SAPIENZA
UNIVERSITÀ DI ROMA

MECHANICAL & BIOMECHANICAL MEASUREMENTS

Research Activities

DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

SSD ING-IND/12

Research Group

Zaccaria (Rino) DEL PRETE	*P.O.*
Eduardo Palermo	*RTD A*
Emanuele Rizzuto	*RTD A*
Livio D'Alvia PhD	*research fellow*
Ilaria Mileti PhD	*research fellow*
Francesca Martelli PhD	*research fellow*
Francesco Rapanotti	*technician*

PhD candidates	*3rd year PhD students*	*2nd year PhD students*	*1st year PhD students*
	Ludovica Apa	**Ilaria Conforti**	**Serena Carraro** **Flavia Forconi**

Scientific Metrics and Awards

Bibliometry (Scopus)

	Del Prete	*Palermo*	*Rizzuto*	*D'Alvia*	*Mileti*	*Martelli*	*ASN PA*	*ASN PO*
Journals & Proc.s	68	42	43	7	9	6	8	15
h-index	13	9	15	2	4	1	6	10
Citations	698	382	998	8	34	4	91	277

Recent Awards :

Best woman in engineering paper - MeMeA 2016
Premio Sapio 2016
BTS young researcher - SIAMOC 2016
Premio Gibertini 2016 – Best poster GMEE GMMT

Big Grants

- PROJECT SEED ITINERE, funder IIT, Italian Ministry of Health, and FILAS Lazio, PI: Paolo CAPPA
- PRIN 2012, funder Italian Ministry of Health
- MD-PAEDIGREE, funder EU, PI: Paolo CAPPA
- PROJECT NATURA at CLNS@Sapienza, funder IIT, PI: Zaccaria Del Prete
- FAR SEAS 2012&2016, funder Ministry of Defense, Co-PI: Zaccaria Del Prete

Laboratories and Cooperation

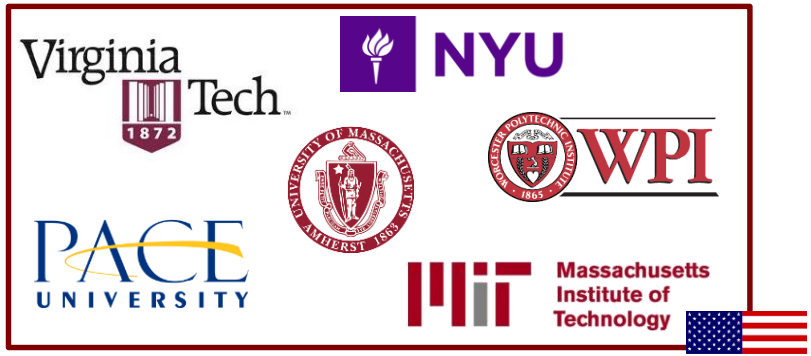
Mechanical and Thermal Measurement Laboratory *(c.o. DIMA)*

Tissue Engineering Laboratory
(c.o. SAIMLAL)

Tissue Biomechanics Laboratory at
Center for *LifeNanoscience@Sapienza - iit*

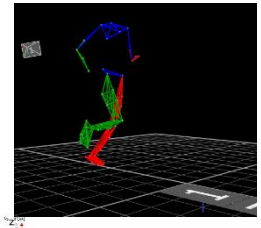
Industrial Engineering Laboratory
Dr. Stefano Rossi RTD-B

Research Partners

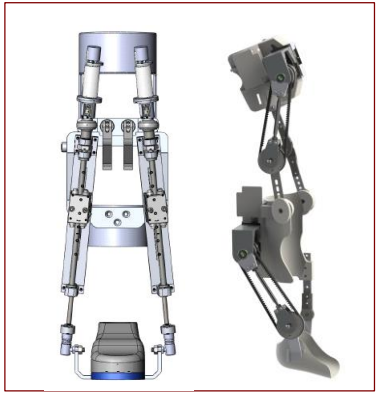


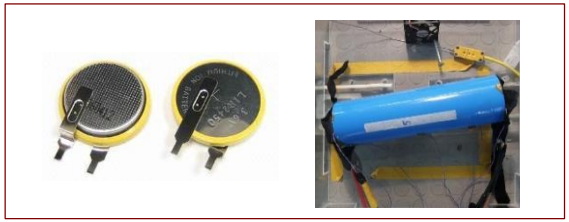
Research Activities

MOTION ANALYSIS



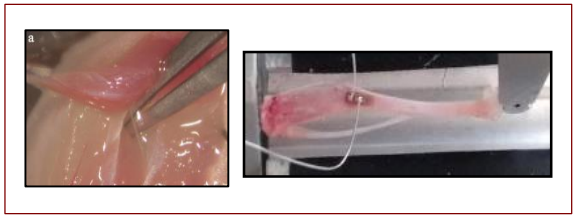
ROBOT MEDIATED THERAPY



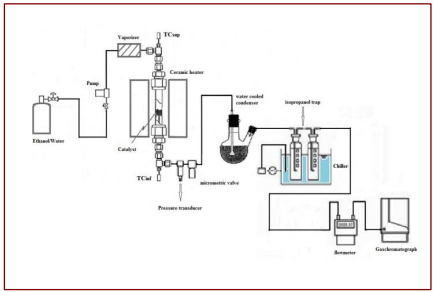


BATTERY PERFORMANCE

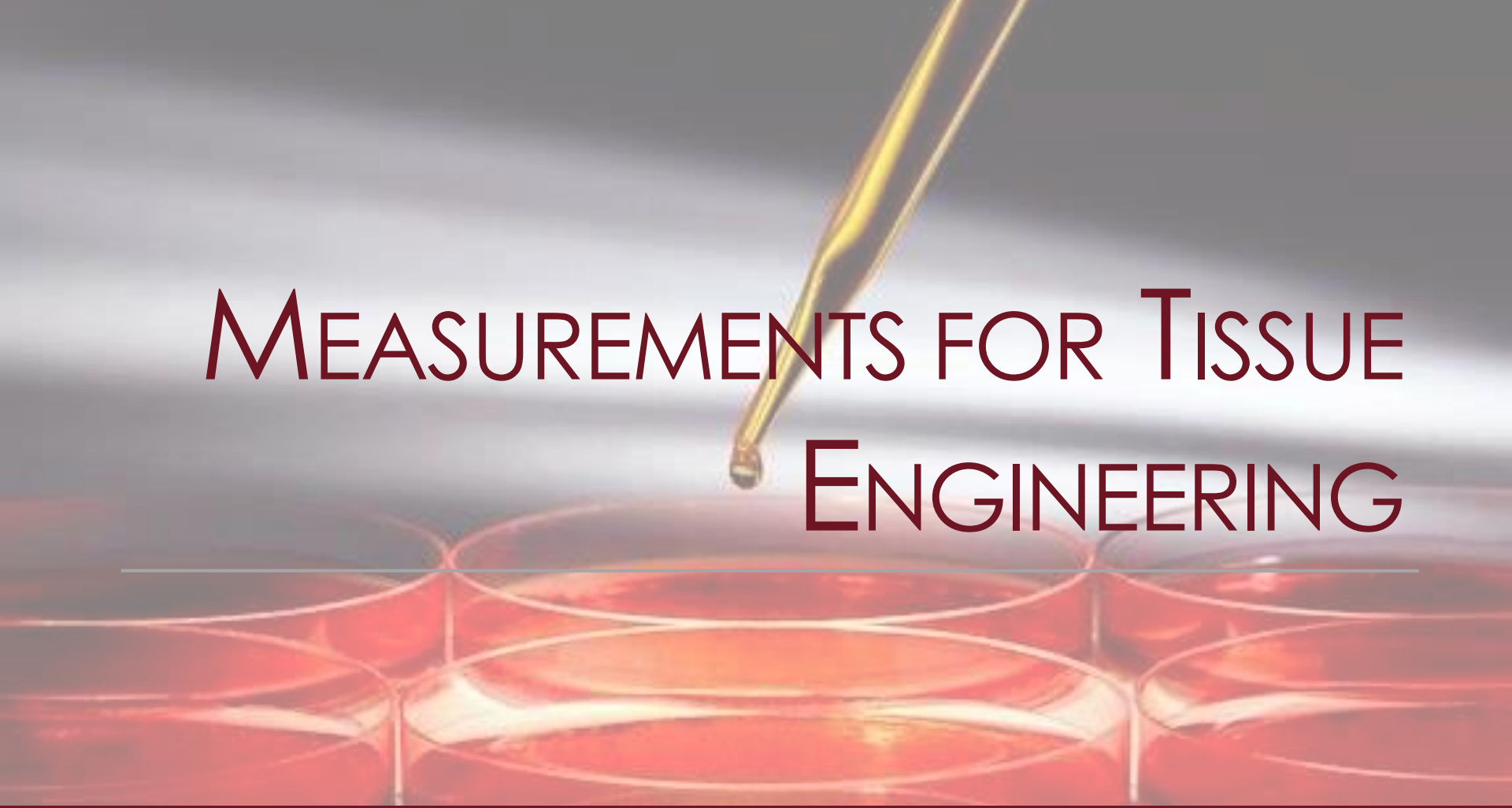
CULTURAL HERITAGE



TISSUES STRAIN



HYDROGEN PRODUCTION



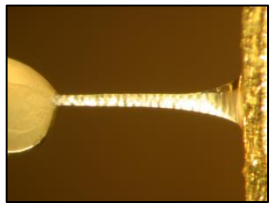
Measurements for Tissue Engineering

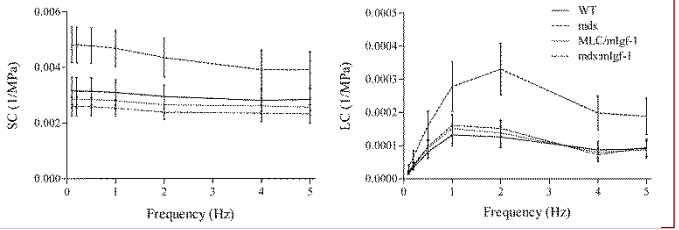
SSD ING-IND/12 Research Activities

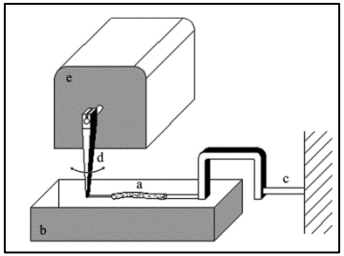
Mechanical Properties Tests

UNIAXIAL TESTING OF MOUSE TENDONS, LIGAMENTS, SKIN

An actuator/transducer stretches samples either in force or in length controlled mode, providing accurate assessment of **σ-ε** relationship.

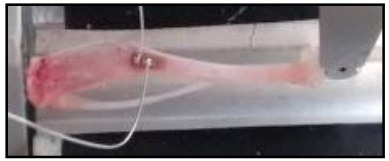


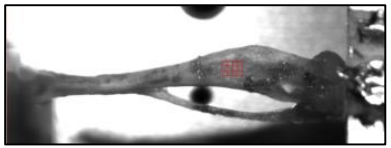


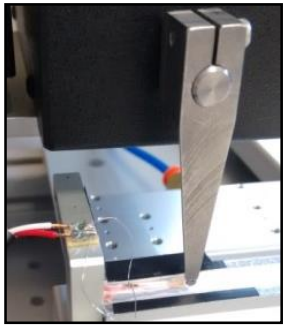


MOUSE TIBIA MECHANICAL PROPERTIES

Resulting local strains are measured either through micro-strain gauges glued on the medial surface of the tibial midshaft or with the DIC.



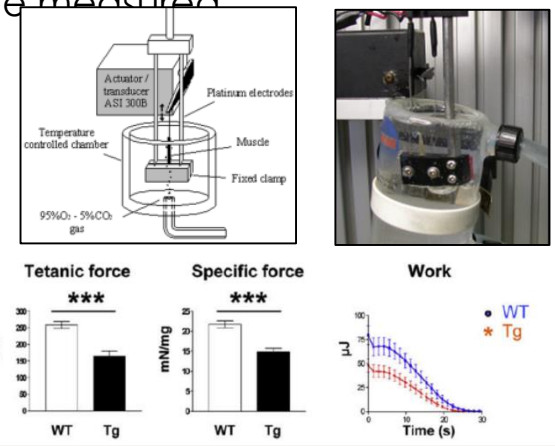


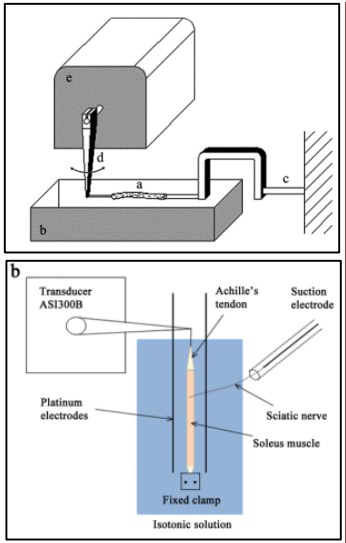


Contractile Properties Tests

MOUSE MUSCLE CONTRACTILE PROPERTIES

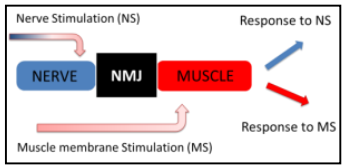
A pulse stimulator excites muscle membrane. Through the actuator/transducer several parameters of muscle contractility are measured

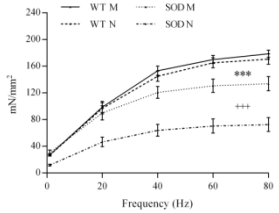


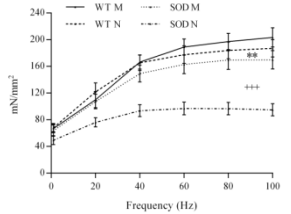


MOUSE NEURO MUSCULAR JUNCTION FUNCTIONALITY

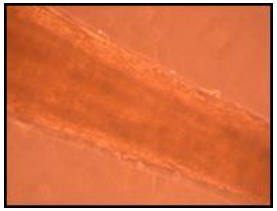
Muscle contractile responses to membrane and nerve stimulations are compared. Discrepancies are a marker of NMJ altered functionality.



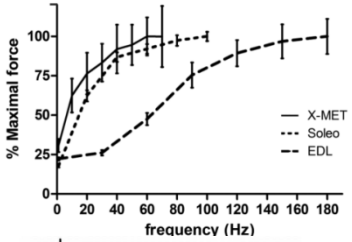




X-MET

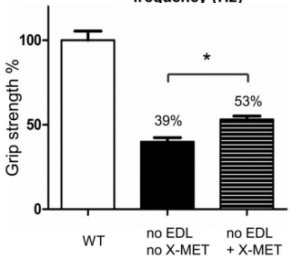


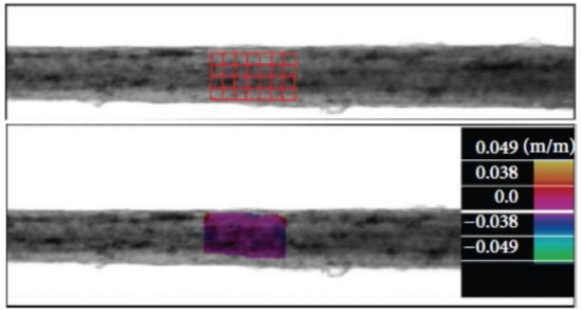
X-MET is an **engineered muscle tissue** with promising applications for both in vitro research and in vivo transplant



Ex vivo measurement of X-MET contractile properties showed:

- ✓ X-MET has a contractile response similar to that of slow muscles
- ✓ X-MET helps injured legs to recover their functionality



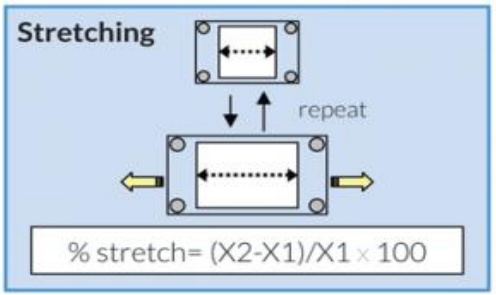


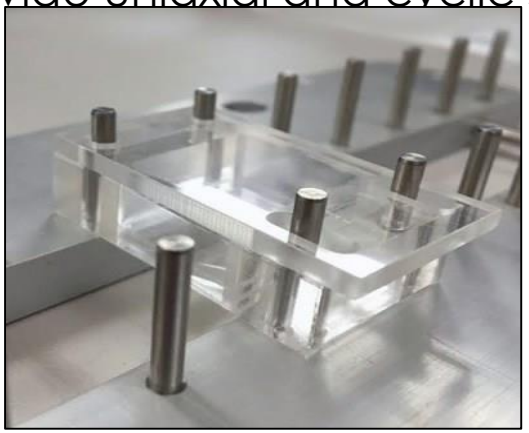
Digital Image Correlation (DIC) applied to small biological tissues allowed for measuring X-MET's spontaneous contraction in a fully contactless way.

Substrate Deformation

Mechanical load is a key-regulator of bone cell activity:
mechanotransduction

A custom-made system was designed to provide uniaxial and cyclic strain in the stretch chamber of a culture dish.

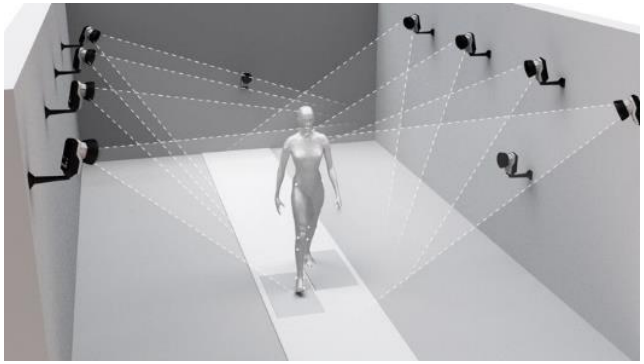




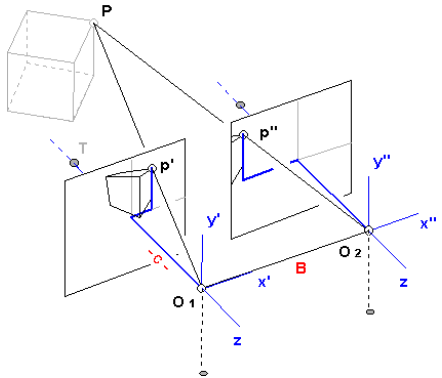
- ✓ The response to cyclic strain is cell type-dependent and altered in cancer cells
- ✓ This in vitro approach permits to investigate the role of mechanical signals in different types of tumors

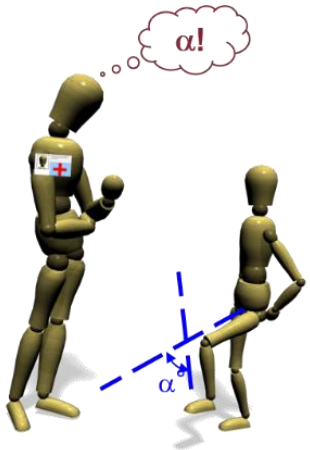
Motion Analysis

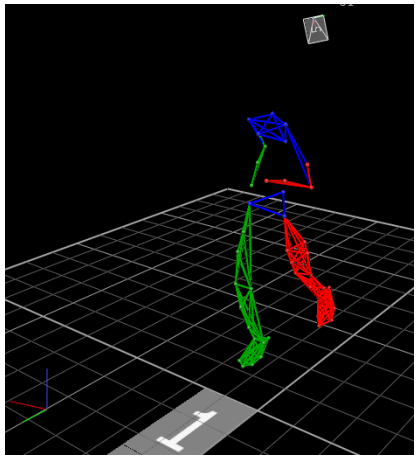
Optoelectronic Systems



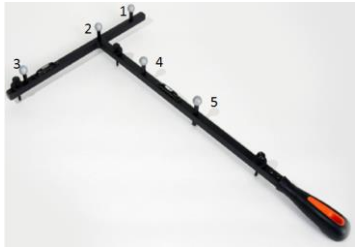
- Human motion analysis performed through stereophotogrammetry
- Definition of kinematic and dynamic models of human body







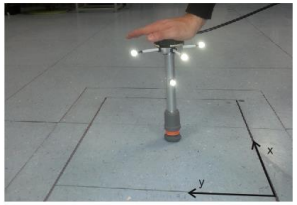
Technical Quality Assurance (TQA)



- Wands were moved for 10 s inside the measurement volume
- RMSE values were lower than the 1% of Full Scale of each platform

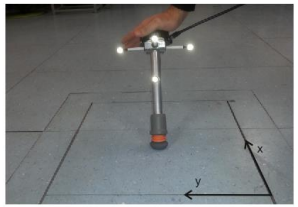
Parameters	Centers		
	OPBG	VUA	KUL
$\overline{12}$ [mm]	0.3	0.8	0.4
$\overline{23}$ [mm]	0.3	0.9	0.4
$\overline{24}$ [mm]	0.3	0.6	0.5
$\overline{25}$ [mm]	0.4	0.5	0.5
$\widehat{125}$ [°]	0.2	0.5	0.3
$\widehat{325}$ [°]	0.3	0.3	0.2

Lower accuracy of Bonita system

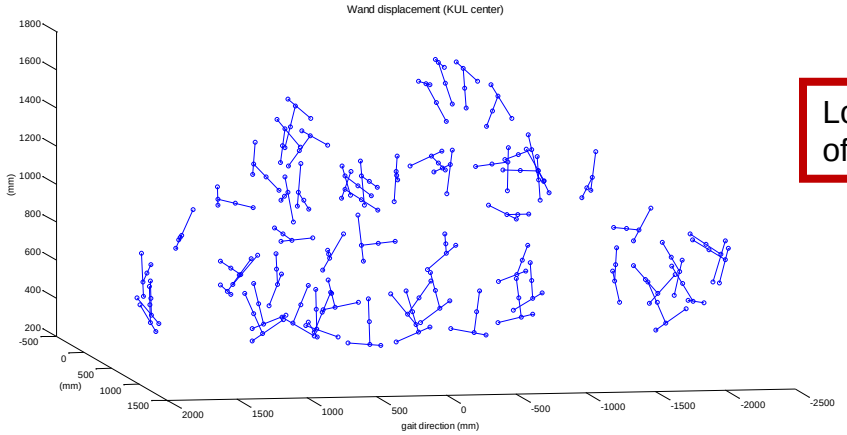


(a)

(b)

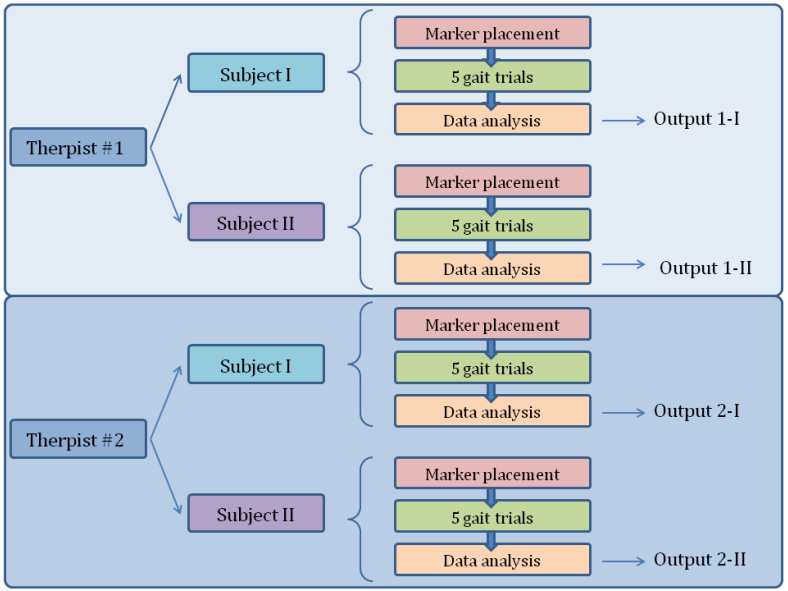


(c)



Reproducibility in Gait Analysis

Aim: gait variables reproducibility due to different operators and laboratories



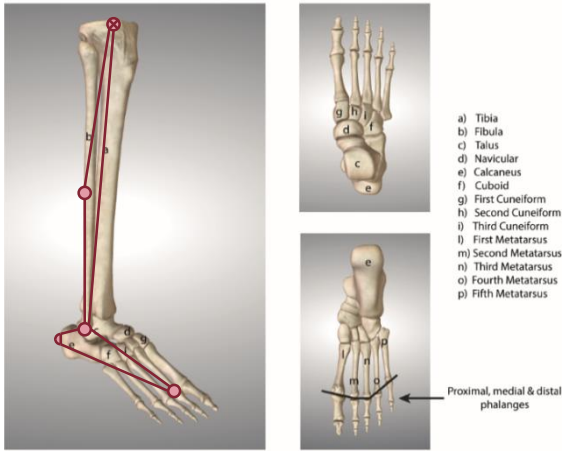
x 2 Marker-sets

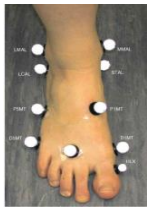
x 2 Laboratories

- ✓ Good reproducibility of gait analysis outputs between two operators and two centers for both marker-sets adopted.
- ✓ Low variability of spatio-temporal parameters between two models.

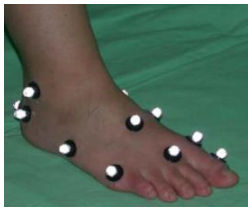
A New Model of the Foot-Ankle Complex

AIM: Design and validate a new model





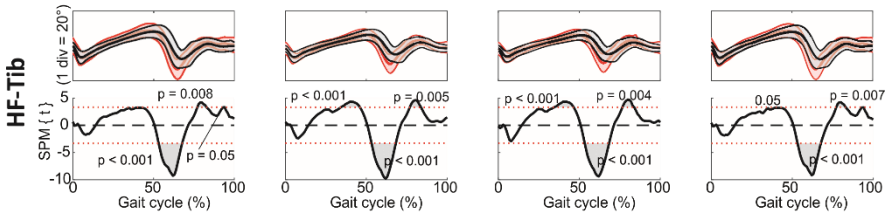
Stebbins et al. 2006



Leardini et al. 2007

Sawacha et al. 2009

Saraswat et al. 2012

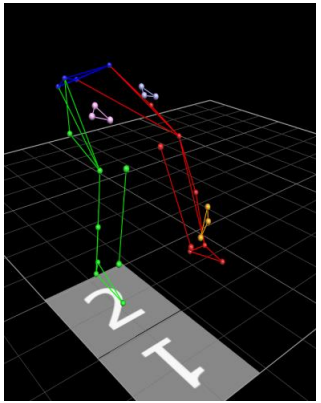


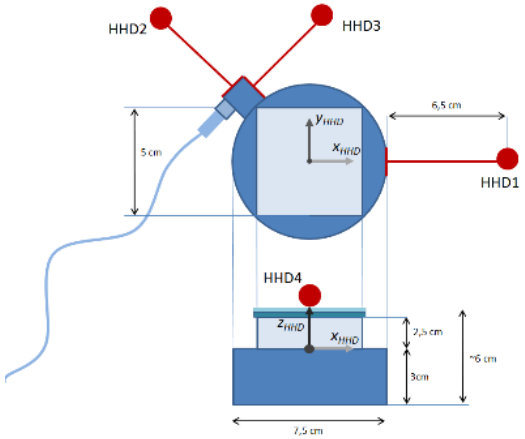
The new model was defined:

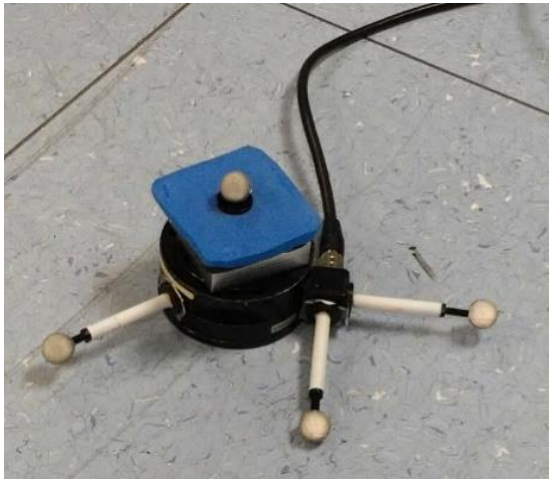
- To describe joints whose range of motion is higher than 5°
- Paying attention to the anatomical definition of the joint axes

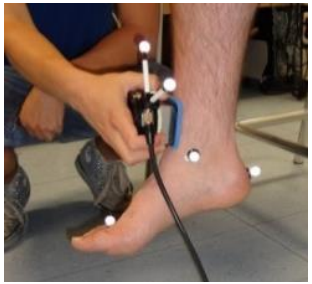
Validation of Clinical Strength Measurements

- **AIM:** Evaluating reliability of muscular strength assessment commonly conducted in clinics
- Design a quality assurance protocol based on Optoelectronic System and a 6-DoF load cell

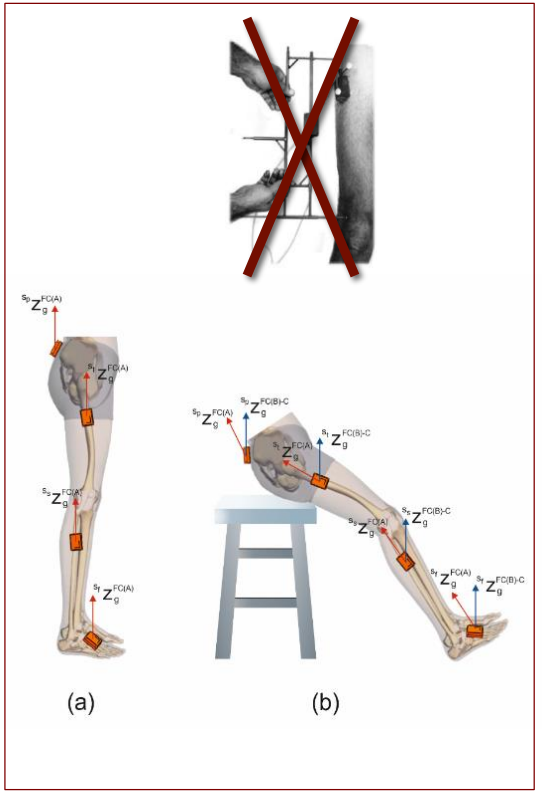








Wearable Gait Analysis



- Inertial measurement units to acquire pose of rigid bodies
- Sensor-to-segment calibration is needed to perform human body kinematics
- A novel procedure designed and validated to allow wearable gait analysis in critical conditions (Palermo et al. 2014)

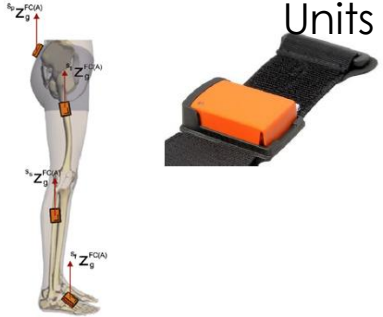
Auditory Cued Gait Analysis & Parkinson

EXPERIMENTAL SETUP

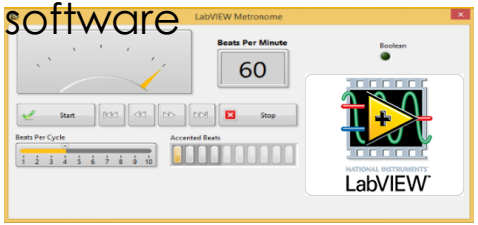
Footswitches

Wireless FM headset

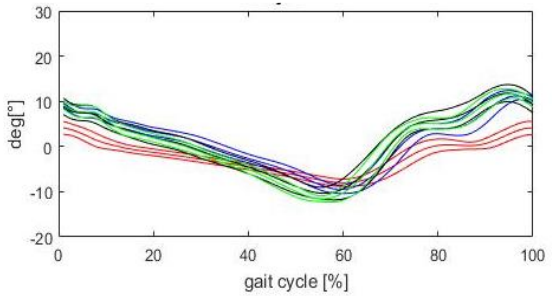
8 Inertial Sensors Units



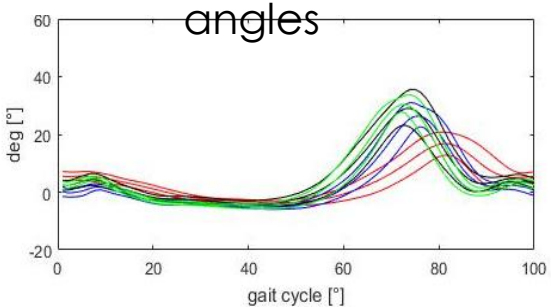
Ad hoc LabVIEW software



Hip angles

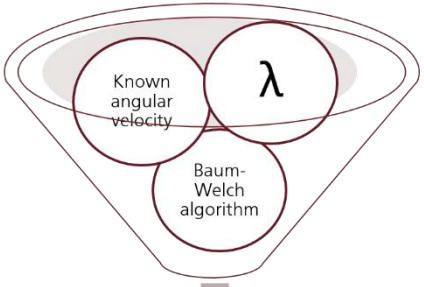


Knee angles



Gait Partitioning with HMMs

- **An algorithm for the identification of hidden states of a system**



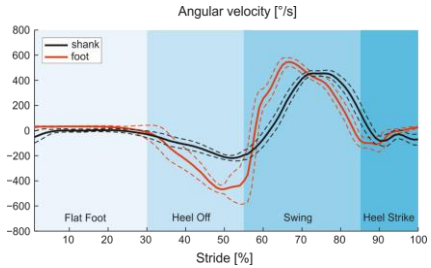
Training model parameters

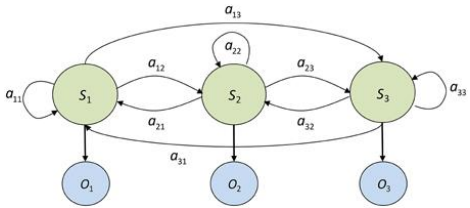
A^{tr}

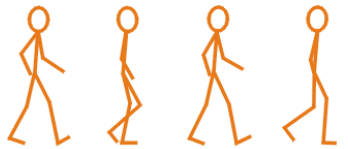
Angular velocity
OBSERVATION

Hidden Markov Model
HMM=λ(A,π)

Hidden phases
LIKELY SEQUENCE



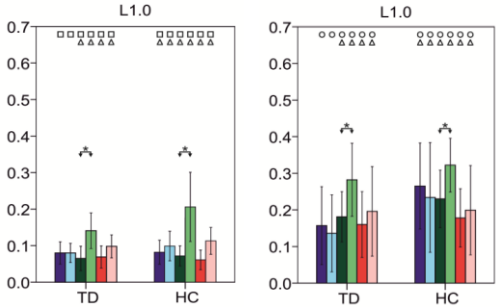




HMMs Applications

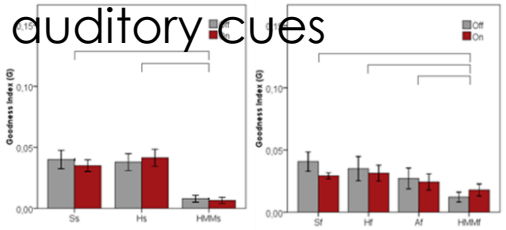
GAIT QUALITY IN CP

Gait phase distribution correlates with level of disease severity



GAIT QUALITY IN PD

Gait phase distribution correlates with Levodopa assumption and auditory cues

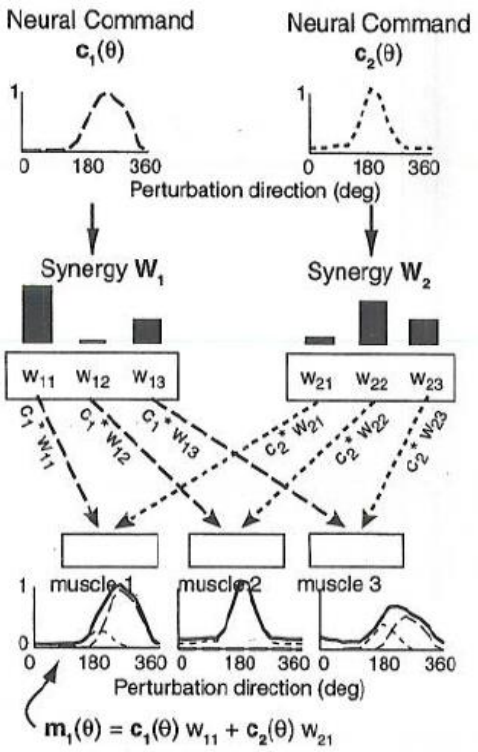


WALKING RACE

A specific HMM to automatically detect faults

Patent Application approved by the CDA

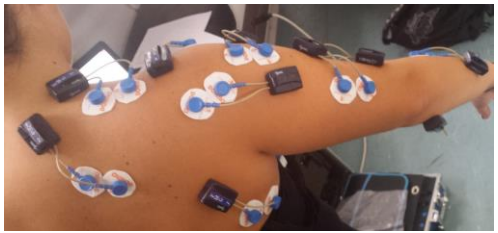
Muscle Synergies

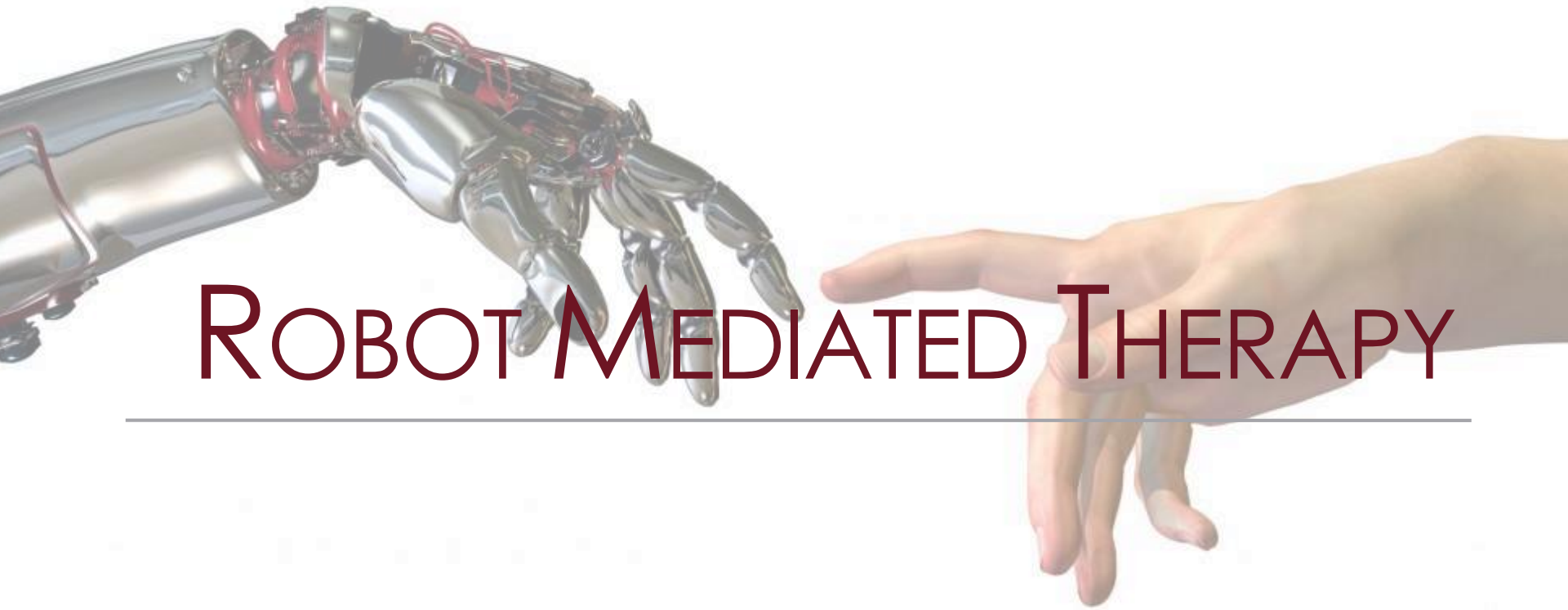


CNS is able to reduce the dimensionality of neural activation

Muscle synergy is a group of muscles that are simultaneously, in space and time, activated by CNS

$$EMG = \sum_{i=1}^{s} W_i \cdot c_i + residual$$



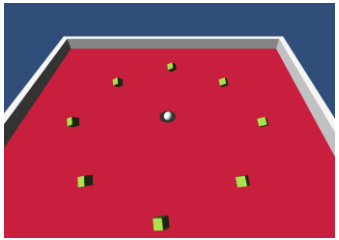


ROBOT MEDIATED THERAPY

Upper Limb

NOVINT FALCON & VIRTUAL REALITY

Haptic device developed to offer force feedback (4.5 N)



Aim: Leveraging 3-DoF low-cost haptic joystick and virtual reality to develop home-based solutions for motor re-

MIT-MANUS

Largely used to evaluate motor performance of subjects with neurological diseases.

Aim: evaluating motor performance in subjects with shoulder laxity, pre and post surgery

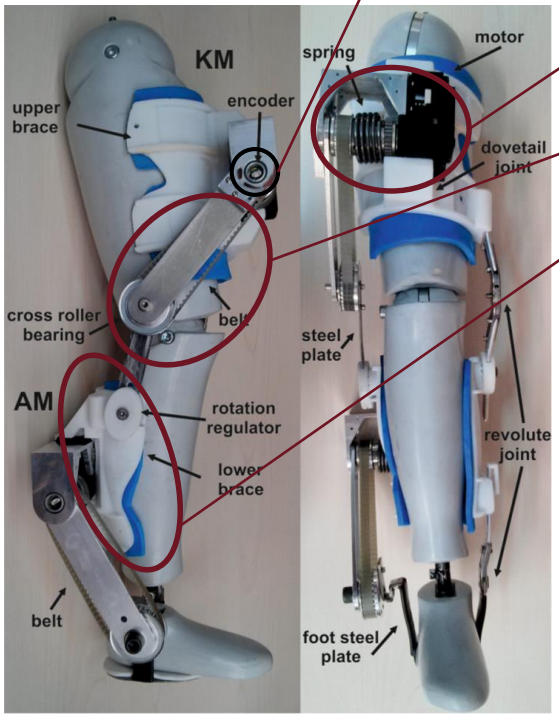
PACE UNIVERSITY

Prof. V. Santilli
Dr. M. Paoloni

Lower Limb

Absolute Encoder to measure rotation of spring

WAKE-Up!



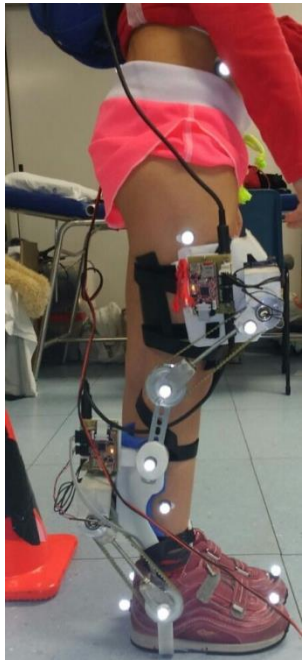
Actuation: Rotary Series Elastic Actuator (RSEA)

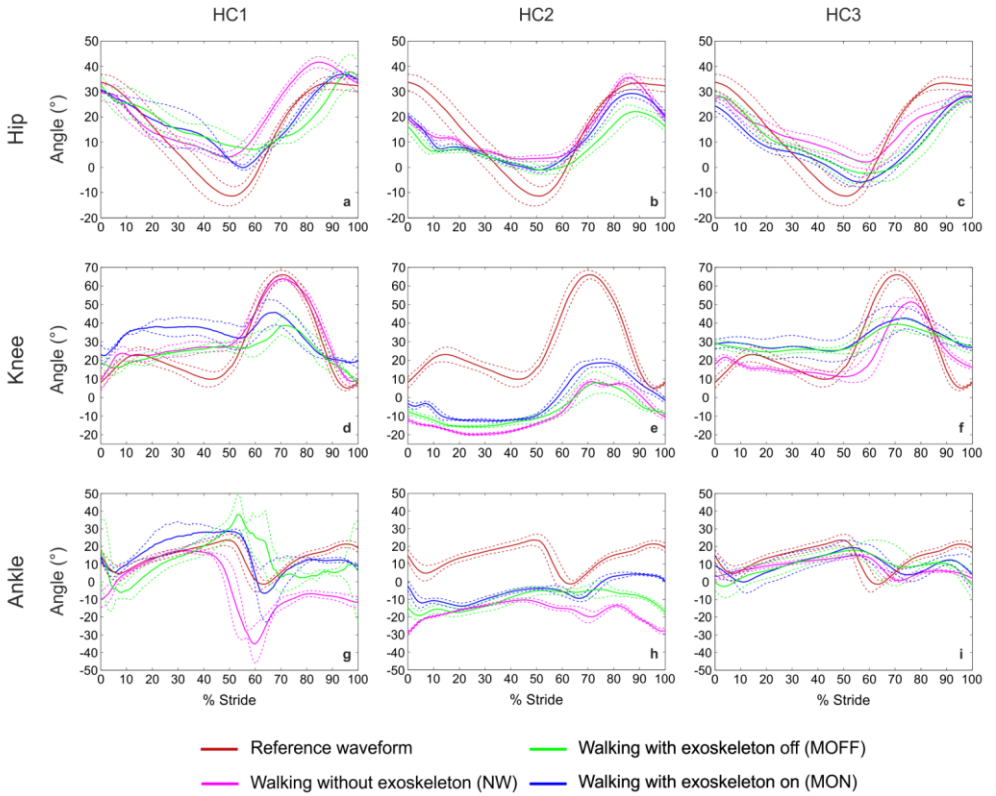
Power Transmission: Belt/pulley stage 1:1.5

Orthosis: 3D scanner & 3D prototyping

- Bi-modular active orthoses to actively assist walk in children with CP (5-13 years)
- Modules (KM-AM) can work together or singularly
- Overall mass 2.5 kg

Lower Limb

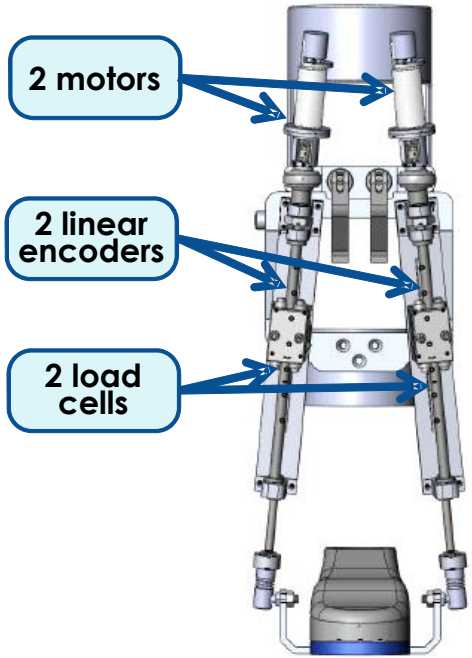




WAKE-Up!

- ✓ Ankle angle at foostrike reaches normal values
- ✓ Higher power needed at the knee

Lower Limb

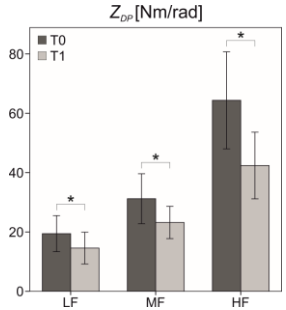


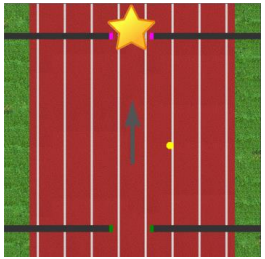
pediAnklebot

Investigation of the stretch reflex mechanism in children with spasticity

Bambino Gesù Ospedale Pediatrico

Measurement of ankle stiffness and impedance after botulinum toxin

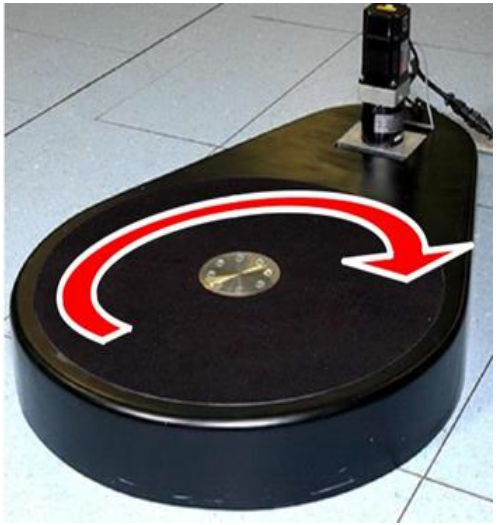




Evaluate smoothness of ankle dorsiflexion motion

Balance

Rotobit



Aim:

- Provide repeated perturbation on transversal plane through robotic platform
- Assess motor response of patients with Parkinson's Disease and atypical parkinsonism

Dr. A. Suppa

MEASUREMENTS FOR CULTURAL HERITAGE

SSD ING-IND/12 Research Activities

Smart Sensor Network

- To identify, for a set of standardized parameters, the best sensors in terms of cost, dimension and performance.
- To increase the scalability of actual monitoring system and give a metrological validation of proposed technologies

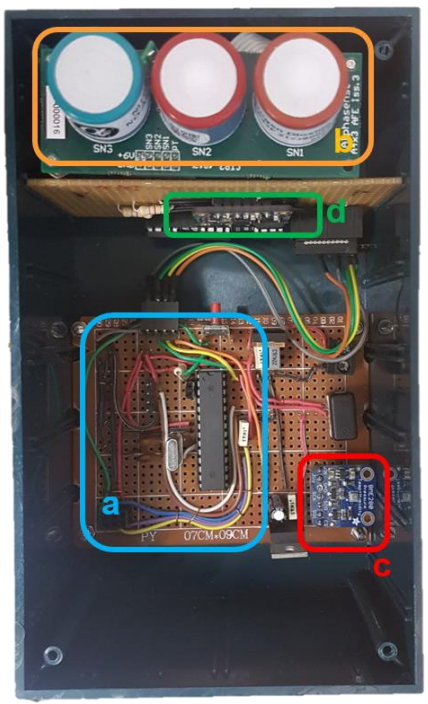
AQM 65 BASE UNIT

Laser particle counter
Nitrogen Dioxide
Nitrogen Oxides
Sulphur Dioxide
Carbon Dioxide

TOTAL PRICE ≈ 33000 €

Stand Alone module
a) Microcontroller Board
b) Electrochemical cell for Gaseous pollutant
c) Sensor I/O atmospheric pressure, temperature and humidity
d) Sensor I/O shock detection

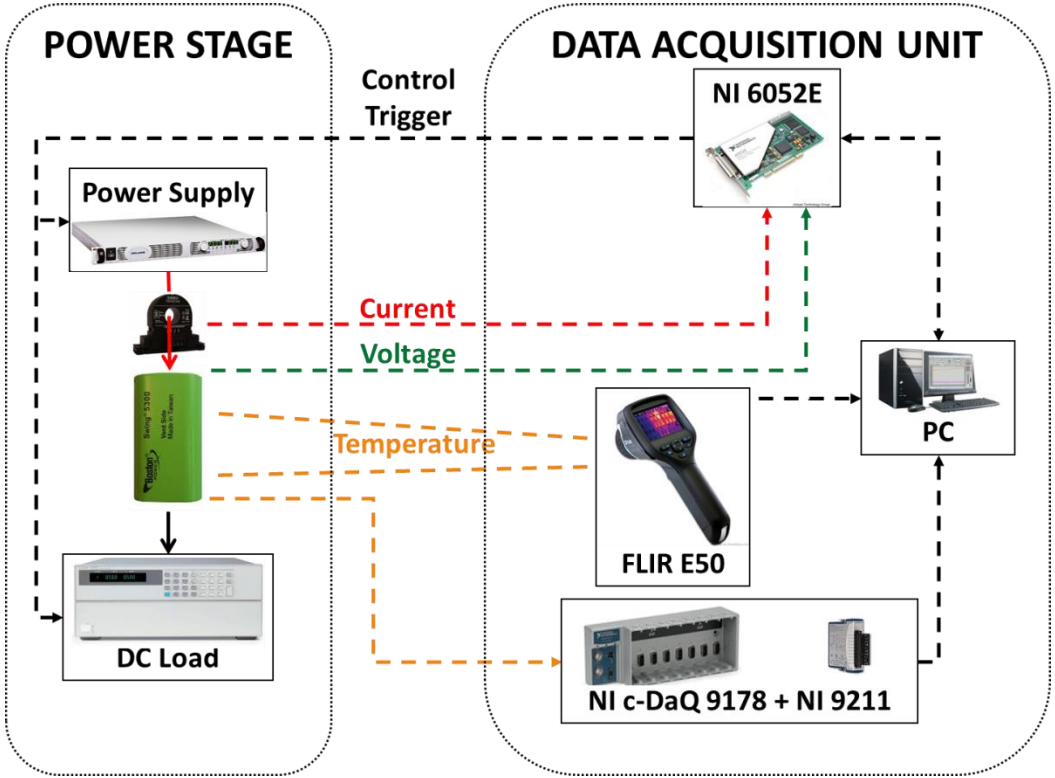
a-prototype price ≈ 1000€



BATTERY PERFORMANCE

MARINA Mmilitare

Automated Battery Test System

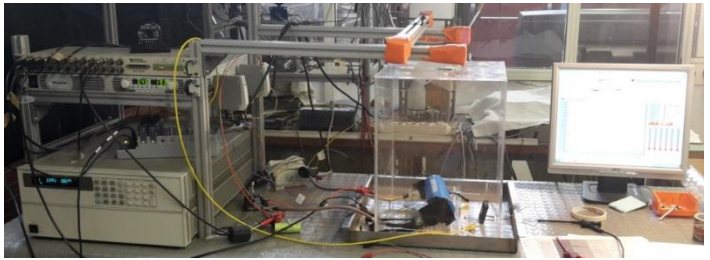


Control

- Voltage
- Charging/Discharging Current

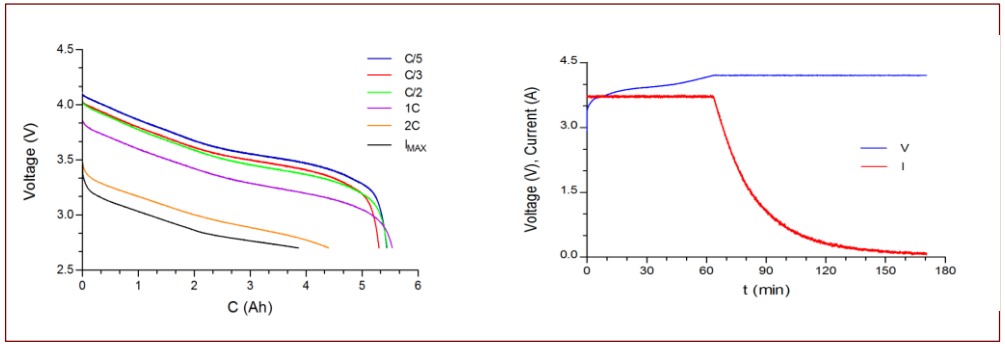
Acquisition

- Cell voltage
- Cell current
- Cell temperature

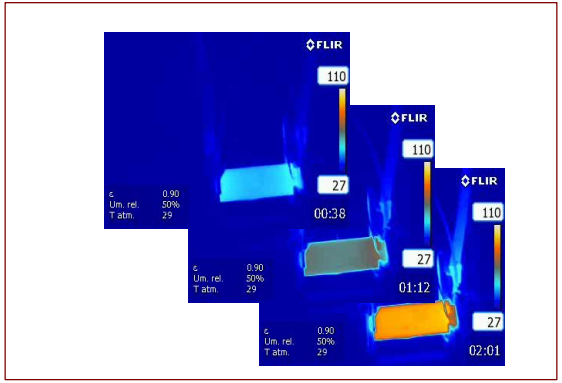


Potential Tests

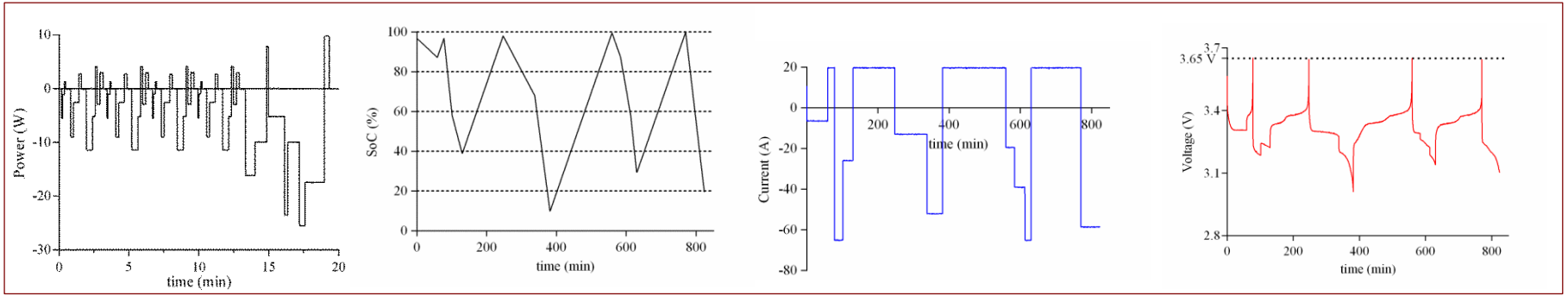
CHARACTERIZATION



THERMAL INVESTIGATION



SIMULATION

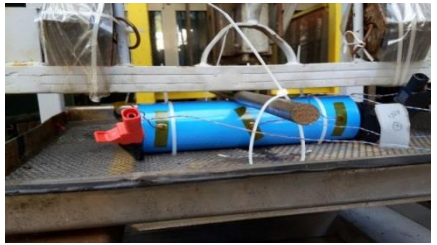


Disruptive Tests

EXPERIMENTAL SETUP

EXTERNAL SHORT CIRCUIT

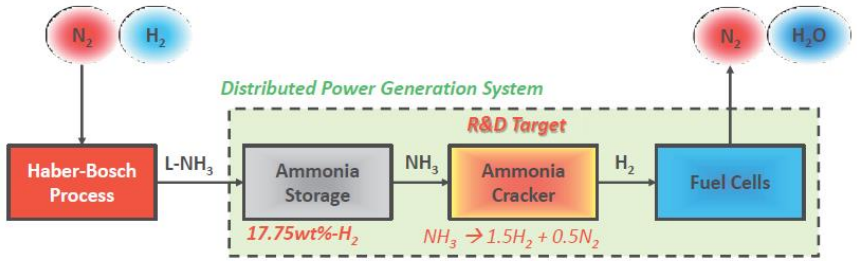
PERFORATIO N



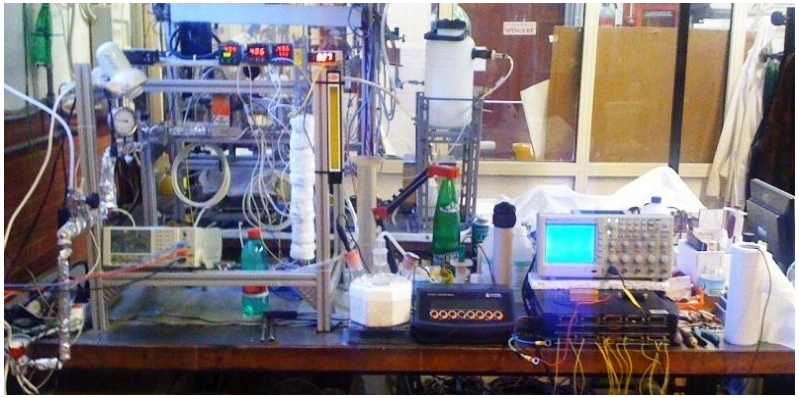
IMPACT

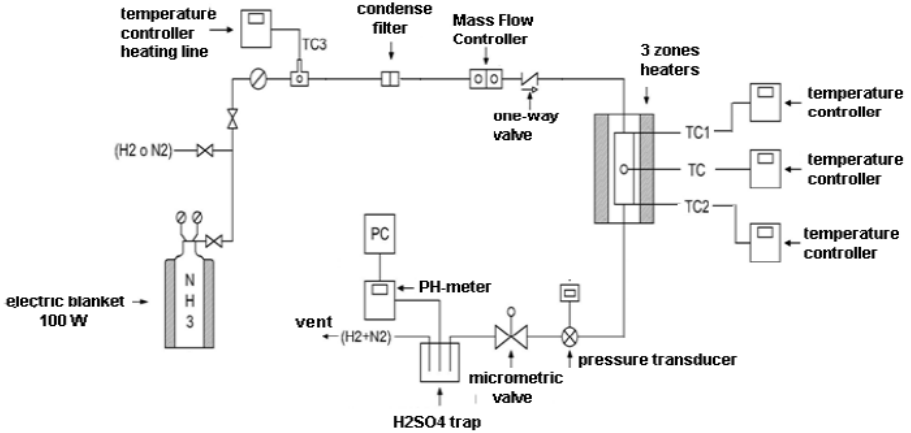
HYDROGEN PRODUCTION

NH_3 as Hydrogen Carrier



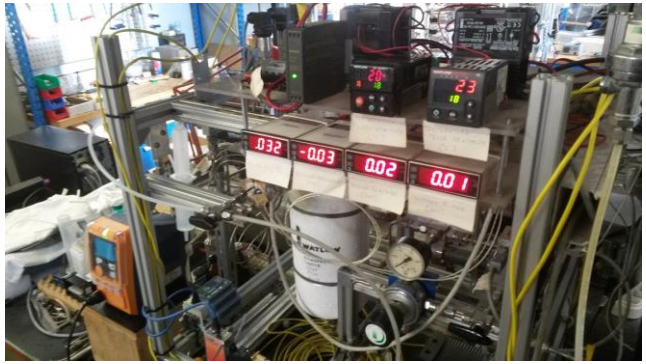
- high hydrogen mass-density (17.75wt%)
- liquid at 0.8MPa (298.15K)
- synthesized by using Haber-Bosch process
- produces no NOx, COx and SOx by ammonia cracking.

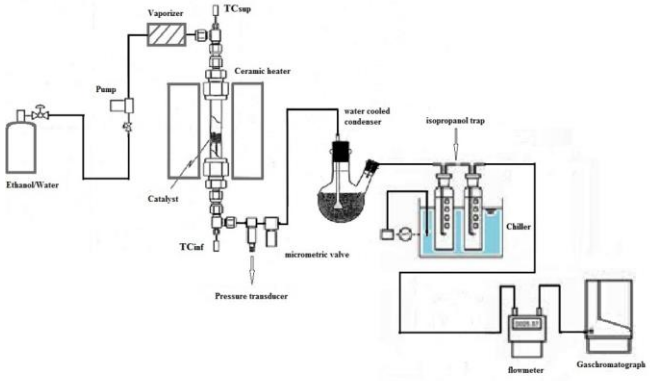


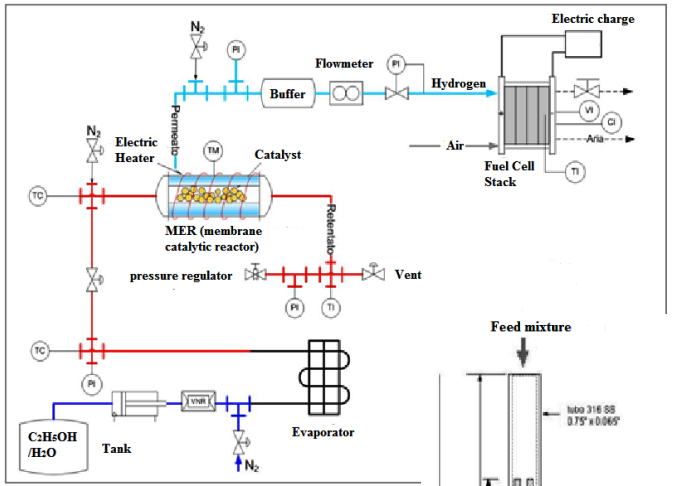


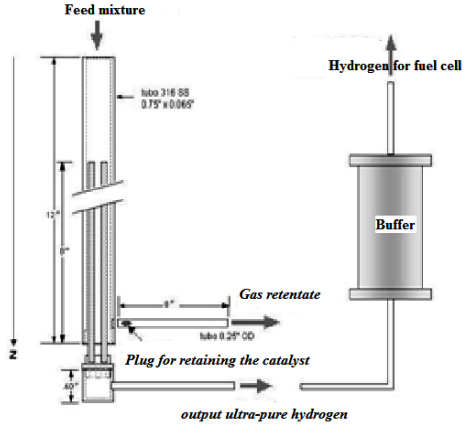
Bio-Ethanol Reforming

WITHOUT MEMBRANE









WITH MEMBRANE