DANIELE ESPOSITO

TUTOR: PROF. PAOLO BIFULCO

XXXIII CYCLE

1 ST YEAR PRESENTATION

Plethysmographic measurements and prosthetic hand control by means of force sensors

BACKGROUND

EDUCATION

B.Sc. in Biomedical Engineering (University of Naples, Federico II)
Design and development of an actigraph for the home measurement of motor activity

M.Sc. in Biomedical Engineering (University of Naples, Federico II)
Design and development of a control system for prosthetic hand

Ph.D. in Information Technology and Electrical Engineering

MIUR fellowship

Biomedical Group
Healthcare Automation, Biomedical Instrumentation and Telemedicine Laboratory

COLLABORATIONS

UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

Industrial Engineering Department
Prof. V.Niola, Prof. S.Savino

Aston University Birmingham

School of Life and Health Sciences
Prof. A.Fratini

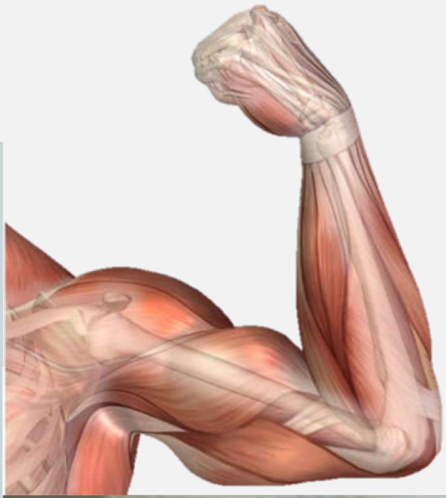
WESTERN SYDNEY UNIVERSITY

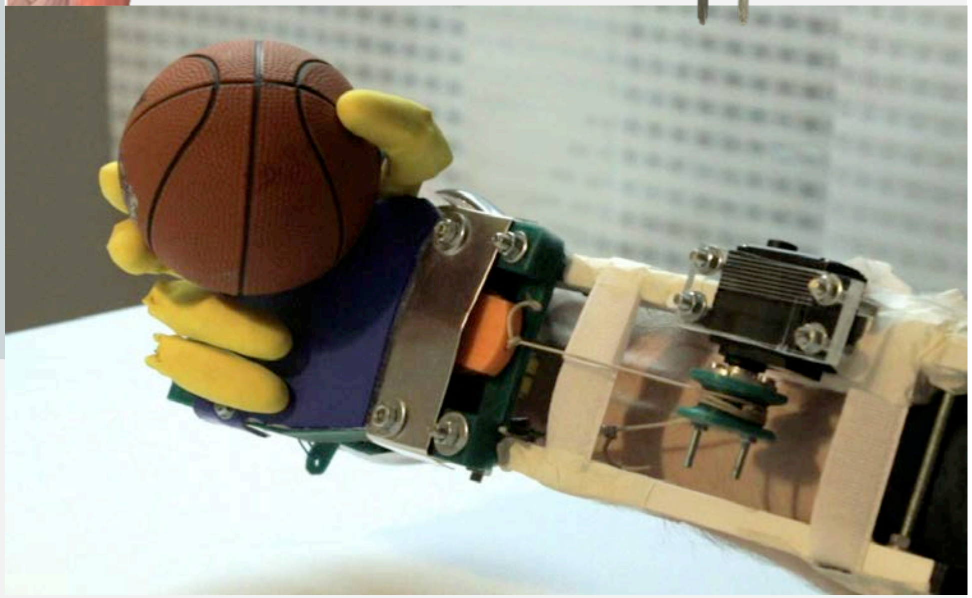
MARCS Institute
Prof. G.D.Gargiulo

RESEARCH ACTIVITY

- Measurement of muscle contraction by means of Force Sensitive Resistors (FSRs) sensors;

- Design of improvements to the prosthetic hand prototype and its control system.

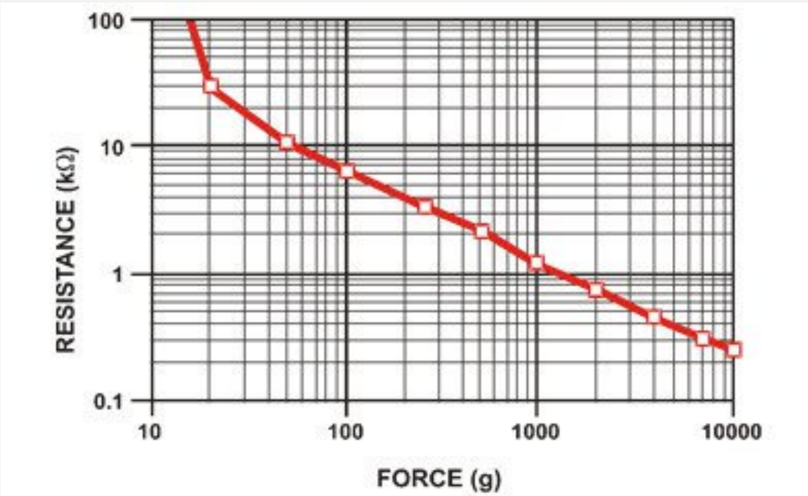




FORCE SENSITIVE RESISTOR (FSR)

Generally, FSRs consist of a conductive polymer, that exhibit a **decrease in resistance with increase in force** applied to the surface of the sensor.

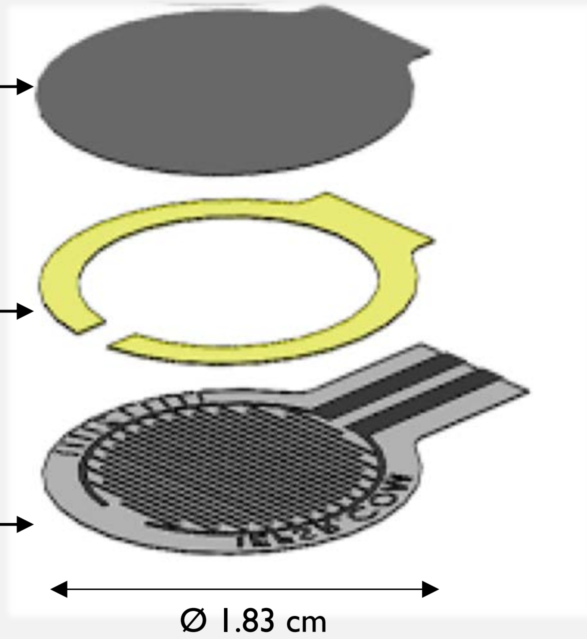
The assembling of the Interlink FSR includes **perimetric spacers** that separate the two membranes holding the **metallic contacts** and the **conductive polymer**.



Membrane with printed conductive polymer

Perimetric spacer

Membrane with printed electrodes

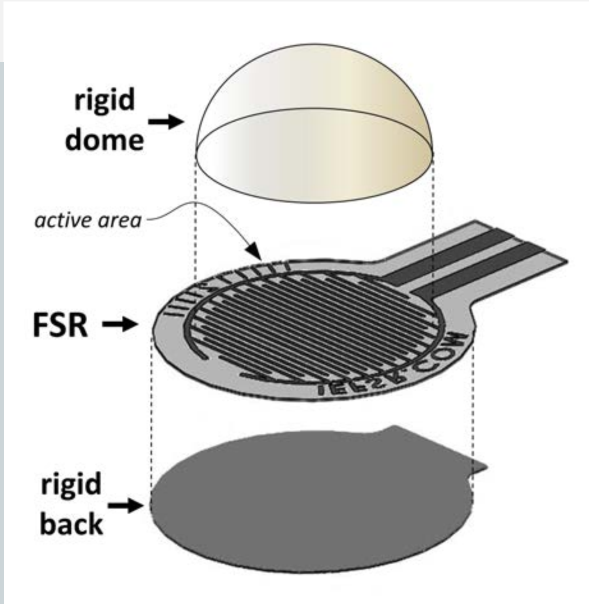


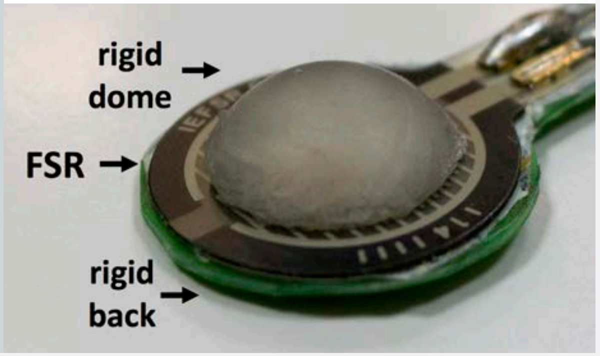
FORCE SENSITIVE RESISTOR (FSR)

In my study a ***Force Sensitive Resistor*** *(FSR)* placed on a patient's skin in correspondence with a muscle belly was used to sense muscle contraction.

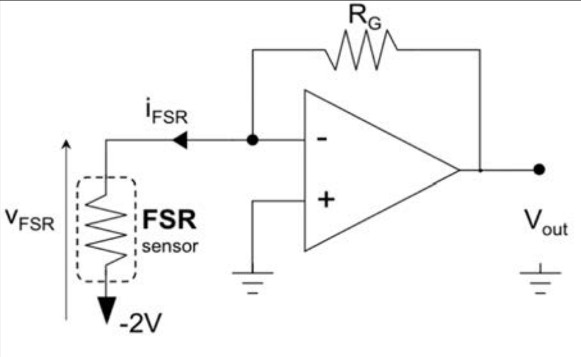
A specific mechanical coupler consisting of a rigid spherical cap (acrylic resin) facing the patient's skin, provides advantageous force transmission to FSR.

The increase of muscular transverse section during contraction, as well as the resultant skin stretching, impresses uniform pressure on the FSR active area via the rigid spherical cup.



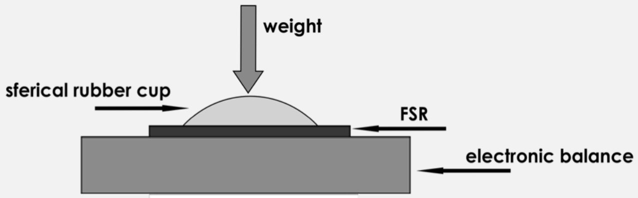


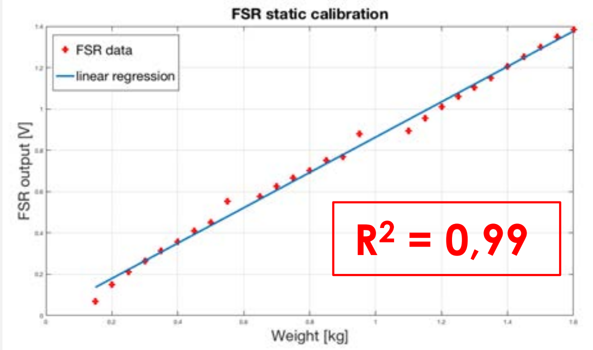
FSR CONDITIONING - STATIC AND DYNAMIC TEST

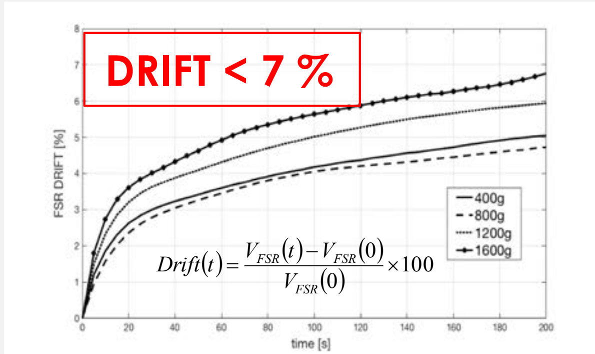


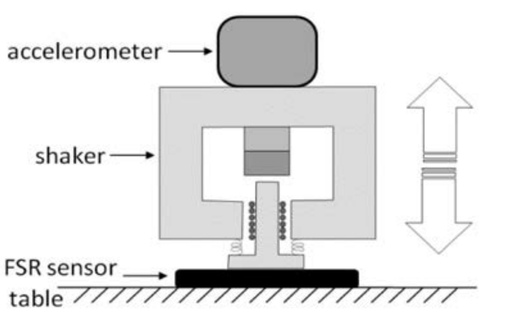
FSR conditioning, by means of an **op-amp trans-impedance amplifier**

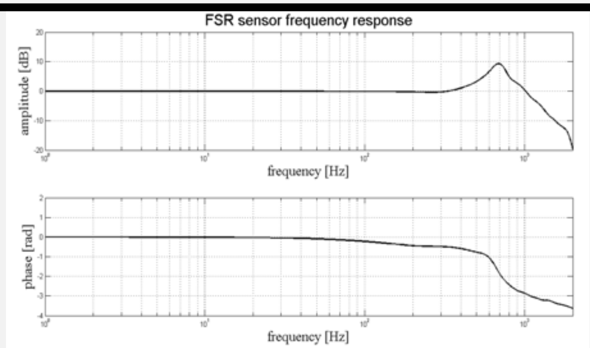
- provides **voltage output proportional to force**
- and **reduces the drift** by fixing the voltage across the FSR









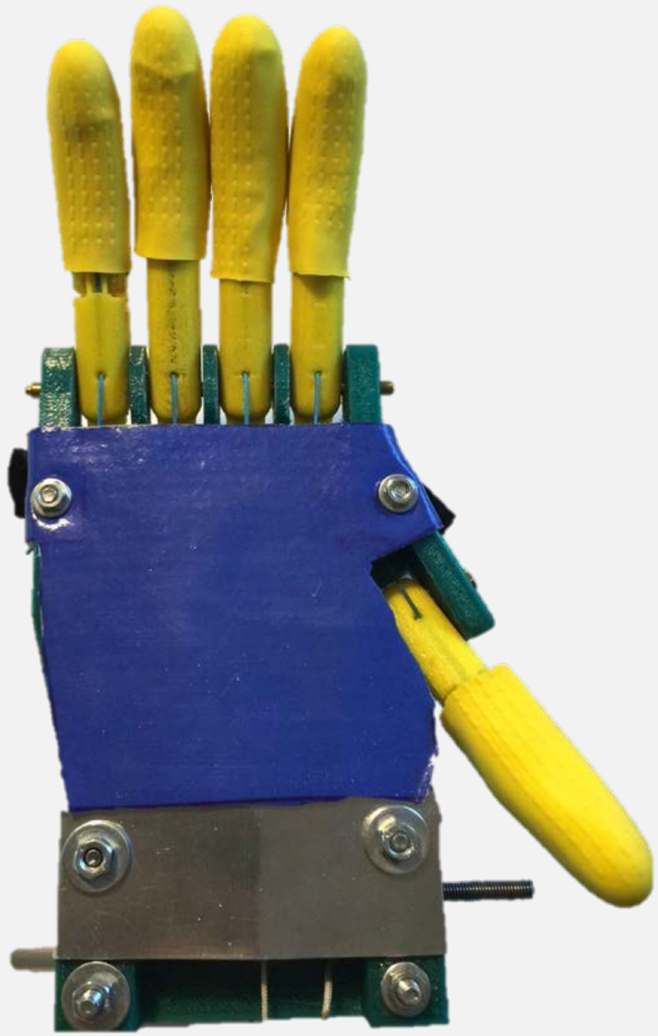


The frequency response of the FSR sensor was found to be large enough to correctly measure the **small mechanical vibrations** generated during muscle contraction (i.e., the **mechanomyography-MMG signal**).

Daniele Esposito

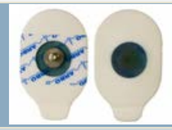
PROSTHETIC HAND

- Produced in PLA using a **3D Printer**;
- Equipped with **5 fingers and 15 phalanges**;
- **Differential mechanical system:** force distribution is always the same, regardless of the type of grip**;**
- **Underactuated:** 1 actuator for 15 phalanges;
- **Low cost** of realization.

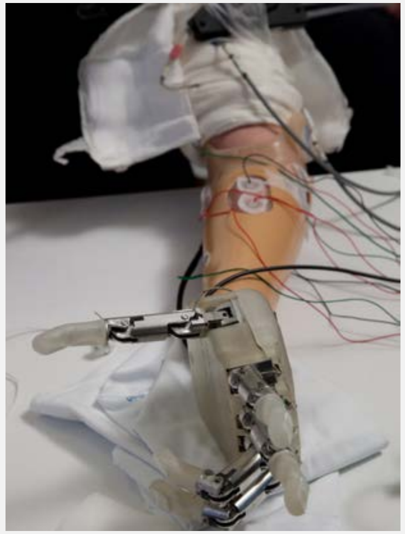


CONTROL SIGNAL FOR PROSTHETIC HAND

Limits of the EMG

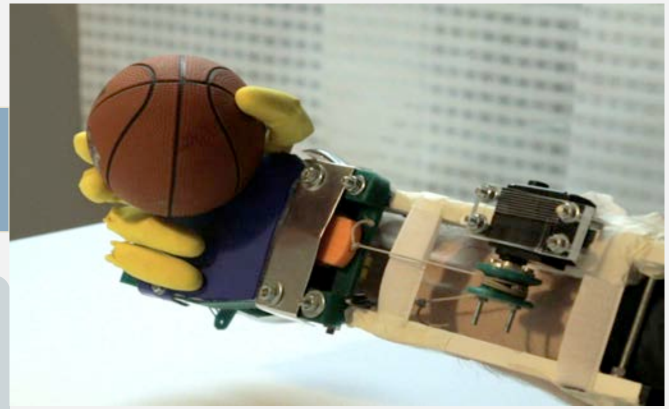


- the need of **electrodes, biopotential amplifiers and conductive gel** for stabilizing the skin/electrode electrical interface;
- **raw EMG signal needs to be pre-processed** (e.g., rectified and low-pass filtered) to extract its envelope;
- recordings are **very sensitive to external electromagnetic interference** and also to other sources of noise (motion artifacts, crosstalk with other biopotentials).



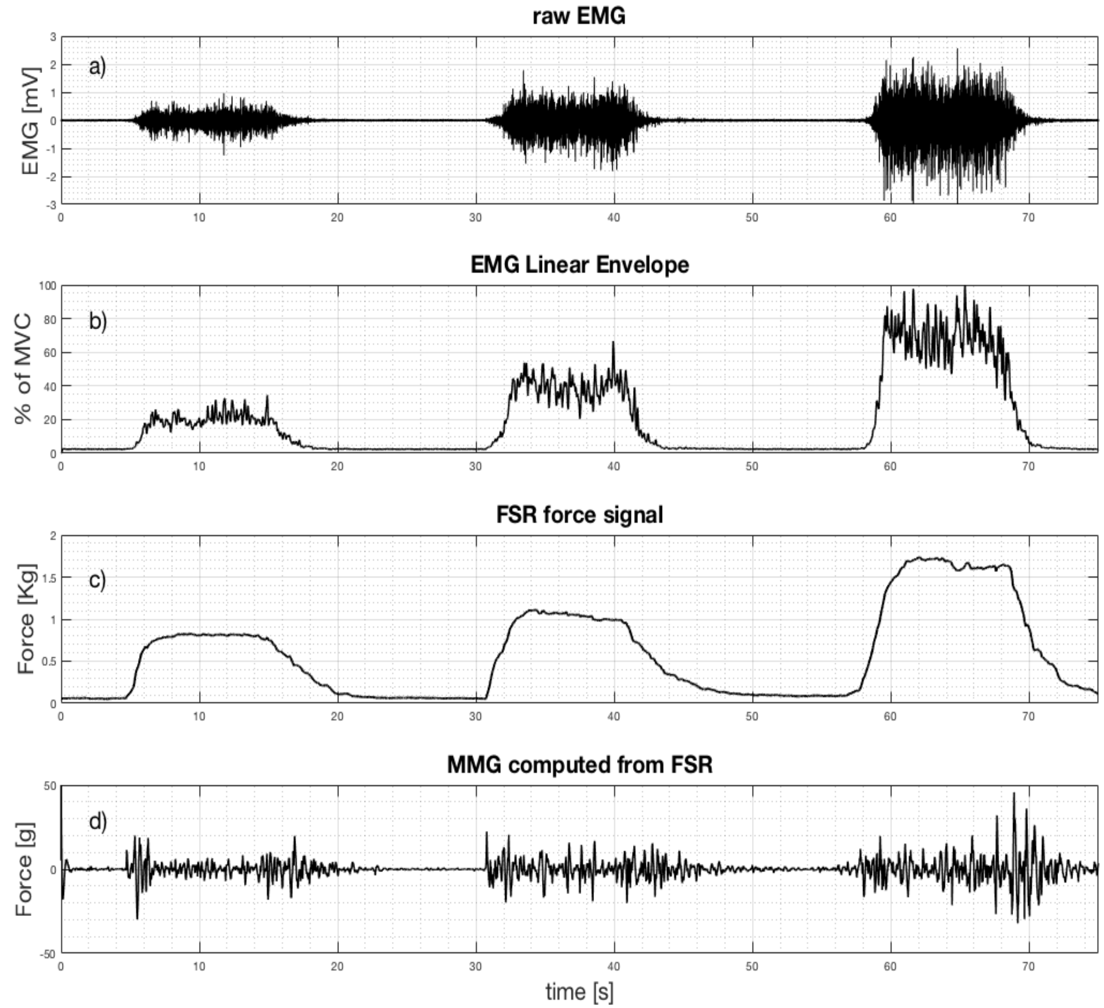
Force Signal

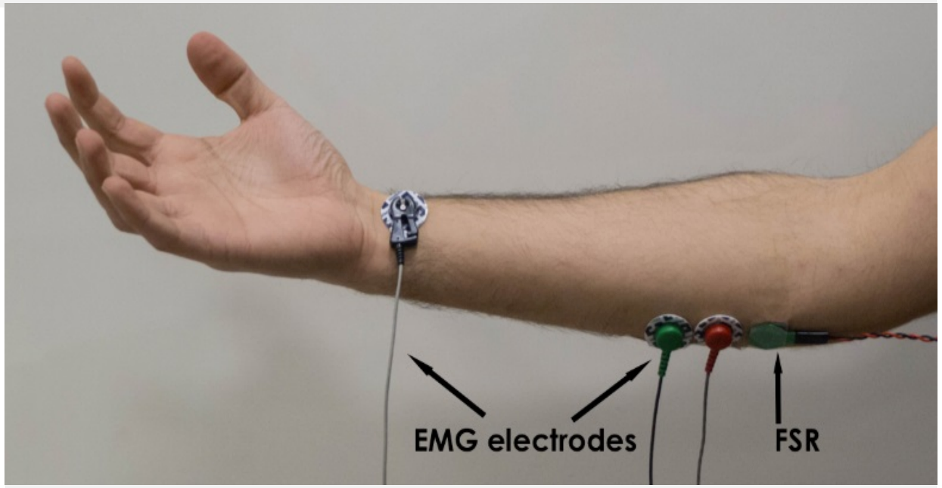
muscle contraction → **muscle volume variation** → **mechanical coupling** → **force sensor**



Daniele Esposito

FORCE SIGNAL VS EMG SIGNAL





There is clearly a good match between the **EMG linear envelope and the FSR force signal**.

The Pearson's correlation coefficient **"r" = 0.93** (*p*-value < 0.0001)

These tests suggest that the **FSR sensor can be a viable alternative to the EMG for controlling the hand prosthesis**.

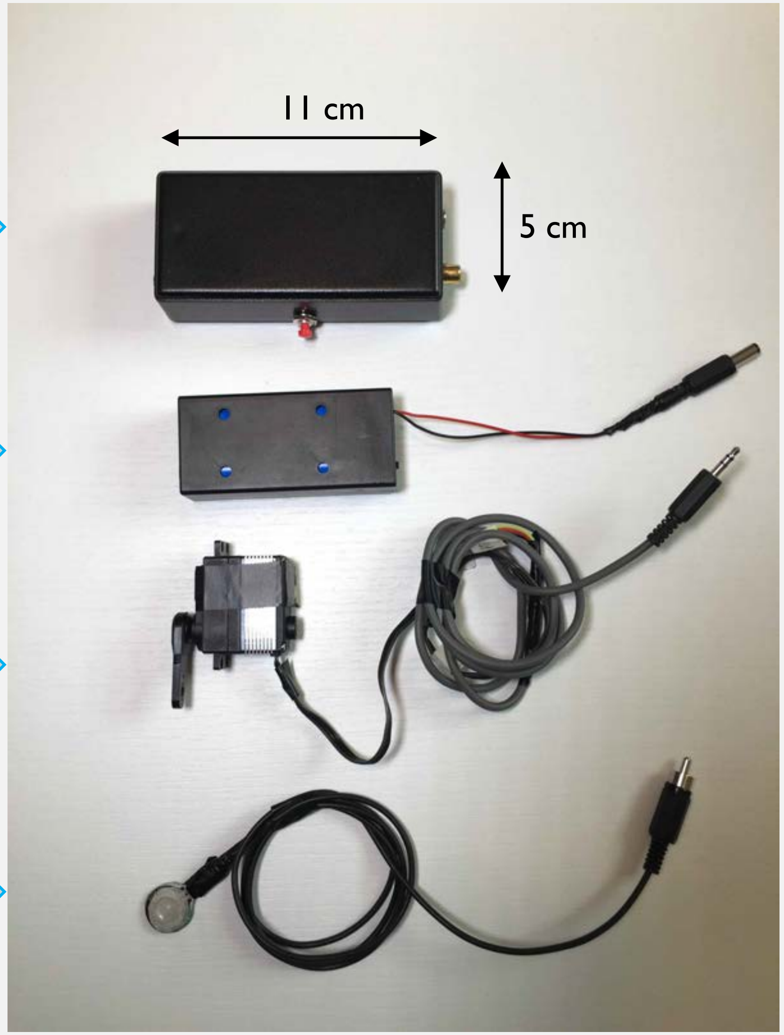
MODULAR PROTOTYPE CONTROL SYSTEM

Control System based on Arduino Nano

Battery Pack

Servomotor

FSR sensor



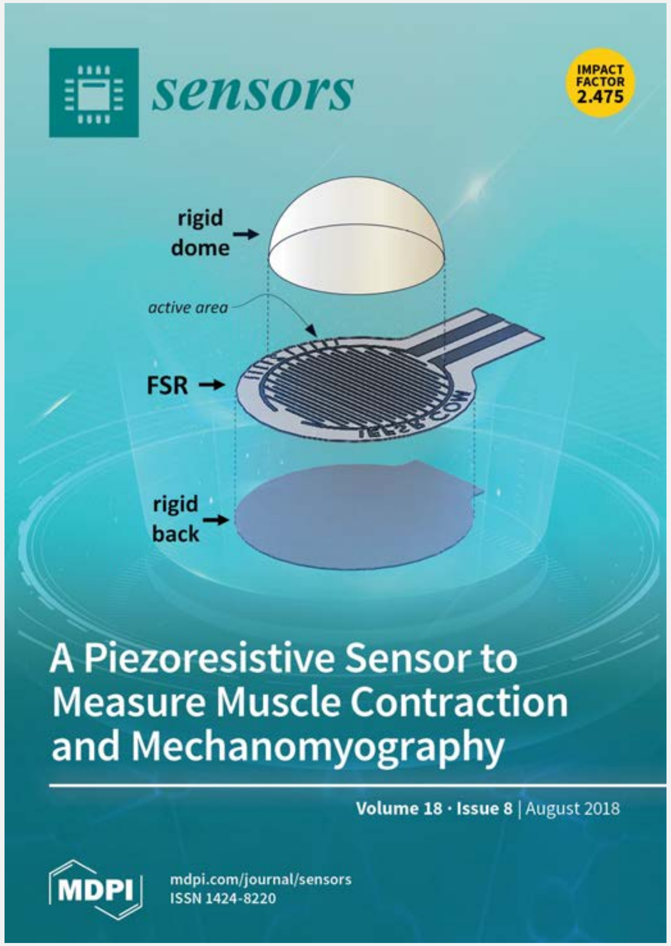
Daniele Esposito

FIRST YEAR PRODUCTION

JOURNAL PAPERS

1. D. Esposito, E. Andreozzi, A. Fratini, G.D. Gargiulo, S. Savino, V. Niola, P. Bifulco; *A Piezoresistive Sensor to Measure Muscle Contraction and Mechanomyography.* Sensors 2018 18(8), 2553, https://doi.org/10.3390/s18082553

2. E. Andreozzi, G.D. Gargiulo, A. Fratini, D. Esposito, P. Bifulco; *A Contactless Sensor for Pacemaker Pulse Detection: Design Hints and Performance Assessment.* Sensors 2018 18(8), 2715, https://doi.org/10.3390/s18082715.



NEXT YEAR

Work in progress:

- ***"array of FSR sensors"*** mounted on the forearm, in order to monitor the simultaneous activation of multiple muscles related to different gestures of the hand (**gesture recognition**);
- evaluation of different applications of FSR sensor for patient monitoring.

Student: Daniele Esposito daniele.esposito@unina.it

Tutor: Paolo Bifulco paolo.bifulco@unina.it

Cycle XXXIII

	Credits year 1								Credits year 2								Credits year 3									
		1	2	3	4	5	6			1	2	3	4	5	6			1	2	3	4	5	6			
	Estimated	bimonth	Bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Total	Check
Modules	20	0	0	0	2.4	6	9.4	17.8	10							0	0							0	17.8	30-70
Seminars	5	0	0	2.8	0	5	0	7.8	5							0	0							0	7.8	10-30
Research	35	5	8	9.2	2.6	4	5.6	34.4	45							0	60							0	34.4	80-140
	60	5	8	12	5	15	15	60	60	0	0	0	0	0	0	0	60	0	0	0	0	0	0	0	60	180

THANK YOU
FOR YOUR KIND ATTENTION