Bergamo, 8 maggio 2015

Jacopo Zenzeri

La Robotica: teorie, modelli ed applicazioni

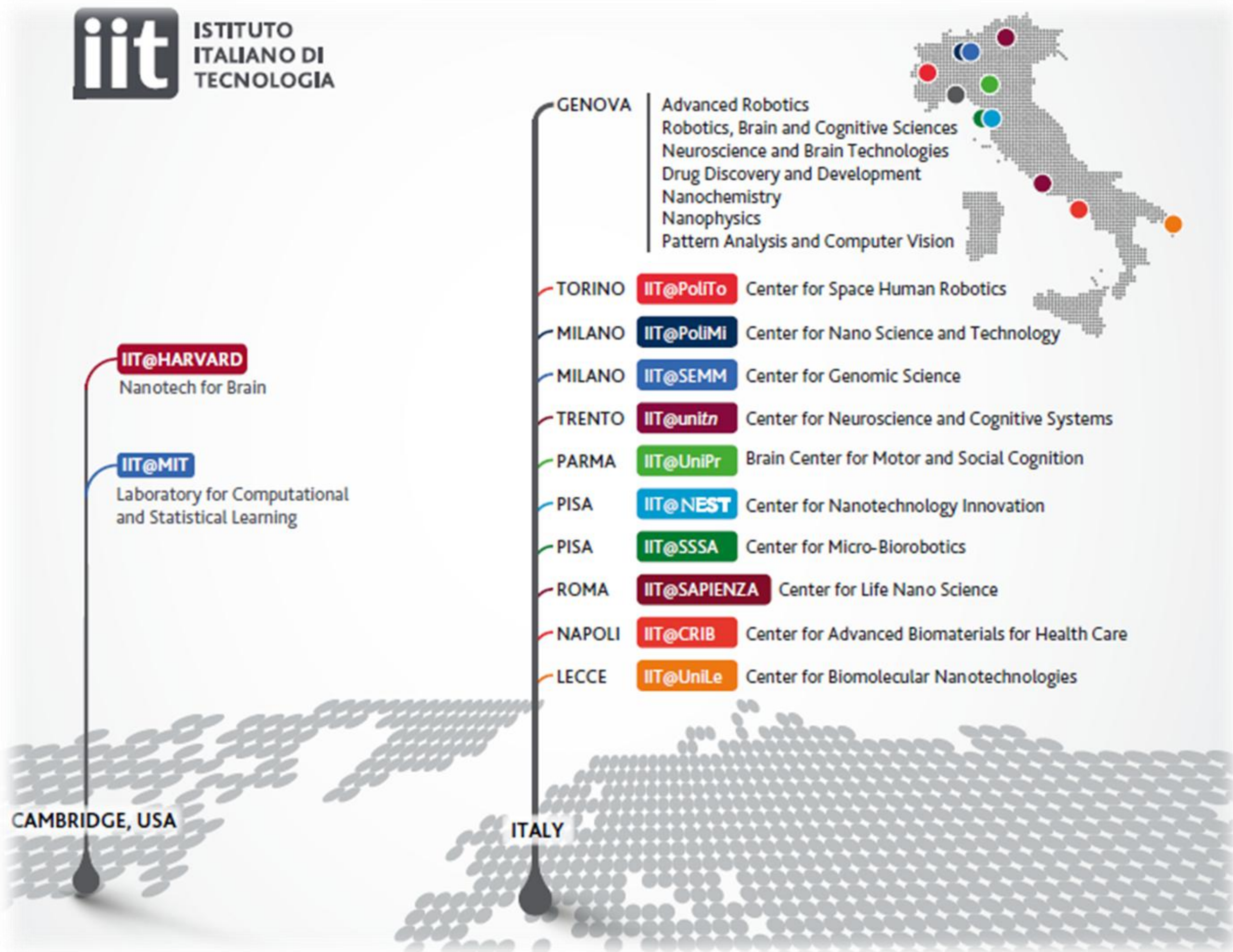
FORMAZIONE DOCENTI – GENERAZIONE WEB

Outline

- L'Istituto Italiano di Tecnologia e la robotica
- I robot e la visione europea della robotica
- La riabilitazione robotica
- Caso di studio 1: Riabilitazione della propriocezione
- Caso di studio 2: Collaborazione con i robot
- Caso di studio 3: Modelli computazionali del cervello per la robotica

L'Istituto Italiano di Tecnologia e la robotica

IIT: Istituto Italiano di Tecnologia



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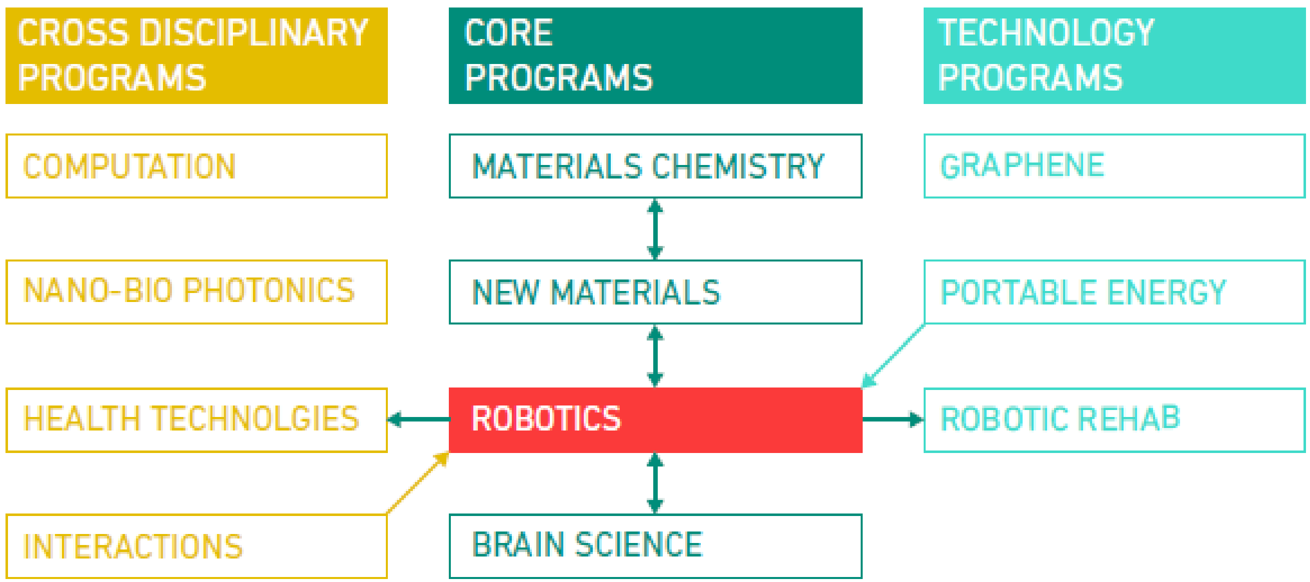
IIT: Istituto Italiano di Tecnologia

Piano strategico 2015-2017



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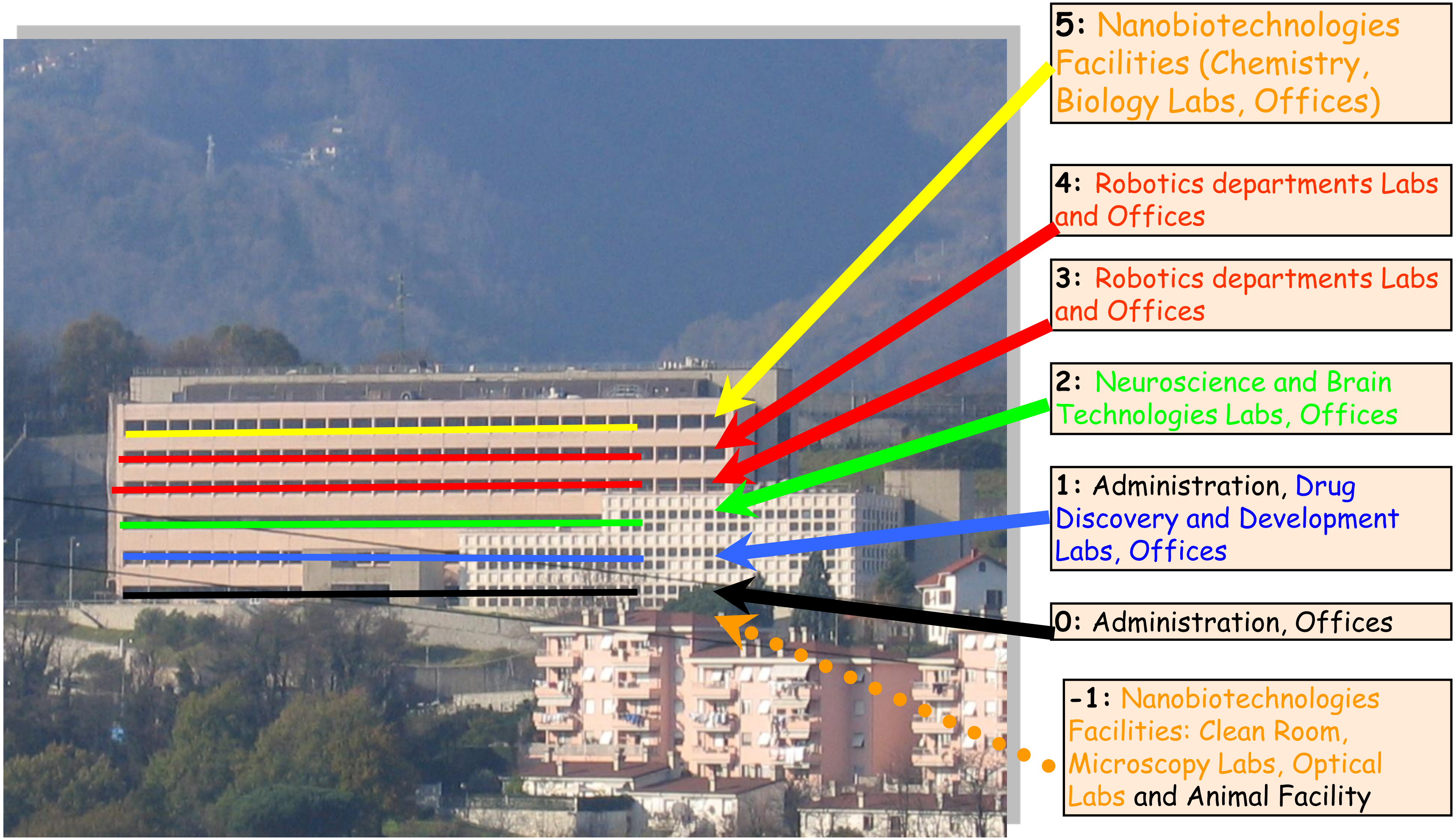
Sede centrale di Genova



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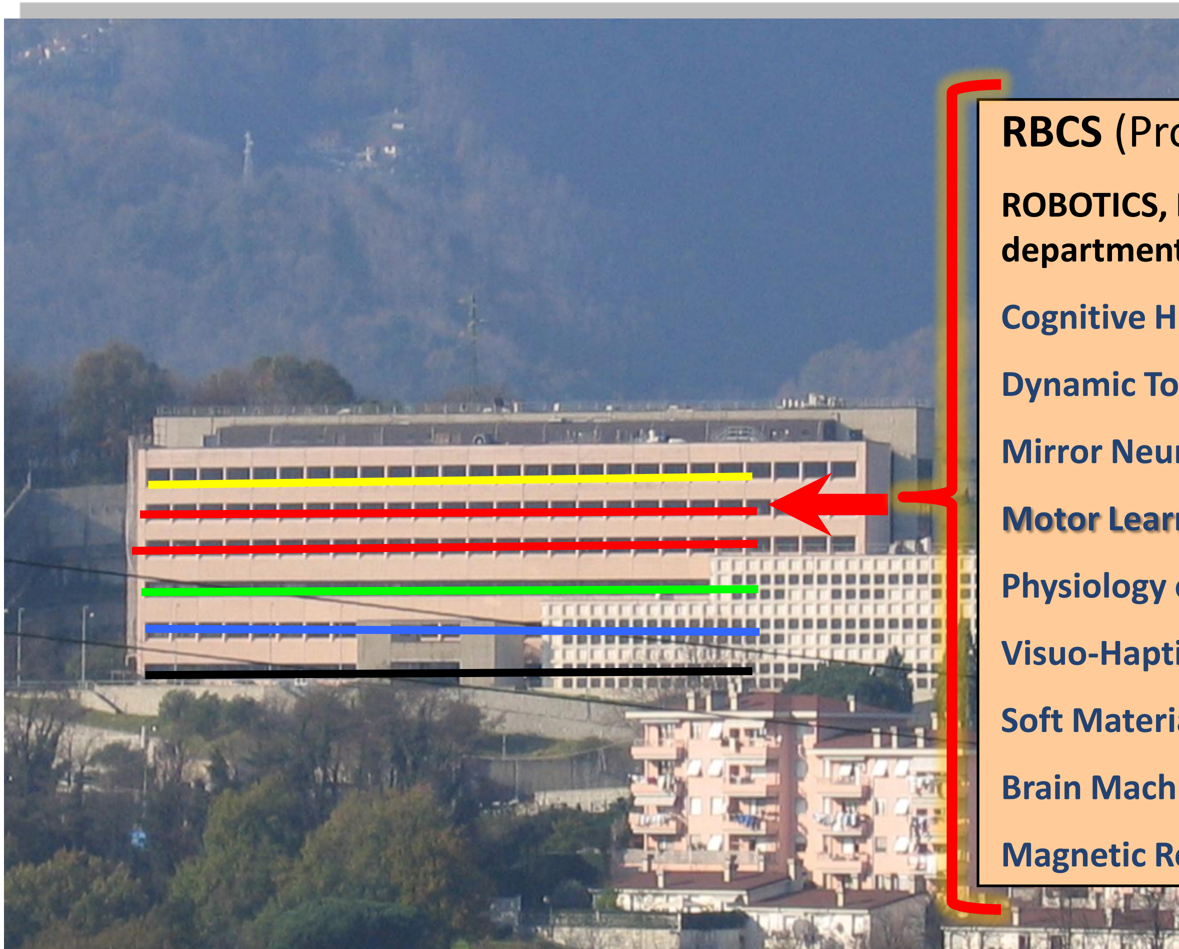
Sede centrale di Genova



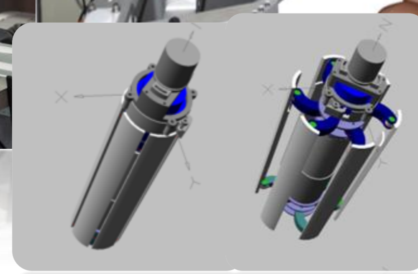
RBCS (Prof. Giulio Sandini)

ROBOTICS, BRAIN and COGNITIVE SCIENCES department

- Cognitive Humanoids
- Dynamic Touch and Interaction
- Mirror Neurons and Interactions
- Motor Learning and Robotic Rehabilitation
- Physiology of Action and Perception
- Visuo-Haptic Perception
- Soft Materials Design
- Brain Machine Interface
- Magnetic Resonance Imaging

Motor Learning and Robotic Rehabilitation Laboratory (MLRR)

RIABILITAZIONE NEUROMOTORIA



MECCANISMI DI APPRENDIMENTO MOTORIO

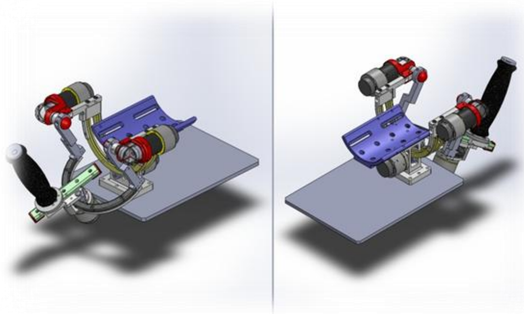
MLRR Lab

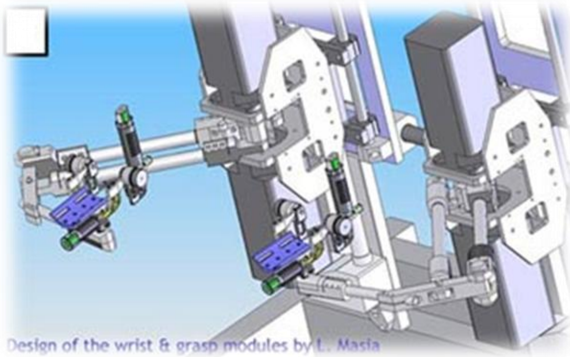
Pietro Morasso (Senior Scientist)

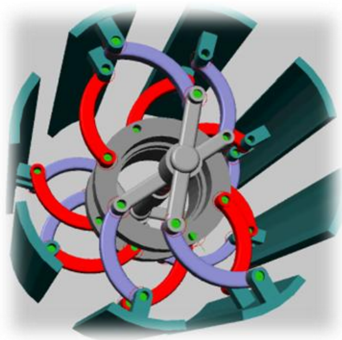
Jacopo Zenzeri (Senior Post Doctoral Researcher)
Valentina Squeri (Senior Post Doctoral Researcher)

Dalia De Santis (Junior Post Doctoral Researcher)

Anna Cuppone (PhD Student)
Francesca Marini (PhD Student)
Edwin Avila (PhD Student)





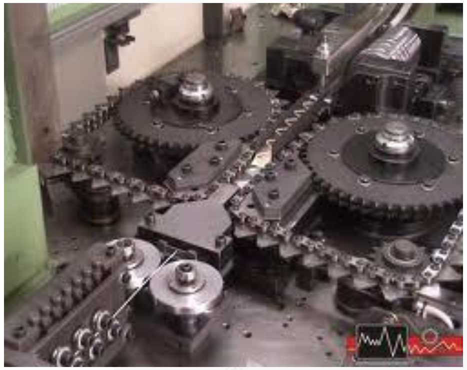


I robot e la visione europea della robotica

Robot VS Macchine

MACCHINE

any device that uses energy to perform some activity. Machines are pre-programmed to follow operations (AUTOMATED MACHINES)



Robot VS Macchine

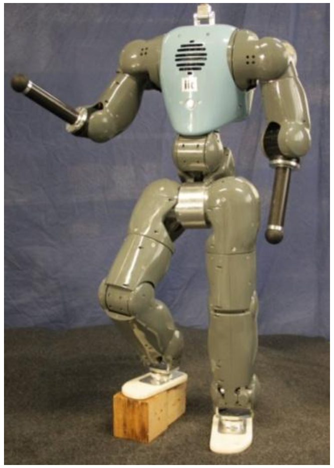
ROBOT

machines that are able to **sense and react** to the environment in order to carry out a complex task **autonomously.**

They are endowed with some forms of artificial intelligence

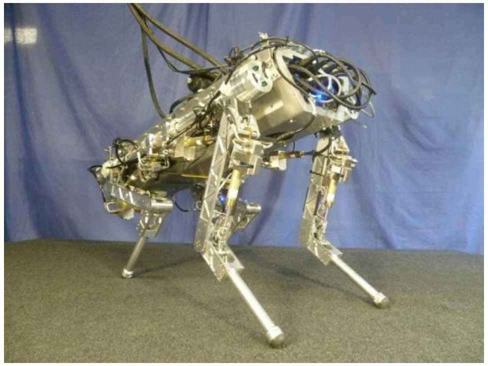
I robot in IIT

iCub



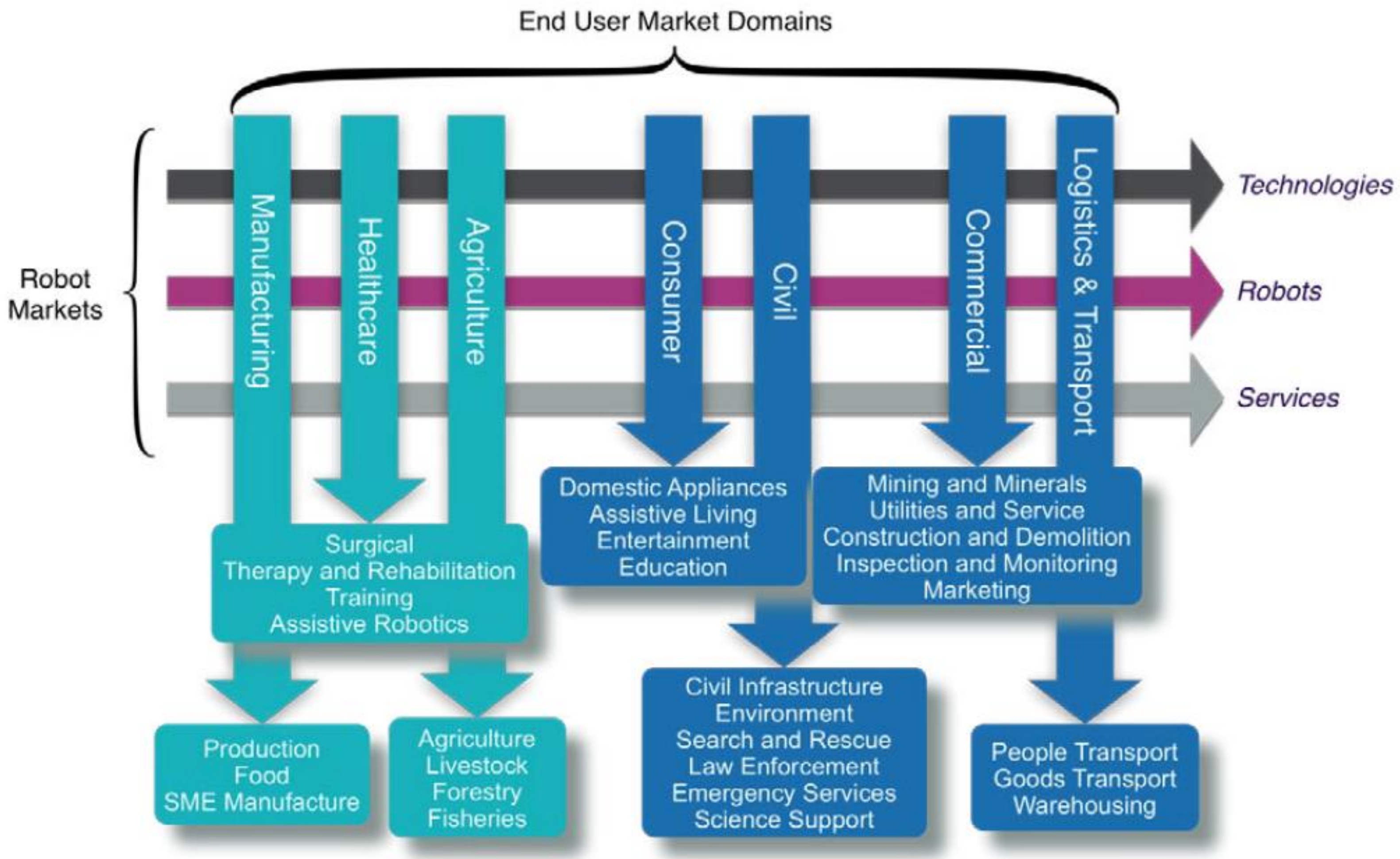
COMAN

HyQ

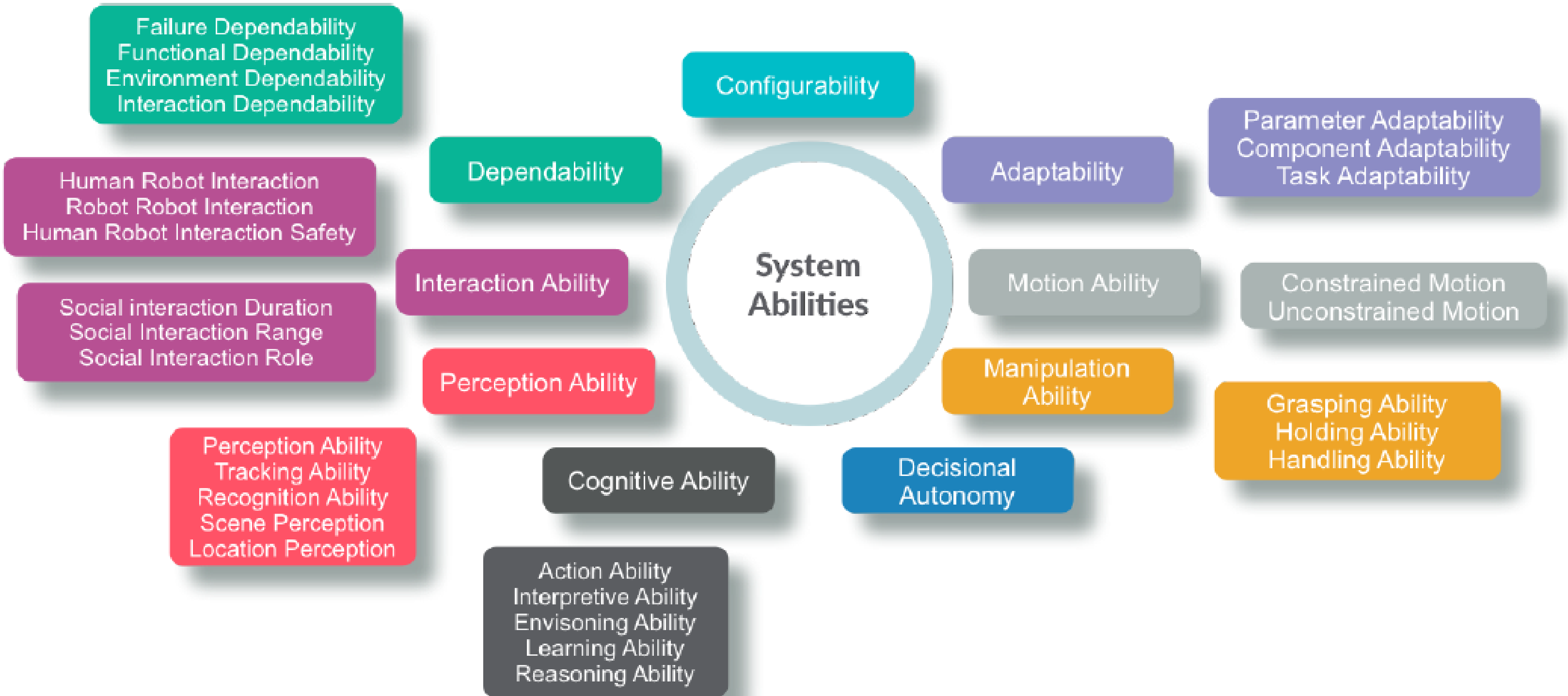


WristBot

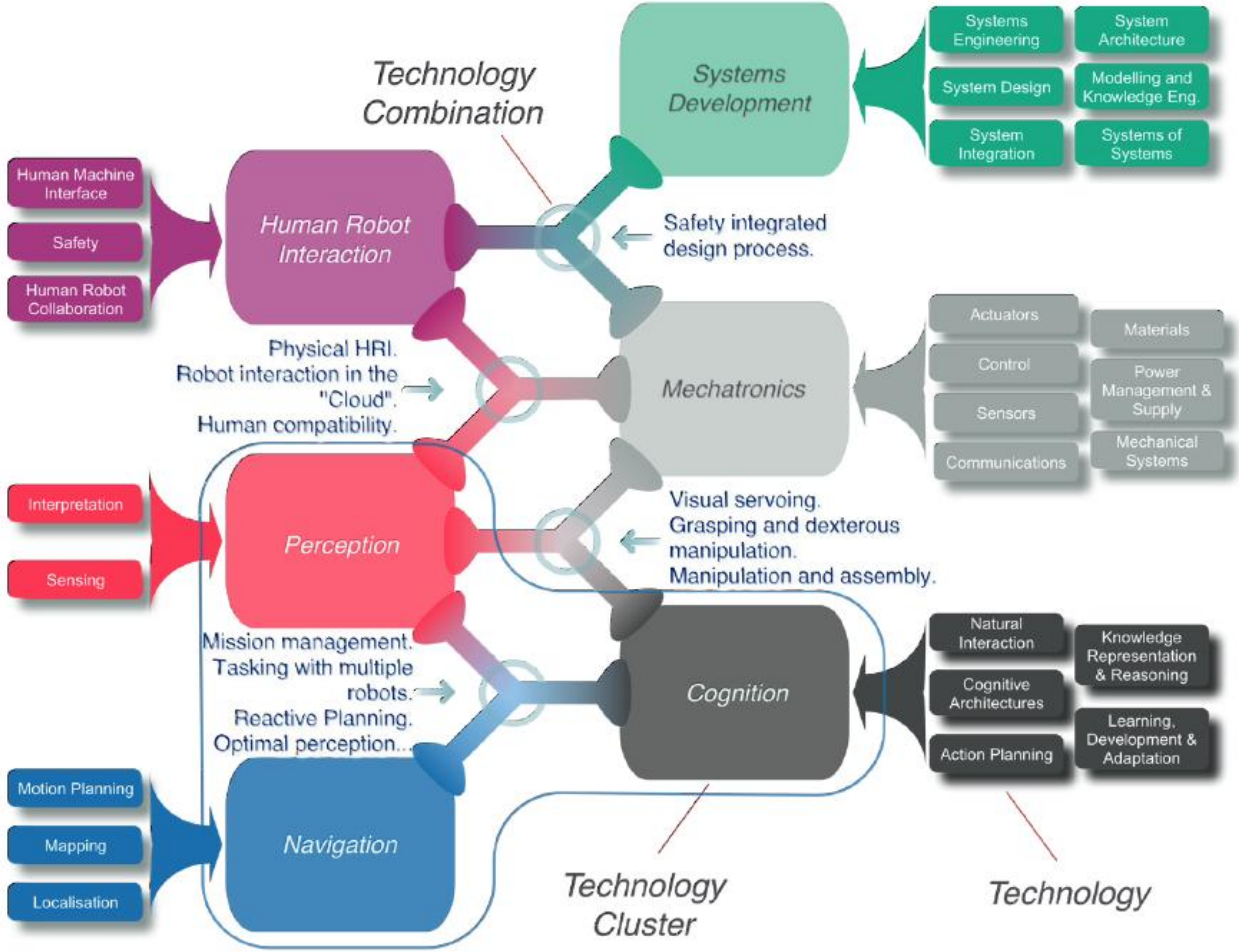
La Robotica: la visione dell'Europa nel 2015



La Robotica: la visione dell'Europa nel 2015



La Robotica: la visione dell'Europa nel 2015



La riabilitazione robotica

Riabilitazione robotica

"Rehabilitation robotics is the use of robotics technology to help restoring function to a person with a physical disability." [International Rehabilitation Robotics organization]

1. **Assistive:** to help someone to do a task (such as feeding)
2. **Prosthetic**: to replaces the function of a part of the body (such as an artificial arm)
3. **Therapeutic**: to helps to improve or recover the function so that they no longer need the robotic device (such as robotic training environment).

Robot assistivi

ARMEO

Hocoma

Honda Walk assist exoskeleton

SmartCane

Exo Bionics exoskeleton

Robot prostetici

John Hopkins university, modular prosthetic arm

DEKA Research arm at The Rehabilitation Institute of Chicago

SoftHand IIT

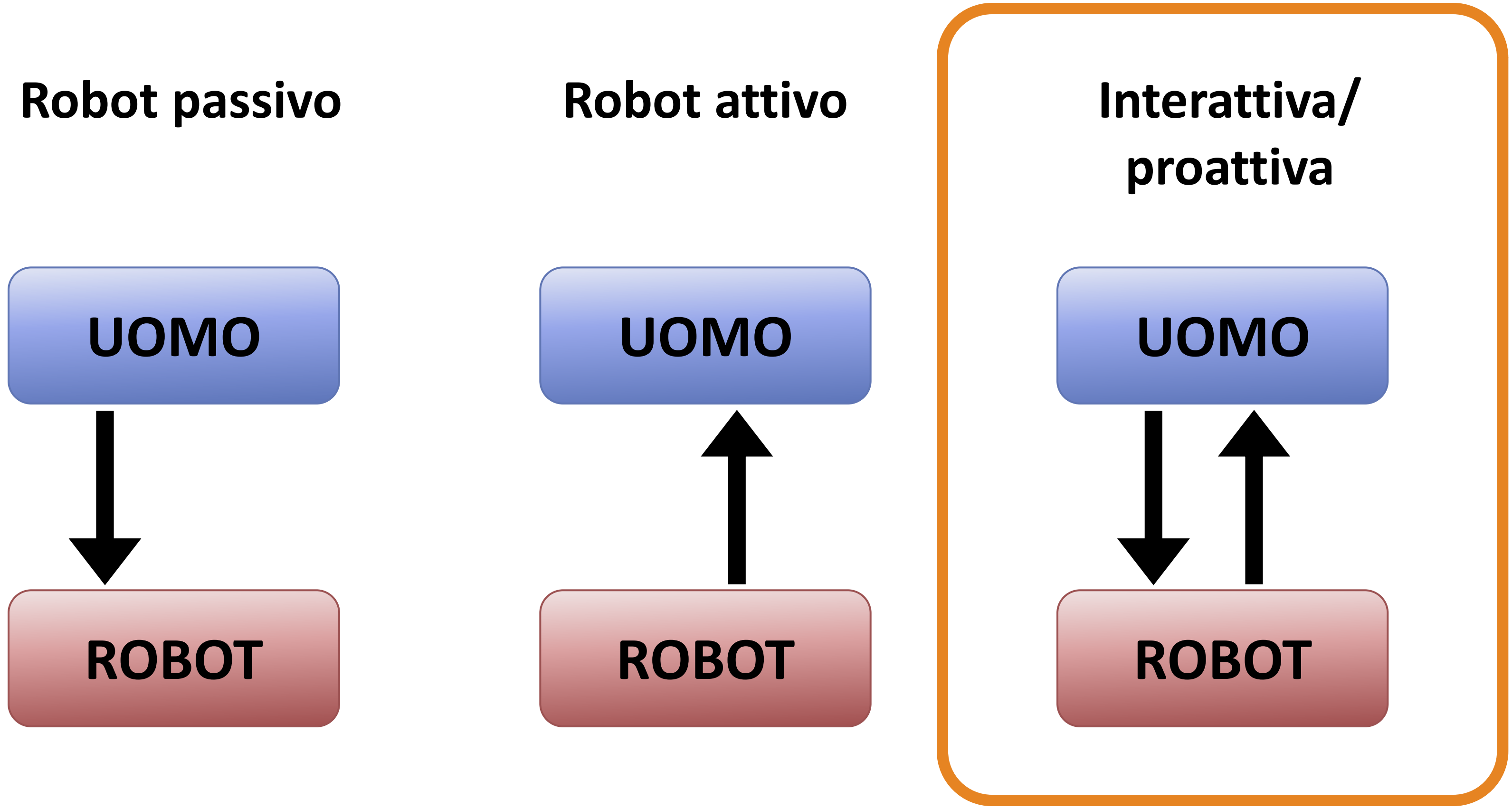
Robot terapeutici

MIT manus: manipulandum for upper limb rehabilitation

G-EO, end effector robot for gait rehabilitation

Lokomat, Hocoma Gait exosckeleton

Interazione fisica Uomo-Robot



Neural plasticity

- Our neural system develops since infancy and goes through a life-long process of use-dependent structural and functional reorganization.

Motor Adaptation

Skills are temporarily modulated to adapt to environmental changes. Adaptation is easily reversible

Motor Learning

Skills are learned over long time windows and result in long-lasting improvements

Neural plasticity

- SLACKING EFFECT

Our motor system behaves like a ‘greedy optimizer’: tends to decrease voluntary control during repetitive, passive mobilizations

PASSIVE vs ACTIVE rehabilitation:
Mobilization is always beneficial, but voluntary control is the engine that moves plastic modulation.

Paradigma di assistenza minima

Bidirectionality

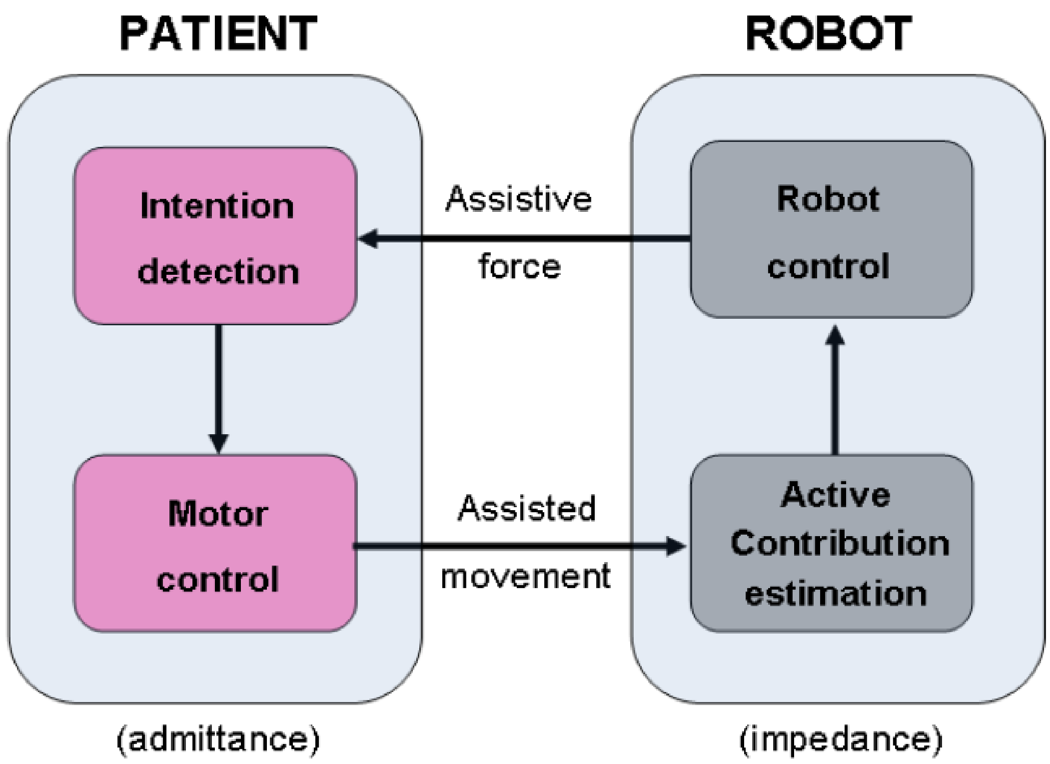
- Our sensorimotor systems is able to accurately plan and generate actions as well as predict and interpret their sensory consequences on the environment.

KINESTHETIC SENSE

It refers to the ability to detect the spatial *position* and/or *movement* of limbs in relation of the rest of the body in absence of visual input

Action and perception share the same representation and act together to drive learning/relearning of task oriented actions

Haptic interfaces

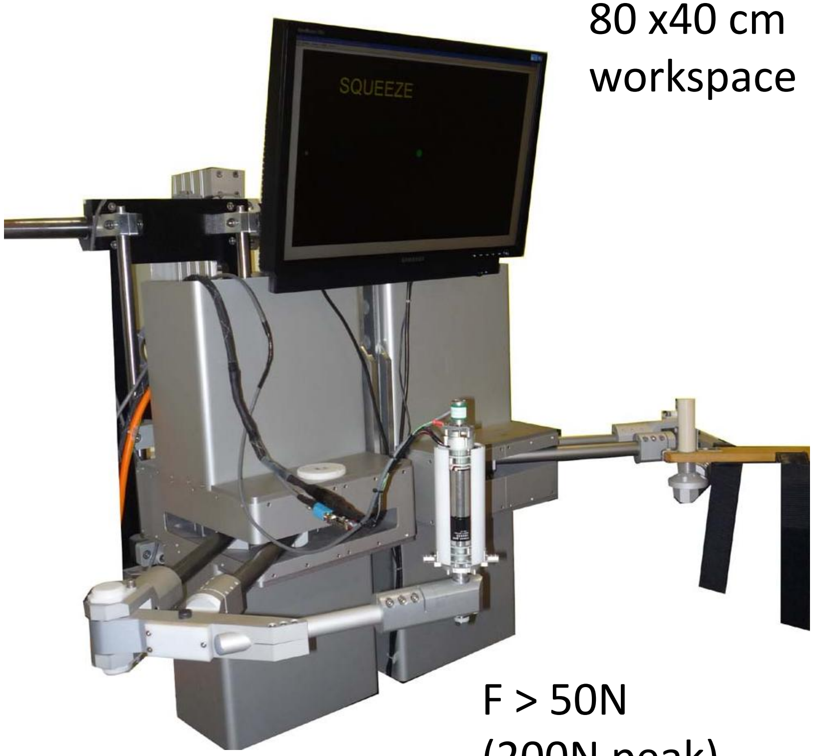


Braccio di Ferro

Bimanual 2-dofs end-effector robot for shoulder-elbow coordinated movements

- Fully Back-driveable
- Direct drive brushless motors
- Minimal endpoint friction and inertia
- Impendance control

80 x40 cm workspace



F > 50N (200N peak)

WristBot

3-dofs <u>exoskeleton</u> for wrist manipulation:

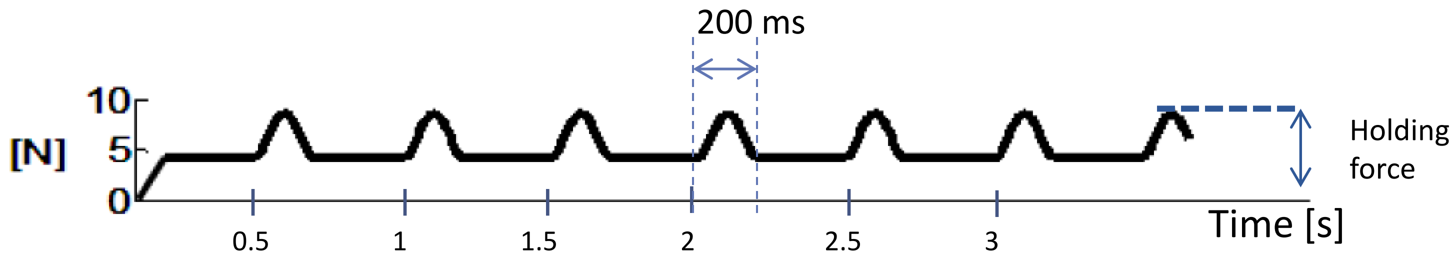
(1) Adduction/abduction
(2) Flexion/Extension
(3) Pronation/Supination

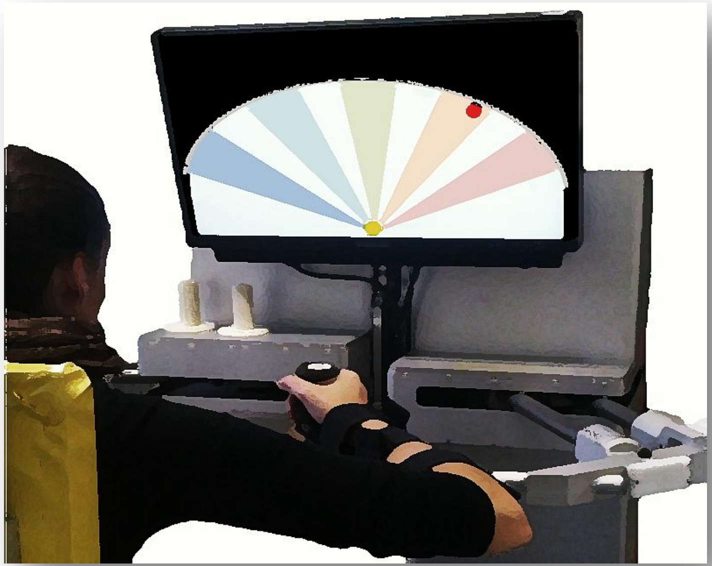
4 brushless motors

Fields of use: Stroke, Orthopedic rehab.,neurological pediatric subjects

Caso di studio 1:
Riabilitazione della propriocezione

Setup sperimentale: paradigma di assistenza pulsata





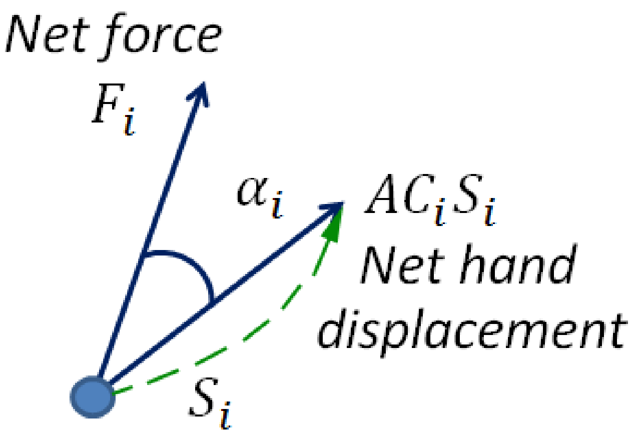
1) Minimizing the force provided by the robot at the interface with the subject
2) Providing the subject with maximal kinesthetic information
3) Assisting the movement in a safe but effective manner

AC index

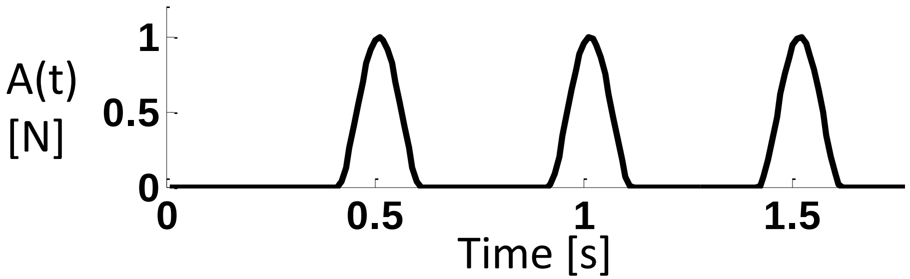
- Measure of coherence between passive and active hand displacement directions with respect to the applied force

$$AC_i = \frac{\left\|\sum_{i=1}^{M} \boldsymbol{v}_i\right\|}{\sum_{i=1}^{M}\left\|\boldsymbol{v}_i\right\|} = \frac{\left\|\sum_{i=1}^{M} \boldsymbol{v}_i\right\|}{S_i}$$

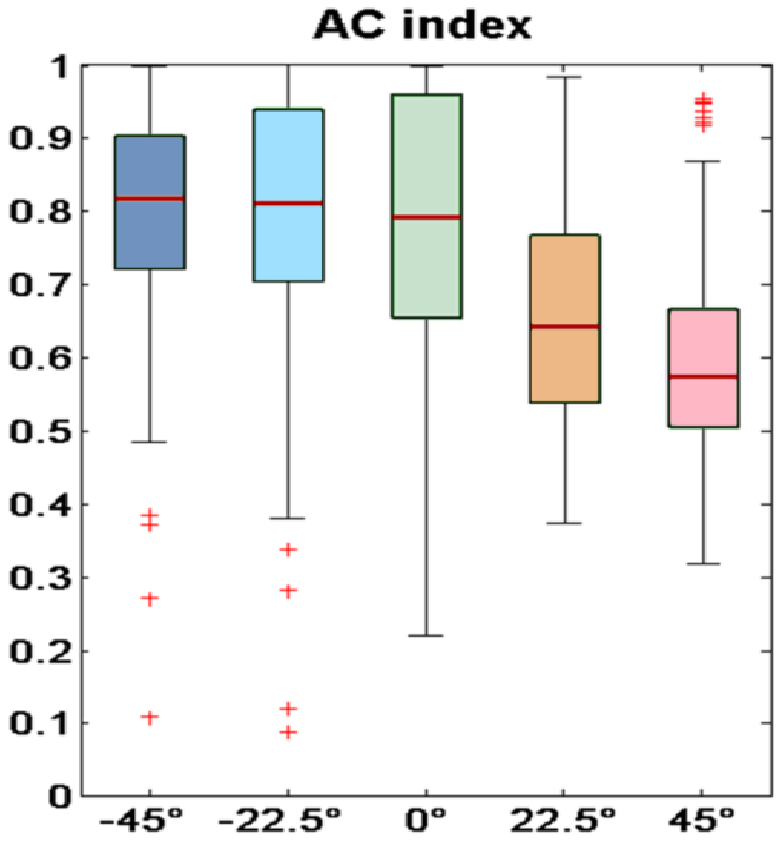
$$AC = \frac{\sum_{i=1}^{nM} \cos\alpha_i \, AC_i S_i}{\sum_{i=1}^{nM} S_i}$$



n = total impulse number
M = samples per impulse period
***v** = hand instantaneous velocity*

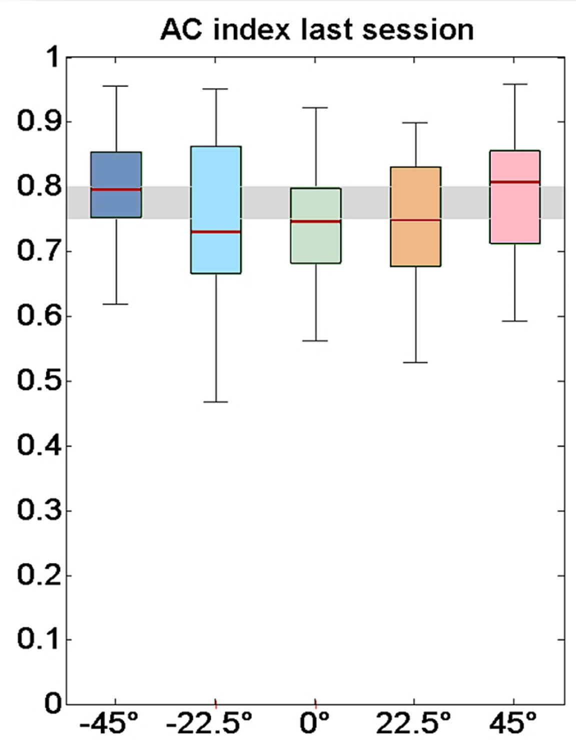


Risultati con soggetti sani

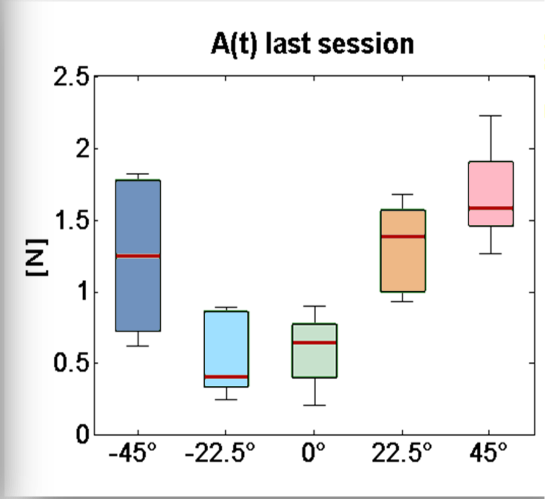


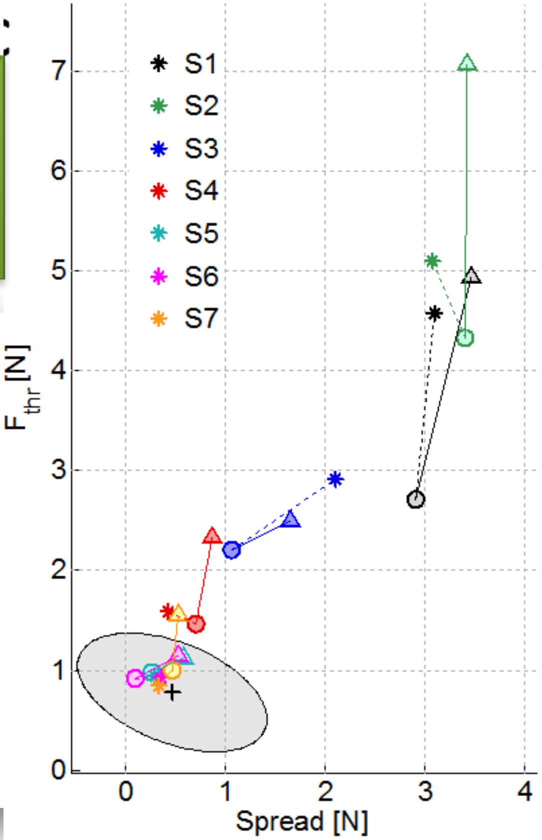
Percezione della forza anisotropica

Risultati con pazienti post-ictus



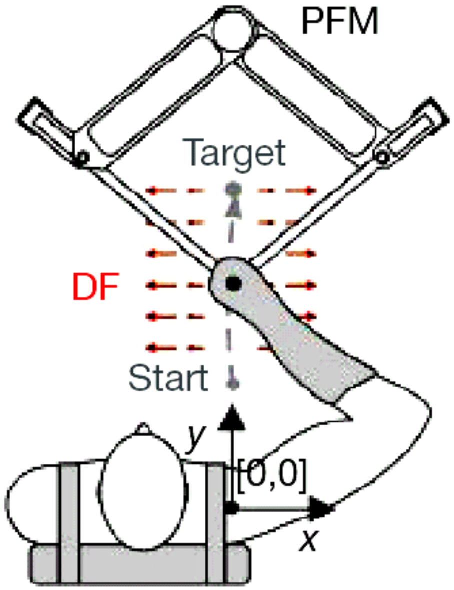
The force is minimized keeping the sensation accurate

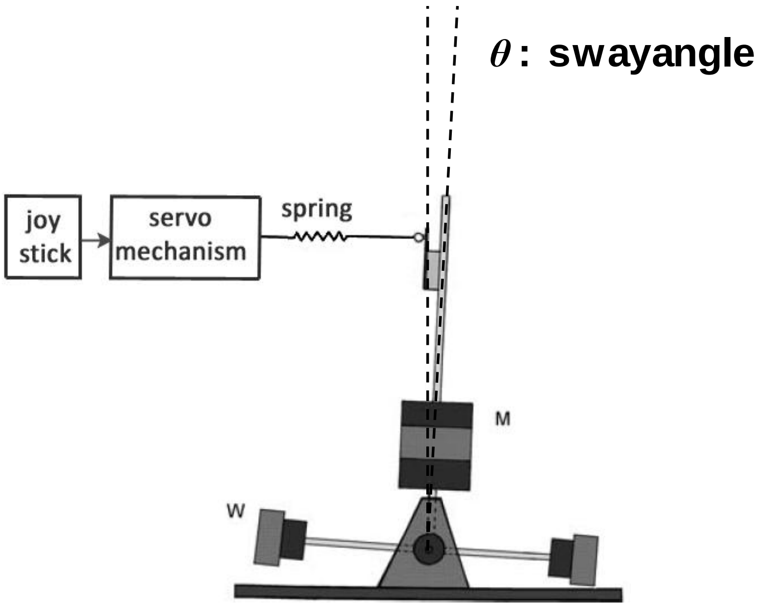




Caso di studio 2: Collaborazione con i robot

Strategie di controllo neurale dei movimenti



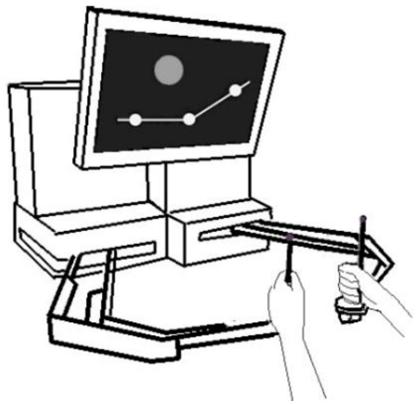


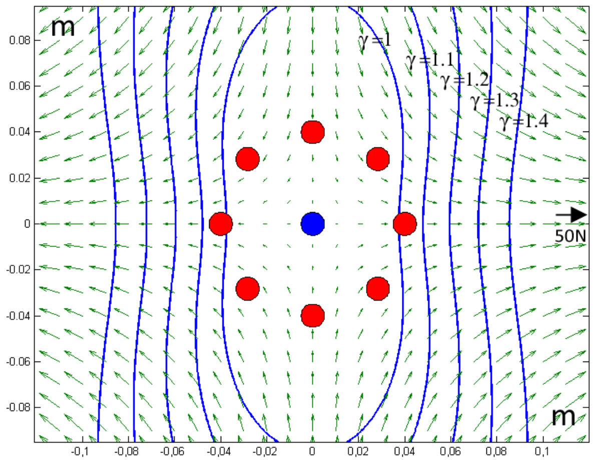
Stiffness Stabilization Strategy (SSS)

Positional Stabilization Strategy (PSS)

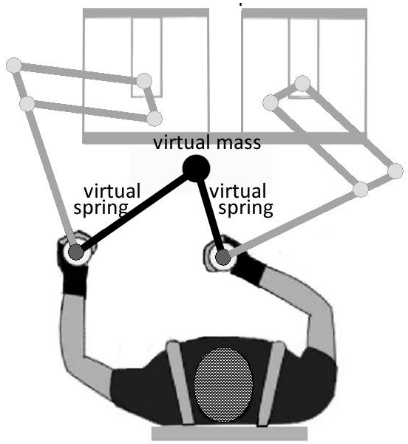
Setup sperimentale

Real Bimanual Manipulandum

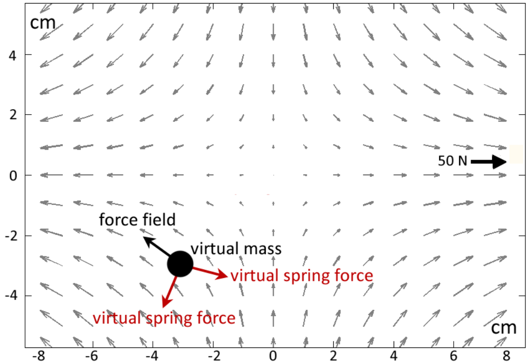




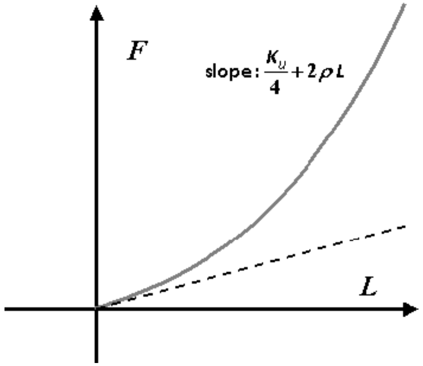
Virtual Underactuated Bimanual Manipulandum



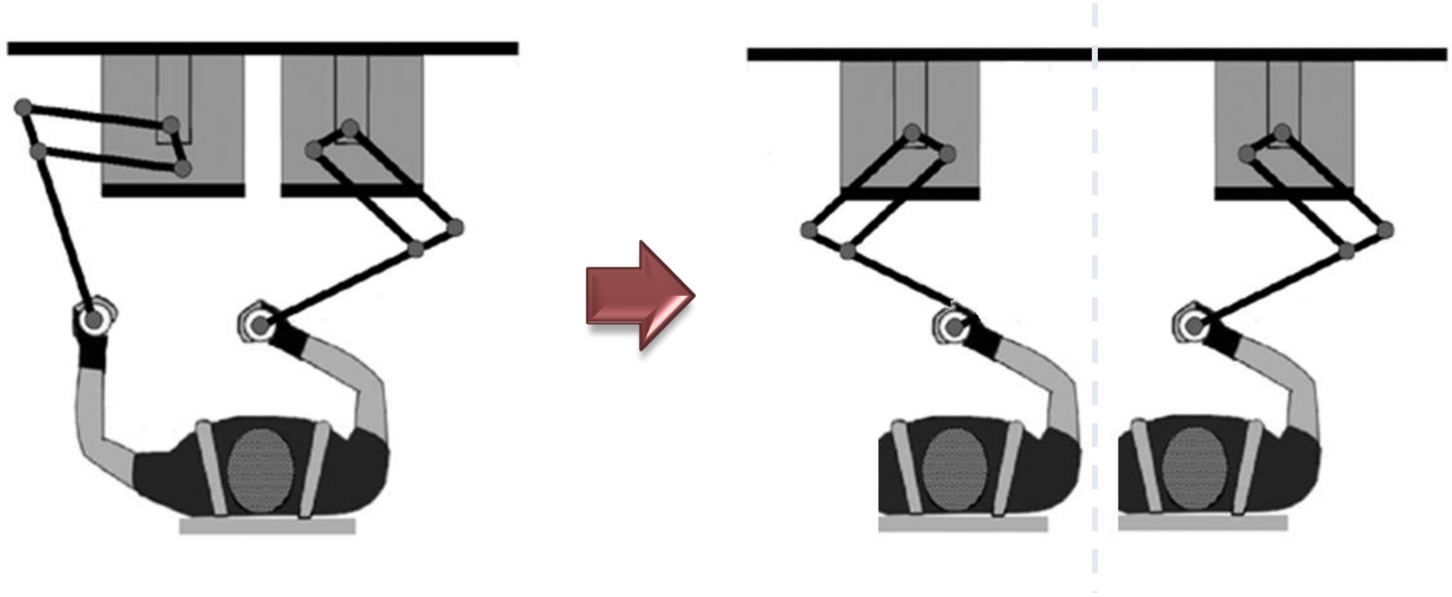
Virtual unstable force field



Virtual non linear springs

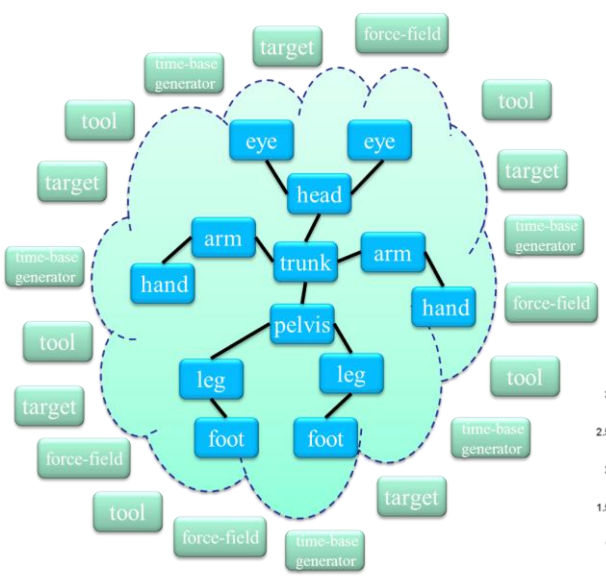


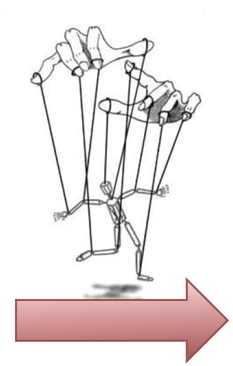
Dalla interazione uomo-robot alla collaborazione uomo-uomo

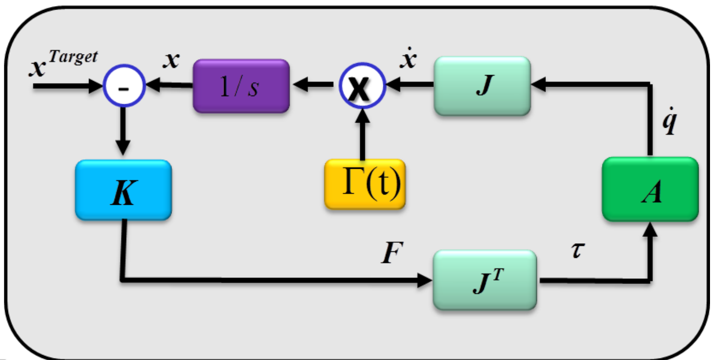


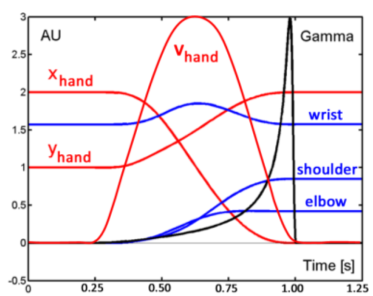
Caso di studio 3: Modelli computazionali del cervello per la robotica

Il concetto di Body Schema







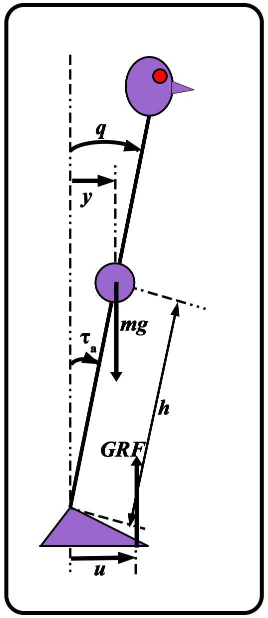


$$\begin{cases} \dot{x} = \Gamma(t) J A J^T K \left(x^{Target} - x\right) \\ \Gamma(t) = \dfrac{\dot{\xi}}{(1-\xi)} \\ \xi(t) = 6\left(\dfrac{t}{T}\right)^5 - 15\left(\dfrac{t}{T}\right)^4 + 10\left(\dfrac{t}{T}\right)^3 \end{cases}$$

Formazione di sinergie nel Whole Body Reaching

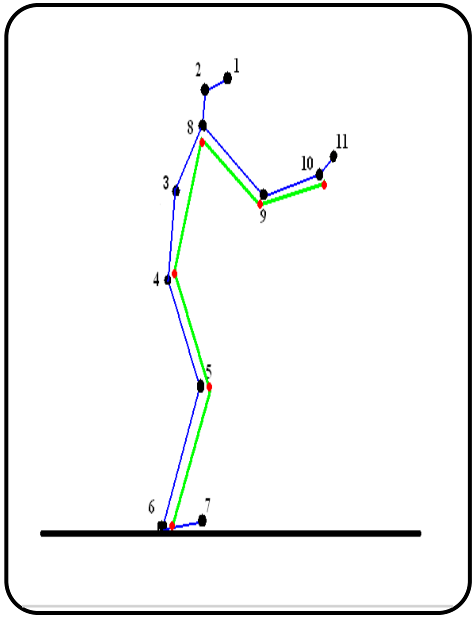
Dalla postura

1 DOF

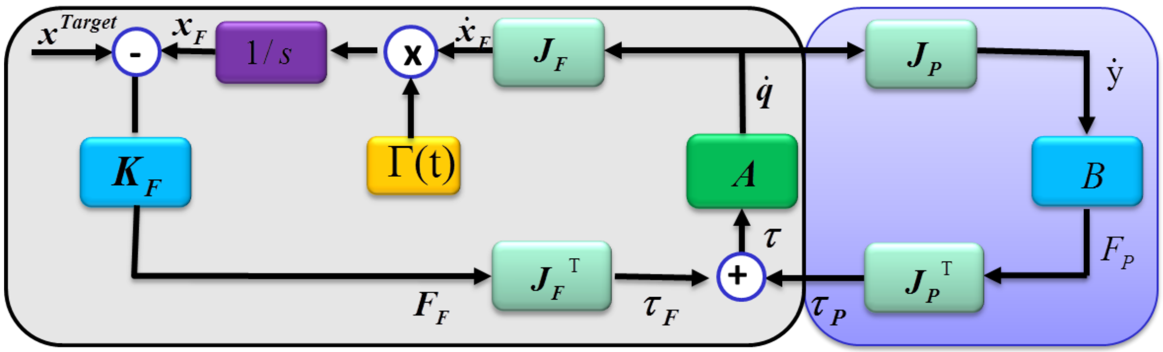


al movimento

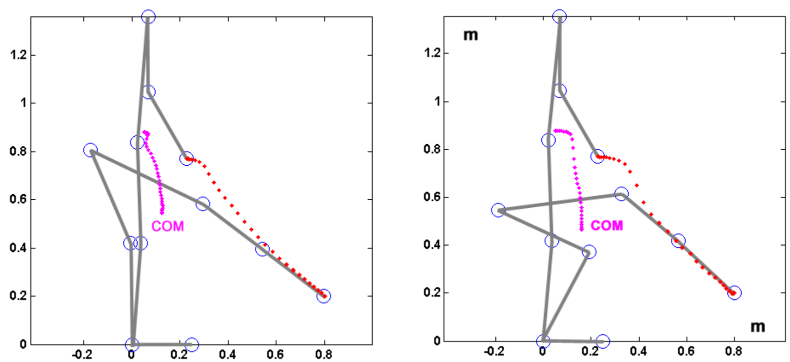
***n* DOF**

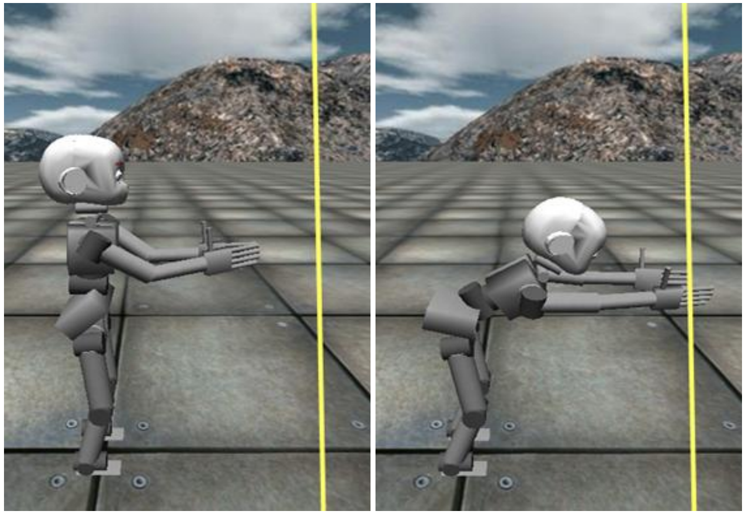


Il nuovo modello

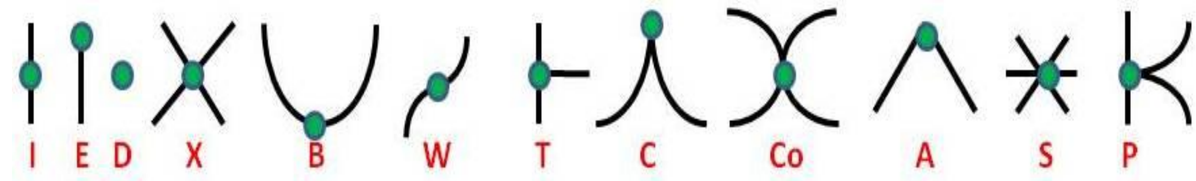


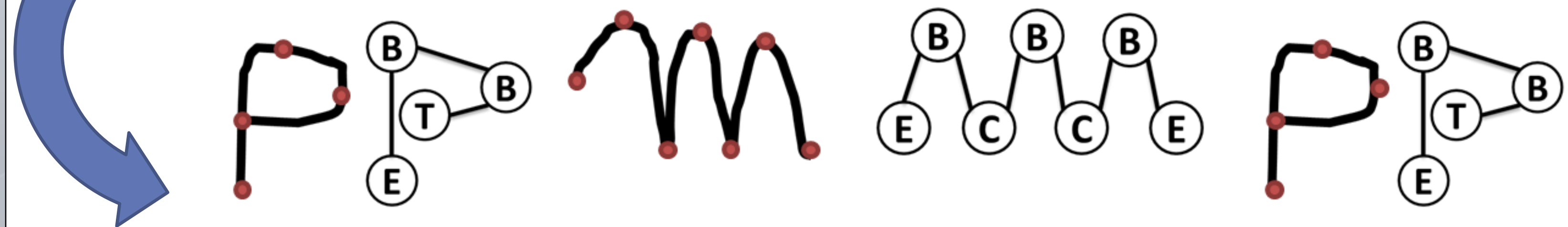
$$
\begin{cases}
\dot{x}_F = \Gamma(t) J_F A \tau \\
\Gamma(t) = \dfrac{\dot{\xi}}{(1-\xi)} \\
\xi(t) = 6\left(\dfrac{t}{T}\right)^5 - 15\left(\dfrac{t}{T}\right)^4 + 10\left(\dfrac{t}{T}\right)^3 \\
\tau = \tau_F + \tau_P \\
\tau_F = J_F^T \; K_F \left(x^{Target} - x_F\right) \\
\tau_P = J_P^T B J_P
\end{cases}
$$



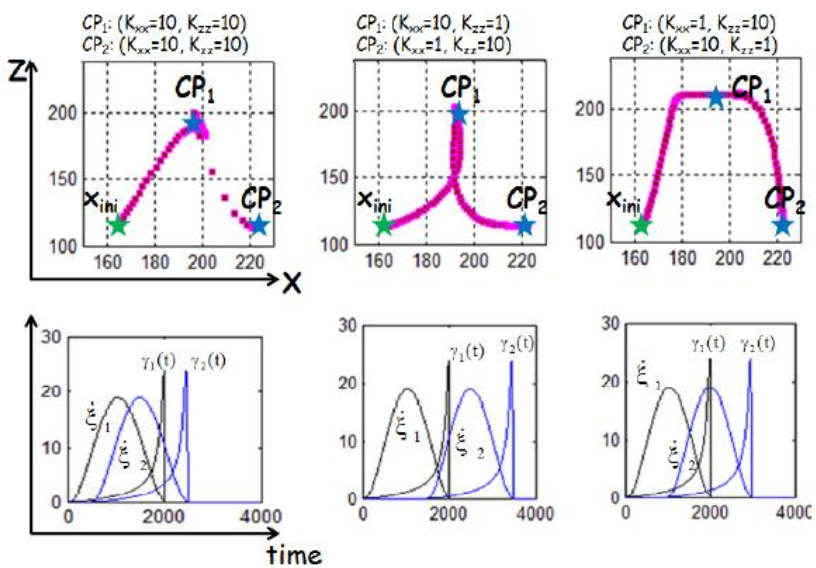


Scrittura corsiva





[E-B-B-T] [E-B-C-B-C-B-E] [E-B-B-T]



Riferimenti

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Grazie per l'attenzione!

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