LIRA-Lab approach to robotics
(in relation to ADAPT)

LIRA-Lab, DIST – University of Genova – Italy

January 20, *2003*

LIRA-Lab "figures"

LIRA-Lab is part of the Department of Communication, Computer and Systems Sciences of the Faculty of Engineering of the University of Genova.

LIRA-Lab was established in 1990 and is currently composed of 7 researchers, one administrative staff and 4 master students doing their thesis.

LIRA-Lab publishes, on average, 20 papers per year in international, refereed conferences and journals.

Main sources of funding are: EU, Italian ministry of research (MIUR), Italian space agency (ASI)

Some Formalized Collaborations

- **Artificial systems and Computational Neuroscience**
  - J. Santos-Victor – Alex Bernardino at IST Lisbon
  - H. Bulthof – Max Plank Institute Tubingen
  - Paul Fitzpatrick CoG team at MIT AI-Lab
- **Neurophysiology and Developmental Psychology**
  - Luciano Fadiga – Univ. of Ferrara
  - Claes von Hofsten – K. Rosander – University of Uppsala
- **Robotics**
  - Enrik Christensen – KTH Stockholm
  - David Hogg – University of Leeds
  - Bern Neuman – University of Hamburg

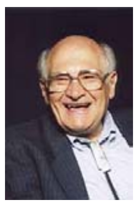
EU Projects CogVis, MIRROR

LIRA-Lab "pillars"

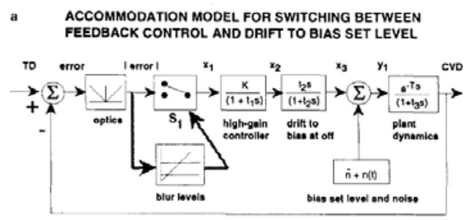
1. Robots as neuroscience reseach tools
2. Developmental approach
3. Learning is a necessary step for understanding
4. New technology comes from new knowledge

…a step back

Mathematical models and system's theory have been useful research tools to evaluate parameters of neural models (e.g. gains, delays, connections etc.)



Larry Stark



"…that made me see that control theory was the mathematical root to understanding how the brain controlled movement." *Larry Stark*

Why moving to hardware models?

1) No need to simulate the environment (including the system's body)

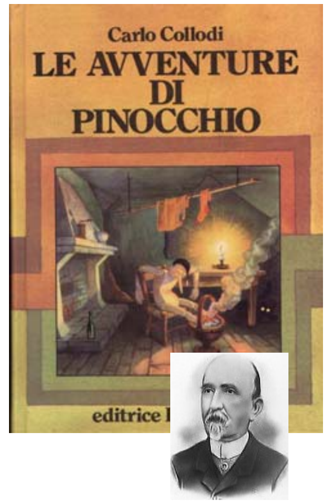
2) Experiments with "real" interactions (a physical system has to obey the rules of the "real world")

3) It is possible to perform quantitative experiments (including experiments impossible with living systems)

4) Technologically feasible

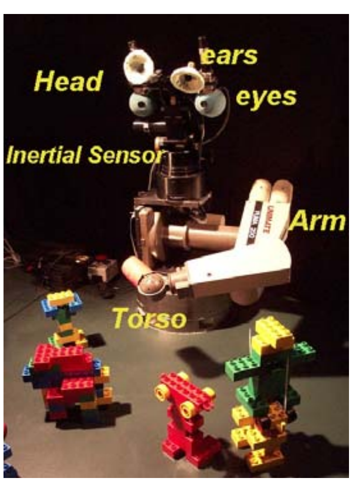
Why Development?

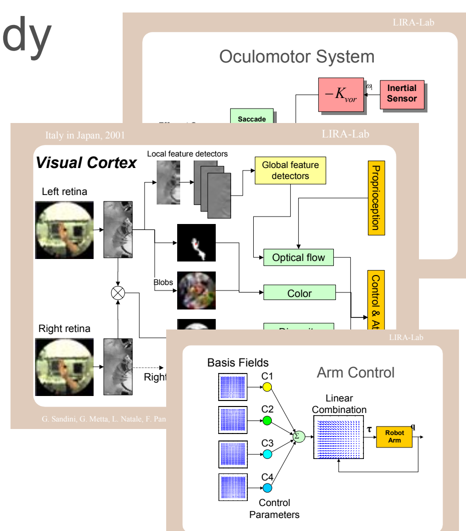
1. Breaking the systems into sub-components leaves unsolved the integration issue (assembly vs. shaping)
2. The system we want to build/understand is complex and highly adaptable (is it possible to pre-program adaptation?)
3. Offers the possibility of studying **the process of building** a complex system
4. Humans are optimized for adaptation not for performance



Carlo Lorenzini

…Babybot's Body





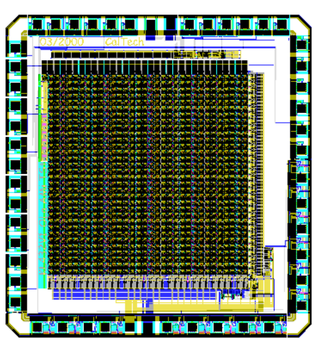
Babybot's head

- 5 degrees of freedom

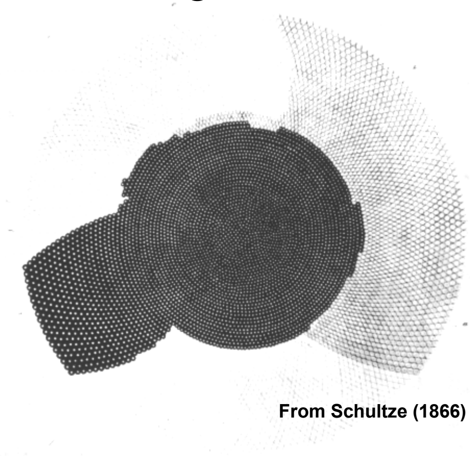
Designed in collaboration with Telerobot (1993) later modified by CM-Ingegneria S.r.l.

Visual Tracking
Stereo vision
Optical flow and image stabilization
Visuo-acustic integration
Visuo-inertial integration
Learning and development

The human retina: a strange sensor….



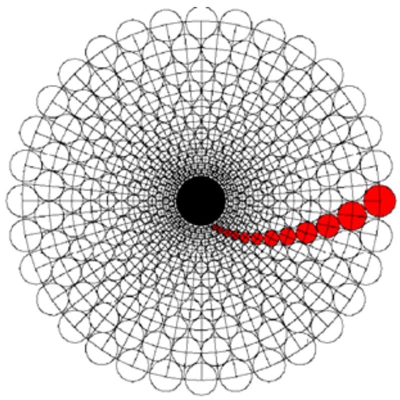
Conventional visual sensor



From Schultze (1866)

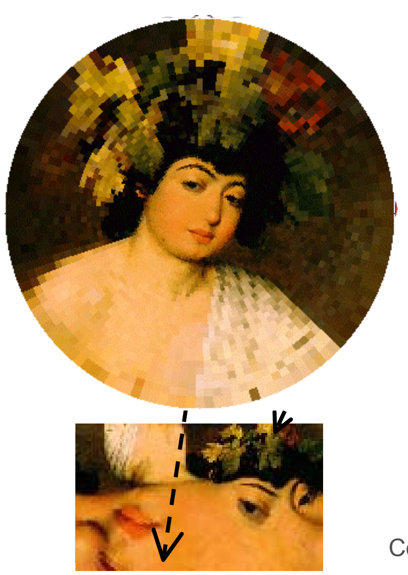
Human visual sensor (1-2 deg)

Babybot's eyes



Log-polar structure
(and logarithmic spirals)

Log-polar (Cortical) Images



Images acquired by a retina-like sensor are rectangular

Cortical Magnification Factor

Camera Prototypes

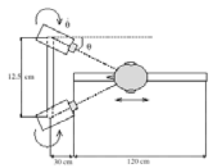
The prototypes available since November 2000 and based on the 33,000 pixels CMOS sensor.

Some Questions Asked

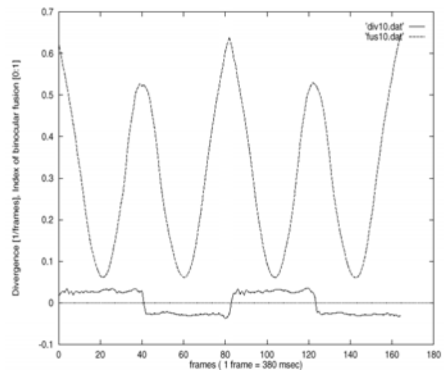
- Visual processing (optical flow, disparity, segmentation and grouping)
- Compliance and force fields in motor control
- Development of gaze (saccades, pursuit, VOR)
- Role of vergence on tuning of VOR gain
- Motor-motor coordination in learning visually guided reaching
- Registration of visual and acoustic maps

...a few answers

Dynamic Vergence



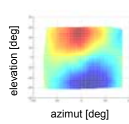
Radial Optic Flow as “fast loop” for vergence control

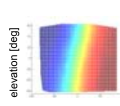


From: Capurro, C., F. Panerai, and G. Sandini, *Dynamic Vergence using Log-polar Images.* International Journal of Computer Vision, 1997. **24**(1): p. 79-94..

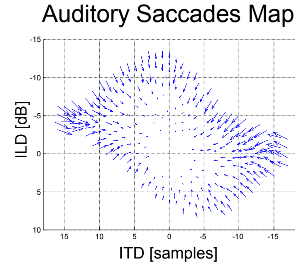
Busettini, C., G.S. Masson, and F.A. Miles, *Radial optic flow induces vergence eye movements at ultra-short latencies.* Nature,, 1997. **390**: p. 512--515

Learning Sound Directed Gaze

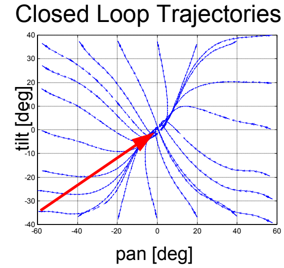




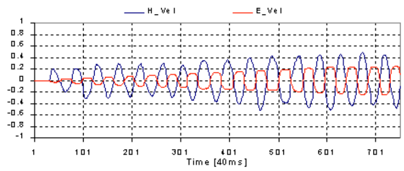
Auditory Saccades Map

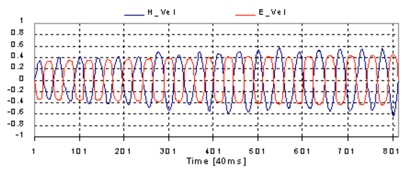


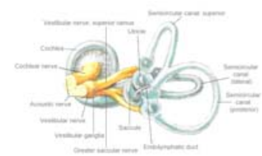
Closed Loop Trajectories



How does VOR Gain adapts?







See: Sandini, G., F. Panerai, and F.A. Miles, *The Role of Inertial and Visual Mechanisms in the Stabilization of Gaze in Natural and Artificial Systems*, in *Motion Vision, Computational, Neural, and Ecological Constraints*, J.M. Zanker and J. Zeil, Editors. 2000, Springer. p. 189-218.

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Visually Guided Reaching

This suggests that head-eye-hand coordination plays an important role in the organization of these movements and leads to the hypothesis that a representation of current gaze direction may serve as a reference signal for arm motor control.

From: Flanders, M., L. Daghestani, and A. Berthoz, *Reaching beyond reach*. Experimental Brain Research, 1999. **126**(1): p. 19-30.

Is it possible to simplify the computation by learning to “touch the fixation point”?

Motor-motor coordination.
Sensorimotor coordination is implemented through a direct mapping of the head motor space into the arm motor space

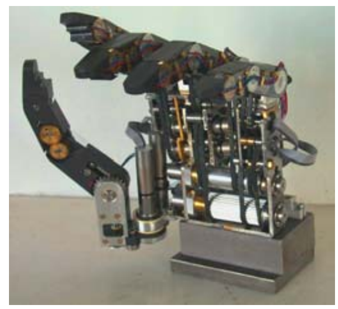
Metta, G., G. Sandini, and J. Konczak. *A Developmental Approach to Sensori-motor Coordination in Artificial Systems*. in *IEEE Conference on System, Man and Cybernetics*. 1998. San Diego (USA).

Video Clip

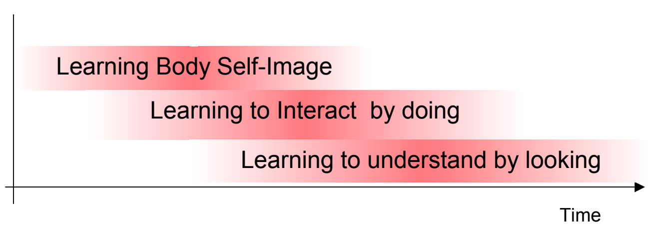
Giulio Sandini

Babybot’s Hand

- 16 degrees joints
- 6 controlled d.o.f.
- Elastic components on all joints



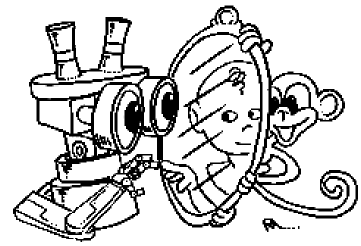
So far mostly learning body image



How can the system really exploit actions to *understand?*

…understand what somebody else is doing

Develop a system able to interpret manipulation actions and predict their effect.



It is easier to understand manipulation if one first learns how to manipulate

…….