Robotics, Brain and Cognitive Sciencs

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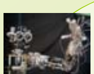
Italian Institute of Technology
Robotics, Brain and Cognitive Sciences Department

Genoa
January 22nd, 2008

Which technologies are missing in today's humanoid robots?

- Technologies supporting learning, recognition and classification of objects and events (e.g. associative memories, stochastic computing, etc).
- Technologies for safe interaction (e.g. artificial muscles with stiffness control, back-drivability…)
- Technologies for massive connections (connectors of the order of thousands of wire per square mm – e.g. optic nerve about 80,000 axons/mm^2)
- Soft flexible sensors and tissues (tendon-like, skin-like, bone-like…)
- Better "batteries" / portable energy production

Which abilities are most lacking in today's humanoids?



- "Prospective/associative" abilities (understanding of the situation)
- Continuous on-line learning from experience
- Social Intelligence (understanding the others)
- Perceptual abilities (e.g. vision, touch etc.)

How this abilities are "implemented" in humans is still largely unknown

Humanoid Robotics

Humanoid robotics research today has to be seen as a *human centered discipline* advancing science and developing new technologies along three main streams…

Human Centered Technologies

1. Build state-of-the-art humanoids
2. Study humans
3. Exploit human-machine interaction

"we do not want to "copy" humans, we also want to "understand"

January 22 - Tuesday

Start	Duration	Title	Speaker
9:20	0:10	Introduction	Giulio Sandini
9:30	1:30	A robotic project	Giorgio Metta
11:00	0:30	*Coffe Break*	
11:30	1:30	Robot Sensing and Manipulation	Lorenzo Natale
13:00	1:30	Lunch	
14:30	1:30	Motor Control	Francesco Nori
16:00	0:30	*Coffe Break*	
16:30	1:30	From sensorimotor learning to robot-therapy	Pietro Morasso
18:00		*End of Day*	

January 23 - Wednesday

Start	Duration	Talk	Speaker
9:30	1:30	From action to perception	Thierry Pozzo
11:00	0:30	*Coffe Break*	
11:30	1:30	Functional Brain Imaging	Franco Bertora
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January 24 - Thursday

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9:30	1:30	Brain Machine Interface	Luciano Fadiga
11:00	0:30	*Coffe Break*	
11:30	1:30	Decoding brain signals	Stefano Panzeri
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January 25 - Friday

Start	Duration	Talk	Speaker
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11:00	0:30	*Coffe Break*	
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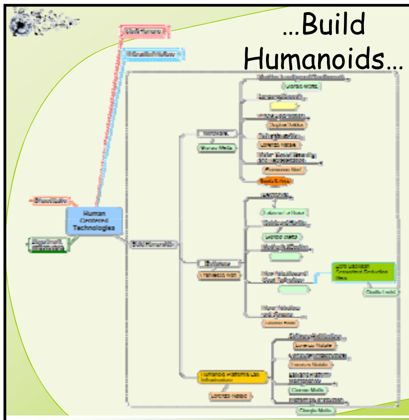
Build Humanoids

Study Humans

Exploit Interface

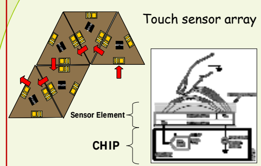
…Build Humanoids…



Ravinder Dahiya
Boris Duran
Marco Maggiali
Vishwanathan Mohan
Marco Randazzo
Jayathu Samarawickarama
Matteo Fumagalli
Serena Ivaldi
Massimiliano Izzo
Lorenzo Jamone
Alberto Parmiggiani
Alexander Schmitz
Toufik Bentalab
Maurizio Biso
Mehmet R. Dogar
Arjan Gijsberts
Ugo Pattaccini
Michele Tavella

…touch and torque sensors

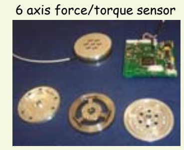
Touch sensor array



Study by Marco Maggiali jointly with UNIGE (prof. Giorgio Cannata) and Giorgio Metta

Patented Recently

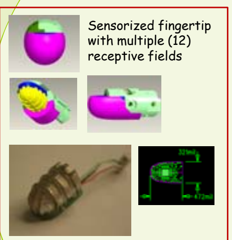
6 axis force/torque sensor



Study by Alberto Parmiggiani and Matteo Fumagalli jointly with Lorenzo Natale

Jointly with Darwin Caldwell and Nick Tsagarakis

ICub Fingertips and Fingernails



Sensorized fingertip with multiple (12) receptive fields

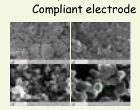
Fingernail for roughness, slip, and contact estimation

Study by Alexander Schmitz, Marco Maggiali, Marco Randazzo with Giorgio Metta and Lorenzo Natale.

Compliant Actuation

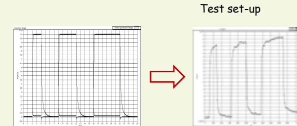
Dielectric elastomer

Compliant electrode



Actuator

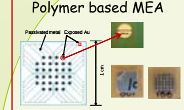
Test set-up



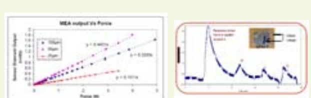
Study by Marco Randazzo jointly with CBA (prof. Ugo Valbusa and Renato Buzio)

Integrated Tactile Sensor Array

Polymer based MEA



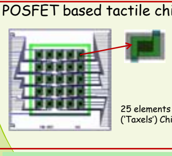
MEA with 32 elements ('Taxels'). A 100 µm thick PVDF-TrFE polymer filmepoxy adhered on the MEA



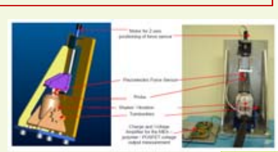
Output vs. force and thickness

Output vs. position

POSFET based tactile chip



25 elements ('Taxels') Chip



TEST Set-up

Study by Ravinder Dahiya jointly with DIBE and IRST (Maurizio Valle and Leandro Lorenzelli)

Modular control in modular contexts

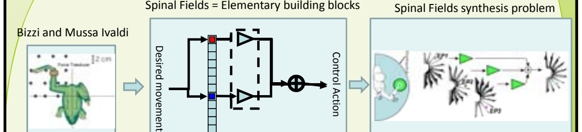
Francesco Nori, Lorenzo Natale, Enrico Chiovetto

Manipulating combined objects can be achieved by combining the individual force fields?

Bizzi and Mussa Ivaldi

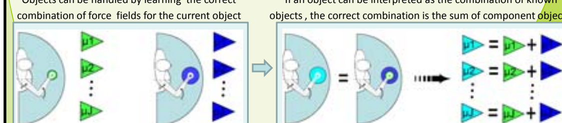
Spinal Fields = Elementary building blocks

Spinal Fields synthesis problem

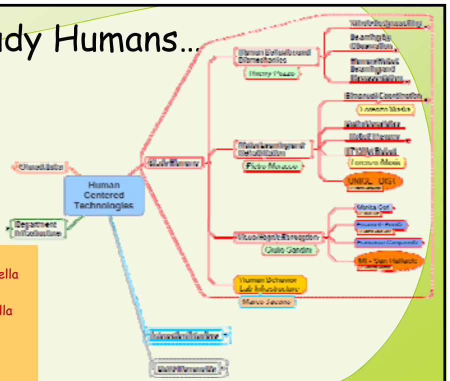


Objects can be handled by learning the correct combination of force fields for the current object

If an object can be interpreted as the combination of known objects, the correct combination is the sum of component objects

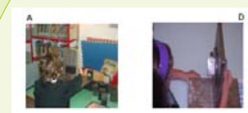


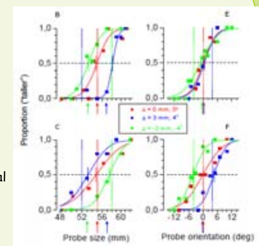
…Study Humans…



Monica Gori
Francesco Campanella
Enrico Chiovetto
Angelo Maria Fiorilla
Alessandra Sciutti
Valentina Squeri
Michela Bassolino
Ambra Bisio
Paola Salmas

Study the development of visuo-tactile integration in children

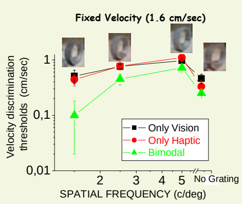


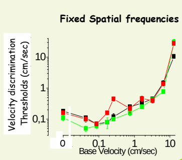


- Visual and haptic integration is not optimal before 8 years of age.
- Before 8 years vision dominates in orientation discrimination and haptic dominates in size discrimination

Study by Monica Gori with Prof. David Burr

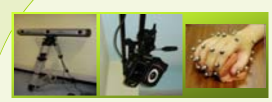
Perception of visual and tactile flow



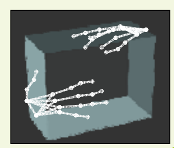


Study by Monica Gori

Action Based Object Representation



- How relevant is "action" in recognizing objects?
- Can the visual sistemm exploit the view of haptic exploration to extract shape information of the explored object?

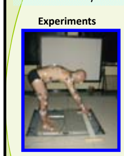


Motor control, coordination and redundancy in humans

Thierry Pozzo, Enrico Chiovetto, Marco Jacono

The main goal is to understand the primary rules of human motor control and coordination at the base of the performance of **complex and multi-goal oriented actions** (e.g. Whole-Body-Reaching). The explanation of the way the CNS can overcome redundancy issues typical of any kinematic chain to be controlled may reveal helpful in humanoid-robotics applications.

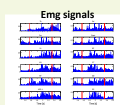
Experiments



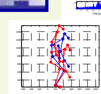
Processing

Kinematics

Emg signals



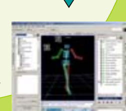
Results



Inverse dynamics

Experimental setup:
✓VICON motion capture system
✓32 Ch. wireless EMG recorder
✓AMTI force platforms

Modeling and humanoid robotics applications

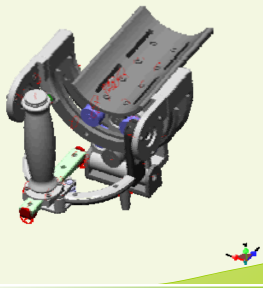


Rehabilitation Robotics

"Braccio di Ferro" designed by Pietro Morasso

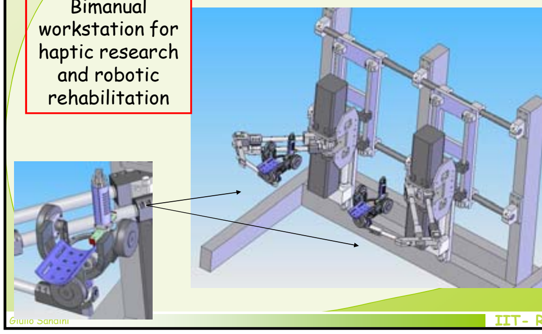
IIT Wrist Robot

Lorenzo Masia



Bimanual Multijoint Coordination in Complex Reaching and Manipulation Tasks

Bimanual workstation for haptic research and robotic rehabilitation

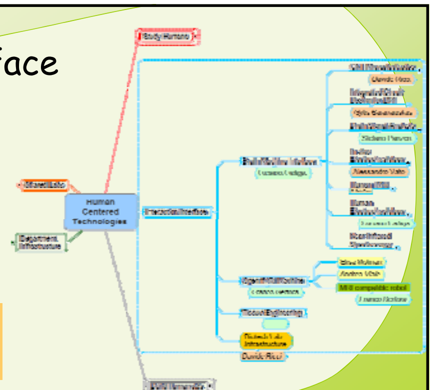


…Interface…

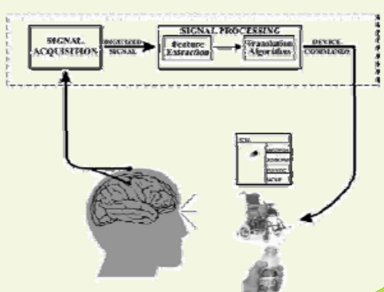
Interface

Luciano Fadiga
Franco Bertora
Stefano Panzeri
Davide Ricci
Alessandro Vato
Gytis Baranauskas
Elisa Molinari
Fernando Montani
Alberto Ansaldo
Andrea Viale

Elisa Castagnola
Giorgio Facco
Giuseppe Notaro
Marianna Semprini



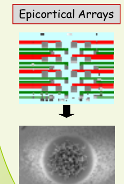
BCI System



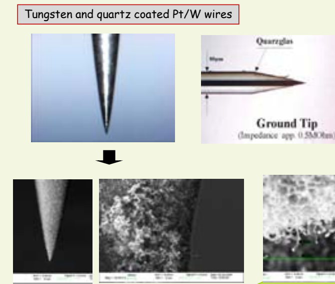
CNT coated electrodes for in-vivo neural recordings

On-going Activities

Epicortical Arrays



Tungsten and quartz coated Pt/W wires

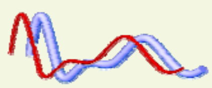


GOAL : enhanced interface impedance properties and biocompatibility

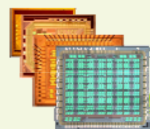
Microelectronics

Brain

Neural Activity



Microelectronics

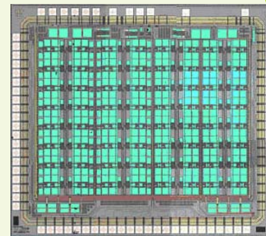


Development of implantable (wireless) devices

Jointly with Milan Politecnico (Prof. Alessandro Spinelli and Dr. Tommaso Borghi)

64 Channel LPC Amplifier

Fabricated in a 0.35-µm 2-poly, 4-metal commercial CMOS process through CMP



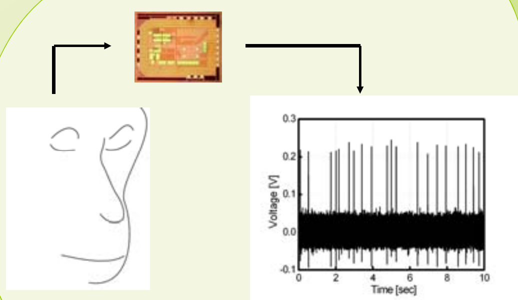
Dimensions

2.6 mm x 3 mm

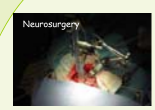
Total Power Consumption

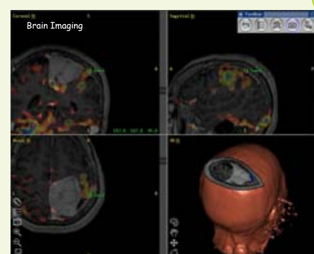
~20 mW

Preliminary recordings



Correlating functions and electrical activity in humans





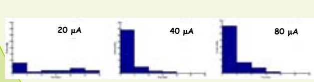
Jointly with University of Udine (Prof. Miran Skrap) and University of Modena (Prof. Carlo Porro)

Artificial Proprioception

Alessandro Vato, Marianna Semprini, Sandro Mussa Ivaldi

In the context of bidirectional Brain Machine Interface operant behavior and multi-channel <u>intracortical microstimulation</u> have been used to develop a new experimental paradigm in which behaving rats served as subject <u>to explore different patterns of electrical pulses delivered to the somatosensory</u> cortex in order to provide proprioceptive information.

Preliminary investigation on threshold perception of external electrical pulses is carried out at Northwestern University using 16 channels microwire array (tungsten 50 µm diameter) chronically implanted in somatosensory cortex.



"Correct response" as a function of stimulus amplitude

Design of an "open" fMRI

Franco Bertora, Elisa Molinari, Andrea Viale

e.g. to allow recording during manual tasks

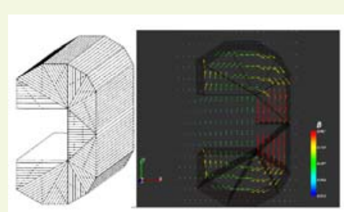


Figure 1 – Magnet schematic and field diagram showing the good field containment within the structure.

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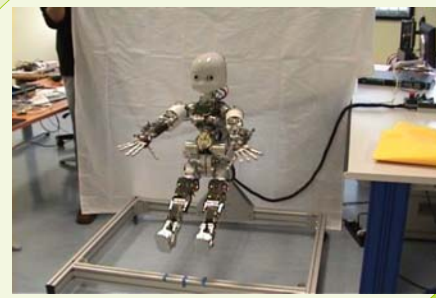
Study Humans

Exploit Interface



…third floor…