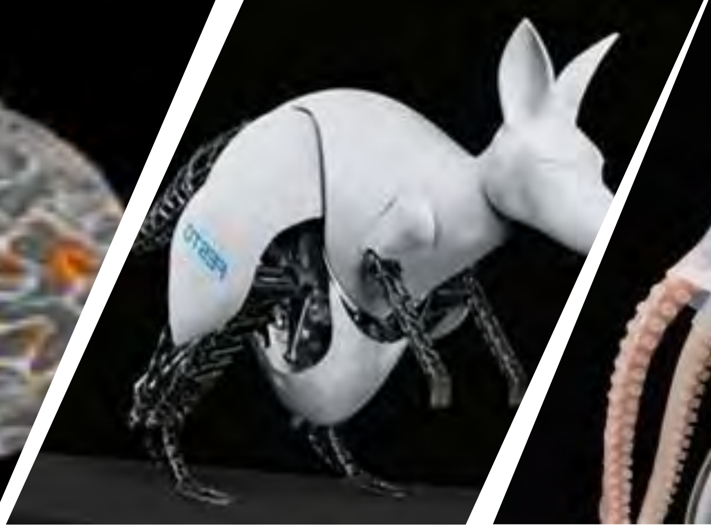
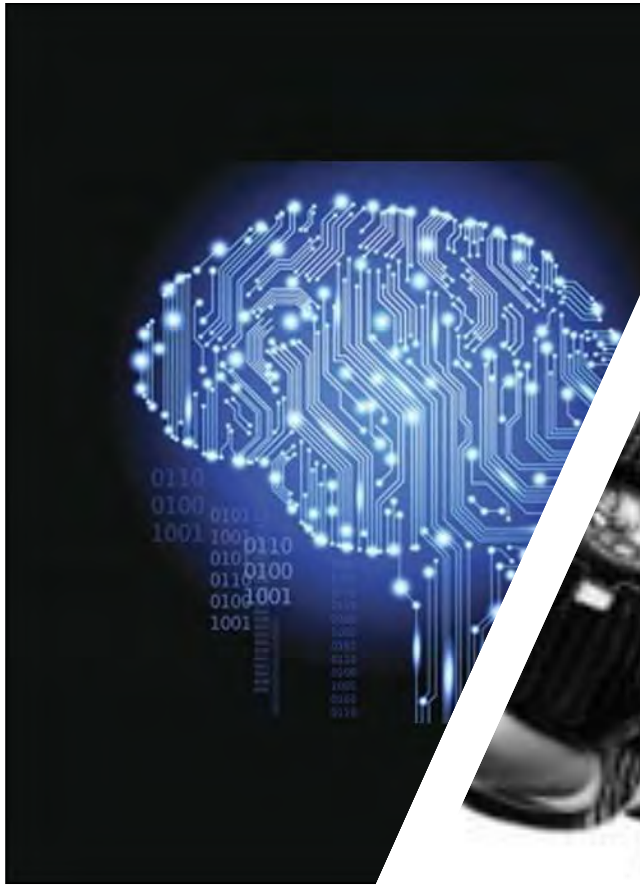
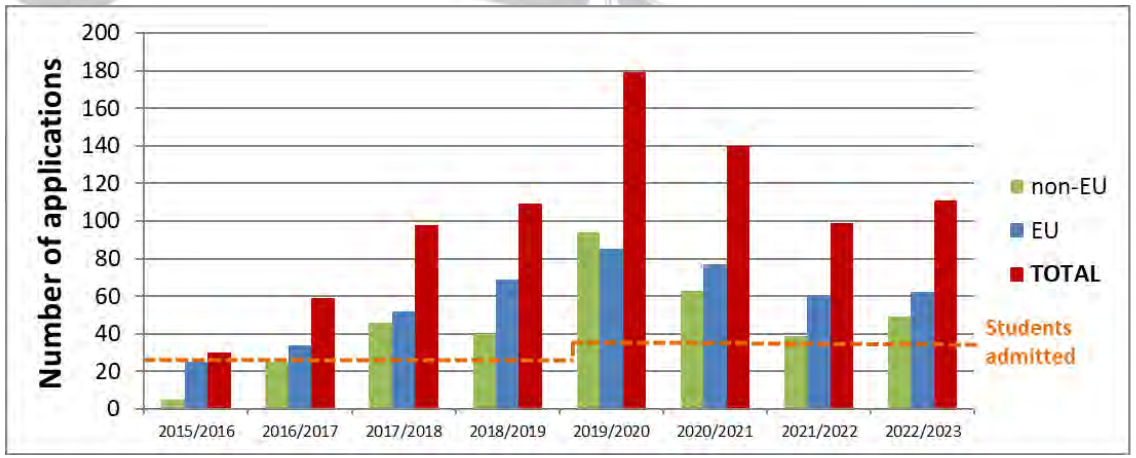




Master of Science in Bionics Engineering

M.Sc. in Bionics Engineering – UNIPI, SSSA and IMT, since 2015



- International program
- Limited enrollment (30 students per year)
- 2 majors: biorobotics and neural engineering

http://www.bionicsengineering.it/

M.Sc. in Bionics Engineering – UNIPI, SSSA and IMT, since 2015

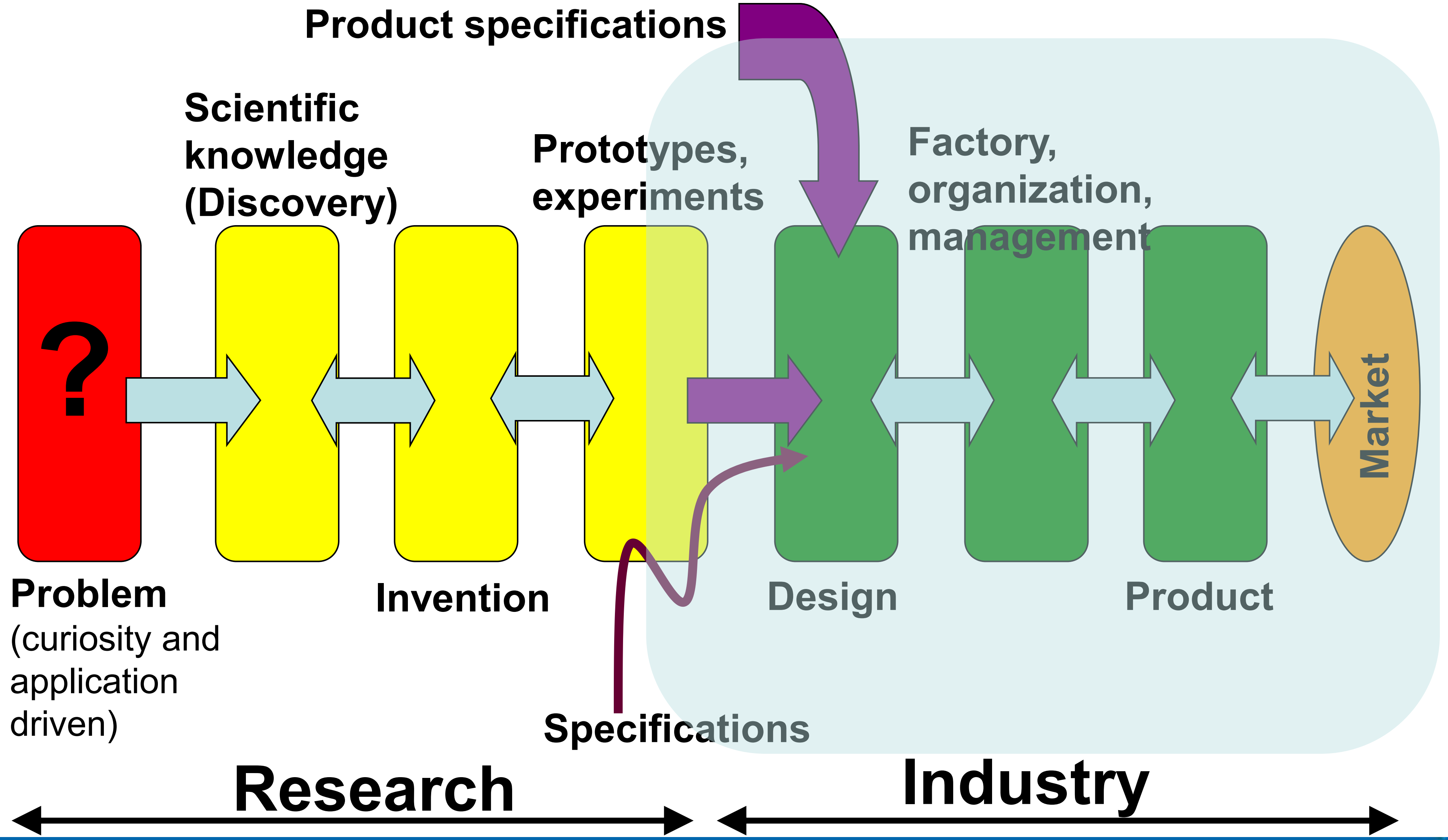
Mission of the M.Sc. in Bionics Engineering

Educating the Engineer of the 21st Century

able to face new challenges and to foster opportunities for Society and Industry

Biorobotics and Neural engineering are a fantastic "gym" to train new INNOVATORS

Going beyond traditional engineering education



The birth of Bionics

Bionics as an inter-science discipline officially dates back to **1958** when **Major J. E. Steele** coined the term making reference to a research program at the **Wright-Patterson Air Force Base in Dayton, OH, USA**

Jack E. Steele

Wright-Patterson Air Force Base

Steele used the term **bionics** to mean "**a life-like system that copies some functions and characteristics of a natural system**"

Science

AAAS

Meetings

Bionics

The unities underlying the behavior of animals, men, and machines were brought into clearer focus at a national symposium held 13–15 September 1960 in Dayton, Ohio. The meeting, under the sponsorship of the Wright Air Development Division of the United States Air Force, was attended by approximately 700 persons. Thirty invited speakers reported new developments concerning methods of information handling used by living systems and artificial models of such systems. The magnitude of the recent advances so impressed the participants that they virtually demanded that such a meeting be made a regular event. This report is based entirely on my notes; I apologize for any errors of fact or interpretation, and for not mentioning many talks because of lack of space.

At the start, H. E. Savely of the Air Force Office of Scientific Research pointed out three aspects of living systems which are worthy of study for incorporation into artificial systems: (i) the extreme sensitivity of certain receptor organs—for example, the ability of certain fish to detect a change in the electric field in the water around them of as little as 0.003 μv/mm; (ii) the ability of even simple living brains to integrate the activity of many sensor and effector organs; (iii) the ability to retrieve information rapidly in the central nervous system; and (iv) the ability to store information at molecular levels, even for periods of generations, as in the chromosomes. An example of the successful use of a living system as a prototype for an artificial system is the application in an optical ground-speed indicator for airplanes of the simple principle in the beetle's visual system that provides information on velocity.

H. E. Savely cautioned (i) that as long as we lack fundamental understanding of the laws of organized complexity, it may not be possible to duplicate the living system; (ii) that nature is limited simply to building on and modifying pre-existing systems and that the living system therefore may not provide the most economical approach to a particular information-handling problem; and (iii) that it is common for the physical scientist to think that he can take a quick look at some biological system, work out the principles in a very short time, and then apply them to the design of some artificial system. Not only is he mistaken in this belief but he is very much like Brer Rabbit attacking the Tar Baby. The harder he attacks the problems of biology the more deeply does he become enmeshed, so that he soon finds himself unable to drop them.

An analysis of the relatively simple servomechanism controlling the size of the pupil of the human eye was presented by Lawrence Stark, now of the Massachusetts Institute of Technology. This paper and one other were the only reports dealing directly with the information-handling mechanisms of living systems—evidence perhaps of the difficulty of such an approach. The other talks dealt with the design of artificial systems. E. E. Loebner of RCA Research Laboratories pointed out that man, because he has few outputs (muscles), has built only a few information inputs into the gear he controls, to match his few outputs. This restriction on the number of inputs has been carried over into equipment not under human control. It would often be preferable to give such equipment multiple inputs, such as man has in his sense organs.

The general logical operations that a computer must perform in order to behave like an organism were described by Peter M. Kelly of Aeronutronics. It must take inputs from a sensory field, code them into groups, act on them by some internal logic, code the outputs, and carry out responses in terms of this output code. The coding of the sensory input to the internal logic can be fixed in advance—that is, preorganized. It is also possible to design machines which are self-organized—that is, capable of learning how to code their sensory input and their output so as to achieve the desired responses to particular sensory situations. Kelly, and also Walter Reitman of Carnegie Institute of Technology, discussed the design of such machines and gave examples of existing machines in which the two types of design are used. (Could it be that when we intuitively judge one type of organism to have more "consciousness' than another, the distinction in physical terms is that it has a greater capacity for self organization?)

W. P. Tanner of the University of Michigan argued that the human being is not completely preorganized so as to give a fixed response for a particular sensory input but is capable of self-organization. Therefore, the human being subjected to psychophysical tests should not be considered to have a sensory threshold but should be treated as a computer which is testing the statistics of the test situation and making decisions which optimize some aspect of that situation. Tanner is analyzing such performances of human beings in auditory test situations.

The problem of designing a machine which can differentiate or recognize one out of all possible sensory functions was discussed by Seymour Papart of the National Physical Laboratory, Teddington, England. The problem is simplified by the fact (i) that the input functions possible are only a portion of all functions, and (ii) that as the number of dimensions of the input functions increase, the chance of separating any two input functions increases, even with a simple machine. He has roughly estimated that one human being during his lifetime could learn up to 10^{8} particles of information. This much learning could be handled by any of the systems of self-organization described at the symposium. (Compare this estimate with the estimate of 10^{13} made some years ago by W. S. McCulloch and of 10^{18} to 10^{18} made by H. von Foerster.)

Artificial devices which recognize patterns, including one device capable of recognizing cancerous cells under the microscope, were mentioned by P. Metzelaar of Space Technology Laboratories. Some machines have given performance superior to the human—for example, a checker playing program for the IBM 704 computer. Other machines have been designed that can predict the future of a sequence from its past. Metzelaar suggested that if the design problems can be solved, the future machine will do preliminary pattern transformations on its sensory inputs in order to reduce the amount of information that must be handled and stored. It will also be able to consider its sensory input in either gross outline or fine detail and know which type of consideration is needed, decide how to divide its attention among its different sensory inputs, and know which of various recognition mechanisms it should use.

In a talk that was as remarkable for its witty asides as for its lucid exposition, A. Novikoff of Stanford Research Institute briefly described integral geometry and illustrated its use in the

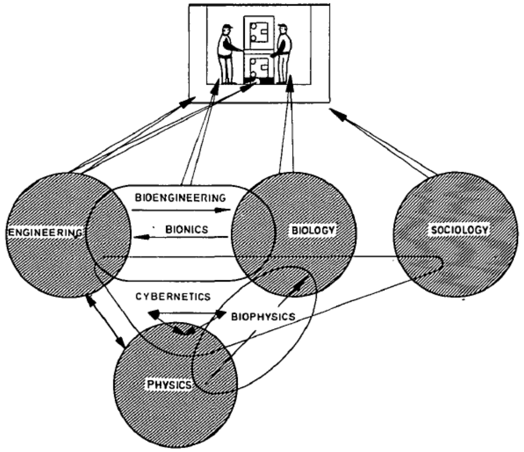
J.E. Steele. *Bionics Symposium: Living Prototypes – The Key to New Technology*, ed. C.H. Gray. New York, 55–60 (1960)

The birth of Bionics

The primary goal of bionics is *"to extend man's* ***physical and intellectual capabilities*** *by prosthetic devices in the most general sense, and to replace man by* ***automata and intelligent machines****"*

Henning Edgar von Gierke

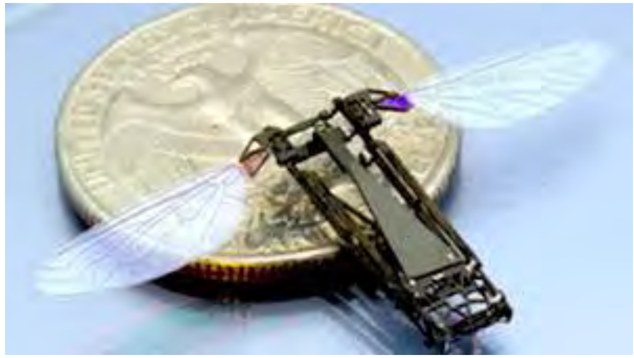
These objectives were pursued by using models from the animal kingdom…

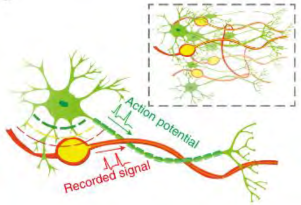


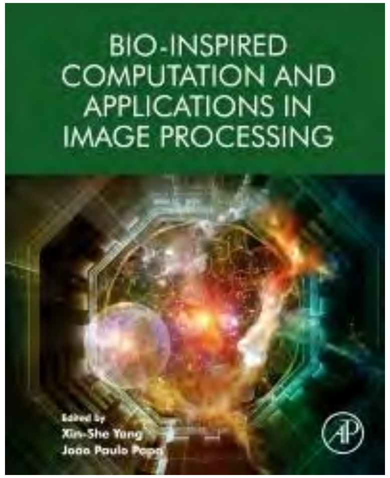
Research efforts were mainly driven by **military applications**

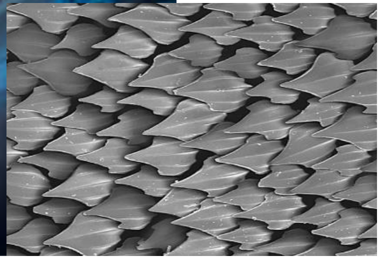
H.E.Von Gierke, W.D. Keidel. Principles and practice of bionics. *Technivision Services* (1970)

Current applications of bionic technologies

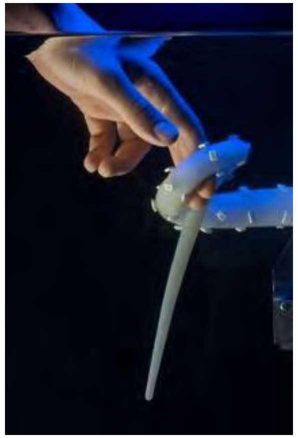


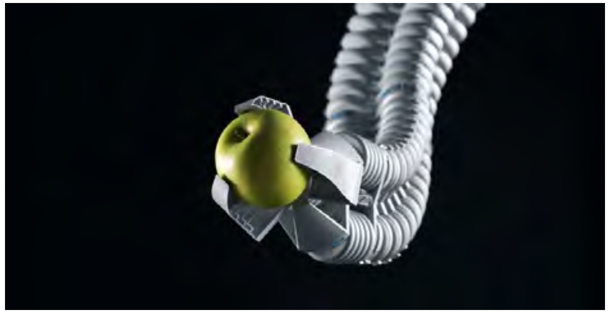


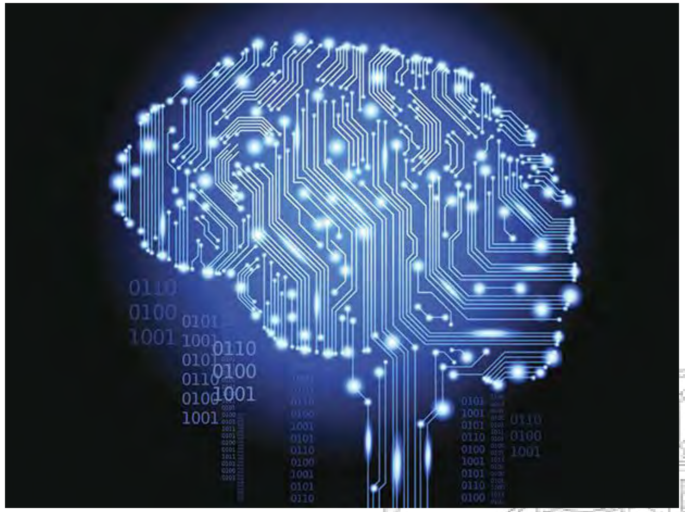




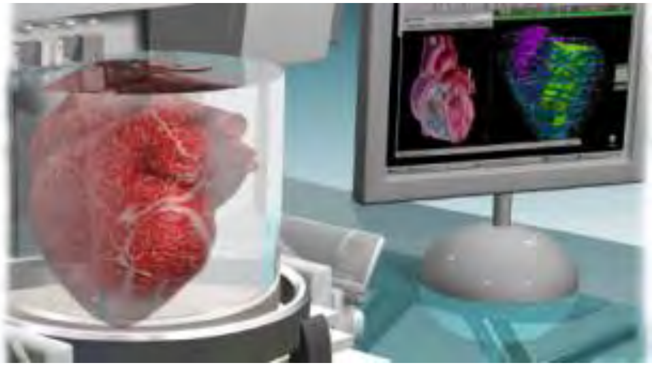
Shark skin-inspired swimsuits

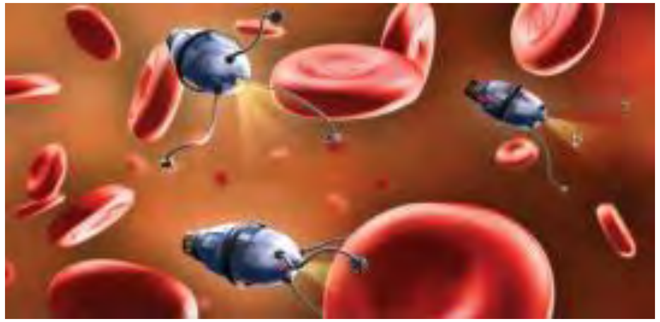






Bionics intended as technologies intimately interacting with the body





We Will End Disability by Becoming Cyborgs

Neural interfaces and prosthetics will do away with biology's failings

By Eliza Strickland
Posted 27 May 2014 | 15:03 GMT

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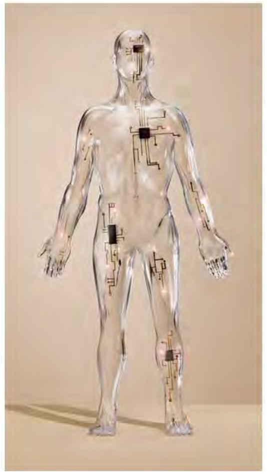
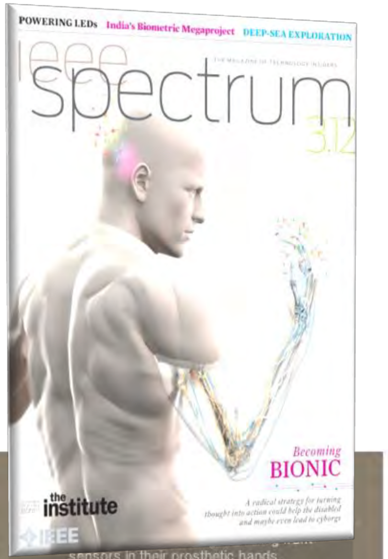
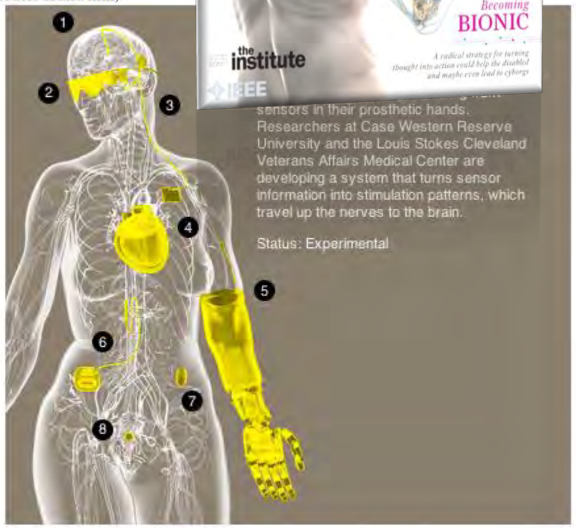


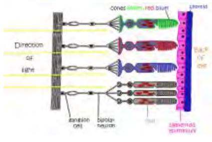
Hugh Herr is a living exemplar of the maxim that the best way to predict the future is to invent it. At the age of 17, Herr was already an accomplished mountaineer, but during an ice-climbing expedition he lost his way in a blizzard and was stranded on a mountainside for three days. By the time rescuers found him, both of his legs wer frostbite and had to below the knee. On healed, Herr spent rooms trying out pr he found them una could he climb with things? Surely, he t technologists could replacement parts t him down.

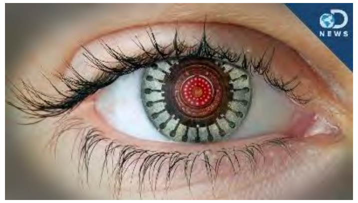
Today, three decad





The Revolution Will Be Prosthetized





Hacking the Human OS > Reading the Code > Monitoring

Diabetes Has a New Enemy: Robo-Pancreas

Sensors, actuators, and algorithms can automatically control blood sugar

By Philip E. Ross
Posted 27 May 2015 | 21:00 GMT

M.Sc. in Bionics Engineering

	1st year		
	1st semester	**2nd semester**	
Mandatory courses common to both curricula	Principles of bionics and biorobotics engineering (Cesare Stefanini) – 6 ECTS	Modeling of multi-physics phenomena (Alessandro Tognetti) – 6 ECTS	Analysis of bionic and robotic systems
	Statistical signal processing (Fulvio Gini) – 6 ECTS	Methods and techniques of measurement and data analysis (Angelo Sabatini) - 6 ECTS	
	Biological data mining (Francesco Marcelloni) – 6 ECTS	Neural and fuzzy computation (Beatrice Lazzerini) – 6 ECTS	Bioinspired computational methods
Mandatory courses specific for the **Biorobotics** curriculum	Mechanics of smart materials and structures (Antonio De Simone) – 6 ECTS	Soft robotics technologies (Matteo Cianchetti) - 6 ECTS	Bioinspired and soft robotics
Mandatory courses specific for the **Neural Engineering** curriculum	Behavioural and cognitive neuroscience (Emiliano Ricciardi) – 6 ECTS	Computational neuroscience (Alessio Micheli) - 6 ECTS	Applied brain science
Elective courses common to both curricula	Advanced materials for bionics (Francesco Greco) - 6 ECTS	Neuromorphic engineering (Calogero Oddo) – 6 ECTS	
	Robot Programming frameworks and IoT platforms (Egidio Falotico) – 6 ECTS	Electronics for bionics engineering (Daniele Rossi) – 6 ECTS	
	Probability and biostatistics (Gaetano Valenza) – 6 ECTS	Artificial intelligent systems for human identification (Enzo Pasquale Scilingo) – 6 ECTS	

M.Sc. in Bionics Engineering

2nd year – Curriculum: Biorobotics		
1st semester	**2nd semester**	
Biomechanics of human motion (Calogero Oddo) – 6 ECTS	Robotic and data-driven rehabilitation (Marco Controzzi) – 6 ECTS	Rehabilitation and assistive technologies
Prostheses (Christian Cipriani) – 6 ECTS	Exoskeletons (Nicola Vitiello) – 6 ECTS	Wearable robotics
Robotics for minimally invasive and targeted therapy (Arianna Menciassi) – 6 ECTS	Bionic organs and tissues (Leonardo Ricotti) – 6 ECTS	Advanced interventional and therapeutic technologies
Design principles for bionic tissue engineering (Arti Ahluwalia) – 6 ECTS		

2nd year – Curriculum: Neural Engineering		
1st semester	**2nd semester**	
Advanced image processing (Nicola Vanello) – 6 ECTS	Integrative cerebral function (Angelo Gemignani) – 6 ECTS	Integrative cerebral function and image processing
Neural tissue engineering (Giovanni Vozzi) – 6 ECTS	Neural interfaces and bioelectronic medicine (Silvestro Micera) – 6 ECTS	Neural prostheses
Interactive systems (Daniele Mazzei) – 6 ECTS	Affective computing (Enzo Pasquale Scilingo) – 6 ECTS	Interactive systems and affective computing
Bionic senses (Alessandro Tognetti) - 6 ECTS		

Final duties: Lab training (3 ECTS) and Thesis (15 ECTS)

M.Sc. in Bionics Engineering

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	Neuromorphic engineering (Calogero Oddo) – 6 ECTS	Electronics for bionics engineering (Daniele Rossi) – 6 ECTS
	Robot Programming frameworks and IoT platforms (Egidio Falotico) – 6 ECTS	

Principles of bionics and biorobotics engineering

Focus

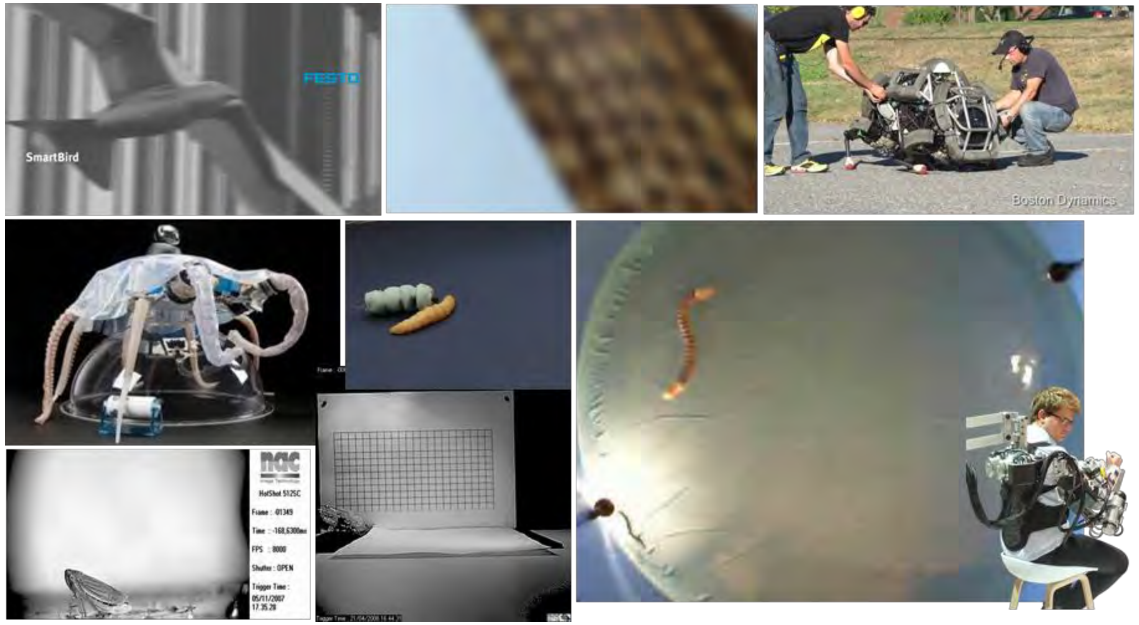
- Make students able to face frontier engineering problems, by combining science and hi-tech approaches (proper of bionics design)

Main Contents

- Historical evolution of bionics, related to robotics and bioengineering;
- Model organisms and biological locomotion principles in different media, and applications in robotics;
- Bionic energy management: comparison between organisms and robots;
- Fabrication technologies at different scales;
- Bioinspired structural design and advanced materials;
- Fundamentals of robot mechanics (schematic of the joints, homogeneous transformations, Jacobian, methods for kinematic and dynamic studies);
- Swarm robotics;
- Ethical issues and legal considerations.

Learning Outcomes

- Providing basic knowledge and principles on design, fabrication, and control processes of bionics systems
- Highlighting current bionics systems and their applications
- Stimulating students directly to develop innovative bionic concepts by exploiting the knowledge acquired during the course



Statistical signal processing

Focus

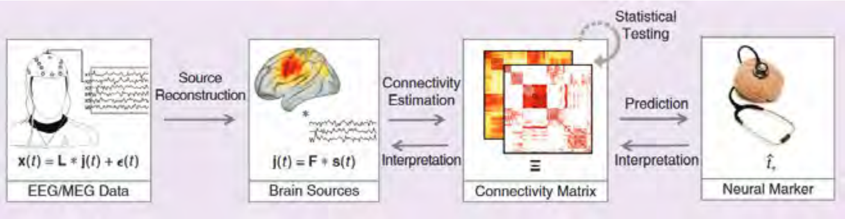
- Statistical signal processing methods for deterministic and random parameter estimation, data analysis, random signal recovery and filtering, model identification, power spectral density estimation.

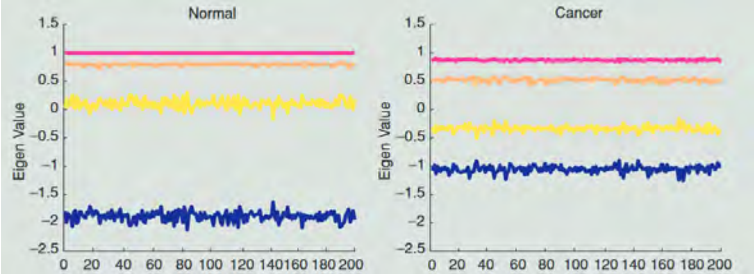
Learning Outcomes

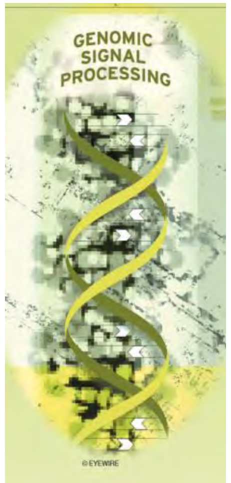
- Background knowledge necessary to solve typical problems by using methods of statistical signal processing

Main Contents

- Orthonormal base signal expansion, Principal Component Analysis (PCA), Sample estimators, Method of moments estimators, Maximum likelihood estimators, Linear and Non Linear Least Squares Least, Bayes estimation, Minimum Mean Square Error (MMSE) and Maximum A Posteriori (MAP) estimation, Linear MMSE (LMMSE) estimation, ARMA modeling, Wiener filter for signal filtering, prediction and interpolation, parametric and non Parametric power spectral density estimation.







Biological data mining

Focus

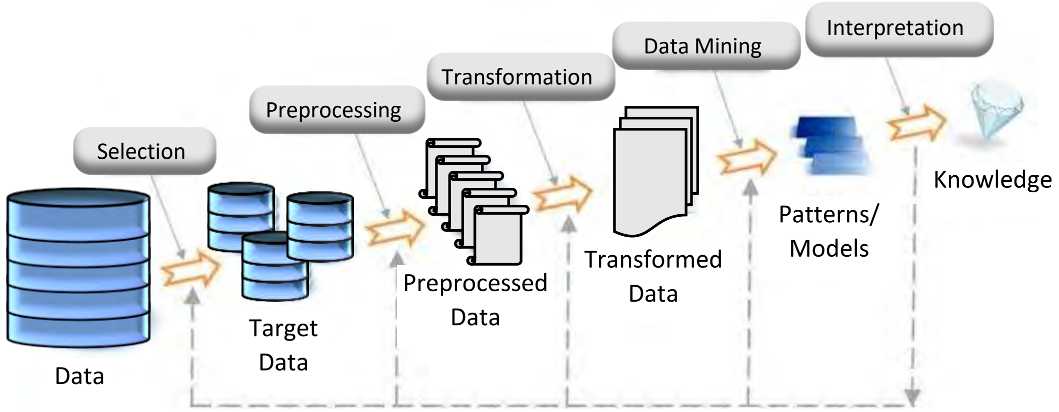
- Main techniques used in Data Mining

Contenuti principali

- Data Preprocessing
- Frequent pattern mining
- Classification
- Clustering
- Outlier Detection
- Laboratories on the application of the methods presented during the course

Learning Outcomes

- To provide a solid knowledge of the main techniques used in data mining. This knowledge will allow identifying the most suitable approach for solving each type of data mining problem.



M.Sc. in Bionics Engineering

	1st year	
	1st semester	**2nd semester**
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	Statistical signal processing (Fulvio Gini) – 6 ECTS	Methods and techniques of measurement and data analysis (Angelo Sabatini) - 6 ECTS
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	Neuromorphic engineering (Calogero Oddo) – 6 ECTS	Electronics for bionics engineering (Daniele Rossi) – 6 ECTS
	Robot Programming frameworks and IoT platforms (Egidio Falotico) – 6 ECTS	

Modeling of multi-physics phenomena

Focus

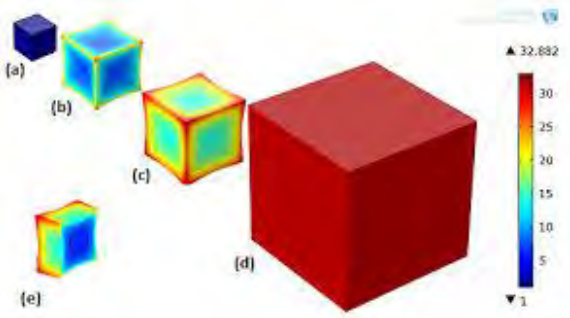
- Computational modeling of multi-physics systems with applications to bionics

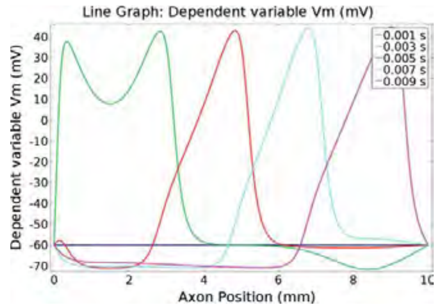
Main Topics

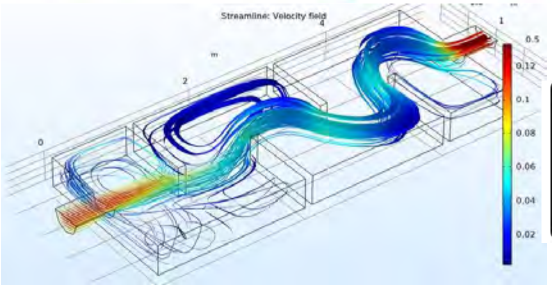
- Weak-form modeling and theory of the Finite Element Method
- Numerical methods and best practices for the solution of non-linear and transient problems
- Linear and non-linear elasticity
- Incompressible flows of Newtonian fluids
- Electromagnetism at low frequencies (biolectric phenomena and neural models)
- Design of sensors and bioinspired devices using computational tools

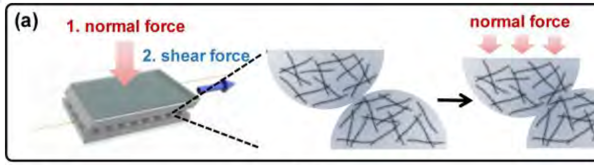
Learning Outcomes

- Fundamental physical concepts, numerical methods and tools for the computational modeling of a wide range of multi-physics phenomena









Methods and techniques of measurement and data analysis

Focus

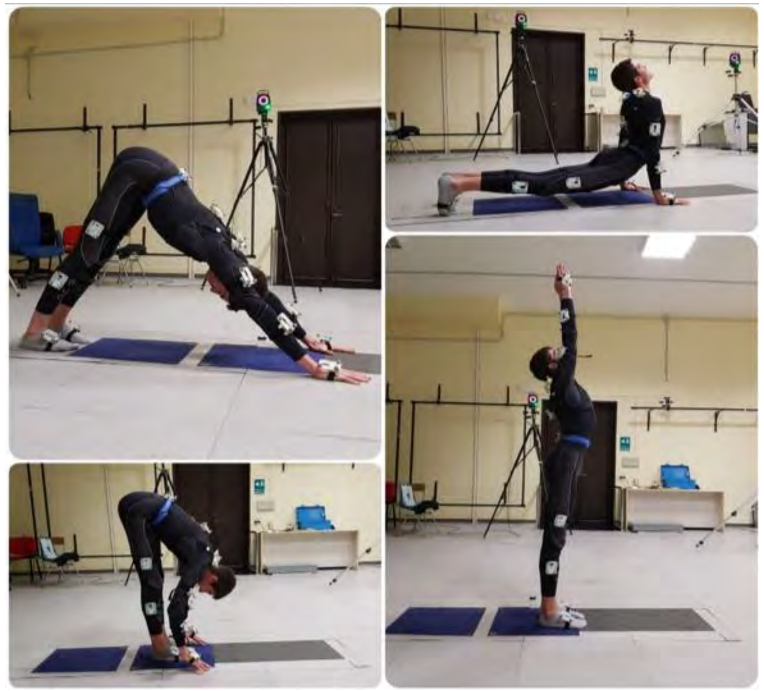
- Methods and techniques in physical measurements for bionic applications

Learning Outcomes

- Measurement problem solving (acquisition and interpretation)

Main Contents

- Application and design of measurement systems
- Measurement systems explained through mathematical modeling
- Signal processing methods for analysis of experimental data



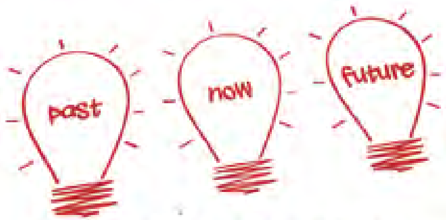
Neural and fuzzy computation

Focus

- Basic concepts and models of Computational Intelligence
- Application of the associated techniques to real-world problems in several application domains

Learning Outcomes

- Design and develop intelligent systems with human-like capabilities in terms of reasoning, learning and adaptation



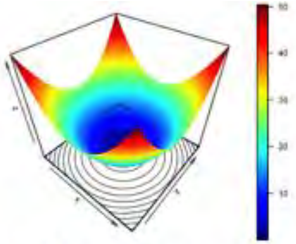
forecasting

profiling

Main Contents

- Artificial neural networks
- Deep learning
- Fuzzy logic
- Fuzzy systems
- Genetic algorithms

decision making



Multi-objective optimization

M.Sc. in Bionics Engineering

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Mechanics of smart materials and structures

Focus

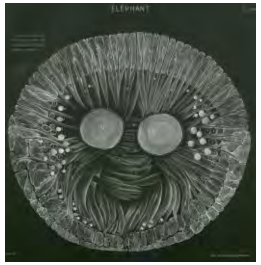
- Non linear mechanics of one-dimensional active and elastic systems in the regime of large deformations: from robotic arms to elephant trunks

Main Topics

- Infinitesimal and finite rotations
- Kinematics and equilibrium of deformable rods
- Material properties and consitutive models
- Prinicple of virtual powers, minimal potential energy, and the Finite Element Method
- Applications: wires and tendons, Euler's elastica and Galileo's beam, bending with large deformations, buckling and post-critical behavior of elastic systems

Learning Outcomes

- Methodological approach for the formulation and solution of shape control problems in biological and robotic systems



Soft robotics technologies

Focus

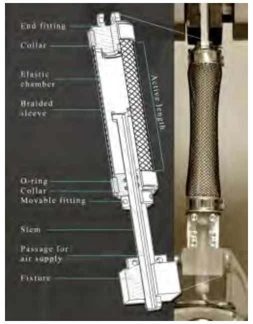
- Use of soft materials for developing soft robots and mechatronics technologies

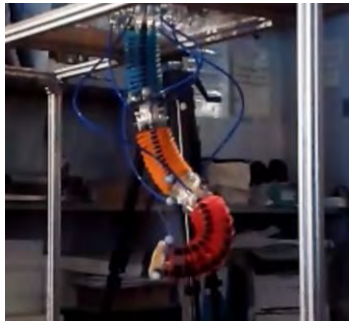
Main Contents

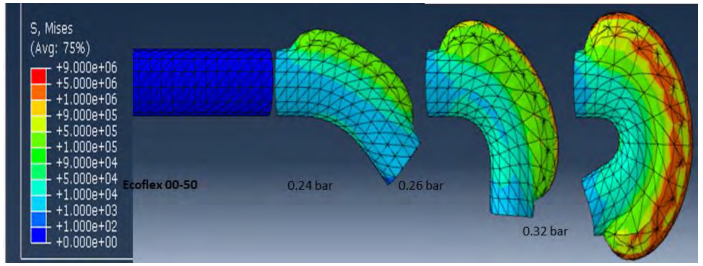
- Bioinspiration and morphological computation
- Novel sensing and actuation technologies
- FEM implemented in ANSYS software for non-linear analysis
- Behaviour and characterization of elastomeric materials

Learning Outcomes

- Use of soft/compliant materials for the design of mechatronic systems through advanced design principles





M.Sc. in Bionics Engineering

	1st year	
	1st semester	**2nd semester**
Mandatory courses common to both curricula	Principles of bionics and biorobotics engineering (Paolo Dario) – 6 ECTS	Modeling of multi-physics phenomena (Alessandro Tognetti) – 6 ECTS
	Statistical signal processing (Fulvio Gini) – 6 ECTS	Methods and techniques of measurement and data analysis (Angelo Sabatini) - 6 ECTS
	Biological data mining (Francesco Marcelloni) – 6 ECTS	Neural and fuzzy computation (Beatrice Lazzerini) – 6 ECTS
Mandatory courses specific for the **Biorobotics** curriculum	Mechanics of smart materials and structures (Antonio De Simone) – 6 ECTS	Soft robotics technologies (Matteo Cianchetti) - 6 ECTS
Mandatory courses specific for the **Neural Engineering** curriculum	Behavioural and cognitive neuroscience (Emiliano Ricciardi) – 6 ECTS	Computational neuroscience (Alessio Micheli) - 6 ECTS
Elective courses common to both curricula	Artificial intelligent systems for human identification (Enzo Pasquale Scilingo) – 6 ECTS	Advanced materials for bionics (Francesco Greco) – 6 ECTS
	Neuromorphic engineering (Calogero Oddo) – 6 ECTS	Electronics for bionics engineering (Daniele Rossi) – 6 ECTS
	Robot Programming frameworks and IoT platforms (Egidio Falotico) – 6 ECTS	

Behavioral and cognitive neuroscience

Focus

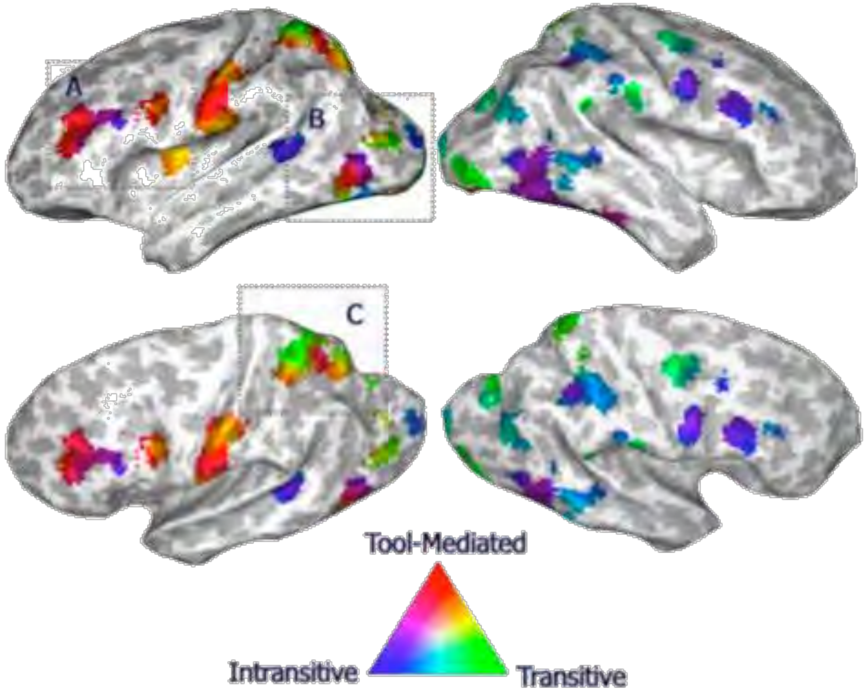
- Neuroimaging has revolutionized neuroscience, allowing us to investigate the neural correlates of behavior and mental functions

Main contents

- basics of brain anatomy and physiology
- neuroimaging methodologies: principles, applications, methods of analysis
- neurobiological correlates of cognition and behavior
- functional neuroanatomy of perception, consciousness and sleep, language, emotions and behavior motor control and representation of action, development of brain-computer interfaces

Objective

The course introduces the theoretical and methodological aspects of cognitive and social neuroscience, introducing to the fundamentals of brain anatomy and physiology, and to neuroimaging techniques



Computational neuroscience

Focus

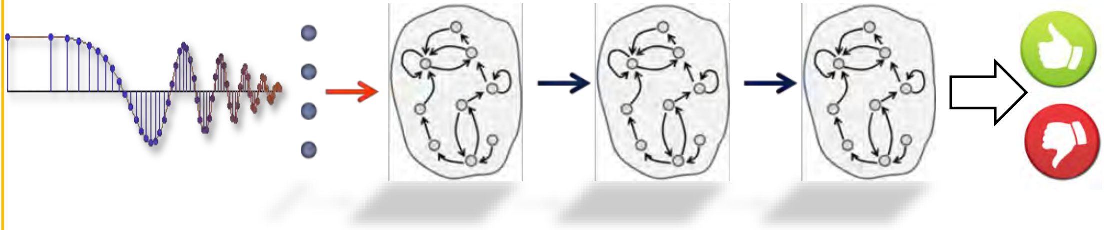
- Introduction to fundamentals of the CNS considering both the bio-inspired neural modelling and computational point of view

Learning Outcomes

- Capability of analysis and development of advanced CNS/Machine Learning models

Main Contents

- Neuroscience modeling
- Spiking and reservoir computing neural networks
- Advanced computational learning models
- Dynamical/Recurrent neural networks



Deep Recurrent Neural Network

M.Sc. in Bionics Engineering

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	Probability and biostatistics (Gaetano Valenza) – 6 ECTS	

Advanced materials for bionics

Focus

- Materials Science & Engineering: materials classes, structure, properties
- Advanced Concepts and applications of materials in Bionics

Learning Outcomes

- solid background in Materials Science & Engineering
- knowledge of uses of modern advanced materials in Bionics Engineering

Main Topics

- Basic traditional topics of Materials Science & Eng.
- Metals, Ceramics, Polymers, Composites
- Advanced Materials Concepts: Biocompatibility, complex Soft Matter, Nanotechnology & Nanostructures, Bioinspired & Stimuli Responsive Materials.
- Investigation & Fabrication Techniques
- Technology & Bionics Applications: materials for bionics, bioelectronics, sensors&actuators in robotics

Robot programming frameworks and IoT platforms

Focus

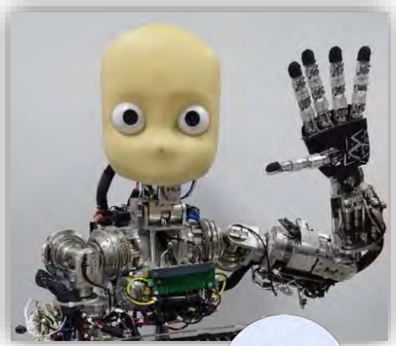
- Software design of autonomous robots and systems
- Robot programming based on different middleware, enhanced by IoT platforms and ancillary hardware peripherals

Learning Outcomes

- Theoretical and practical competences in robotic and SoM programming with IoT platforms and ancillary hardware peripherals

Main Topics

- Robotic middleware (ROS, YARP)
- Communication mechanisms
- Robot control with robotic operative systems
- SoM programming with hardware peripherals
- IoT platforms and cloud programming



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Neuromorphic engineering

Focus

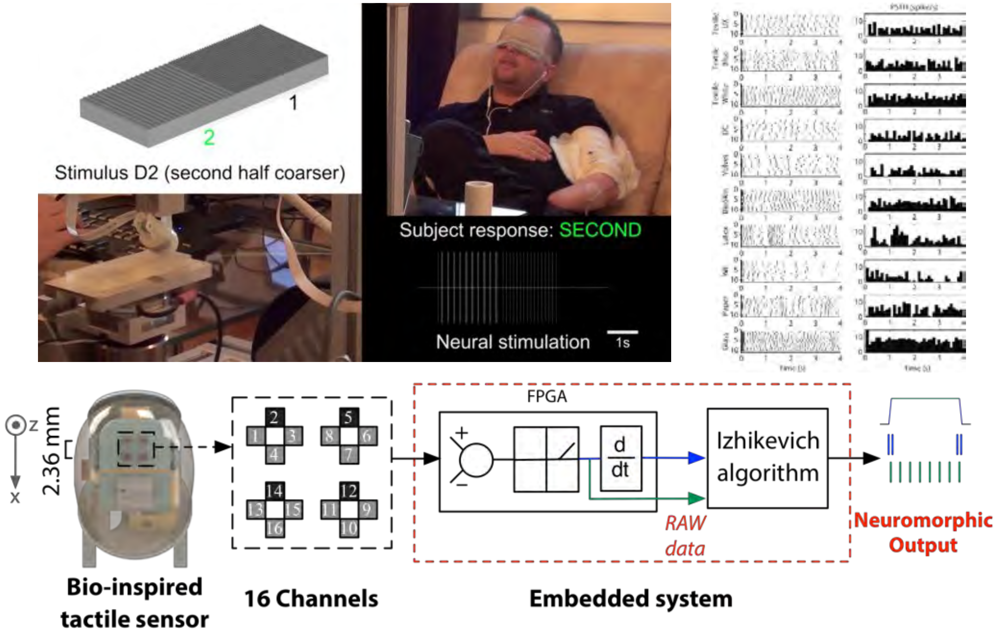
- Computational and physical models that emulate neuron dynamics

Learning Outcomes

- Neurorobotic systems and neurophysiological data for restoring sensori-motor functions

Main Contents

- Technologial solutions for embedded spiking systems
- Signal processing techniques for spiking signals (artificial or physiological)
- Methods for simulating neuron dynamics (e.g. Izhikevich model)
- Use and design of neuromorphic systems



Electronics for bionics engineering

Focus

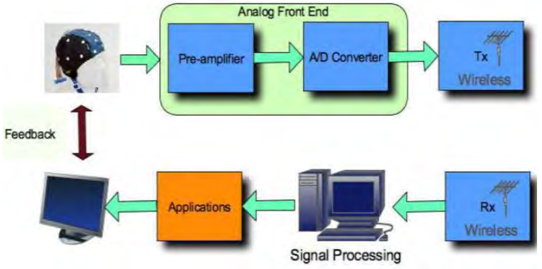
- Analysis and design of the building blocks of an electronic system for the acquisition and processing of biological sensor data

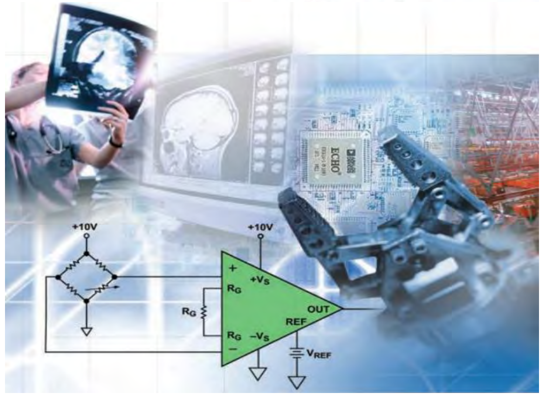
Learning Outcomes

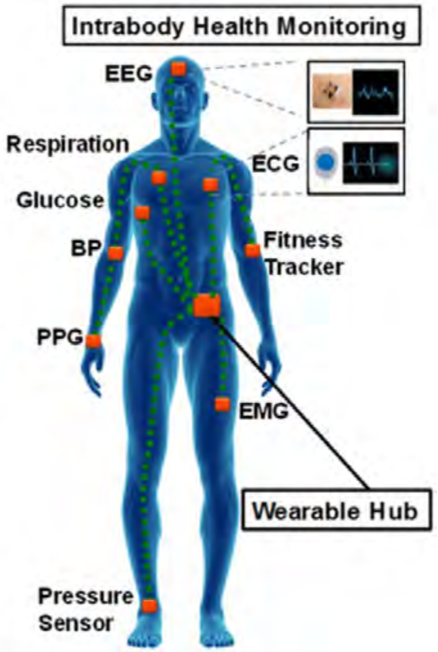
- Acquisition of a solid knowledge of the techniques and methods related to the design of sensor based electronic systems

Main Contents

- Analog front-end building blocks: instrumentation amplifiers, filters and ADC/DAC converters
- Digital interfaces transferring digitalised sensor data to an embedded microcontroller
- Design principles for energy and power efficient electronic systems for wearable applications







Artificial intelligent systems for human identification

Focus

- Advanced techniques to verify or recognize the identity of a living person based on the analysis of biological/physiological traits and/or behavioural features.

Main contents

- Recognition, identification and verification
- Privacy, security and ethics
- Physiological biometric systems: fingerprint recognition, face recognition, iris recognition, retina recognition, hand recognition, vein patterns
- Behavioral biometric systems: keystroke dynamics, signature recognition, voice recognition, gait recognition

Learning Outcomes

- Acquire basic knowledge to process physiological and behavioural features to recognize the identity of a living person.

M.Sc. in Bionics Engineering

2nd year – Curriculum: Biorobotics	
1st semester	**2nd semester**
Biomechanics of human motion (Calogero Oddo) – 6 ECTS	Robotic and data-driven rehabilitation (M. Chiara Carrozza) – 6 ECTS
Prostheses (Christian Cipriani) – 6 ECTS	Exoskeletons (Nicola Vitiello) – 6 ECTS
Robotics for minimally invasive and targeted therapy (Arianna Menciassi) – 6 ECTS	Bionic organs and tissues (Leonardo Ricotti) – 6 ECTS
Design principles for bionic tissue engineering (Arti Ahluwalia) – 6 ECTS	

2nd year – Curriculum: Neural Engineering	
1st semester	**2nd semester**
Advanced image processing (Nicola Vanello) – 6 ECTS	Integrative cerebral function (Angelo Gemignani) – 6 ECTS
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Interactive systems (Daniele Mazzei) – 6 ECTS	Affective computing (Enzo Pasquale Scilingo) – 6 ECTS
Bionic senses (Alessandro Tognetti) - 6 ECTS	

Final duties: Lab training (3 ECTS) and Thesis (15 ECTS)

Biomechanics of human motion

Focus

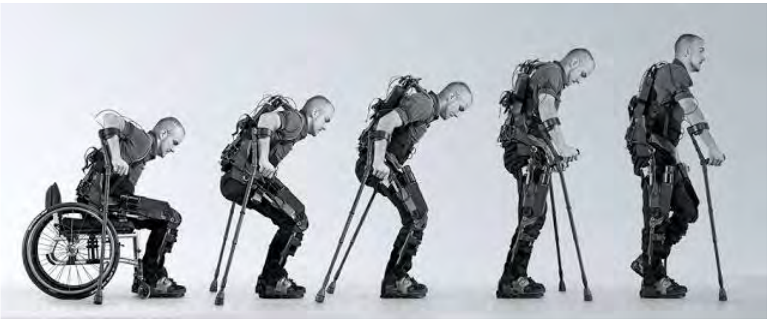
- Biomechanics of human movements and physiological principles underlying motor control.

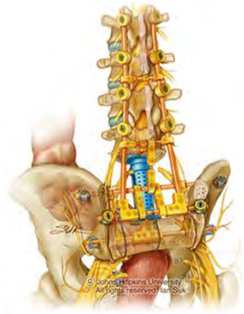
Main Topics

- 3D kinematics and kinetics;
- physiology of muscle contraction
- modeling of muscle-tendon actuators;
- numerical methods to solve dynamic models adopted in biomechanics;
- EMG signals
- instruments in a motion lab

Learning Outcomes

- Methodological approach for the study of human motion during dynamic motor tasks mediated by muscle-tendon actuators





Prostheses

Focus

- Upper limb prostheses
- Embedded controls

Main Contents

- Basic components of myoelectric and body-powered arms (batteries, mechanical, electrical, suspension systems)
- Architecture, operation and peripherals of the microcontroller

Learning Outcomes

- Ability to discuss the design choices of a modern prosthetic arm
- Ability to design and implement in a microcontroller a control system for a prosthesis

Robotics for minimally invasive and targeted therapy

Focus

- Robots, intelligent tools, integrated mechatronic systems, from the *MACRO* to the *micro* scale, to improve accuracy and repeatability in medical interventions.

Main Contents

- Contributions of robotics, mechatronics and bioengineering in minimally invasive surgery and targeted therapy.
- Autonomous robots, tele-operated robots, hand held tools, shared control robots for surgery.
- Endoluminal approaches and miniature robots towards the micro scale.

Learning Outcomes

- Knowledge and tools to design robots and mechatronic tools for surgical / diagnostic / therapeutic applications.

Design principles for bionic tissue engineering

Focus

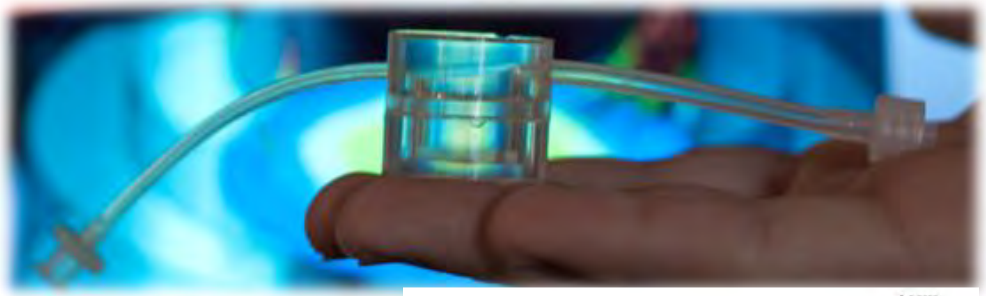
- *in vitro* models, artificial organs & delivery systems using technology based on stem cells, organoids, smart materials & smart fabrication

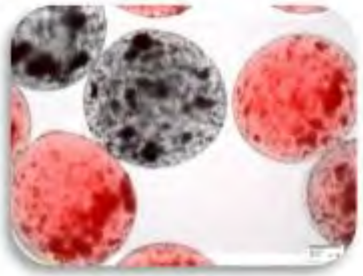
Main contents

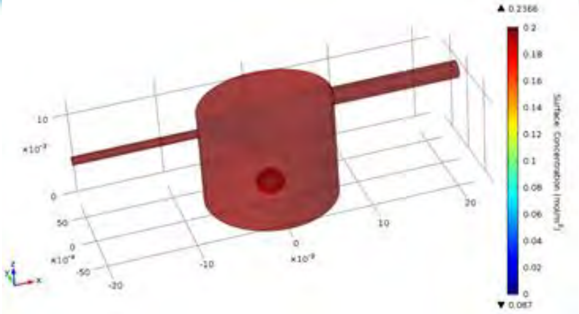
- Cells and cellular models
- Quantitative models of cell-material interaction
- Stem cell and organoid technology
- Design criteria for 3D constructs
- Fluidic system design

Learning Outcomes

- Design and application of cell-based models







M.Sc. in Bionics Engineering

2nd year – Curriculum: Biorobotics	
1st semester	**2nd semester**
Biomechanics of human motion (Vito Monaco) – 6 ECTS	Robotic and data-driven rehabilitation (Marco Controzzi) – 6 ECTS
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2nd year – Curriculum: Neural Engineering	
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Bionic senses (Alessandro Tognetti) - 6 ECTS	

Final duties: Lab training (3 ECTS) and Thesis (15 ECTS)

Robotic and data-driven rehabilitation

Focus

- Robotics and its current scenario for rehabilitation
- Data-driven and evidence-based translational research in rehabilitation

Learning Outcomes

- current trends in rehabilitation
- clinical trials and translational research
- data-driven and evidence-based rehabilitation

Main Topics

- the fourth industrial revolution and the digital transformation: evolution of robotics (rehabilitative, assistive, collaborative, social)
- basic translational and experimental research to assess robotic prototype in clinical settings;
- evidence-based studies in clinical rehabilitation
- machine learning methods implementation, validation and its diagnostic tools in applications in the field of bioengineering and rehabilitation

Exoskeletons

Focus

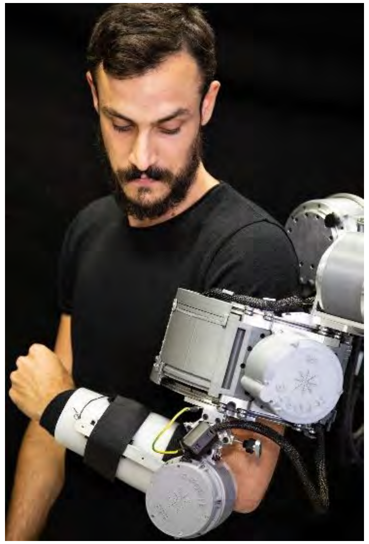
- Lower- and upper-limb exoskeletons for rehabilitation and assistance
- Exoskeletons for industrial applications
- Lower-limb prostheses

Main Contents

- State of the art of lower-limb prostheses, lower- and upper-limb exoskeletons for rehabilitation and asssistance
- Design principles of ergonomic wearable robots
- Series-elastic actuators
- Physical and cognitive human-robot interfaces
- Control architectures for exoskeletons and prostheses
- Hands-on programming of real-time embedded controllers

Learning Outcomes

- Design of wearable powered robots for movement assistance, rehabilitation, augmentation and/or functional replacement
- NI LabVIEW Real-Time and FPGA programming



Bionic organs and tissues

Focus

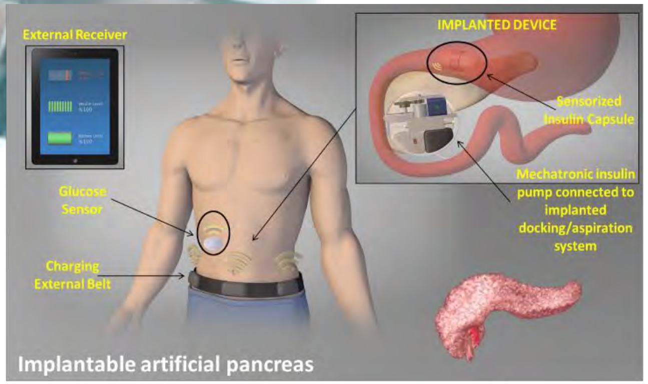
- Artificial and bioartificial organs and tissues
- Regenerative medicine

Main Contents

- Artificial and bioartificial substitutes of muscle, cartilage, pancreas, heart, kidney, etc.
- Miniaturized implantable mechatronic devices
- Biomaterials promoting tissue regeneration
- Microfabricated structures and smart materials for bionic organs and tissues

Learning Outcomes

- Technologies and approches to regenerate or substitute human organs and tissues
- Hands-on awareness of chemistry, microfabrication and molecular biology



Implantable artificial pancreas

M.Sc. in Bionics Engineering

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Final duties: Lab training (3 ECTS) and Thesis (15 ECTS)

Advanced image processing

Focus

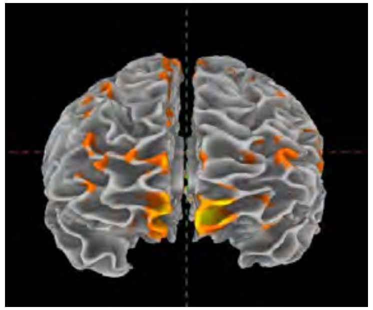
- Models and Methods fo brain function analysis

Learning Outcomes

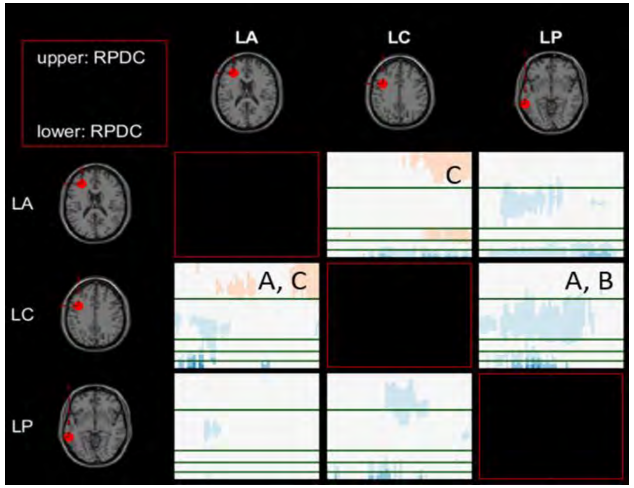
- How different methods for brain function studies are applied
- Link between experimental desgin and data analysis approaches

Main Contents

- Functional Magnetic Resonance Imaging (fMRI)
- Brain connectivity from fMRI and Electroencephalography (EEG)
- Source imaging from EEG e MRI



fMRI analysis



Time frequency analysis of brain connectivity

Neural tissue engineering

Focus

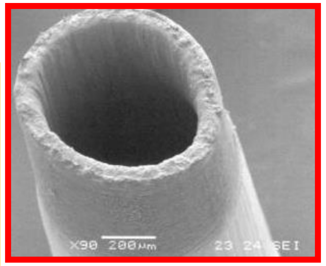
- Technological processes and materials to build neural grafts and promote their interaction with physiological neural tissue

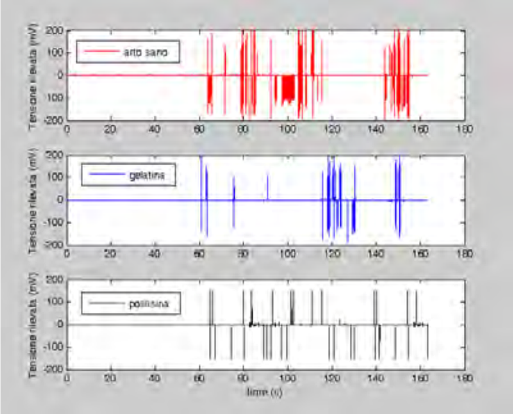
Learning Outcomes

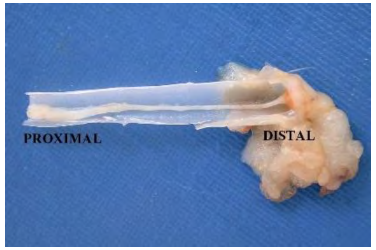
- Acquire the strategies to develop grafts and scaffolds that can be implanted to promote nerve regeneration and to repair neural damage

Main Contents

- Bioactive materials and their characterisation
- 2D and 3D Fabrication
- Neuro-Chemical functionalisation







Interactive systems

Focus

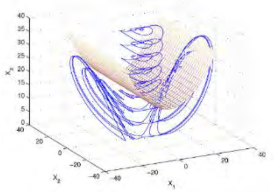
- Design of interactive robots and machines
- Advanced techniques for monitoring and process physiological signals for studying emotions

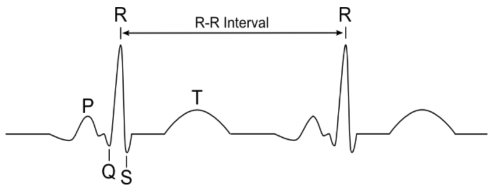
Main Contents

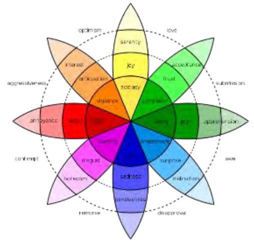
- Human-centred Design
- Internet of things
- Physiology of emotional response
- Computatitonal modeling of emotions
- Eye tracking, body movement analysis and facial emotion recognition

Learning Outcomes

- Design of systems able to interface with humans and based on a “human-centered design”
- monitor and process of physiological signal corresponding to different emotional states







Bionic senses

Focus

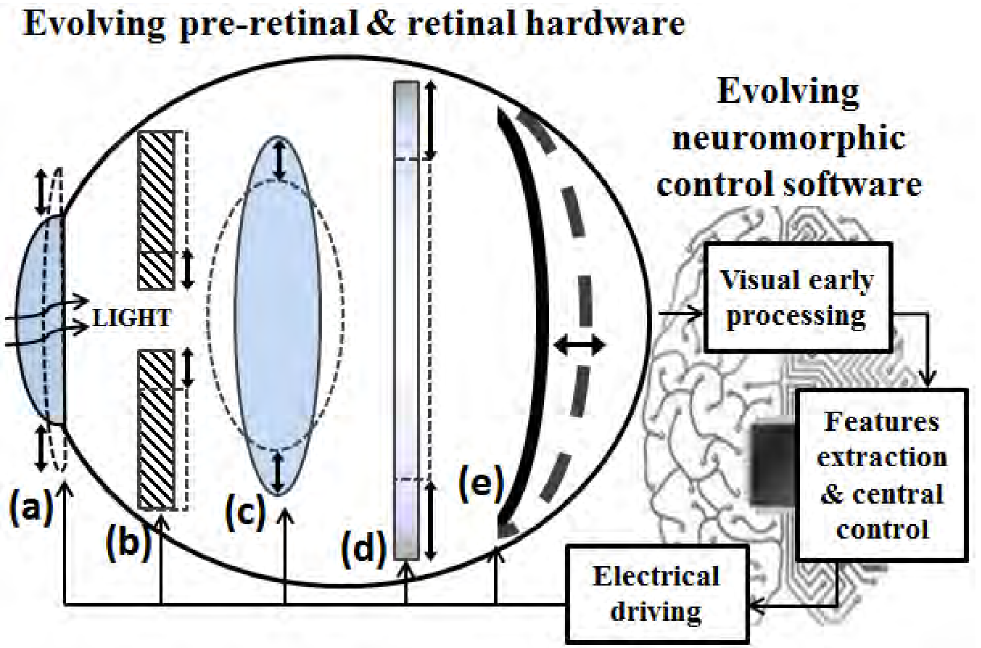
- Pre-neural and neural components of human and animal senses.
- Bionics senses design

Learning Outcomes

- Engineering artificial sensing and perceptual systems through biological principles to implement neural-prostheses to restore lost functions, for human augmentation and bio-inspired perceptional machines

Main Contents

- Introduction to natural senses
- Properties of biological receptors
- Physics of pre-neural media
- Sensations and perceptions
- The human senses
- Modeling and design of bionic senses



M.Sc. in Bionics Engineering

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Bionic senses (Alessandro Tognetti) - 6 ECTS	

Final duties: Lab training (3 ECTS) and Thesis (15 ECTS)

Integrative cerebral function

Focus

- Cognitive and emotional brain functions as the by-product of the activity of anatomo-functional distributed and integrated brain networks.

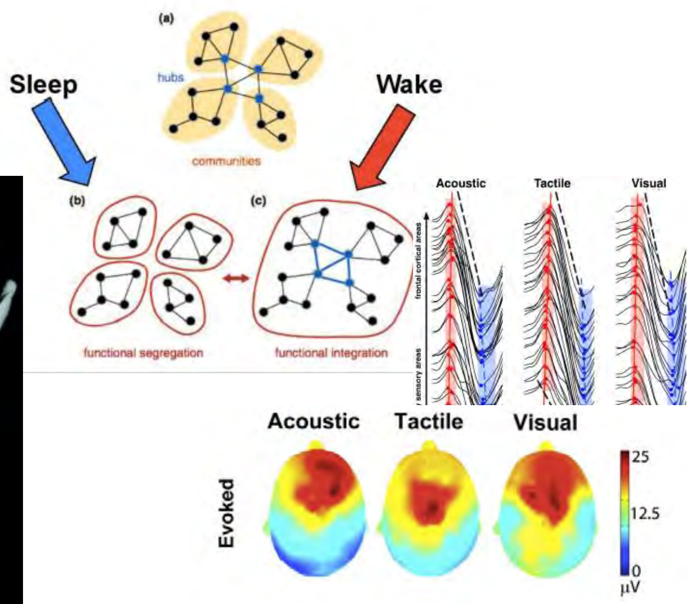
Learning Outcomes

- Methodological aproach for the study of complex brain functions and their biological bases

Main Contents

- Node and rich-clubs in the human connectome
- Sleep, mentation and dreaming
- Biological bases of consciousness
- Theory of mind and mirror neuron system
- Empathy in the emotional context

  Stress in the context of body and mind integration



Neural interfaces and bioelectronic medicine

Focus

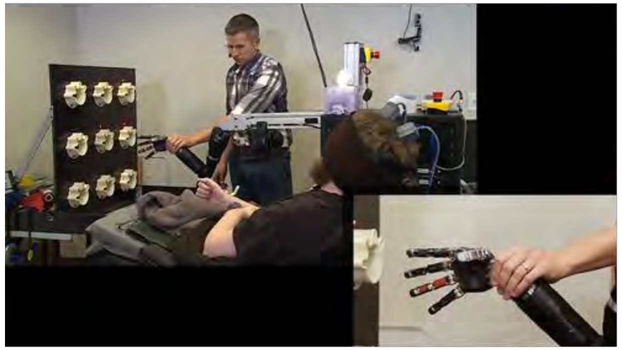
- Implantable neuroprostheses

Main Contents

- Brain-to-machine interfaces
- Artificial limbs with neural control
- Sensory and motor neuroprostheses
- Neuromodulation of the autonomic nervous system

Learning Outcomes

- Provide students with methodologies for the development and validation of implantable systems for neuromodulation



Affective computing

Focus

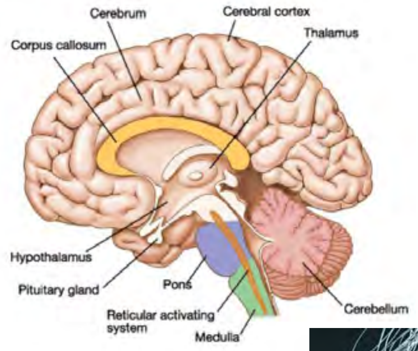
- Advanced computational techniques and instrumentations for monitoring and process physiological signals for studying emotions.

Main contents

- Physiology of emotional response; Computational modeling of emotions; Origin, processing and monitoring of ECG, breathing pattern, EDA and voice; Nonlinear methods and models for biomedical signal processing; Eye tracking, body movement analysis and facial emotion recognition

Learning Outcomes

- Acquire basic knowledge to monitor and process physiological signal corresponding to different emotional states.



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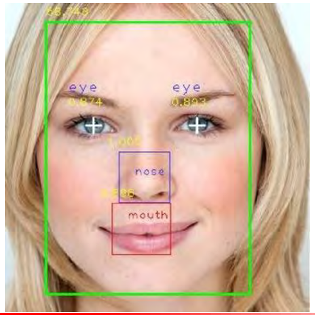

M.Sc. in Bionics Engineering

2nd year – Curriculum: Biorobotics	
1st semester	**2nd semester**
Biomechanics of human motion (Vito Monaco) – 6 ECTS	Robotic and data-driven rehabilitation (M. Chiara Carrozza) – 6 ECTS
Prostheses (Christian Cipriani) – 6 ECTS	Exoskeletons (Nicola Vitiello) – 6 ECTS
Robotics for minimally invasive and targeted therapy (Arianna Menciassi) – 6 ECTS	Bionic organs and tissues (Leonardo Ricotti) – 6 ECTS
Design principles for bionic tissue engineering (Arti Ahluwalia) – 6 ECTS	

2nd year – Curriculum: Neural Engineering	
1st semester	**2nd semester**
Advanced image processing (Nicola Vanello) – 6 ECTS	Integrative cerebral function (Angelo Gemignani) – 6 ECTS
Neural tissue engineering (Giovanni Vozzi) – 6 ECTS	Neural interfaces and bioelectronic medicine (Silvestro Micera) – 6 ECTS
Interactive systems (Daniele Mazzei) – 6 ECTS	Affective computing (Enzo Pasquale Scilingo) – 6 ECTS
Bionic senses (Alessandro Tognetti) - 6 ECTS	

Final duties: Lab training (3 ECTS) and Thesis (15 ECTS)

Lab training (3 CFU)

This activity will consist of 75 h of Lab training that the student will perform in dedicated facilities and laboratories, with the aim to increase his/her experience in laboratory practice.

Thesis (15 CFU)

The final examination involves the preparation of a report on a research activity, and in its presentation and discussion.