CSE 591: Human-aware Robotics

Instructor: Dr. Yu ("Tony") Zhang

Location & Times: CAVC 359, Tue/Thu, 9:00--10:15 AM
Office Hours: BYENG 558, Tue/Thu, 10:30--11:30AM

September 15, 2016

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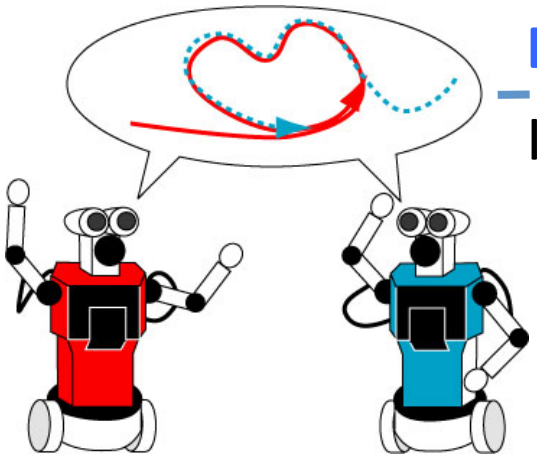
Slides adapted from Aude G. Billard and Abhishek Pal

Human-robot Communication



Explicit

Implicit

- NLP
- Gesture recognition
- Learning from demonstration

Outline

- Gesture recognition
  - Gesture type
  - Technologies behind
- Learning from demonstration
  - Problems in LFD
  - Symbolic level
  - Trajectory level
  - Refinement
  - Other issues

What are Gestures

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Types Of Gestures

- Gesticulation:

Spontaneous movements of the hands and arms that accompany speech.

Types Of Gestures

- Language-like gestures:

Gesticulation that is integrated into a spoken utterance, replacing a particular spoken word or phrase.

Types Of Gestures

- Pantomimes

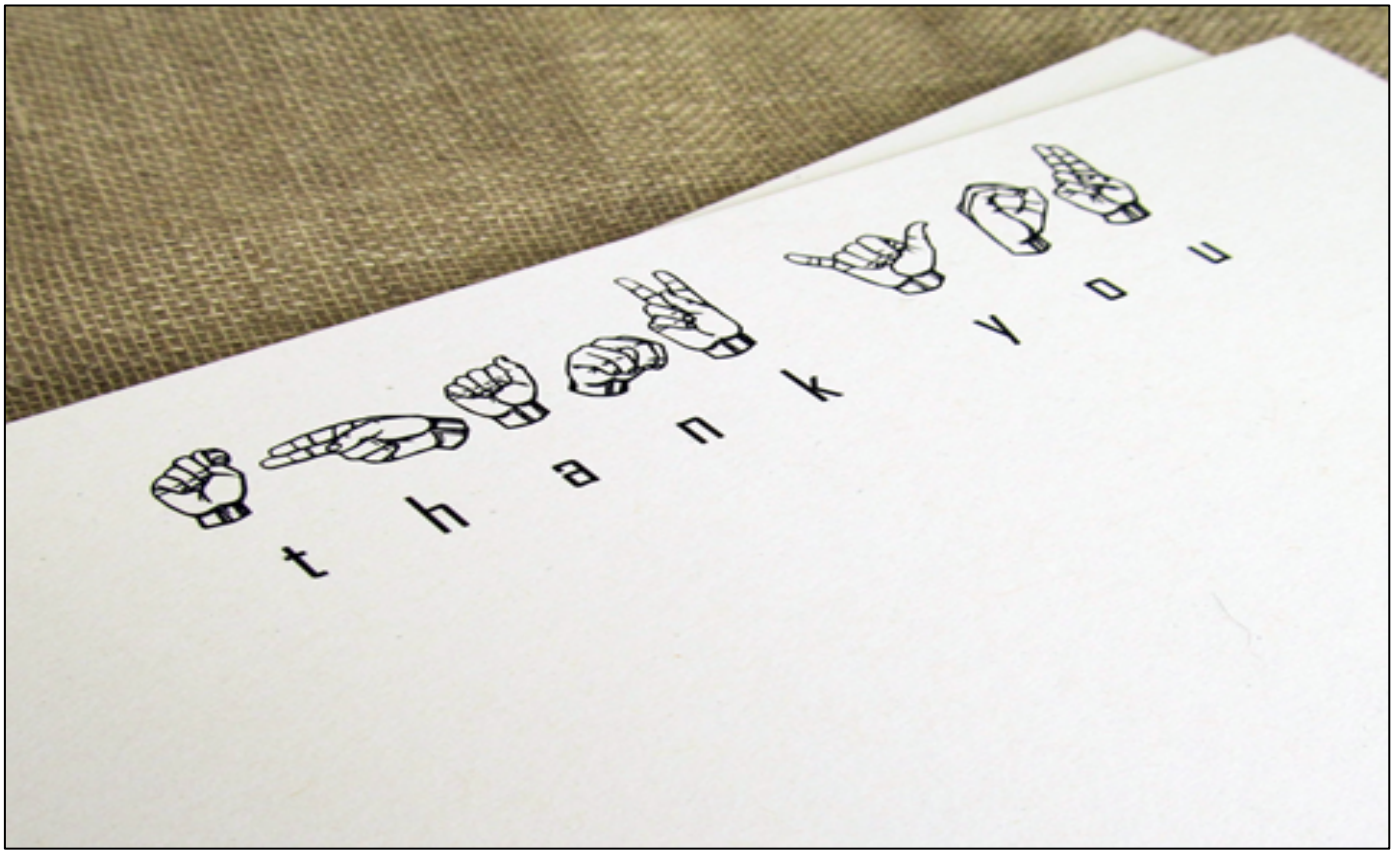
Pantomime

- is an art of dramatic representation by means of facial expressions and body movements rather than words. Pantomime, or mime, has always played a part in theater.
- Pantomime, or dumb show, was essential to commedia dell'arte, an improvised comedy that arose in 16th-century Italy and spread throughout Europe.

Types Of Gestures

- Sign languages.:

Linguistic systems, such as American Sign Language, which are well defined.



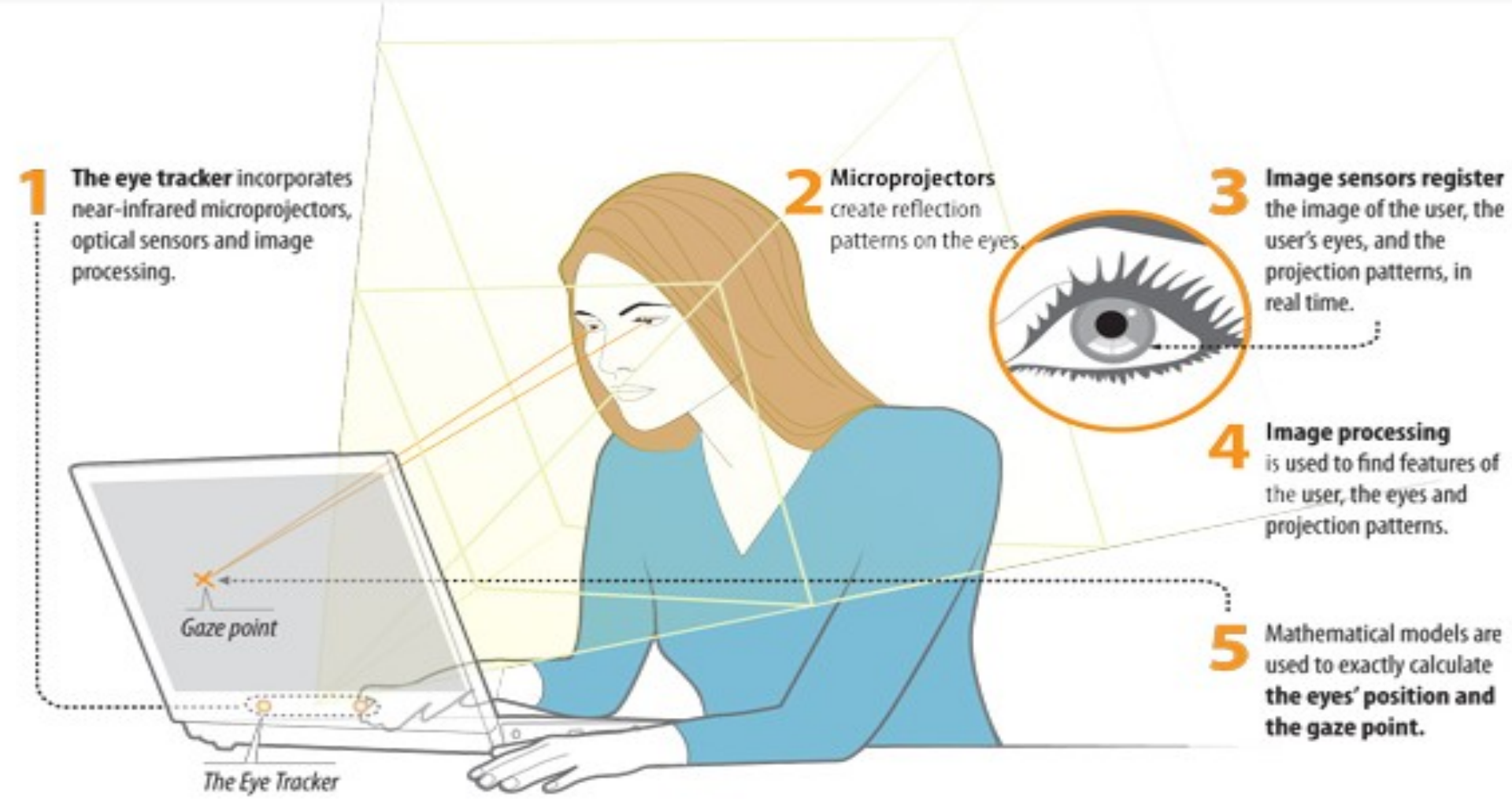
Hand Gesture Recognition

https://www.youtube.com/watch?v=uXiImb5BzGE

Facial Gesture Recognition

https://www.youtube.com/watch?v=n8wJ8tjmnmU

Eye Gesture Recognition



Eye Gesture Recognition

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Gesture Sensing Technologies:

Contact type:

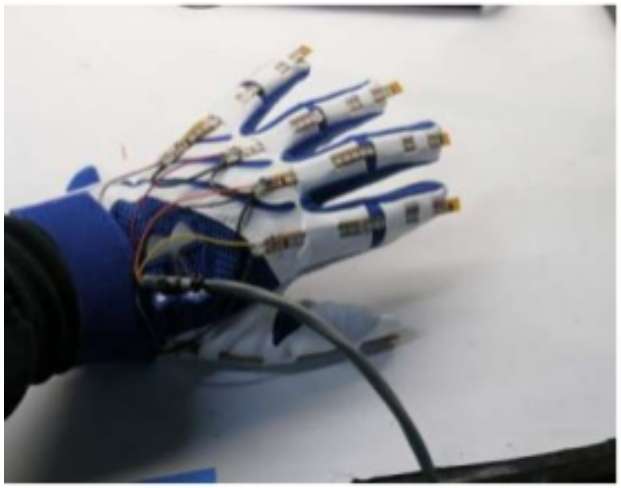
- Touch based gestures

Non-Contact:

- Device Gesture Technologies
- Vision-based Technologies
- Electrical Field Sensing

Device Gesture Technologies

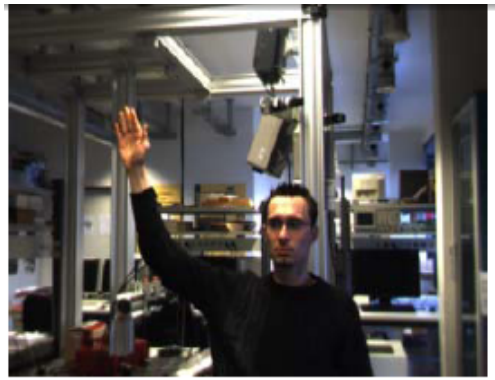
Device Sensing Technology



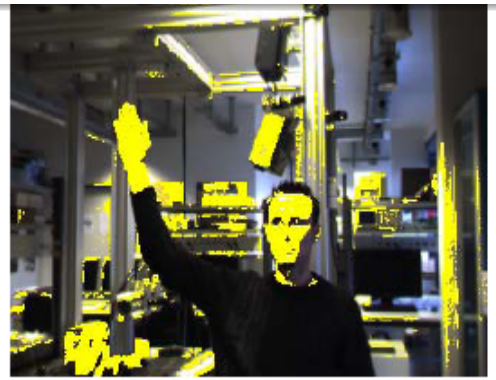
Device-based techniques use a glove, stylus, or other position tracker, whose movements send signals that the system uses to identify the gesture.

The glove is equipped with a variety of sensors to provide information about hand position, orientation, and flex of fingers.

Vision Based Technologies



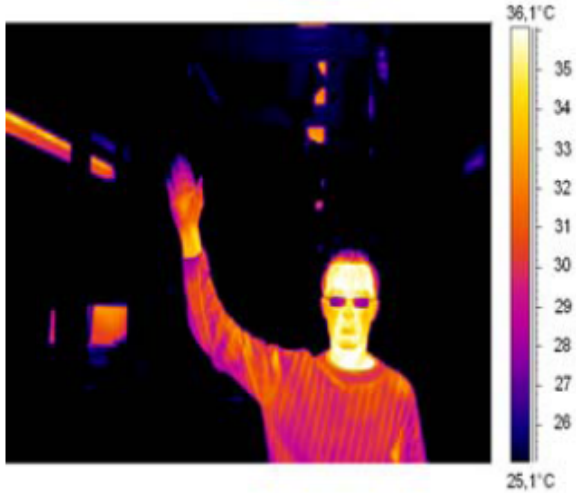
(a) Original



(b) Single camera

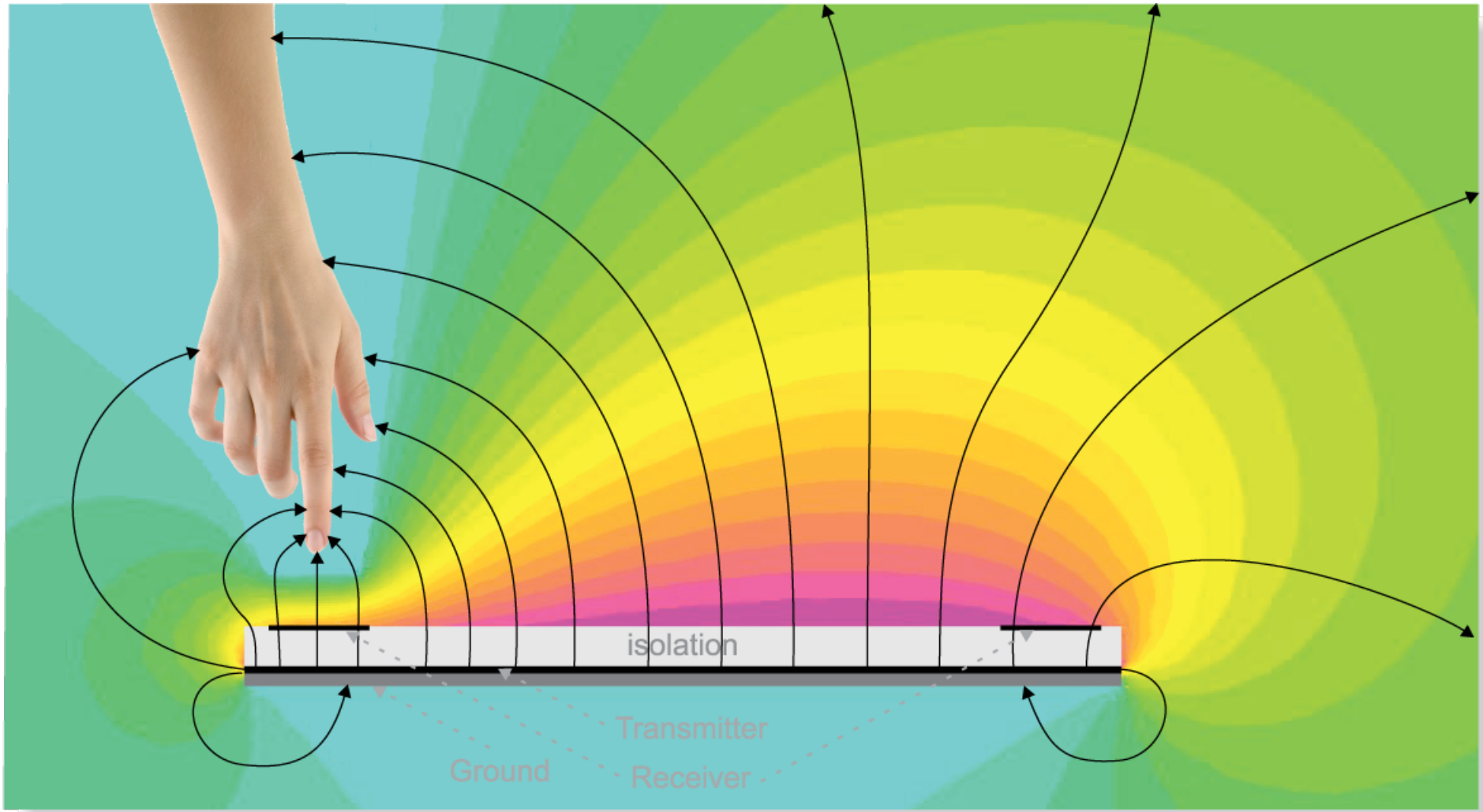
(c) Stereo camera

(d) Depth information

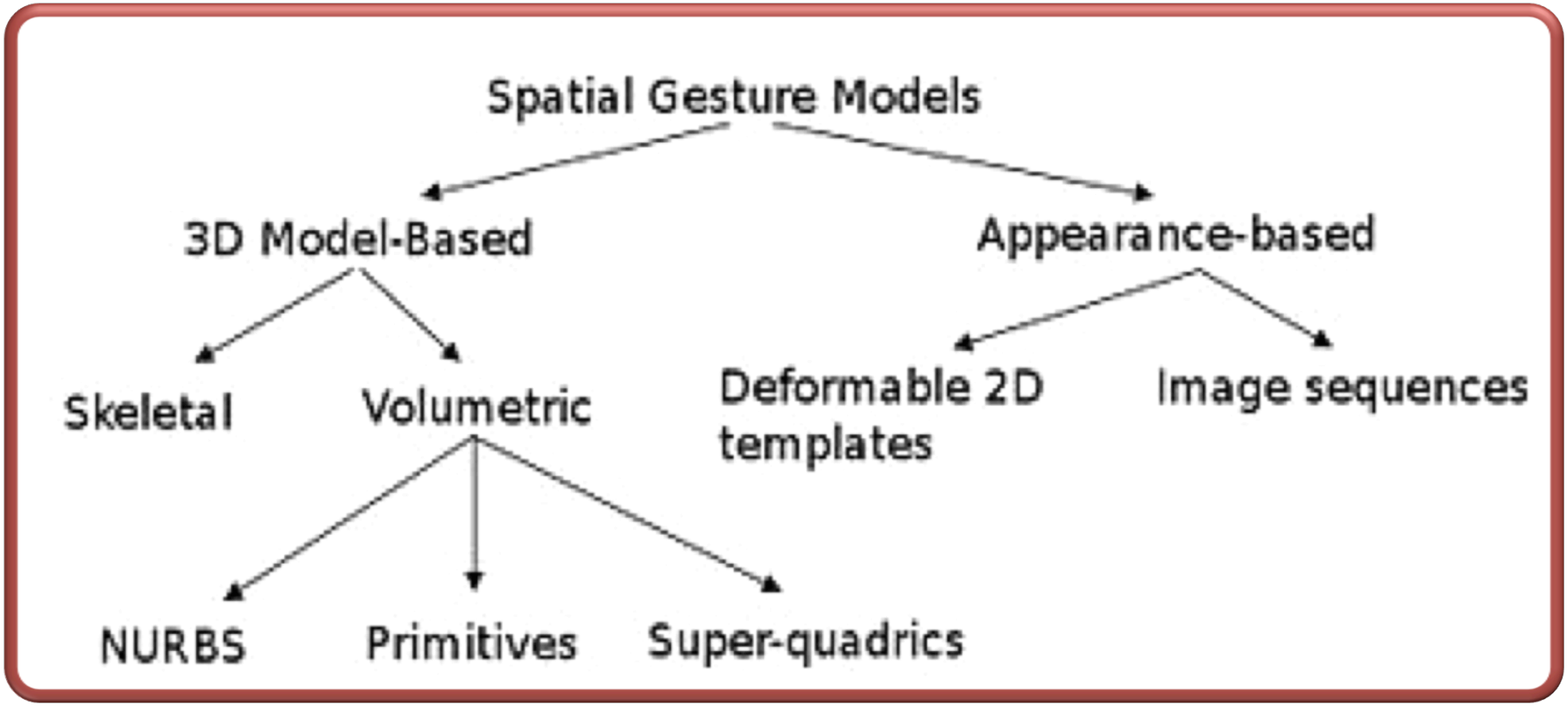


(e) Thermal camera

Electrical Field Sensing



Algorithms


Spatial Gesture Models
3D Model-Based
Appearance-based
Skeletal
Volumetric
Deformable 2D templates
Image sequences
NURBS
Primitives
Super-quadrics

Gesture Recognition Challenges

1.Latency

Image processing can be significantly slow creating unacceptable latency for video games and other similar applications.

2.Lack of Gesture Language

Different users make gestures differently, causing difficulty in identifying motions.

3.Robustness

Many gesture recognition systems do not read motions accurately or optimally due to factors like insufficient background light, high background noise etc.

4.Performance

Image processing involved in gesture recognition is quite resource intensive and the applications may found difficult to run on resource constrained devices.

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INCREMENTAL LEARNING OF GESTURES BY IMITATION IN A HUMANOID ROBOT

SYLVAIN CALINON AND AUDE BILLARD

LASA LABORATORY - EPFL
CH-1015 LAUSANNE, SWITZERLAND
HTTP://LASA.EPFL.CH

ACM/IEEE International Conference on Human-Robot Interaction.
March 9-11, 2007. Washington DC, USA.

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Calinon, S. and Billard, A. (2007) **Incremental Learning of Gestures by Imitation in a Humanoid Robot**. in Proceedings of the ACM/IEEE International Conference on Human-Robot Interaction (HRI).

What is Imitation

What is Imitation

- "True" imitation: Ability to learn new actions not part of the usual repertoire
- The appanage of humans only, and possibly great apes

- Whiten & Ham, *Advances in the Study of Behaviour, 1992*
- Savage & Rumbaugh, *Child Devel, 1993*

Slide from A.G. Billard

Characteristics of Imitation

- Innate Facial Imitation (newborns → 3 months)
  Tongue and lips protrusion, mouth-opening, head movements, cheek and brow motion, eye blinking
- Delayed imitation up to 24 hours

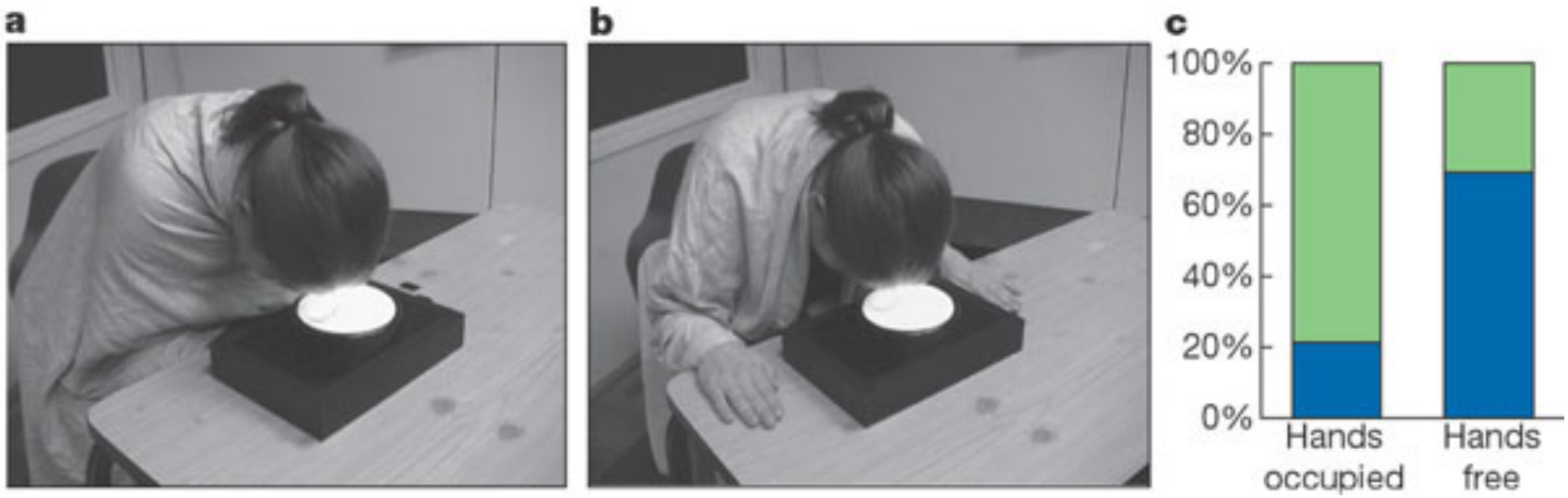
→ Imitation is mediated by a stored representation

Meltzoff & Moore, *Early Development and Parenting, 1997*
Meltzoff & Moore, *Developmental Psychology, 1989*

Slide from A.G. Billard

Characteristics of Imitation

- Infants aged 14 months.
- Children imitate new action to achieve the same goal only if they consider it to be the most rational alternative.

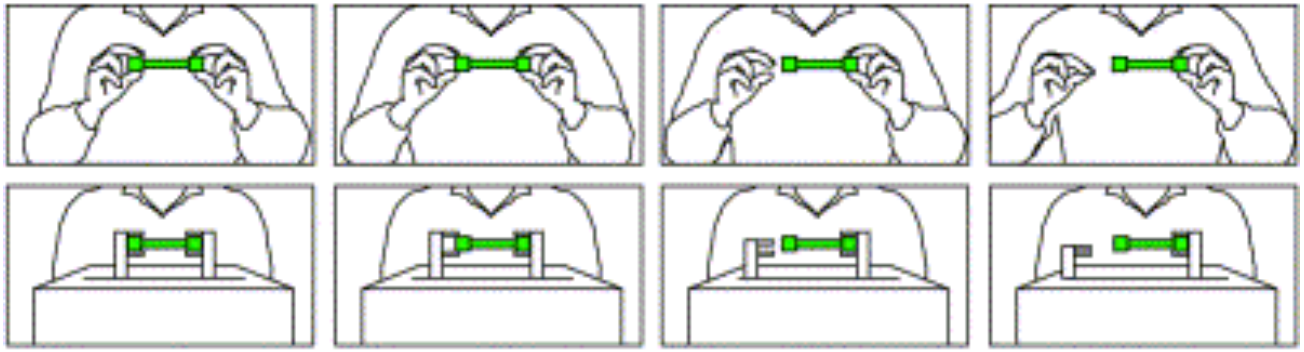


•Gergely, Bekkering, Giraly, *Nature* **415**, 755, 2002

Slide from A.G. Billard

Characteristics of Imitation

- 18-months infants
- Learn from unsuccessful examples



- Meltzoff, *Dev. Psychol.* ***31****, 1995.*

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Advantages: When is Imitation useful?

- It is a powerful means of transferring skills
- It speeds up the learning process by showing possible solutions or conversely by showing bad solutions
- Natural interface

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Disadvantages:
When is Imitation not useful?

- Not appropriate: When a good solution for the teacher is not a possible solution for the learner
- Disadvantageous: When it induces you in error - bad teacher (e.g. phoebia of spiders)

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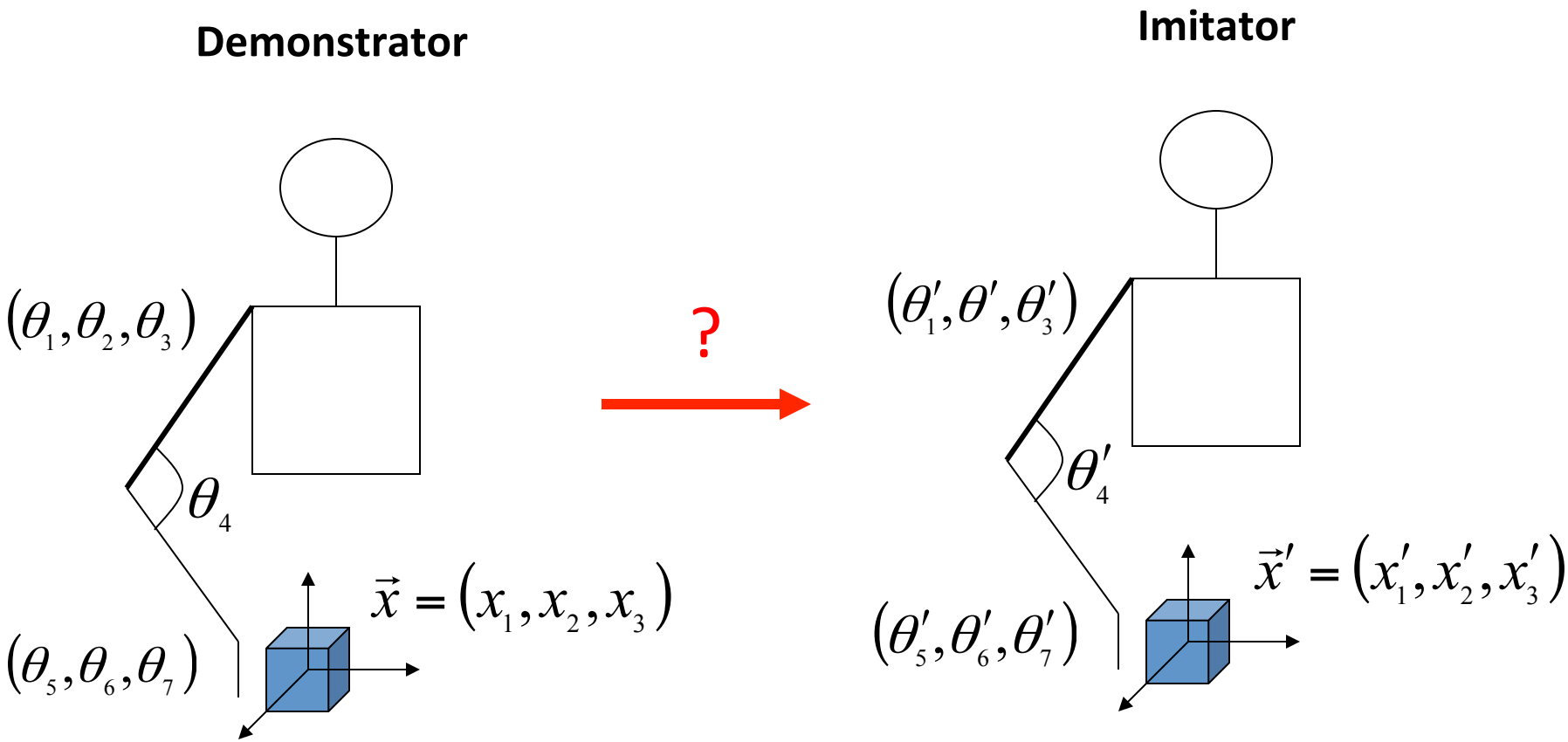
The Transfer Problem



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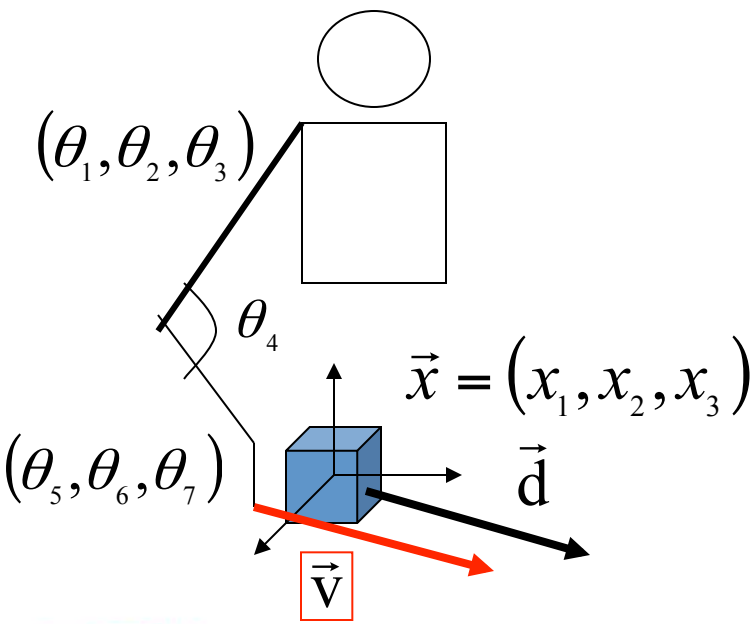
What to imitate?

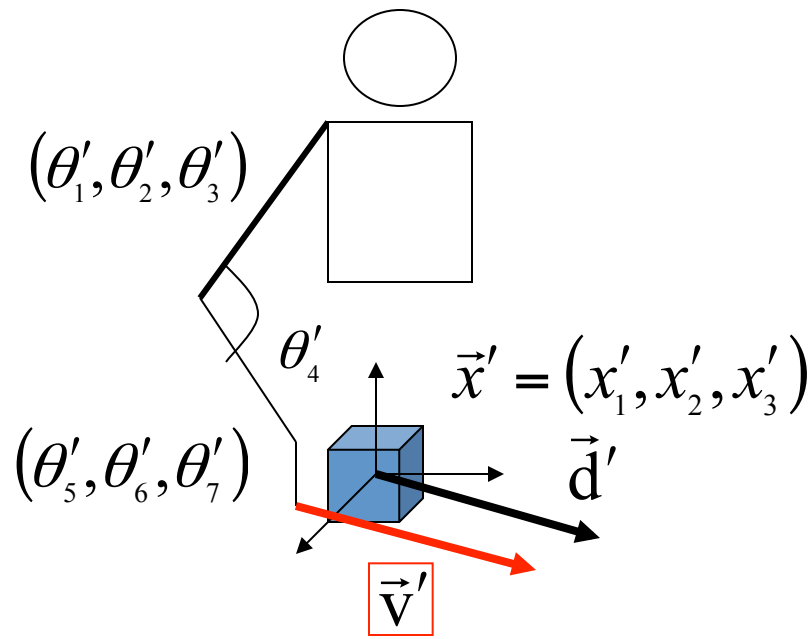
$\vec{x} = \vec{x}'$ **Same Object, same target location**

$\vec{\mathrm{d}} = \vec{\mathrm{d}}'$ **Same direction of motion**

$\vec{\mathrm{v}} = \vec{\mathrm{v}}'$ **Same speed, same force**

$\vec{\theta} = \vec{\theta}'$ **Same posture**





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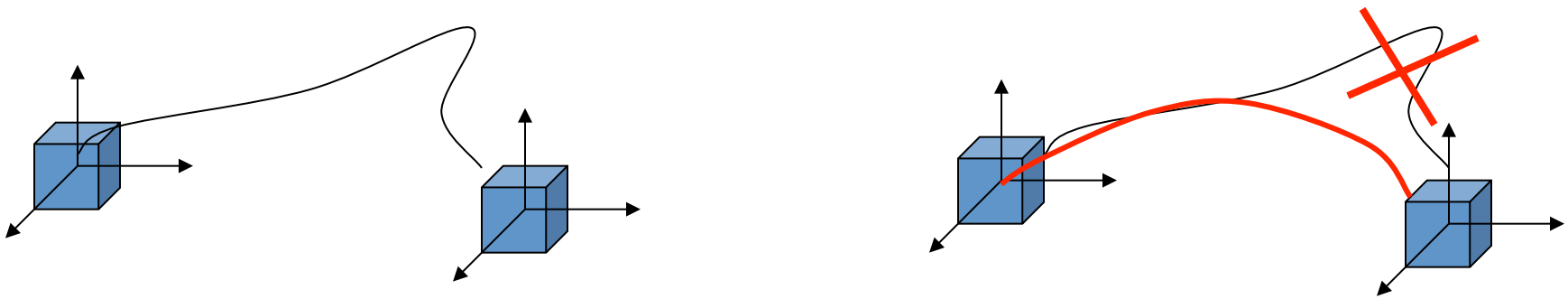
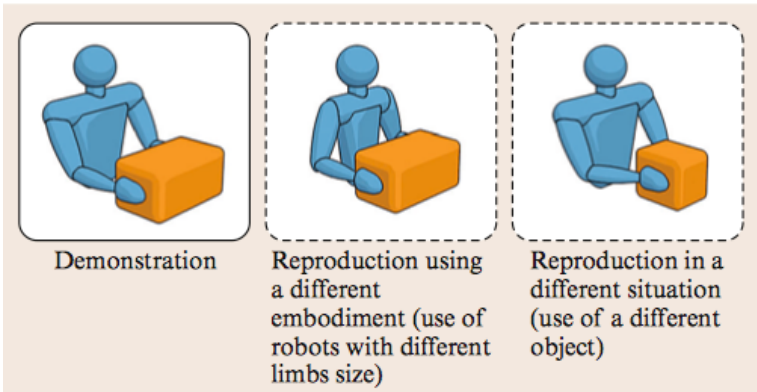
How to Imitate?
The correspondence problem

Demonstration

Imitation

?





No solutions (smaller range of motion)

→ **Find the closest solution according to a metric**

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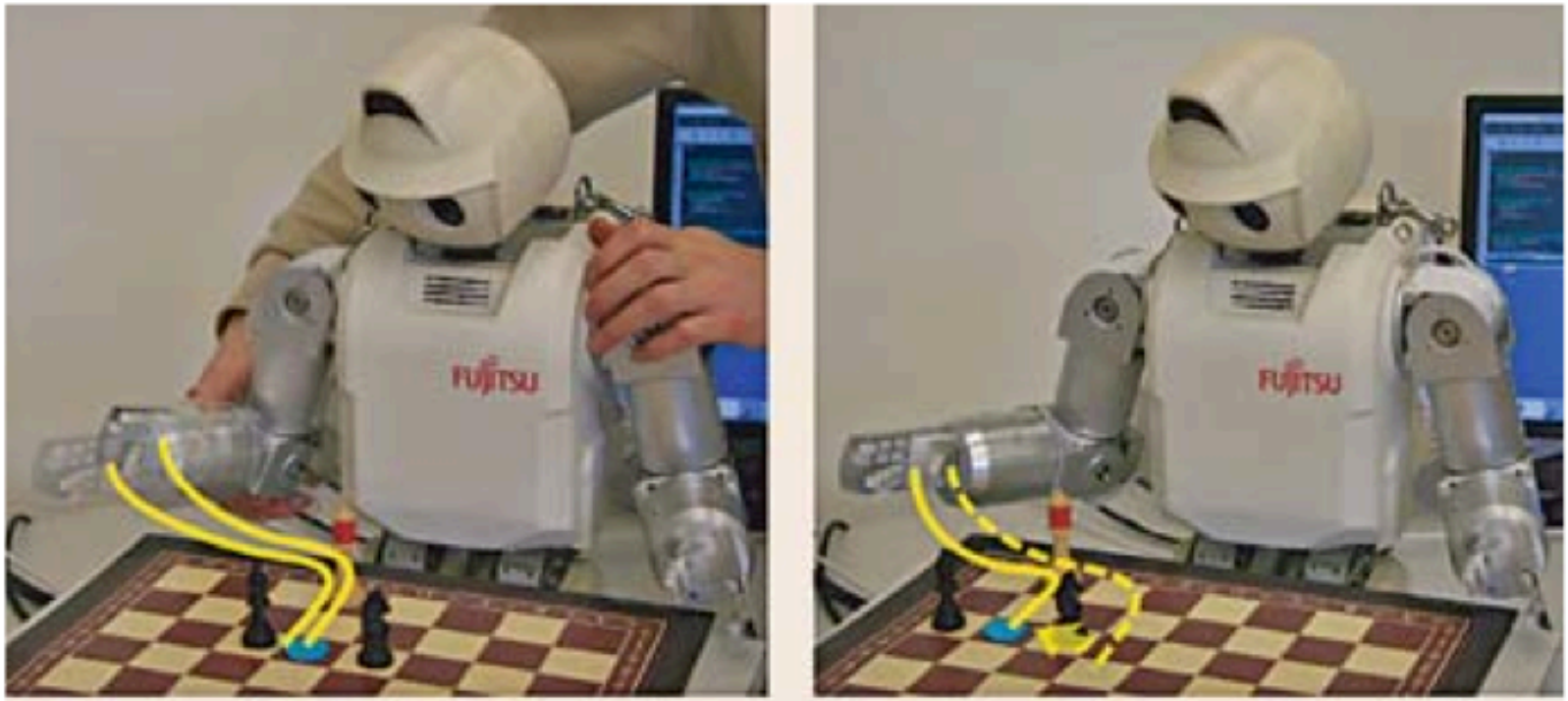
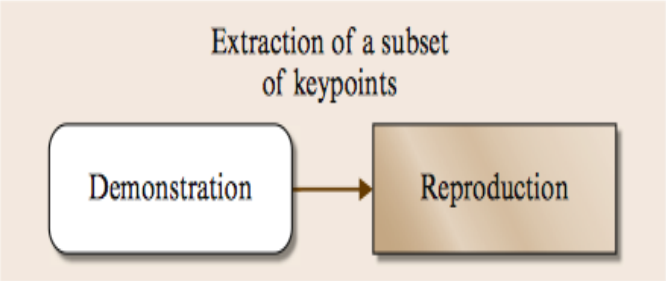
Imitate from Demonstration



Observation of multiple demonstrations

Reproduction of a generalized motion in a different situation



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Robot programming by demonstration
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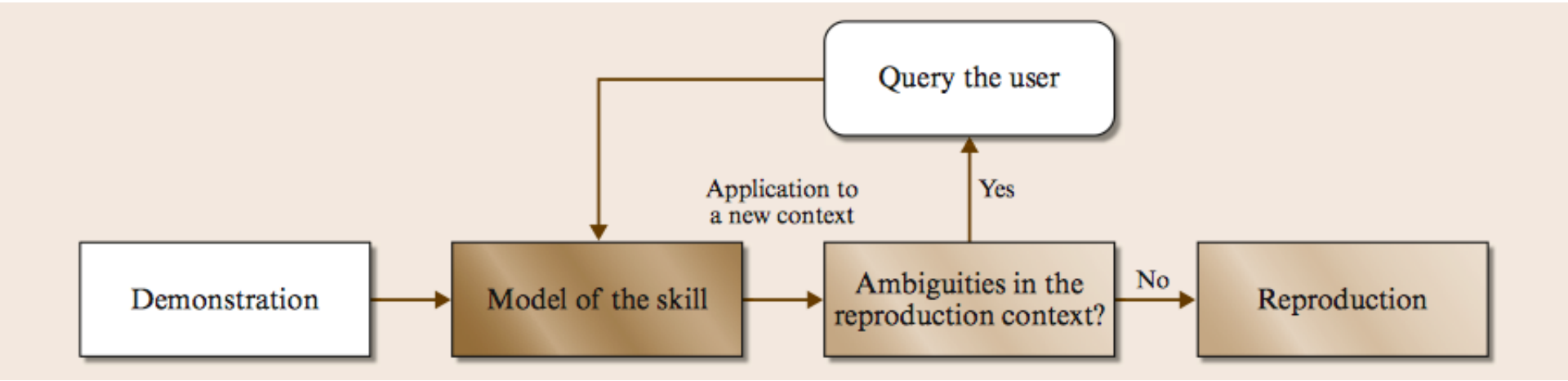
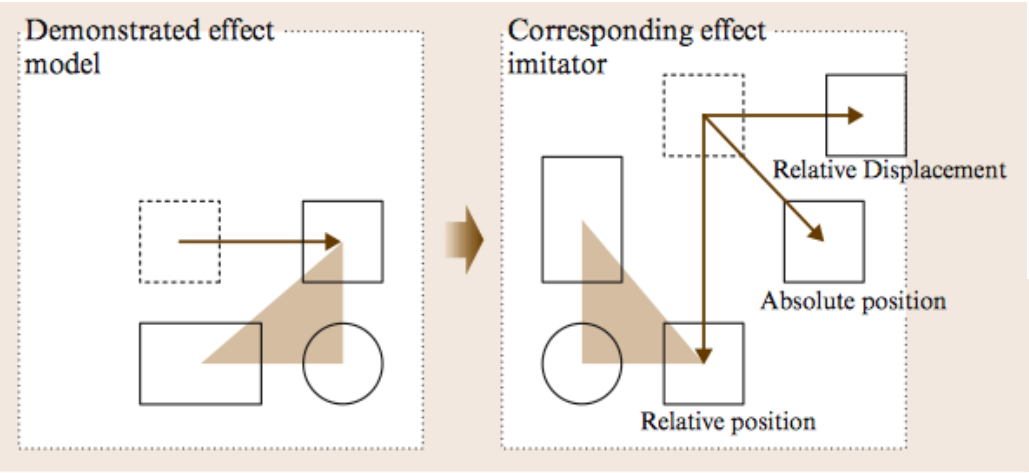
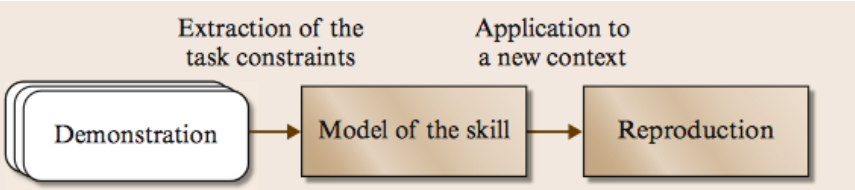
Refinement & Generalization

User feedback



Metric for imitation performance





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One-Shot Learning Methods

- Segmentation of demonstration into primitives
- Classification of gestures into predefined states (e.g. grasp, collision)
- Built-in controller for producing sequences of states

- Kuniyoshi et al. IEEE Trans. on Robotics and Automation,1994.
- Dillmann et al, Robotics & Autonomous Systems, 2001.
- Ritter et al, Rev Neuroscience, 2003
- Aleotti et al, Robotics & Autonomous Systems, 2004.

Slide from A.G. Billard

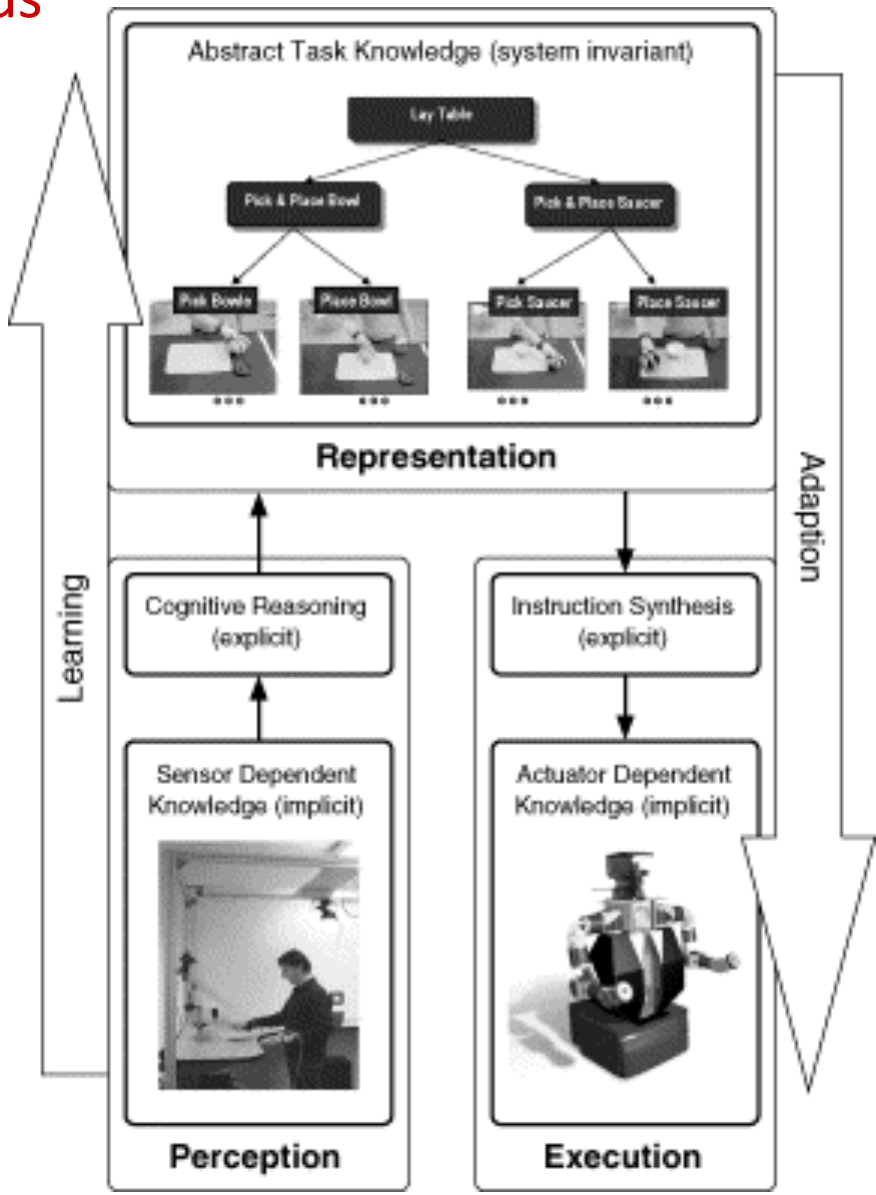
One-Shot Learning Methods

Explicit teaching/learning:
- Reasoning about tasks
- Verbal instructions

State Recognition:
For each sensor a context-dependent model based on background knowledge is provided: '*opening the refrigerator door*', '*extracting the bottle*' and '*closing the door*'

Task Reproduction:
Store action sequences in a tree-like structure of macro-operators

R. Dillmann, Robotics & Autonomous Systems 47:2-3, 109-116 2004



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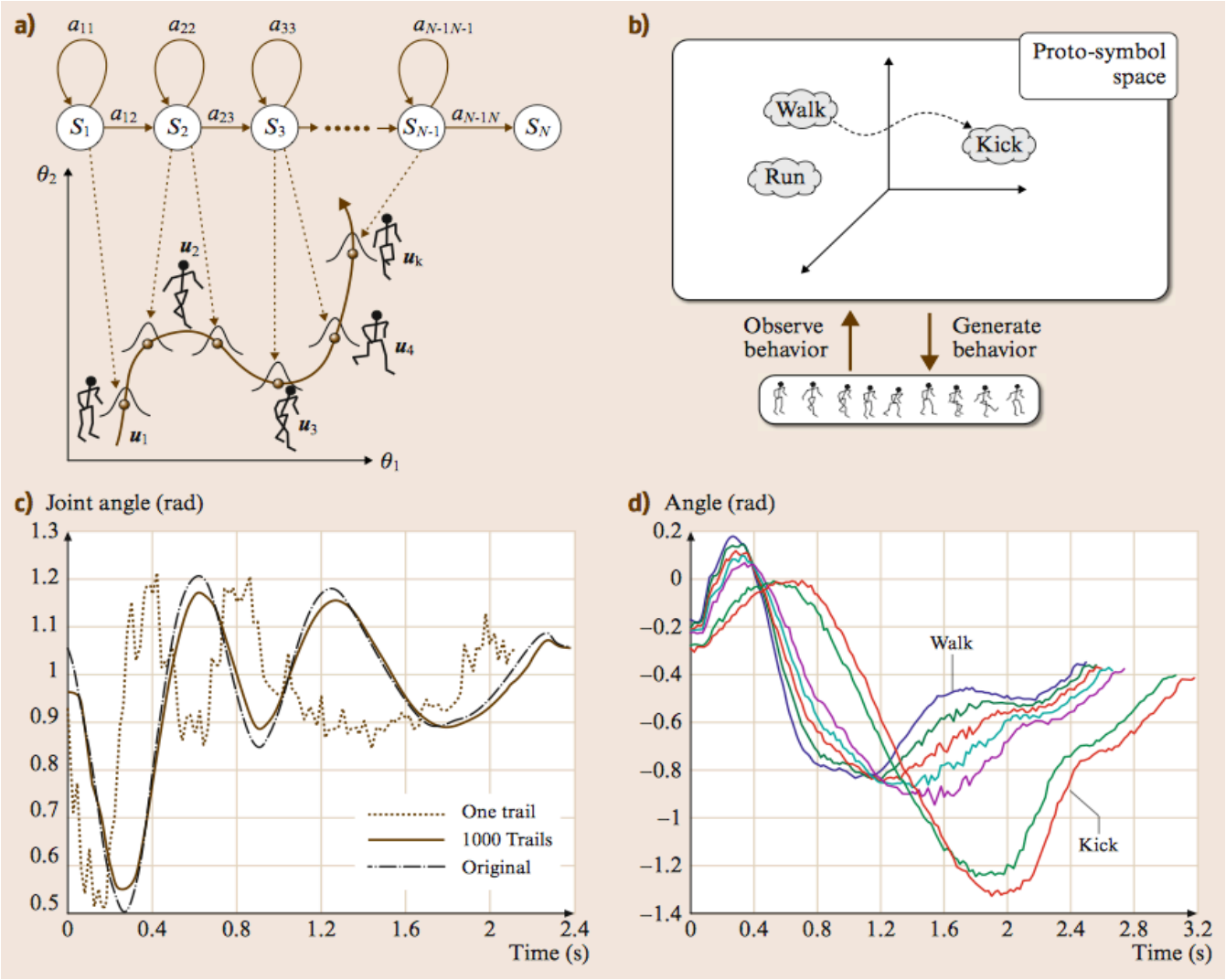
HMM



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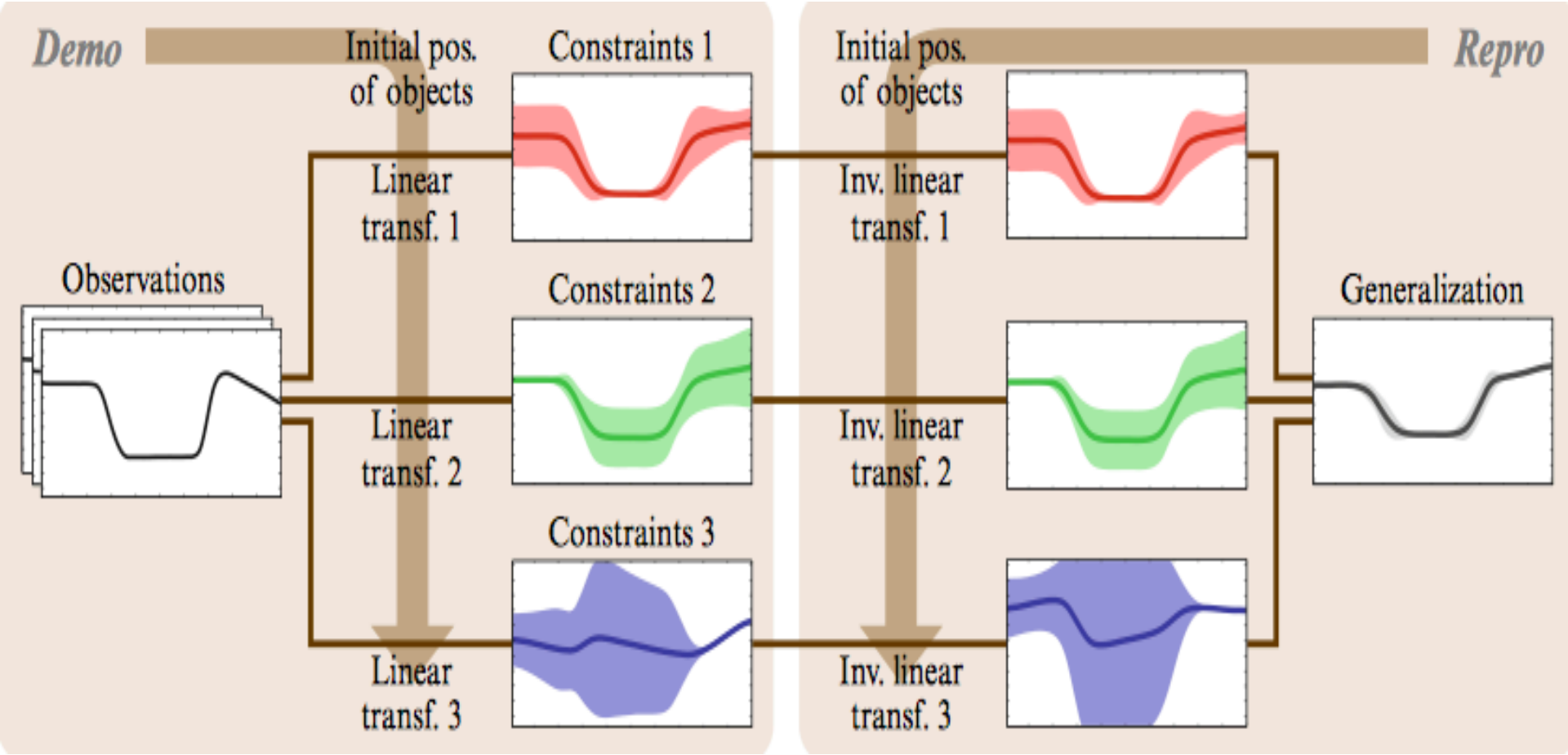
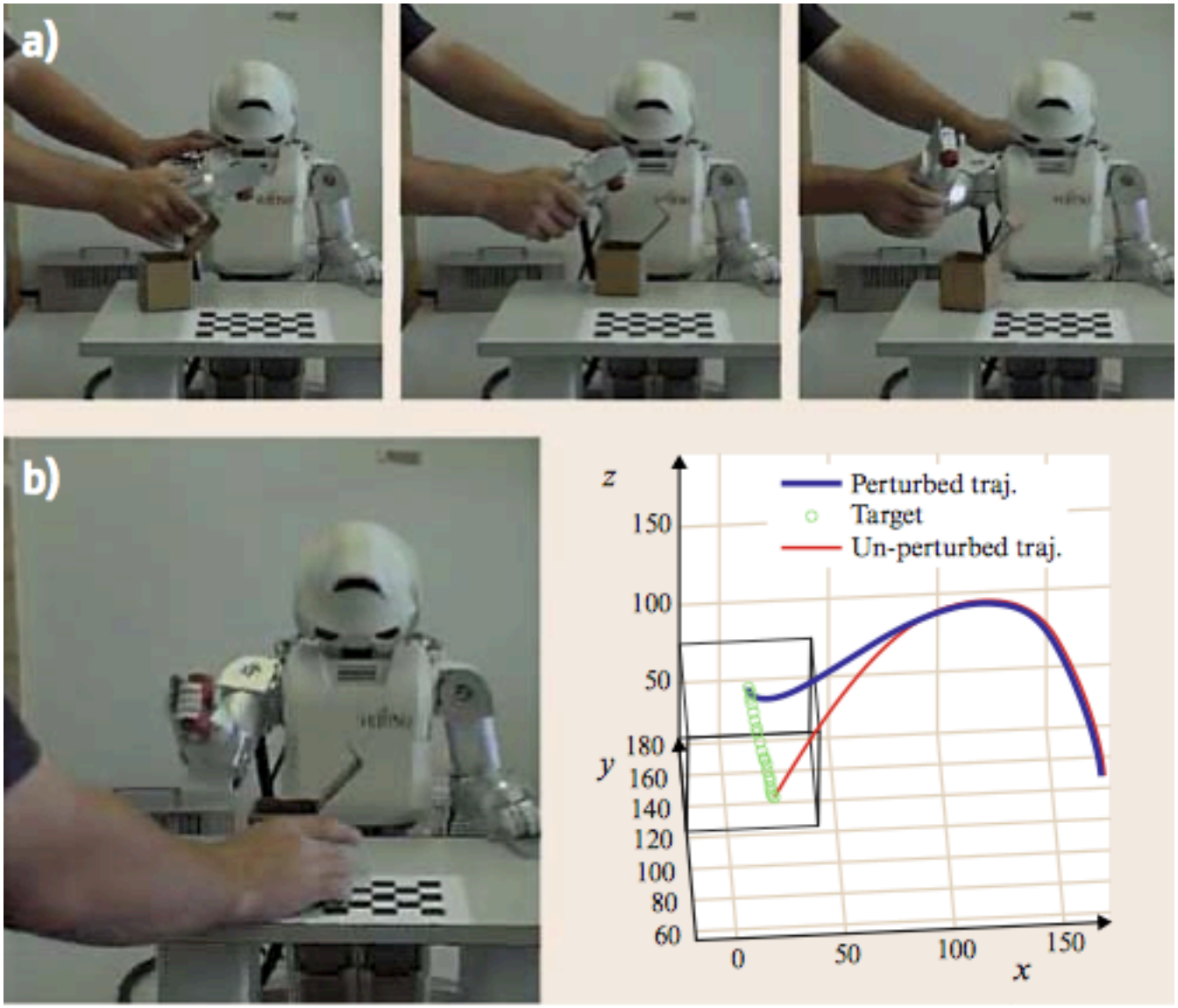
GMR


Demo
Initial pos. of objects
Constraints 1
Linear transf. 1
Observations
Constraints 2
Linear transf. 2
Constraints 3
Linear transf. 3
Initial pos. of objects
Inv. linear transf. 1
Inv. linear transf. 2
Inv. linear transf. 3
Repro
Generalization

Dynamical Systems



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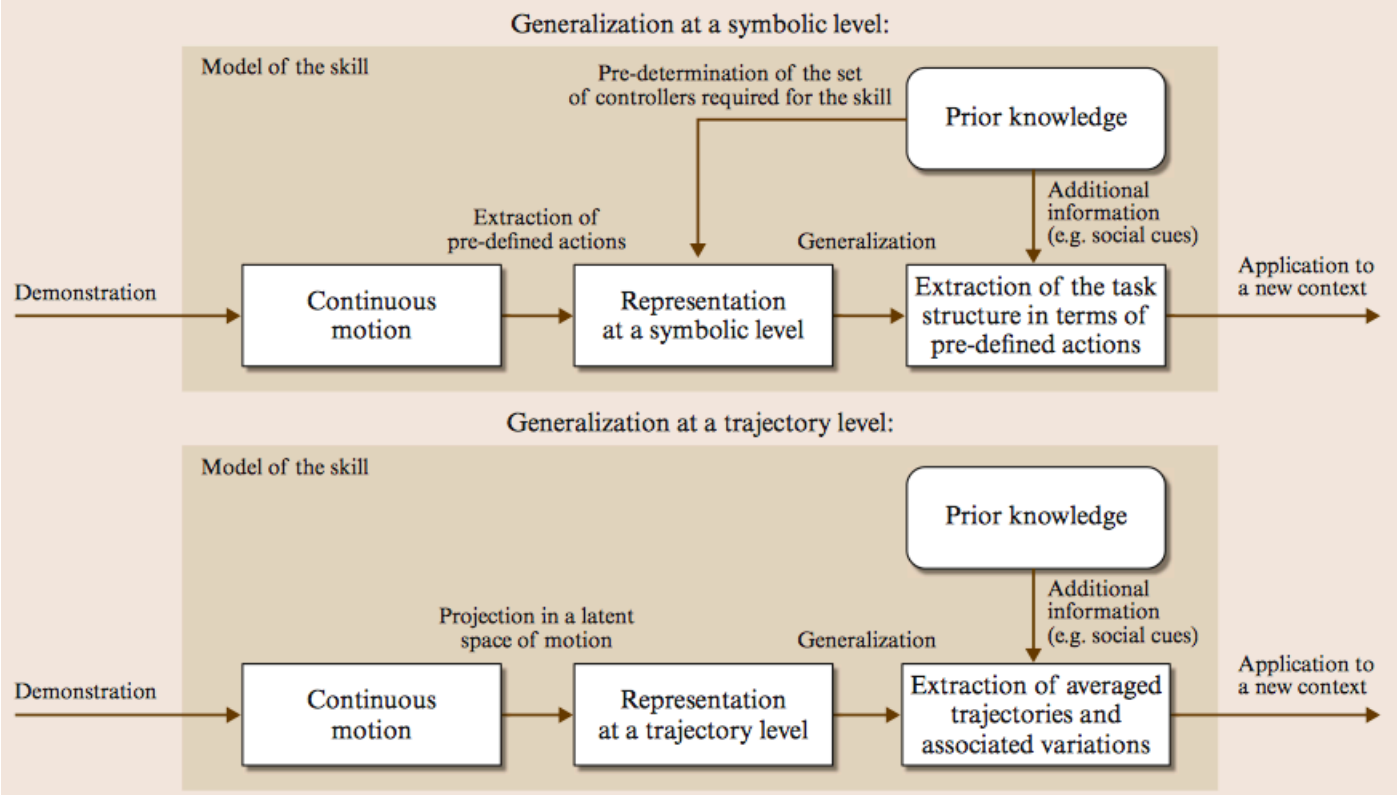
Comparison



	Span of the generalization process	Advantages	Drawbacks
Symbolic level	Sequential organization of pre-defined motion elements	Allows to learn hierarchy, rules and loops	Requires to pre-define a set of basic controllers for reproduction
Trajectory level	Generalization of movements	Generic representation of motion which allows encoding of very different types of signals/gestures	Does not allow to reproduce complicated high-level skills

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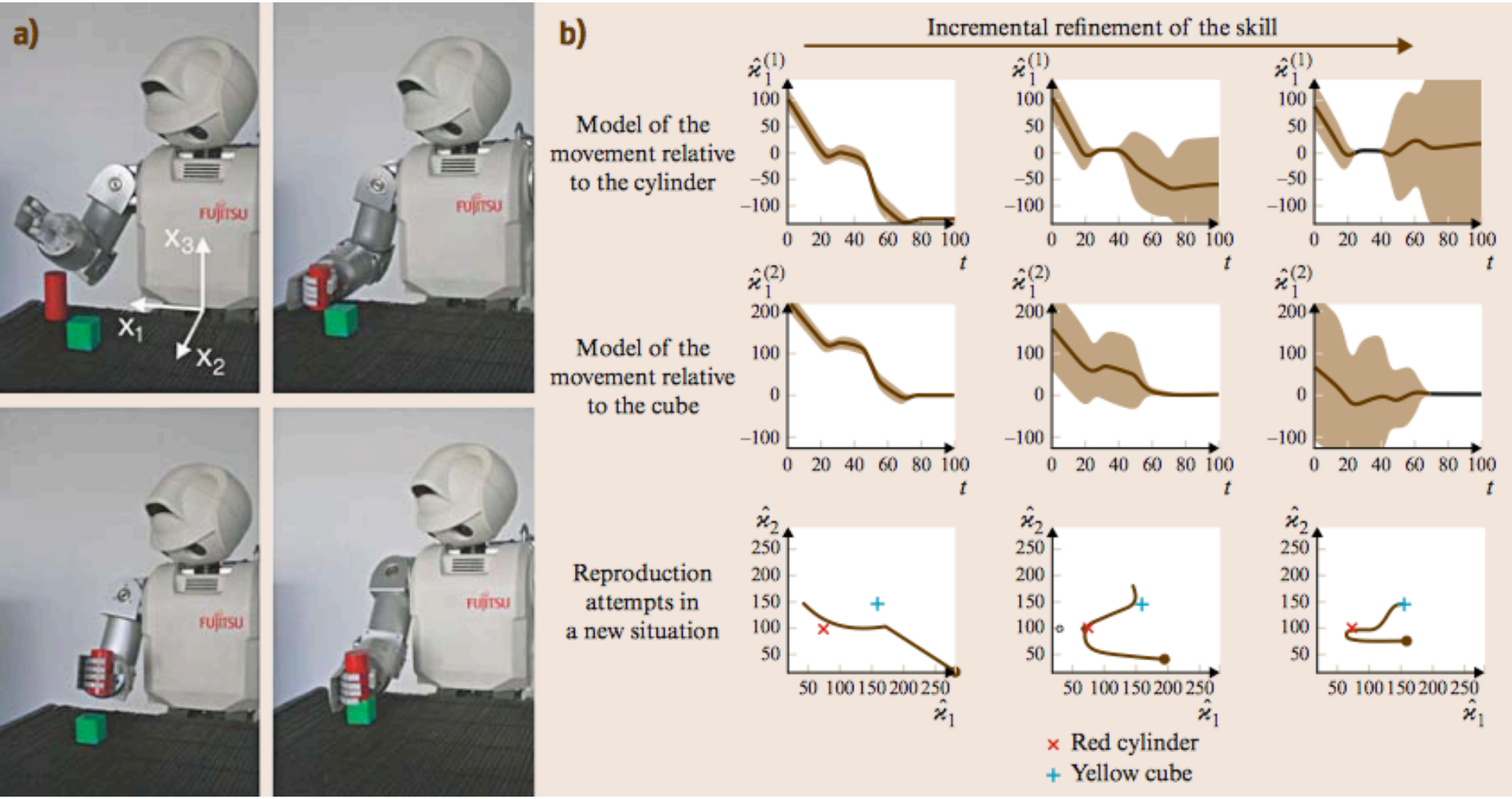
Incremental Refinement



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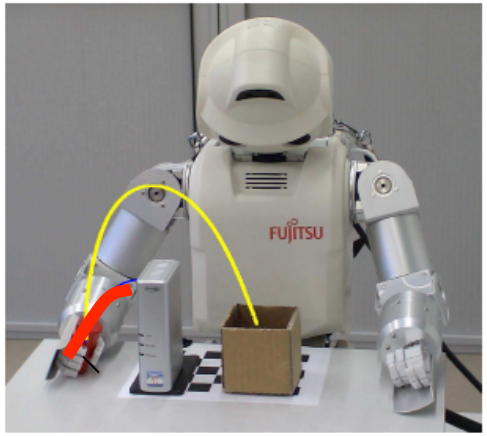
Refinement via Iterative Refining

- Require new demonstrations
- If the novel situation differs Importantly from the demonstrated ones, then adapting the demonstrated trajectory is no longer sufficient to satisfy the task.



→ Need to relearn the task -- Reinforcement Learning

→ Need to define a new metric – the reward

Solution

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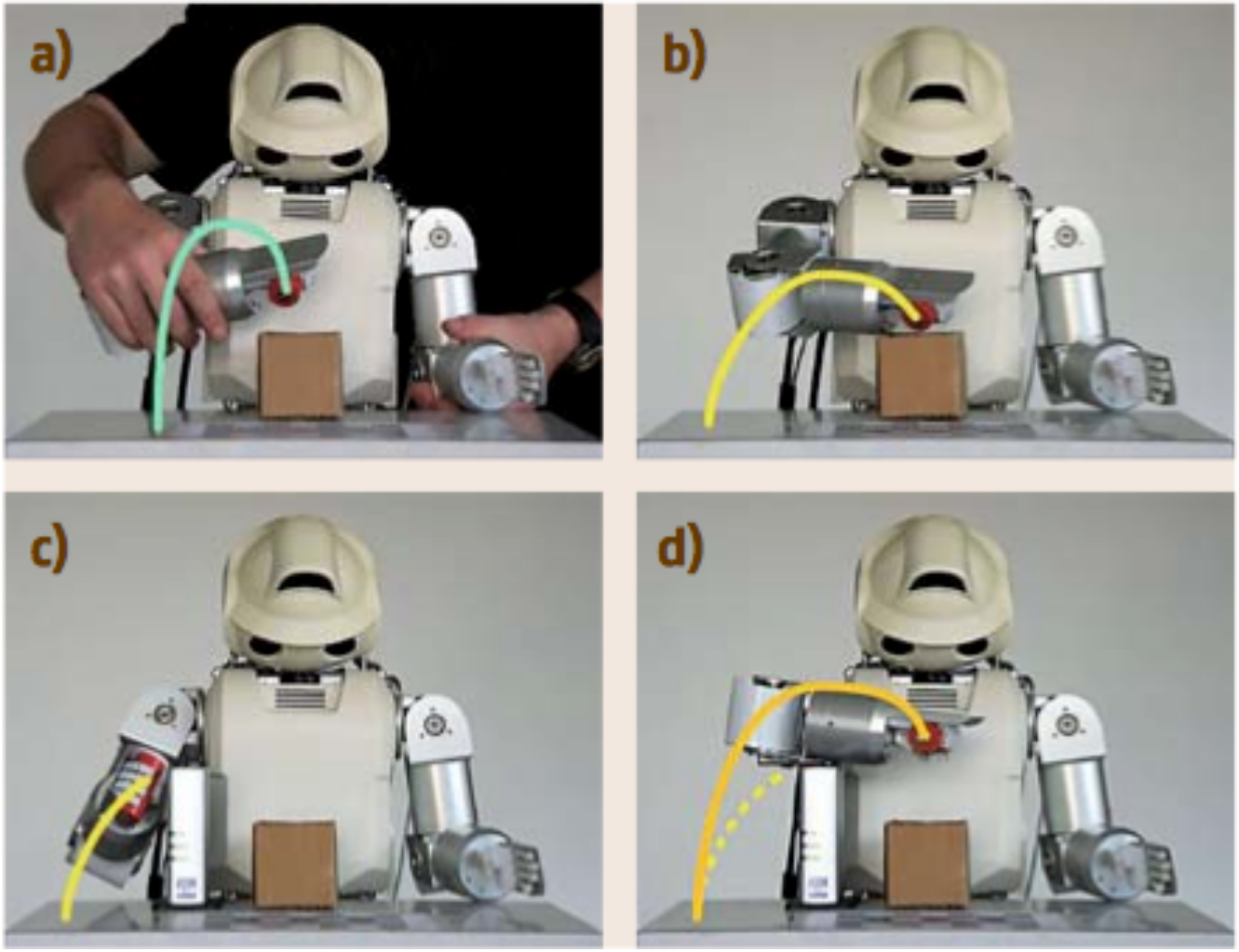
Refinement via Reinforcement learning



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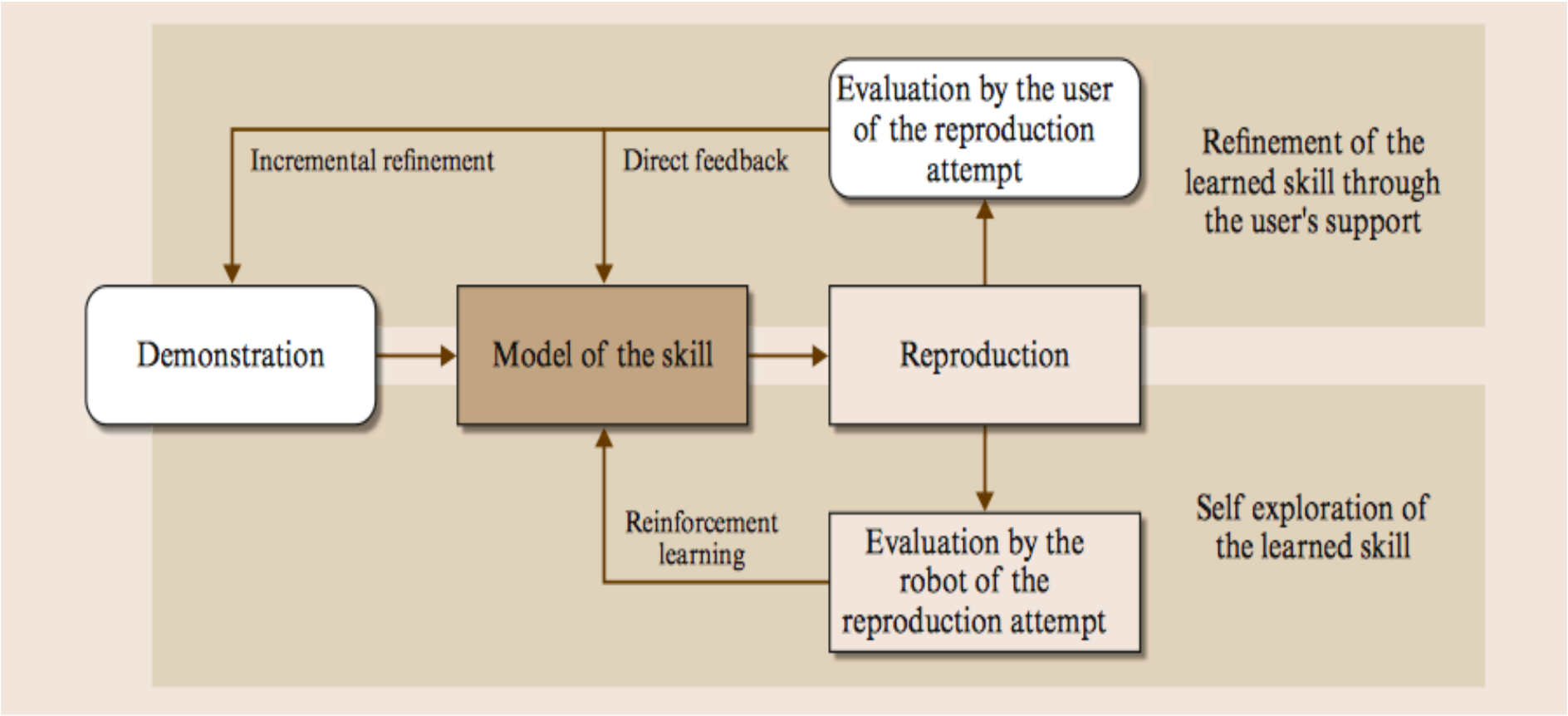
Refinement


Evaluation by the user of the reproduction attempt
Incremental refinement
Direct feedback
Refinement of the learned skill through the user's support
Demonstration
Model of the skill
Reproduction
Reinforcement learning
Evaluation by the robot of the reproduction attempt
Self exploration of the learned skill

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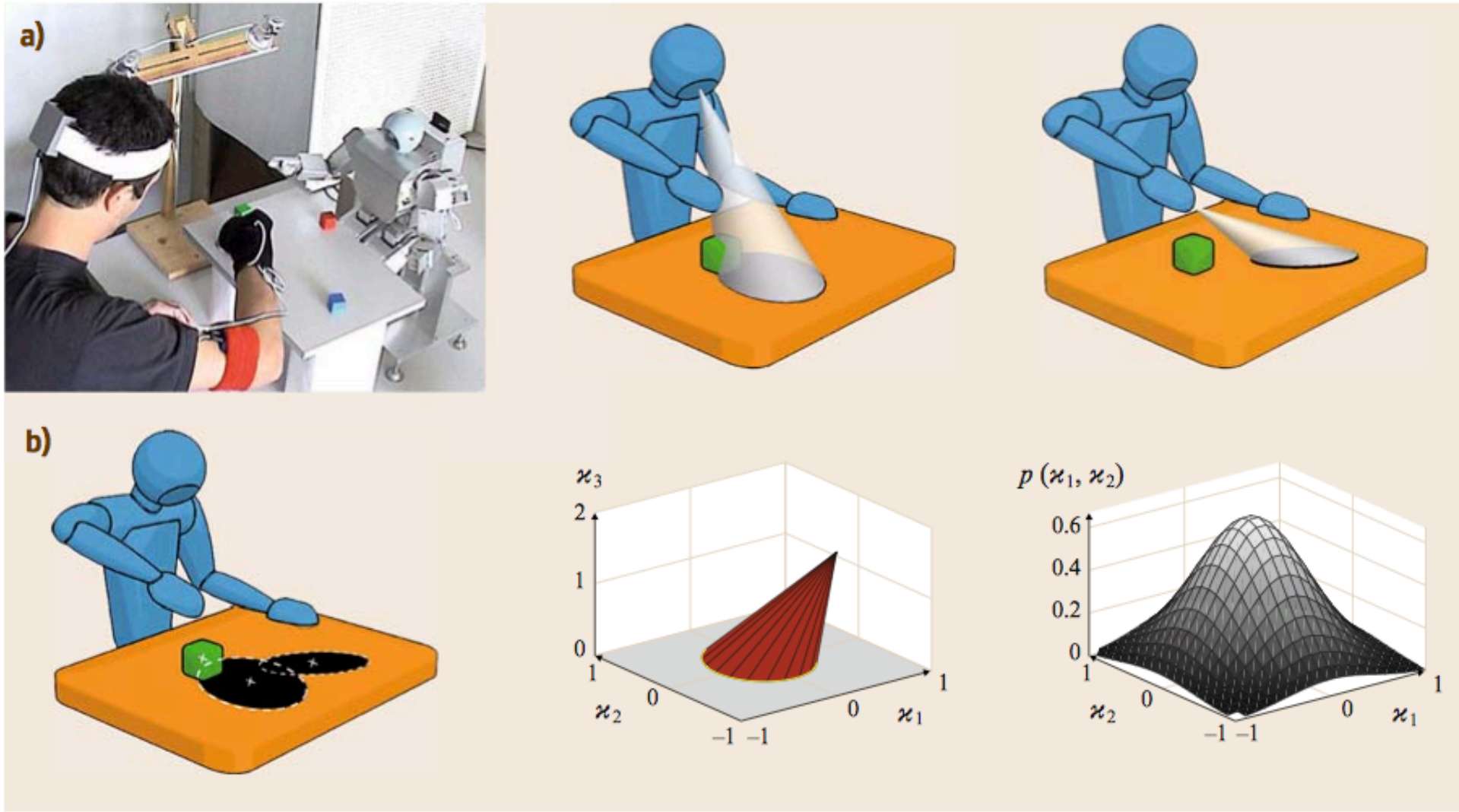
Human-robot interaction



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