

# Robotics, Brain and Cognitive Sciences

Giulio Sandini  
Italian Institute of Technology  
Robotics, Brain and Cognitive Sciences Department

Genoa  
January 22<sup>nd</sup>, 2008

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# 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<sup>2</sup>)
- Soft flexible sensors and tissues (tendon-like, skin-like, bone-like...)
- Better "batteries" / portable energy production

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# 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

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# 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...

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# Human Centered Technologies

- Build state-of-the-art humanoids
- Study humans
- Exploit human-machine interaction

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

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Year	Speaker	Title
<b>January 22 - Tuesday</b>		
9:20	Giulio Sandini	Introduction
9:30	Giorgio Metta	A robotic project
11:00	Coffy Brest	Coffee Break
11:30	Lucrezio Natale	Robot Sensing and Manipulation
13:00		Lunch
14:30	Francesco Nori	Motor Control
16:00	Coffy Brest	Coffee Break
16:30	Pietro Morasso	From sensorimotor learning to robot-therapy
18:00		End of Day
<b>January 23 - Wednesday</b>		
9:30	Thierry Pozzo	From action to perception
11:00	Coffy Brest	Coffee Break
11:30	Franco Bertoa	Functional Brain Imaging
13:00		Lunch
14:30	Darwin Caldwell	Haptics
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16:30	Darwin Caldwell	End Effectors and Manipulation
18:00		End of Day
<b>January 24 - Thursday</b>		
9:30	Luciano Fadiga	Brain Machine Interface
11:00	Coffy Brest	Coffee Break
11:30	Stefano Fancini	Decoding brain signals
13:00		Lunch
14:30	Paolide Bucci	Nanomaterials for biointerfaces and robotics
16:00	Coffy Brest	Coffee Break
16:30	Lee Miller	The Ins and Outs of Brain Machine Interfaces
18:00		End of Day
<b>January 25 - Friday</b>		
9:30	Jean-Guy Fontaine	Robotics and technological transfers
11:00	Coffy Brest	Coffee Break
11:30	Jean-Guy Fontaine	From teleoperation to telepresence
13:00		Lunch - End of Week

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### ...Build Humanoids...

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

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### ...touch and torque sensors

Touch sensor array

Sensor Element

CHIP

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

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### 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.

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### Compliant Actuation

Dielectric elastomer

Compliant electrode

Actuator

Test set-up

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

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### Integrated Tactile Sensor Array

Polymer based MEA

MEA with 32 elements ('Taxels'). A 100 μm thick PVDF-TrFE polymer film epoxy 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)

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### Modular control in modular contexts

Francesco Nori, Lorenzo Natale, Enrico Chiovetto

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

Spinal Fields = Elementary building blocks

Spinal Fields synthesis problem

Bizzi and Mussa Ivaldi

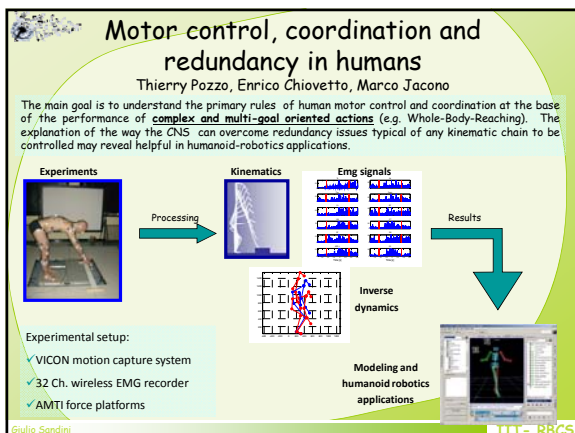
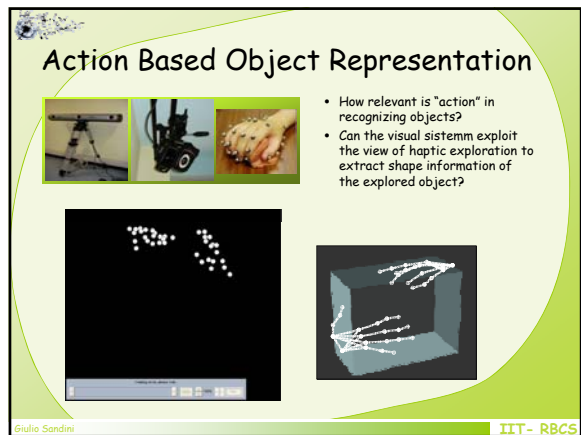
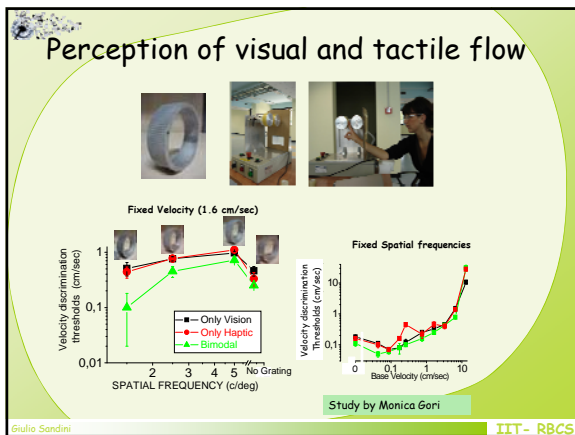
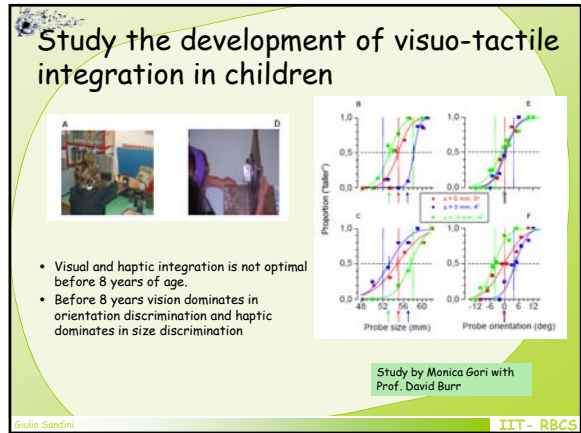
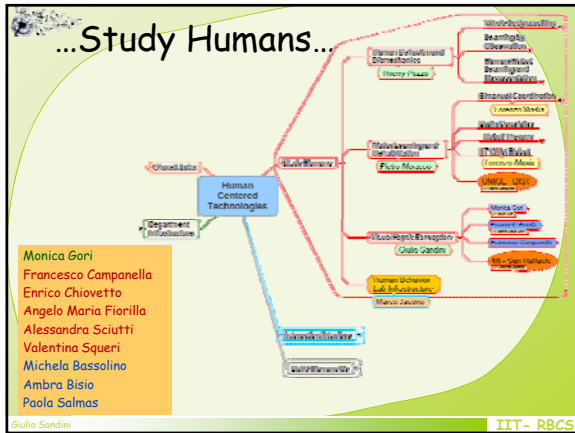
Desired movement

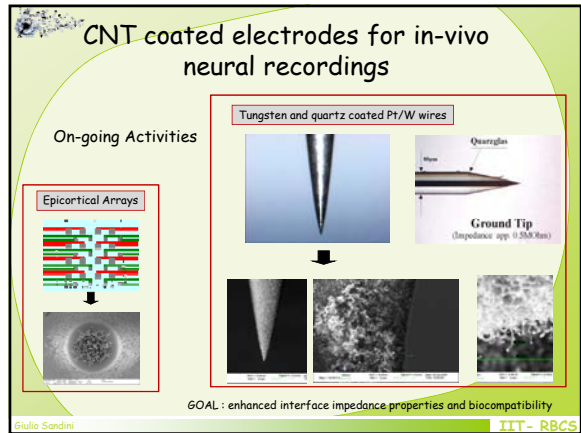
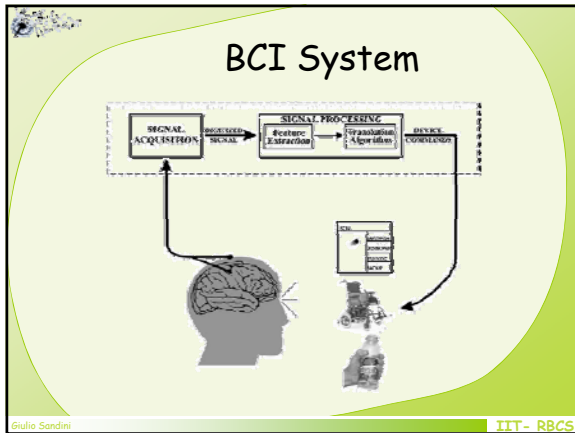
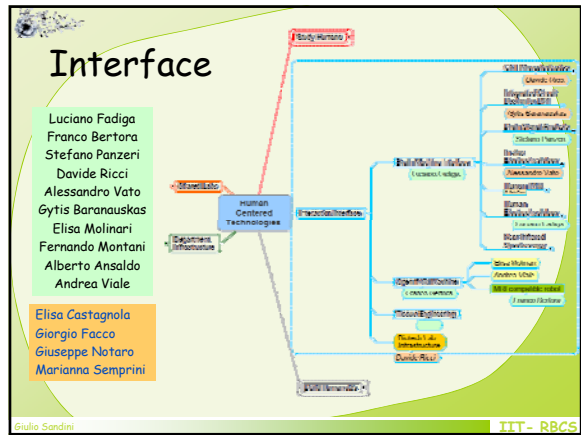
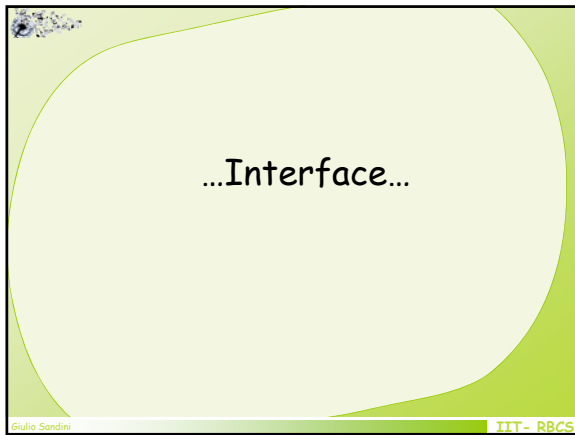
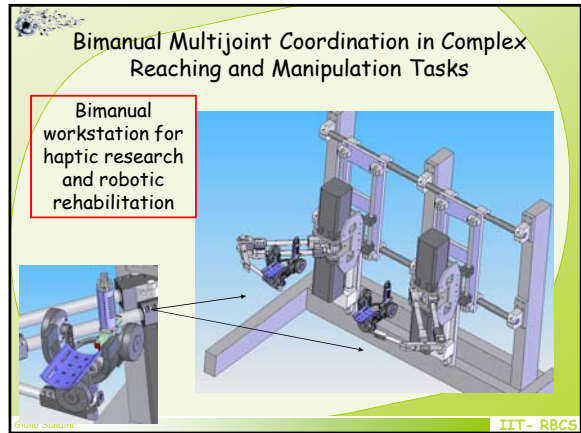
Control Action

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


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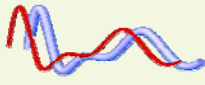


## Microelectronics

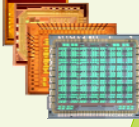
Brain



Neural Activity



Microelectronics




**Development of implantable (wireless) devices**

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

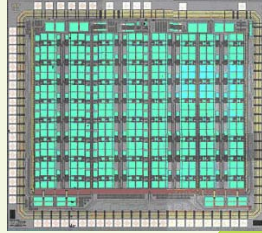
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## 64 Channel LPC Amplifier

Fabricated in a 0.35- $\mu\text{m}$  2-poly, 4-metal commercial CMOS process through CMP




**Dimensions**  
2.6 mm x 3 mm

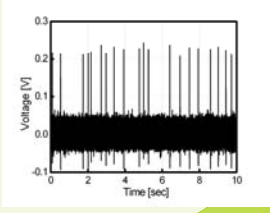


**Total Power Consumption**  
~20 mW

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## Preliminary recordings






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## Correlating functions and electrical activity in humans

Neurosurgery



Brain Imaging




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

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## Artificial Proprioception

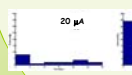
Alessandro Vato, Marianna Semprini, Sandro Mussa Ivaldi

In the context of bidirectional Brain Machine Interface operant behavior and multi-channel intracortical microstimulation have been used to develop a new experimental paradigm in which behaving rats served as subject to explore different patterns of electrical pulses delivered to the somatosensory 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  $\mu\text{m}$  diameter) chronically implanted in somatosensory cortex.

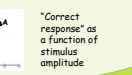
20  $\mu\text{A}$



40  $\mu\text{A}$



80  $\mu\text{A}$



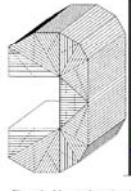
\*Correct response\* as a function of stimulus amplitude

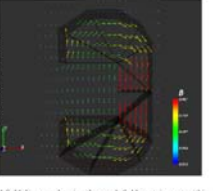
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## Design of an "open" fMRI

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 contrast within the structure.

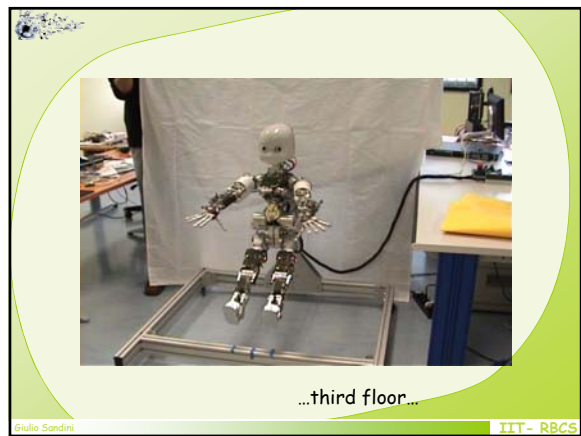
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Build Humanoids

Study Humans

Exploit Interface



...third floor...