Intellectual Output_O1:
EMERALD e-book for developing of biomimetic mechatronic systems

MODULE 6
BIOMECHATRONICS

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EUROPEAN NETWORK FOR 3D PRINTING OF BIOMIMETIC MECHATRONIC SYSTEMS - EMERALD

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EUROPEAN NETWORK FOR 3D PRINTING OF BIOMIMETIC MECHATRONIC SYSTEMS

MODULE 6– BIOMECHATRONICS

Project Title	**European network for 3D printing of biomimetic mechatronic systems 21-COP-0019**
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Module	**Module 6 – Biomechatronics**
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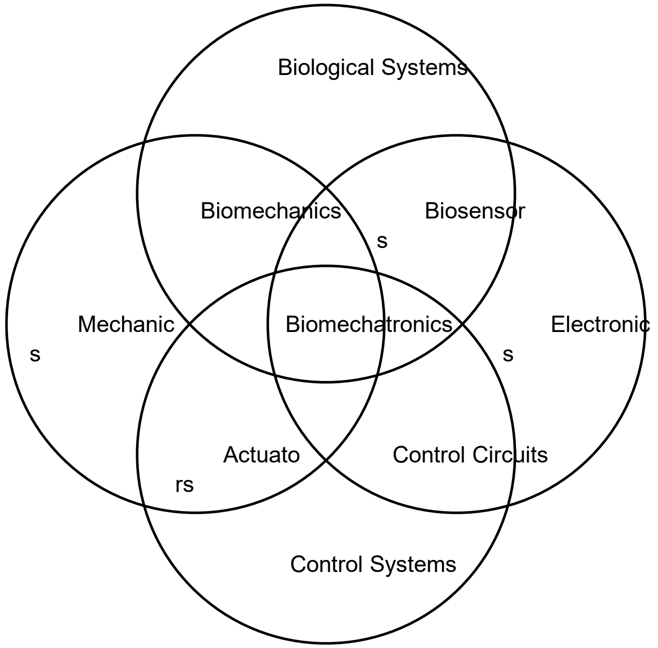

Biomechatronic is a combination of complementary fields.

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The History and Development of Biomechatronics

The origins of biomechatronics can be traced back to the early 20th century, with the development of prosthetic devices that used mechanical components to mimic the movement of natural limbs [4]. In the 1960s and 1970s, the field of biomechanics emerged, which focused on the study of the mechanics of human movement and its applications in the design of artificial limbs and other devices [1]. In the 1980s and 1990s, the field of biomechatronics emerged, which combined the principles of biomechanics with electronics and control systems to create more advanced and sophisticated technologies [3].

In recent years, there have also been significant advances in the development of exoskeletons, which are wearable devices that can assist with movement and support the body's weight [10]. Exoskeletons can be used to assist individuals with spinal cord injuries or other mobility impairments to walk, as well as to enhance the physical capabilities of individuals without disabilities, such as military personnel or athletes [6].

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Current and Future Applications of Biomechatronics

Biomechatronic technologies have a wide range of applications in the medical, sports, and entertainment industries [1]. In the medical field, biomechatronic devices are used to assist with surgeries, monitor and treat patients, and rehabilitate individuals with disabilities or impairments [5]. Examples of medical applications of biomechatronics include artificial limbs, exoskeletons, and assistive devices for individuals with spinal cord injuries [11].

In the sports industry, biomechatronic technologies are used to design advanced athletic training equipment and to enhance the performance of professional athletes [6]. These technologies can be used to improve strength, endurance, and speed, as well as to prevent injuries [9]. In the entertainment industry, biomechatronic technologies are used to create realistic special effects and to design interactive experiences [10].

Looking to the future, it is likely that the field of biomechatronics will continue to evolve and expand into new areas.

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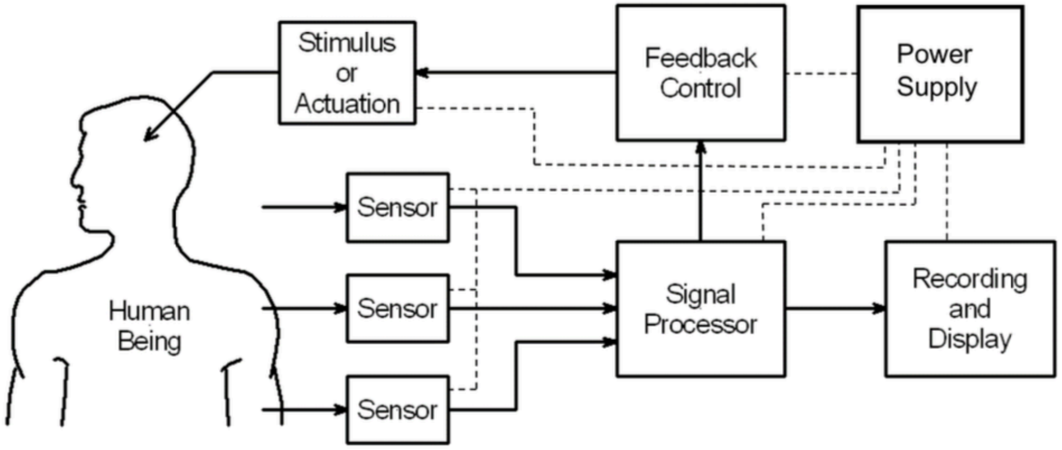
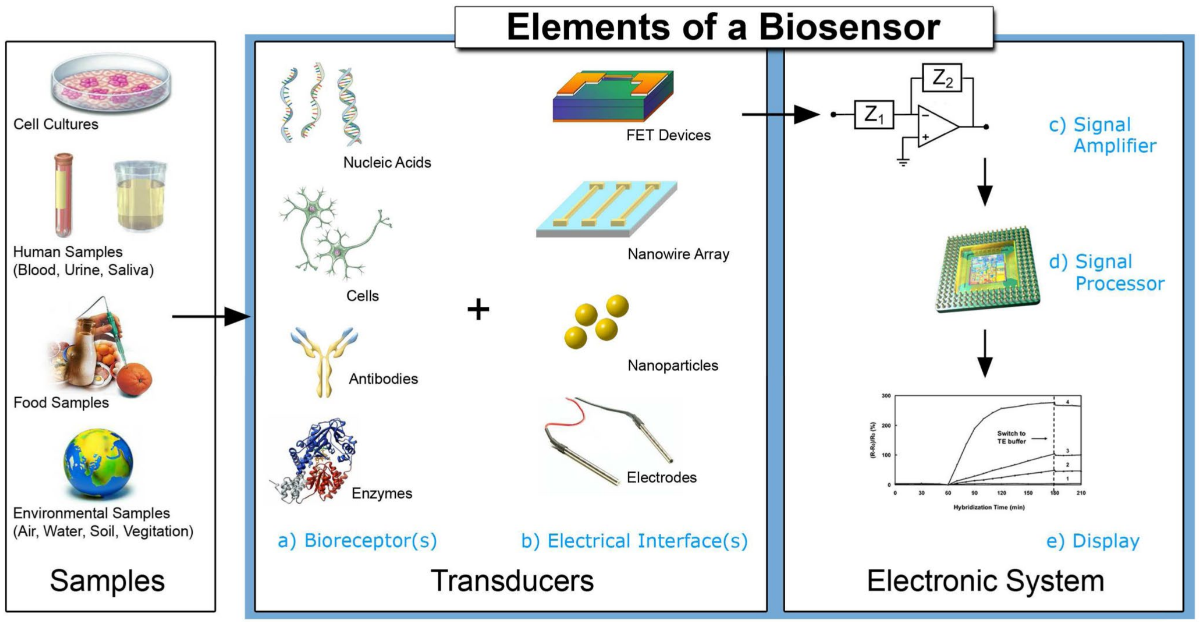


Principle of operation of biomechatronic system



Principle of operation of biosensors

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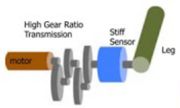
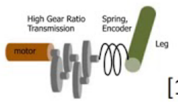
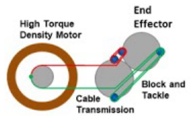
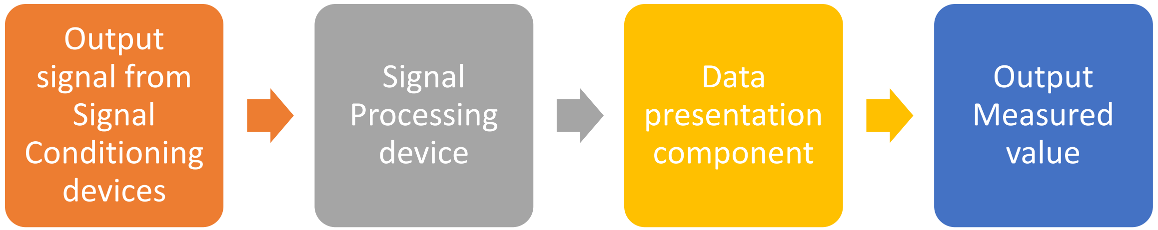
Quasi-Direct Drive: A New Actuation Paradigm

Position Control

Force control

	Geared Motor with Force/Torque Sensor	Geared Motor with Series Elastic Unit	Quasi Direct Drive Actuator
Bandwidth	Medium	Low	High
Backdrivability	Low	High	High
Weight	Medium	Heavy	Light
Actuation paradigm	 [1]	 [1]	

Quasi-direct drive in biomechatronic devices: paradigm shift [17]



Signal transferring in biomechatronic devices

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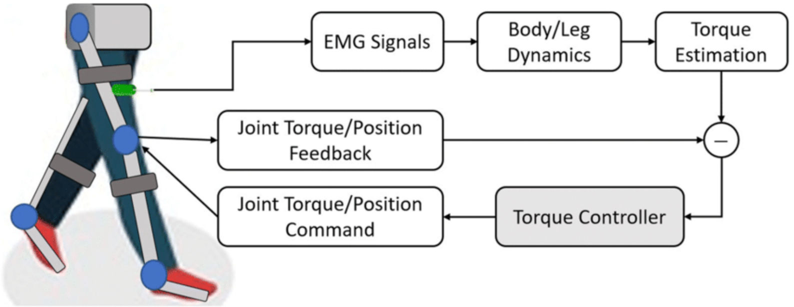
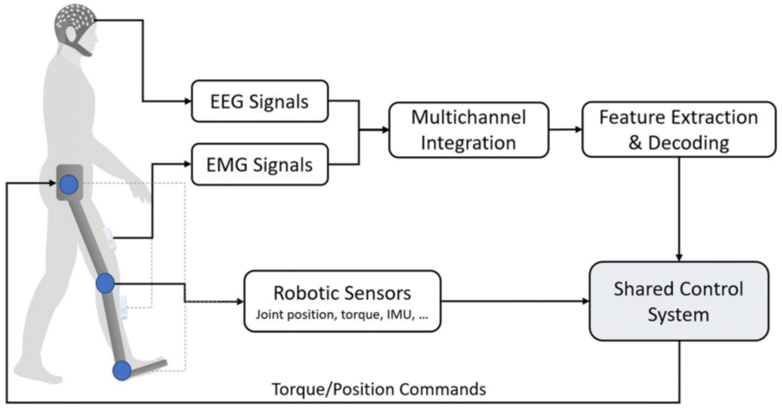
Lower limb exoskeleton control scheme



(a)



(b)

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Examples of biomechatronic systems

1. Teaching Motion Control in Mechatronics Education Using an Open Framework Based on the Elevator Model

This paper proposes a new open prototyping framework, shown in figure 2, for teaching motion control in mechatronics education using low-cost commercial off-the-shelf components and tools. The framework contains theoretical lectures as well as hands-on laboratory projects that mix surface and deep learning components to help students to create connections and enhance their knowledge. The course structure and main themes are described, and the suggested framework, which incorporates an elevator model, is detailed.

The all in one servo lab (AIOSL).

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Examples of biomechatronic systems

2. A Novel Adaptive Sliding Mode Controller for a 2DOF Elastic Robotic Arm

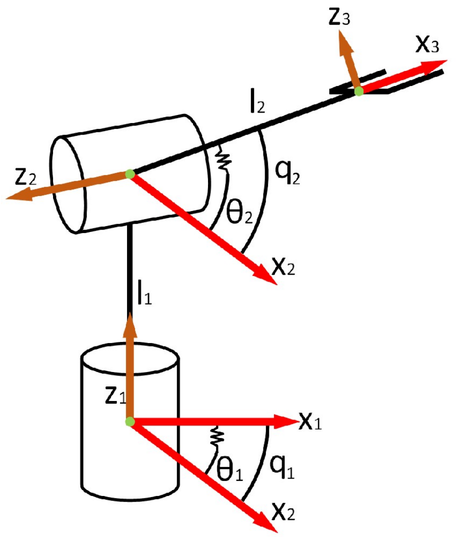
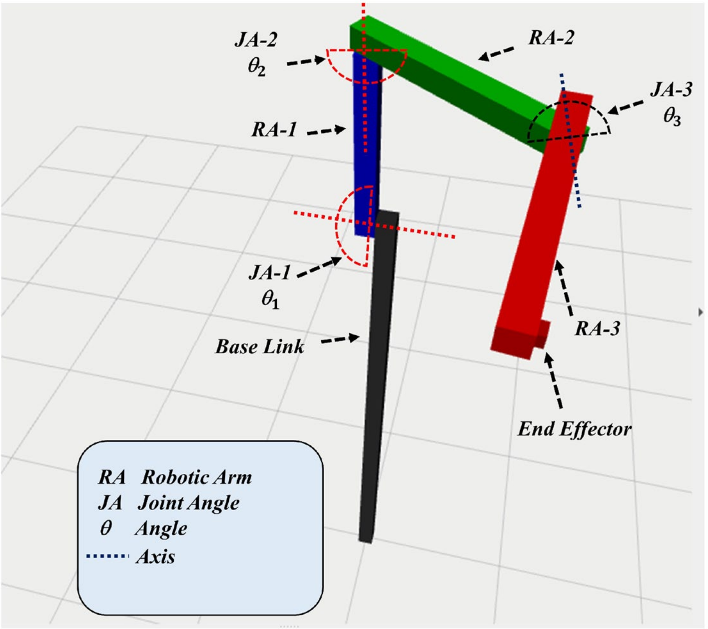
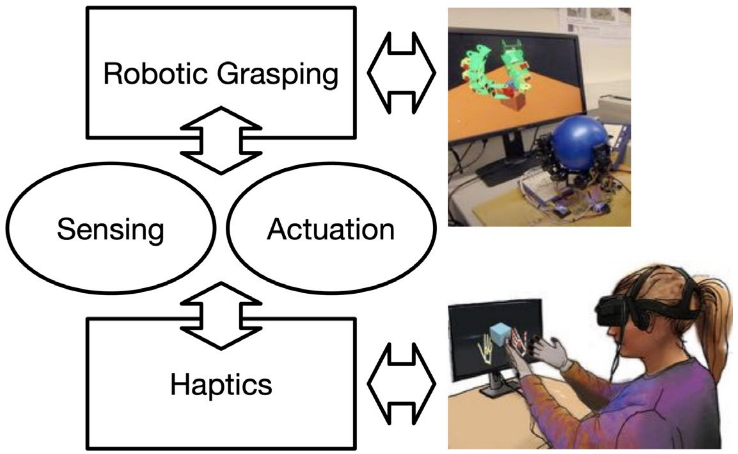


Diagram of the elastic robot arm



Kinematic model of the 3-DOF manipulator designed in ROS-RVIZ. JA represents the the joint angles while RA represents the arm length.



The combination of the advancements in sensing/actuation technology with the betterment of haptic rendering represents a promising opportunity towards the achievement of an effective human-robot interaction (HRI).

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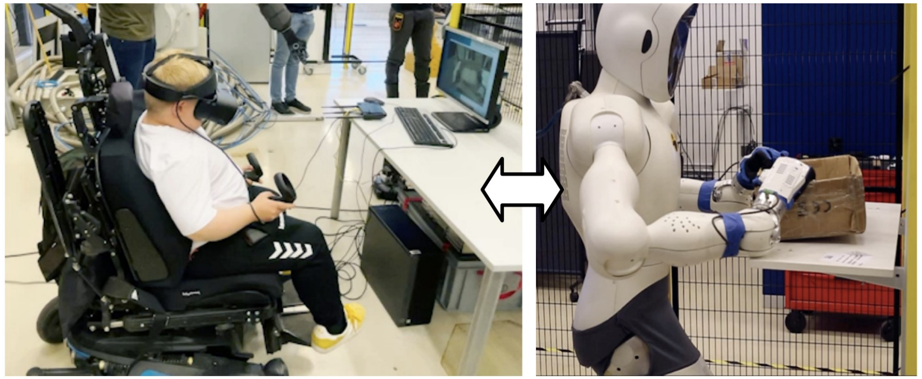
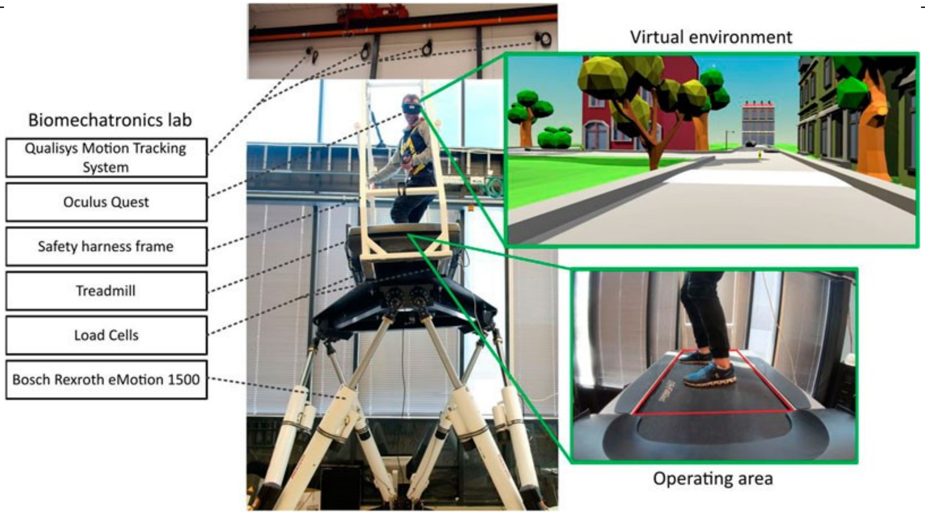
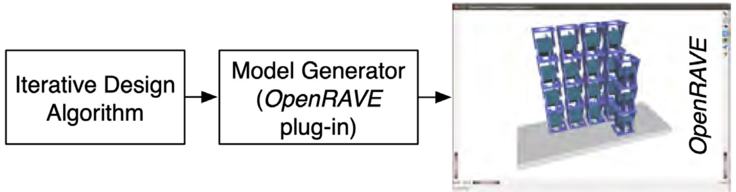


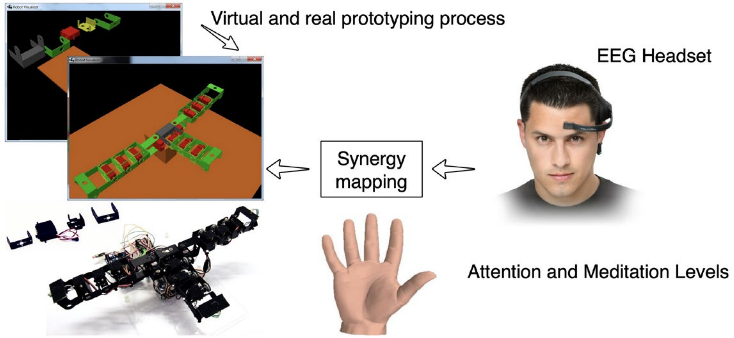
A mixed reality (MR) enabled proprio and teleoperation of a humanoid robot for paraplegic patients.



Biomechatronics lab.



The idea of realising a plugin for OpenRAVE that allows for a fast and automated generation of different modular hand models.



To show the potential of the new ModGrasp control architecture, a mind-controlled, three-fingered modular manipulator is presented. A demo video is available on-line at http://youtu.be/2CIYboez9r0.

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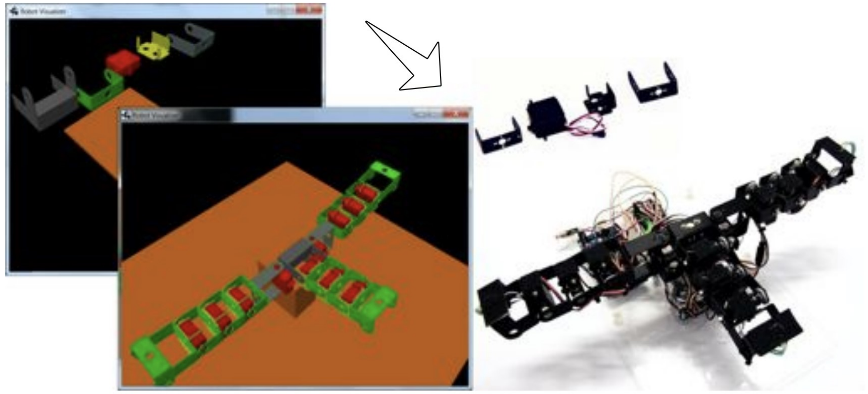
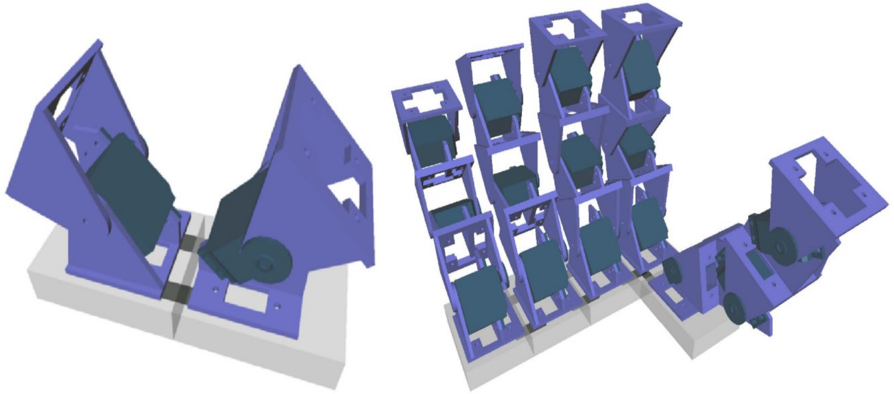


The idea of realising an integrated virtual and physical rapidprototyping framework for the design, simulation and control of low-cost sensorised modular hands.



The modular grasping idea: thanks to its flexibility, the device can reproduce both simple grippers and more sophisticated kinematics like anthropomorphic robotic hands

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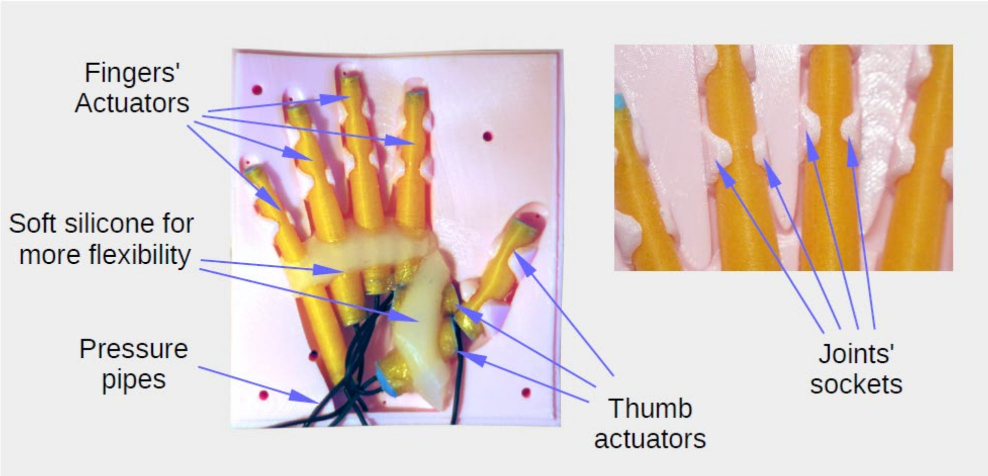
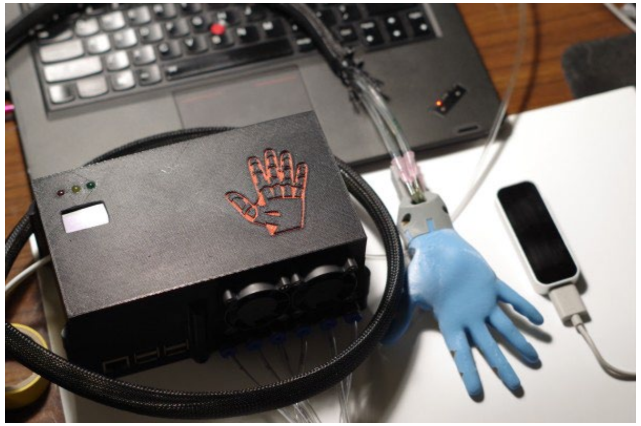
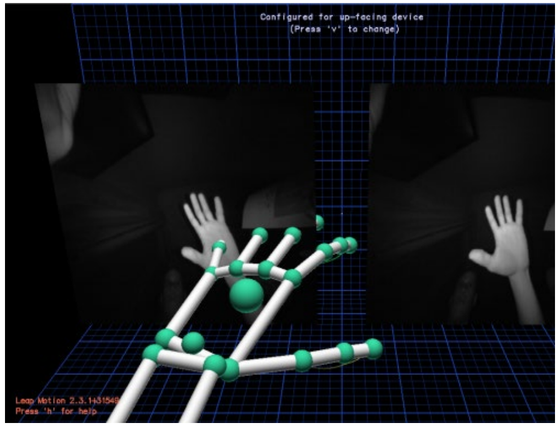
Soft biomimetic prosthetic hand



Alignment of pneumatic actuators in the main mould



The control unit and the LeapMotion controller



LeapMotion-based hand tracking

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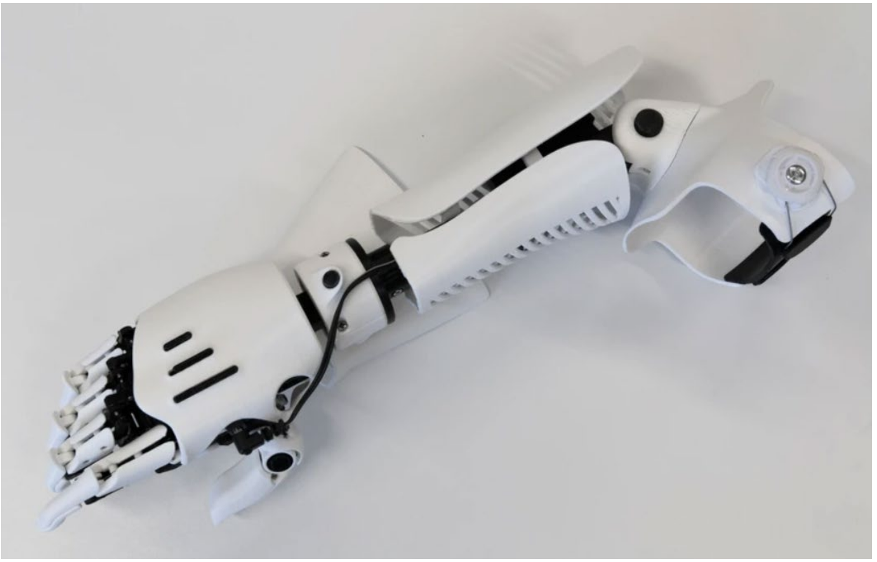
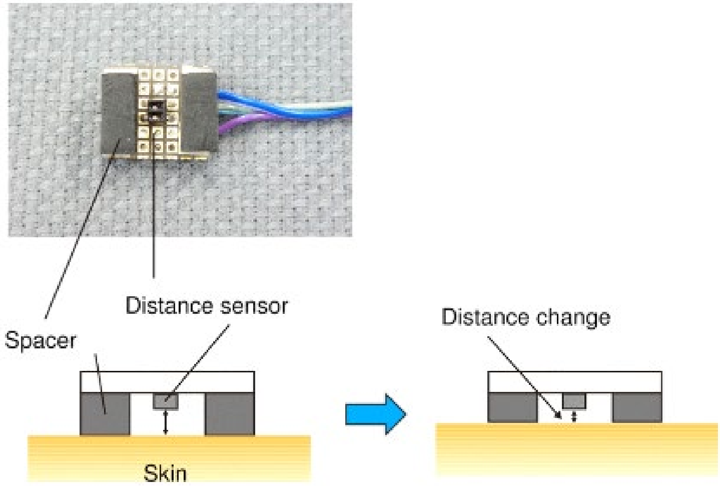
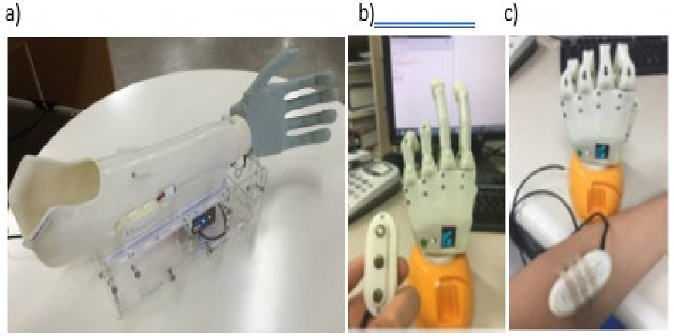
Rigid prosthetic hands



A view of the fully assembled prosthetic hand made by Rodolfo Antonio Salido Benítez [19]



Method of operation of the proximity sensor used [19]



(a) A single-channel electromyography (EMG) sensor was installed in the socket where the maximum voltage change in the amputated forearm was checked. (b, c) A prosthesis model with a surface EMG sensor detects the site of the largest voltage change in the myoelectric signal in the stump when the patient moves the rest of the forearm muscle. The voltage change is displayed on a screen on the hand. This model can be used for pre-application testing and for patient observation, three-dimensionally [21]

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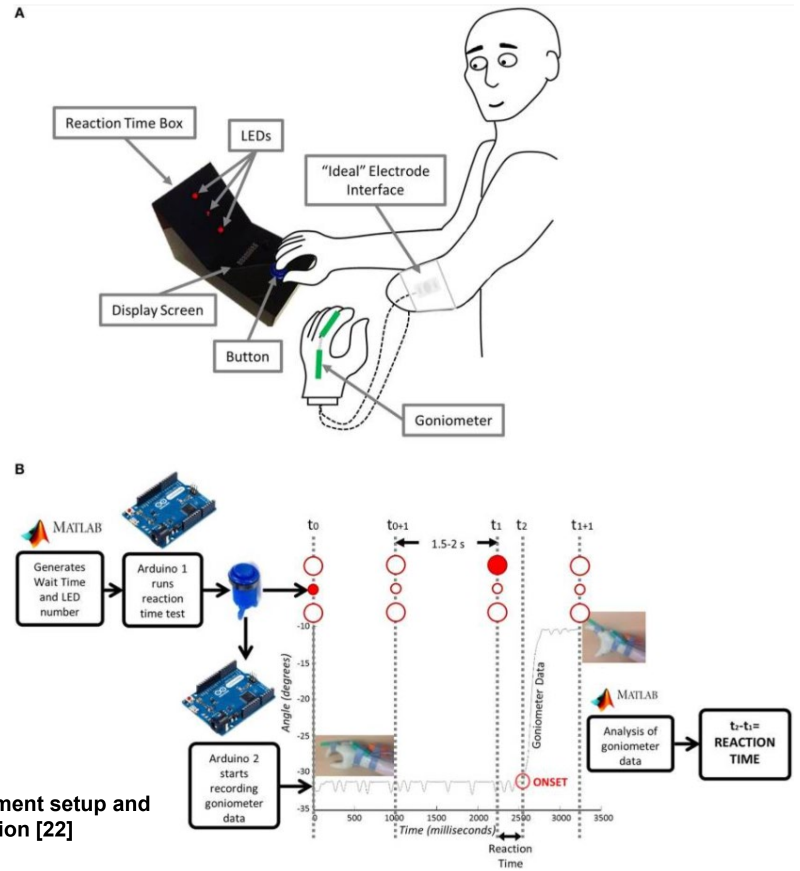
Rigid prosthetic hands

A prosthesis simulator for use in anatomically intact individuals. The socket is designed to fit over the forearm and fist. Straps allow the socket to be pressed against the person's arm. It is not possible to customize the electrode placement for each person [22]



Reaction time test: (A) Experiment setup and (B) basic instrumentation [22]

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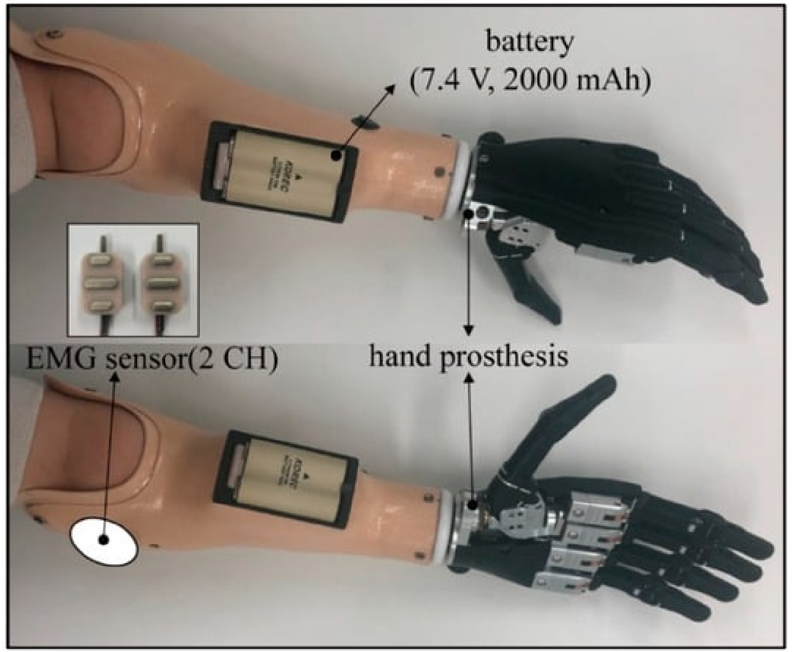

The developed multifunctional myoelectric hand prosthesis system [23]

The hand gestures and grip motions performable by the hand [23]

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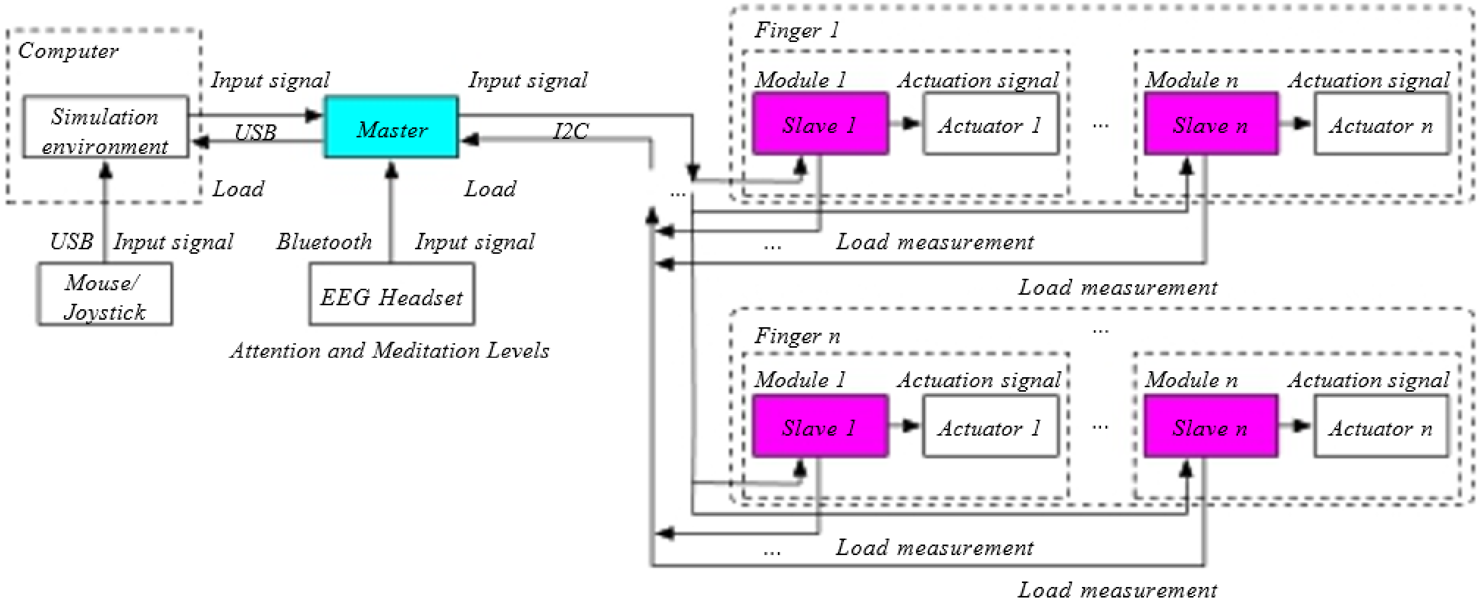
Bioinspired robotic hands – modular grasping (ModGrasp)



ModGrasp architecture

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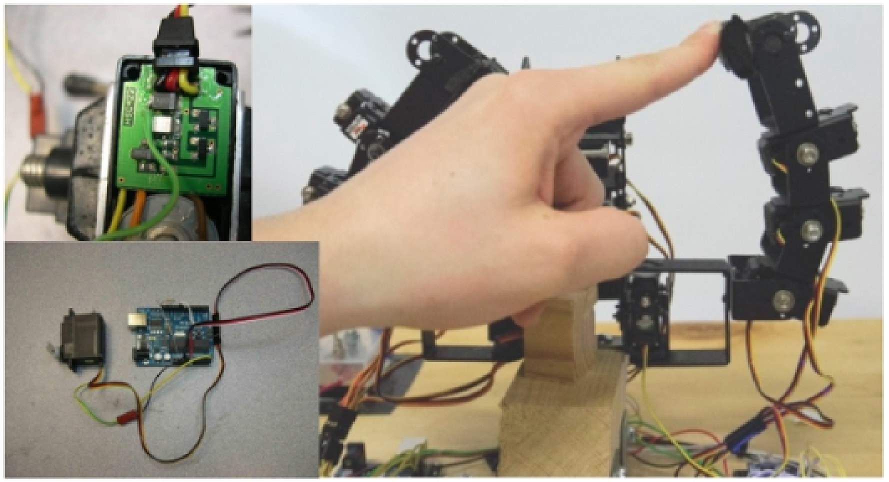
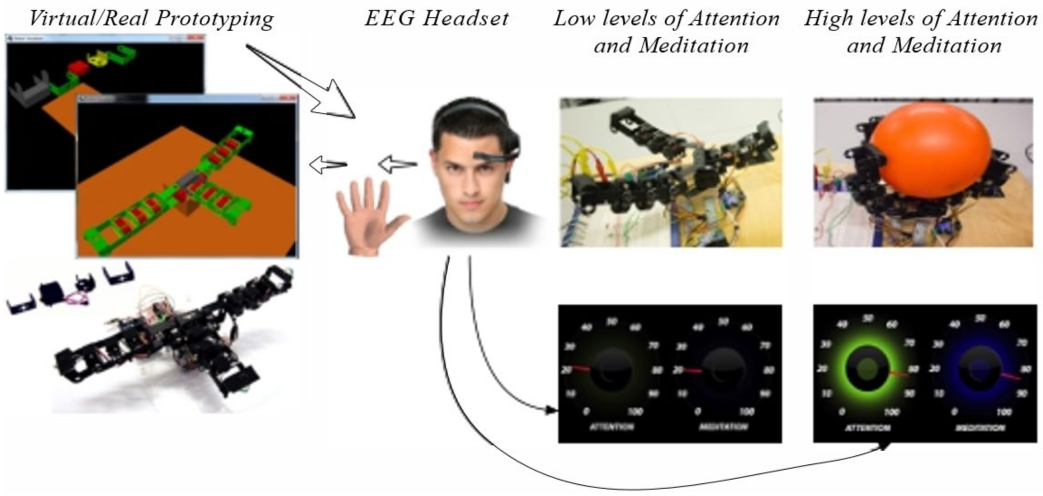
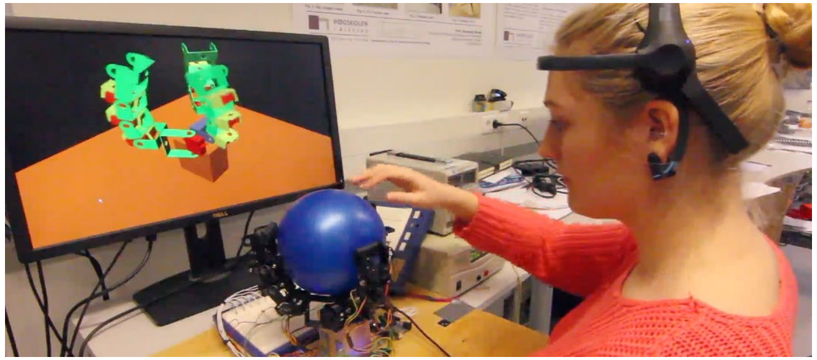


ModGrasp implementation – sensing of torque





ModGrasp implementation – mind control – concept (top) and experiment (bottom) [27]

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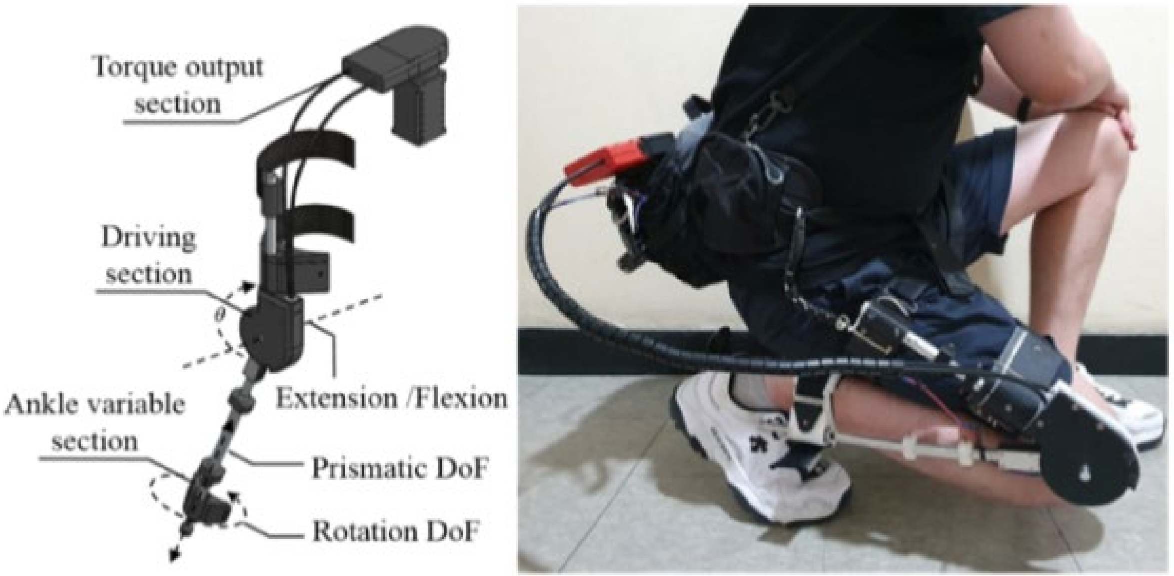
Biomechatronic exoskeletons

Alpha prototype of a wheelchair-exoskeleton hybrid robot in standing position (for walking over obstacles) and in wheelchair mode (for safe and energy-efficient movement over smooth surfaces) [28]



The full appearance of the exoskeleton and the actual wearing appearance, which presents the range of operation. The exoskeleton has three degrees of freedom (DoF). The knee has a flexion/extension DoF, the angle of which is indicated by θ. In addition, the ankle has a passive rotation DoF and a passive prismatic DoF. The range of motion of the exoskeleton is 145◦. The compliant structure allows the user to sit completely [30]

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Summary

In this e-learning module, basics of biomechatronics were shown. Some key concepts, descriptions of exemplary systems, as well as technical problems, challenges and opportunities were mentioned. The aim of this module was to familiarize the readers with the notion and get their attention to biomimetic, mechatronic systems possible to manufacture using additive manufacturing.

Despite the challenges, the potential benefits of biomechatronic systems are enormous. Biomechatronics has the potential to revolutionize healthcare and rehabilitation, enabling individuals with disabilities and injuries to regain function and independence. In addition, biomechatronic systems could be used to create entirely new functions that are not possible with biological systems alone. This could lead to new opportunities in fields such as robotics and space exploration.

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Summary

In conclusion, biomechatronics is an interdisciplinary field that holds enormous promise for the future of healthcare and rehabilitation.

Biomechatronic systems incorporate biological and mechanical components to achieve a specific function, and can be used for a variety of applications, including prosthetics, exoskeletons, and medical devices. Developing these systems requires a deep understanding of both biology and mechatronic engineering, and researchers in this field must be skilled in a wide range of disciplines.

The potential benefits of biomechatronic systems are enormous, and this field is likely to continue to grow in importance in the coming years.

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