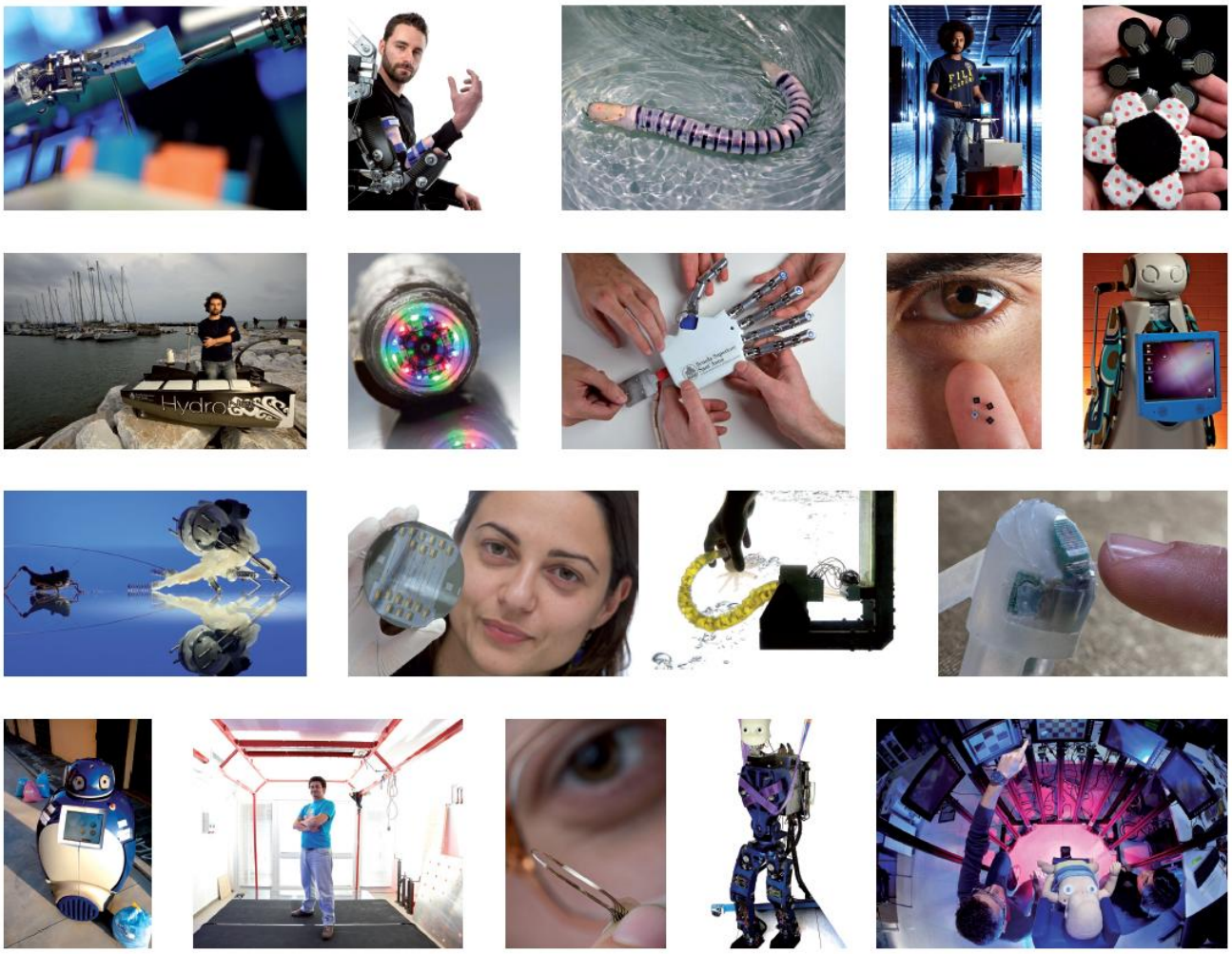
the BioRobotics Institute



Scuola Superiore Sant'Anna

di Studi Universitari e Perfezionamento

BioRobotics: quest for fundamental understanding (**science**) and consideration of use (**engineering**)

BioRobotics Science: using robotics to **discover new principles**

BioRobotics Engineering: using robotics to **invent new solutions**

The BioRobotics Institute

"The mission of the BioRobotics Institute is educating the Engineer of the 21st Century, a competent, interdisciplinary, creative inventor and entrepreneur, able to manage new technological and scientific challenges, ready to take up new opportunities for society and industry, and acting as a linking bridge towards centres of knowledge worldwide."

Prof. Paolo Dario,
Director of the BioRobotics Institute

Institute Annual Meeting - Volterra, 2016

Advanced education, **frontier research** and **exploitation of research results**: this is the BioRobotics Institute, one of the six Institutes of Sant'Anna School of Advanced Studies.
The BioRobotics Institute was born in 2011 and wants to act as a linking bridge among international centres of knowledge and to create a new concept of engineers that are scientists, inventors, entrepreneurs, able to invent and solve problems.
The BioRobotics Institute has built and consolidated a vast wealth of knowledge and expertise in the fields of **surgical-, bio-inspired-, service-, industrial- and neuro-robotics, neural and rehabilitation engineering and their ethical, legal, social and economic implications.**
Currently, The BioRobotics Institute ranks first among all Engineering Department in Italy (on the basis of data published by **ANVUR – National Agency for the Evaluation of University and Research**).
The mission of the BioRobotics Institute is based on three pillars:

- **Education**, which includes all levels of training: PhD program, Master Science in Bionics Engineering, other courses offered by the faculty members of the BioRobotics Institute;

- **Research**, organized in: research area, laboratories, joint laboratories;
- **Technology Transfer**, which promotes the foundation of start-up companies, the Intellectual property protection and management, the ability to invent and deposit patents, the acquisition of third-party contracts by industry.

The headquarter of the BioRobotics Institute is located at the **Polo Sant'Anna Valdera (PSV)** established by Sant'Anna School of Advanced Studies as a research park in the industrial city of Pontedera (15 minutes by train from Pisa and 45 minutes by train from Florence), with a surface of 6,300 mq. The BioRobotics Institute has other facilities in Tuscany dedicated to research activities: **Service robotics and ambient assisted living Laboratory** (Peccioli – Pisa); **Industrial biorobotics Laboratory** (Collesalvetti – Livorno); **Research Centre on sea technologies and marine robotics** (Livorno). The Polo Sant'Anna Valdera hosts on its premises one of the centres of the Italian Institute of Technology (**Centre for Micro-BioRobotics IIT@SSSA**).

Entrance of BioRobotics Institute

The BioRobotics Institute has a dense network of collaborations in Italy, Europe and worldwide with the most important research institutes, universities and industrial representatives due to the many collaborative projects and initiatives. Each year, the BioRobotics Institute welcomes a large number of international visiting researchers, faculty and lecturers and organizes international events and meetings. At present the BioRobotics Institute includes over 200 people (17 faculty members, 75 Post docs, more than 90 PhD students, technical and administrative assistants, research fellows, and a variable number of master students and visiting researchers - around 30), it is involved, as the coordinator or as a partner, in more than **65 international and national research projects**, including one funded by European Research Council, and it spun out **25 start-up companies**.

Education

The education of the BioRobotics Institute includes the **PhD program in BioRobotics**, the **Master Science in Bionics Engineering** (started in 2015 and a limited enrolment), and **other courses** offered by the faculty members of the BioRobotics Institute.

With the goal of providing **graduate students** with the knowledge, experience, and skills to become leaders in robotics research and education, the BioRobotics Institute offers diverse opportunities at all levels of education, in order to inspire and educate the next generation of **roboticists** and **bioengineers**. At the BioRobotics Institute, education involves a process starting from children up to PhD students. In this framework, the Institute has set up a regional network on Educational Robotics developing training courses for teachers and new tools that enable primary, secondary and high school students to expand upon their interest in robots.

PhD program in BioRobotics

The PhD program in BioRobotics is a three-year course of advanced studies and supervised research. Students are admitted following a successful entrance examination and, at the end of the program, the PhD degree is conferred to students who have fulfilled the requirements and passed a final examination with thesis dissertation.

The PhD in BioRobotics aims at educating highly competent researchers with the potential to be leaders in this area. The students are educated in a stimulating and multidisciplinary environment, creative and original research work.

Doctoral research projects are carried out in very well equipped, state of- the-art laboratories (in such fields as **biorobotics**, **micro** and **nanotechnology**, **biomimetics**, **prosthetics**) and through

individual and team work performed under the supervision of a committed full-time faculty. The students investigate how biological systems work from an engineering viewpoint, and make use of such knowledge to pursue challenging research projects aimed at modeling, designing and building novel components and systems for biomedical applications. At the end of the PhD program, students will possess solid scientific and engineering skills, the ability to conceive and carry out original research projects, and an autonomous entrepreneurship spirit.

Master of Science in Bionics Engineering

The Master of Science in Bionics Engineering aims at educating highly qualified students in the fields of medicine, biology, neuroscience, rehabilitation and surgery. Bionics indicates the research area which integrates the most advanced robotics and bioengineering technologies with life sciences, with the ultimate goal of inventing and deploying a **new generation of biomimetic machines, human-centred healthcare and assistive technologies**.

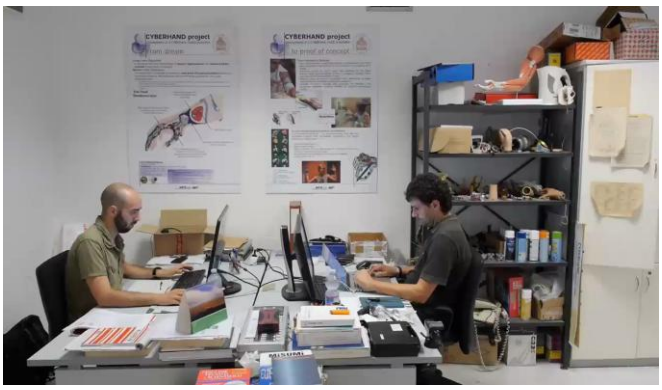
The Master of Science is jointly managed with the Department of Information Engineering of University of Pisa. It is characterized by a limited enrolment (20 students). The program started in the Academic Year 2015-2016 (September 2015) and is offered in English. Students are admitted to the program following a successful entrance examination. Candidates must hold a Bachelor of Science (B.Sc.) in an engineering discipline or any equivalent diploma.

Other courses offered by the faculty members of the BioRobotics Institute

The Faculty of the Institute offers courses in several disciplines related to **medical robotics**, **rehabilitation robotics**, **neural engineering**, **biomechatronics, soft robotics**, to Honor students of the Sant'Anna School of Advanced Studies, and undergraduate students of Biomedical Engineering at the University of Pisa.

Photo credit: Hauke Seyfarth

Research



Research's Lab

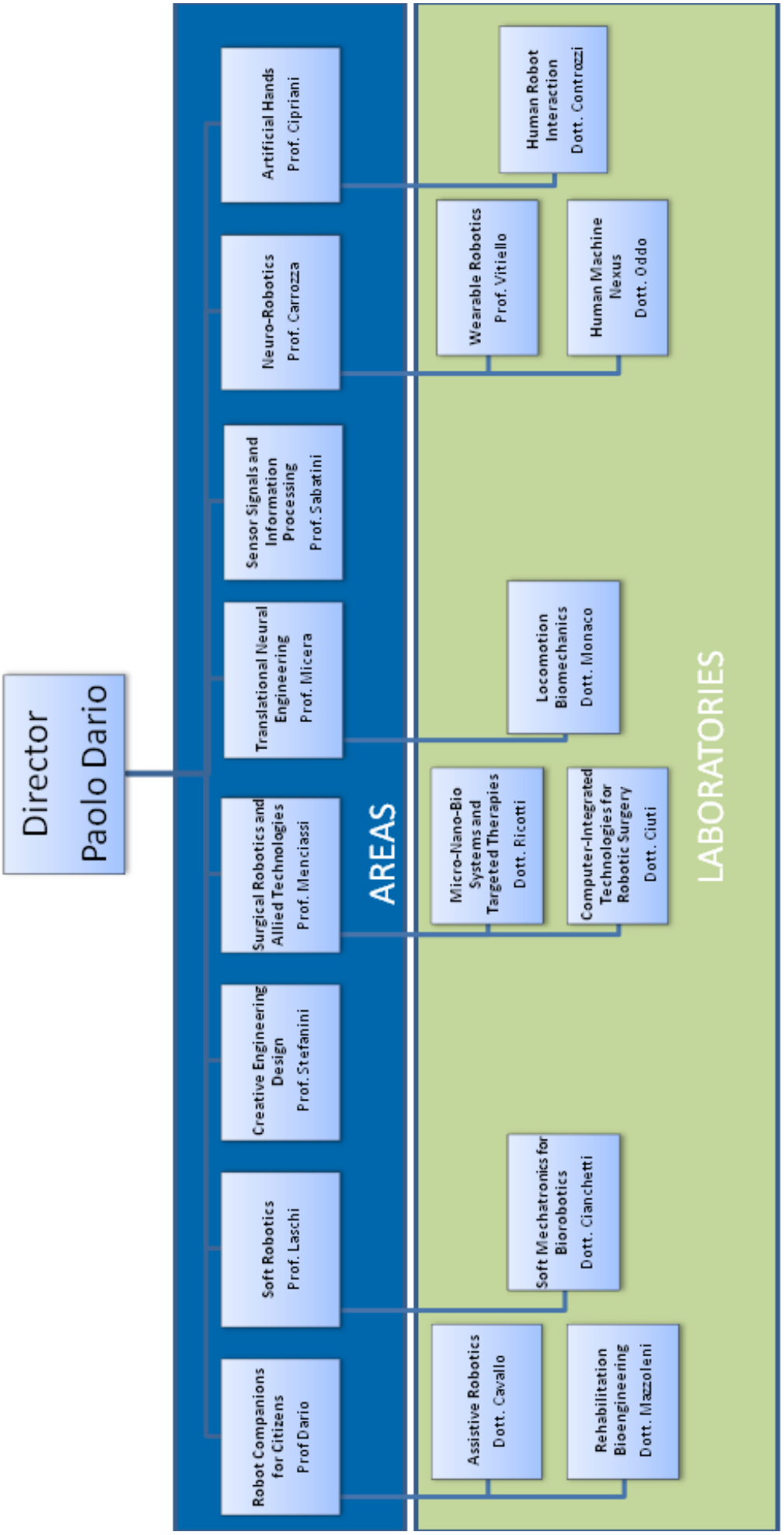
Research at the BioRobotics Institute

Biorobotics is an emerging scientific-technological area which merges robotics and biomedical engineering; in particular it is the science and the technology of the design and development of bioinspired robotics systems with biomedical application. While maintaining a unique vision on this topic, the research at the BioRobotics Institute is articulated in **Areas and Laboratories**. Research Areas are led (PI) by Professors or Associate Professors, while the Research Labs are coordinated by Assistant Professors.

Areas and Labs are:

- **Robot Companions for Citizens**, Paolo Dario (includes the **Service Robotics and Ambient Assisted Living Lab**, led by Filippo Cavallo, and the **Rehabilitation Bioengineering Lab** led by Stefano Mazzoleni).
- **Soft Robotics**, Cecilia Laschi (includes the **Soft Mechatronics Technologies Lab**, Matteo Cianchetti).
- **Creative Engineering Design**, Cesare Stefanini.
- Surgical Robotics and Allied Technologies, Arianna Menciassi (includes the **Computer-Integrated Technologies for Robotic Surgery Lab**, Gastone Ciuti, and the **Micro-nano-biosystems and targeted therapies Lab**, Leonardo Ricotti).
- **Translational Neural Engineering**, Silvestro Micera (includes the **Locomotion Biomechanics Lab**, Vito Monaco).
- **Sensor Signals and Information Processing**, Angelo Maria Sabatini.
- **Neuro-Robotics**, Maria Chiara Carrozza (includes the **Wearable Robotics Lab**, Nicola Vitiello and the **Human-Machine Nexus Lab**, Calogero Oddo).
- **Artificial Hands**, Christian Cipriani (includes the **Human-Robot Interaction Lab**, Marco Controzzi).

Research Areas are not static. New Areas can be established when they reach critical mass of funds, people and research activities. Conversely Areas or Labs can be closed. The priorities of research are: **quality scientific production**; **the impact on social life**; **technology transfer**.


Director
Paolo Dario
AREAS
Robot Companions for Citizens
Prof Dario
Soft Robotics
Prof. Laschi
Creative Engineering Design
Prof. Stefanini
Surgical Robotics and Allied Technologies
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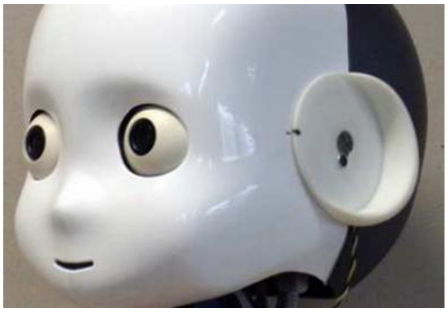
LABORATORIES
Assistive Robotics
Dott. Cavallo
Rehabilitation Bioengineering
Dott. Mazzoleni
Soft Mechatronics for Biorobotics
Dott. Cianchetti
Micro-Nano-Bio Systems and Targeted Therapies
Dott. Ricotti
Computer-Integrated Technologies for Robotic Surgery
Dott. Ciuti
Locomotion Biomechanics
Dott. Monaco
Wearable Robotics
Prof. Vitiello
Human Machine Nexus
Dott. Oddo
Human Robot Interaction
Dott. Controzzi

Robot Companions for Citizens Area



Major scientific and engineering breakthroughs are needed to develop high performance, complex artificial systems, like robots, as Companions that are safe, social, dependable, sustainable and skilled, literally going beyond the current mechatronics paradigm. Nature can be an extraordinarily rich and matchless reference for inspiring, conceiving and designing novel robotic systems. The aim of this research area is to develop a **new generation of assistive robot companions**, underpinning technologies and bionic solutions to help citizens of all ages, from infants to elderly, and in different scenarios (in the factory, at home, in farms or in marine scenarios), that are characterized by an extremely **high efficiency**, **robust behaviour in unstructured environments**, **low cost and novel design for acceptability**. The use of robotics as a method to increase the quality of scientific and technical education in school and the ethical, legal, social and economic issues are also investigated.
This new generation of robot Companions fully integrated in the society requires the mobilization of multidisciplinary scientific and technological excellence, the building of dedicated robotics research infrastructures, and the study of ethical, legal, social and economic implications.
The research area focus mainly on the fields of: **Neurodevelopmental BioEngineering**, **Marine Robotics**, **Ethical, Legal, Social and Economic Issues of Robotics**, **Humanoid Robotics** and **Educational Robotics**.

The scientific responsible is prof. Paolo Dario.

Polo Sant'Anna Valdera (PSV)
Viale Rinaldo Piaggio, 34 – 56025 – Pontedera, Pisa

Neurodevelopmental BioEngineering

Neurodevelopmental engineering is an interdisciplinary research area at the intersection of developmental neuroscience and biomedical engineering, mainly concerned with quantitative analysis and modeling of human behaviour during neural development. The aim of this research is the **development of novel mechatronic devices for ecological, unobtrusive assessment of infant development**.
These tools could help in assessing motor impoverishment or sensitivity to therapy, but also experimenting new therapeutic interventions.

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Marine Robotics

Research activities in the field of marine robotics are carried out at the **Research Centre on Sea Technologies and Marine Robotics**.

The laboratory is located in Livorno and it is specialized for the design, development and validation of new technologies and robotic systems for marine application.

In particular, research in marine robotics is conducted on: surface and underwater autonomous systems; underwater manipulator control and environmental sensors; bioinspired aquatic robots; novel concepts of soft marine robots.

Research Centre on Sea Technologies and Marine Robotics
Viale Italia 6 - 57126 – Livorno

Ethical, Legal, Social and Economic Issues of Robotics

The ethical, legal, social and economic issues (**ELSi**) of robotics have been a concern since the start of research activities at the BioRobotics Institute.

In 2004, together with Kazuo Tanie and Ron Arkin, Paolo Dario founded the **Technical Committee on Roboethics of the IEEE Robotics and Automation Society**, bringing ethics in the heart of the international community of robotics. Since then, the Institute has organised many national and international events on ELSi, for both academics and laypeople, in collaboration with scientists, philosophers, theologians, sociologists, lawyers, economists, and artists. Currently, research on ELSi is carried out in the framework of two EU funded projects, Robot-Era and RoboLaw.

The objective of this research area is to study the ethical implications raised by robotics in research and applications, including social, legal, economic and anthropological issues. Some of the research topics of interests are: **robotics and employment**; **robot market and insurance**, **legal status of robots**; **acceptance of social robots**.

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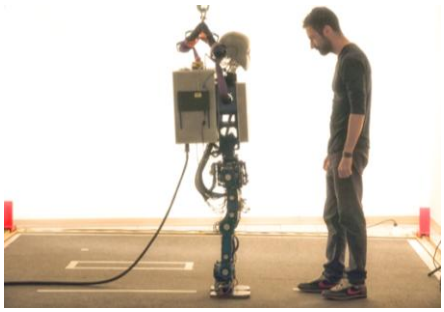
Humanoid Robotics



The main objective of the humanoid robotics is the study and the robotic implementation of **neuroscientific models** of sensory-motor coordination on **humanoid platform**. This has a twofold benefit: improving the performances of the robotic platform interacting with the real world and validating the neuroscientific models through a comparison between robot and biological system performances. In particular the research focuses on the implementation of models of gaze control, sensory-motor anticipation, adaptive controllers based on neural networks and stabilization mechanisms for the biped locomotion.

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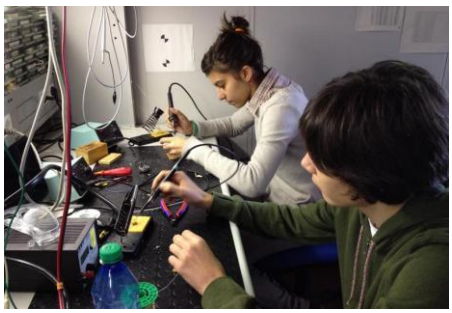
Educational Robotics



Educational Robotics consists in the use of robots as a channel for teaching and education.
Despite being appropriate for teaching science, math and technology (**STEM** subjects: Science, Technology, Engineering and Mathematics), it has also many connections with other school subjects such as literature, arts and theatre thus becoming a new educational paradigm called **STEAM** (**Science, Technology, Engineering, Arts and Mathematics**).
Robotics is extremely motivating: learning with robots increases children engagement and a student-centred learning approach. It develops a problem-solving attitude, foster a trans-disciplinary approach and encourage team work. Research in this field is focused on the study of the methodology for implementing Educational Robotics in schools and on the measurements of its effects on students' learning.

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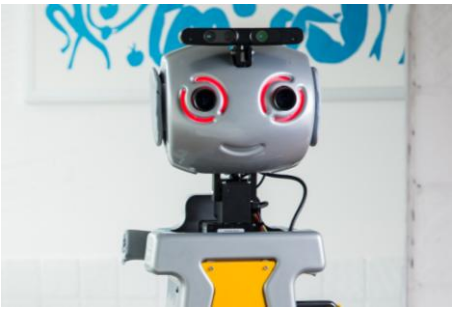
Assistive Robotics Laboratory



The aim of the Assistive Robotics Lab is to design and develop **ICT** and **robotics solutions** to provide support and assistance to citizens in daily life activities. Particularly the studies carried out in the Active and Assisted Living field aims to integrate robotics, internet, cloud, mobile and electronic technologies for applications, such as healthcare, agriculture, logistic and manufacture. The main scientific challenges to enhance the abilities and capabilities of robotic systems revolve around the physical and cognitive human robot interaction, the integration in intelligent environments and the dependable design.

The scientific responsible is Filippo Cavallo.

Service Robotics and Ambient Assisted Living
Via Boccioni, 1 – 56037 – Peccioli, Pisa

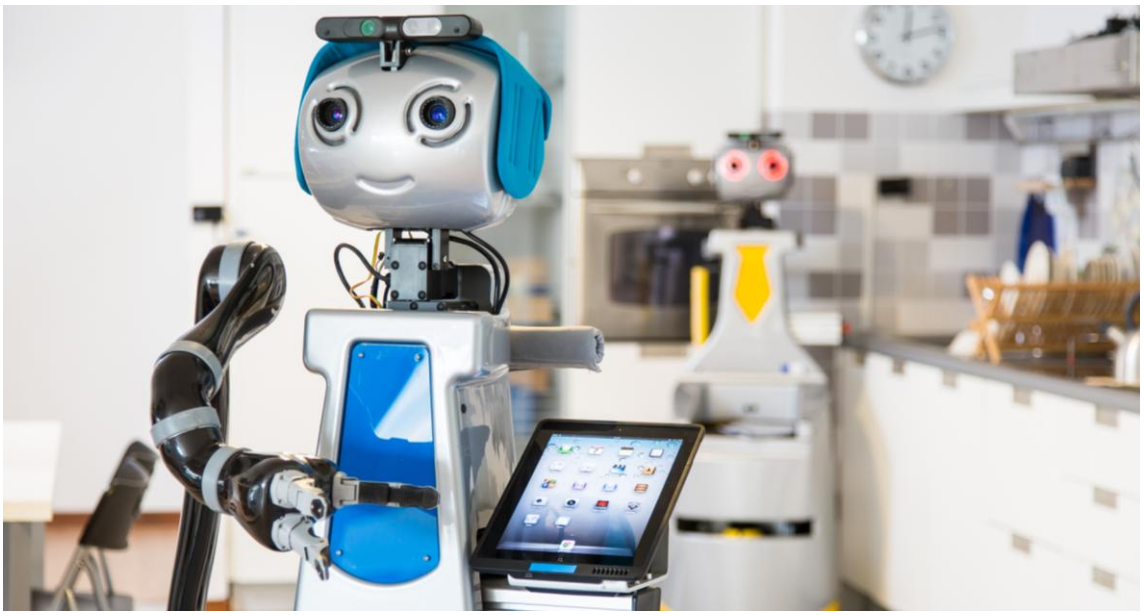
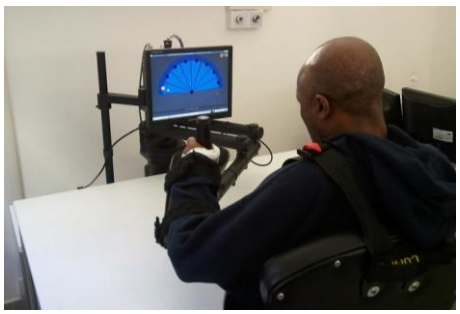


Photo credit: Hauke Seyfarth

Laboratory of Rehabilitation Bioengineering



The main mission of Laboratory of Rehabilitation Engineering is to design, develop and validate innovative technologies for neurological, musculo-skeletal and cardio-pulmonary rehabilitation through a daily collaboration between bioengineers and healthcare professionals.

Ongoing research activities include Robot-assisted neurorehabilitation; Assistive robotics; Telerehabilitation and telemonitoring applications for cardio-pulmonary rehabilitation; Analysis of patient-ventilator interaction; Analysis of athletes ventilatory response to exercise; Upper limb and locomotion functional assessment.

The scientific responsible is Stefano Mazzoleni.

Auxilium Vitae
Borgo San Lazzaro, 5 – 56048 – Volterra, Pisa

Auxilium Vitae

Soft Robotics Area

Soft Robotics Octopus - Photo credit: Jennie Hills, London Science Museum

The growing need for robots in service tasks, in unstructured environments, in contact with humans, is leading to release the basic assumption of rigid parts in robotics.
The role of soft body parts to increase adaptability and robustness appears clear in natural organisms. Compliance, or softness, are also needed for implementing the principles of embodied intelligence, or morphological computation, a modern view of intelligence, attributing a stronger role to the physical body and its interaction with the environment.
Soft robotics is an interdisciplinary field in robotics that deals with robots built out of soft and deformable materials capable to actively and safely interact with humans and the environment. Soft robotics is not just a new direction of technological development, but a **novel approach to robotics**, unhinging its fundamentals, with the potential to produce a new generation of robots, in the support of humans in our natural environments.

The scientific responsible is prof. Cecilia Laschi.

Polo Sant'Anna Valdera (PSV)
Viale Rinaldo Piaggio, 34 – 56025 – Pontedera, Pisa

Photo credit: Massimo Brega

Soft Mechatronics for Biorobotics Laboratory

Soft, elastic and deformable systems with variable stiffness are key factors for safe and effective interactions with physical unknown environments, opening to robots a wide range of application possibilities.

Soft robotics can show all its potentiality only if all the components of the system are contextually taken into consideration, going beyond even the biomechatronic approach in terms of integrated design.

Several efforts have been focused on the development of new sensors, actuators, batteries and mechanisms that are based on **soft, flexible or variable stiffness technologies**, but the most has yet to be done.

In particular, actuators represent the real bottle neck, but in the last few years new and promising soft mechatronics technologies are emerging thus offering new possibilities to fill the gap between natural and artificial muscles.

The scientific responsible is Matteo Cianchetti.

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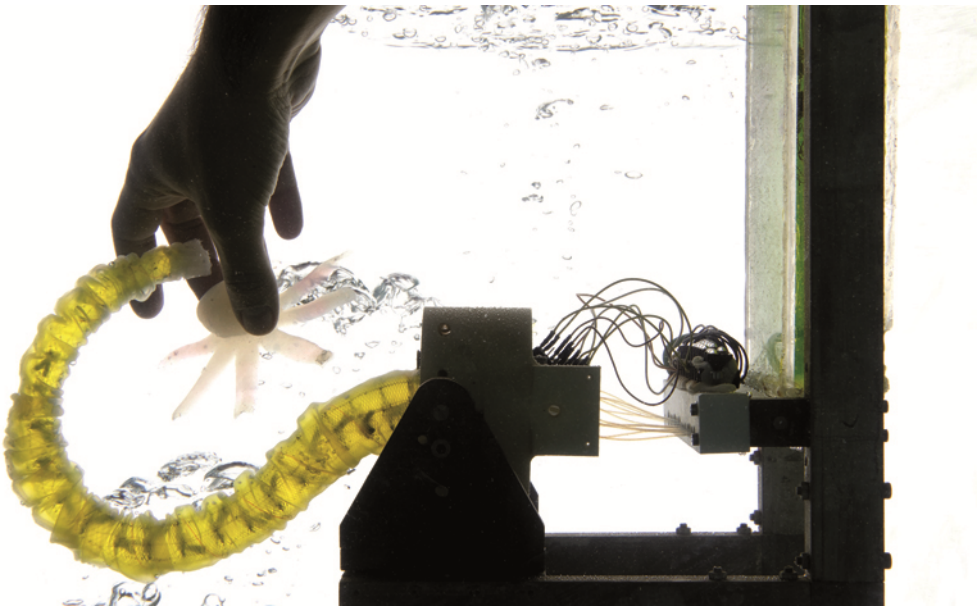


Photo credit: Massimo Brega

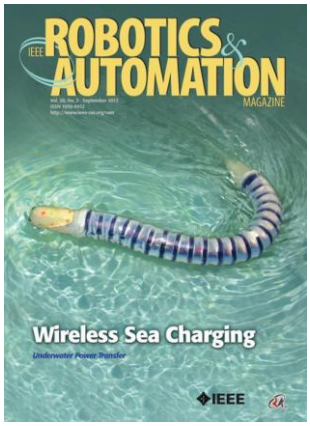
Creative Engineering Design Area

A small team of motivated, creative and competent young researchers with multidisciplinary background works on challenging research projects, often in the framework of industrial collaborations.

Level of success is measured by evaluating results on a regular basis, in terms of number of original articles published on international journals, exploited IP, alumni placement.

Merging creativity with robust engineering approaches and methodologies is the key to the **development of radically new machines and usable systems**.

Creative engineering design in robotics and biorobotics is a way to bridge **research and industrial innovation**, to develop acceptable and sustainable robots, and to educate creative students.



Robotic Lamprey - cover page of IEEE R&A, Vol. 20, no. 3, september 2013

The area of Creative Engineering Design at the BioRobotics Institute of Sant'Anna School of Advanced Studies is focusing on this effort, by adopting specific approaches such as **Design Thinking** and **Human Centered Design**.

The scientific responsible is prof. Cesare Stefanini.

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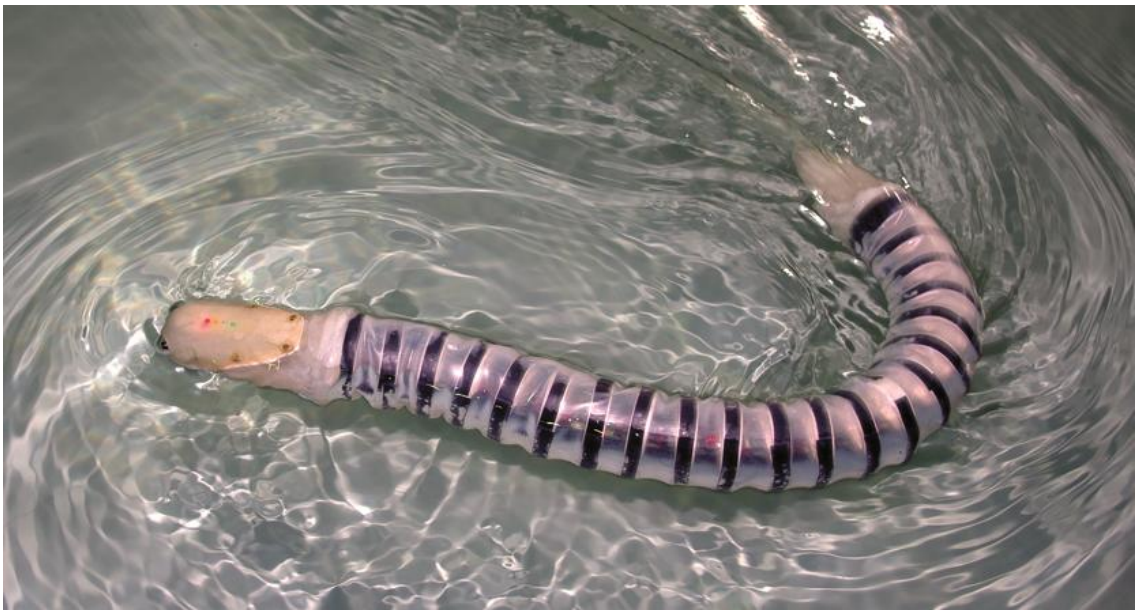

Surgical Robotics and Allied Technologies Area

Investigating problems, identifying enabling technologies and developing solutions for addressing the field of minimally invasive and targeted therapy and diagnosis. Development of endocavitary robots, capsules, instrumented catheters, and probes able to operate and navigate in the human body for diagnostic and therapeutic applications. Therapy and diagnosis can be performed in the human abdomen, in the cardiovascular system, in the gastrointestinal tract, but also in other hard-to-reach districts.

Within this framework, the mission of the Surgical Robotics and Allied Technologies Area, that includes the Laboratories of Computer-Integrated Technologies for Robotic Surgery and Micro-nano-bio systems and targeted therapies, is to **combine micro/nano/bio technologies**, **molecular biology**, **chemistry**, **physics**, **robotics/microrobotics/computer-integrated technologies**, for enabling future high quality (accurate and repeatable), early and minimal invasive key technologies.

The scientific responsible is prof. Arianna Menciassi.

Polo Sant'Anna Valdera (PSV)
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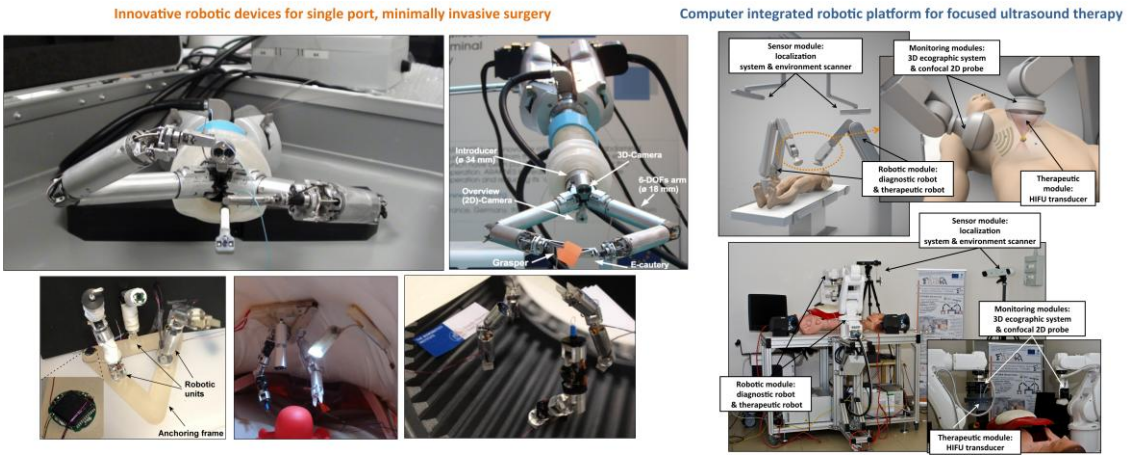
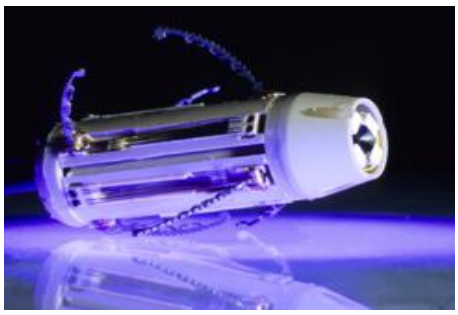


Computer-Integrated Technologies for Robotic Surgery Laboratory



Active locomotion endoscopic device

Medical robots have a significant potential to fundamentally change surgery and interventional medicine as part of a broader, information-intensive environment that exploits the complementary strengths of humans and computer-based technology. Robotic systems for surgery are computer-integrated systems (i.e., surgical CAD/CAM or surgical assistants) in which the robot/tool itself is just one element, i.e. the end-effector, of a larger system designed to assist (with a pre-programmed/semiautonomous, teleoperated or hands-on compliant control) a surgeon in carrying out a surgical procedure that may comprise preoperative planning, intraoperative registration to presurgical plans, use of a combination of robotic assist and manually controlled tools for carrying out the plan, and postoperative verification, analysis and follow-up.

Within this framework, the mission of the Computer-Integrated Technologies for Robotic Surgery Laboratory is the **invention, prototyping and clinical validation** of computer-integrated platforms and smart devices as means for effective, reliable and minimally invasive diagnosis and therapy.

The scientific responsible is Gastone Ciuti.

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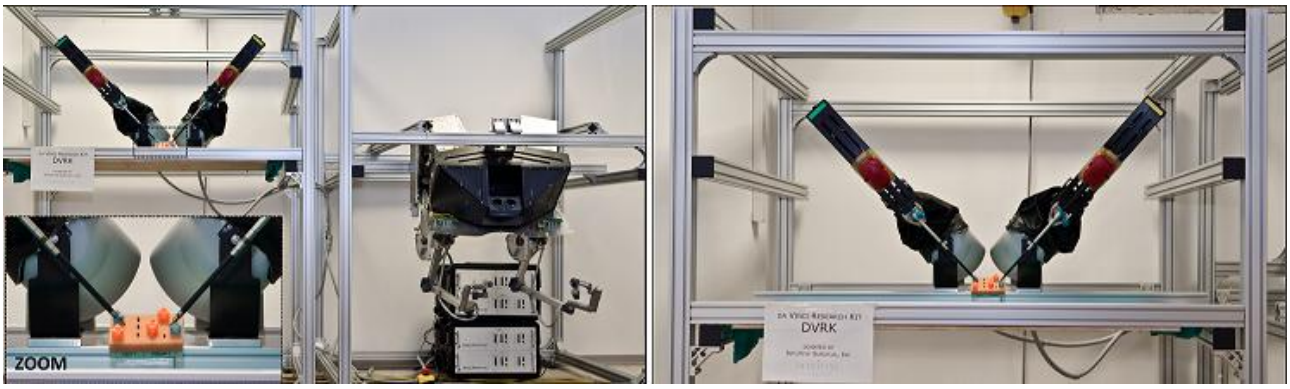
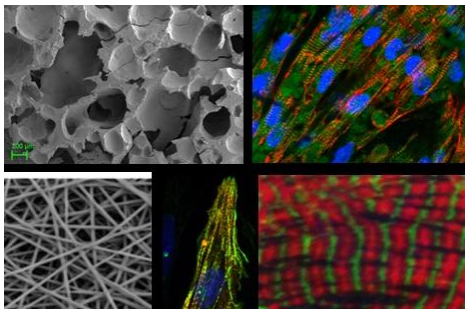


The daVinci Research Kit (dVRK) robotic platform

Micro-Nano-Bio Systems and Targeted Therapies Laboratory



The research mission of the Micro-Nano-Bio Systems and Targeted Therapies Lab is grounded on a strongly interdisciplinary approach and on the hypothesis that a properly driven cross-fertilization between mechatronics, materials science, biotechnologies and molecular biology can produce:

- Disruptive technological advancements for the development of new flexible and scalable machines, based on smart materials and biohybrid devices, integrating living cells and tissues with artificial components;
- A dramatic improvement of targeted and minimally invasive therapies, enabling an important leap of several medical treatments: to achieve this objective, a combination of insights coming from applied physics and materials science (e.g. concerning novel responsive materials), surface functionalization strategies and ad hoc technological tools will be needed;
- Innovative technological tools enabling significant discoveries in Life Sciences: heterogeneous ICT-based microdevices and nanostructured materials may give a key contribution to tissue engineering and regenerative medicine, allowing at the same time to unveil fundamental principles related to healthy or diseased cells/tissues and their organization in 3D functional structures.

The scientific responsible is Leonardo Ricotti.

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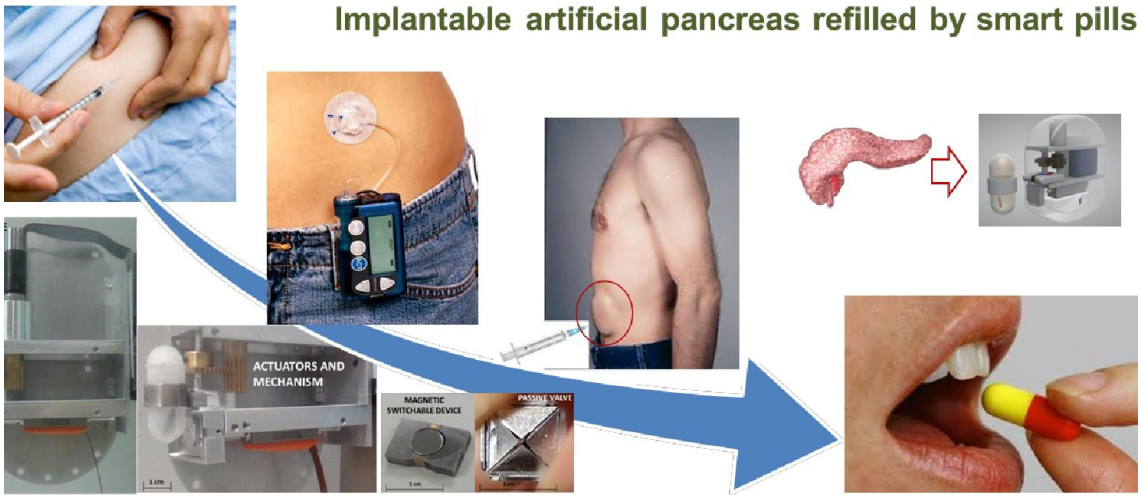
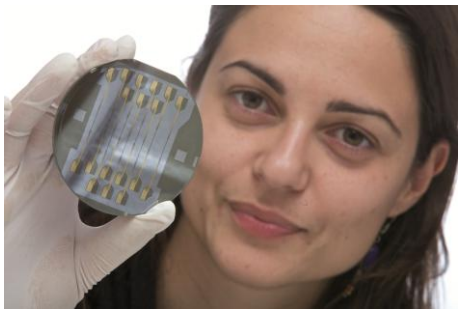


Translational Neural Engineering Area



Neuroengineering is a novel discipline combining engineering including micro and nanotechnology, electrical and mechanical, and computer science with cellular, molecular, cognitive neuroscience with **two main goals**: increase our basic knowledge of how the nervous system works; develop systems able to restore functions in people affected by different types of neural disability.

In this framework the goal of the TNE Laboratory is to develop personalized neuroprostheses to **improve the quality of life of disabled people** by exploiting the potentials of neuroscience-driven approaches. In particular, we are working on the development of novel implantable neural interfaces, neuroprosthetic technologies to restore locomotion and grasping sensory-motor functions, bionic artificial limbs, advanced computational algorithms, novel approaches to understand motor control.

The TNE lab is also actively involved in three joint laboratories on *neural control of movements* (with the University of Pisa and the University Hospital of Pisa, Prof. Bruno Rossi and Dr. Carmelo Chisari) and on *translational neurorehabilitation* (with the Institute of Neuroscience of the Italian National Research Council, CNR, Dr. Matteo Caleo). The TNE Lab also collaborates with the Movement assistance and rehabilitation laboratory (MARE Lab), led by Dr. Nicola Vitiello.

The scientific responsible is prof. Silvestro Micera.

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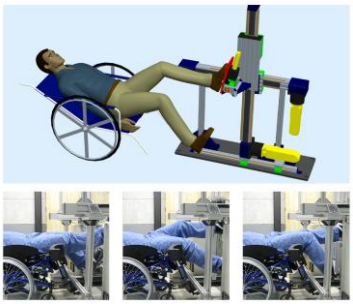
Viale Rinaldo Piaggio 34 – 56025 – Pontedera, Pisa

Locomotion Biomechanics Laboratory



The research interests of the Locomotion Biomechanics Lab's team concern the effects of neuromuscular adaptations resulting by aging and neuro-musculo-skeletal disorders on locomotion-related motor tasks. This ambitious objective relies on the evidence that safe and autonomous walking capabilities allow persons to **maintain independence during daily activities**, to **enjoy social relationships** and to **retain good emotional vitality**. In addition, walking is the most natural form of physical activity, thus providing persons with extensive benefits significantly improving the quality of their life. Accordingly, our studies are aimed at achieving a quantitative assessment of the effects of aging and disorders on locomotion-related motor tasks, and identifying suitable strategies to recovery safe and autonomous walking capabilities.

In this framework, the main activities of our team consists in:

- investigating the fundamental principles underlying human locomotion;
- developing robotic platforms to promote the recovery of locomotion capabilities of persons affected by neuro-musculo-skeletal diseases;
- developing suitable strategies to counteract the lack of balance and prevent the fall risk.

The scientific responsible is Vito Monaco.

Polo Sant'Anna Valdera (PSV)
Viale Rinaldo Piaggio, 34 – 56025 – Pontedera, Pisa

Sensor Signals and Information Processing Area

The research activities mainly concern the design, development, and validation of wearable sensor systems for applications in the field of human motion monitoring, functional assessment, fall detection and fall risk assessment.

The core activity of the lab is based on deploying body area networks that are built around custom-made magneto/inertial measurement units, enriched with, e.g., monocular camera systems and barometric altimeters.

Of special interest to the group is the development and validation of the **computational methods**, either machine learning or stochastic filtering methods, that are needed for automatically recognizing the human activity (**context detection**), and for estimating the biomechanical parameters of relevance to each recognized activity (**functional assessment**).

Robotic walking aid

The scientific responsible is prof. Angelo Maria Sabatini.

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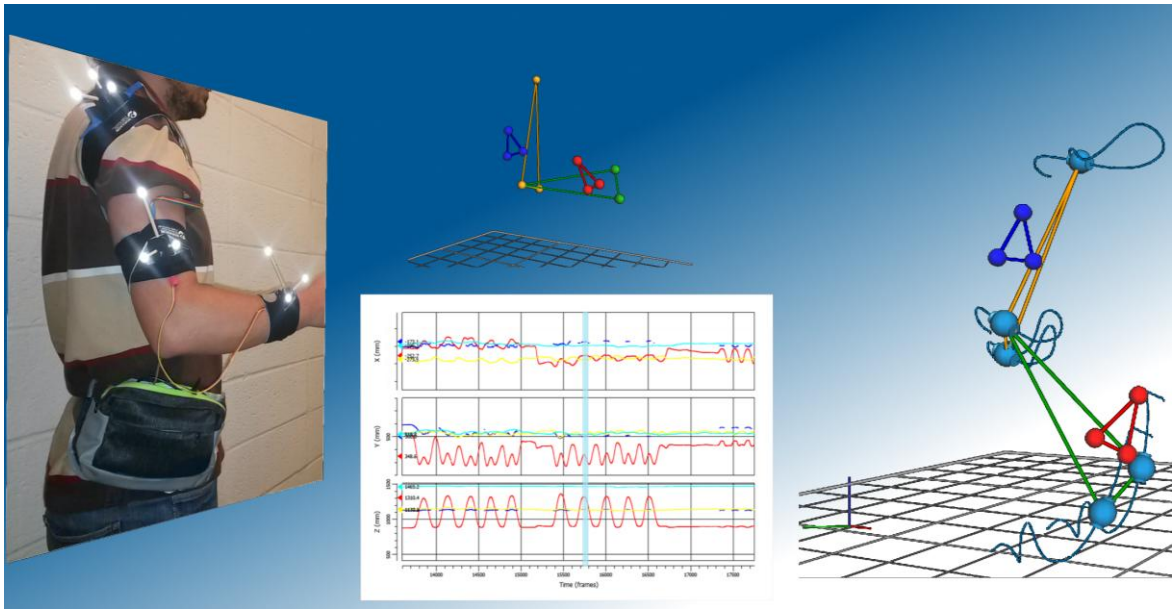
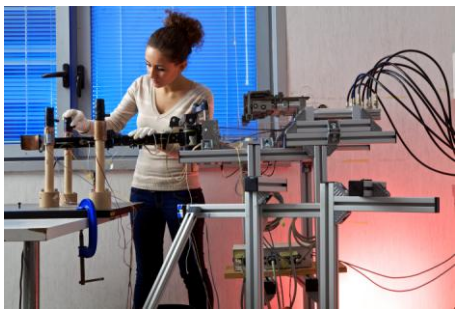


Neuro-Robotics Area



The dream: to develop wearable robots allowing the human-robot symbiosis

Symbiosis: *"a close, prolonged association between two or more different organisms of different species that may, but does not necessarily, benefit each member"* (American Heritage Dictionary). The robot becomes a physical, mechanical agent which actively supports (healthy, elderly and disabled) people in performing activities of daily living.

Is "physical" human-exoskeleton symbiosis doable?

In 1960s, in "Man-Computer symbiosis", J.C.R. Licklider formulated a vision of human-computer symbiosis in which computers and humans would become fluidly interdependent and share goals. In 2010s, in many tasks, human and computer share goals and are interdependent.

The method

We develop robotic devices for applications in rehabilitation and daily-life assistance of people affected by movement disorders; such devices interact with the human subjects at cognitive and physical levels, realizing bidirectional flows of information and mechanical power. We also develop robotic models (physical platforms) for the investigation of neuroscience theories and we exploit results of the neuroscience investigation to design and develop robotic systems.

Research Topics: **Wearable assistive machines**; **Artificial sense of touch**; **Rehabilitation robotics and tele-rehabilitation**.

The scientific responsible is prof. Maria Chiara Carrozza.

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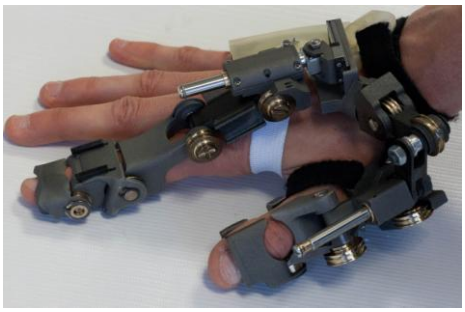
Wearable Robotics Laboratory



Ageing population affects society welfare sustainability. The ageing of the population is one of the most critical challenges current industrialized societies will have to face in the next years, and threatens the sustainability of our social welfare.
In 40 years from now, nearly 35% of the European population will be older than 60, hence the urgency to provide solutions enabling our ageing society to remain active, creative, productive and, above all, independent.
Among many diseases, gait disorders and upper-limb impairment are common and often devastating companions of ageing, leading to reductions in quality of life and increased mortality.

Within this framework, the mission of the Wearable Robotics Laboratory is the invention, prototyping and clinical validation of wearable robots (also called exoskeletons or powered orthoses) for assisting, rehabilitating or augmenting human movement.

The scientific responsible is prof. Nicola Vitiello.

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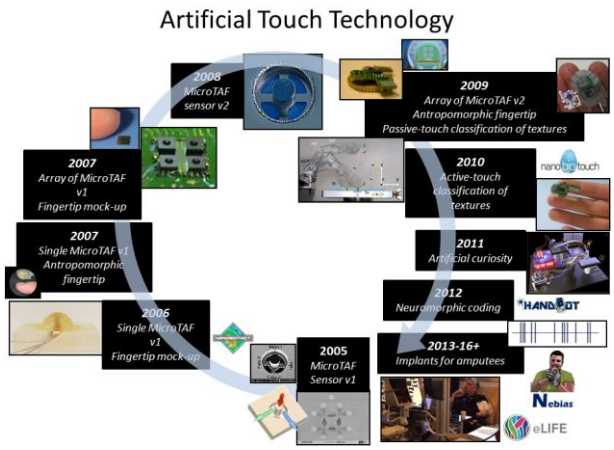
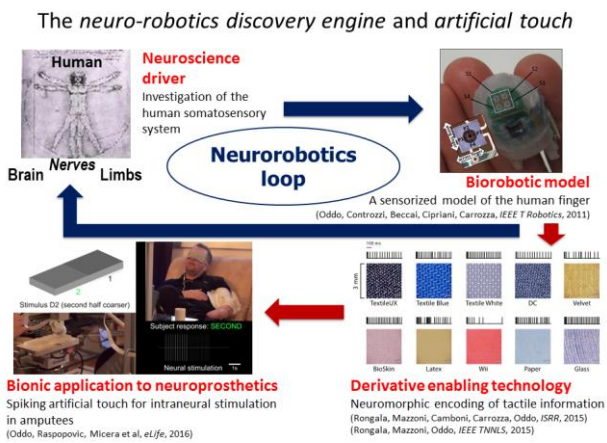
Human Machine Nexus Laboratory

The Human Machine Nexus laboratory mainly targets the engineering of an artificial tactile sense in parallel to the investigation of human touch. We develop and integrate novel transducers, both synthetic and bio-hybrid. We implement **neuromorphic systems**, with natural spiking coding of tactile information. We analyse neural data to unveil the neuronal processes underlying the human sense of touch, and we implement behavioural protocols to characterize the perception of tactile features.





This body of neuroscientific knowledge and the developed biorobotic technologies converge in a key application domain in **upper limb neuroprosthetics**, with complementary interests stemming towards safe human-machine co-work, tele-presence for medical robotics and hand-held consumer electronics.

The scientific responsible is Calogero Oddo.

Polo Sant'Anna Valdera (PSV)
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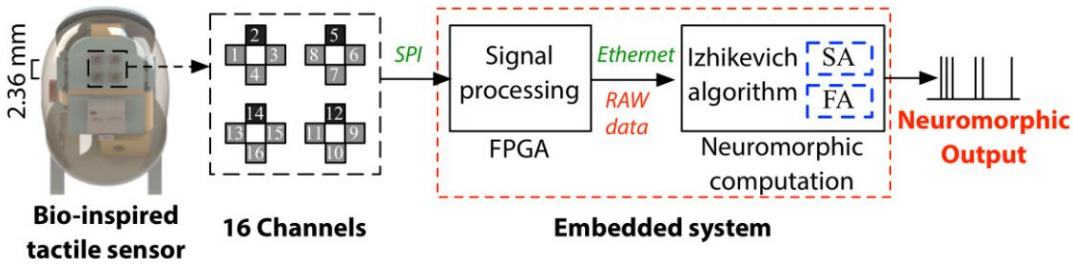

Artificial Hands Area

The **Artificial Hands Area (AHA)** pursues research in **mechatronics** and **human-machine interfaces (HMI)** with the goal of developing advanced robotic limbs to be used as **thought-controlled prostheses**. Current research topics include: the (high-tech) observation of the human hand; the design of artificial hands, digits, wrists and elbows, their transmission and artificial sensory system; the design of control architectures and intuitive control strategies; the use of biological signals for the physiological control of prehension; the development and clinical validation of bi-directional non-invasive (wearable) interfaces through novel assessment tools; the investigation and comparison of shared-control strategies between user and the prosthesis; the incorporation of sensory feedback strategies into one's sensorimotor control.

The AHA co-founded with INAIL Prosthetic Centre the REPAIR Lab (Rehabilitation Engineering and Prosthetics Applied Innovation & Research) in Budrio (Bologna).

The AHA spun out Prensilia (www.prensilia.com), a company that develops and commercializes artificial hands worldwide, since 2009.

The scientific responsible is prof. Christian Cipriani.

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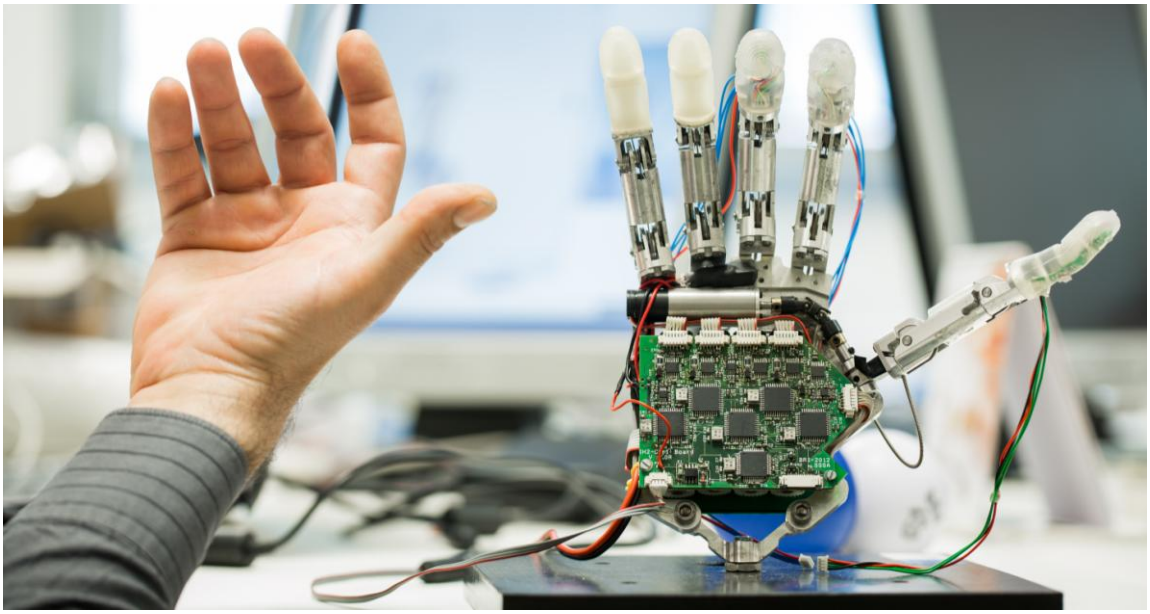
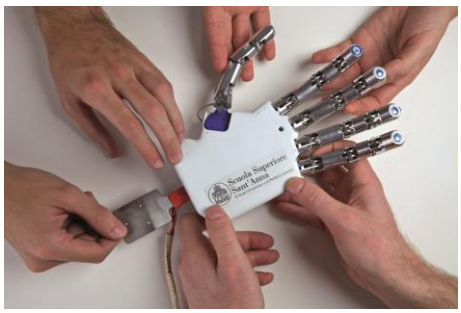


Photo credit: Hauke Seyfarth

Human Robot Interaction Laboratory



The Human-Robot-Interaction Laboratory is part of the Artificial Hands Area of the BioRobotics Institute. Current research topics include **robotic hands** and **dexterous grasping**, **cognitive robotics** and **human-robot interaction**.

What do people expect from robots? The possibility of working in close collaboration with a robotic colleague is perhaps one of the most fascinating results that the world expects from the robotics research community. Nowadays industrial robots are specifically designed for constrained or restricted sets of tasks in structured environments, and more important are neither designed nor programmed for collaborating fluently with humans. To date, Human Robot interaction is unintuitive, restrictive, and limited to a rigid command-and-response fashion. There's a huge need for flexible, capable, safe robots, namely, a new generation of industrial machines very different from the bulky and expensive manipulators existing today. Within the factories this new class of robots could work directly alongside employees with no safety caging merging the benefits of the fully manual assembly and fully automated manufacturing lines. At home this cooperative robot would provide assistance to the human in domestic activities as carrying heavy objects, or simply gently passing a bottle of water.

The scientific responsible is Marco Controzzi.

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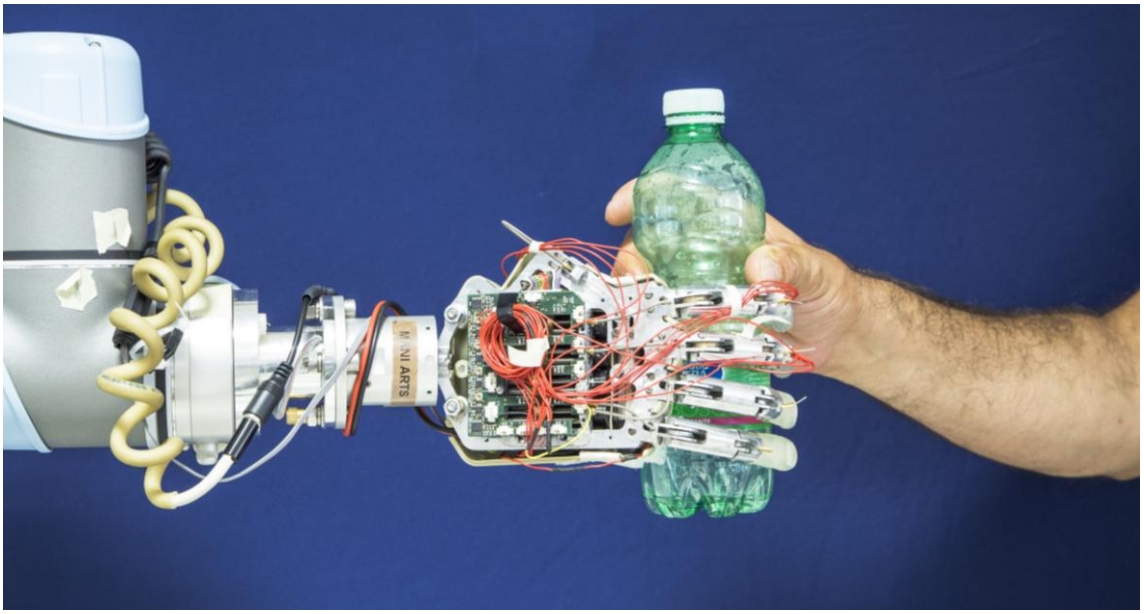


Joint Laboratories

In addition to the Research Areas and to the Laboratories, the Biorobotics Institute is involved in **Joint Research Labs** with clinical institutions. These Joint Labs are devoted to translational research activities such as: rehabilitation bioengineering, movement assistance, translational neurorehabilitation, analysis and treatment of neuromotor disorders, neurodevelopmental bioengineering, upper limb prosthetics.

The Joint Laboratories are:

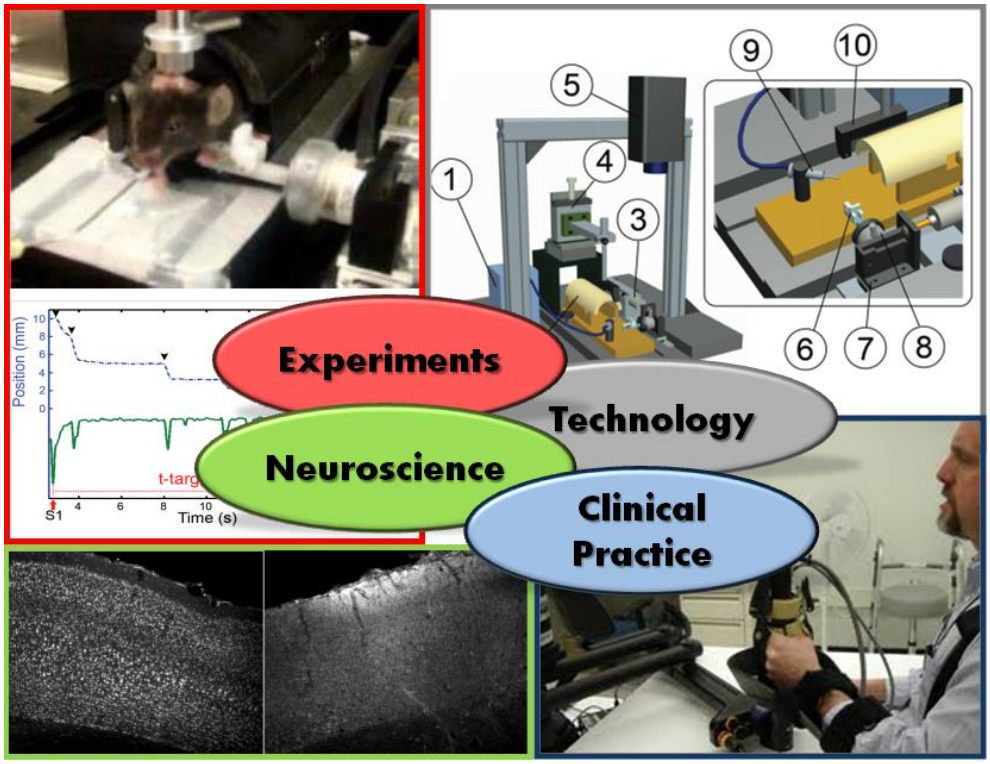
- **Translational Neurorehabilitation Laboratory**, joint laboratory with CNR, Neuroscience Institute (Pisa)
- **Laboratory for Analysis and Treatment of Neuromotor Disorders (ATND)**, joint laboratory with University Hospital of Pisa (Pisa)
- **Robotic and Biomechatronic Technologies Laboratory in Neurorehabilitation**, joint laboratory with Fondazione Stella Maris for Neurodevelopment bioengineering (Tirrenia, Pisa)
- **Movement Assistance and REhabilitation Laboratory (MARE Lab)**, joint laboratory with Fondazione Don Carlo Gnocchi (Firenze)
- **BioRobotics for Parkinson disease Laboratory**, joint laboratory with ASL (Massa Carrara)
- **Rehabiltation Engineering and Prosthetics Applied Innovation & Research (REPAIR Lab)**, joint laboratory with INAIL Centro Protesi (Vigorso di Budrio, Bologna)

Translational Neurorehabilitation Laboratory

The Translational Neurorehabilitation Laboratory provides a closer **interaction between basic neuroscientists, neural and rehabilitation engineers, and clinical neurologists**. Our mission is to expand current understanding of brain function and disease by performing preclinical experiments on animal models of nervous system disorders, and translate this knowledge into novel therapies by developing innovative robotic and ICT-based applications.

Current research activities include:

- study of brain function after stroke (anatomy, electrophysiology, behaviour)
- robot-based motor rehabilitation in a rodent model of stroke
- epilepsy-induced modifications of visual function
- closed-loop detection and suppression of epileptic seizures



CNR – Consiglio Nazionale delle Ricerche
Via Giuseppe Moruzzi, 1 - 56124 - Pisa

Laboratory for Analysis and Treatment of Neuromotor Disorders (ATND)

The ATND Lab provides a closer interaction between rehabilitation engineers and physicians to study neurobehavioral changes in people with neuromotor disorders, and to develop new clinical approaches and technologies for motor rehabilitation.

Current research activities and tools include:

- Analysis of movement (kinematics, kinetics) to assess post-stroke motor impairment and post-rehabilitative modifications;
- Advanced analysis of neurophysiologic modifications following stroke (electroencephalography, electromyography, transcranial magnetic stimulation);
- Robot-based upper- and lower-limb post-stroke rehabilitation (MOTORE, Lokomat).

Azienda Ospedaliera Pisana
Via Paradisa, 2 - 56125 - Pisa

Robotic and Biomechatronic Technologies Laboratory in Neurorehabilitation

The Robotic and Biomechatronic Technologies Laboratory in Neurorehabilitation is a place where different but convergent experiences and competences meet together; the purpose is **the design**, **the clinical testing** and **the maintenance of new methods and instruments** aimed at the behavioural study of the neurobiological mechanisms, which are basic for the early development of the human brain, as well as the motor, perceptual and integrative functions (visual exploration, grasping, manipulation, locomotion, navigation), both in healthy children and with neuromotor disabilities.

Furthermore, starting from these experiences, knowledge and prototypes can be transferred in rehabilitation, or created ex novo, in order to re-educate the functions explored.

Fondazione Stella Maris for Neurodevelopment Bioengineering
Viale del Tirreno, 331 - 56018 - Tirrenia, Pisa

Movement Assistance and REhabilitation Laboratory (MARE Lab)

MARE Lab is a joint laboratory between The BioRobotics Institute and the centre for rehabilitation **Fondazione Don Gnocchi** located in Florence.

This laboratory aims at carrying out the experimental validation of wearable robots for motion assistance and rehabilitation with real end users such as elderly people affected by gait disorders, transfemoral amputees or hemiplegic patients. This laboratory is equipped with a motion tracking system, a **EMG recorder**, a device to monitor human physiological parameters, direct/indirect calorimeters and the **SENLY platform** for investigating fall biomechanics and strategies for its risk mitigation.

This laboratory is currently exploited by members of different laboratories/areas of The BioRobotics Institute, such as: Wearable Robotics Laboratory, Translational Neural Engineering Laboratory, Locomotion Biomechanics Laboratory and Human-Machine Nexus Laboratory.

Fondazione Don Carlo Gnocchi
Via di Scandicci, 269 - 50143 – Firenze

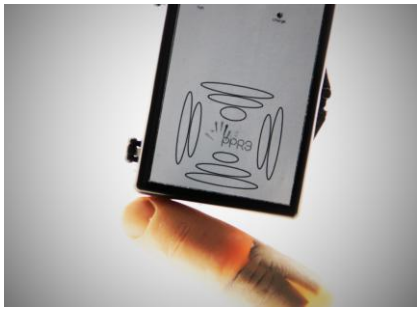
BioRobotics for Parkinson disease Laboratory

The BioRobotics for Parkinson disease Laboratory focuses on prevention, monitoring and management of Parkinson's disease (PD) and its co-morbidities, from screening for pre-frailty states (e.g. subjects with idiopathic hyposmia), to early diagnosis, rehabilitation and assistance according to the level of the pathology.

The activities concern the combination of **mHealth applications**, **cooperative ICTs**, **Cloud technologies** and **wearable/portable integrated devices**, which empower patients to pursue healthy lifestyles and to manage their health and disease in cooperation with their formal and informal caregivers and with professional medical staff across different care settings and environments.

ASL Massa
Via Flavio Baracchini, 1- 54100 – Massa

Rehabilitation Engineering and Prosthetics Applied Innovation & Research (REPAIR Lab)



The REPAIR Lab results from a collaboration between the BioRobotics Institute and the INAIL **(National Workers' Compensation) Prosthetic Center.** The main research fields of the lab are: biorobotics, prosthetic devices and interfaces, neurorobotics and recovery of motor and sensory functions after amputation or neurological injury. The objective is to bridge the engineering research and development with the rehabilitation activities conducted by physicians and therapists in direct contact with the patients.

Currently the BioRobotics Institute and INAIL collaborate at the following project:

- **PPR3 project (Development of prosthetic finger phalanges)**: The project aims aimed at developing new biomimetic, articulated and instrumented prosthetic finger phalanges, both controlled by invasive and non-invasive interfaces able to implement intuitive motor control and realistic sensory feedback (www.ppr3.eu).

Scientific Responsibles:

- *Christian Cipriani, Professor of the BioRobotics Institute*
- *Rinaldo Sacchetti, Technical Director at INAIL*

Centro Protesi Inail
Via Rabuina 14 - 40054 - Vigorso di Budrio, Bologna

INAIL Prosthetic Center

Technology Transfer

Exploitation of scientific research activities is one of the institutional tasks of The BioRobotics Institute. The ultimate goal here is to bring the benefits of our research into the society by fostering the development of novel of new products and services.

Within this framework, the following main actions are carried out:

- Intellectual property protection and management;
- The ability to invent and deposit patents;
- Foundation of spin-off companies;
- The acquisition of third-party contracts by industry.

In the last 20+ years, the BioRobotics Institute has launched **25 start-up companies** and filed more than **70 national/international patent applications**.

In particular, the BioRobotics Institute supports Local Development policies by applying the results of frontier and excellence research to the needs for quality-of-life improvement as well as to the social, economic and cultural development of the territories in which it operates, by:

- "transferring" both people, “trained” to innovation and new technologies, suitable for creating new products and to the socio-economic and business context; and knowledge, through patent policies or new spin off companies;
- working in close collaboration with local and national institutions, with public and private entities and, on a broader scale, with all the stakeholders (schools, enterprises or organizations) who share a common interest in a strong, sustainable and measurable growth.

Industrial BioRobotics Laboratory

Applied research, **innovative solutions** and **systems to improve industrial growth and competitiveness**: the research is mainly focused on companies' needs in the field of robotics, automation and mechatronics. The Industrial Biorobotics Lab copes with unstructured problems and finds innovative solutions taking inspiration from nature. The aim is to drive partners to develop new products and processes.

The scientific responsible is Stefano Roccella.

Industrial BioRobotics Laboratory
Via delle Colline, 100 - Collesalvetti, Livorno

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