Humanoid Technologies

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Italy-Japan 2005 Workshop
September 8, 2005

LIRA-Lab Research Pillars

1. Robots as neuroscience research tools
2. Developmental approach
3. Learning is a necessary step for understanding

The LIRA-Lab Human Pillars

…in collaborations with..

Artificial Systems and Computational Neuroscience

- Paolo Dario – Scuola S. Anna Pisa
- Rolf Pfeifer – University of Zurich
- Jose' Santos-Victor – Alex Bernardino IST Lisbon
- Aude Billard – EPFL – Lausanne
- Hideki Kozima – NICT Japan
- Rodney Brooks – CSAIL MIT
- Gordon Cheng – ATR Japan
- Yasuo Kuniyoshi – University of Tokyo
- Darwin Caldwell – University of Salford
- ….

RobotCub.org

Neurophysiology and Developmental Psychology

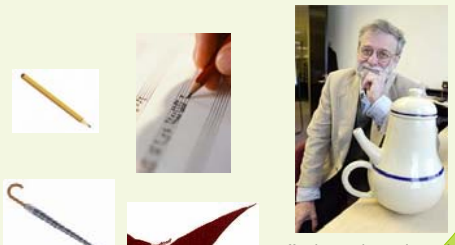
- Luciano Fadiga – Univ. of Ferrara
- Claes von Hofsten – Kerstin Rosander – Univ. of Uppsala
- Jacqueline Nadel – CNRS Paris
- Arlette Streri – University Pierre and Marie Curie, Paris
- Fancisco Lacerda – University of Stockholm
- Kerstin Dautenhahn – University of Hertfordshire
- ….

Humanoid Technologies must explicitly support *human-like functions*

- Learning from experience;
- Predicting the effect of actions;
- Recognition and generalization;
- Reasoning about events and taking decisions;
- Communication with humans and robots
- …

These are dynamic processes based on (or learned through) interactions: a **physical body** is an essential tool.

Actions are essential to understand the difference between….



Affordance depends on the goal of the action

So far, emphasis on two fields and the related technologies

Neuroscience

Robotics

During the talk I will present some of our activities and, toward the end, a bit of a research agenda

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Main objective has been the study of **sensorimotor and cognitive development** by investigating the interaction between the individual (human or robot) and the environment.

By studying and implementing a system that "develops" we want to realize a system that builds itself (as a human baby)

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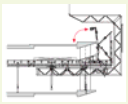
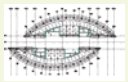
Building systems requires infrastructures…





…which are not evident in the "final system"

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The "process of building" a human being is based on learning thought interaction with the environment and with others

Shaping the self

Interacting with others

The world and the body have regularities that can be exploited (we need human-like shape!)

To understand one needs to be able to do

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Understanding actions is easier if the system has learned the effects of its own actions on objects

Representation of objects includes the actions that have been performed upon it and their effects.

This representation allows you to predict the future course of events

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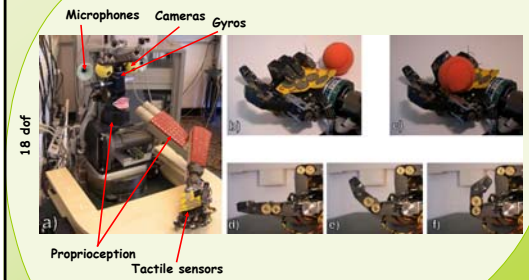
Babybot…



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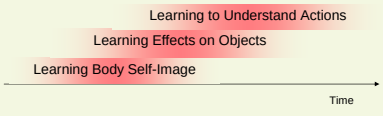
Exploit actions to learn and understand while following a developmental path



Phased development

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Learning to stabilize gaze



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Learn about gravity

(Control based on "force fields")



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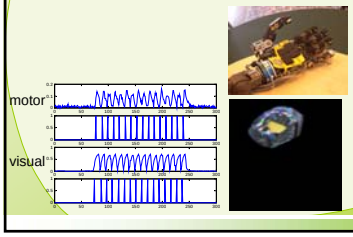
Learn about your own body (Where is my hand?)

- Learn to localize the body (e.g. the hand)
- The body is a "unique entity" in the environment since it is actively controlled
- Find correlation between action and visual perception



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At the end the system can direct the gaze using arm's proprioception


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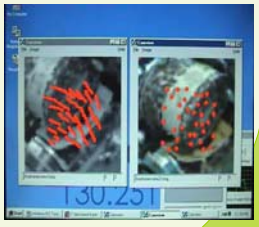
Learning Object Models through Active Manipulation

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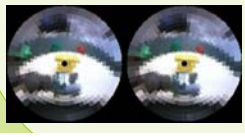
Learning the effects of actions

The robot has to learn the effect of its own actions on objects and been able to consistently repeat it

A simple example: learning the direction of approach for correct pushing.



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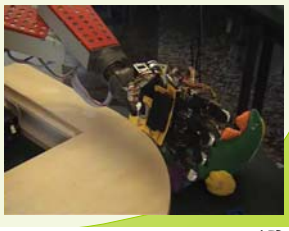
Learning to discriminate by grasping

...how can the robot grasp an unknown object ?

- 16 joints
- 6 degrees of freedom



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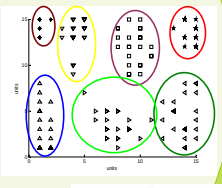
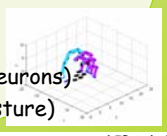
6 objects





- 2D Self Organizing Map (100 neurons)
- Input: proprioception (hand posture)

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Complex behavior

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In spite of these results the humanoid is still implemented by assembling robot components with a human shape

They are not “humanoids” in many respects:

- Made of rigid materials (catastrophic consequences of failures)
- Low-level degree of autonomy (development is driven from the “outside”)
- Compared to humans still very limited learning and adaptation (humans are optimized for this!)
- Too much energy consumption (..assuming unlimited resources..)

Solutions in biological systems are always “multi-technological”

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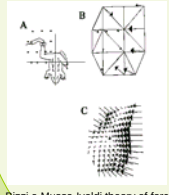
Solutions in biological systems are always multi-technological

Autonomous (*intelligent*) manipulation depends as much on how the controller works (mind) as on the physical properties of the muscles



Bizzi e Mussa-Ivaldi theory of force fields
Exploit visco-elastic properties of muscles

Can be simulated but some major advantages are lost

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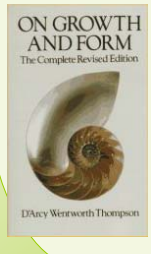
Are we considering all dimensions (technologies)?

Form and function are correlated in biological systems



Physical growth and morphological change may be an essential ingredient also for artificial systems

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…not all morphological regularities require complex (global) computation…

Even potatoes can compute morphological regularities…

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We know that "natural" minds are shaped by interactions

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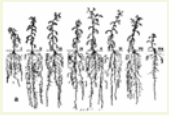
In nature also the bodies are shaped by interactions

Micromechanical hypothesis of mosaic assembly



Lucia Galli, TRENDS in Neuroscience Vol. 25 No. 12 – December 2002

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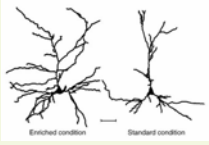
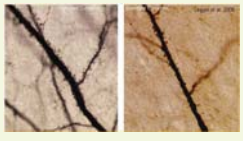
In biological systems body and mind co-develop

Development and learning are associated to morphological changes at neuronal level





Is this unique of biological systems?

Can we think about "artificial growth"?

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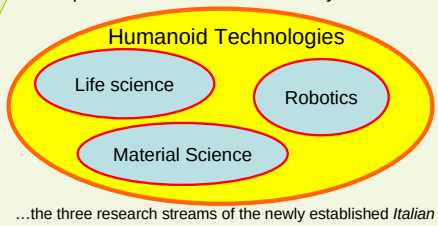
…the missing dimension…

…so far we have attempted to study the adaptation of the mind but the body is fixed…



…the three research streams of the newly established *Italian Institute of Technology* (www.iit.it).
IIT will invest about 30 M€/year starting at the end of 2005 on "humanoid technologies".

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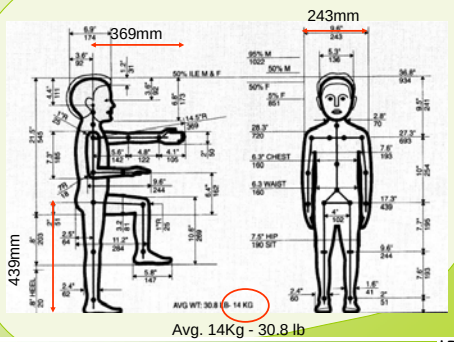
Some missing technologies…

- technologies for physical interface of biological tissues and artificial materials (not only neurons but also skin and bones)
- Technologies for massive connections (connectors of the order of thousands of wires per square mm – e.g. optic nerve about 80,000 axons/mm2)
- Technologies implementing function through stochastic connectivity
- Technologies implementing 3D networks of computational units
- technologies of "growing, living" materials

Present humanoid…

Future: RobotCub



Avg. 14Kg - 30.8 lb

RobotCub Consortium

No	Name	Short Name	Main Expertise in Project
1	University of Genova – DIST (Giulio Sandini, David Vernon, Giorgio Metta)	UGDIST	Cognitive Robotics – Vision and Manipulation
2	Scuola S. Anna – Pisa (Paolo Dario)	SSSUP	Cognitive Robotics – Manipulation Hardware
3	University of Zurich (Rolf Pfeifer)	UNIZH	Cognitive Robotics – Audition and Touch
4	University of Uppsala (Claes von Hofsten)	UNIUP	Cognitive development of manipulation skills in humans
5	University of Ferrara (Luciano Fadiga)	UNIFE	Physiology of Manipulation control in humans
6	University of Hertfordshire (Kerstin Dautenhahn)	UH	Cognitive Behavior and Interaction
7	IST Lisbon (Jose Santos-Victor)	IST	Cognitive Robotics – Eye-head coordination
8	University of Salford (Darwin Caldwell, John Gray)	UNISAL	Robotics – Locomotion
9	Ecole Polytechnique Federal de Lausanne - (Aude Billard, Auke Ijspeert)	EPFL	Cognitive Behavior and Interaction (Billard - ASL) Locomotion (Ijspeert - LSL)
10	Telerobot S.r.l. (Francesco Becchi, David Corsini)	TLR	Mechanical design and manufacturing
11	European Brain Research Institute (Emilio Bizzi)	EBRI	Sensorimotor Coordination and motor cognition
12	MIT Computer Science and Artificial Intelligence Laboratory (Rod Brooks)	CSAIL	Cognitive Humanoid Robotics
13	University of Minnesota - Dept. of Neurology (Juergen Konkzak)	UNIMN	Developmental Psychology
14	Communications Research Laboratory, Japan (Hideki Kozima)	CRL	Humanoid Robotics and Development
15	University of Tokyo - Department of Mechano-Informatics, (Yasuo Kuniyoshi)	UNITK	Humanoid Robotics
16	ATR Computational Neuroscience Laboratories – Kyoto – (Gordon Cheng)	ATR	Neuroscience and Humanoid Robotics

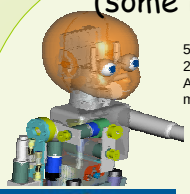
RobotCub: an *open* system!

Robot-Cub scientific goal is to study the development of cognitive manipulation skills (manipulation,imitation, gesture communication)

Robot-Cub engineering goal is to build a humanoid platform whose design is open to the scientific community and can be duplicated and improved by the community of its users.

We are looking for other projects willing to join RobotCub with the same open attitude.

iCub (some initial design)



55 DOF
25 Kg
Able to crawl, sit and manipulate with two hands

Conclusions

- Learning to interact is essential to understanding
- "functional" humanoids require multiple technologies
- Some basic technologies are still missing

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