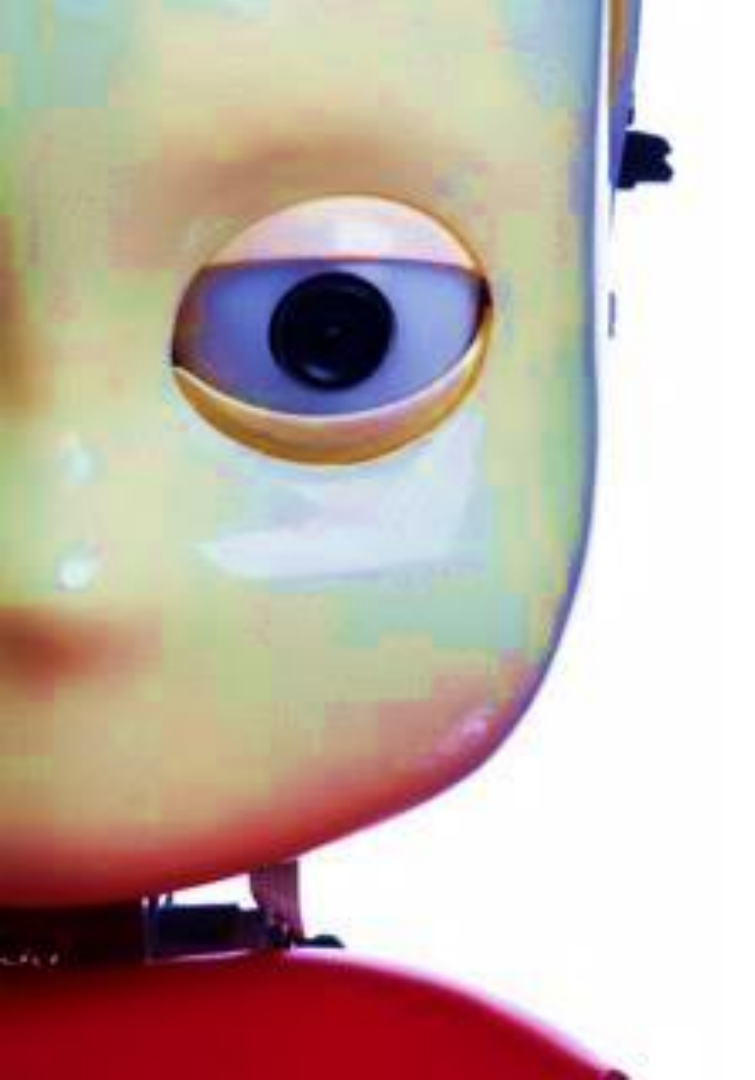

iCub

a shared platform for research in robotics & AI

Woods Hole, MA

Giorgio Metta & the iCub team

Istituto Italiano di Tecnologia

Via Morego, 30 - Genoa, Italy

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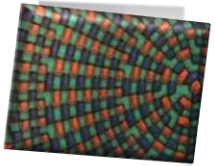
we have a dream

the iCub

price: 250K€
30 iCub
distributed since 2008
about 3-4 iCub's/year

why is the iCub 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 (DSPs)
- **reproducible platform:** community designed
  - reproducible & maintainable yet evolvable platform
  - large software repository (~2M lines of code)

why humanoids?

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Please see the video.

- scientific reasons
  - e.g. elephants don’t play chess

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- natural human-robot interaction

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- challenging mechatronics

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- fun!

why open source?

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- repeatable experiments

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- benchmarking

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- quality

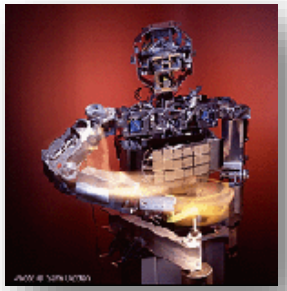
this resonates with industry-grade R&D in robotics

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

2000-2001

Image is in the public domain.



2001-2002

2003

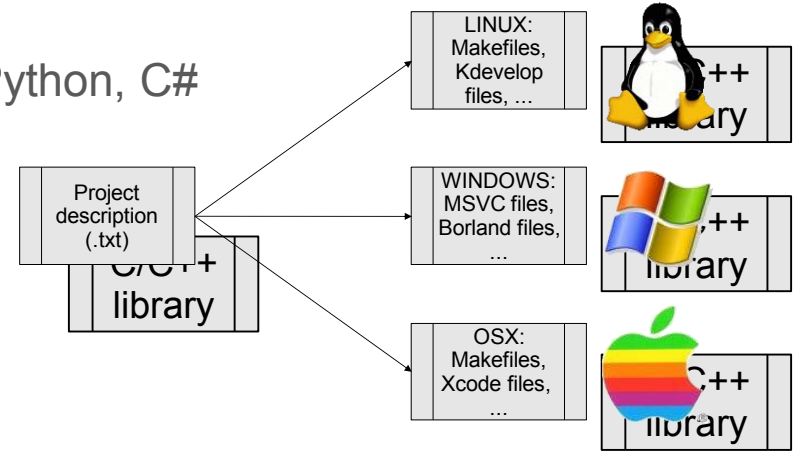
Courtesy of Laboratory for Integrated Advanced Robotics. Used with permission.

2004-Today

Image of Tibi Robot removed due to copyright restrictions.

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#



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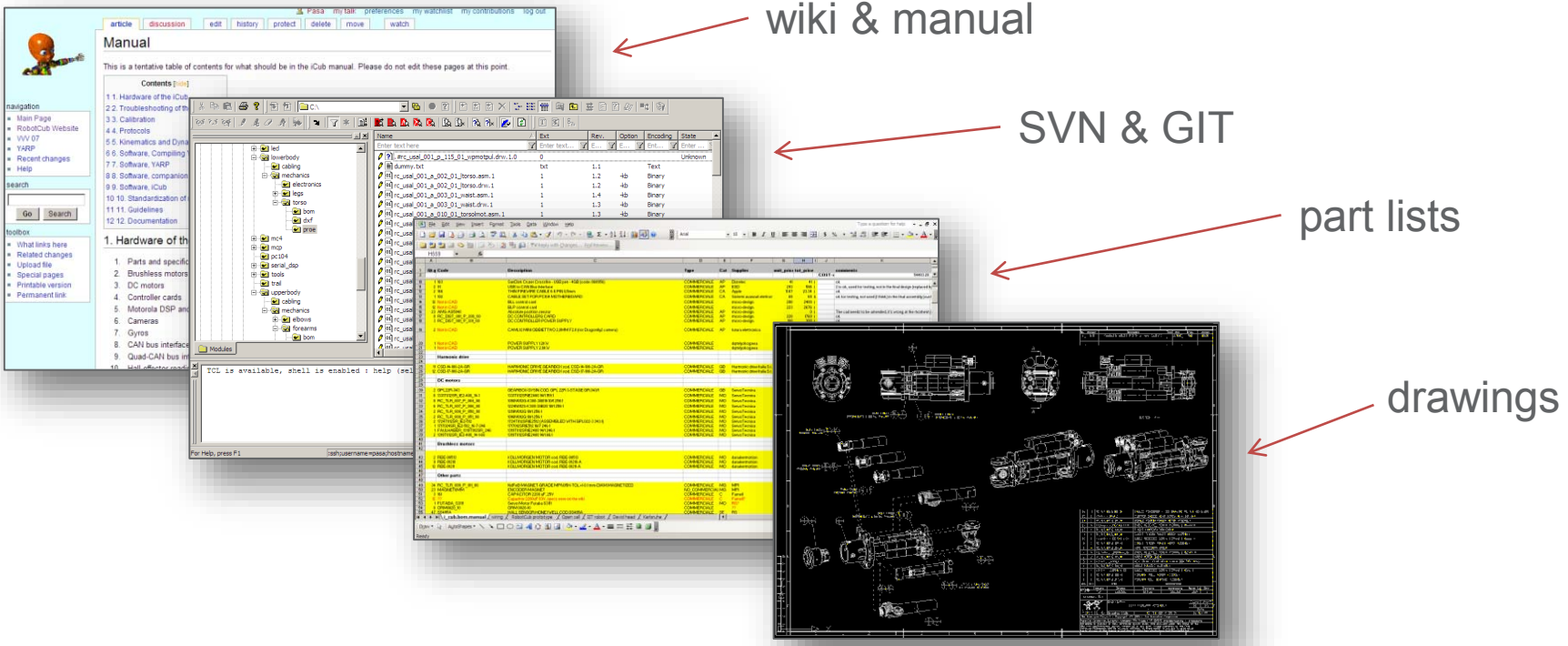
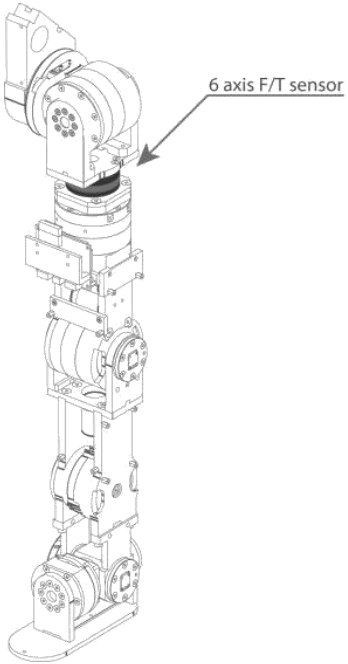
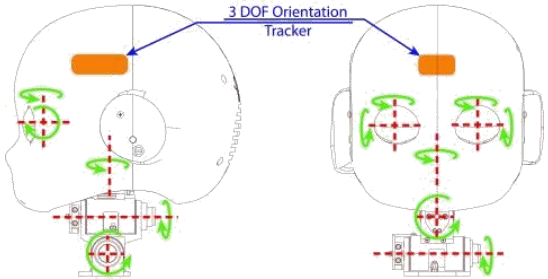
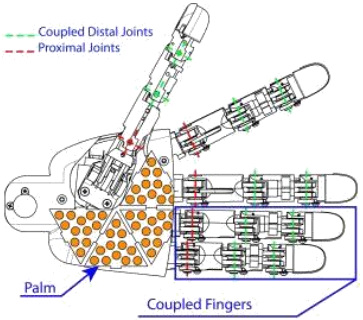
open source

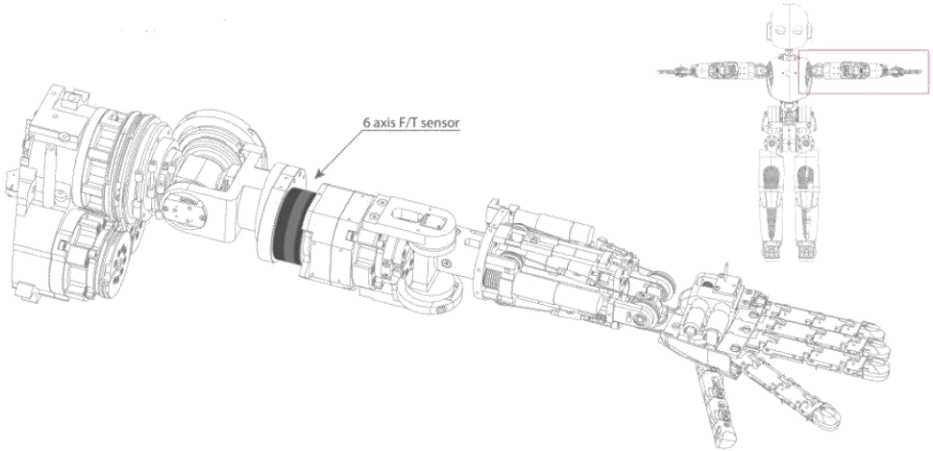


iCub sensors









the robot skin

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capacitor

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

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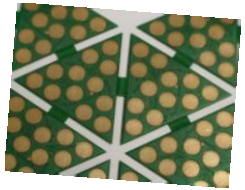
soft material: e.g. silicone
parameters: dielectric constant, mechanical stiffness, etc.



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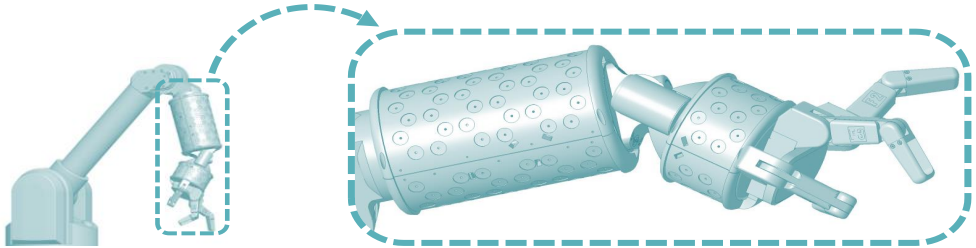
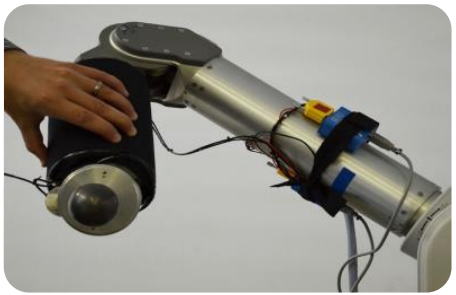
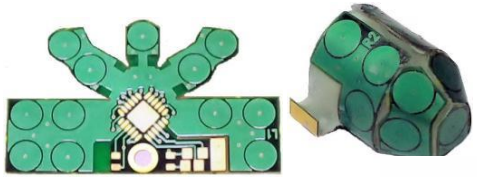
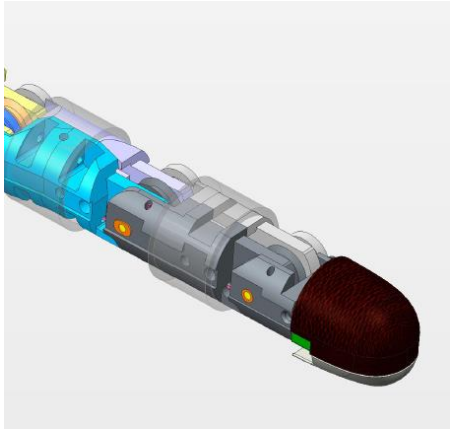
electrodes: etched on a flexible PCB
parameters: shape, folding, etc.

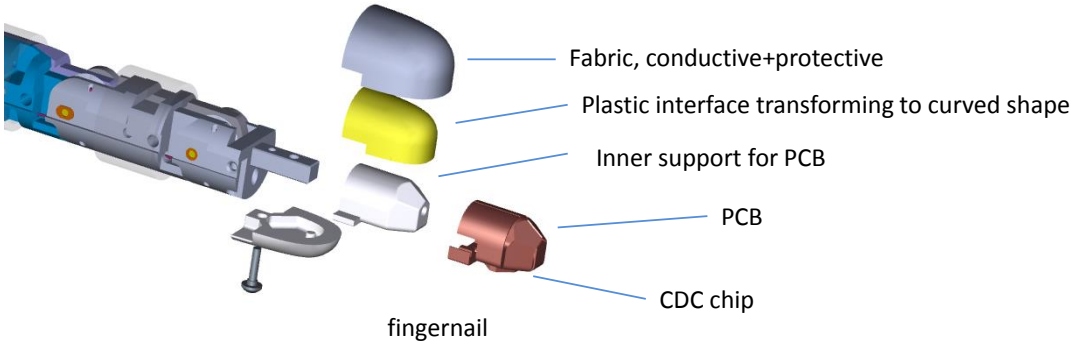






12 sensors
14.5 x 13 mm





learning dynamics

- learning body dynamics
  - compute external forces
  - implement compliant control

- so far we did it starting from e.g. the CAD models
  - but we'd like to avoid it

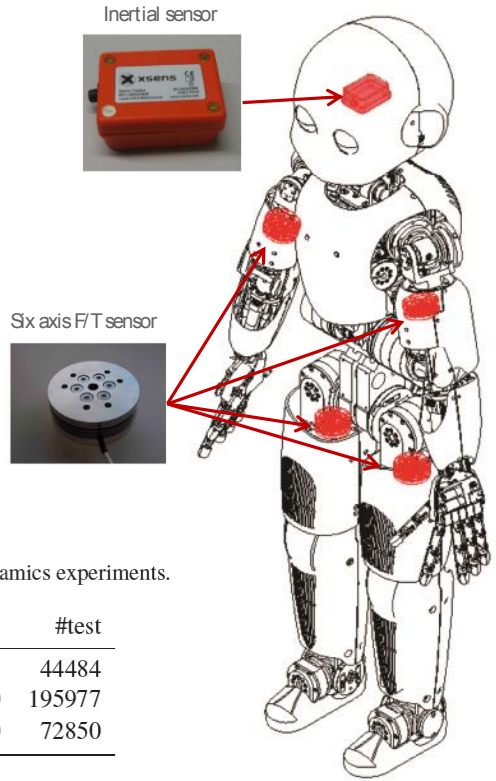
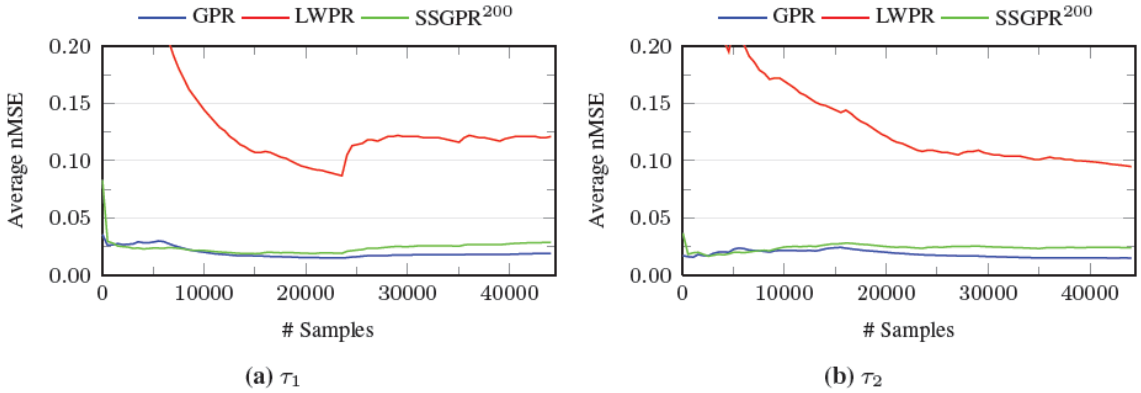


Table 5.2: Datasets used for the incremental dynamics experiments.

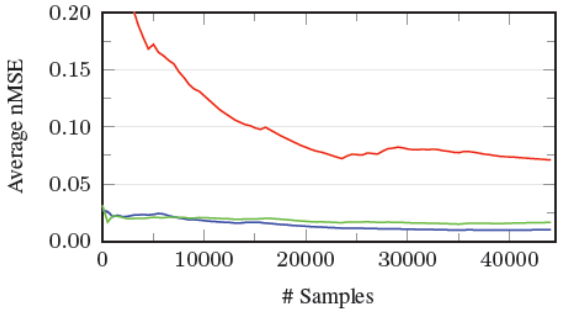
	#joints	output	#train	#test
Sarcos	7	$\tau \times 7$	4449	44484
James	4	$[F, \tau]_{x,y,z}$	15000	195977
iCub	4	$[F, \tau]_{x,y,z}$	15000	72850

incremental experiments

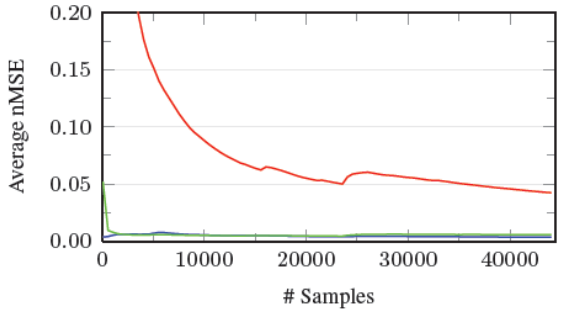


(a) τ_1

(b) τ_2



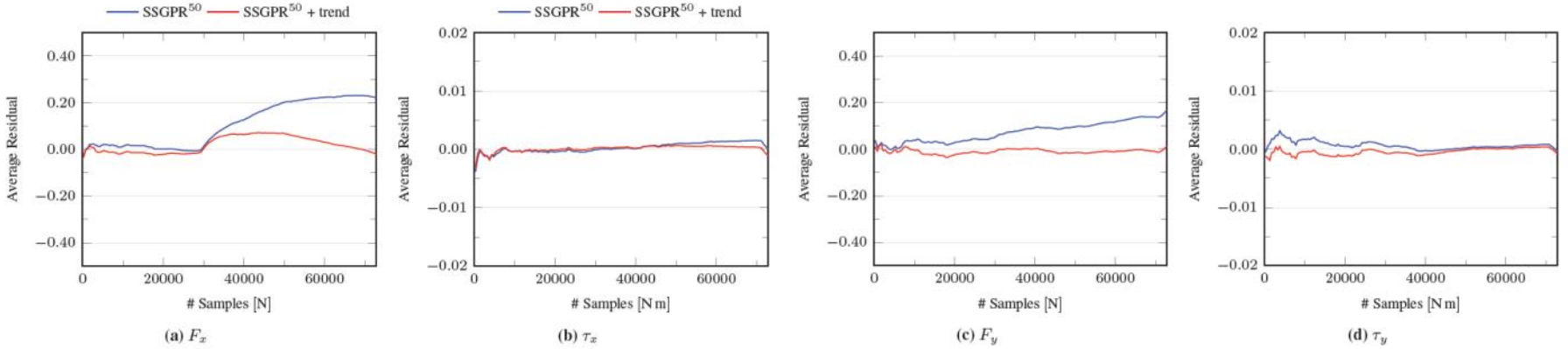
(c) τ_3



(d) τ_4

temperature compensation

$$\phi(\boldsymbol{x}) = \frac{\sigma_f}{\sqrt{D}} \left[\sin\left(\langle \boldsymbol{\omega}_1^{\mathrm{T}}, \boldsymbol{x} \rangle\right), \cos\left(\langle \boldsymbol{\omega}_1^{\mathrm{T}}, \boldsymbol{x} \rangle\right), \cdots, \sin\left(\langle \boldsymbol{\omega}_D^{\mathrm{T}}, \boldsymbol{x} \rangle\right), \cos\left(\langle \boldsymbol{\omega}_D^{\mathrm{T}}, \boldsymbol{x} \rangle\right), t\right]^{\mathrm{T}}$$



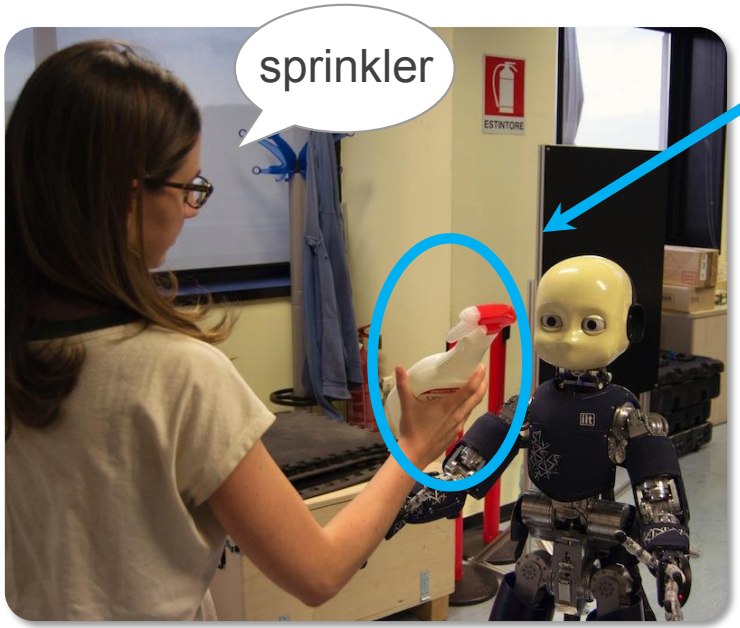
(a) F_x (b) τ_x (c) F_y (d) τ_y

dataset

Verbal (weak) Supervision

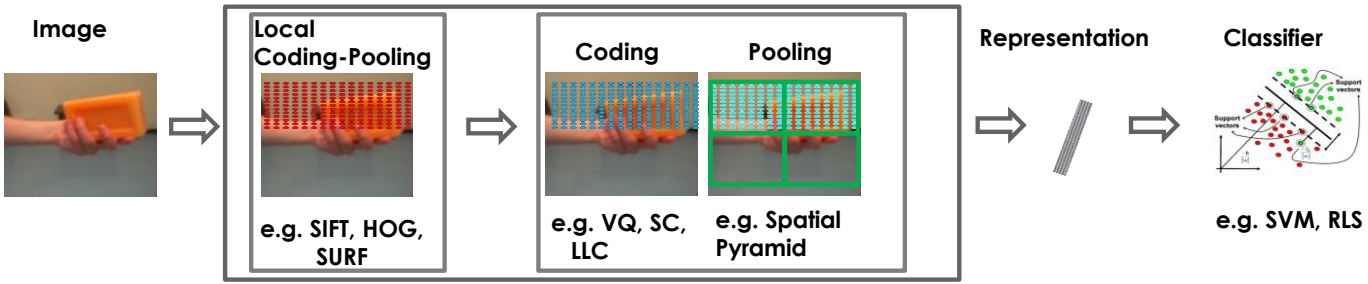
Motion Detection

Human "Teacher"

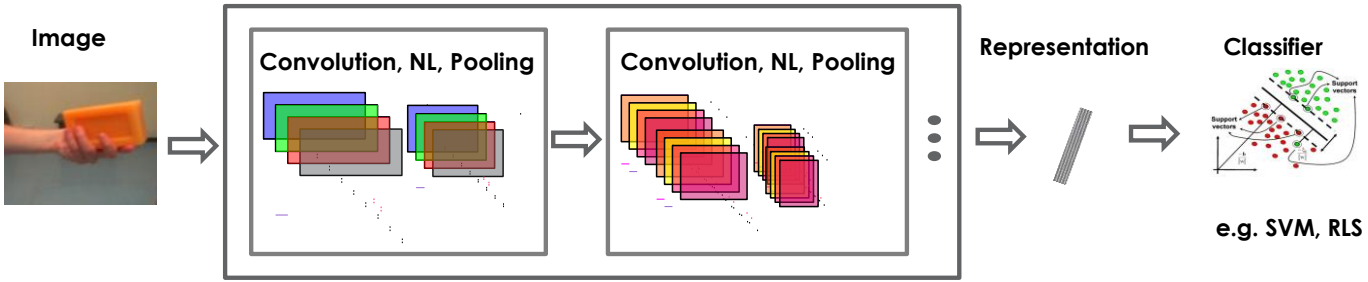


methods

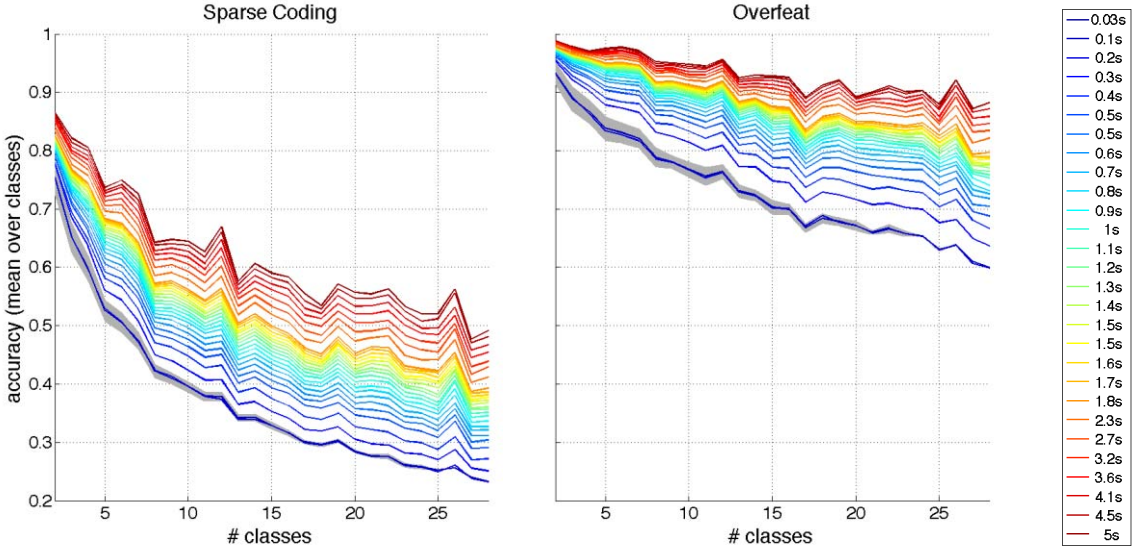
Mainstream Object Recognition Pipelines:



Convolutional Neural Networks:



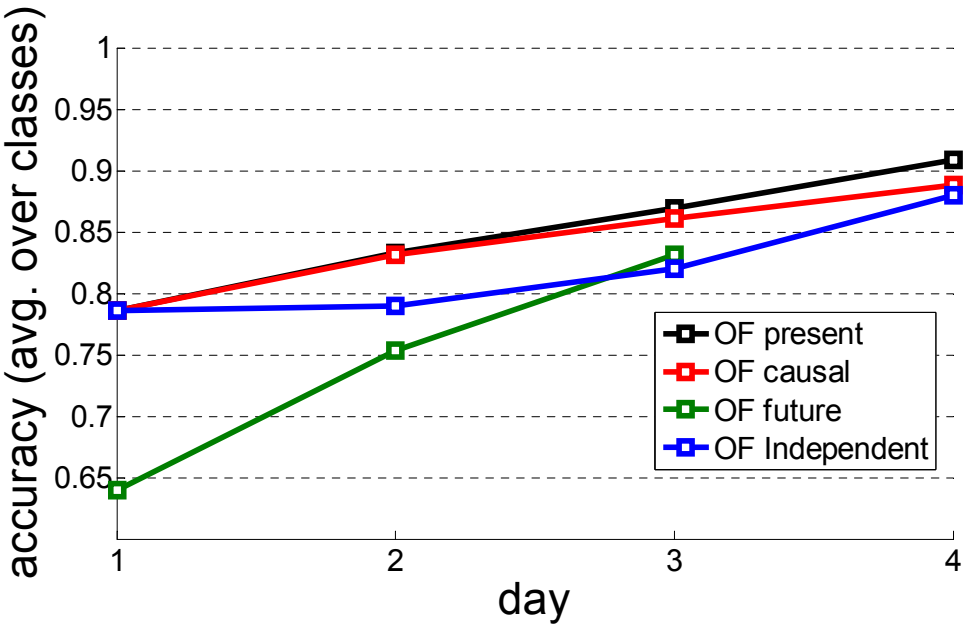
exploiting continuity in time



incremental learning

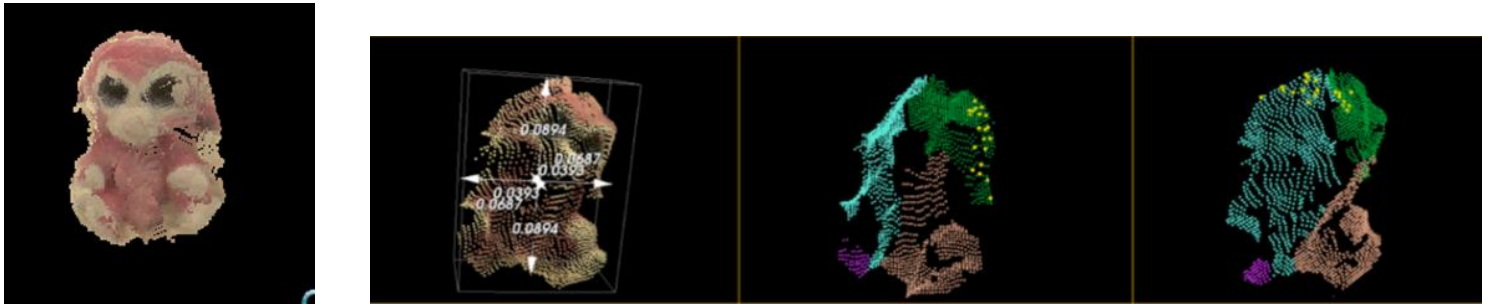
Cumulative learning on the 4 days of acquisition. Tested on:

- **Present**: test on current day
- **Causal**: test on current and past days
- **Future**: test on future days (current not included)
- **Independent**: train & test on current day only

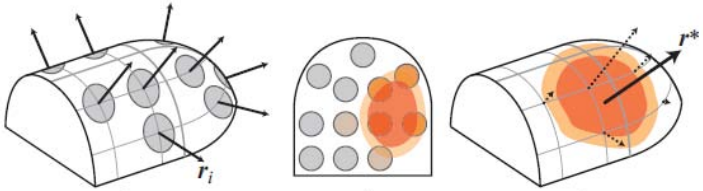


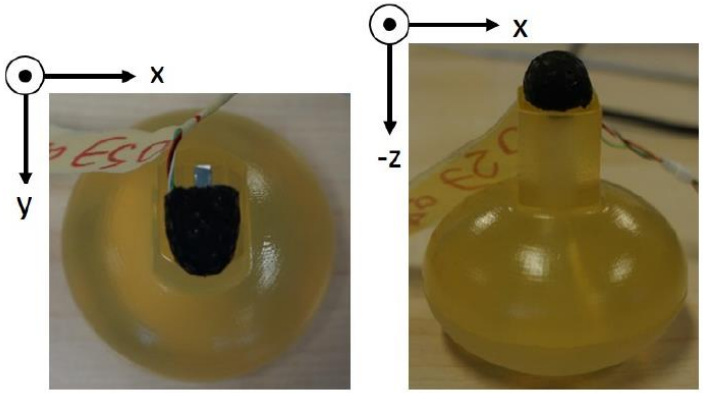
3D vision for grasping

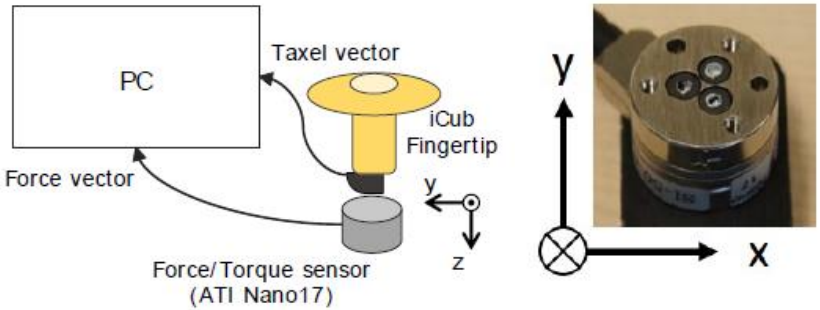
Input Segmentation Disparity



force reconstruction







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Resource: Brains, Minds and Machines Summer Course
Tomaso Poggio and Gabriel Kreiman