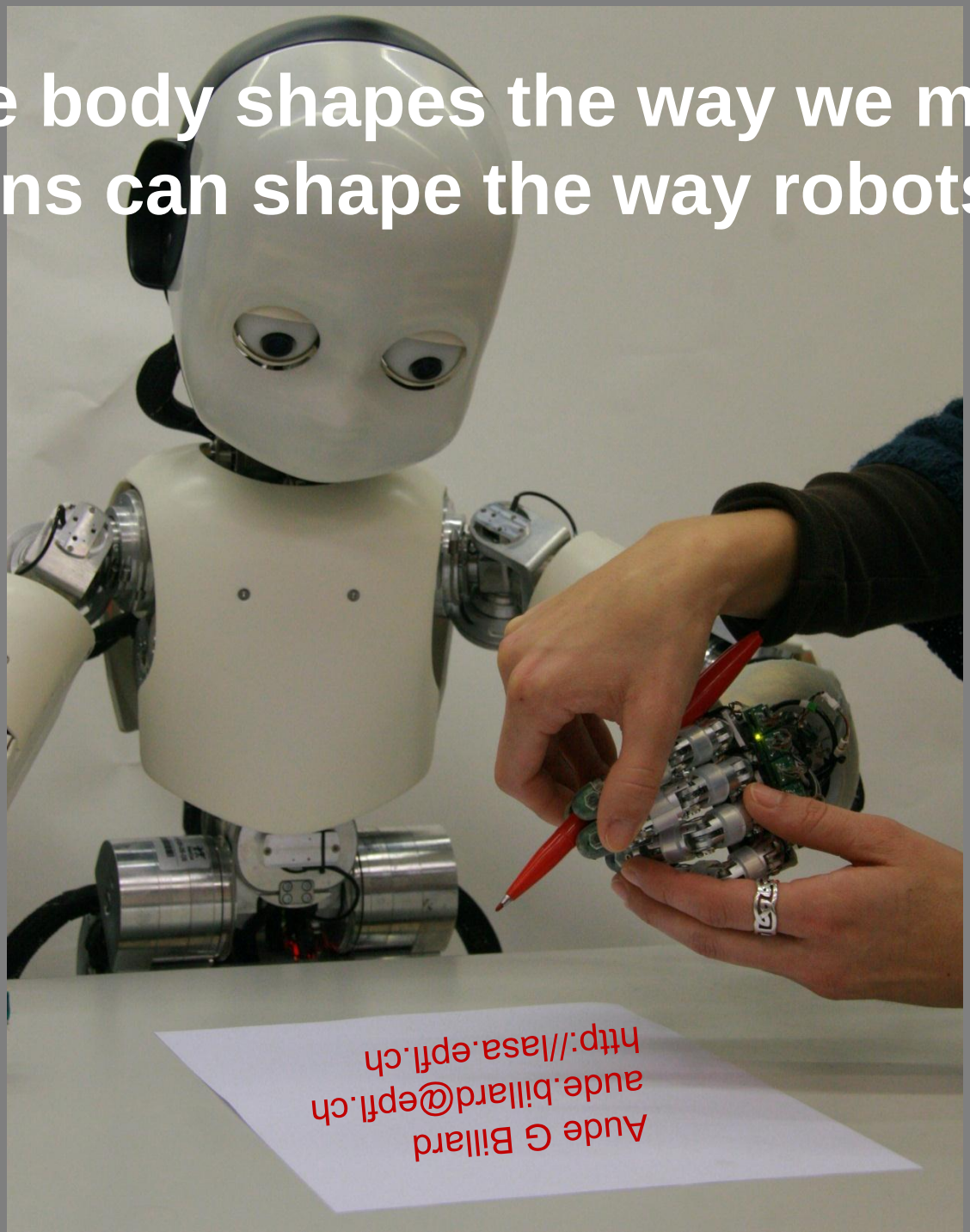
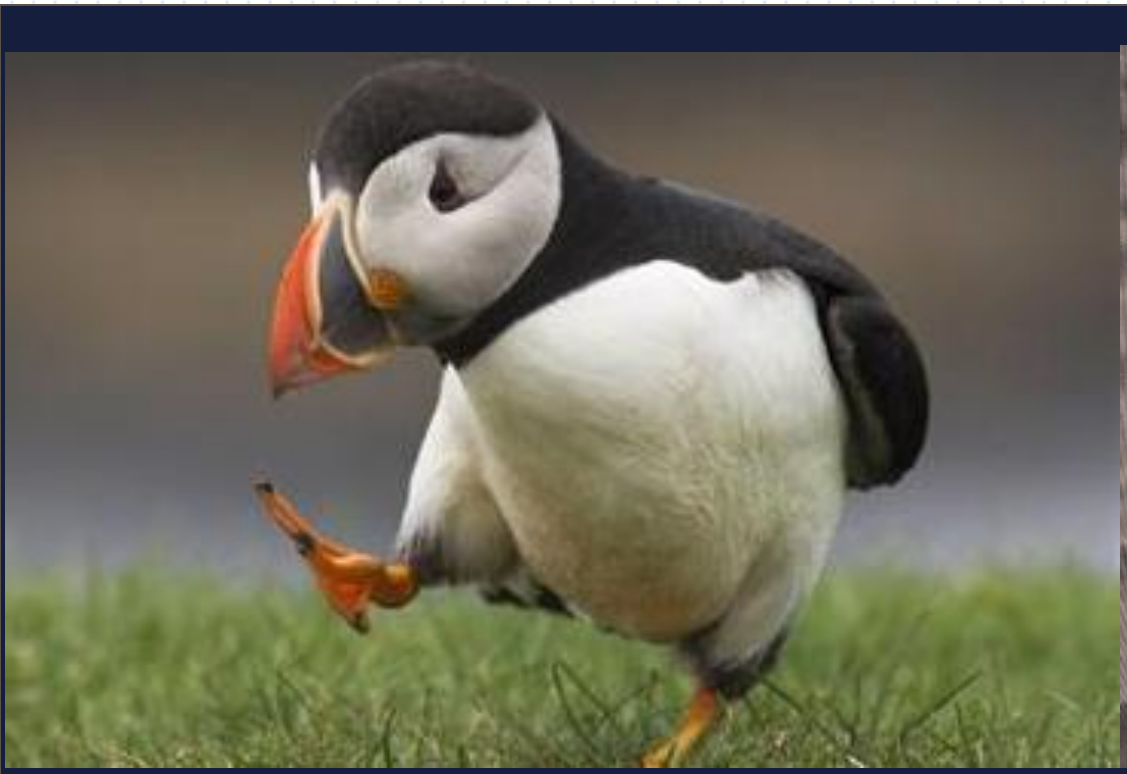
How the body shapes the way we move
How humans can shape the way robots move



How the body shapes the way we move



Evolution has shaped the body and the control system simultaneously so as to optimize the animal’s overall motor control system

With enough training….

…we can get bodies to do things for which they were not designed for in the first place, but this requires tedious and long training periods.

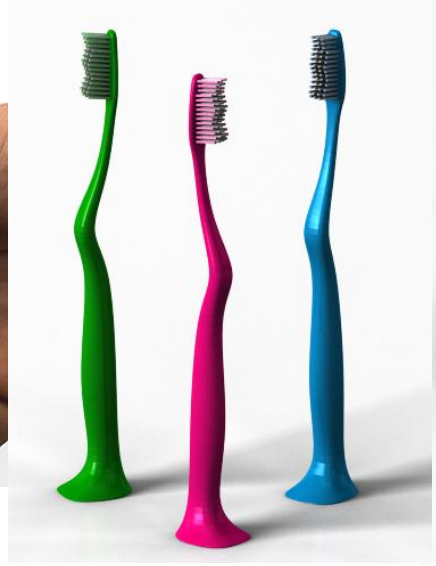
How the body shapes the way we move

Robots should have arms and hands that are similar to human hands and arms

How the body shapes the design of tools

Robots should help us in our daily tasks

- manipulate the same objects
- objects are designed for the human hand



Bent to our needs!

Learning a Variety of Grasps on a Cylinder

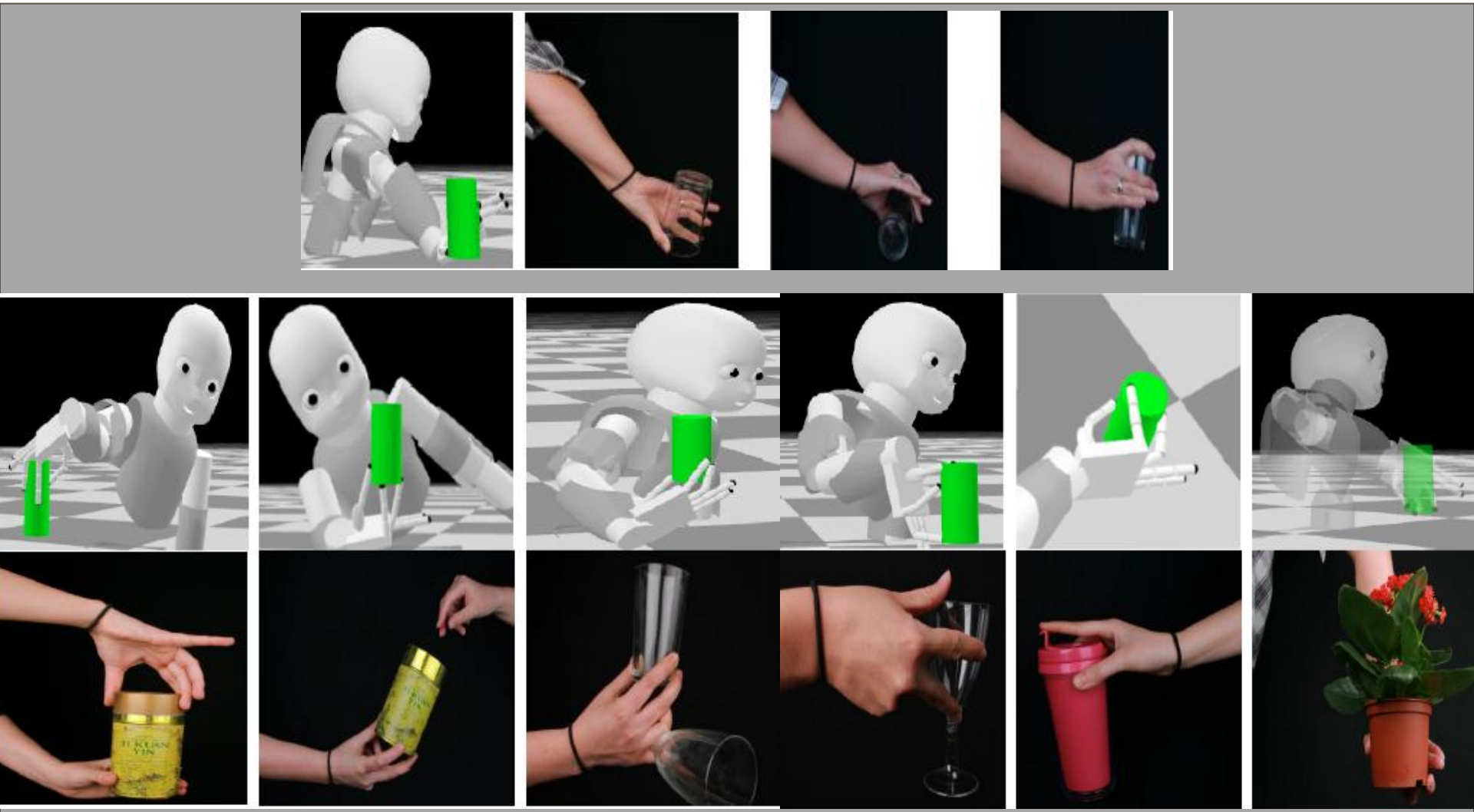
Grasping usually finds the optimal set of grasping points

Learning a Variety of Grasps on a Cylinder

Humans place their fingers in various ways on objects.
The grasp are action-dependent and depend on how to manipulate the object.

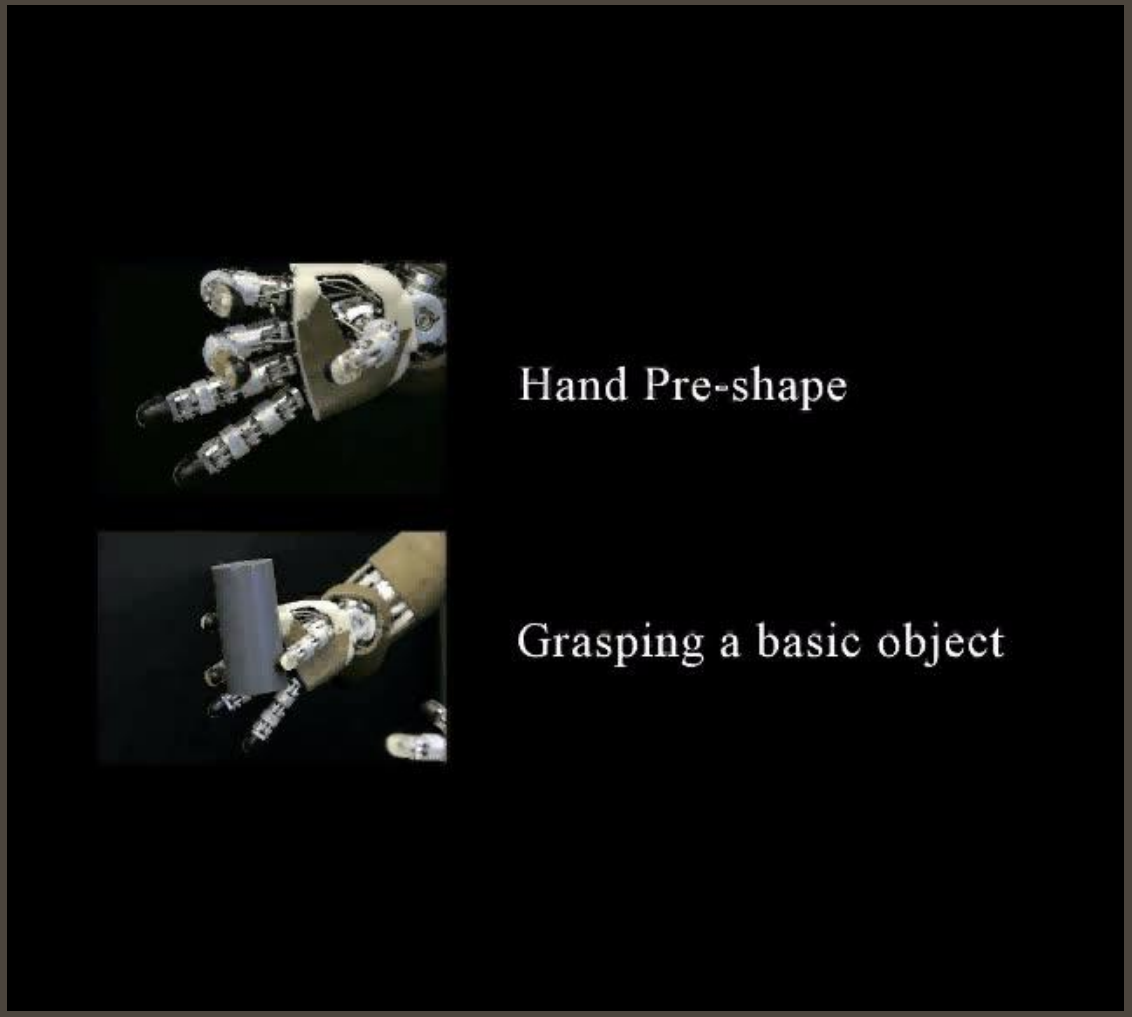
This variety of posture can then be used to adapt grasping motion depending on external constraints

Learning a Variety of Grasps on a Cylinder



El'khoury, Li and Billard, 2012

Use Variety of Grasps to Hold a Variety of Objects



Use Variety of Grasps to Hold a Variety of Objects

How humans can shape the way robots move

Robots should move and act in a way that is similar to the way humans move and act

Why?

- *Makes robot's motions more predictable*
  → *Increase safety during human-robot interaction*
  → *Easier for robots and humans to collaborate*

- *Human motions have all these nice properties (robustness to perturbation, smoothness, energy efficiency), which we seek robots to have.*

How do humans adapt when perturbed?

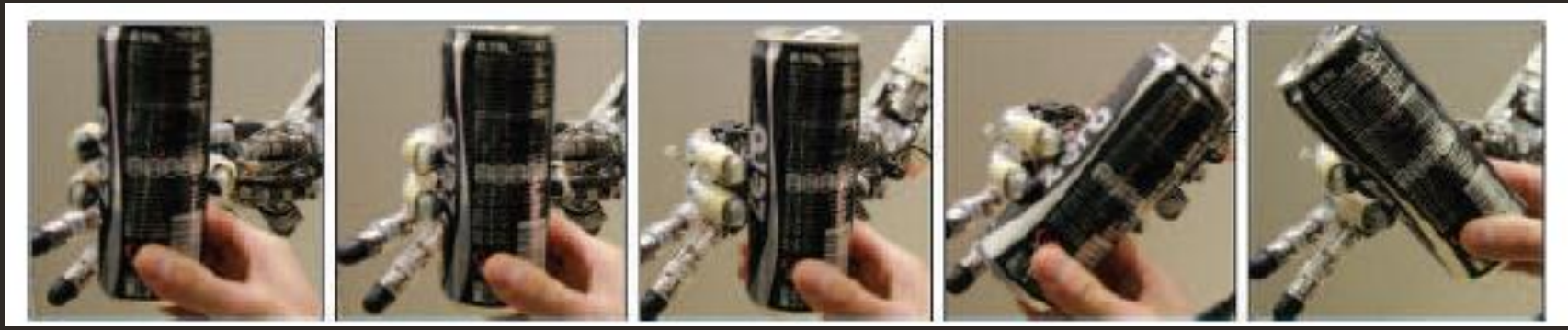
Can we learn to adapt the same way?

If robots adapt to perturbations the same way as humans do, they may again be more predictable and their reaction will be less dangerous for humans

Learning Compliant Grasping

Traditionally, a grasp = optimal placement of fingers onto an object

Knowing the extent to which one can adapt this grasp is useful for safe manipulation.



Learning how to comply with external perturbations
while maintaining a firm grasp.

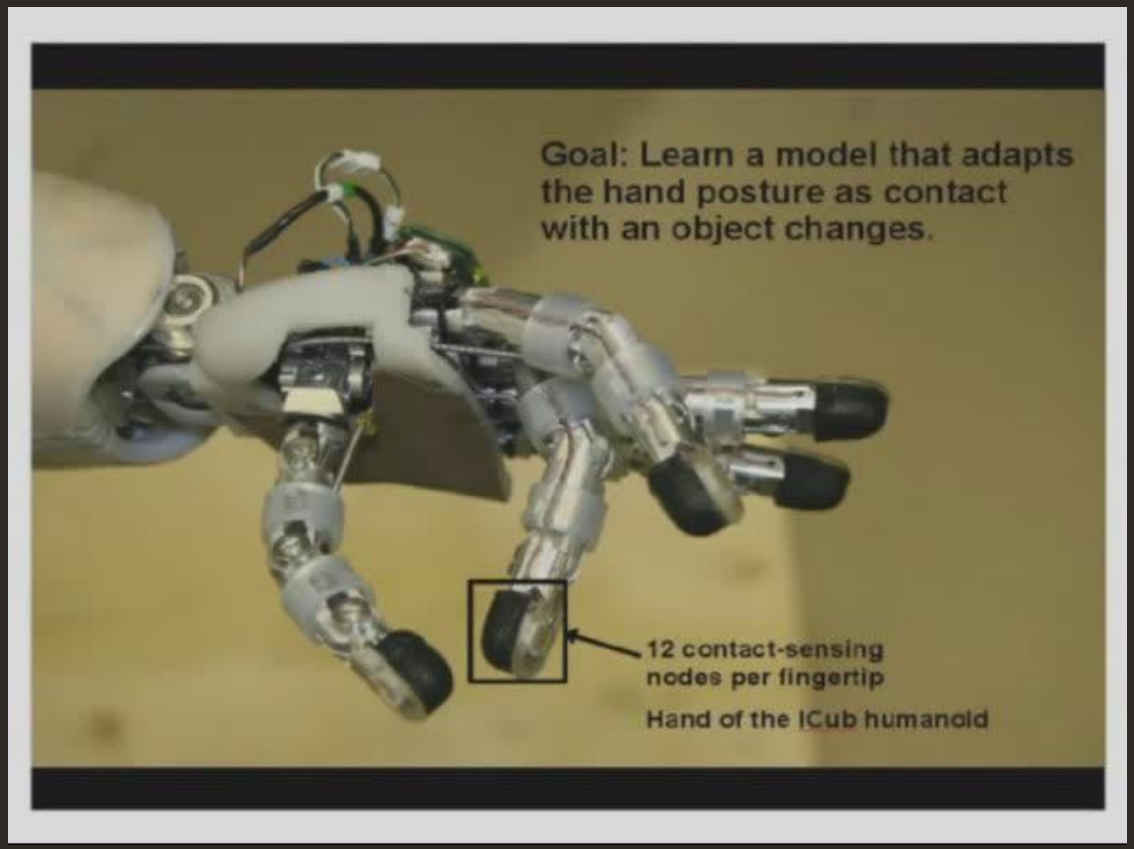
Sauser, Argall and Billard, Autonomous Robots, 2011

Learning Compliant Grasping

Default behavior – too stiff

Sauser, Argall and Billard, Autonomous Robots, 2011

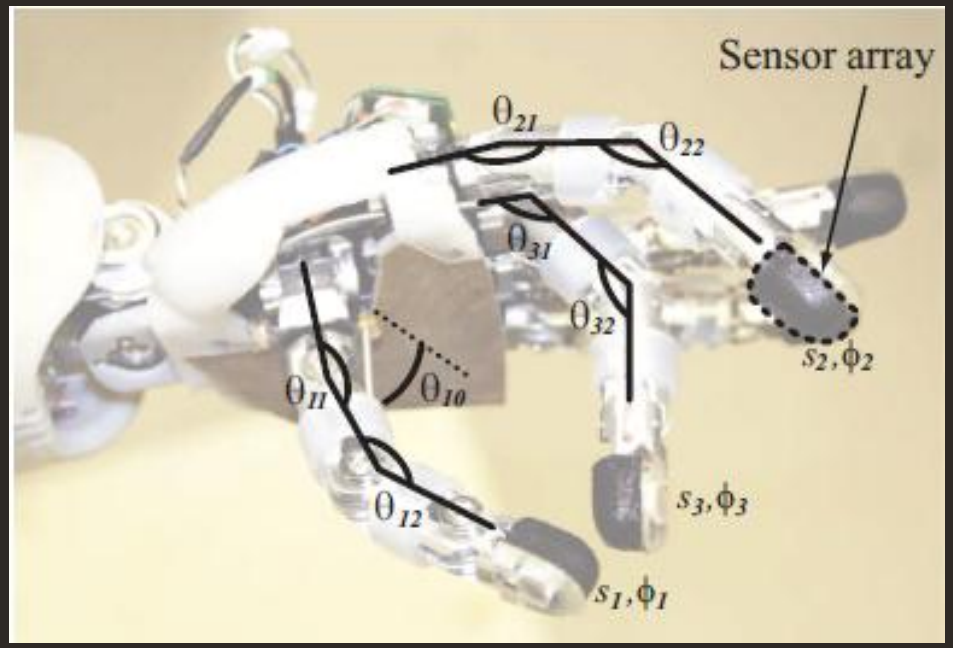
Learning Compliant Grasping

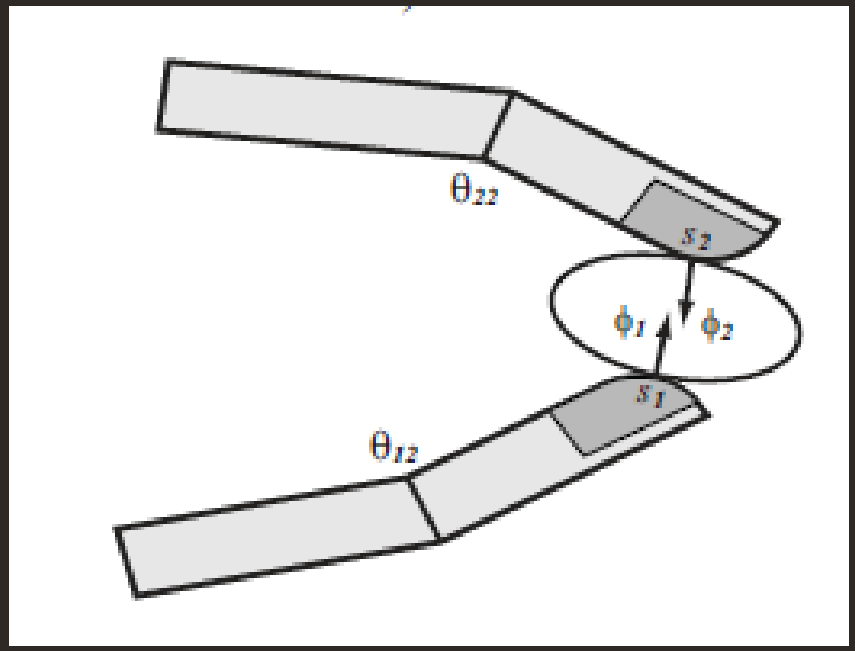


Sauser, Argall and Billard, Autonomous Robots, 2011

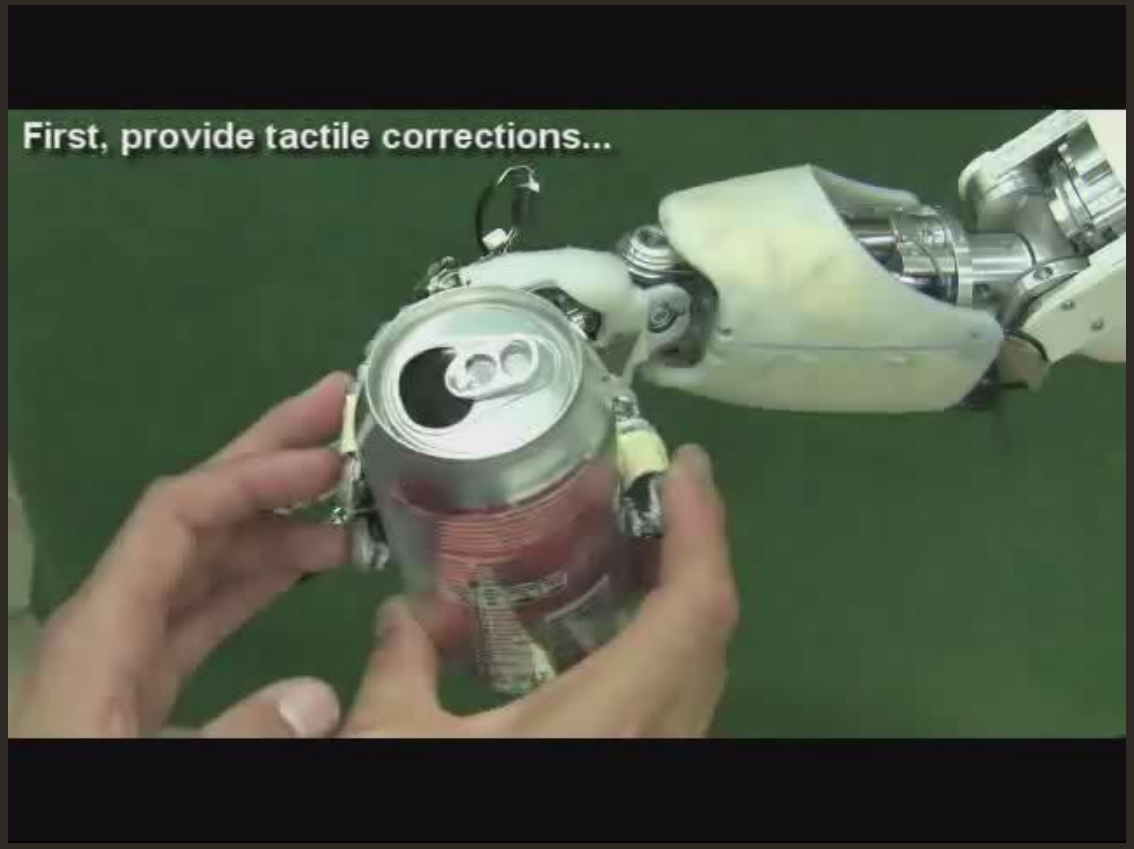
Learning Compliant Grasping

Learn a probabilistic mapping $p(\phi, s, \theta)$ between contact signature of the object (normal force ϕ and tactile response s) and fingers' posture θ.



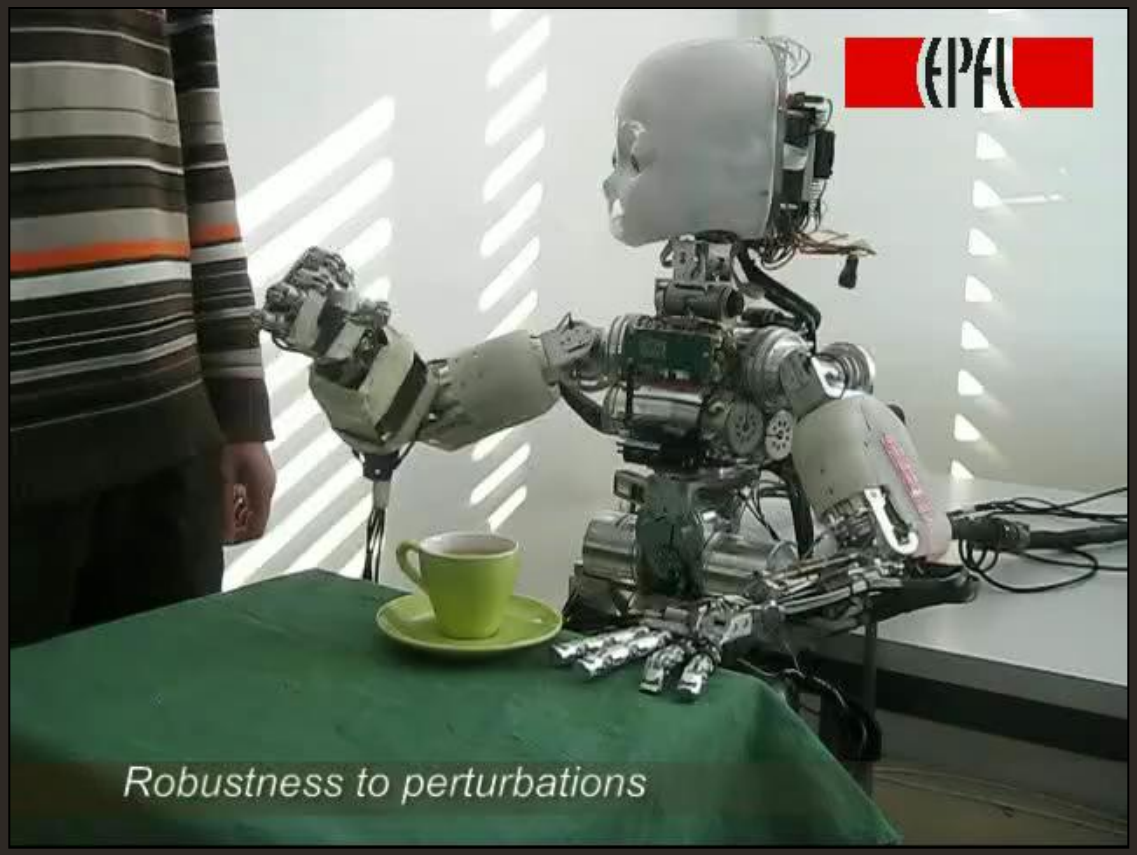


Learning Compliant Grasping



Sauser, Argall and Billard, Autonomous Robots, 2011

Designing Adaptive Robots



Modeling robot motions with Dynamical Systems provides control laws that ensure to reach the target even, when perturbed

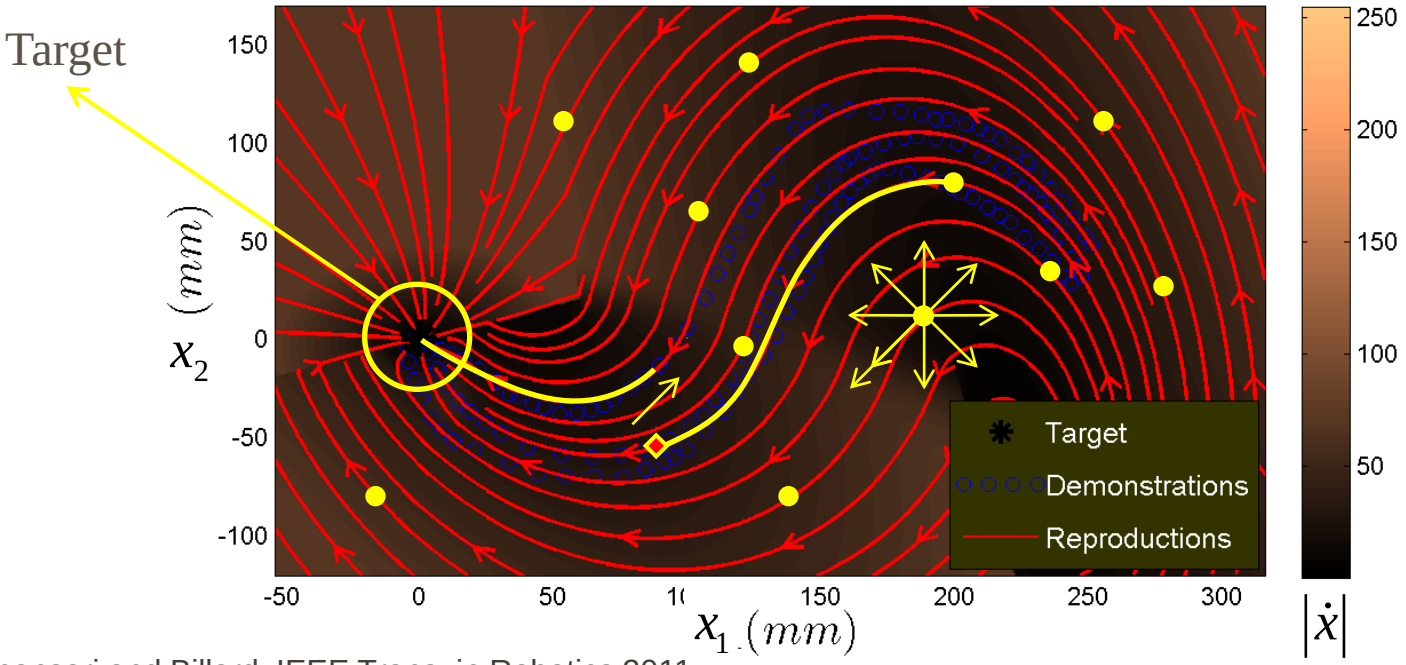
Khansari and Billard, IEEE Trans. in Robotics 2011

Designing Adaptive Robots

Autonomous dynamical system with asymptotically stable attractor

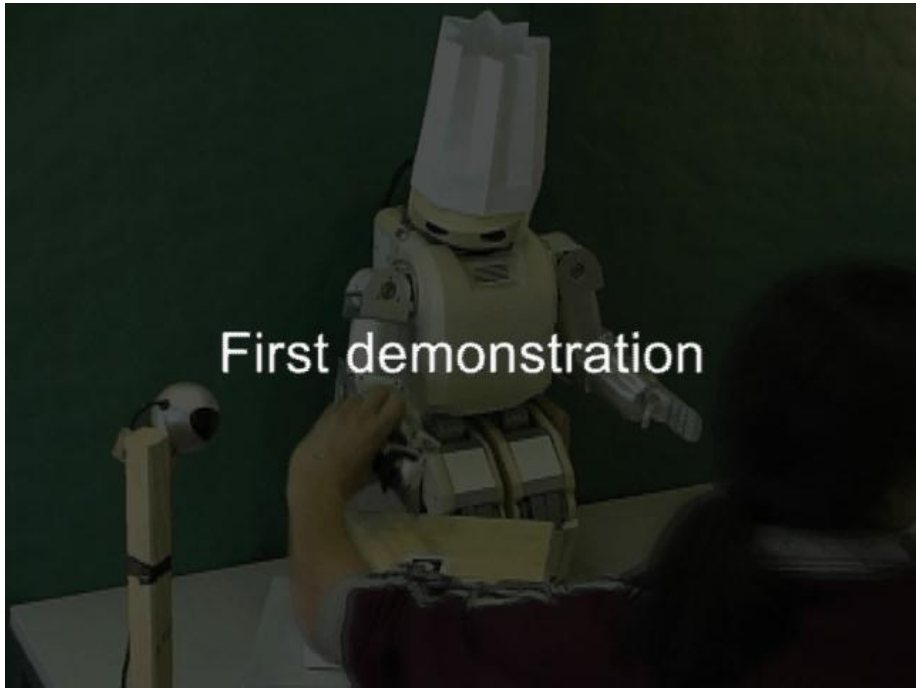
Single law of motion → Robust to perturbation

Control law $\dot{x} = f(x)$ *with stable attractor* $\dot{x}^* = f(x^*) = 0$



Khansari and Billard, IEEE Trans. in Robotics 2011

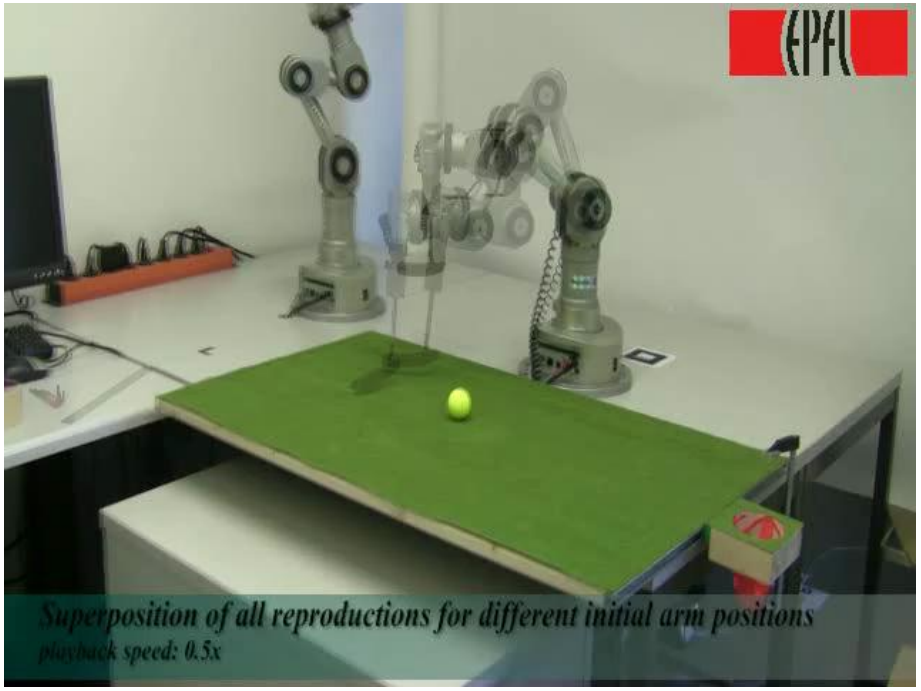
Designing Adaptive Robots through Human Demonstration



Learning a skill is more than simply replaying a trajectory.
It requires to understand what a skill is.

To learn this, one needs to show several demonstrations
to *generalize* across sets of examples.

Designing Adaptive Robots through Human Demonstration



Learning a skill is more than simply replaying a trajectory.
It requires to understand what a skill is.

To learn this, one needs to show several demonstrations
to *generalize* across sets of examples.

Learning Compliant Reaching

Too stiff – Spills the liquid

Too compliant – spill the liquid outside the glass

Kronander and Billard, *ICRA 2012*

Learning Compliant Reaching

Learning Compliant Manipulation through Kinesthetic and Tactile Human-Robot Interaction: the pouring task.

Klas Kronander and Aude Billard

Take-Home Message

Robots should have bodies that resemble our body if they are to manipulate objects designed for us

The body shapes the way we move
→ Humans shape the way robots move

- Copy the way humans adapt to perturbation
  - On-the-fly reactivity
  - Task-dependent adaptive impedance
- Copy the dynamics of human motion
  - Robustness to perturbations
  - Makes robots' motions more predicable, hence safer

robotics
Swiss National Centre of Competence in Research
AMARSi
SEVENTH FRAMEWORK PROGRAMME
ROBOSKIN
Skin-Based Technologies and Capabilities for Safe, Autonomous and Interactive Robots