the iCub project
an open source platform for research in embodied cognition

MIT
May 9th, 2012

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the Italian Institute of Technology
• rbcs (in short)
  – neuroscience
  – robotics

• robotics
  – iCub intelligence
  – iCub hardware
  – iCub software
  – iCub production
what are we looking for?

• the focus of our research 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
Manipulation of environment can facilitate perception

Experiments by Giorgio Metta and Paul Fitzpatrick

Illustrations by Shun Iwasawa
…a bit of (additional) history

- RobotCub (FP6): started 2004 – finished 2010, initial design
- ITALK: started 2008, extensions to language
- Poeticon: started 2008, supported the development of fingertips – finished 2011
- CHRIS: started 2008, supported the development of force control (for safety)
- RoboSKIN: started 2009, took over the development of a skin system
- Viactors: started 2009, study on intrinsic compliance and variable stiffness
- AMARSi: started 2010, compliance and learning, motor richness
- ImClever: learning and intrinsic motivations
- ROSSI: sensorimotor and social interaction
- Xperience: started 2011, cognitive architecture & affordances
- EFAA: started 2011, social interaction and learning from interaction
- Darwin: started 2011, manipulation and assembly
- Poeticon++: starting 2012, language and action
RobotCub goals

✓ design a **humanoid robot** platform, namely the iCub

✓ make it the **platform of choice** for researchers in artificial cognitive systems

✓ study **cognition** from a developmental perspective (neuroscience)
iCub community goals now

✓ maintain and improve the iCub to keep it alive

✓ make it the platform of choice for researchers in artificial cognitive systems

✓ study cognition from a multitude of points of view
iCub is an open source international endeavour initially funded by the EU project RobotCub

- a full humanoid robot
- is 104cm, weighs 22 kg
- has 53 degrees of freedom
- can crawl, sit and manipulate
- open design as LGPL/GPL
why is the iCub so special?

- **hands**: we started the design from the hands
  - 5 fingers, 9 degrees of freedom, 19 joints

- **sensors**: human-like, e.g. no lasers
  - cameras, microphones, gyros, encoders, force, tactile...

- **electronics**: flexibility for research
  - custom electronics, small, programmable (DSP)

- **reproducible platform**: community designed
  - reproducible & maintainable yet evolvable platform
why humanoids?

• scientific reasons
  – e.g. elephants don’t play chess

• natural human-robot interaction

• challenging mechatronics

• fun!
why open platforms?

- repeatable experiments
- benchmarking
- quality

this resonates with industry-grade R&D in robotics
development tools
Yet Another Robot Platform

- YARP is an open-source (LGPL) middleware for humanoid robotics

- history
  - an MIT / Univ. of Genoa collaboration
  - born on Kismet, grew on COG, under QNX
  - with a major overhaul, now used by the iCub project

- C++ source code (some 400K lines)

- IPC & hardware interface

- portable across OSs and development platforms
exploit diversity: portability

• operating system portability:
  – Adaptive Communication Environment, C++ OS wrapper: e.g. threads, semaphores, sockets

• development environment portability:
  – CMake

• language portability:
  – via Swig: Java (Matlab), Perl, Python, C#
the entire project is under LGPL/GPL
• connections can use different protocols
• ports belong to processes
• processes can be on different machines/OS
attention system
Attention system

\[ d = -d_{\text{max}} \quad d = -1 \quad d = 0 \quad d = +1 \quad d = +d_{\text{max}} \]

\[ d \text{ is used as control signal (zero = foveation)} \]
attention system
attention system
active segmentation with fixation

- the fixation point lies inside a particular region of arbitrary shape and size in the scene which can either be an object or just a part of it

- a (probabilistic) boundary edge map of the image is generated using all available low level cues

- this edge map is transformed into the polar space with the center at the fixation point and the path through this edge map that optimally splits the map into two parts is determined

- graph cut is used to find globally optimal solution to this binary segmentation problem

active segmentation with fixation

reaching
refine reaching through learning
reaching: control vs. desired
iCub sensorization
\[ e = \tau - \tau_d \]
\[ \hat{\omega}_e = \begin{bmatrix} I & 0 \\ -[r_{se}]_x & I \end{bmatrix} \cdot (w_s - w_i) \]
\[ \hat{t}_e = J^T(q) \cdot \hat{\omega}_e \]
\[ e = \hat{t}_e - \tau_d \]
\[ u = k_p \cdot e + k_d \cdot \dot{e} + k_i \cdot \int e \]
\[ \tau_d = K \cdot (q - q_d) + D \cdot (\dot{q} - \dot{q}_d) \]
Test of the dynamical model
main idea: build a soft capacitor

- **ground plane**: e.g. conductive fabric
- **parameters**: mechanical properties, impedance, etc.

- **soft material**: e.g. silicone
- **parameters**: dielectric constant, mechanical stiffness, etc.

- **electrodes**: etched on a flexible PCB
- **parameters**: shape, folding, etc.
skin

principle

lots of sensing points

structure of the skin
skin evolution (fingertips)
skin evolution: large areas