
maximiliano.mollura@polimi.it

Keywords: Hearing loss, Hearing screening, Telemedicine, Machine Learning

Radiology and multimodal MRI Image Processing
Prof. Riccardo Barbieri

Thesis projects:

- 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 hosteoporosis



HUMANITAS RESEARCH HOSPITAL

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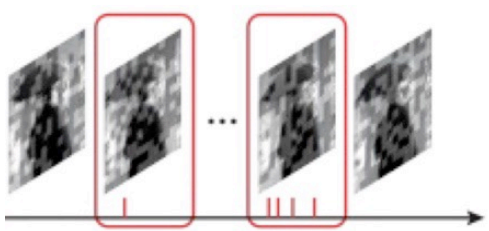
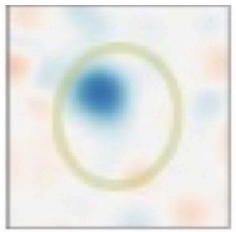
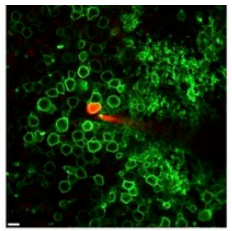
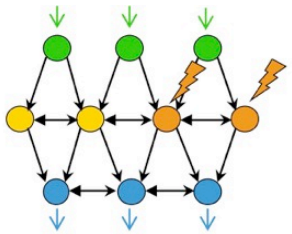
Master Thesis Internship @ Vision Institute, Paris
Prof. Riccardo Barbieri

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 scenes1. 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

INSTITUT DE LA VISION PARIS

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Machine Learning Analysis for Imagined Speech Classification using EEG signals - Profs. Barbieri/Mainardi

Rationale. Imagined Speech (IS), the cognitive process of mentally envisioning words, presents itself as an intuitive framework for Brain-Computer Interfaces in communication, and its exploration holds the potential to enhance the lives of individuals afflicted by conditions that inhibit their ability to communicate.

- **Thesis Aim:** The thesis aims to develop Machine Learning and Deep Learning algorithm to classify Imagined Speech exploiting biomedical non-invasive signals such as Electroencephalography (EEG). The thesis will explore novel classification paradigms, with a specific emphasis on the neurophysiological aspects of IS, aiming to advance brain-computer interaction and deepen our comprehension of its neurological underpinnings.

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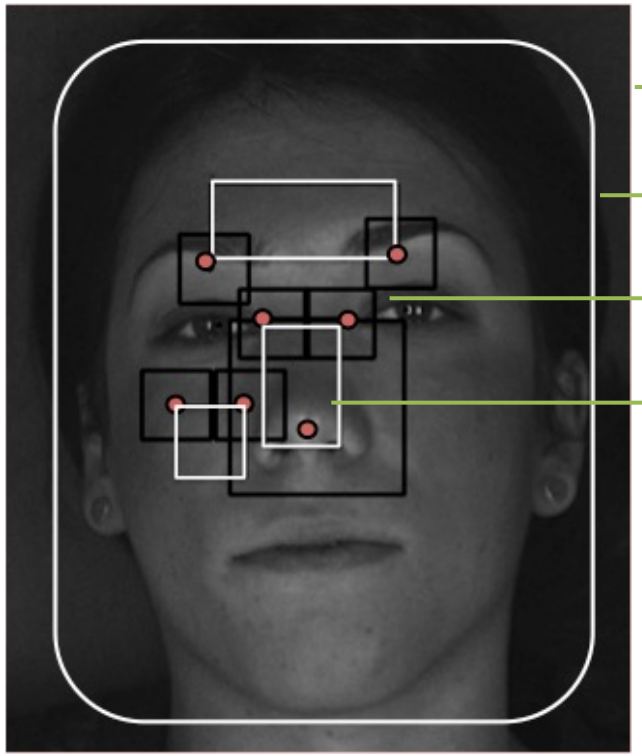
luca.mainardi@polimi.it

Noncontact video monitoring of cardiovascular dynamics - Profs. Barbieri/Mainardi



Frame 1

Face Detection

Identification of 7 fiducial points

Identification of 3 Regions of Interest

Forehead Nose Cheek

VIDEO CAMERA

Rationale. Vital signs can be detected by a contactless camera. We have recorded face and hand videos, from which we have been able to extract time-series associated with the respiratory and cardiac rhythms.

- **Thesis Aim:** The thesis aims at developing advanced algorithms to extract features associated with cardiovascular system dynamics and control, such as Heart Rate Variability and Respiratory Sinus Arrhythmia.

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luca.mainardi@polimi.it

Cardiovascular Risk prediction in Mediterranean population. (Prof. Luca Mainardi)

- **Rationale.** The work is part of the EraPerMed project funded by EU named "Personalised Prognostics and Diagnostics for Improved Decision Support in Cardiovascular Diseases". The project aims at new data analysis methods (AI, ML, signal processing) to develop more powerful risk assessment methods that are accurate, robust, and explainable.
- **Thesis Aim**: The thesis will explore AI methods for ECG analysis and risk prediction. In particular, it will develop signal processing & AI/ML methods for digital biomarkers derivation in advanced utilization of ECG and multivariable information in diagnosis and prognosis of CVD. Northern Europe populations and Mediterranean populations will be compared.
- In collaboration with TUNI (Finland)

For more info: luca.mainardi@polimi.it
Skill: Phyton/Matlab programming, Data analysis, AI/ML tools

Asynchronous classification of ErrP events through Siamese Neural Network in BCI application. (Prof. Luca Mainardi)

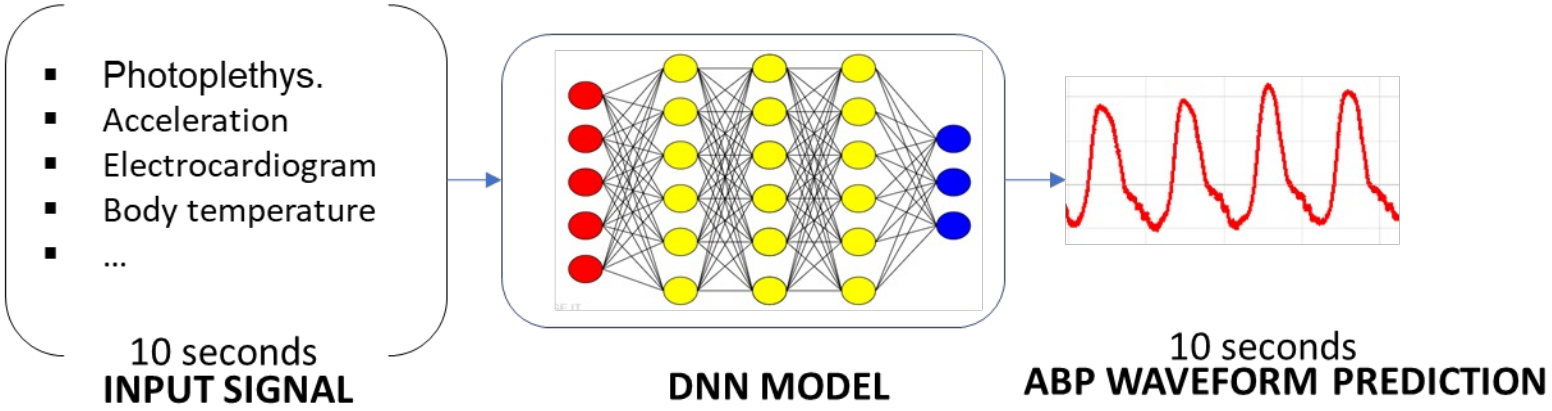
- **Rationale.** Neuro-engineered Bran Computer Interface (BCI) systems are designed to interpret user intention at pre-defined timepoints (synchronous). No BCI system for asynchronous Error Potential detection is able to perform with sufficient reliability.

- **Thesis Aim**: Continuous detection of Error Potential events without prior knowledge of their occurrence. A customized Siamese Neural Network will be designed and applied to data collected during experiments conducted in the B3Lab facilities. These experiments will use a Unity-developed ErrP stimulating protocol, where the are classified asynchronously. A prototype for a closed-loop BCI system that relies on real-time Error Potential detection will be developed.

For more info: luca.mainardi@polimi.it
Skill: Phyton/Matlab programming, neural system knowledge, AI/ML tools

Cuffless method for ABP Measurement (Prof. Luca Mainardi)

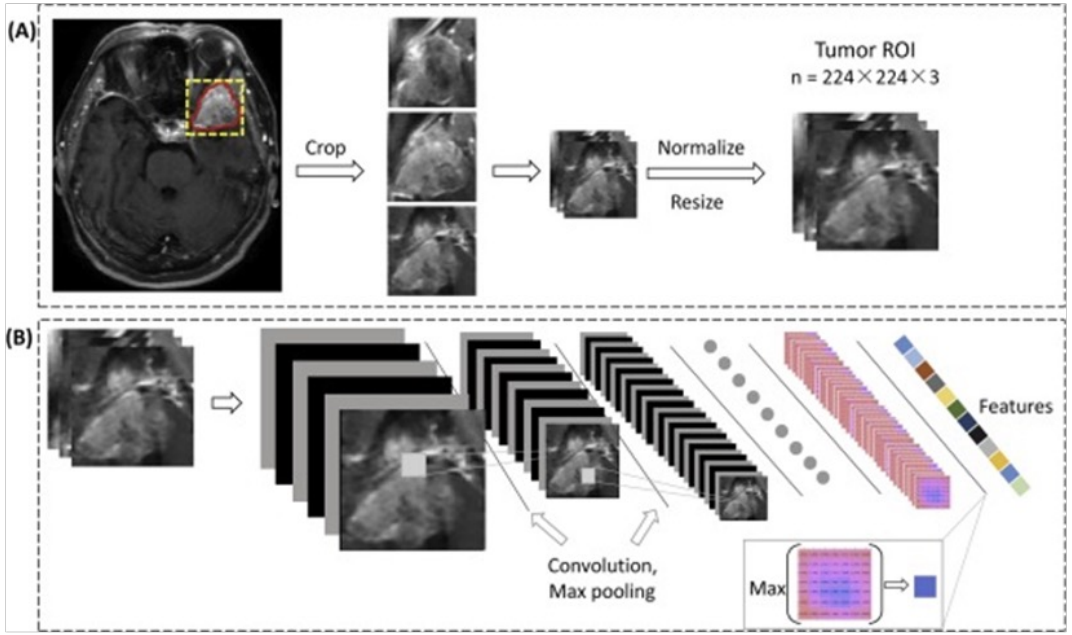
- **Rationale.** Cuffless blood pressure (BP) measurements have high potentials to improve the awareness, treatment, and management of hypertension, providing continuous non-intrusive measures to be implemented in garments or smartwatches.
- **Thesis Aim**: While a variety of methods exist claiming to provide robust cuff-less BP measurements (using various signal such as ECG, PPG, accelerometer), a fully validated solution is not available. The thesis will approach the problem by developing a DNN able to estimated the ABP signal from other cardiovascular measurements performed by smartwatches.



For more info:
luca.mainardi@polimi.it
pietro.cerveri@polimi.it
Skill: Phyton/Matlab programming, Cardiovascular system knowledge, AI tools.

Radiodgenomic Biomarkers integrations for prediction of disease evolution in diffuse midline glioma (Prof. Luca Mainardi)

- **Rationale.** Diffuse midline glioma (DMG) H3 K27M-mutant is a tumor of the Central Nervous System (CNS). In DMG patients, there is the need to identify non-invasive biomarkers for predicting response to therapy and thus possibly guide personalized patient management or, at least, skip useless and toxic treatments.
- **Thesis Aim**: In a previous work a set of Radiomic signatures have been identified. In this thesis, they will be integrated by other biomarkers coming from gene-analysis, microbiome analysis and clinical scores to provide an overall score able to predict patient predisposition to respond to therapy.
- In collaboration with INT, Milano.



For more info:
luca.mainardi@polimi.it
Skill: Phyton/Matlab, Data analysis, AI tools.

Sensing by Smart-Glasses
(Prof. Luca Mainardi)

- **Rationale.** New-generation garments are more then fashion objects and can be used for various tasks including bio-sensing.
- **Thesis Aim.** We will assess the quality of recorded EEG signals when obtained by a reduced set of leads placed near the earlobe and on the nose. Experimental sessions eliciting brain responses (through visual or acoustic stimuli) will be designed and conducted at the Luxottica SEL Laboratory (Luxottica Laboratory facilities at POLIMI). Recorded signals will be compared with those obtained by 10-20 cap system. Different electrode position, electrode type (gel or dry) and stimuli will be tested. A prototype hardware for recordings of those potentials will be finally designed and realized.

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pietro.cerveri@polimi.it
Skill: SW and HD design.

Consiglio Nazionale delle Ricerche

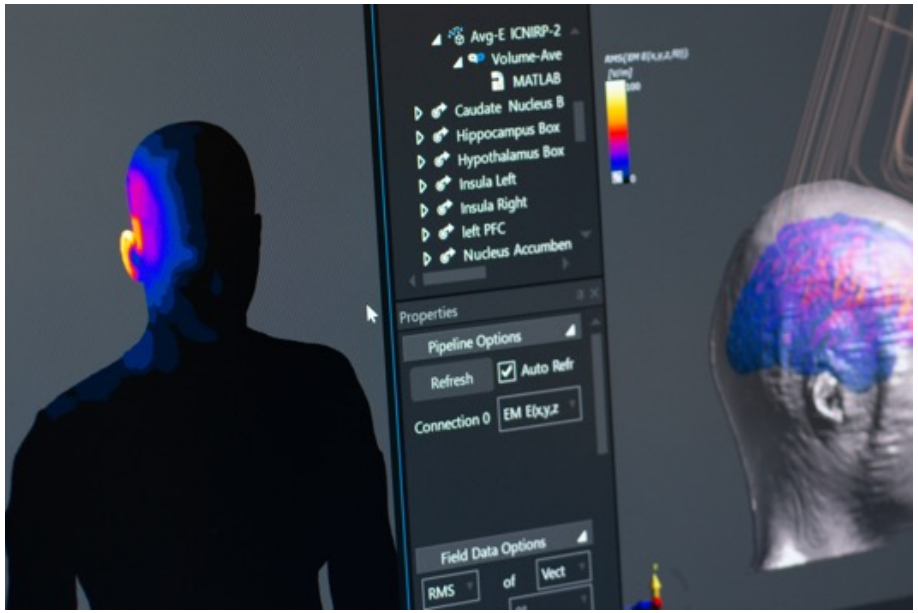
Proposte di tesi
9 Novembre 2023

Laboratorio di Bioelettromagnetismo «Emanuele Biondi» (IEIIT-CNR, DEIB POLIMI)

Cnr-Istituto di **Elettronica** e di **Ingegneria** dell'**Informazione** e delle T**elecomunicazioni**

FACILITIES

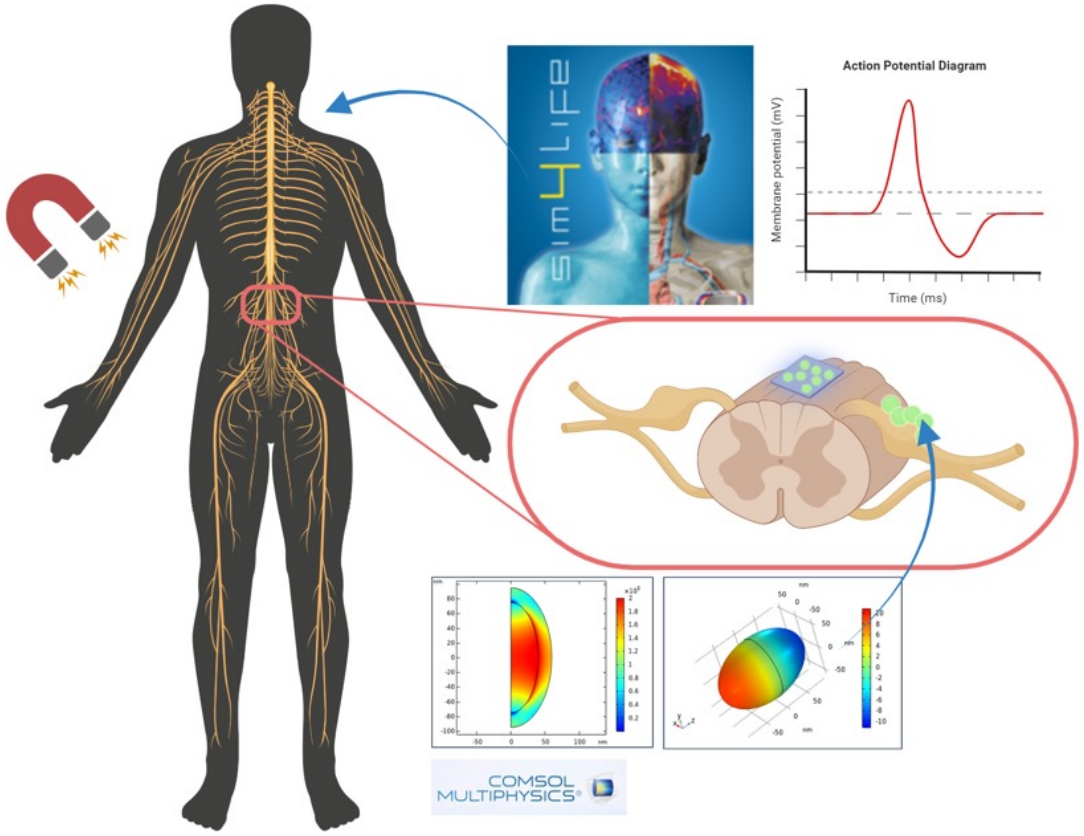
- Laboratory of Bioelectromagnetics Emanuele Biondi (IEIIT-CNR, DEIB POLIMI) (Building 21, ground floor)



- High performance workstations
- software for electromagnetic computations
- cutting-edge computational anatomical models
- software codes for EMF stochastic dosimetry and statistical modeling of EMF exposure
- Personal measurement devices
- Environmental measurement device

EMF-MED: MASTER THESIS PROPOSAL

- Magnetoelectric nanoparticles as nanotransducers: a novel wireless nerve stimulation technology



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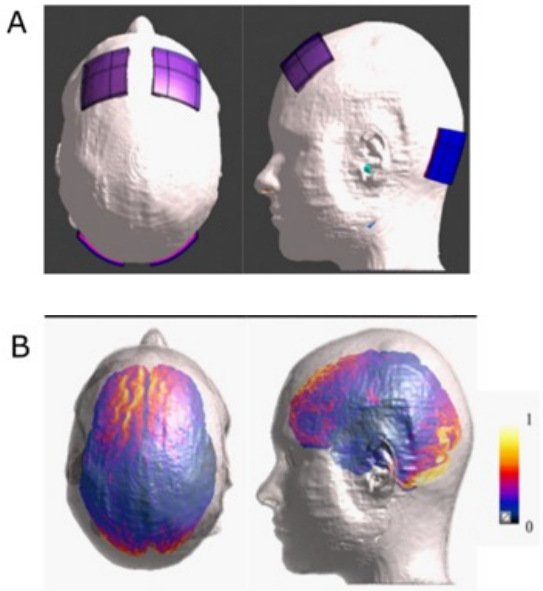
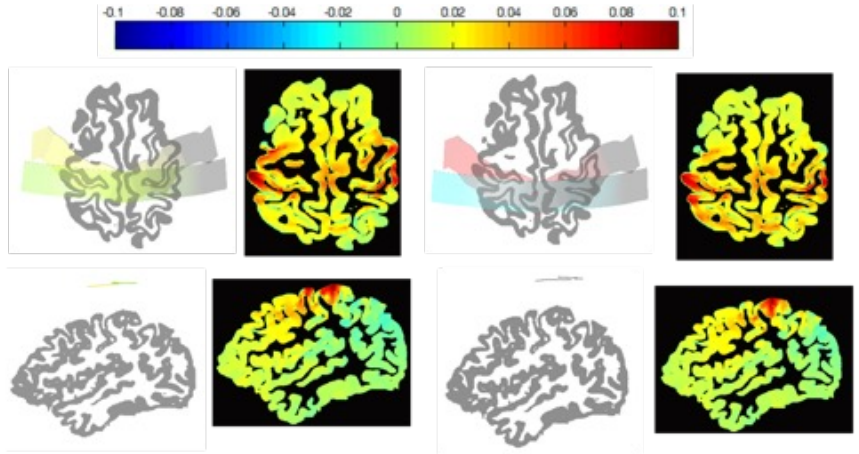
EMF-MED: MASTER THESIS PROPOSAL

- Toward a tailored neurotherapy: development of an individualized-dose transcranial direct current stimulation (tDCS) protocol





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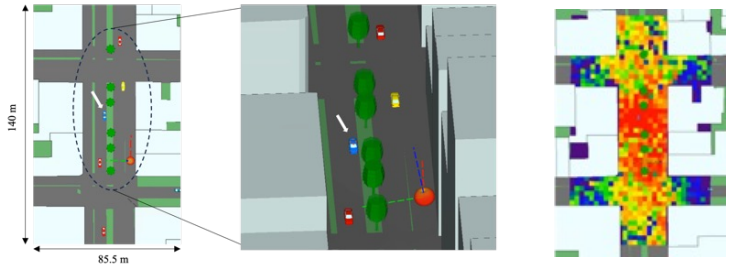
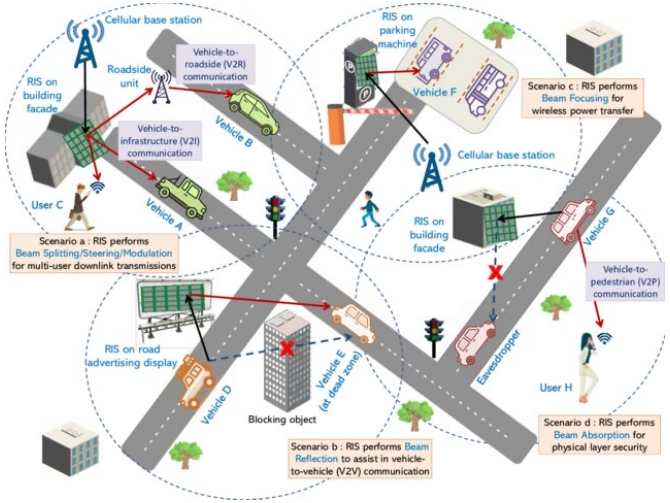
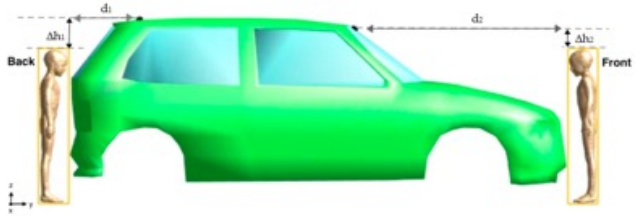
EMF-SAFE: MASTER THESIS PROPOSAL

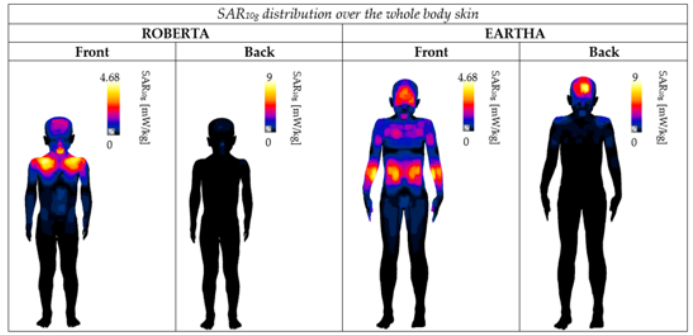
- Mobility transport of the future, intelligent surfaces and 6G: modelling human EMF exposure in urban connectivity





http://dx.doi.org/10.36227/techrxiv.16606718.v1





https://doi.org/10.3390/s23115170

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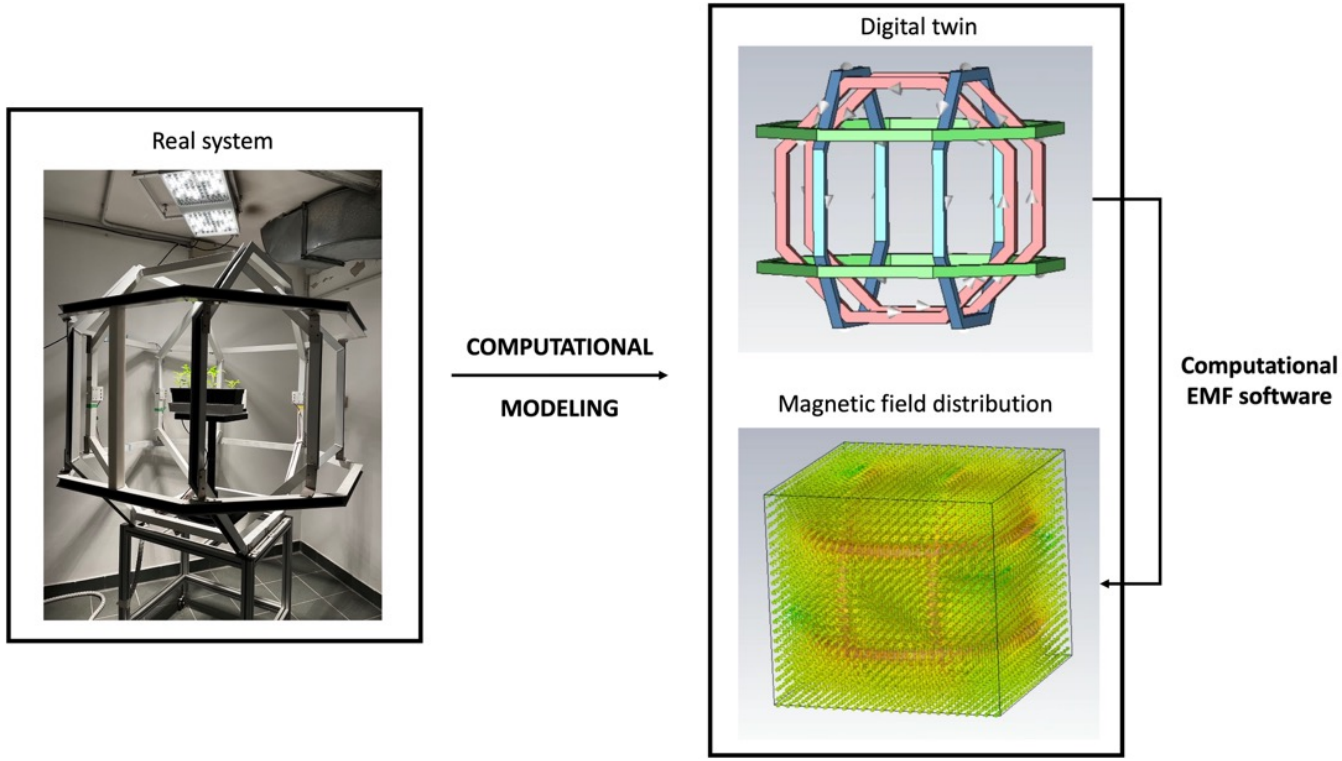
EMF-SAFE: MASTER THESIS PROPOSAL

- One Health in space: modeling and optimization of plant grow in absence of magnetic field



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