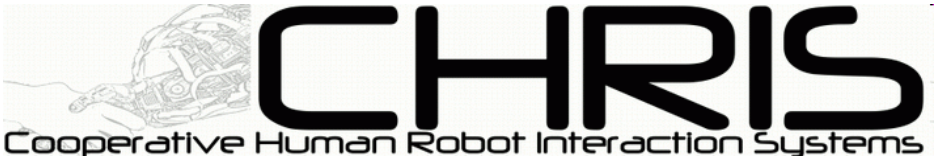


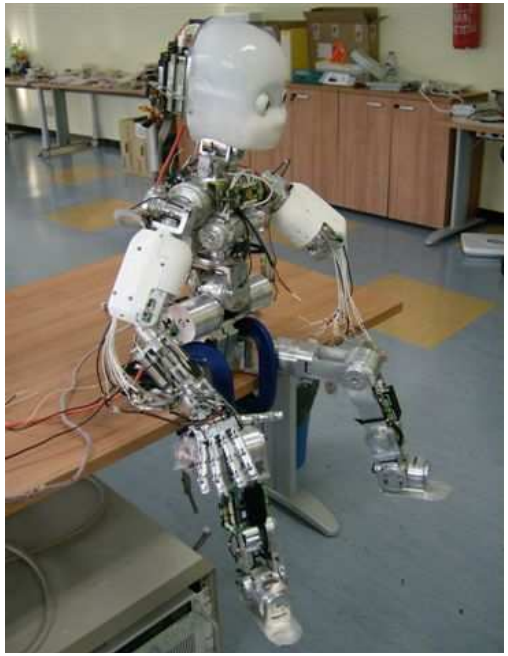
Neuroscience Contributions to Human-Robot Cooperation

Peter Ford Dominey, INSERM
Stem Cell and Brain Research Institute,
Lyon, France

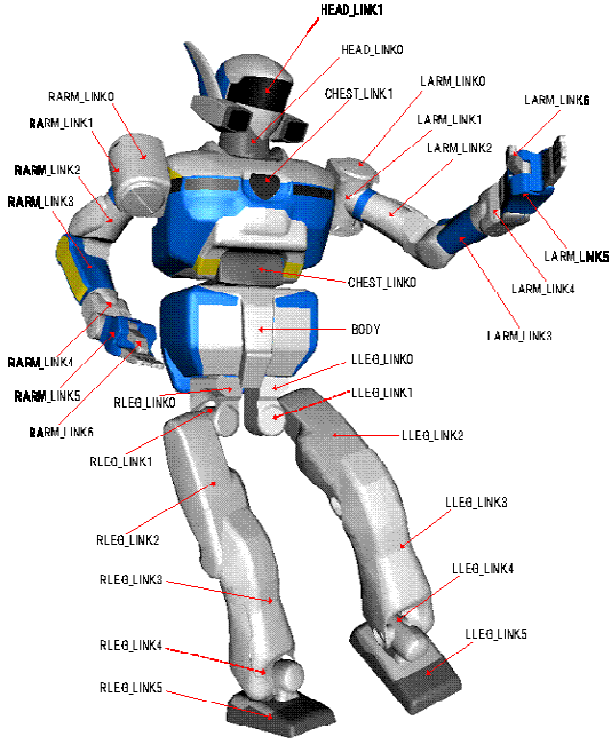
Comprendre
AMORCES

JNRR 2009

How can humans interact with complex robots?



iCub – FP6 IST RobotCub
IIT Genoa 53DOF



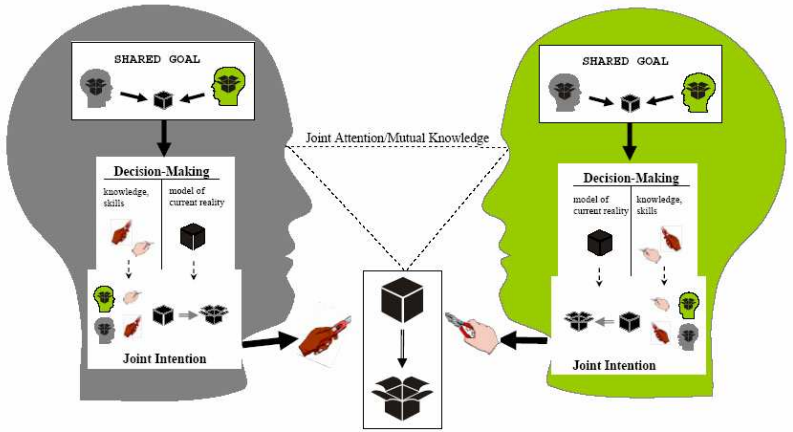
HRP-2 n°14 AIST-CNRS JRL
LAAS Toulouse 35 DOF

Exploit Human Behavior and Neuroscience:
Language & Action Perception

Plan

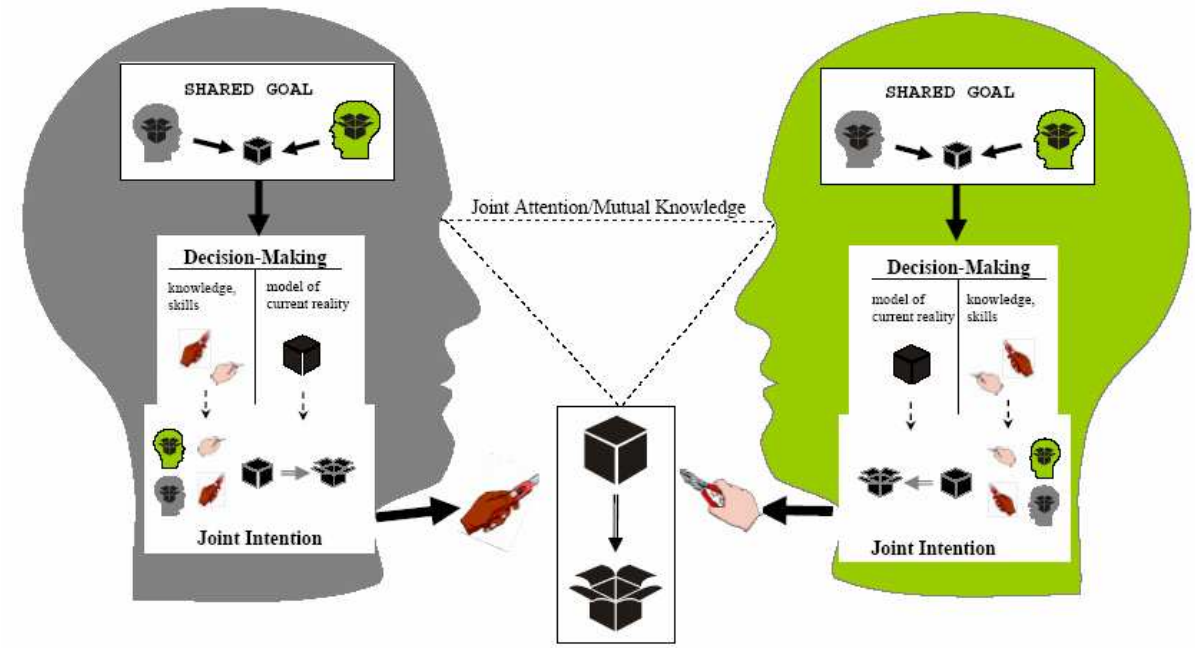
- Define Cooperation
  - Functional Requirements for Cooperation
  - A Scenario for Human-Robot Cooperation
- Language for Cooperation
  - Neurophysiology
  - Robot Implementation
- Action Perception for Cooperation
  - Neurophysiology
  - Robot Implementation
- Conclusion and Future Directions

Cooperation



- Two agents
- Participating in task that
  - Neither can perform alone
  - Requires coordinated action
- The coordination is specfied
  - Through spoken langauge
  - Through observation
- Not only coordinated action, but a shared goal

Functional Requirements for Cooperation – cahier des charges



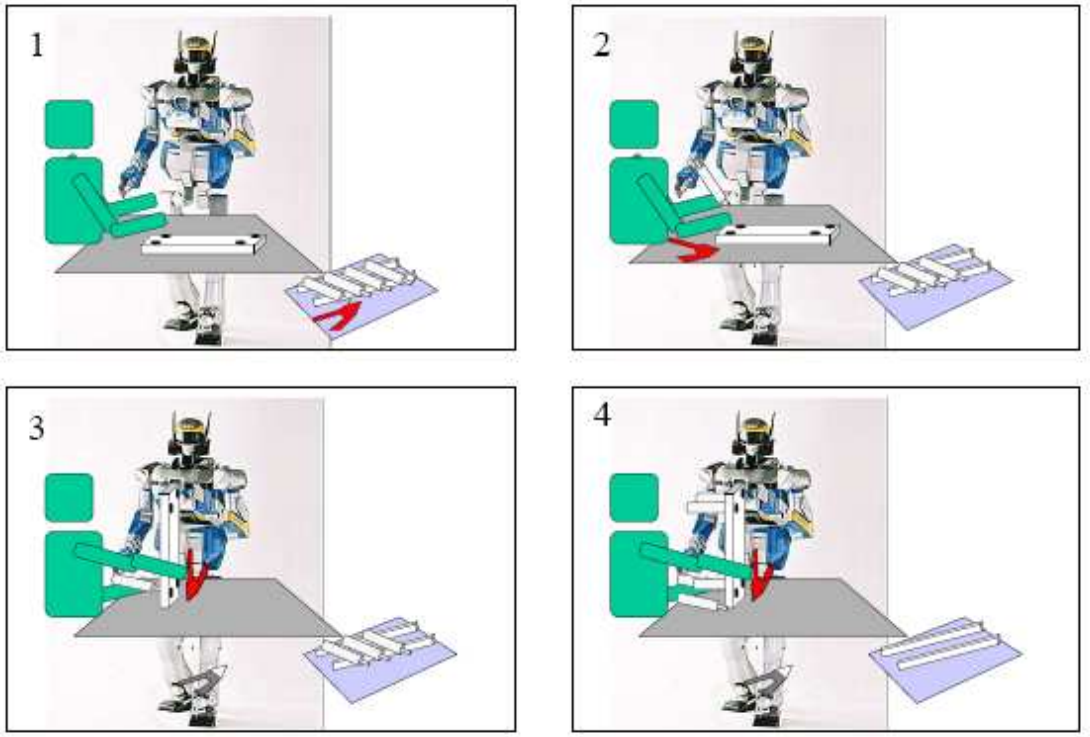
Tomasello et al. (2005)
Behavioral and Brain Sciences

(1) Perceive physical states of objects,
(2) Perceive physical actions performed by agents that can change the states of these objects
(3) Distinguish between self and other in this context
(4) Perceive the emotional responses of others.
(5) statistical learning mechanism
(6) Manipulate shared representations with lmanguage

Dominey (2005) BBS
Comment on Tomasello

A Scenario for Human-Robot Cooperation: the Robot Apprentice

- Context
  - Cooperative table assembly task
  - « Innate » primitives
    - Reach, grasp(x), pass…
  - Repeated subtasks, allows learning during the task
    - Leg1, leg2 ..
- The robot works with the human to assemble the table
  - And learns about the shared task
  - To progressively acquire skill

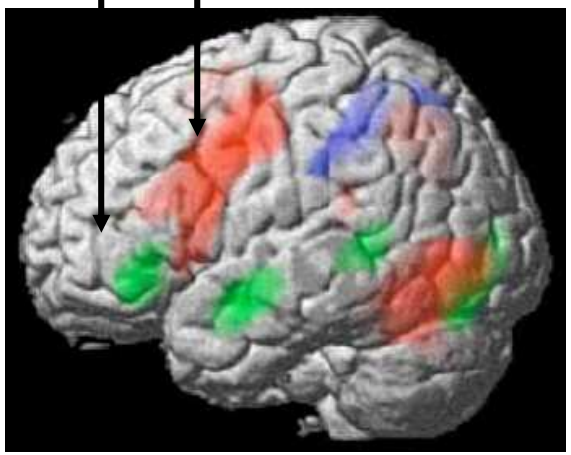


Kawada Industries HRP-2 Platform
CNRS-AIST Joint Robotics Laboratory
LAAS, Toulouse, France

Neurophysiology of Language: Mapping Sentences to Action

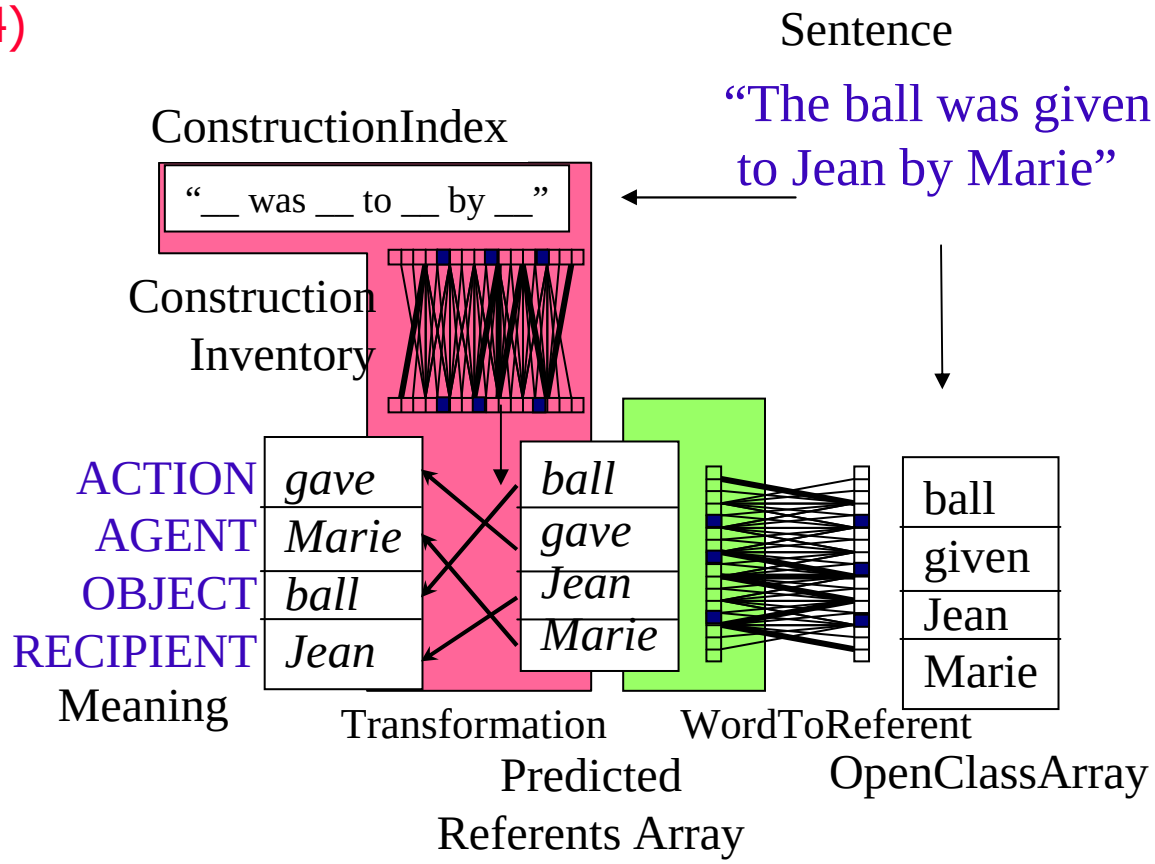
Word Meaning (BA45)

Structural Mapping (BA44)



Human sentence processing fMRI Study

(Hoen, Dominey et al. Cortex, 2006)
(Tettamanti et al. 2005)



(Dominey, Hoen, Inu, Journal of Cognitive Neuroscience 2006)

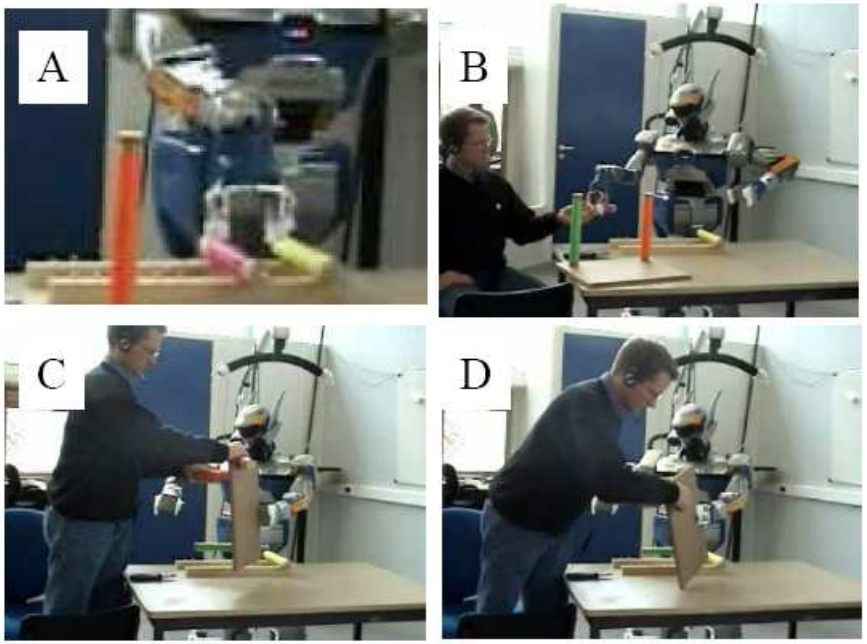
Implementation of Language 1: Learn Generalized Behavior with Language

- H: Give me the ***green*** leg
- R: « show me how to give »
- H:

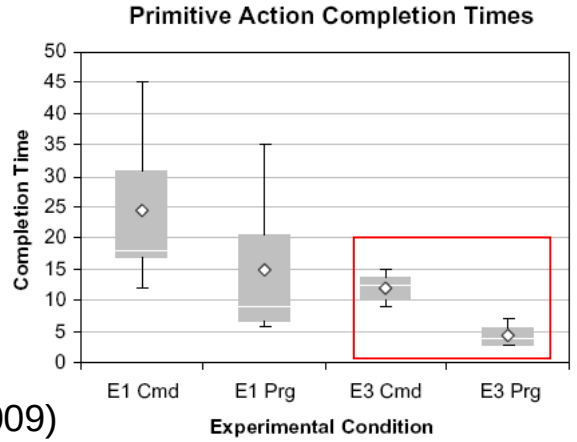
  Take the ***green*** leg

  Turn right

  Open right hand
- Training with one example
  - *Green* is passed as an argument to TAKE
  - Take generalizes over (yellow, rose, green, orange)




```
Give me the $VAR1 leg {
   Take the $VAR1 leg
   Turn right
   Open right hand
   Ready position
   }
```



JRL, AIST-CNRS LAAS Toulouse,
Dominey, Mallet, Yoshida (2007ab, 2008, 2009)

Implementation of Language 2: Progressive Levels of Anticipation

- Level 0
  - New task
  - Robot asks for confirmation
- Level 1
  - Eliminate need for speech verification
- Level 2
  - Propose anticipated next action
- Level 3
  - Take initiative for next action
- Life long learning
  - As interaction history becomes richer, so does the behavioral repertoire

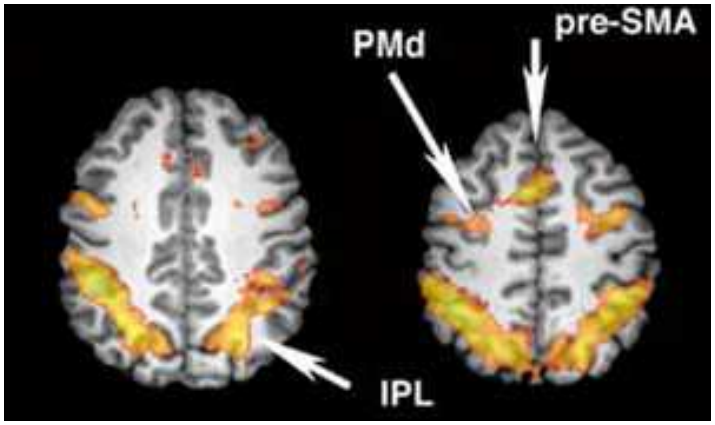
iCub Humanoid – RobotCub FP6
Italian Institute of Technology

Dominey, Metta, Nori, Natale (2008) IEEE Humanoids

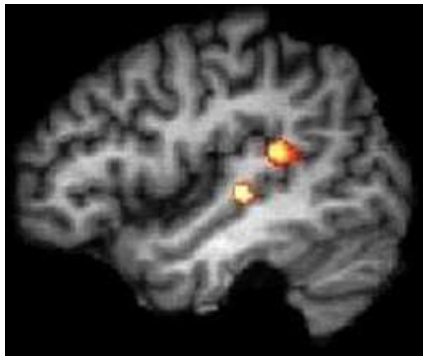
Neurophysiology of Action Perception

- Complex events decomposed into primitives (e.g. contact)
  - Kotovsy, Baillargeon 1998
  - Dominey & Boucher 2005
- Action sequences encoded in Fronto-Parietal networks
  - Buccino 2004, Frey 2008
- Self-other distinction and goal-based reasoning in Temporal lobe
  - Pelphrey et al. 2004, Brass et al. 2007

Buccino et al. 2004

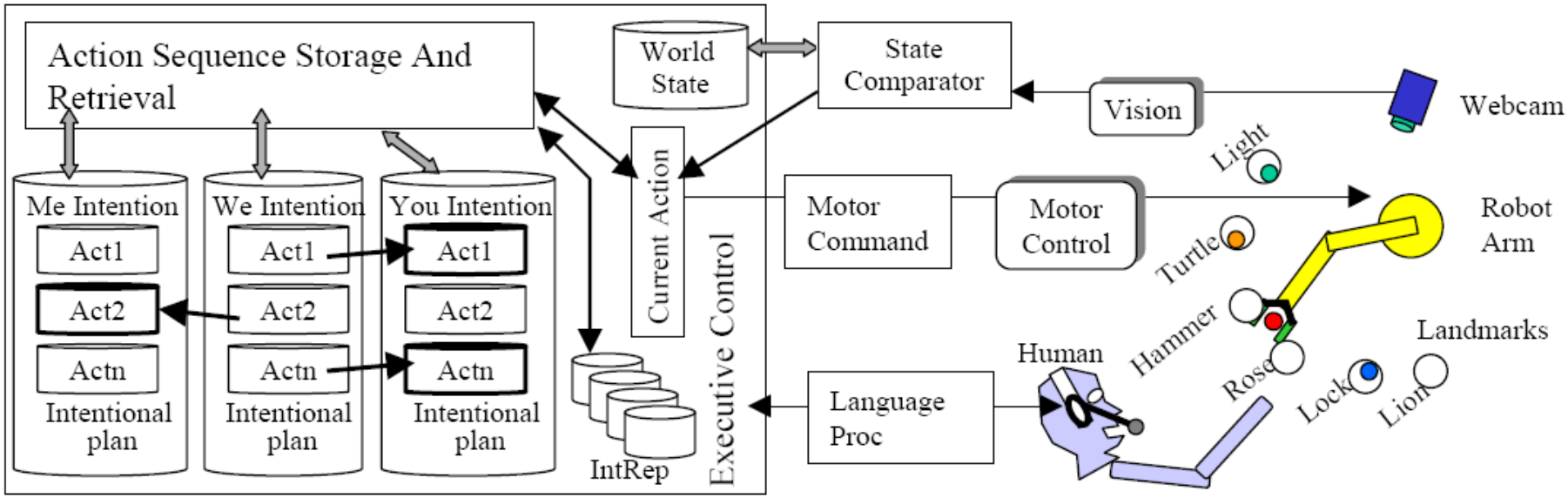


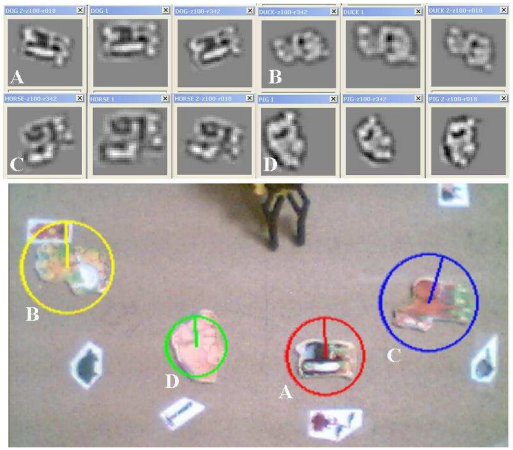
Frey, Gerry 2008



Brass et al. 2007

Implementing Action Perception 1: Shared Plans



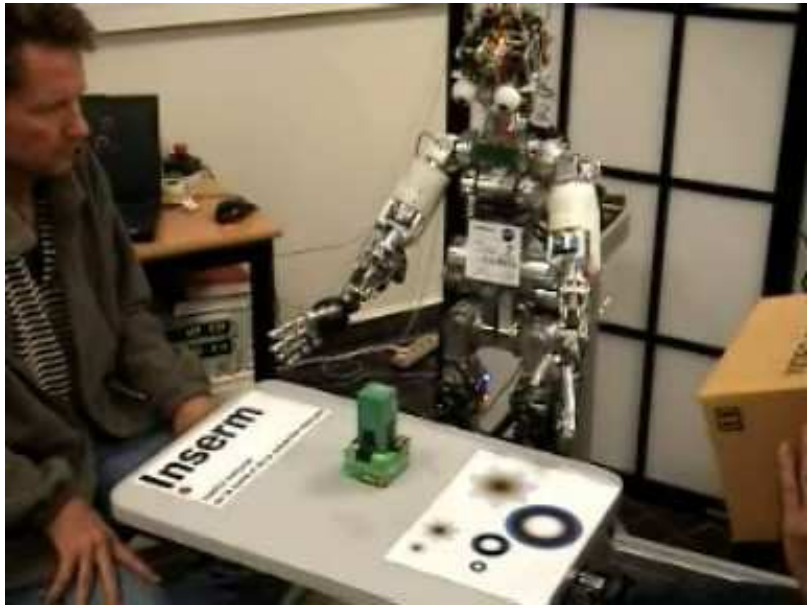


1. Commanded action
   'Put the dog next to the light'
2. Imitation
3. Shared Plans
4. Helping
5. Role reversal

Dominey & Warneken (2009) New Issues in Psychology

Implementing Action Perception 2: Learn Cooperative Behavior by Observation

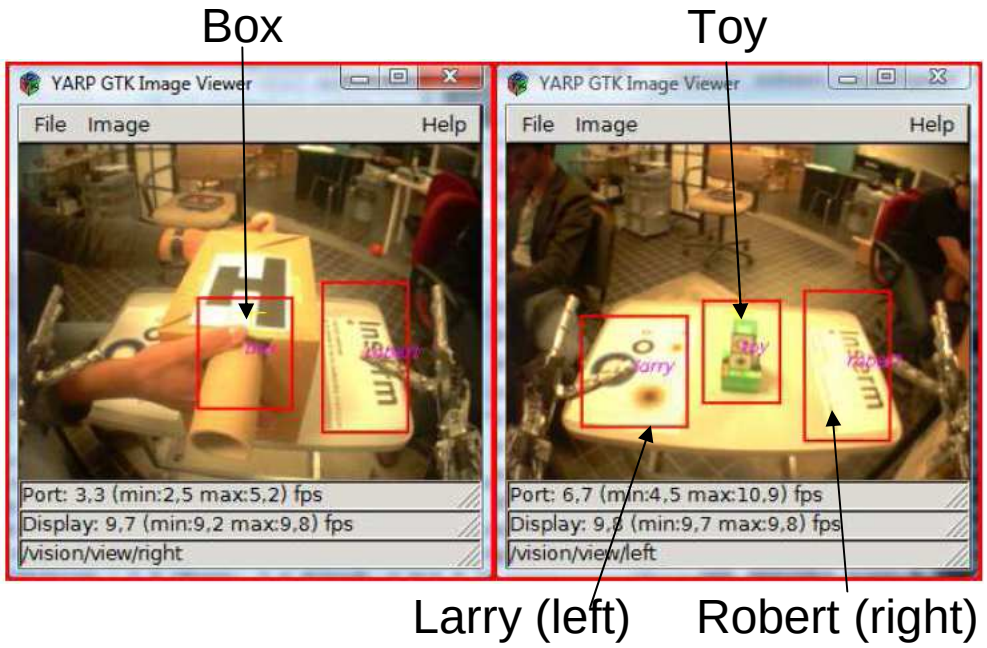
- Robot observes two humans cooperate
- Attributes actions to each agent in a coordinated sequence
- Then can participate in the cooperation
- Can ‘reverse roles’ taking role of either human
- Based on behavioral studies (Warneken, Tomasello)



Lallee, Warneken, Dominey (2009) Epigenetic Robotics Venice, Italy

Implementing Action Perception 2: Learn Cooperative Behavior by Observation

- Perception
  - Box, Toy, Larry, Robert
- Perceptual primitives
  - Appear, disappear
- Actions
  - Put(object, agent),
  - Take(object, agent)
- Attribute action to agents
- Form shared plan
- Use it in cooperation
- Role reversal



Summary

- Neurophysiological solutions exist for
  - Language – coordiation of cooperation
  - Action observation, imitation
  - The close link between action and language
- We can learn from these solutions
- Demonstrated this for
  - Using grammatical constructions to learn new behaviors
  - Using vision to build shared plans
- Rich source of inspiration for the future
  - Sensory-motor coordination
  - Attention systems
  - Emotion/evaluation

- To be done: Identify robust « primitives » existing today in the robotics community to be used in cooperative human-robot interaction.

Acknowledgements

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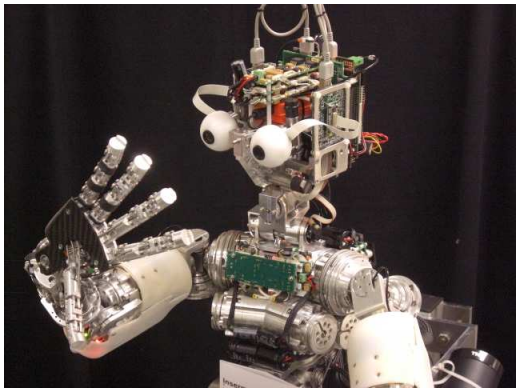
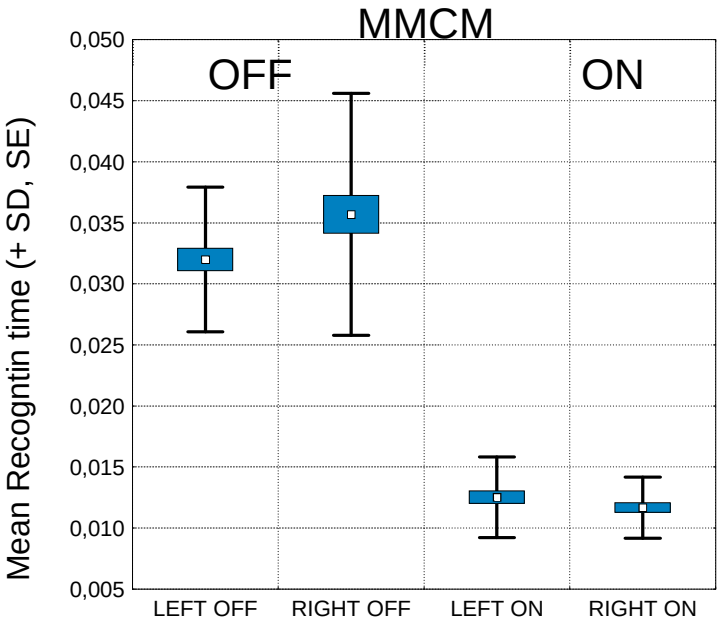
  - INSERM
  - IIT
  - JRL-AIST-CNRS

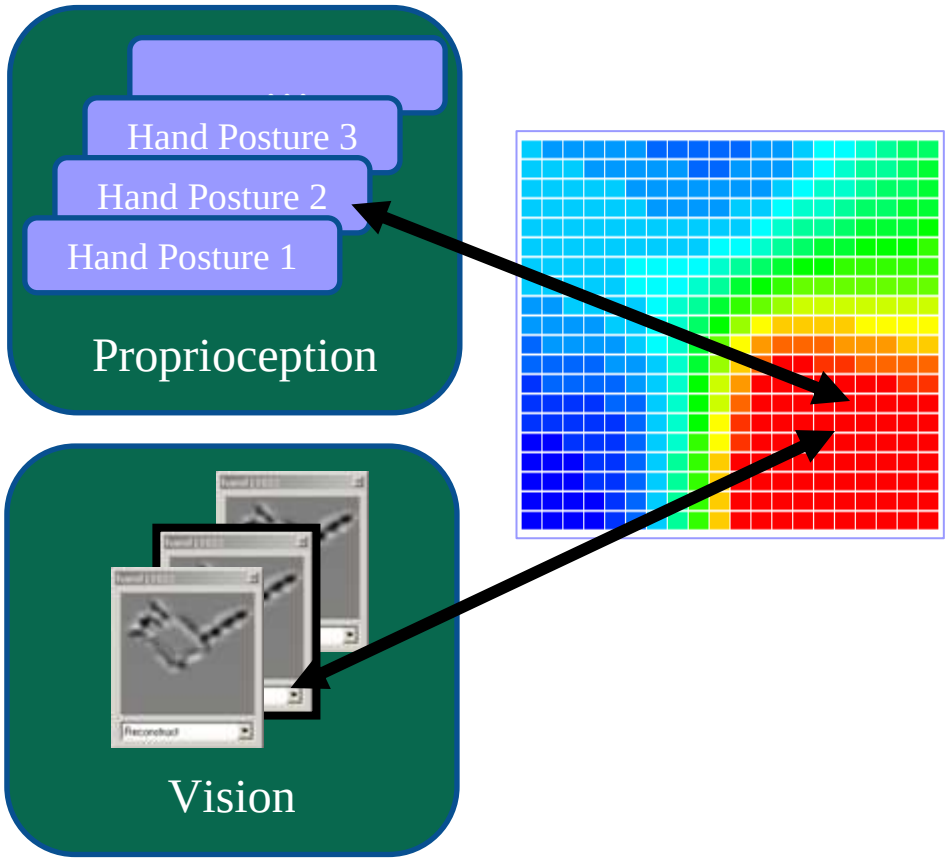
Thanks for your attention.

Future Directions: Visuomotor Coordination in Parietal Cortex



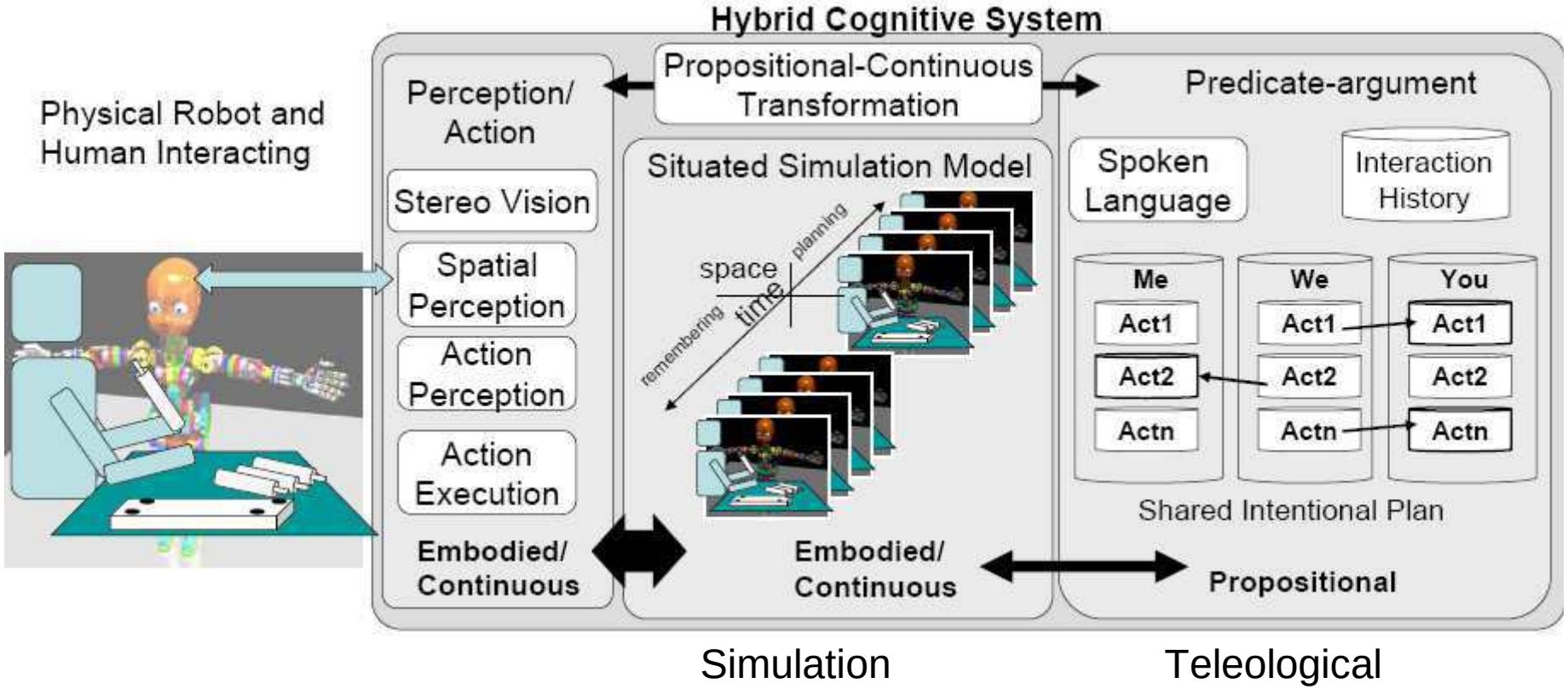
iCub (Robotcub project)





Lallee et al. (2009) Society for Neuroscience, Chicago

Internal Simulation and the Hybrid Cognitive System



Madden, Hoen, Dominey (2009) Brain and Language
iCub project – Lyon, June 2009