Robotica Antropomorfa I

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Lezione 1

Programma

- Tema principale
  - Partiamo dalla biologia (es. un articolo di neuroscienza)
  - Arriviamo a vedere l'implementazione in un robot biomorfo
- Contorno
  - Concetti generali di robotica, controllo, ecc.

Altre cose…

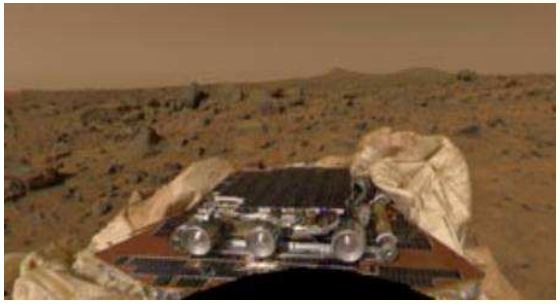
- Mailing list:
  - robotica@liralab.it
- Il mio email:
  - pasa@liralab.it
- Articoli da leggere
  - minima conoscenza dell'inglese per leggere articoli di carattere tecnico (e le slide!)

Ma c'e' qualcosa di interessante?

AIBO, 2a generazione!

SDR

HRP



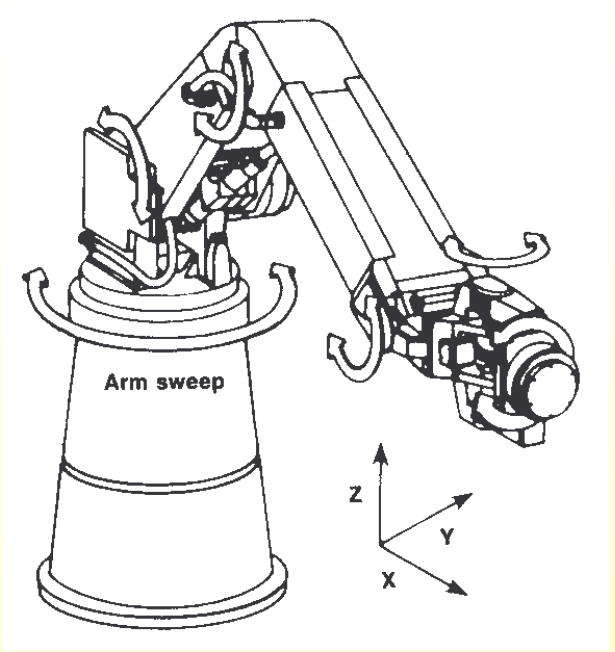
Robonaut (NASA)

SDR, Sony Corp.

Asimo, Honda

Once upon a time in robotics…

- You started by studying “links” connected through joints, and actuated by electrical motors!
- What we’re doing is a bit different:
  - Sensors
  - Control
  - Actuation
  - AI
- Integrated design, any single component but also their combination is important



Questions

- How do morphology and functionality (of the system) interact in solving a task?
  - It's not just a matter of a single component
- What do we try to do, and why is this useful?
  - Is this activity scientifically and/or technologically relevant?

One possible interpretation

- Try to understand the brain (in solving a certain task) by building a physical simulacrum in digital technology
- Learning by building: try to learn something in the process of building something else
- Try to build more flexible and adaptable machines: e.g. automotive (high class cars might have 100eds of microprocessors, sensors, and some actuators)
- There's no Einstein equivalent yet in AI (in a broad sense)

But why building a body…

- Theory of embodiment
  - Ref: Brooks' elephants don't play chess
- In short:
  - If you have a body you're bound to a certain type of interaction w/ the environment
  - The environment is the best representation of itself. Always up to date
  - A realistic environment is very difficult to simulate

Neurophysiology comes to help this position

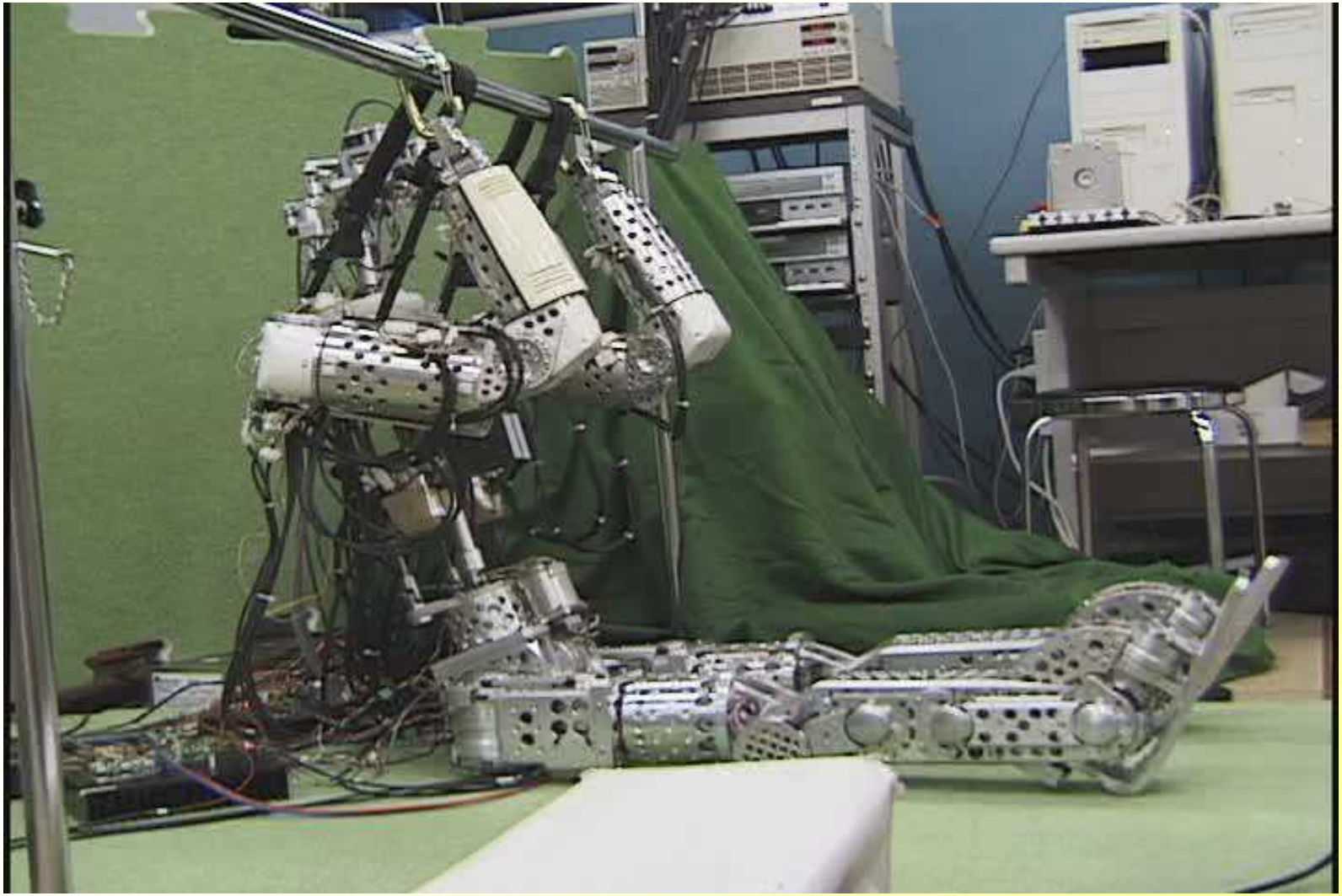
- Action (the control of our own body) is related to the way we perceive the world (sensory perception)
- Very common paradigm: perceive first, then compute, and eventually act
- Neurophysiology example: later, in a few slides time!
- In the past:
  - Active vision or purposive vision

Why are things so hard!

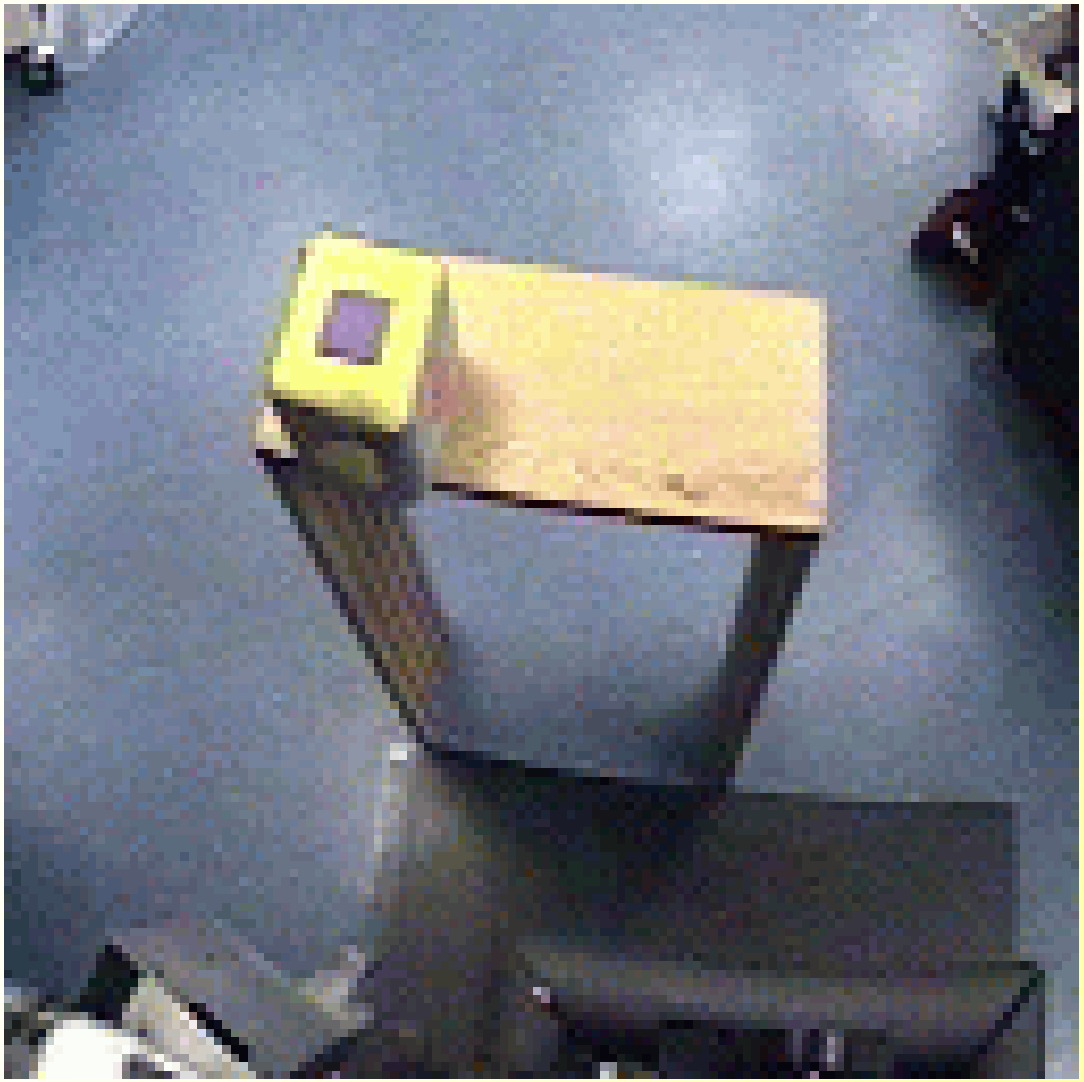
- People overlooked the problem(s)
- To behave appropriately we need adaptation and learning
  - Our daily environment is too difficult for a non-flexible robot
- Computers are not powerful enough
- We've got some of the models and/or parameters wrong

Development

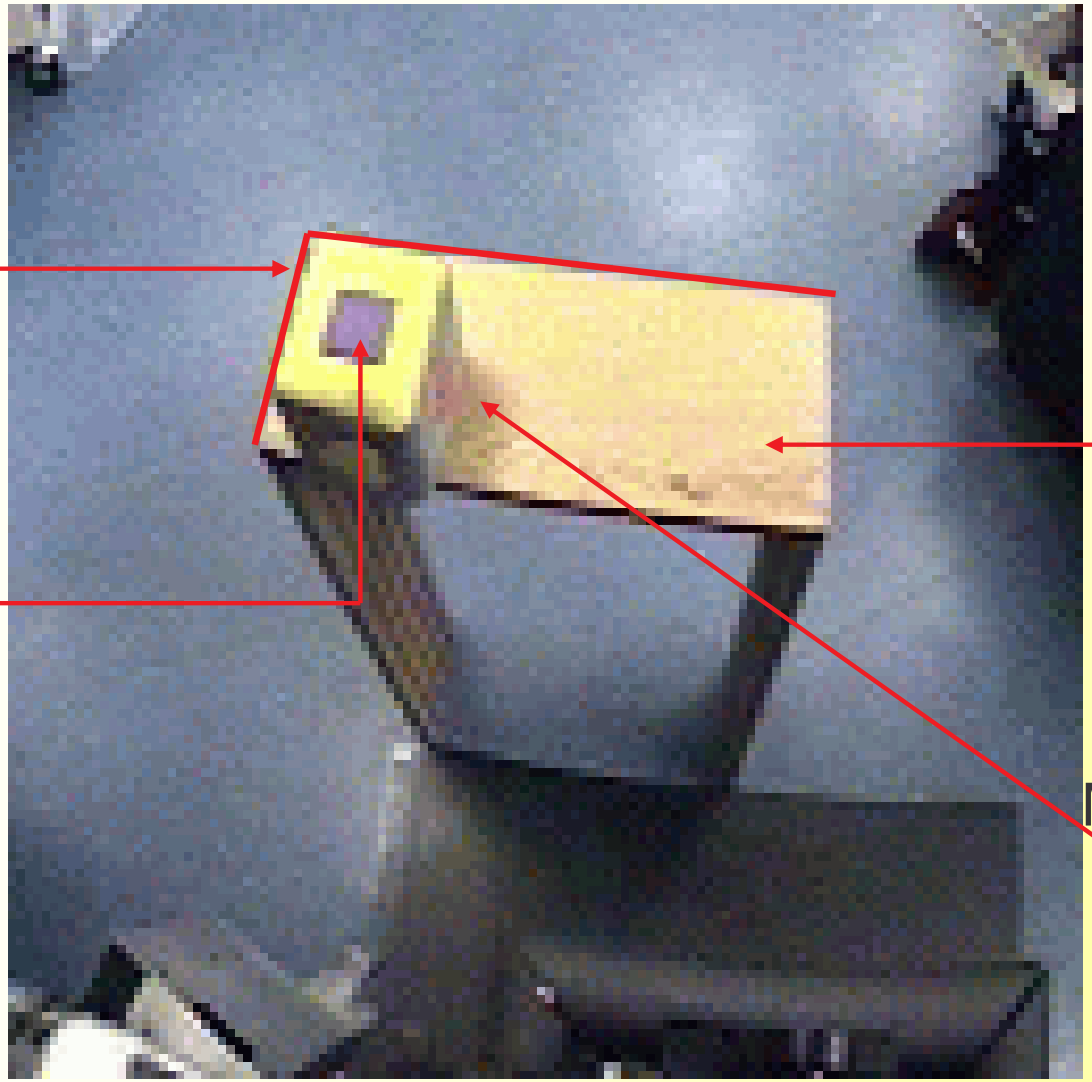
- From the engineering perspective it might be appealing to study "development"
- How the controller of a "biological" robot evolves over time
- From the simpler to the painstakingly complicated



A Simple Scene?



A Simple Scene?



Edges of table and cube overlap

Cube has misleading surface pattern

Color of cube and table are poorly separated

Maybe some cruel grad-student glued the cube to the table

Active Segmentation

Active Segmentation

Objects come to existence because they are manipulated

Fixate target | *Track visual motion…* | *(…including cast shadows)* | *Detect moment of impact* | *Separate arm, object motion* | *Segment object*

Which edge should be considered?

Maybe some cruel grad-student glued the cube to the table

Color of cube and table are poorly separated

Cube has misleading surface pattern

Goal

Investigate the **development** of the association between **visual** information and **motor** commands in the learning, representation, and understanding of complex **manipulative gestures**

Linking Vision & Manipulation

- A link from robotics
  - Active vision: Good motor strategies can simplify perceptual problems
- A link from neuroscience
  - Mirror neurons: Relating perceived actions of others with own action may simplify learning tasks

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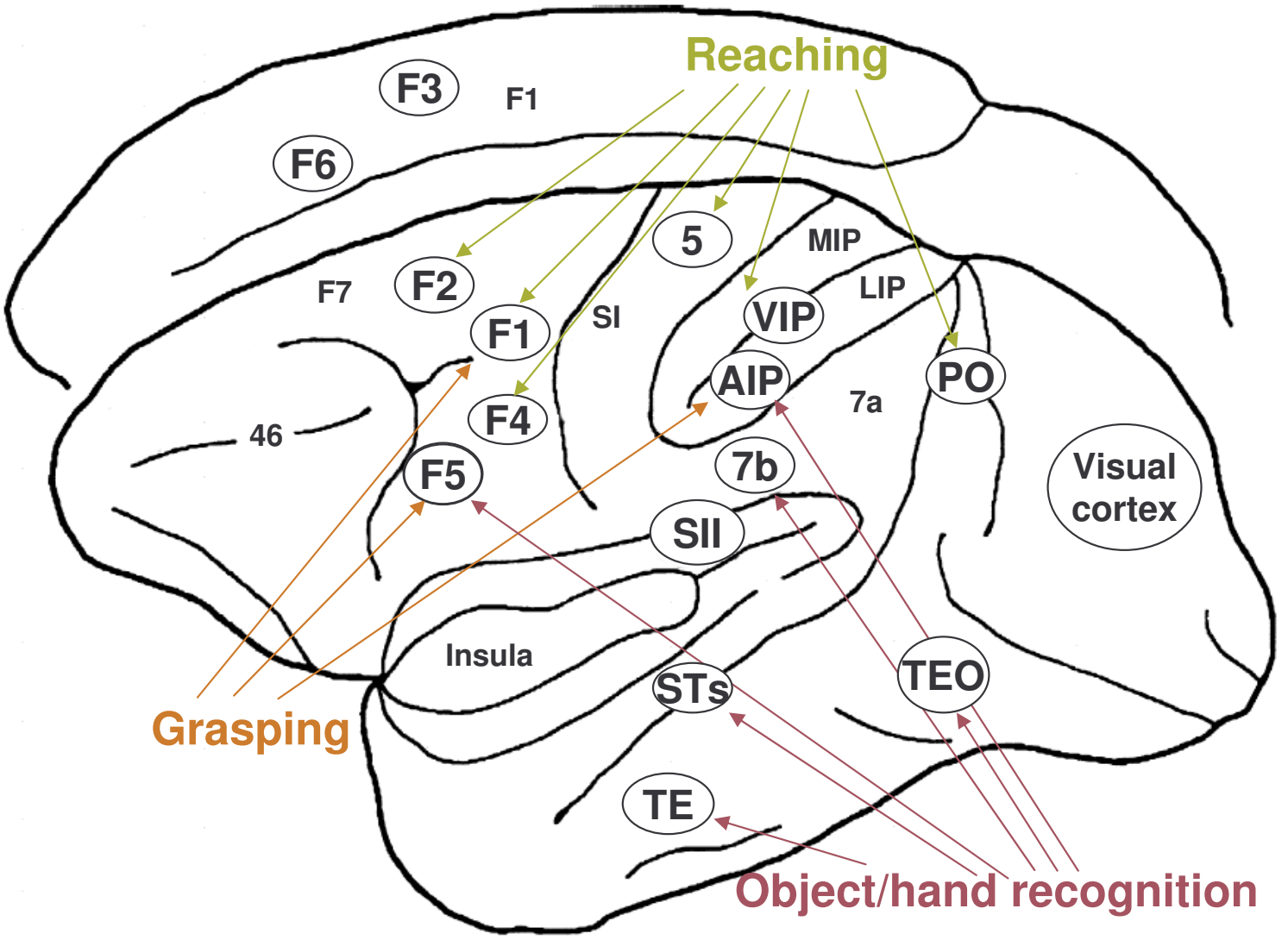
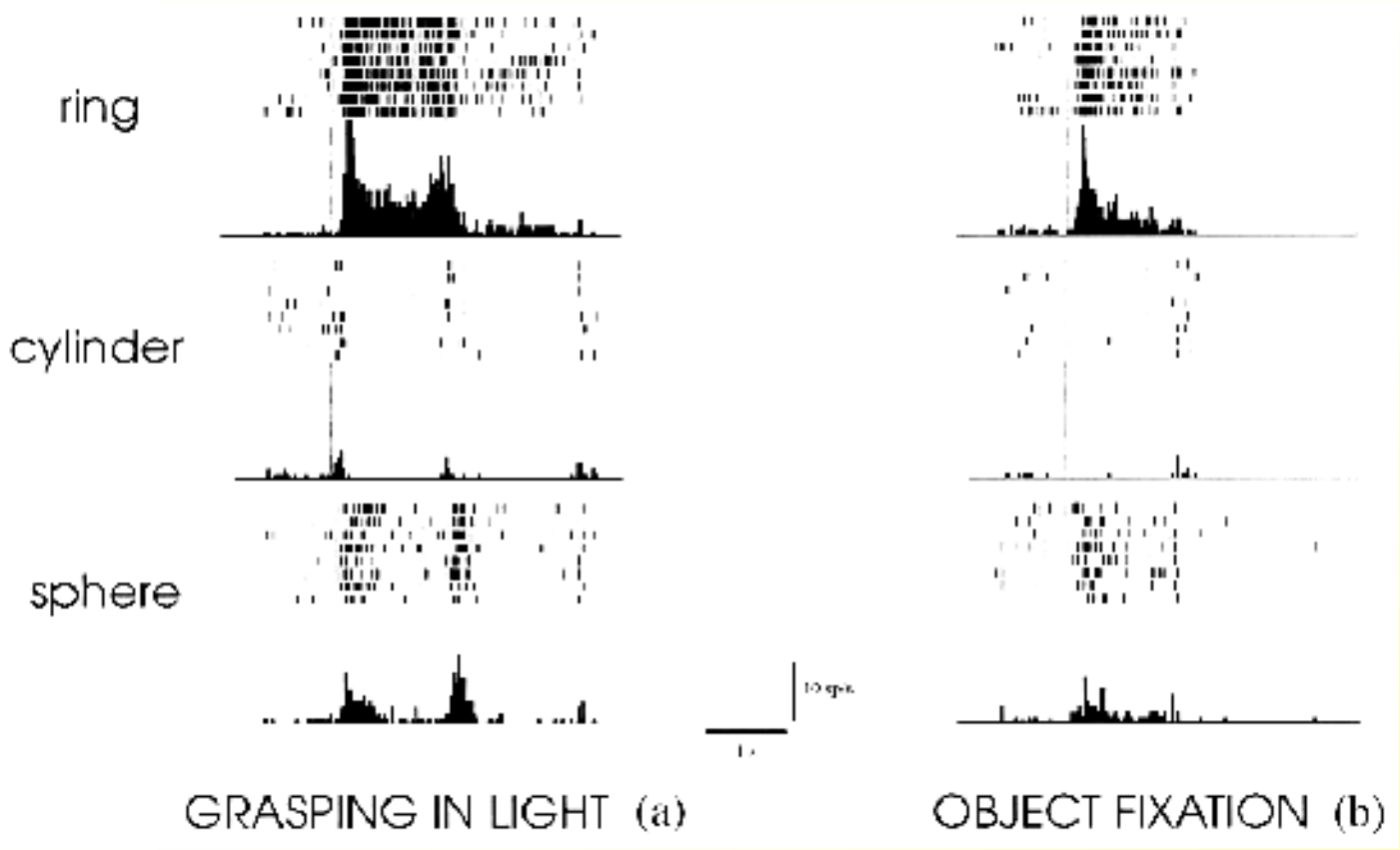
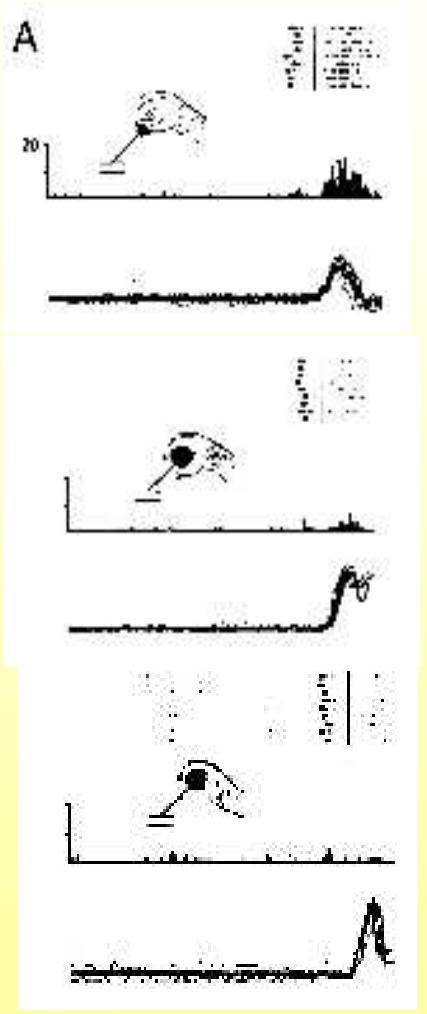
Object directed actions



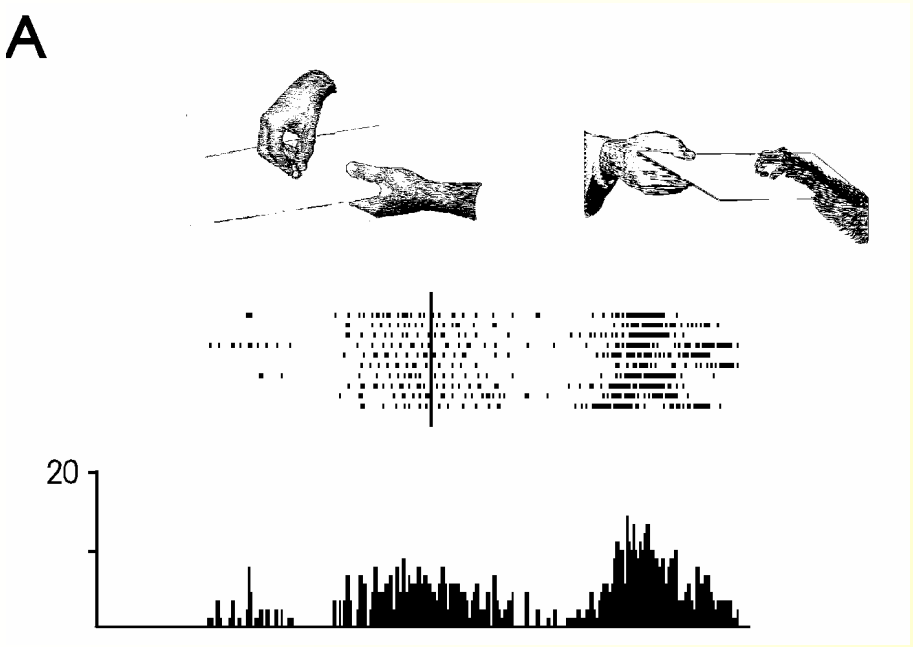
Canonical neurons

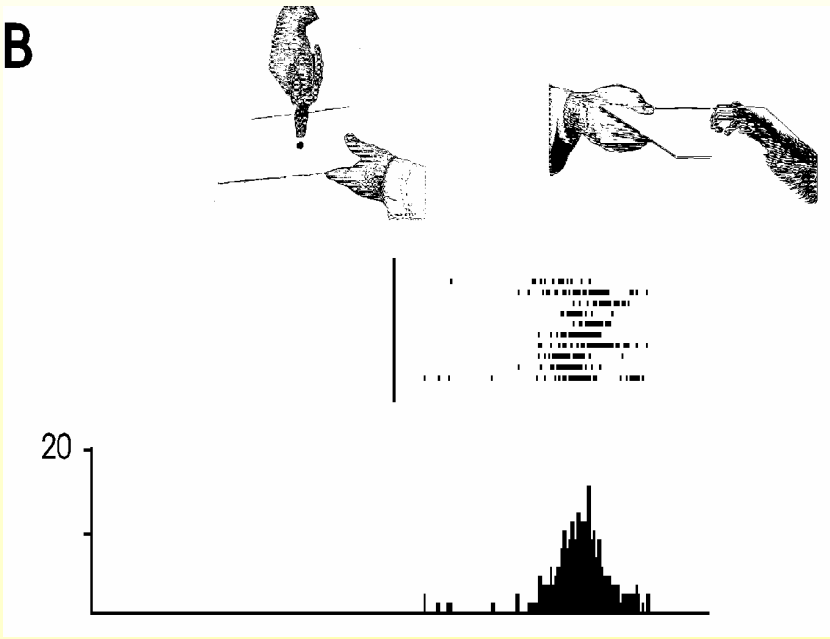




From: Jeannerod M., Arbib, M.A., Rizzolatti, G., Sakata H., *Grasping object: the cortical mechanisms of visuomotor transformation.* Trends in Neuroscience, 1995. **18**: p. 314-320.

Mirror neurons





From: Fadiga, L., L. Fogassi, V. Gallese, and G. Rizzolatti, *Visuomotor neurons: ambiguity of the discharge or "motor" perception?* International Journal of Psychophysiology, 2000. **35**: p. 165-177.

F5 neurons

Canonical neurons

Active when manipulable objects are presented visually

Mirror neurons

Active when another individual is seen performing manipulative gestures

Development in a two-stage model

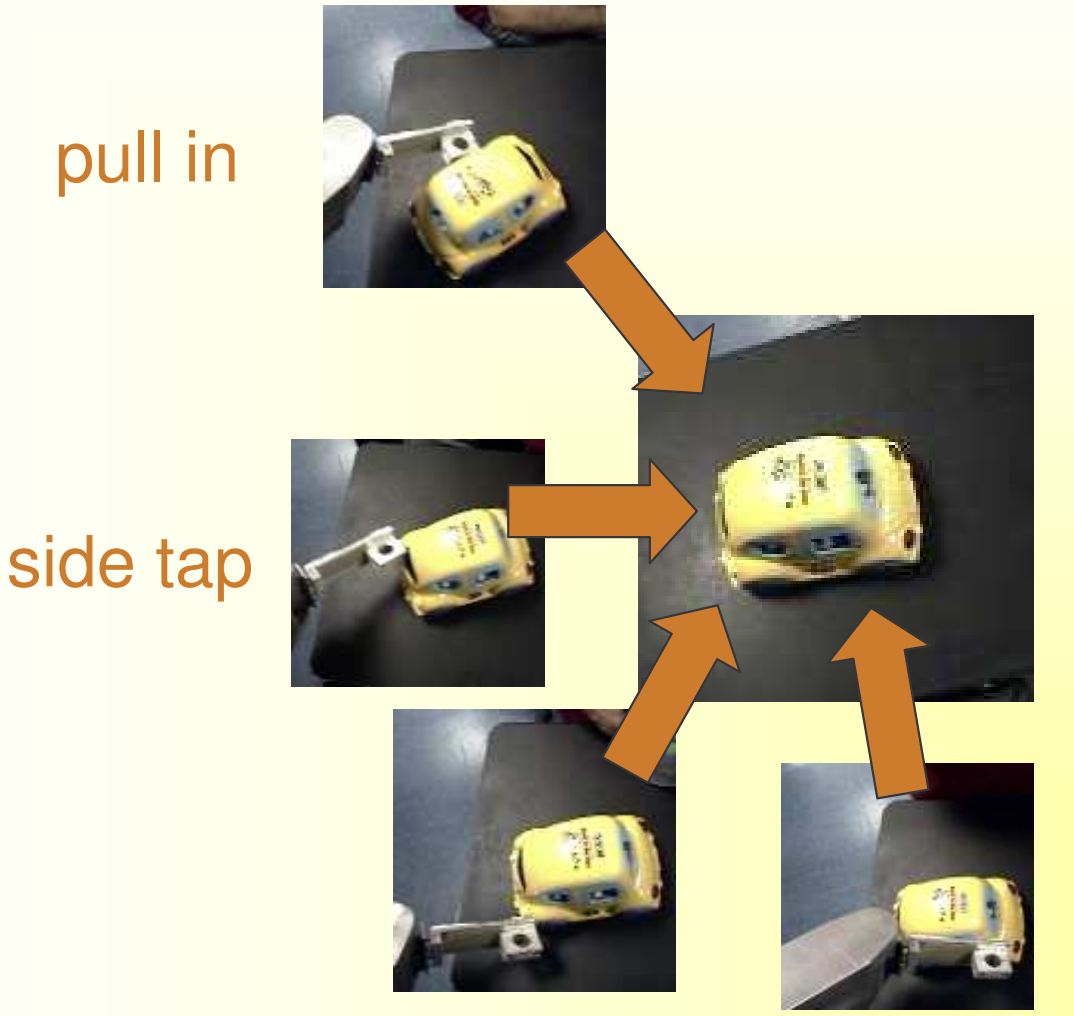
- **First:** learn to interact with objects.
  - Manipulate objects.
  - Acquire the motor primitives.
  - Build the *canonical neurons* representation.
  - Learn by interacting with the environment (the error is measured directly).
- **Second:** learn the *mirror* representation.
  - Correlate the experimenter's action with the performed action (goal).
  - This requires *canonical neurons* to be constructed in advance.
  - Learn by interpreting the goal of the action.

Some prerequisites

Simplest Form of Manipulation

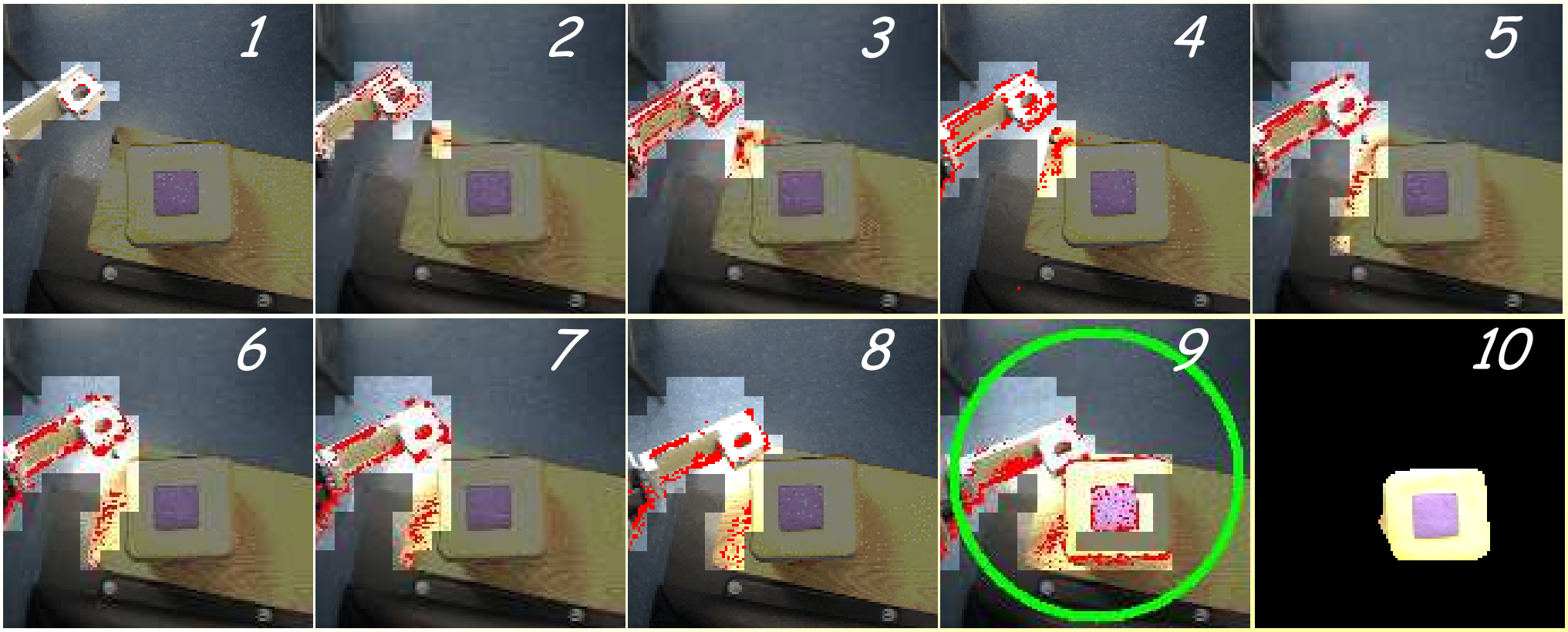
- What is the simplest possible manipulative gesture?
  - Contact with object is necessary; can't do much without it
  - Contact with object is sufficient for certain classes of affordances to come into play (e.g. rolling)
  - So can use various styles of poking/prodding/tapping/swiping as basic manipulative gestures
  - (if willing to omit the *manus* from manipulation…)

Gesture “vocabulary”



Exploring an affordance: rolling

Point of Contact

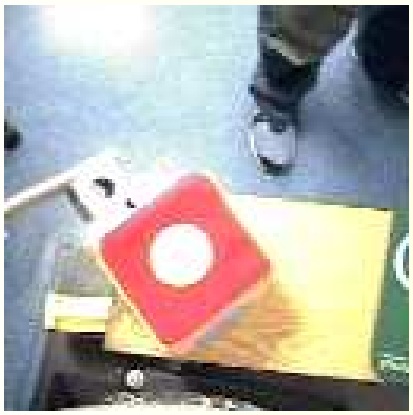


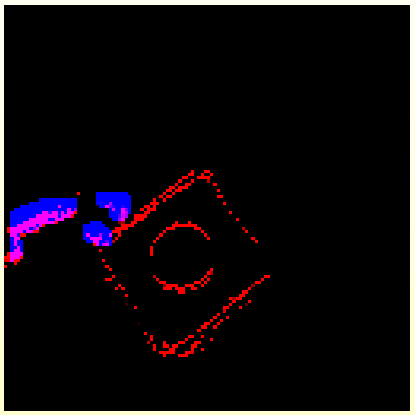
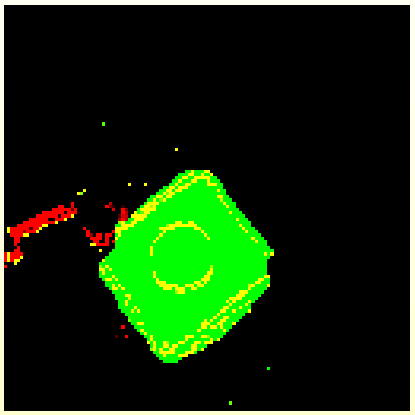
Motion spreads continuously
(arm or its shadow)

Motion spreads
suddenly, faster
than the arm itself
→ contact

Segmentation

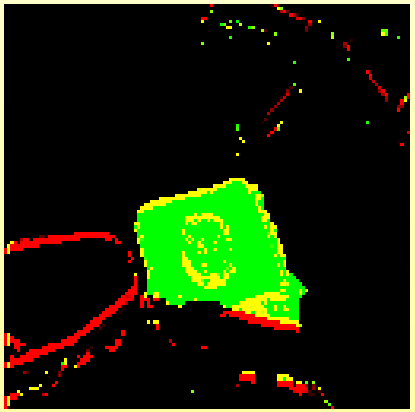
Side tap



Back slap



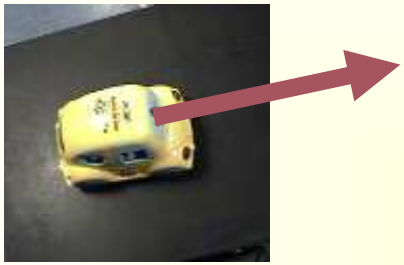
Prior to impact

Impact event

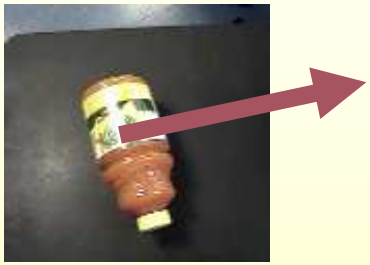
Motion caused
(red = novel,
Purple/blue = discounted)

Segmentation
(green/yellow)

Exploring an affordance: rolling

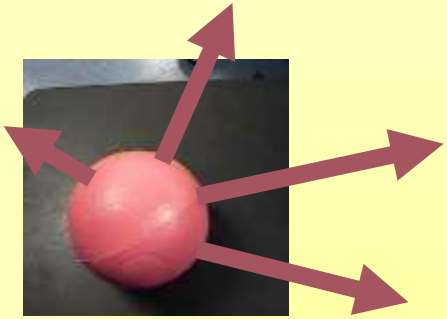


A toy car: it rolls in the direction of its principal axis



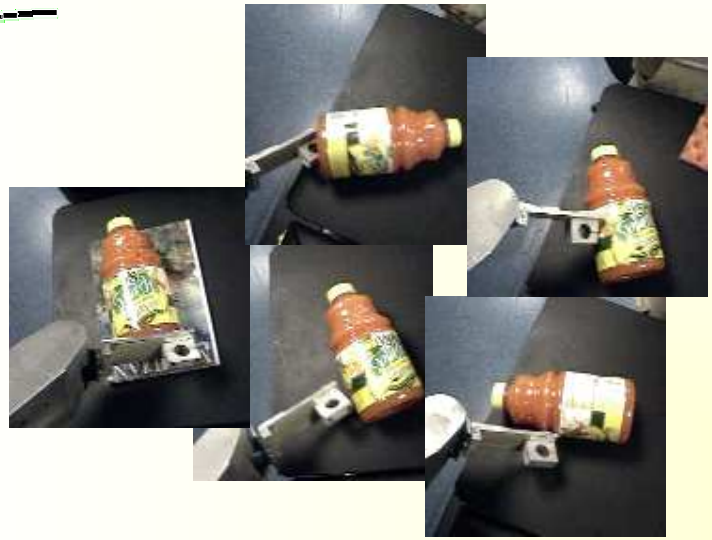
A bottle: it rolls orthogonal to the direction of its principal axis

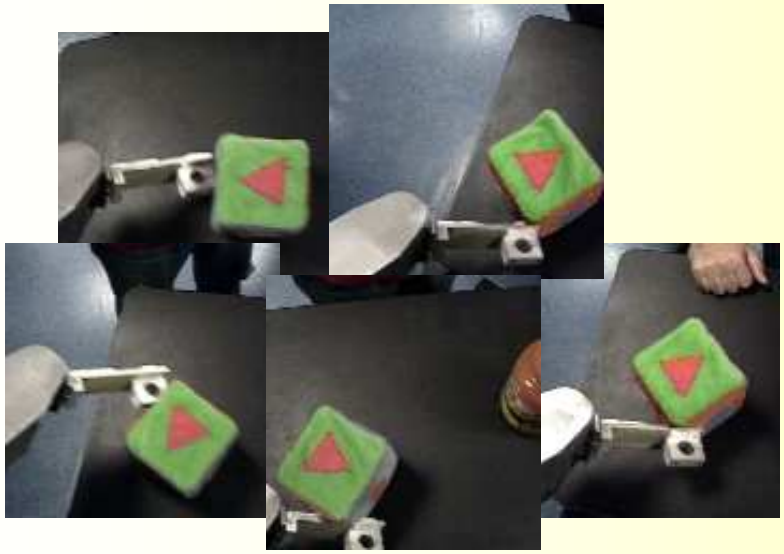
A toy cube: it doesn't roll, it doesn't have a principal axis

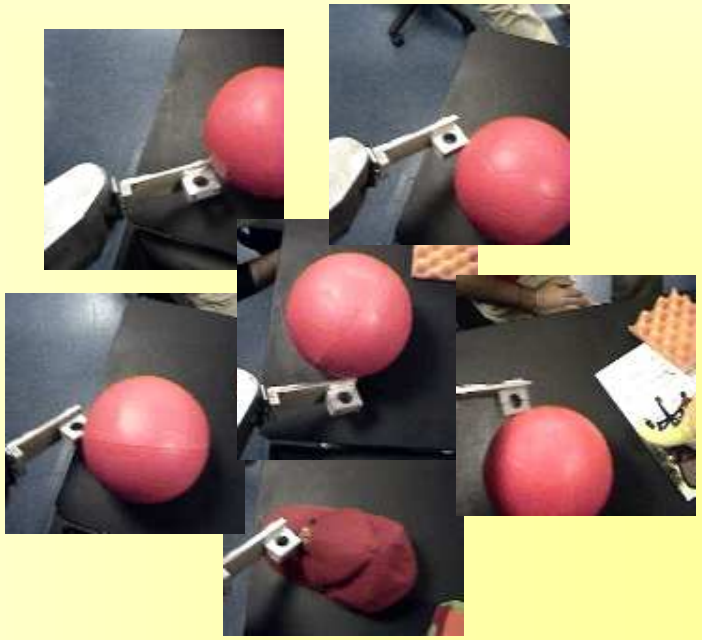


A ball: it rolls, it doesn't have a principal axis

Forming object clusters







Preferred direction of motion

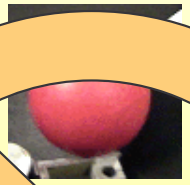
Bottle, “pointiness”=0.13

Rolls at right angles to principal axis

Car, “pointiness”=0.07

Rolls along principal axis

Cube, “pointiness”=0.0

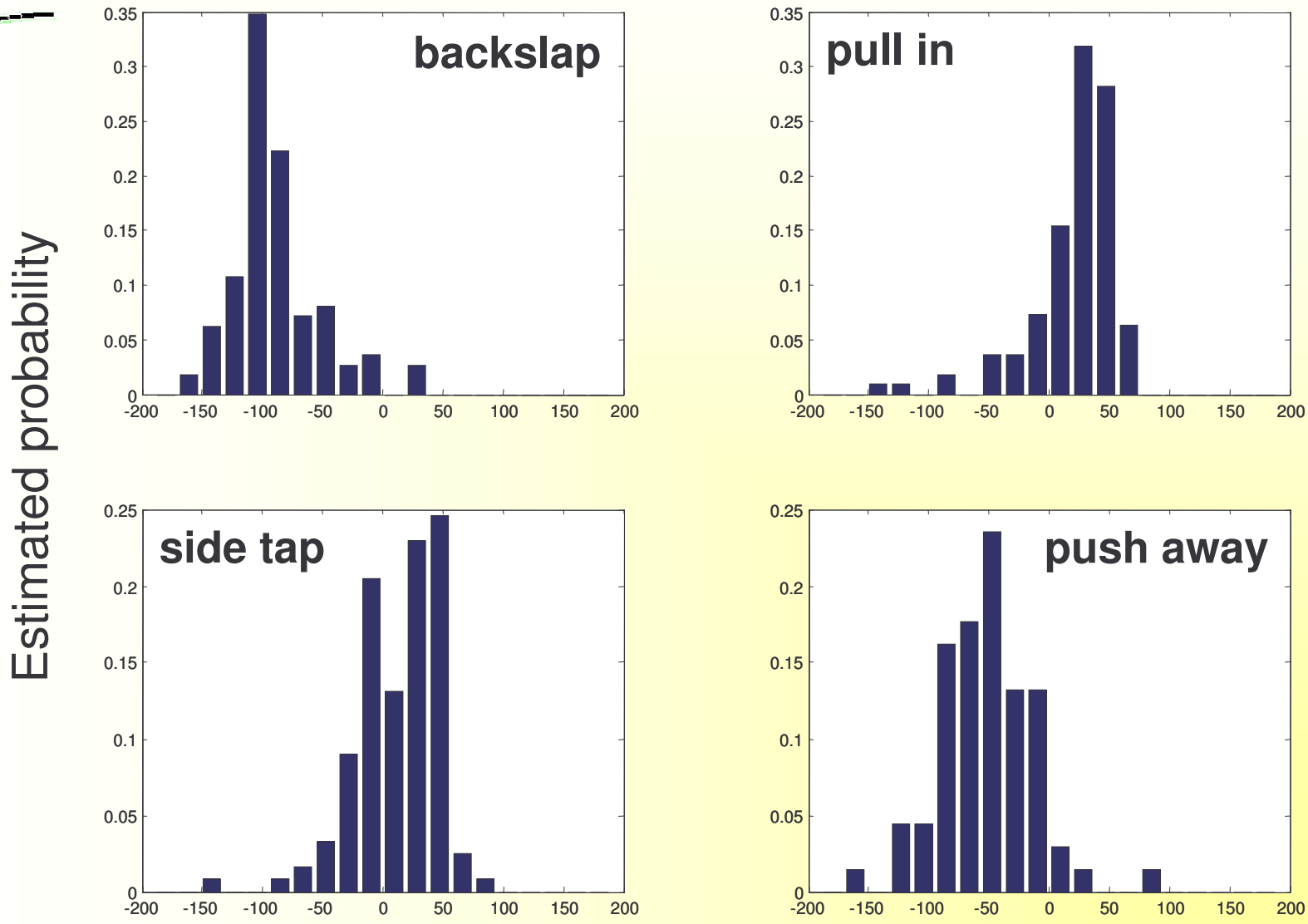


Ball, “pointiness”=0.02

estimated probability of occurrence

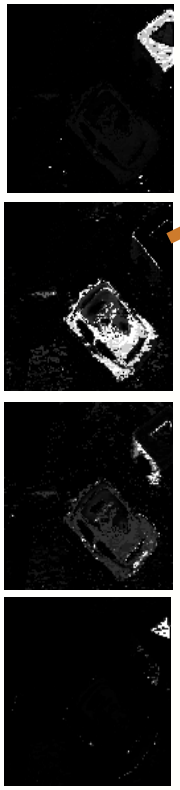
difference between angle of motion and principal axis of object [degrees]

The geometry of poking

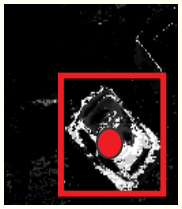


STAGE 1

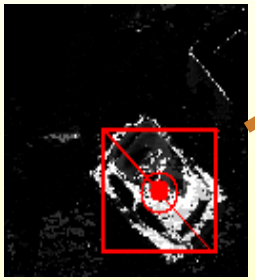
Behavior: poking according to affordance



identify and localize object

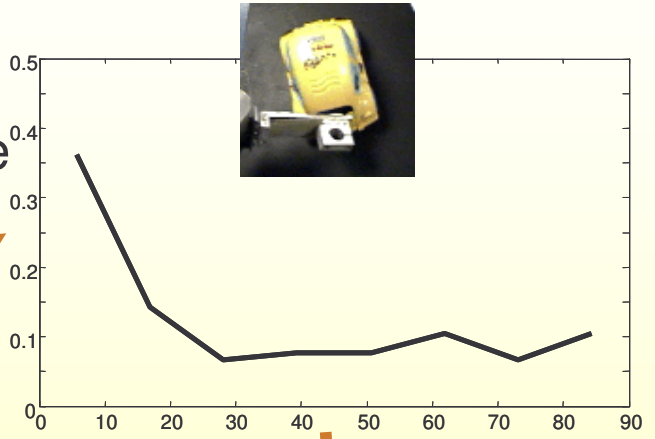


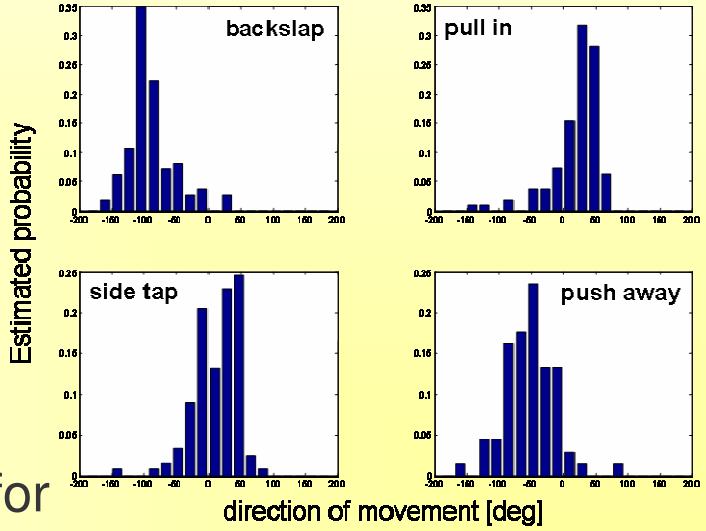
Search rotation



Previously-poked prototypes

Look for affordance

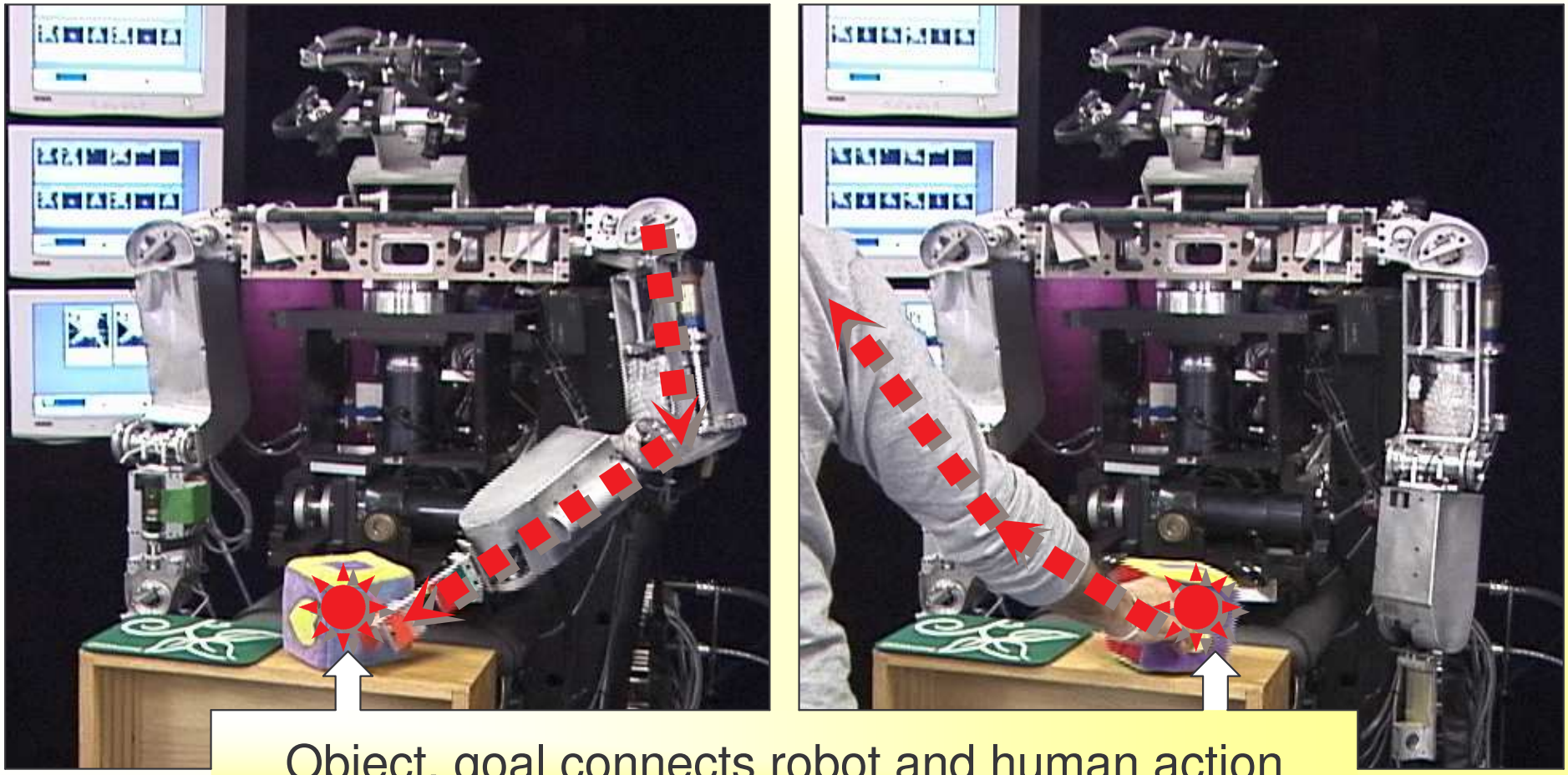




Look for action to satisfy affordance

Behavior: poking according to affordance

Understanding a foreign manipulator

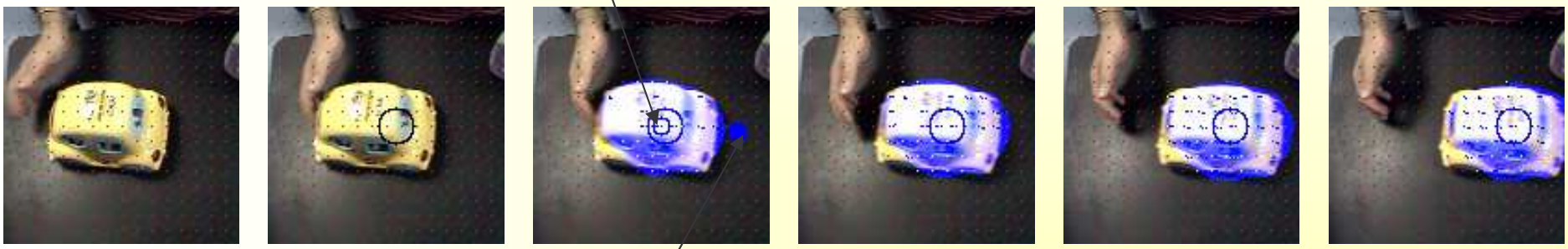


Object, goal connects robot and human action

Interpreting observations

"The robot can actually tell this was a side tap"

Initial position



Final position

A foreign manipulator (human) pokes an object
The direction of movement is compared with the object afforadance

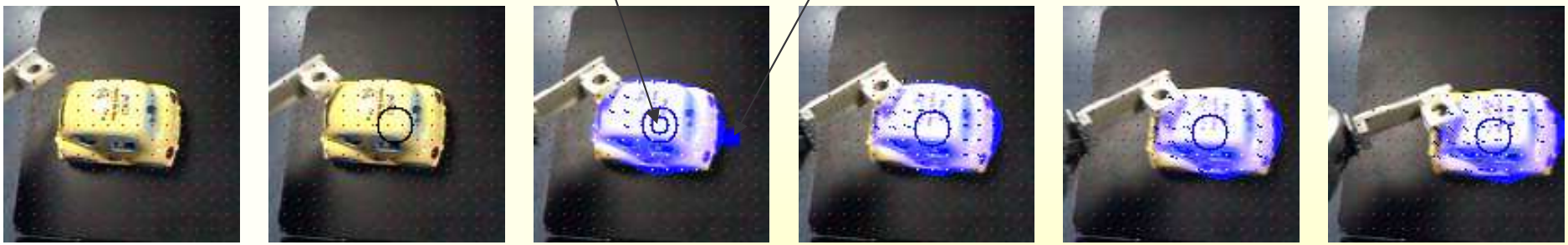
STAGE 2

Behavior: mimicry

Initial position

Final position

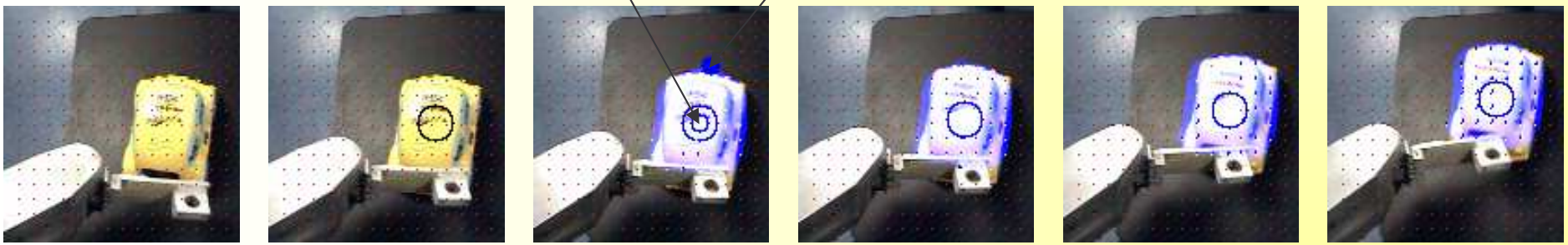
Example 1



Initial position

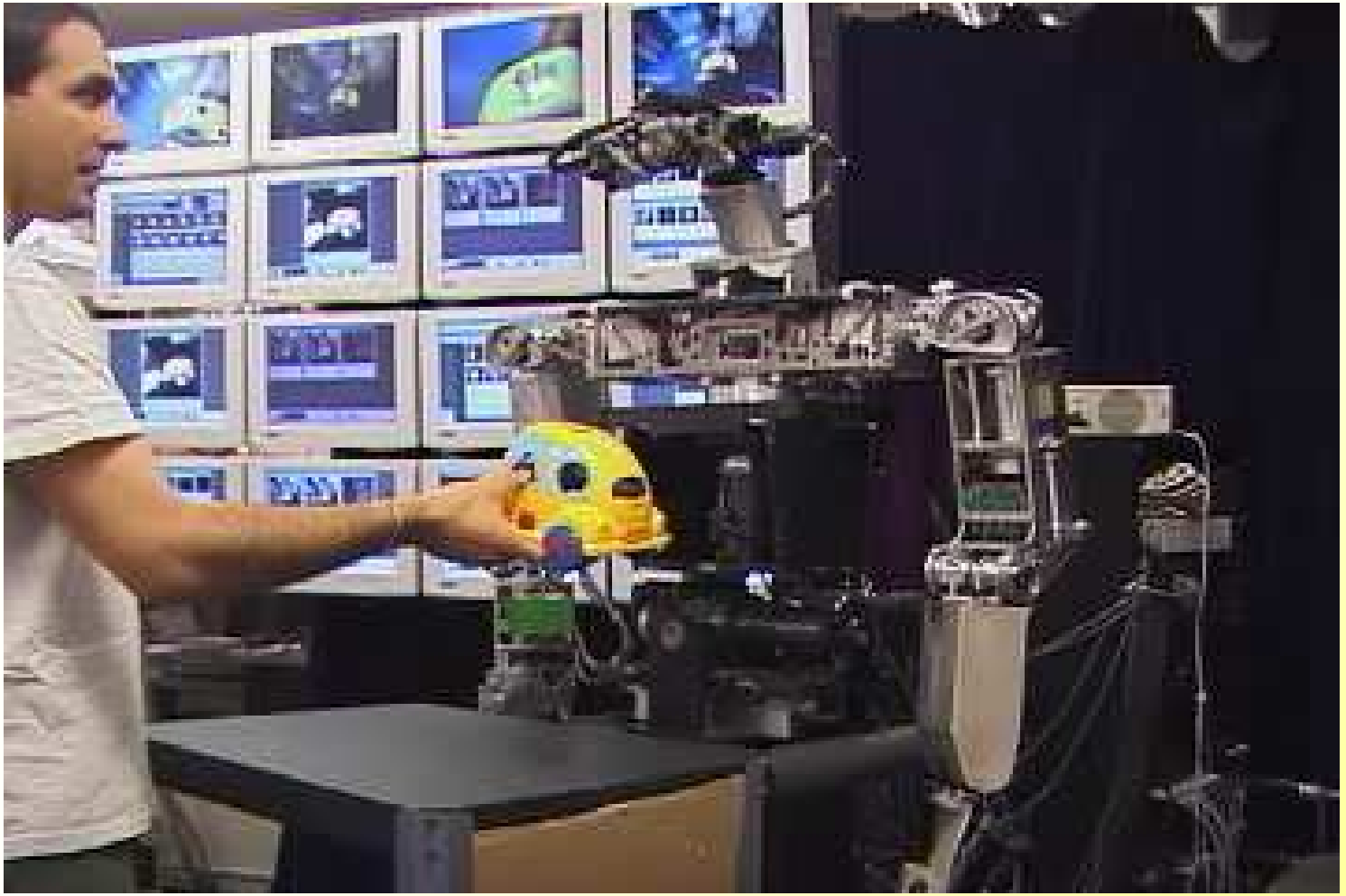
Final position

Example 2



The robot mimics the observed action trying to fulfill the goal rather than an actual movement

Behavior: mimicry



Manipulation guided vision instead of vision guided manipulation