Laboratorio di Bioingegneria

Università di Genova

DIBRIS DIPARTIMENTO DI INFORMATICA, BIOINGEGNERIA, ROBOTICA E INGEGNERIA DEI SISTEMI

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Dalla Ricerca di Base alla clinica
Sviluppo di nuove tecnologie per la diagnosi, terapia, riabilitazione ed assistenza

Outline

- the Bioengineering Laboratory fact sheet
- areas of R&D activities
  - description
  - equipment/instrumentation
  - services
- education and tranining
- networking and discussion

The Bioengineering Lab in brief

2012

Gruppo di Bioingegneria (bio.dibris.unige.it)
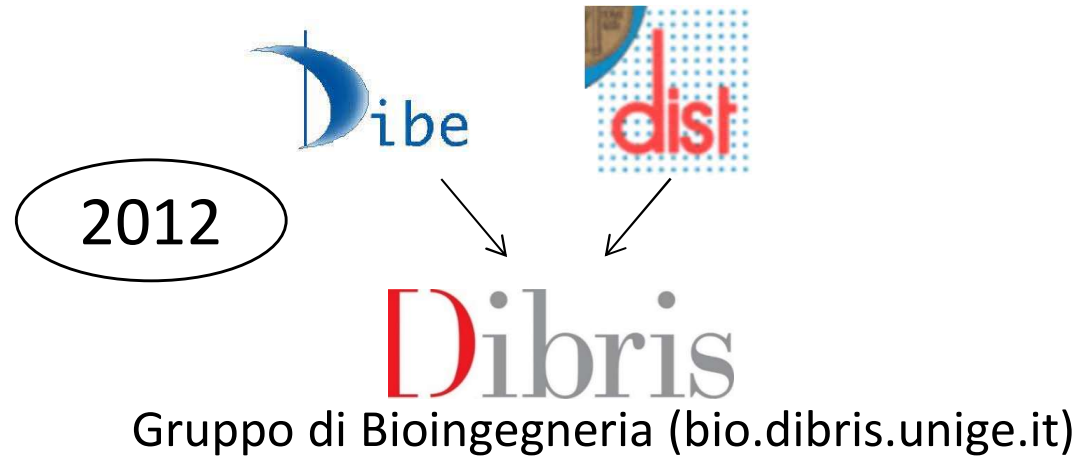
2015

«Laboratorio di Bioingegneria» recognized by regional government (Regione Liguria) as large-size (category II) research infrastructure

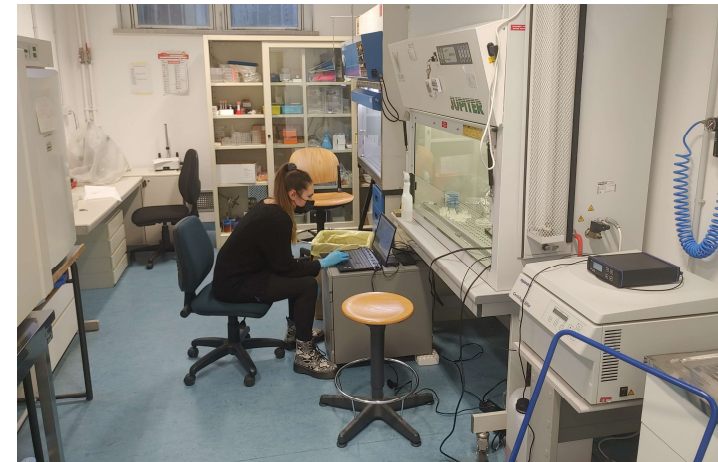# The Bioengineering Lab in brief

2021

who: 20 permanent academic staff
30 PhD students and postDocs

- robotics/automation
- computer science
- mechanical engineering (DIME)

where: via Opera pia / viale Causa

chemical lab (synthesis, characterization)

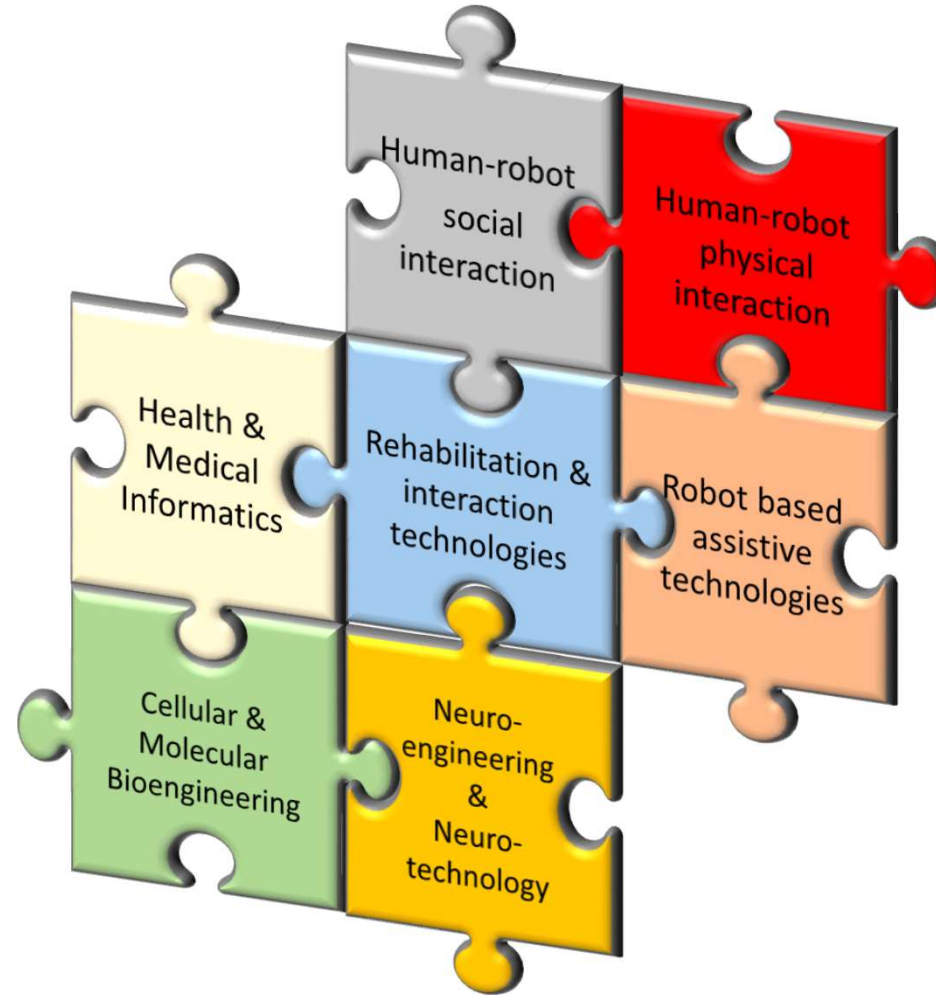*Cell culture lab (primary cultures, cell lines, neurons from human iPSCs)*
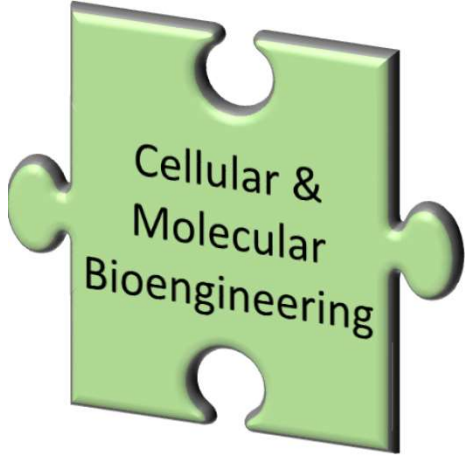
what:
- basic and applied research
- technology transfer
- education and training

mechatronic facility (fast prototyping, additive manufacturing)

The Bioengineering Lab

Cellular & Molecular Bioengineering

- *in vitro* structural and functional characterization of biomolecules, cells and biological tissues at the micro- and nano-scale
- development of molecular and cell pattering techniques
- development of biomimetic scaffolds for "organ on a chip" devices
- development of nanoengineered materials for targeted and controlled release of drugs
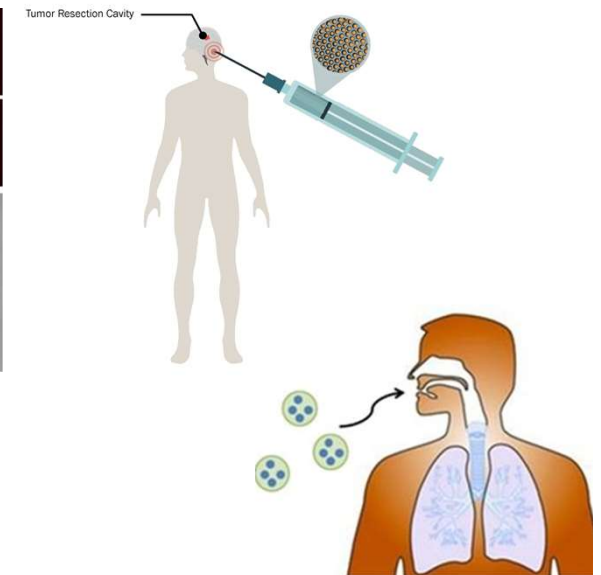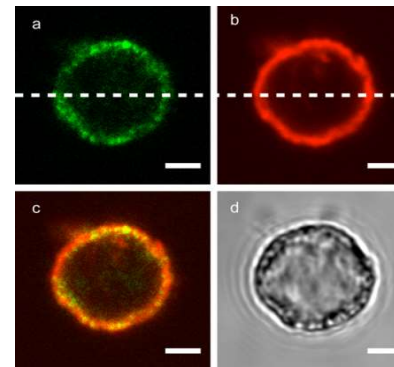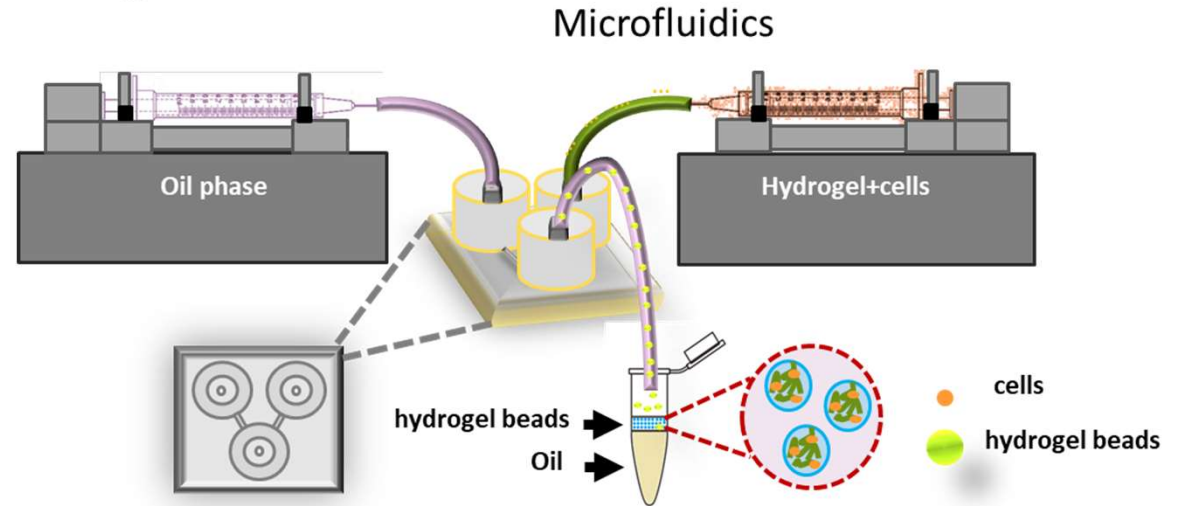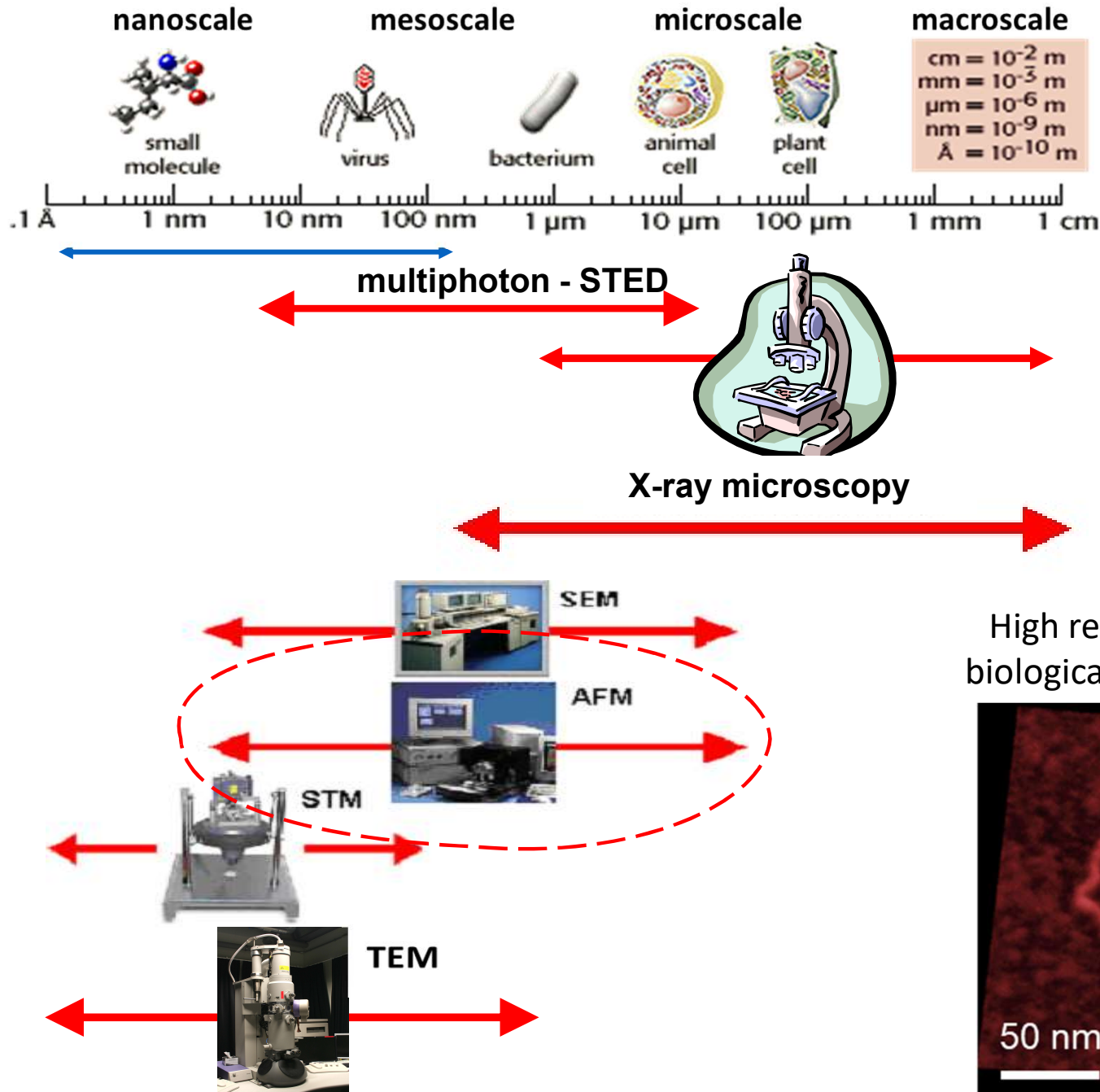
Equipment/instruments

Processing
- plasma treatment
- spin coater
- micro-encapsulation unit
- Electrospraying/Electrospinning Unit

Characterization
- UV-VIS NIR spectro-photometer
- QCM
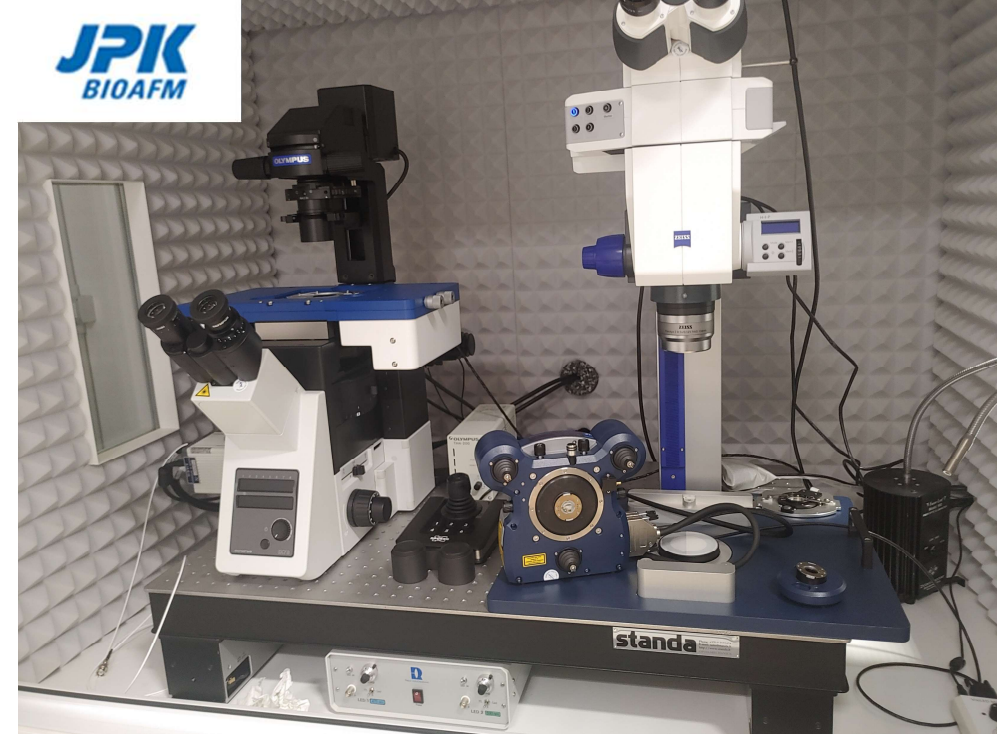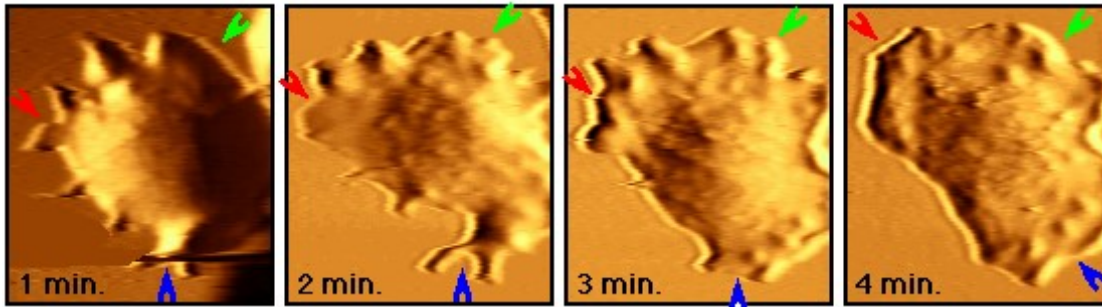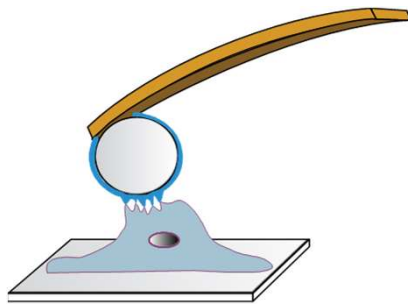- optical/scanning probe microscopes SPM

Microfluidics

Oil phase

Hydrogel+cells

hydrogel beads

Oil

cells

hydrogel beads

Tumor Resection Cavity

Nanotechnology, biology, and microscopy

High resolution imaging of biological molecules in action

Nanowizard 4 XP AFM

BRUKER

JPK BIOAFM

non destructive topography imaging of living cells

1 min. | 2 min. | 3 min. | 4 min.

cell-substrate adhesion force

mechanical measurements of human articular cartilage
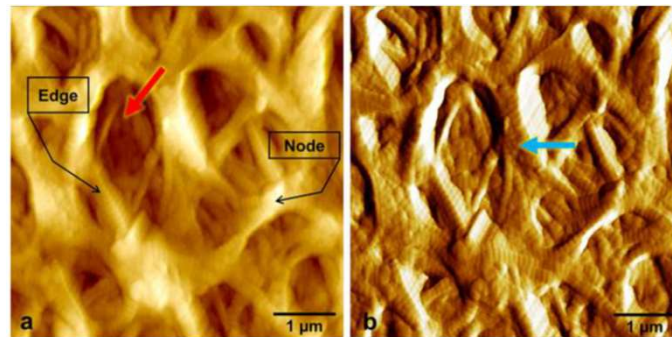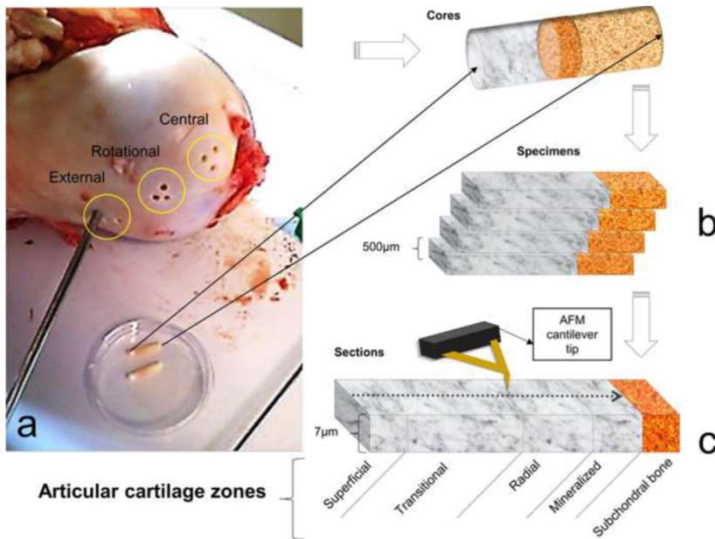
topography of fresh biopsies

Cores

Specimens

500µm

AFM cantilever tip

Sections

7µm

Articular cartilage zones

Superficial, Transitional, Radial, Mineralized, Subchondral bone

Central, Rotational, External

a

b

c

Edge, Node

1 µm

a

1 µm

b

nanostiffness [kPa]

low

collagen meshwork disruption

high

grade 0

grade 1

grade 2

grade 3

■ OA grade 0
● OA grade 1
♦ OA grade 2
★ OA grade 3

loss of GAGs

age of patient [years]
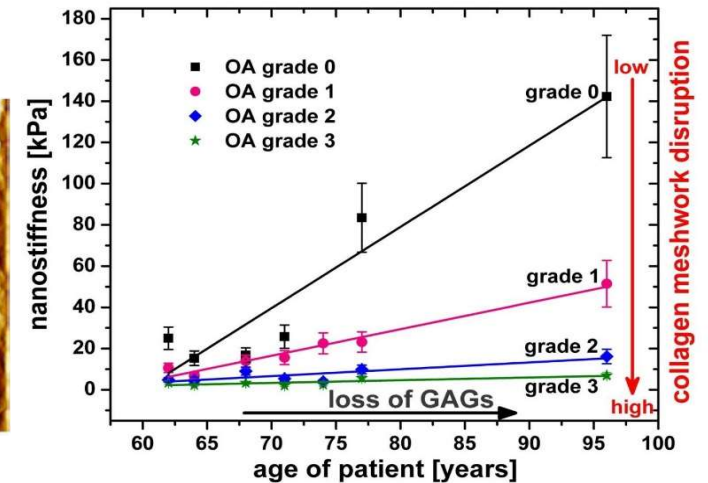
Stolz et al. *Nature Nanotech* (2009)
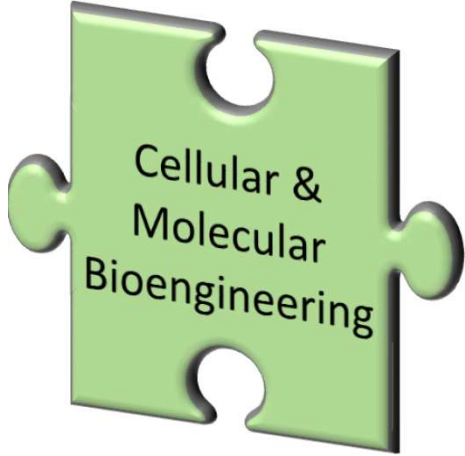
Cellular & Molecular Bioengineering

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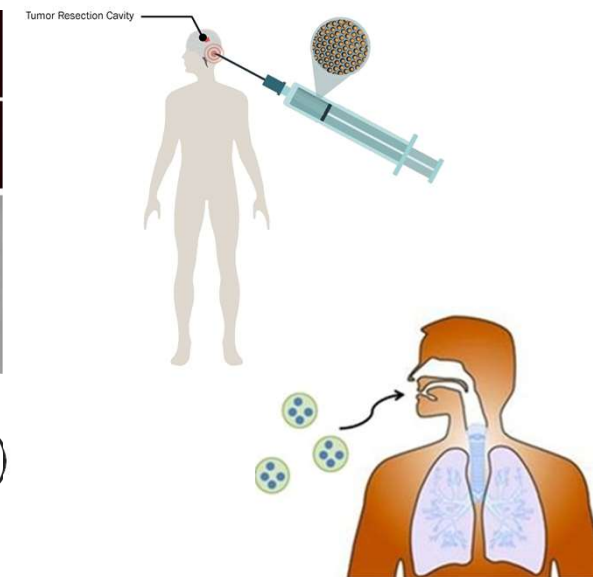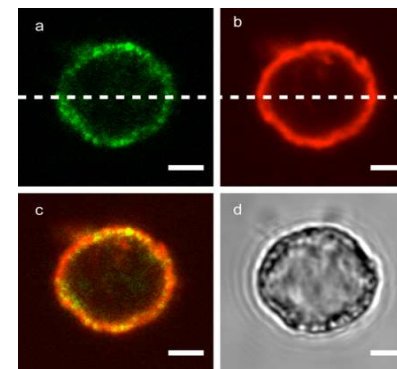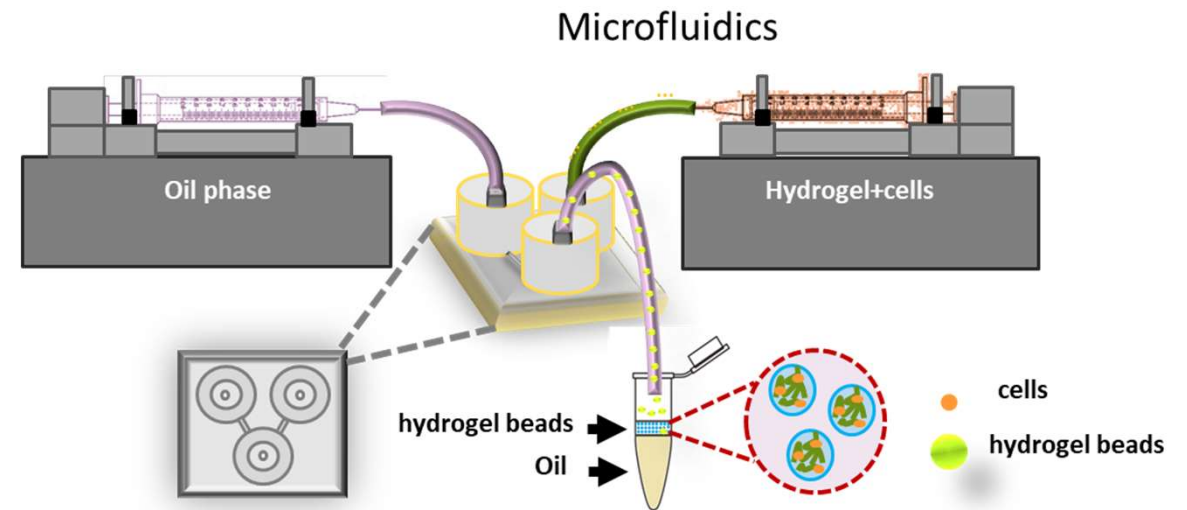
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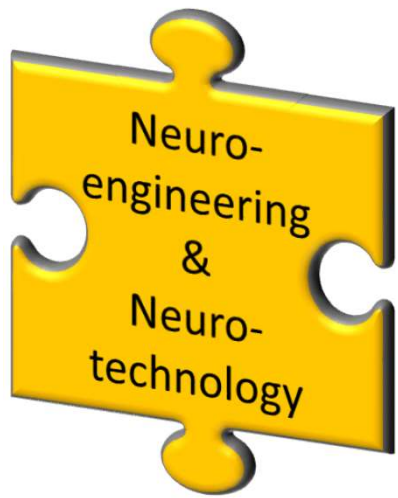- Electrospraying/Electrospinning Unit

Characterization
- UV-VIS NIR spectro-photometer
- QCM
- optical/scanning probe microscopes SPM

Services

- surface analysis (topography, tribology, interactions, nanomechanics)
- development of AFM based sensing/clinical diagnostic assays

Neuro-engineering & Neuro-technology

- neuro-electronic interface
- brain-on-a-chip and 3D neuronal networks
- (neuro)electroceutical
- neuroprosthetics
- computational neuroscience and advanced data analysis tools

Micro-Electrode Arrays (MEAs)

~ 50000 cells

5 cm
Pre-coated with poly-D-lysine and laminin

1.64 mm

Equipment/instruments

- Systems for *in vitro* electrophysiology (microelectrode arrays)
- System for *in vivo* electrophysiology (microelectrode arrays)
- Systems for *human* electrophysiology (EEG)
- Workstations for neural computation
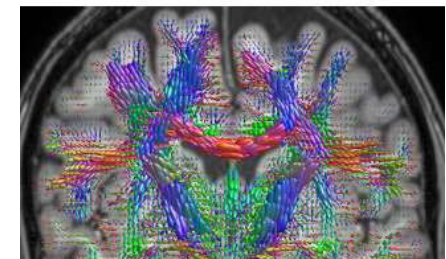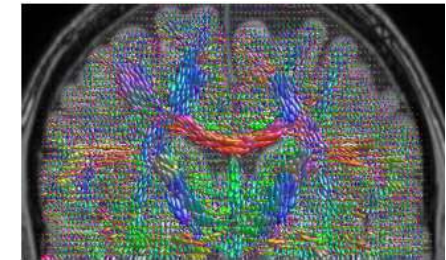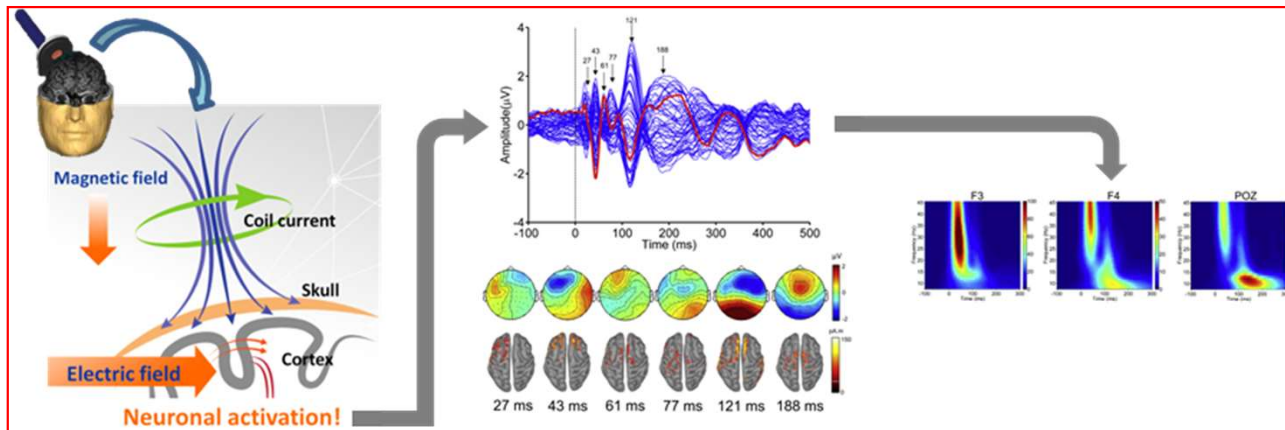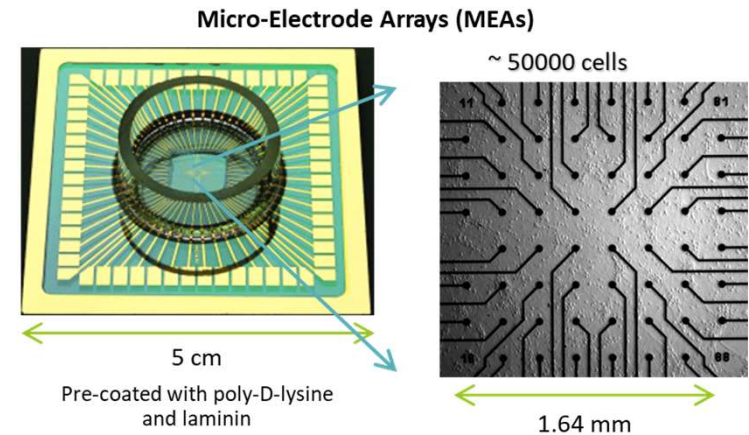
Services

- *In vitro* neurotoxicology tests for personalized medicine
- Medical Image Processing and Analysis (structural and functional imaging).
- *Neural* data analysis

Health & Medical Informatics

- design and development of health information systems to be applied in hospitals and other clinical environments implementing international standards for interoperability
- natural language processing in healthcare
- data security and privacy in healthcare
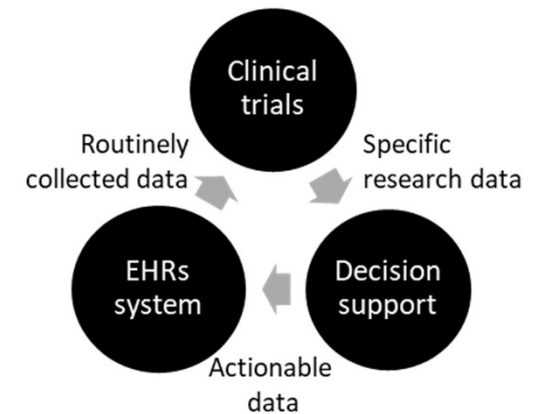
Equipment/instruments

- Data server equipped with Database Management Systems
- Standard-based tailored software for data extraction and FAIR-fication
- Software tools for information extraction based on artificial intelligence and natural language processing methods
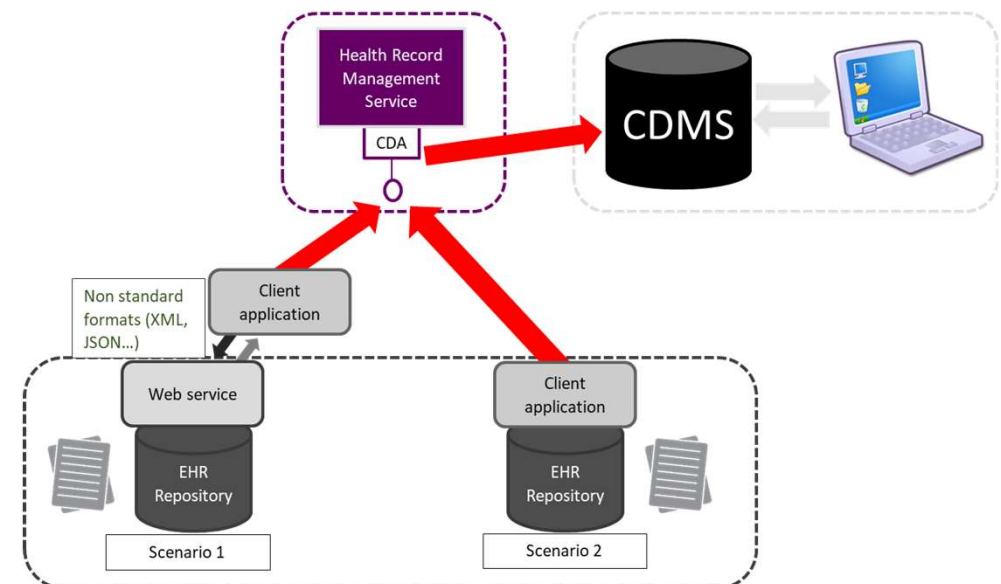
Services

- Data extraction and meta-analysis for clinical studies

Layered structure

Rehabilitation and Interaction Technologies

- Neural control of movement
- Robot-assisted rehabilitation
- Action-perception transfer
- Sensorimotor interaction (joint action)
- Movement biomechanics
- Movement analysis

Equipment/instruments
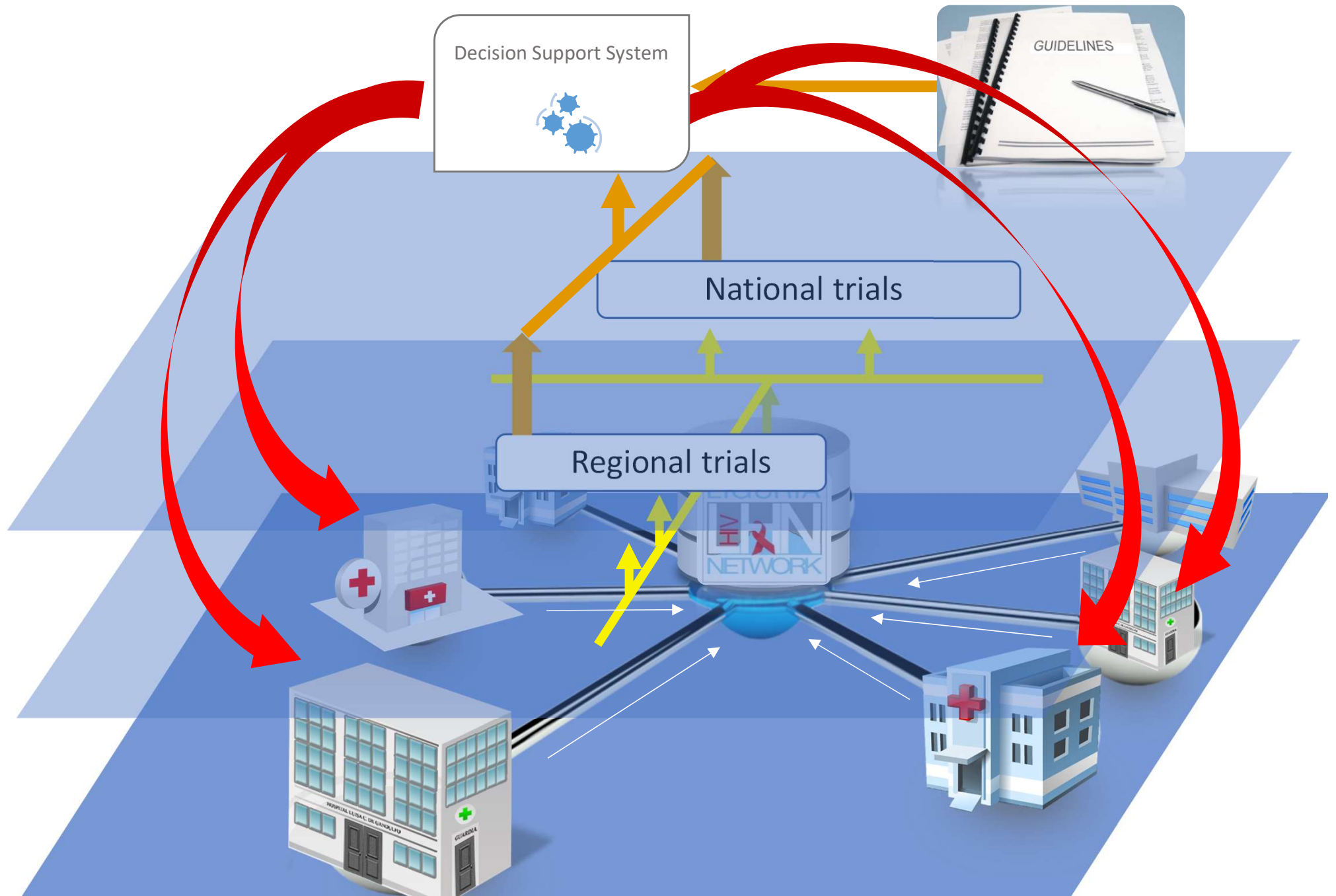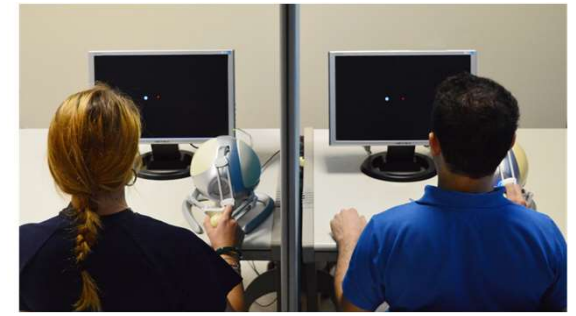
- <u>Movement analysis and neural correlates of movement</u>
  Motion capture system (VICON), multichannel IMU system (Xsens, **Cometa**), various markerless devices, 16-channel wireless EMG system (Cometa Wave Plus)
- <u>Visual perception and action-perception interplay</u>: Wearable and bench-mounted eye trackers, 3D high resolution laser scanner (Konica Minolta), Head Mounted display (HTC Vive), Depth cameras (Intel RealSense, ZED Mini)
- <u>Haptic interfaces and rehabilitation robotics</u>
  planar manipulandum braccio di ferro, **dyadic interface (Articares H-MAN)**, Novint Falcon, Phantom Omni
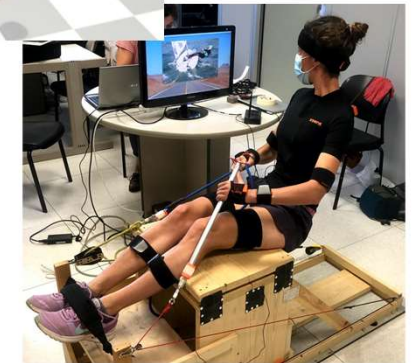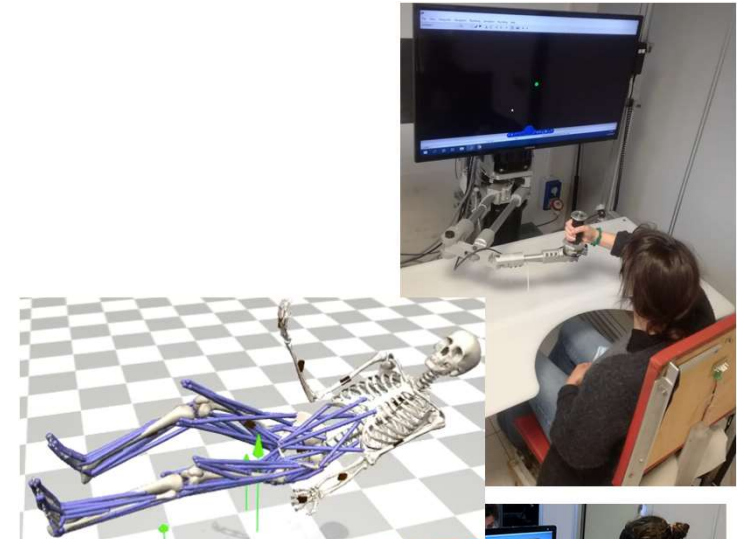
Services

- Movement analysis and biomechanical assessment for clinical, sports applications
- Assessment of sensory, motor and cognitive functions (incl. interaction, decision, memory)
- Wearable devices and mobile solutions for personalised medicine
- Simulators for medical training
- Assessment of performance and efficacy of medical devices

Motion Capture System (VICON)

6x IR Cameras: 330Hz @2.2MP
1xColor camera
Synchronization with other devices
Nexus 2 software
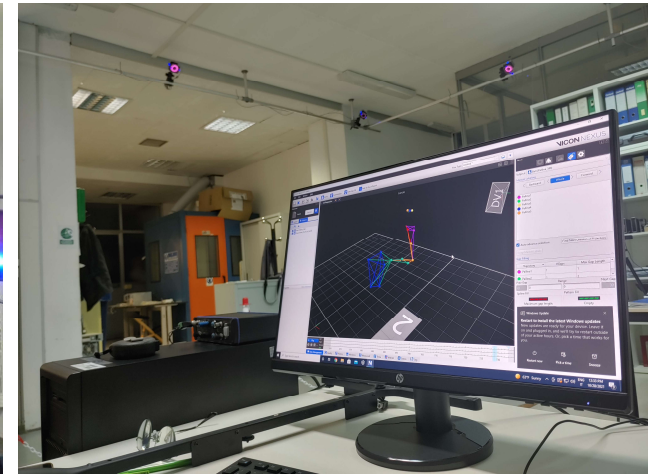
- Movement analysis in humans and robots
- Characterisation of human sensorimotor functions
- Functional assessment in persons with neuromotor impairment
- Performance optimisation and injury prevention in sports
- Workplace ergonomy
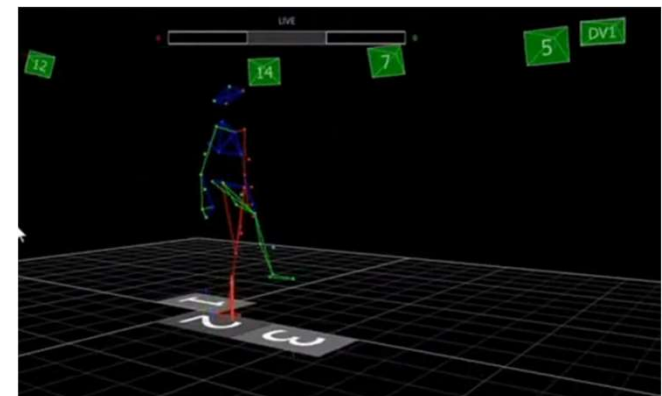
Dyadic haptic interface (H-Man/Articares)

Cartesian haptic manipulandum
Workspace: 30 x 30 cm
Maximum force: >20 N
Max stiffness: 1000 N/m
Weight <20 kg

- Experimental apparatus to investigate the mechanisms of human-human interaction (joint action)
  - Basis for design of collaborative robots
  - Assessment of interaction capabilities (eg autism, schizophrenia)
- <5 worldwide
- The two robots can be used separately, for instance in rehabilitation applications
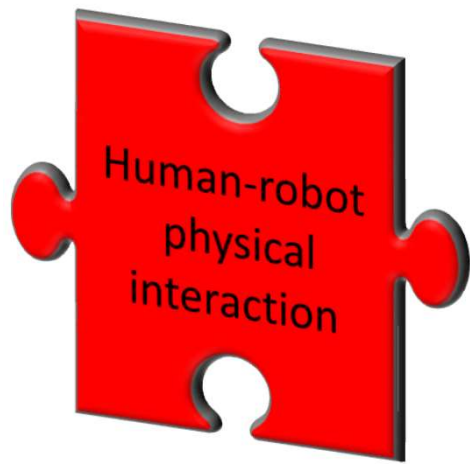
Human-Robot Physical Interaction

Goal technologies for next generations of collaborative robots capable of **safe** and **smooth** adaptation to humans and objects for:

Assistance

Collaboration

Touching robots is the paradigm based on interactive robots and machine augmentation for the inclusion in the social and work environment of the ageing population, reduced working capacity operators, or simply weaker people, in order to limit the effects of diversity (age, force, weight, reduced capability, etc.) on physical work activity, improving and enabling a wider inclusion.

Robots touching is the paradigm based on interactive robots required to engage safe collaboration with humans in collaborative and cooperative operations.

Side view

End Effector

Top view

Wrist

Forearm

Elbow

Arm

Stand/Shoulder

Front of the trunk
Shoulder
Arm
Elbow
Forearm
Back of the trunk
Hip
Leg

(b)

Conceptual Sketch

Medical

Industrial

Human-Robot Physical Interaction: technology

Sequence of motion primitives

Control

Tactile Sensing

Proximity Sensing

Panda robotic system (Franka Emika GmbH)
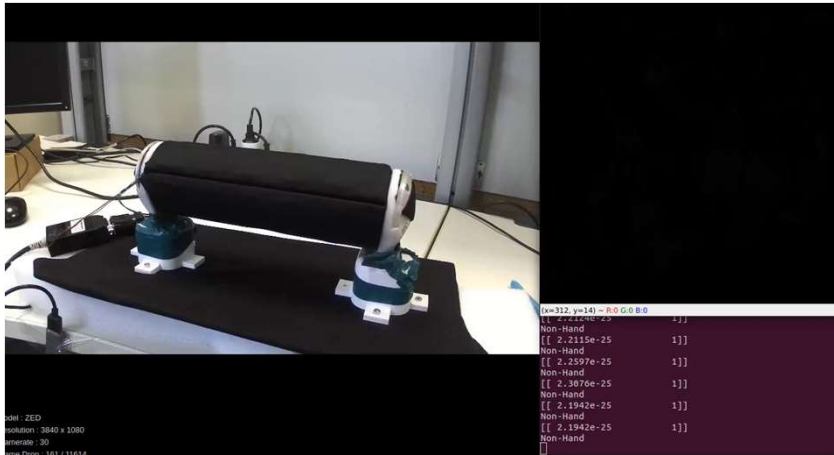
Human touch recognition and segmentation

Sensor based impedance control

Human-robot physical interaction

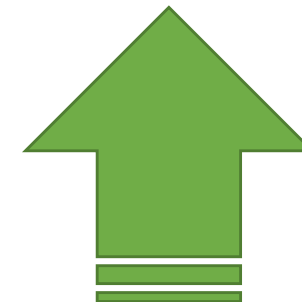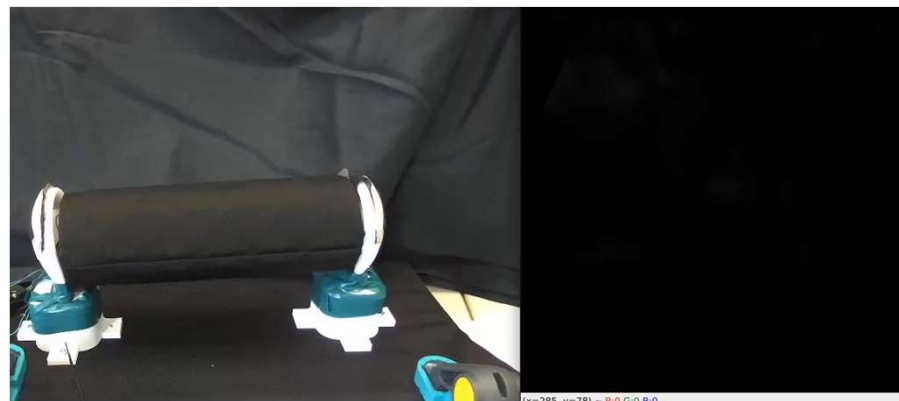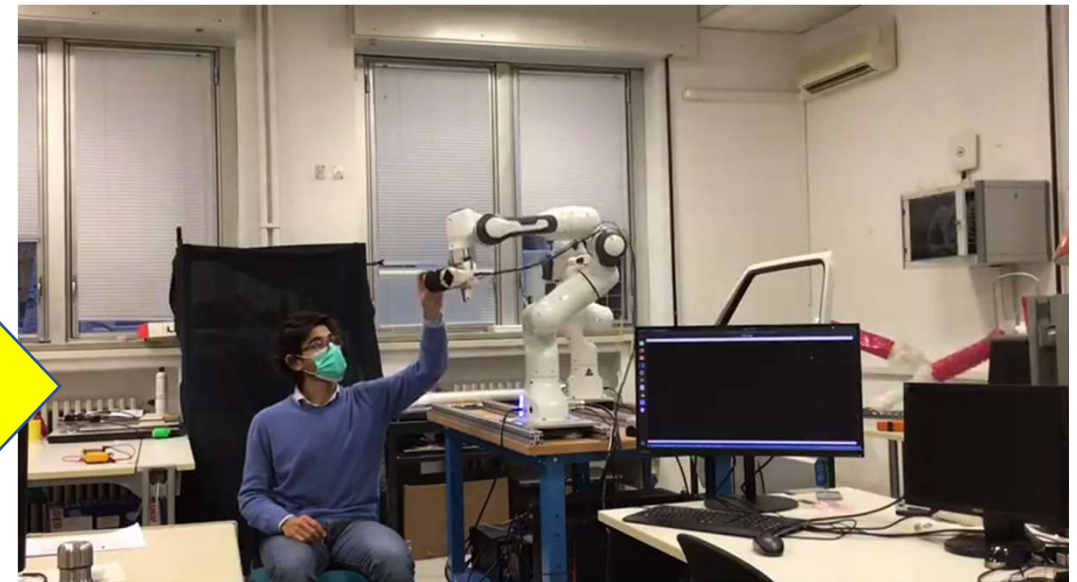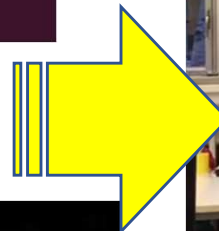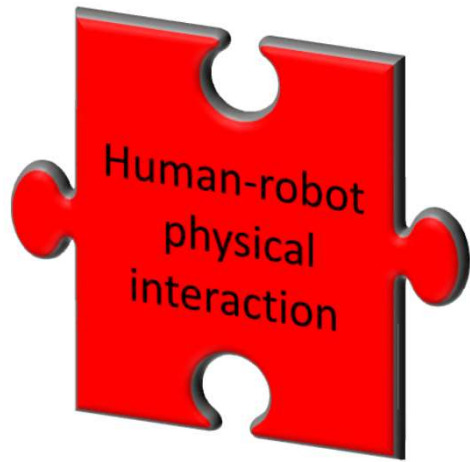- Technologies for collaborative robots capable of safe and smooth adaptation to humans and objects for **assistance** and **collaboration**
- *touching robots*
- *robots touching*

Equipment/instruments

- 2 robot **Franka-Emika**
- 1 robot umanoide BAXTER
- Development and test set-up for tactile sensors
- Development systems for mechatronic systems

Services

- Control of robot manipulators
- Control of Human-Robot interaction
- Control architectures for robots
- Tactile sensor technologies (hw/sw)
- Mechatronics
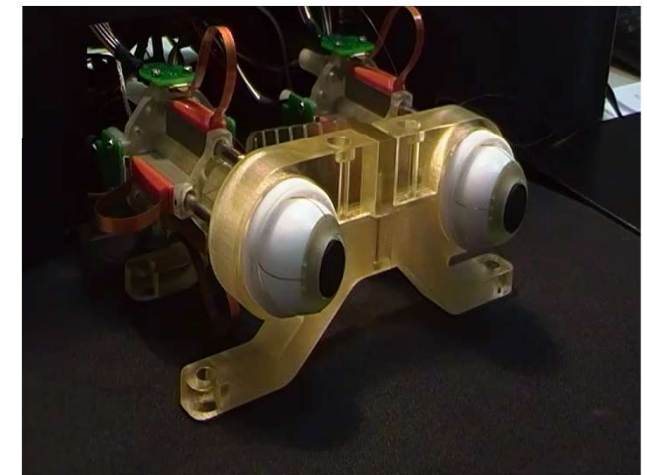
Human-robot social interaction

- Fully autonomous social robots featuring
  - Different perceptual and motor capabilities
  - Size
  - Cost

- for
  - **Social/Health assistance** for home/hospice care of elderly people;
  - Communication with **people in lockdown**;
  - **Reception** for visitors and clients (hotels, resaurants, malls, public offices etc.);
  - **Education**.

Real world target applications

Solutions

Cloud based system CAIR (Culturally Aware Interactive Robot) for

- **Verbal interaction Interazione verbale** for continuous and general dialogue (on several topics) with people including also multiparty interaction;
- **Planning execution and monitoring** of actions;
- Human-robot and robot-robot interaction based on «**trust metrics**»;
- *Affective interaction* for emotion identification and synthesis;
- *Culturally-competent interaction* to adapt the robot behavior to the cultural background of the human.

Equipment/instruments

- ## Cloud CAIR clients for
  - Pepper (SoftBank Robotics, **available**)
  - NAO (SoftBank Robotics, **available**)
  - Prof. Einstein (Hanson Robotics, **available**)
  - **<u>Tiago</u>** (PAL robotics, **under development**)
  - DJI Mavic (DJI, **under development**)
  - SPOT (Boston Dynamics, **under development**)
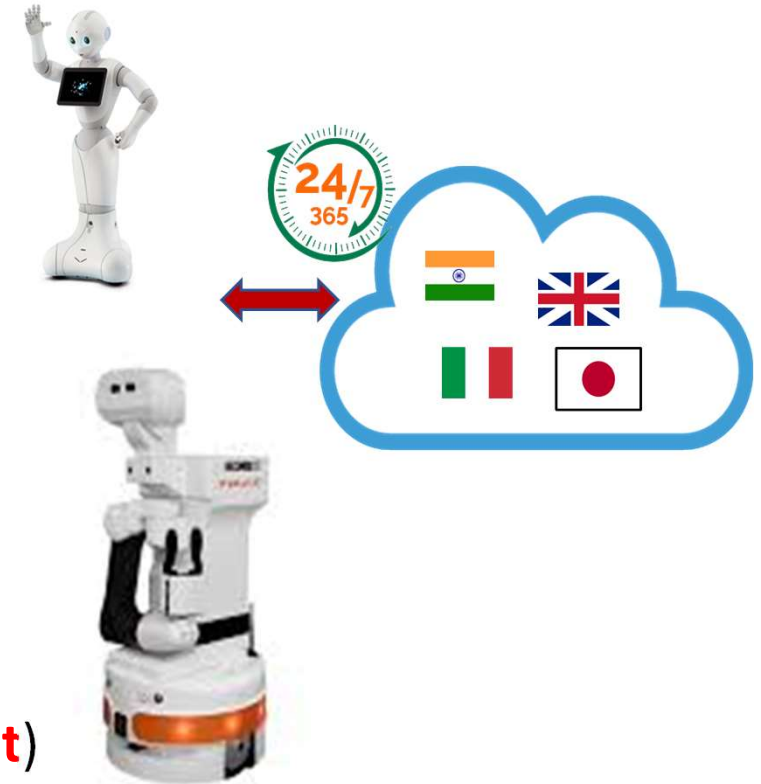
Services

Solutions to Cloud interface for:
  ROS (Willow Garage, **available**);
  APIs for custom applications (**available**).
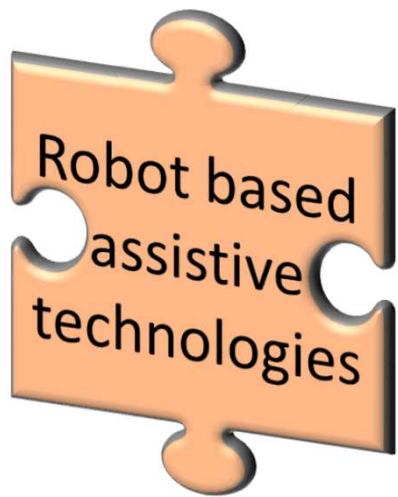
A knowledge-based approach towards Human Activity Recognition in Smart Environments

1/ It is estimated that approximately 20% of the world's population will be of age 60 or older by 2050.

2/ Need to provide - at home - healthcare services for the older people, such that they can live safely and independently for longer periods of time. These services would rely on human activity recognition.

3/ In general, HAR can enable companion-robots/digital-assistants in smart homes to provide contextually relevant and proactive support to the home users.
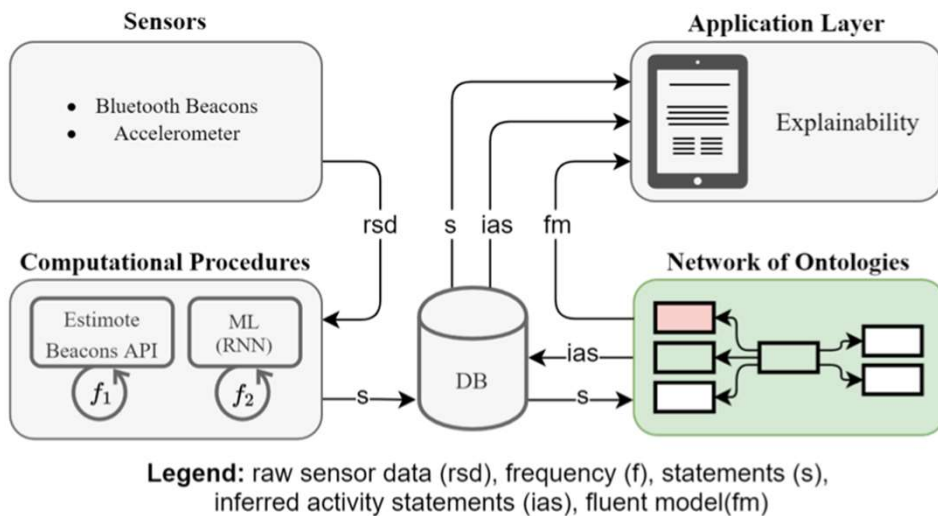
Robot based assistive technologies

Sensors
- Bluetooth Beacons
- Accelerometer

Application Layer
Explainability

Computational Procedures
Estimote Beacons API f_1

ML (RNN) f_2

DB

Network of Ontologies

rsd   s   ias   fm

—ias—

—s—

—s—

Legend: raw sensor data (rsd), frequency (f), statements (s), inferred activity statements (ias), fluent model(fm)

Università di Genova — DIBRIS DIPARTIMENTO DI INFORMATICA, BIOINGEGNERIA, ROBOTICA E INGEGNERIA DEI SISTEMI

A knowledge-based approach towards Human Activity Recognition in Smart Environments

PhD Student: Syed Yusha Kareem
Supervisor: Fulvio Mastrogiovanni

Trigger Recommendations for Elderly With a Contextualized Phrasebook
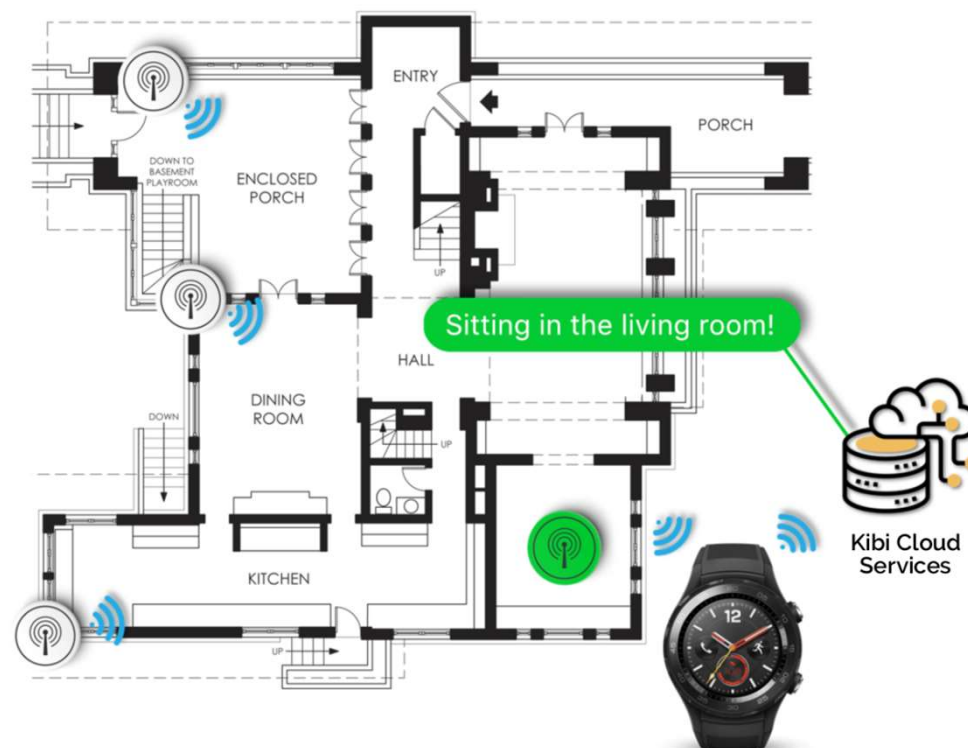
Objective

Start a verbal interaction for persuading an elderly person to maintain an healthy lifestyle (based on ADL)

Scenario

A smart environment able to reason on the topological position of the habitats

Contribution

A contextualized phrasebook to trigger the interaction through a query engine

Robot based assistive technologies
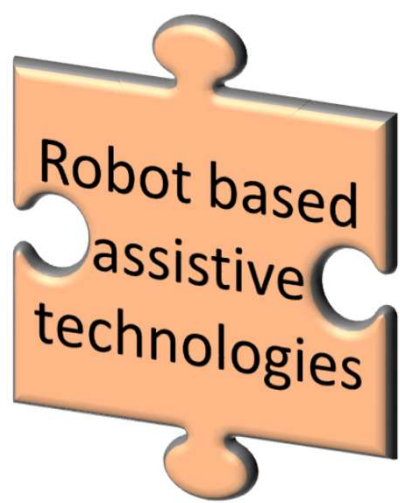
Equipment/instruments

- Motion capture **VICON**
- Inertial motion measurement units (**Xsens**)
- Wearable motion detection devices

Services

- Applications for healthcare to monitor elderly people at home or hospice
- Other engineering services provided by TESEO s.r.l.

Addestramento e formazione

- Laurea in Ingegneria Biomedica
  500 studenti (~25% fuori regione)
- Laurea Magistrale in *Bioengineering*
  120 studenti (~35% fuori regione)
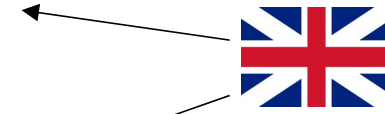- Laurea Magistrale in *Robotics Engineering*
  70 studenti (30 internazionali: European Master in Advanced Robotics (EMARO+))

- dal 2022: Master in Medical Technology and Digital Health
  40 studenti del corso di Laurea in Medicina e Chirurgia

- Dottorato di Ricerca in Bioengineering and Robotics
  - 10 borse/anno

La rete: istituti di ricerca
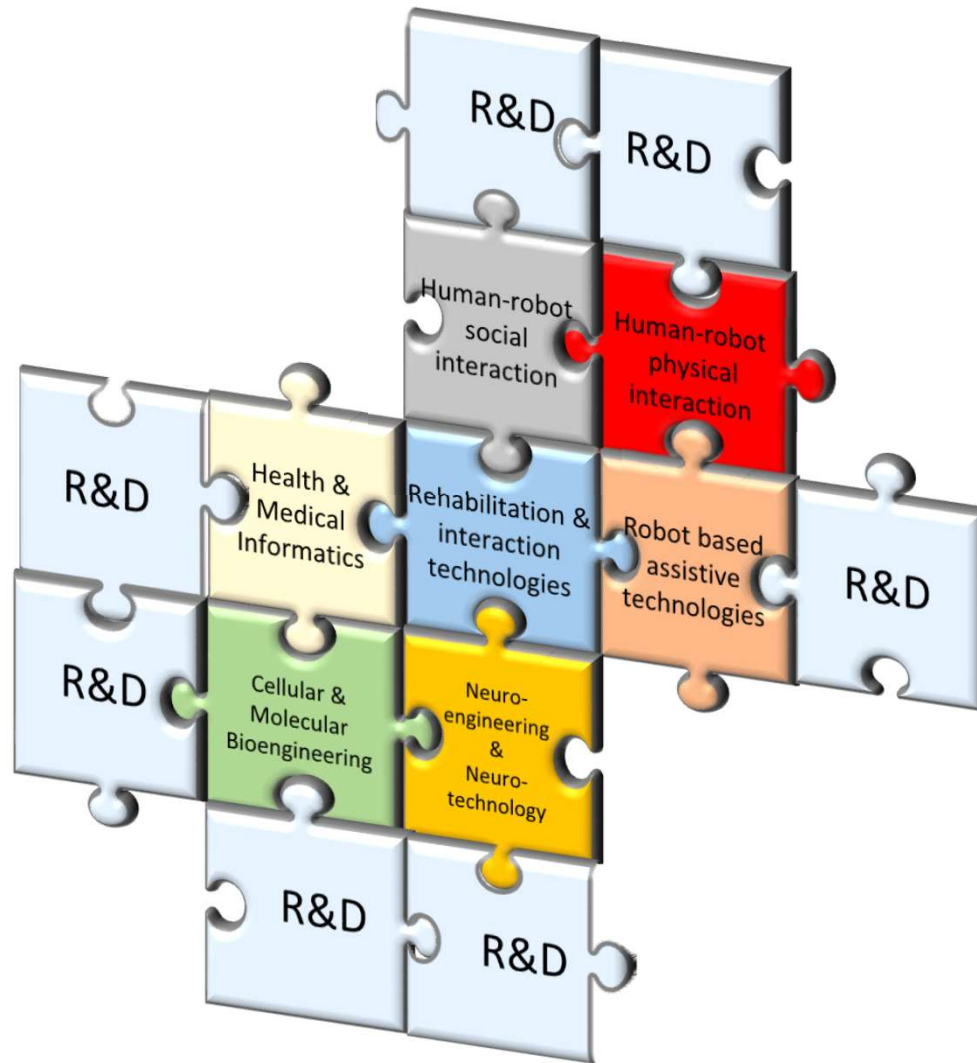
Accordi/convenzioni

- IIT
- CNR –IBF -IMEM – IIET
- Fondazione Bruno Kessel
- University College London
- Queen Mary University
- King's College London
- Kazan Federal University
- Ecole Polytechnique Fédérale de Lausanne
- Neuroscience Center, University of Helsinki
- Universitatsklinikum Wurzburg
- Imperial College of Engineering and Medicine, London
- McGill University, Montreal
- Northwestern University
- Rehabilitation Institute of Chicago
- Osaka University
- Technological University of Singapore
- Tokyo Institute of Technology
- Hiroshima University
- Michigan State University
- Gannon University

La rete: industria
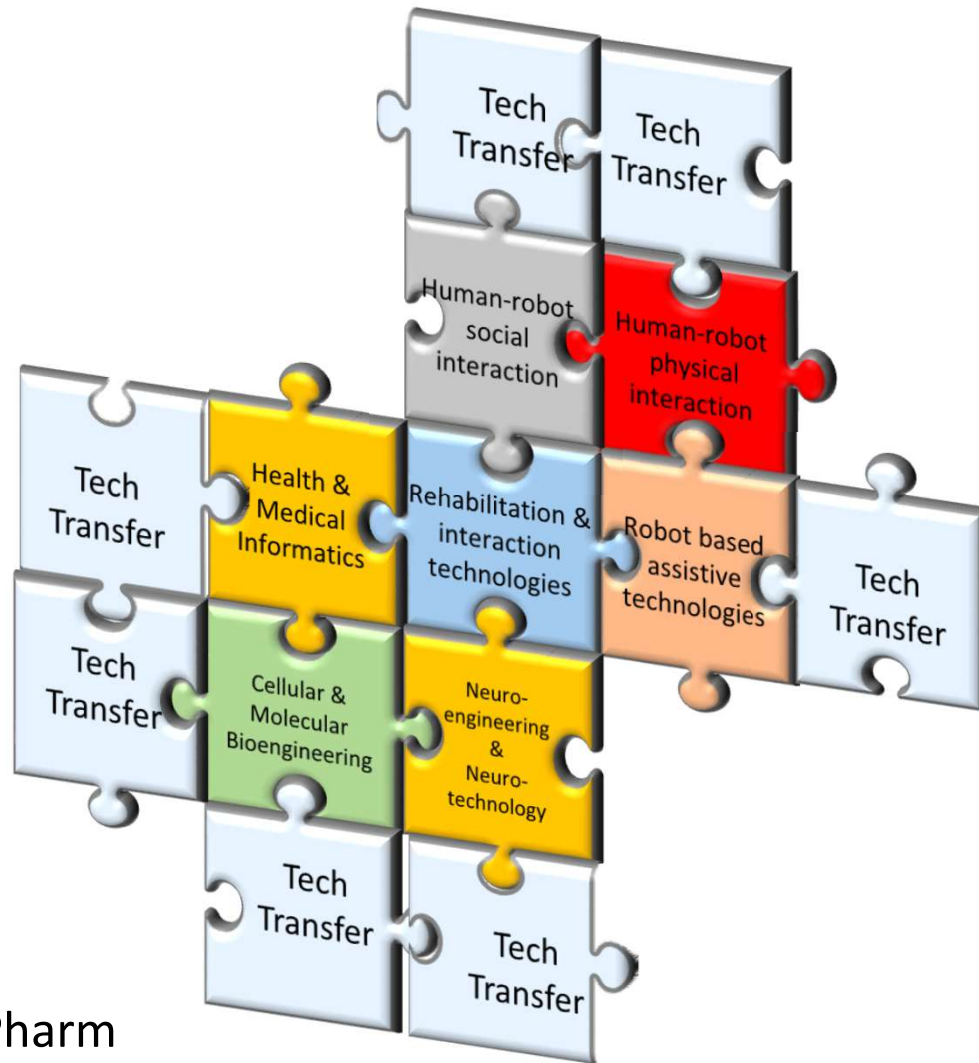
Spin off

- Bio3DmatriX
- ScreenNeuroPharm
- Healthropy
- Germina
- Teseo

Contratti/consulenze

- MOVENDO s.r.l. (Genova, Italia)
- ILLO s.r.l (Genova, Italia)
- SWHARD (Genova, Italia)
- Singular Perception (Genova, Italia)
- 3Brain AG (Switzerland)
- ETT Spa (Genova, Italy)
- Sitem srl (Genova, Italy)
- Centro Ricerche FIAT (Torino, Italy)
- Fincantieri (Trieste, Italy)
- CETENA (Genova, Italy)
- Tahles Alenia Space (Torino, Italy)
- LEONARDO (Genova, Italy)
- GraalTech (Genova, Italy)
- COMAU Robotics (Torino, Italy)
- Genova Robot s.r.l. (Genova, Italy)
- Humana Vox srl (Genova, Italy)
- ...

Sviluppo della rete

Obiettivo strategico: fare rete con strutture sanitarie

Laboratori congiunti/convenzioni esistenti

- laboratorio congiunto con IRCCS Istituto Giannina Gaslini
  - Laboratorio di imaging funzionale a 3 Tesla (LIFT): diagnostica delle patologie del sistema nervoso centrale e periferico nell'età pediatrica
- laboratorio congiunto con Ospedale Santa Corona di Pietra Ligure
  - The Italian Spinal Cord Laboratory (S.C.I.L.): sviluppo di sistemi per riabilitazione ed assistenza di pazienti con lesioni del midollo spnale
- Convenzione con Fondazione Maugeri IRCCS: Bioingegneria per la riabilitazione

on going

- laboratorio congiunto con Policlinico San Martino IRCCS advanced medical diagnositcs (2022)
- laboratorio congiunto con DINOGMI, DISSAL e CNR-IMATI: computational neurology (2022)

Sviluppo della rete

Obiettivo strategico: fare rete con PMI e centri di eccellenza

Laboratori congiunti/convenzioni esistenti

- laboratorio congiunto con "Centro di servizio di Ateneo di simulazione e formazione avanzata" (SIMAV)

    Joint lab for Emerging Technologies in Simulation (JETS): hardware and software technologies applied to medical simulation

- laboratorio congiunto con 3Brain: sviluppo di sistemi per elettrofsiologia *in vitro*
- laboratorio congiunto con NextStage: tecnologie per telemonitoraggio in ambito clinico e teleriabilitazione
- The Israeli-Italian Virtual Lab on Artificial Somatosensation for Humans and Humanoids (Artouch-lab): Measuring and modeling sensory-motor performance during interactions and manipulation tasks for humans and humanoids
- Convenzione con Humana Vox: tecnologie per la riabilitazione e l'assistenza socio-sanitaria