Robots, Brain and Cognitive Sciences

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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/mm²)
• 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”
...Build Humanoids...

Bayvan Dahiya  
Beren Duran  
Marco Maggiali  
Vishwanathan Mohan  
Marco Randazzo  
Zeynep  
Sohrabi  
Matteo Fumagalli  
Serena Zivoli  
Massimiliano Izzo  
Lorenzo Jamone  
Alberto Parmiggiani  
Alexander Schmitz  
Toufik Bentalab  
Maurizio Biso  
Mehmet R. Dogar  
Argy Spyridakis  
Ugo Pattaccini  
Michele Tavella

...touch and torque sensors

Touch sensor array  
6 axis force/torque sensor

ICub Fingertips and Fingernails

Sensorized fingertip with multiple (12) receptive fields  
Fingernail for roughness, slip, and contact estimation

Compliant Actuation

Dielectric elastomer  
Compliant electrode  
Actuator  
Test set-up

Integrated Tactile Sensor Array

Polymer based MEA  
POSPEF based tactile chip

Modular control in modular contexts

Francesco Nori, Lorenzo Natale, Enrico Chiovetto

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

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...

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.

Perception of visual and tactile flow

- Fixed Velocity (1.6 cm/sec)
- Velocity discrimination threshold (cm/sec)
- Spatial frequencies (c/deg)

Action Based Object Representation

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

Motor control, coordination and redundancy in humans

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

- VICON motion capture system
- 32 Ch. wireless EMG recorder
- AMTI force platforms

Results

Experimental setup:

- Kinematics
- Eng signal
- Iverse dynamics
- 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
Francesco Bartens
Stefano Panzeri
Davide Ricci
Alessandro Vato
Gyris Baranoskas
Elisa Molinari
Fernando Montani
Alberto Ansaldo
Andrea Viale

Elisa Castagnola
Giorgio Fauci
Giuseppe Natore
Marina Semprini

BCI System

CNT coated electrodes for in-vivo neural recordings
On-going Activities

Tungsten and quartz coated Pt/W wires

GOAL: enhanced interface impedance properties and biocompatibility
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 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 microelectrode 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
Build Humanoids
Study Humans
Exploit Interface