ISTITUTO ITALIANO
DI TECNOLOGIA

the RobotCub project

Giorgio Metta (just presenting) and many others

Cognitive Humanoids Laboratory
Dept. of Robotics, Brain and Cognitive Science
Italian Institute of Technology

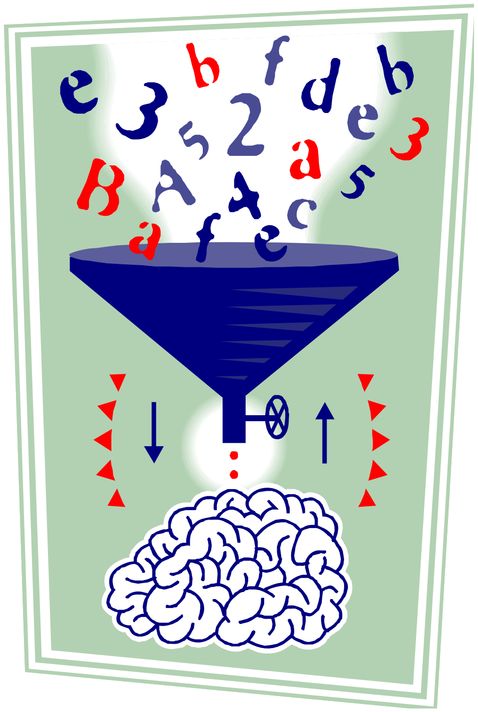
Our background

- The main focus of our activities is in the implementation of biologically sound models of cognition in robots of humanoid shape
- This has the two-fold aim of:
  - furthering our understanding of brain functions
  - realizing robot controllers that can learn and adapt from their mistakes

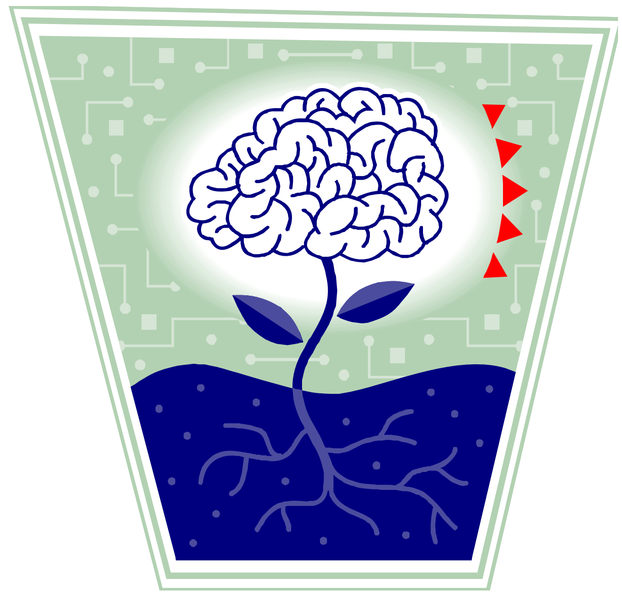
By means of…

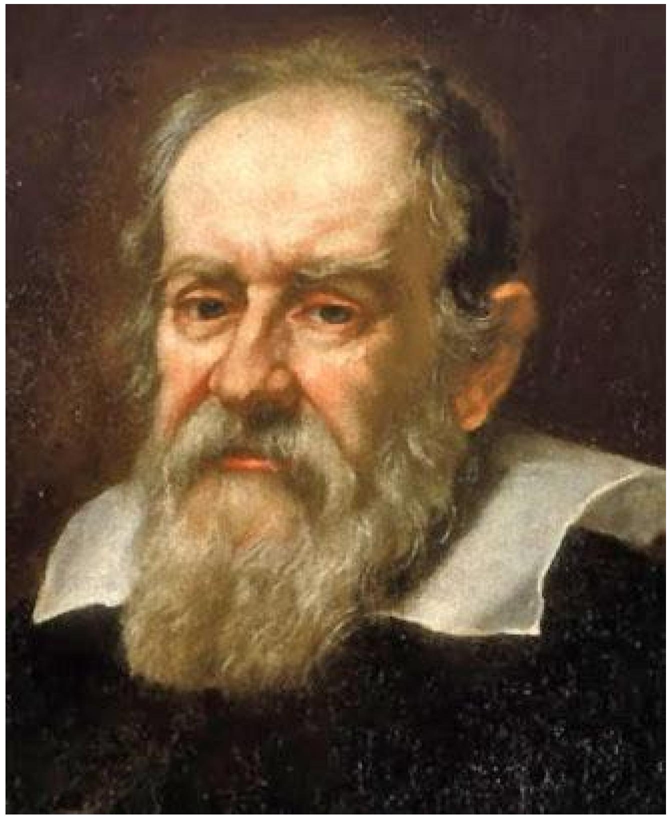
- Reverse engineering:
  - Study and be inspired by biological systems
- Models:
  - Robots and mathematical/control models
- Global approach:
  - Sanity check by implementing everything on a real physical platform, complete systems, real feedback from the environment

The kernel of the problem

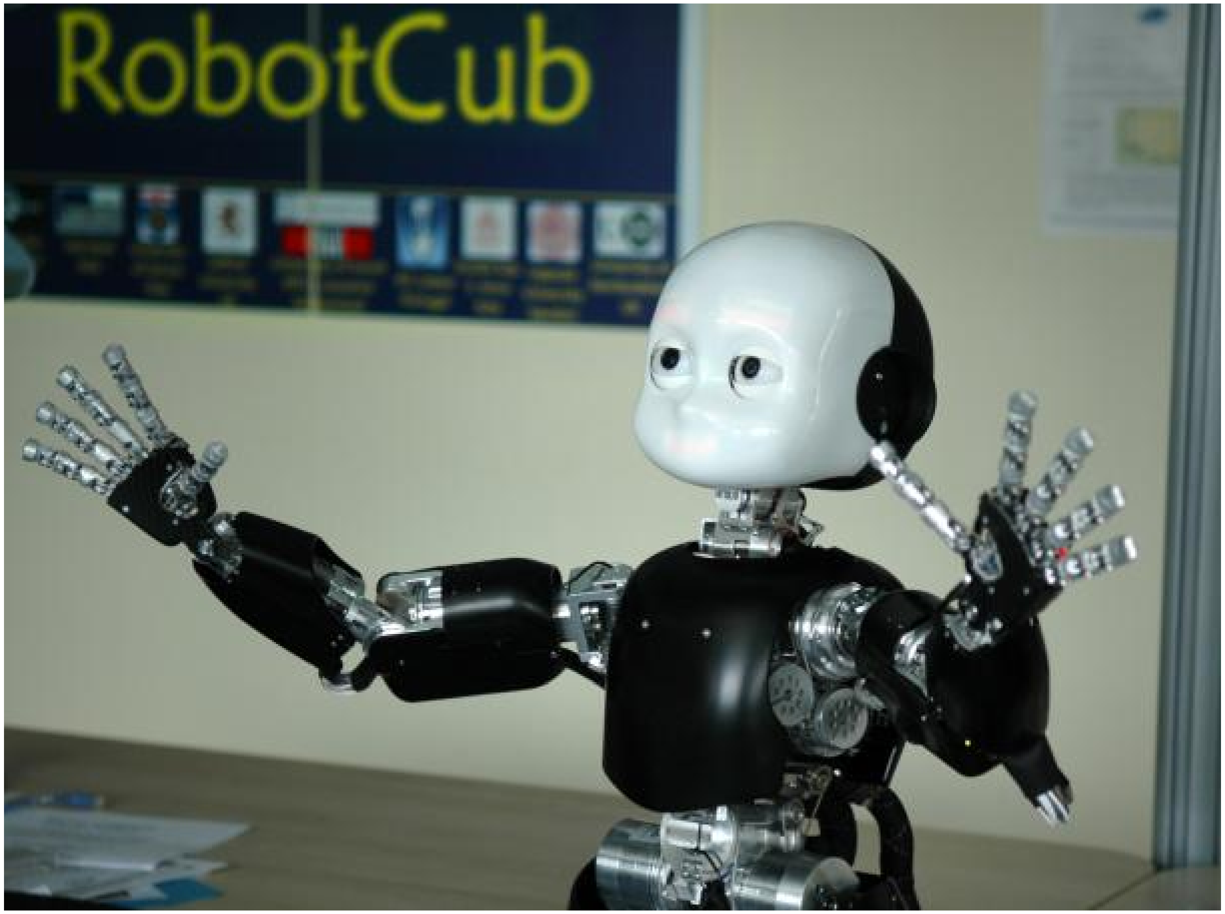


OR





Our telescope…



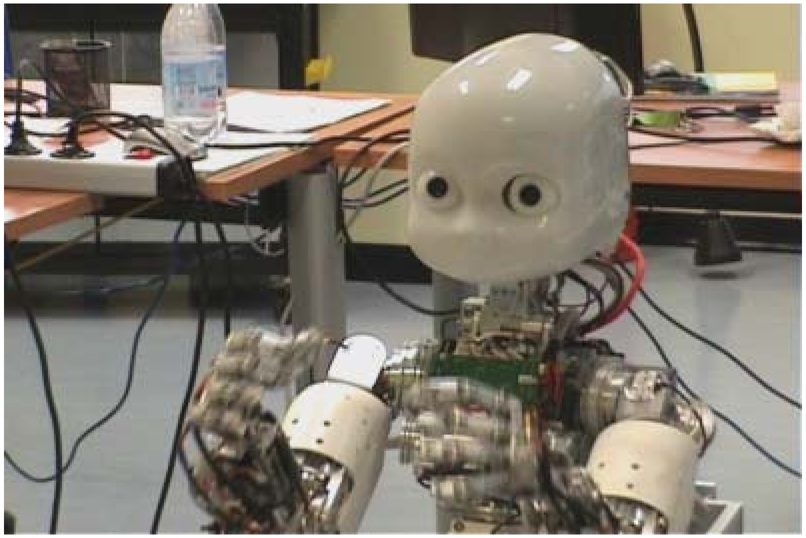
The iCub: quick summary

The **iCub** is the humanoid baby-robot designed as part of the **RobotCub** project

- The iCub is a full humanoid robot sized as a three and half year-old child
- The total height is 104cm
- It has 53 degrees of freedom, including articulated hands to be used for manipulation and gesturing
- The robot will be able to crawl and sit and autonomously transition from crawling to sitting and vice-versa
- The robot is GPL/FDL: software, hardware, drawings, documentation, etc.

Degrees of freedom

- Head: vergence, common tilt + 3 dof neck
- Arms: 7 dof each
  - Shoulder (3), elbow (1), wrist (3)
- Hands: 9 dof each ► 19 joints
  - 5 fingers ► underactuated
- Legs: 6 dof each
  - Hip (3), knee (1), ankle (2)
- Waist: 3 dof



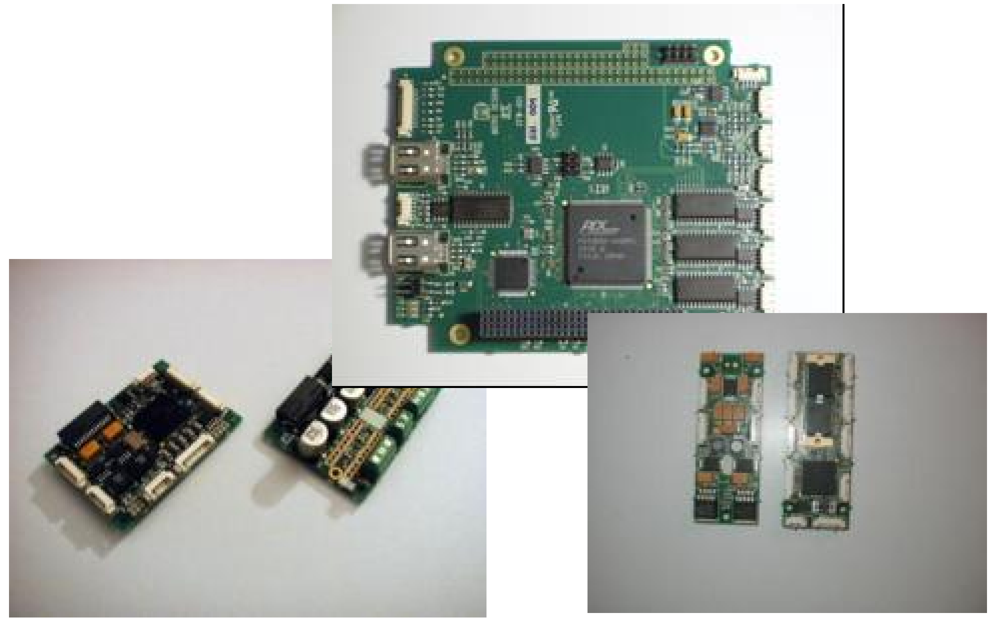
Σ = 53 dof (not counting the facial expressions)

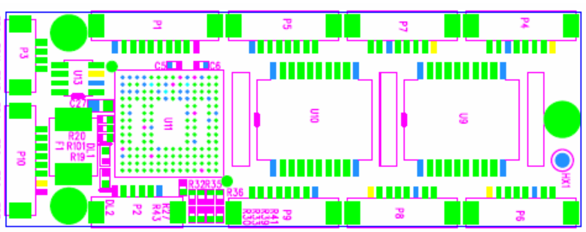
Sensorization

- Absolute position
  - On most joints, AMS magnetic encoder (12 bits)
- Cameras
  - Pointgrey Dragonfly2 firewire cameras (typical 640x480@30pfs)
- Microphones, speaker
  - Standard condenser electrect miniature microphones
  - Pinnae
- Gyroscopes, linear accelerometers
  - Xsense: Mtx

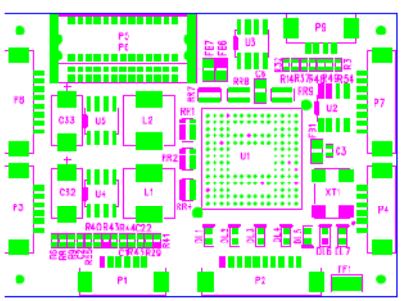
Custom electronics

- Motor control
  - C programmable DSP 40 MIPS
  - Motorola DSP56F807
  - PWM, ADC, Digital I/O, etc.
  - 4DC motors (1A max each)
  - 2BL motors (6A cont, 20A peak)
  - CAN bus interface





80x30mm

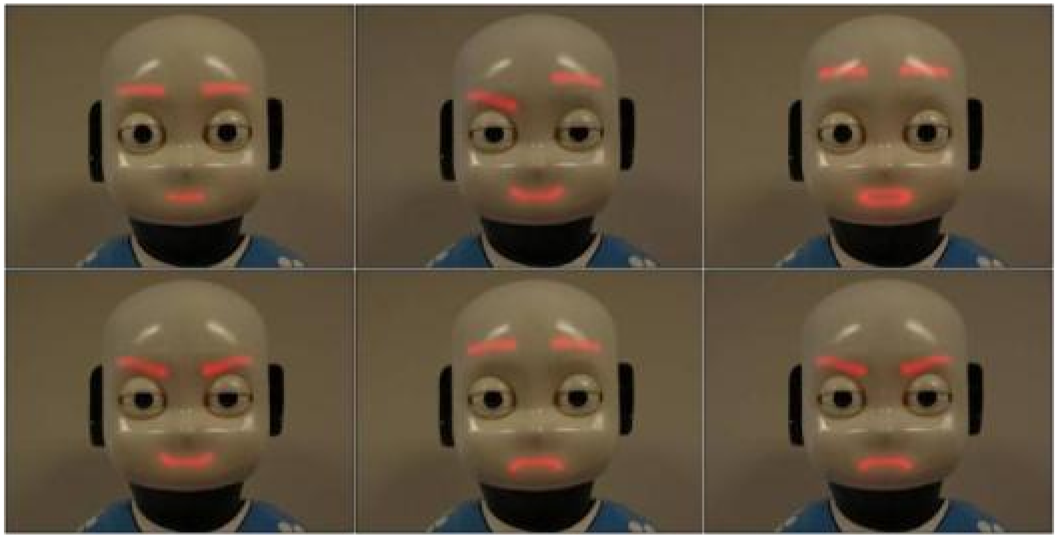


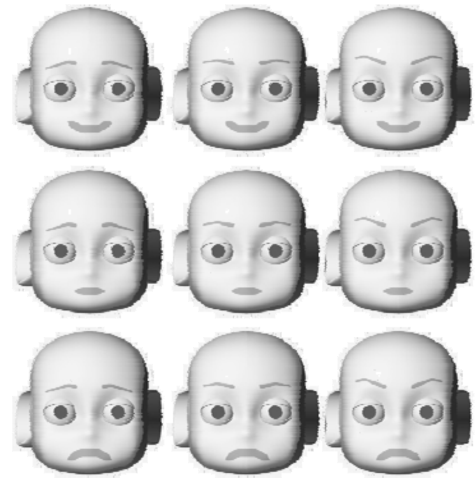
58x42mm

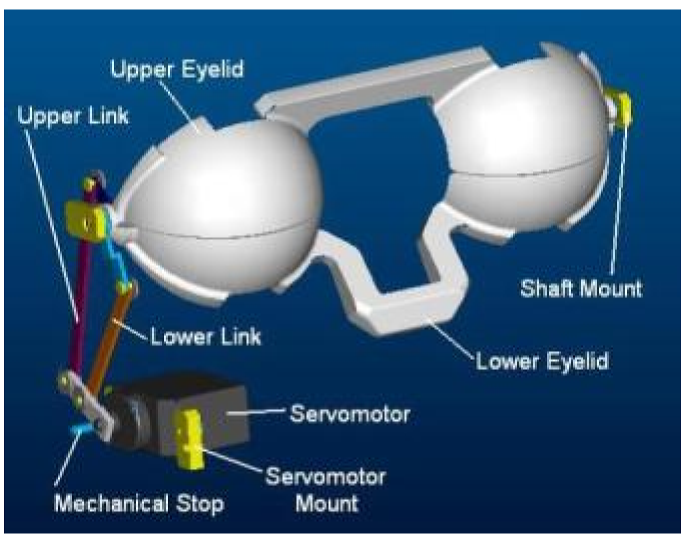
Input/output:

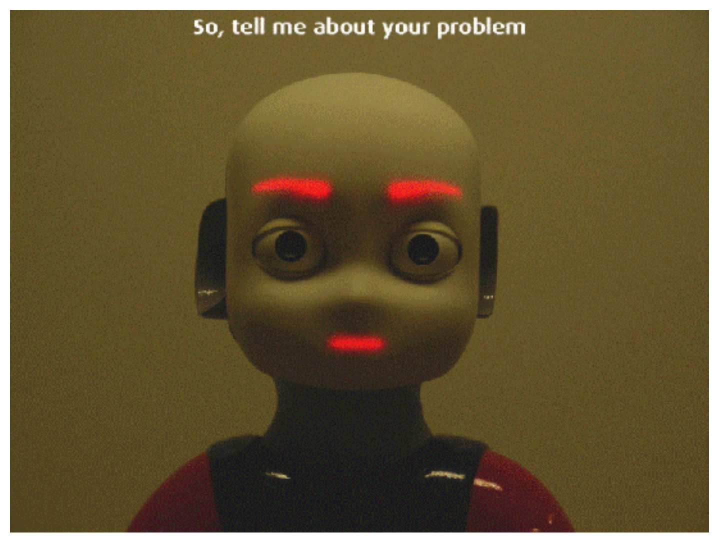
- PC104 digital I/O card with 4 CAN bus (soon 10), firewire, and audio amplification
- Miniature analog to CAN converter card
- Miniature strain gauge signal conditioning and acquisition card

Facial expressions

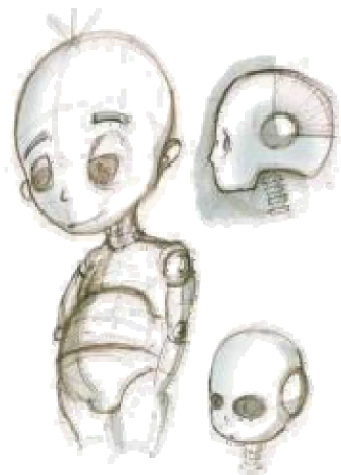


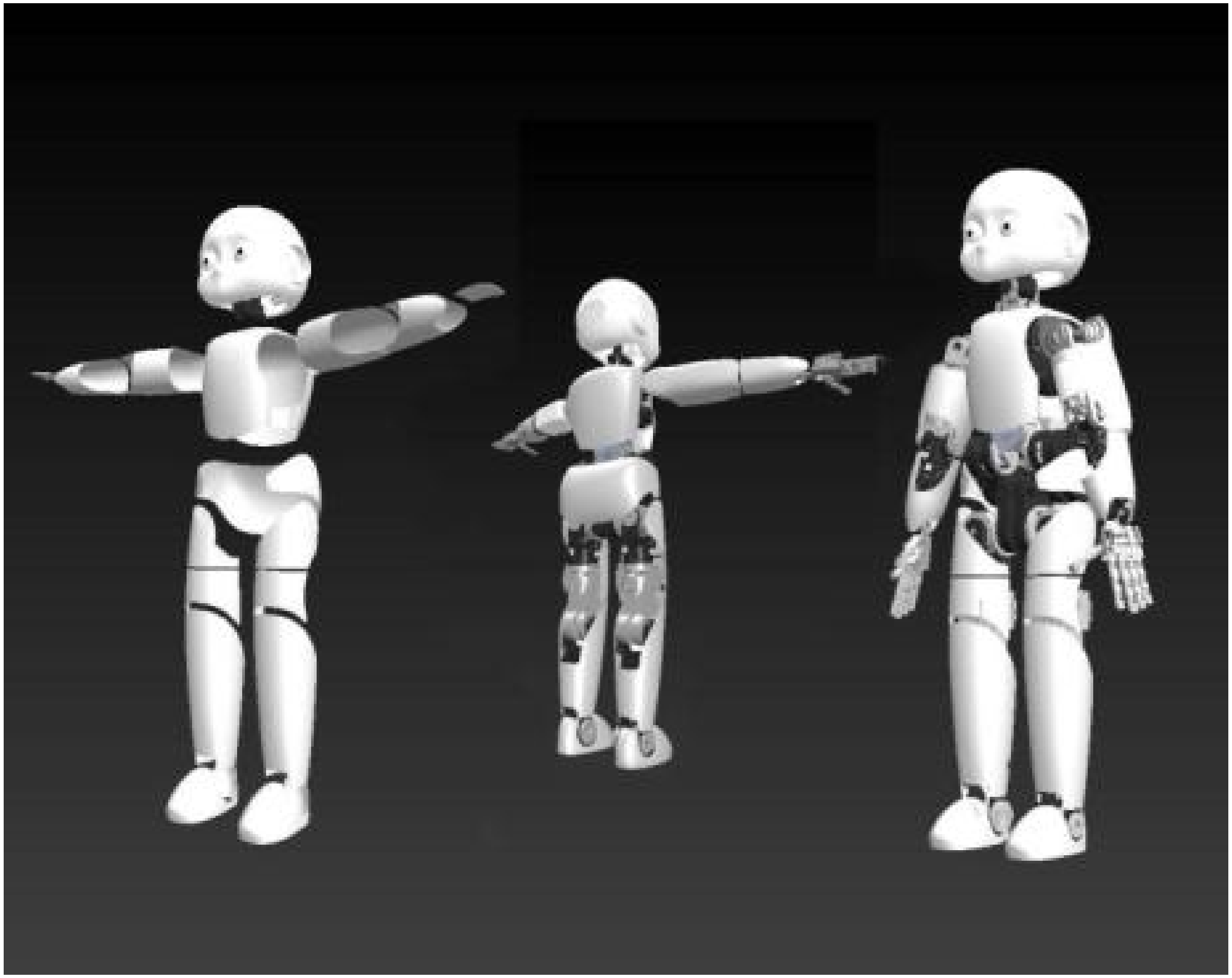






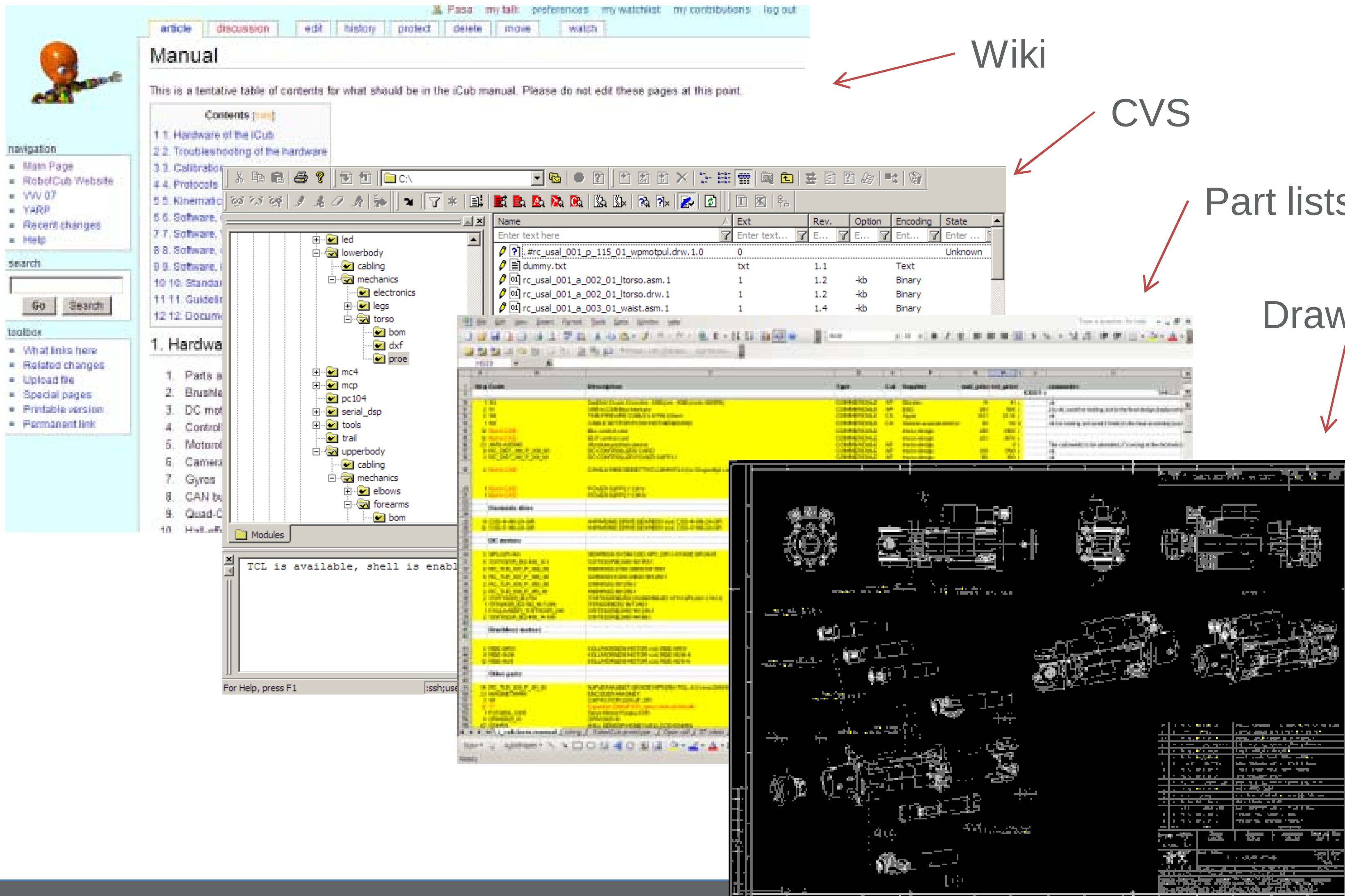
Body cover: concept



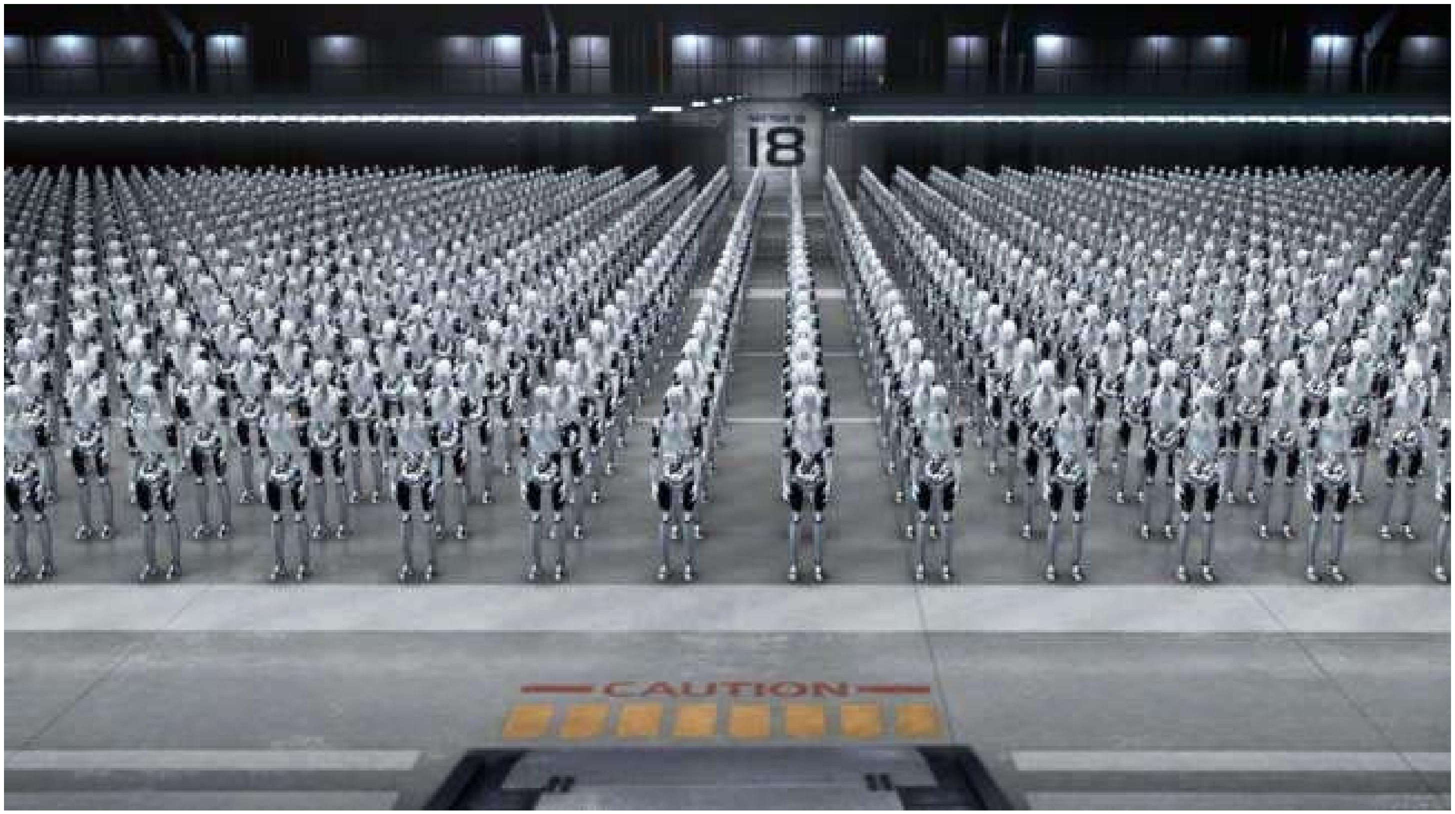


iit

open source



At the end of the project we will have 18 working platforms



Promoting the iCub

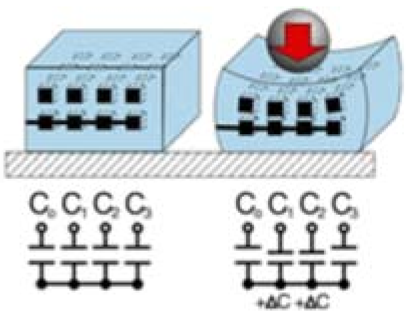
- RobotCub Open Call
  - 31 participants, 7 winners will receive a copy of the iCub free of charge
  - UPMC Paris, Imperial London, Inserm Lyon, TU Munich, METU Ankara, Pompeu Fabra Barcelona, Urbana-Champaign USA, IST Lisbon, EPFL Lausanne
- Further development…
  - EU project ITALK: 4 iCub’s have been built
  - EU project ImClever: 3 iCub’s will be built
  - EU project RoboSkin: a skin system compatible with iCub
  - EU project CHRIS: safety features for the iCub
- Collaborations
  - University of Karlsruhe: new and longer legs
- Simulator:
  - Open Source simulator based on ODE/Newton and as a model in Webots

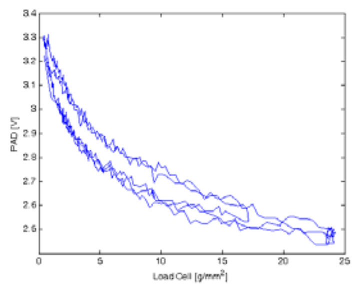
In the pipeline (iCub v2)…

- Force control: joint level sensors, SEA or stain gauges based sensing
- Skin/tactile sensors: almost everywhere on the robot surface
- Robot general improvements: e.g. zero-backlash everywhere, better control electronics, higher resolution position sensors, better camera and lenses

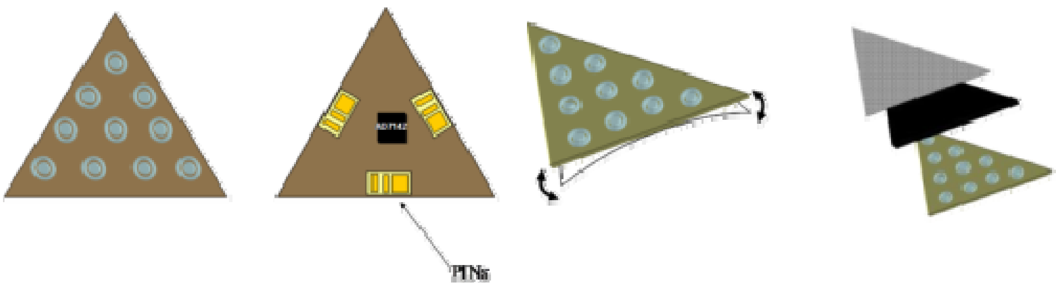
The skin

Principle

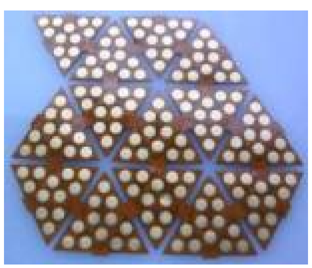


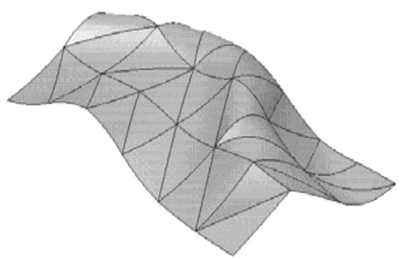


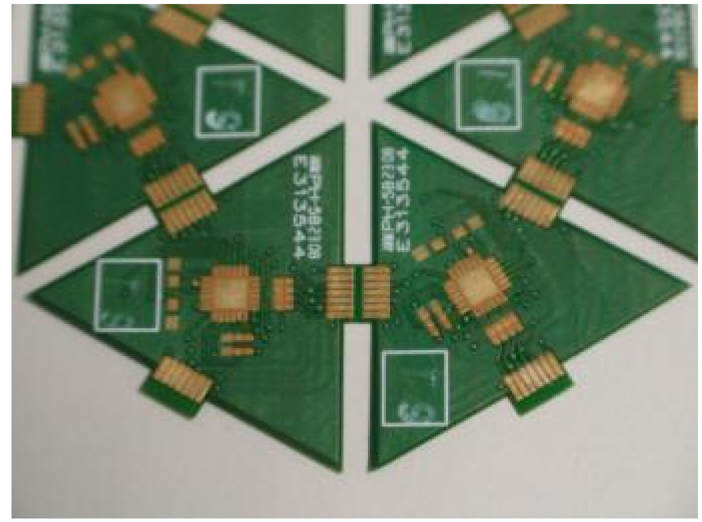
Lot of sensing points

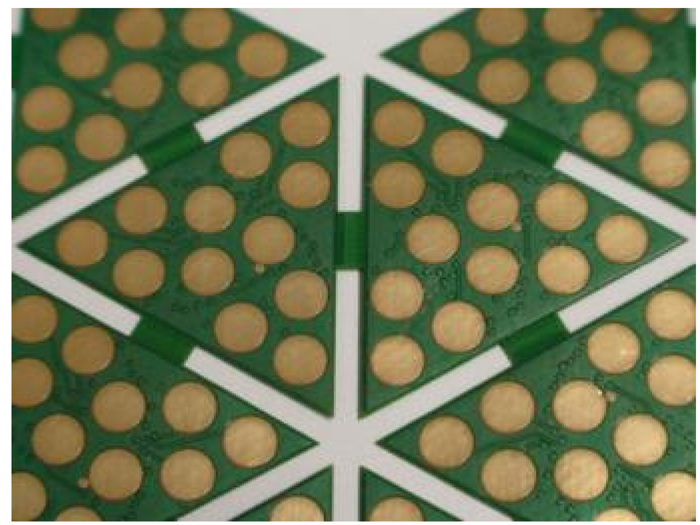


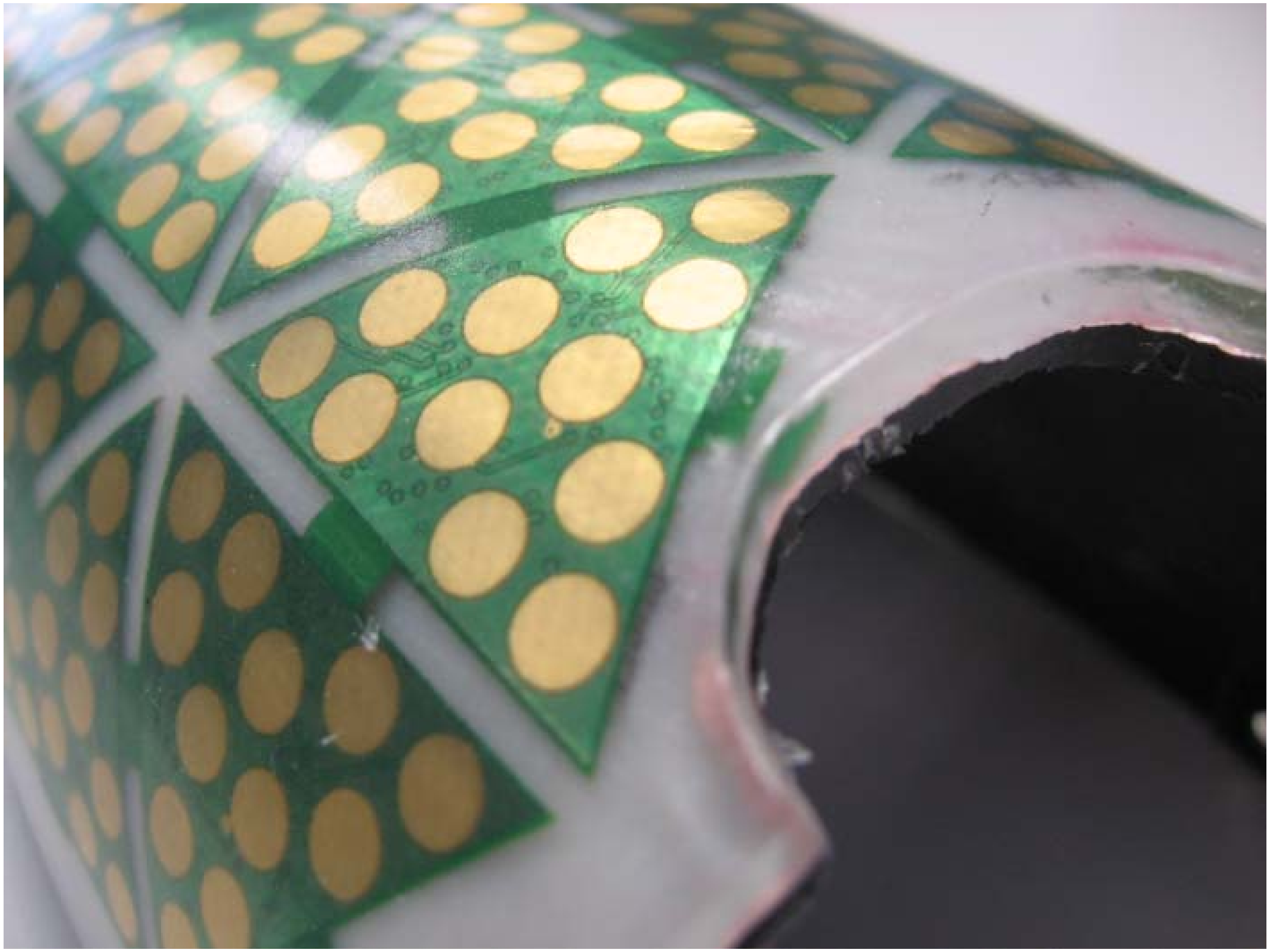
Structure of the skin

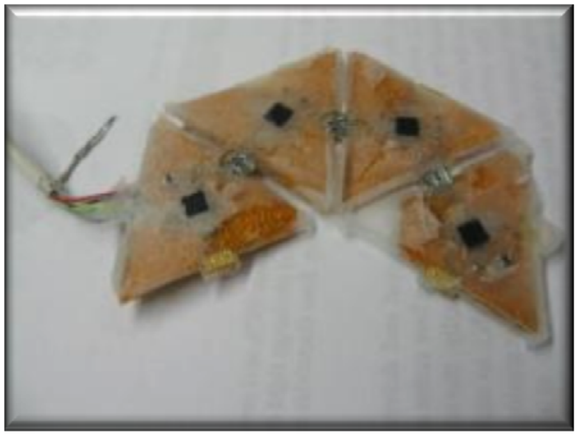






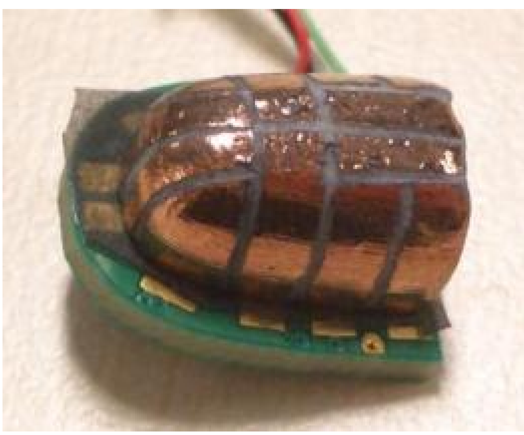


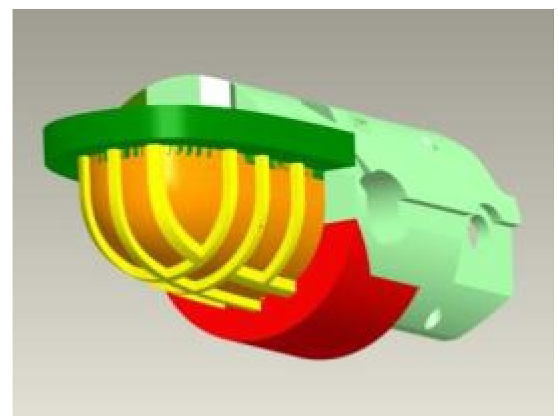




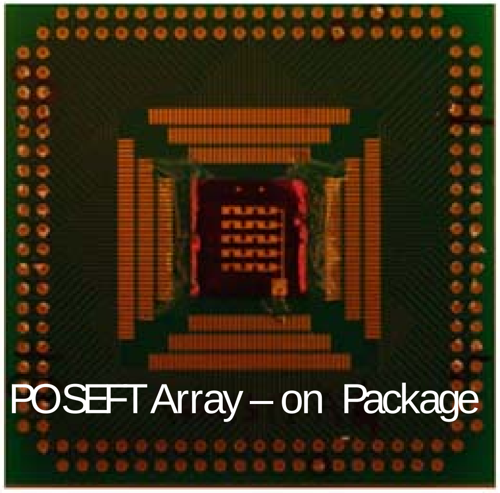
Fingertips

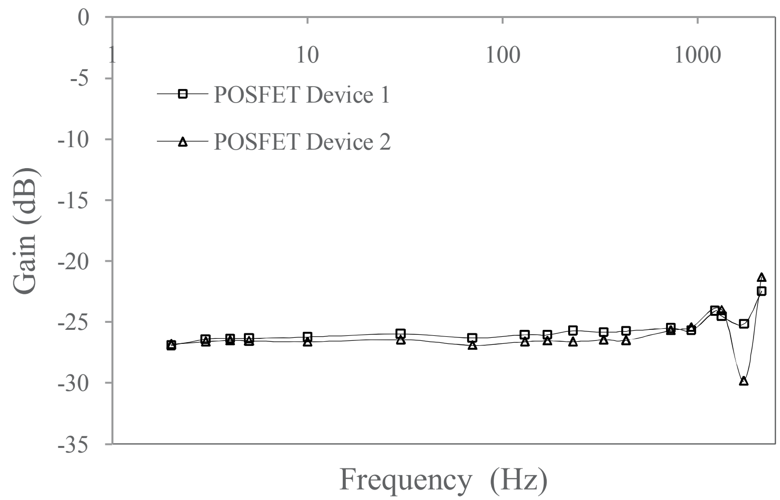
- Capacitive pressure sensor with 12 sensitive zones
- 14.5 mm long and 13 mm wide, sized for iCub
- Embedded electronics: twelve 16 bit measurements of capacitance
  - either all 12 taxels independently at 50 Hz or an average of the 12 taxels at about 500 Hz

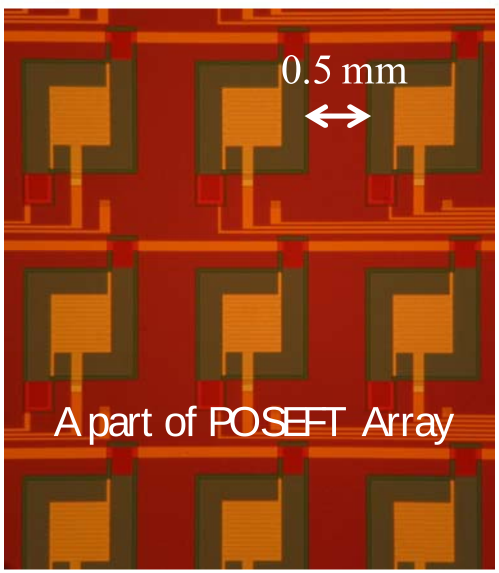




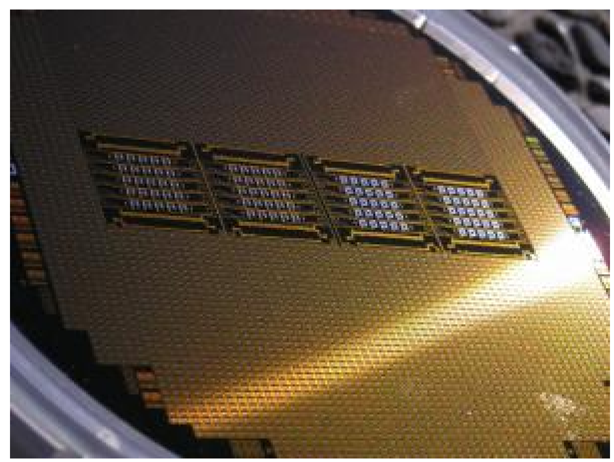
POSFET based tactile array





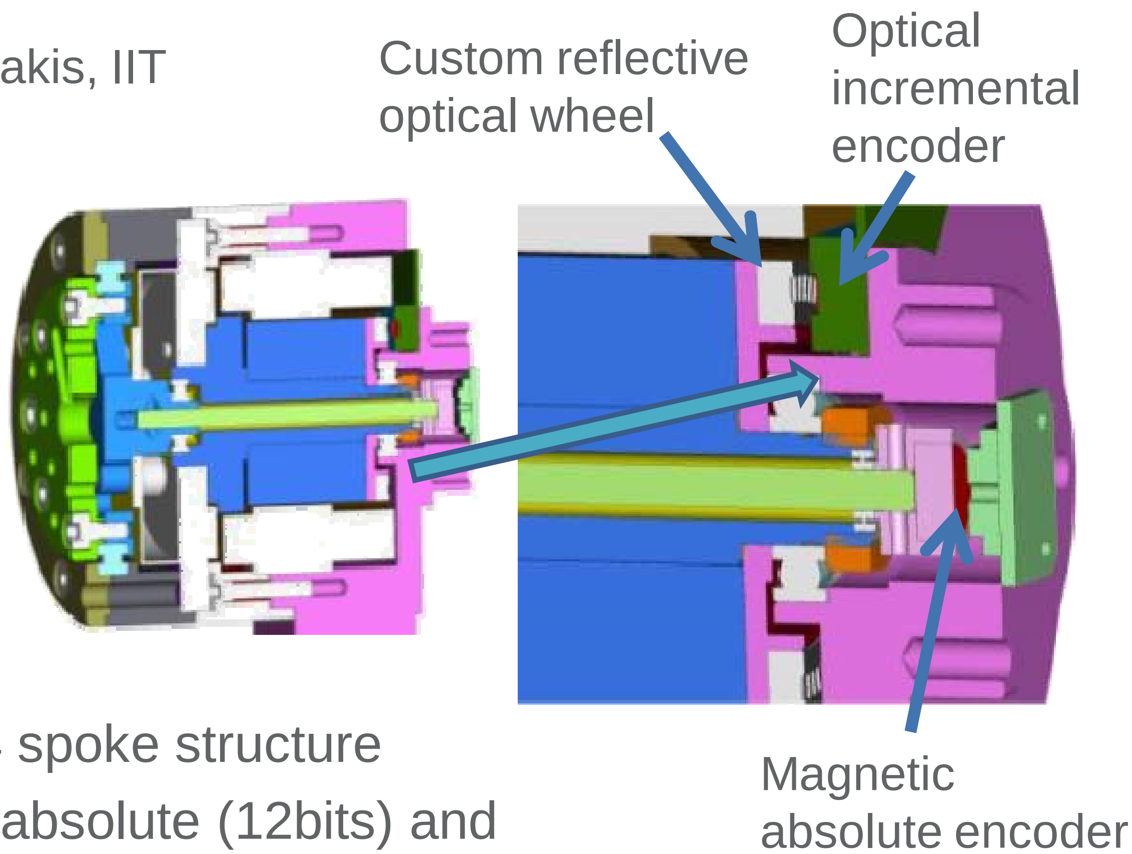


Gain-Phase plots (2 Hz – 2.1 KHz Freq) for various POSFET tactile sensors



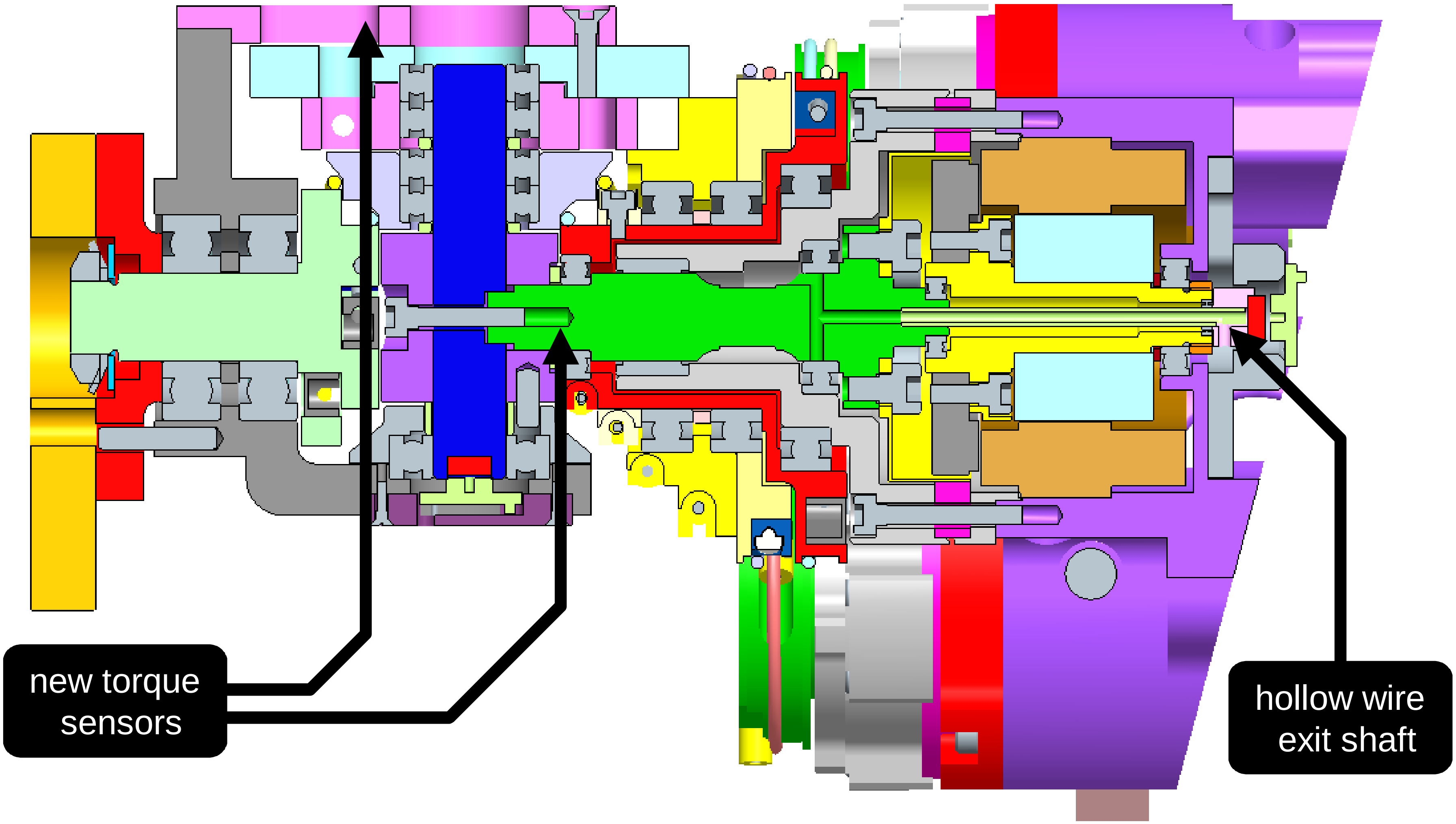
Joint-level torque sensing

Design: Nikos Tsagarakis, IIT



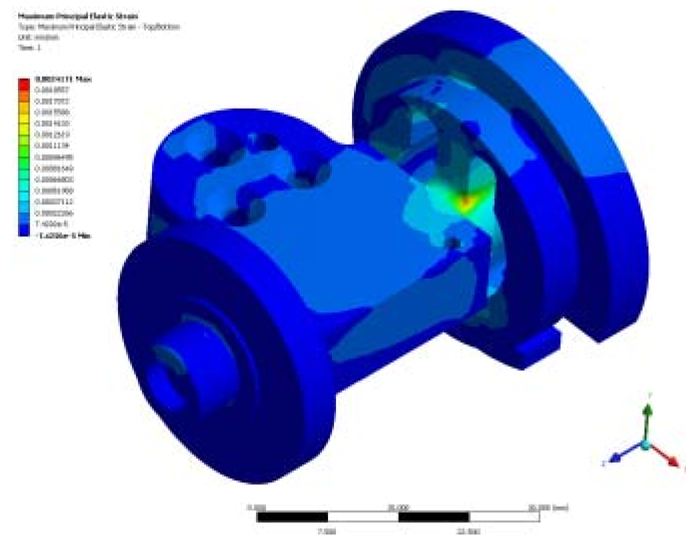
- Torque sensing: 4 spoke structure
- Position sensing: absolute (12bits) and incremental (19bits)
- Maintain the original motor size
- Allow active compliance regulation

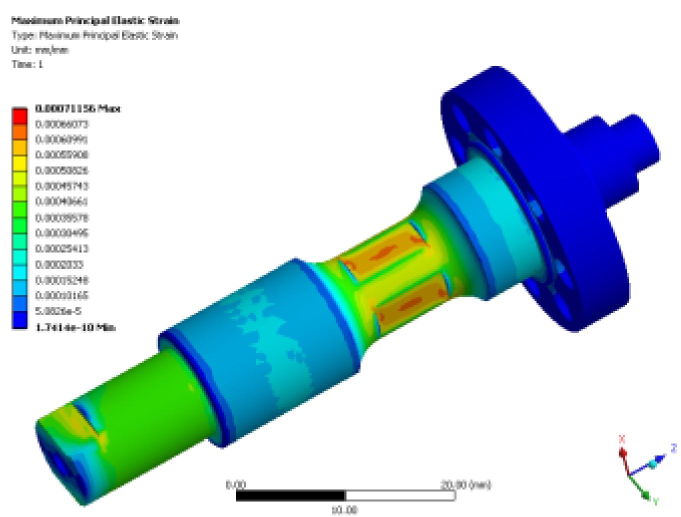
Shoulder joint sensorization

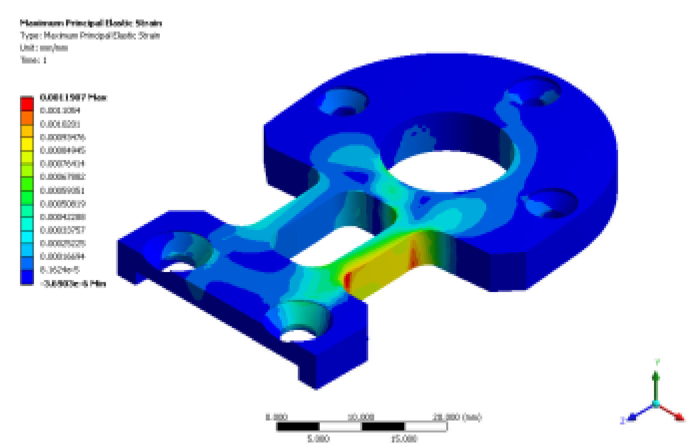


FEM analysis

- Optimal strain patterns and sensors placement have been calculated with FEM analysis



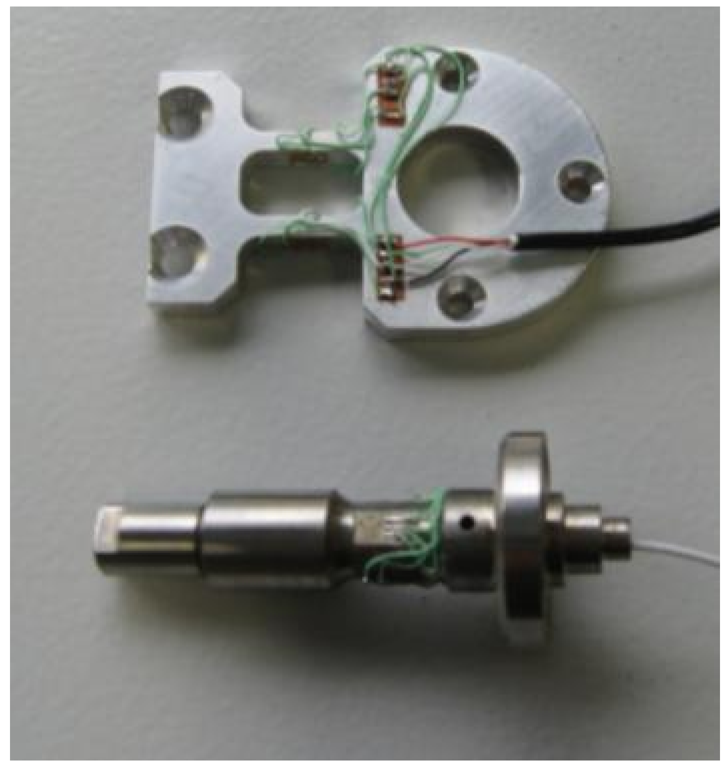




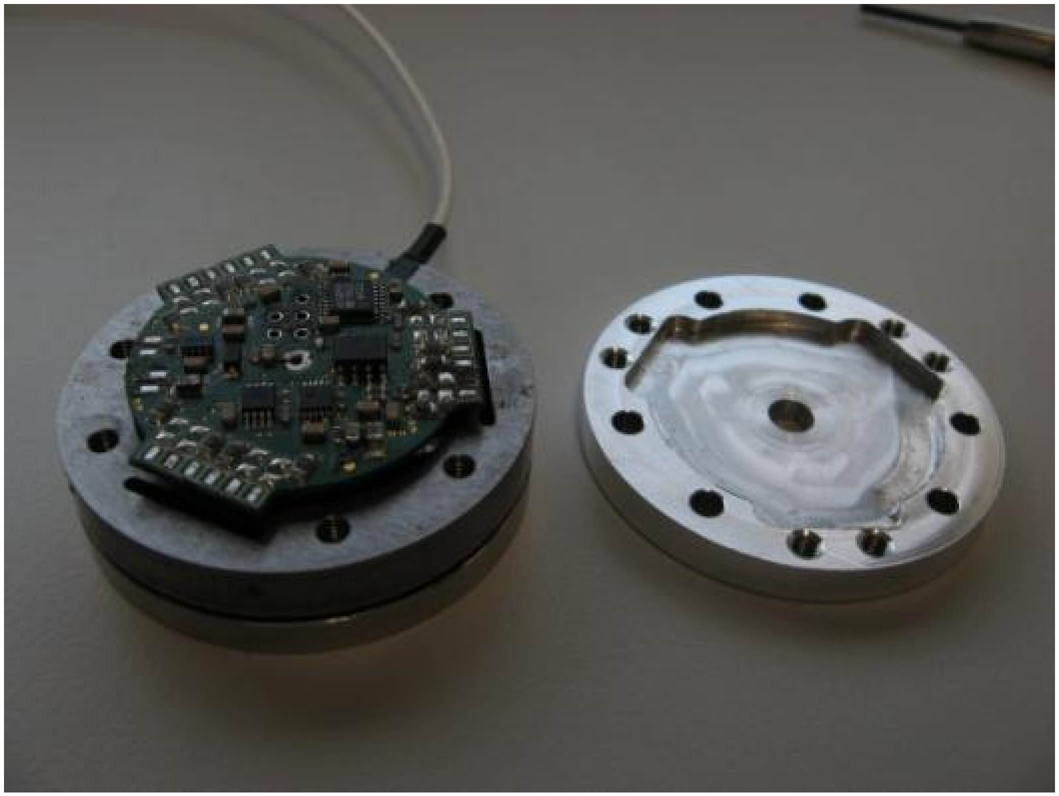
Sensor gauging and wiring

- Before

- After (gauges glued, 10h curing, pads gluing & wiring)



6-axis force/torque sensor



- Semiconductor strain gauges
- On board signal conditioning, sampling, and calibration
- Digital output: CAN bus

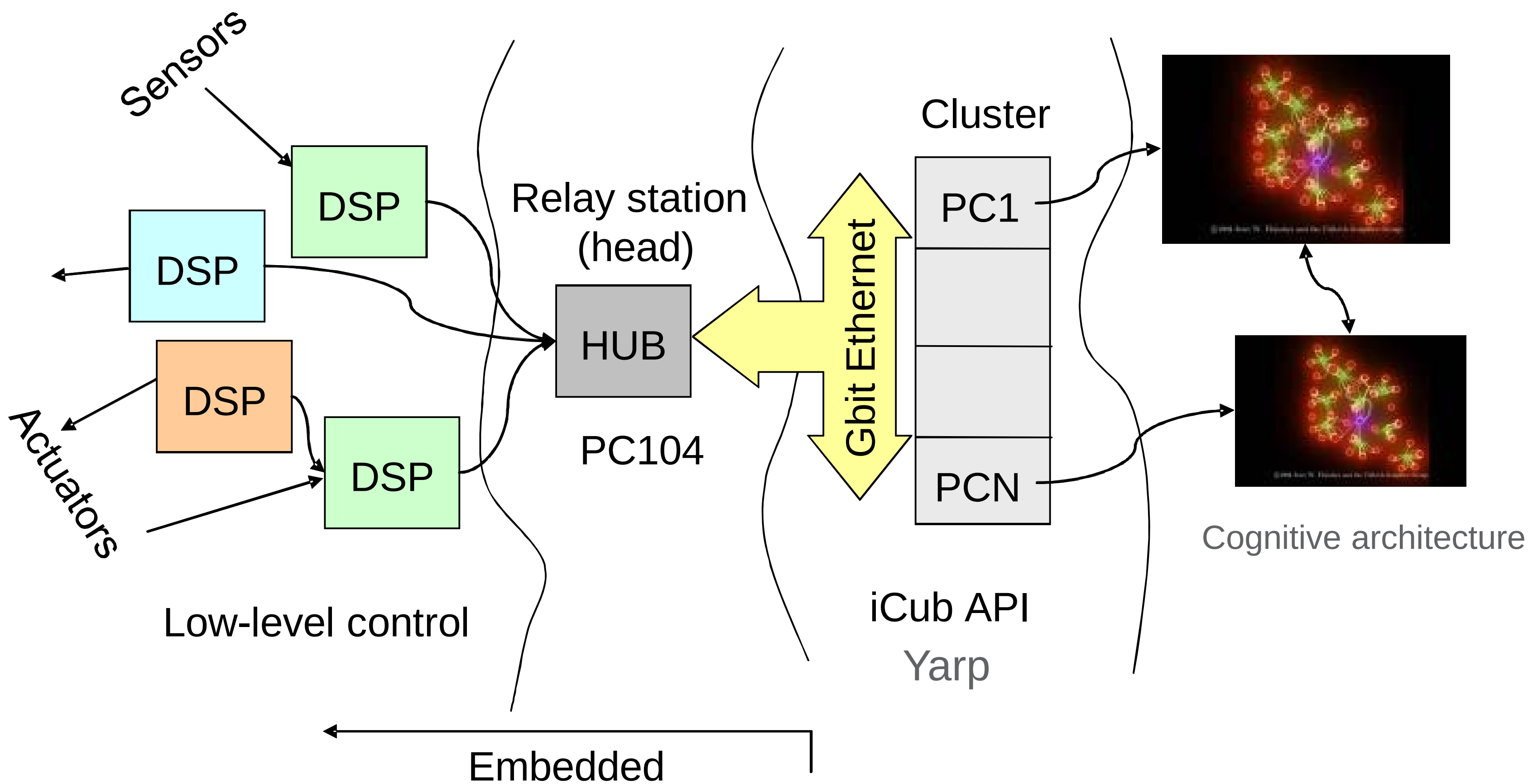
Mechanics: Nikos Tsagarakis, Darwin Caldwell
Electronics: Claudio Lorini

The Software

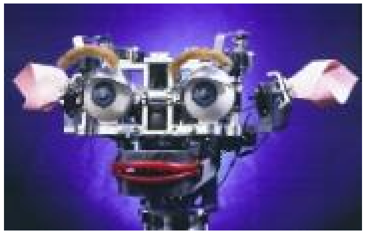
- Goals:
  - Foster collaboration in “space” and “time”…
  - … since we’re a large Consortium and we don’t want to re-invent the wheel too often
  - Manage the complexity of the hardware…
  - … since humanoid robots are complicated

  - We improved existing Open Source libraries supporting a major overhaul of YARP to the iCub (new code base)

iCub hardware/software structure



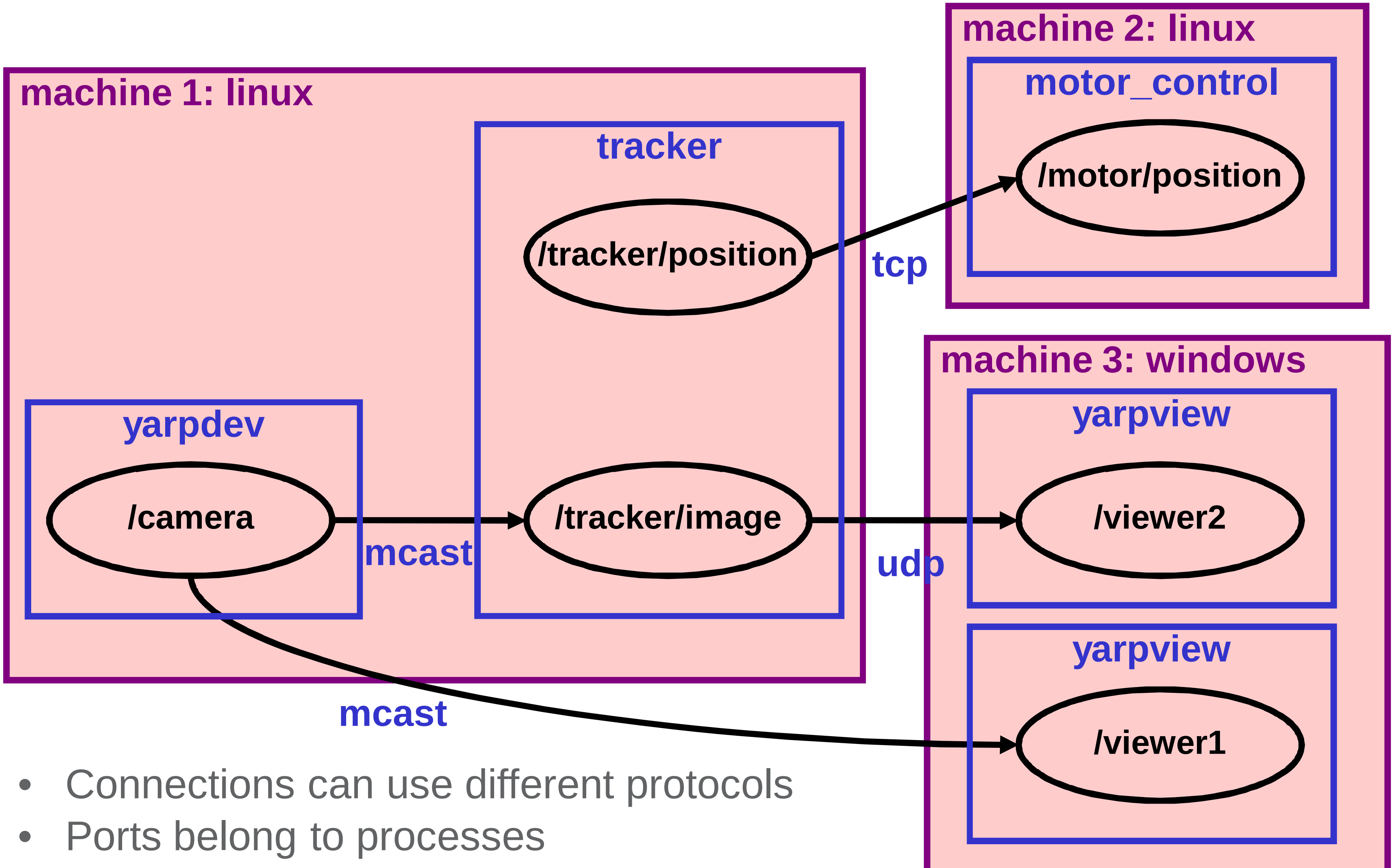
YARP



- YARP is an open-source middleware for humanoid robotics
- History
  - An MIT / Univ. of Genoa collaboration
  - Born on Kismet, grew on COG
  - With a major overhaul, now used by RobotCub consortium
  - Exists as an independent open source project
  - C++ source code
- In short: it is the plumbing

- It factors out:
  - the data flow: inter-process communication
    - it is often useful to keep algorithms away from the plumbing
  - the hardware: device drivers model
    - it is useful to avoid references to the hardware in the source code
- …while being portable:
  - across OS and development tools
  - across languages
    - libs in C++, bindings for many other languages

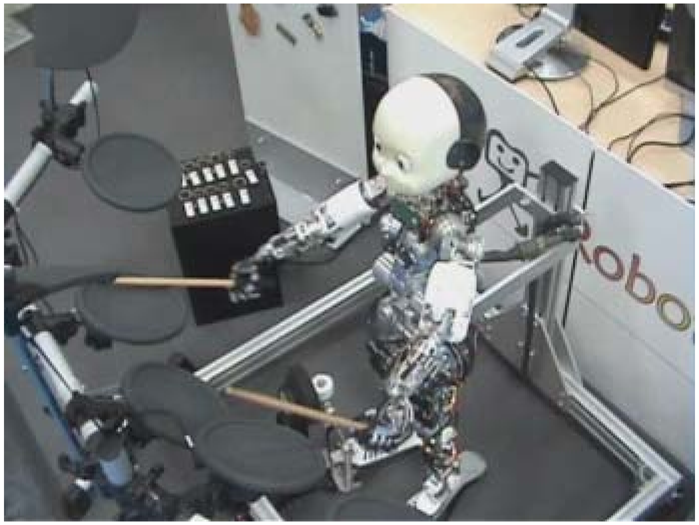
Typical YARP Network



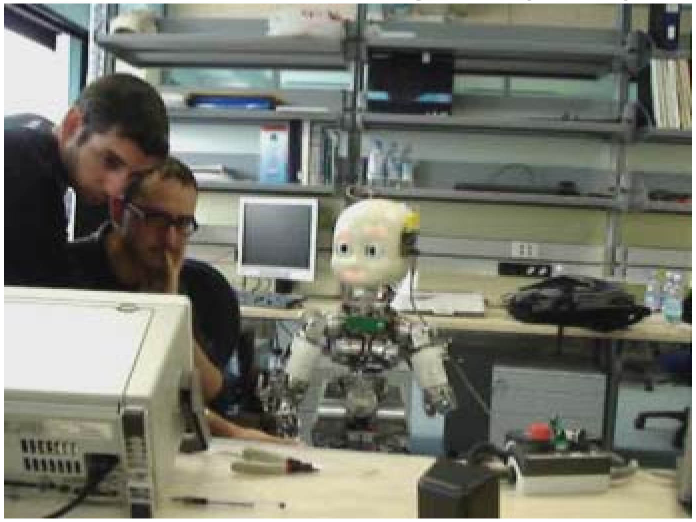
- Connections can use different protocols
- Ports belong to processes
- Processes can be on different machines/OS

The iCub


With Peter Ford-Dominey (INSERM, Lyon)


With Auke Ijspeert, Ludovic Righetti, Sarah Degallier (EPFL)


With a lot of students
@ RobotCub summer school 2008


With VisLab (IST Lisbon)