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

\[ \sum = 53 \text{ dof} \] (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

**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
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

new torque sensors

hollow wire exit shaft
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

- DSP
- HUB
- Gbit Ethernet
- PC104
- PCN
- Cluster
- iCub API
- Yarp
- Cognitive architecture

Sensors
Actuators
Low-level control
Embedded

Relay station (head)
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
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)