Towards the development of cognitive robots

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- Motivation and goals
- The simulation theory of cognition
- Making robots to imagine for acting
- On-going experimental scenarios
    - Rehabilitation robotics
    - Vendor robotics
- Conclusions and future work

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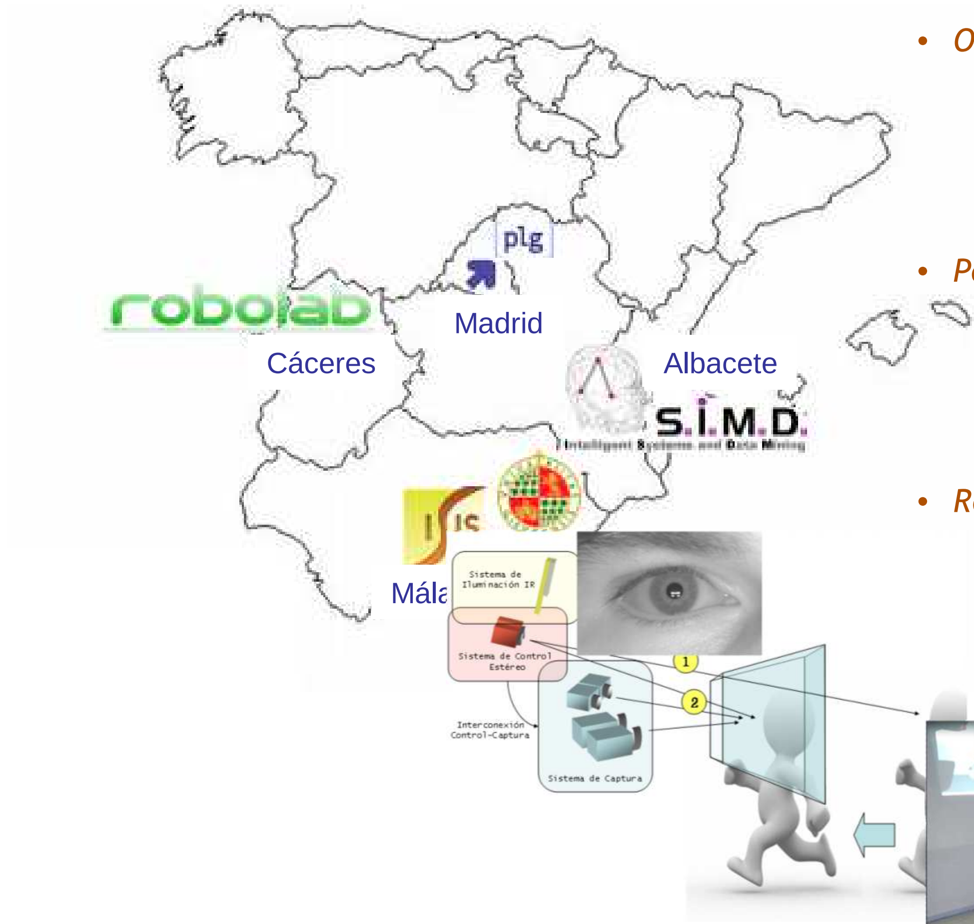
Who are we? ISIS/RoboLab groups



- *Our goals: present and future*

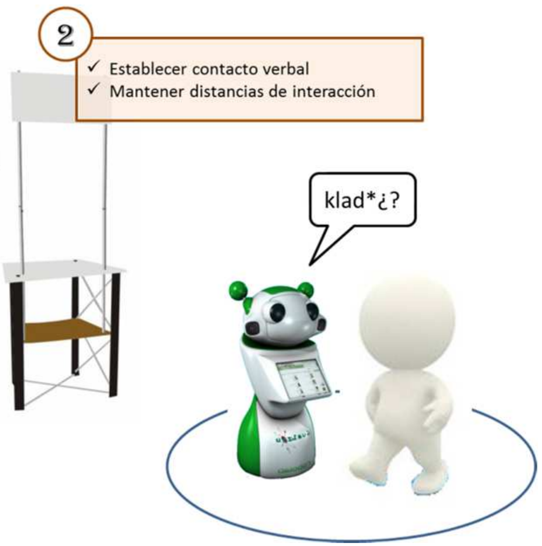
  The development of robots that can share the environment with us, exhibiting a correct (social) behavior.

- *People*

  A small group at Málaga and Cáceres (Spain) but with a lot of friends that know a lot about robotics, computer vision, mathematics…

- *Realities*

  Integra project (200K EU
  Therapist project (200K
  Adapta project (300K EU



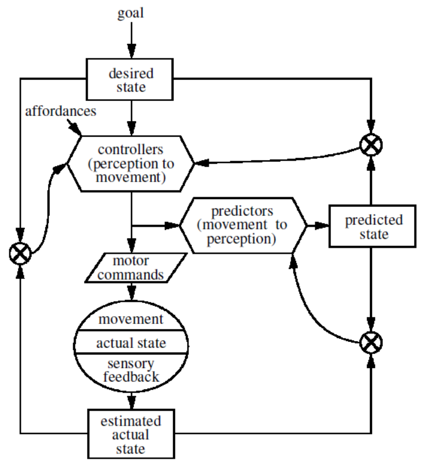
MUECAS, LOKI and URSUS – RoboLab

Motivation Robots for acting

- *From motor control …*

Control of action

A well-functioning motor system is an essential requirement if the robot is to move through the environment safely, reach and grasp objects and learn new skills.



Abnormalities in the awareness and control of action

- C. Frith, S. Blakemore, D. Wolpert, 2000

But the problem is also to determine *which* actions to perform and in which order, and *how* to perform these actions.

MUECAS, LOKI and URSUS – RoboLab

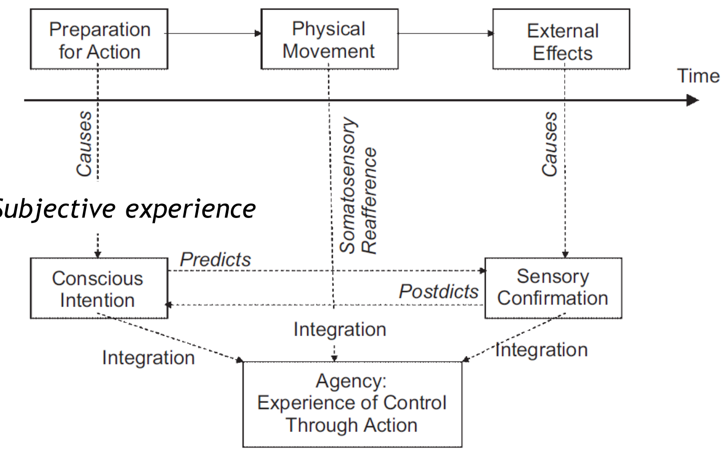
Motivation Robots for acting

- *… to robotics agency*

Robotics agency

The experience of agency refers to the experience of *being in control both of one's own actions* and, through them, of *events in the external world.*

Acting on the outer world

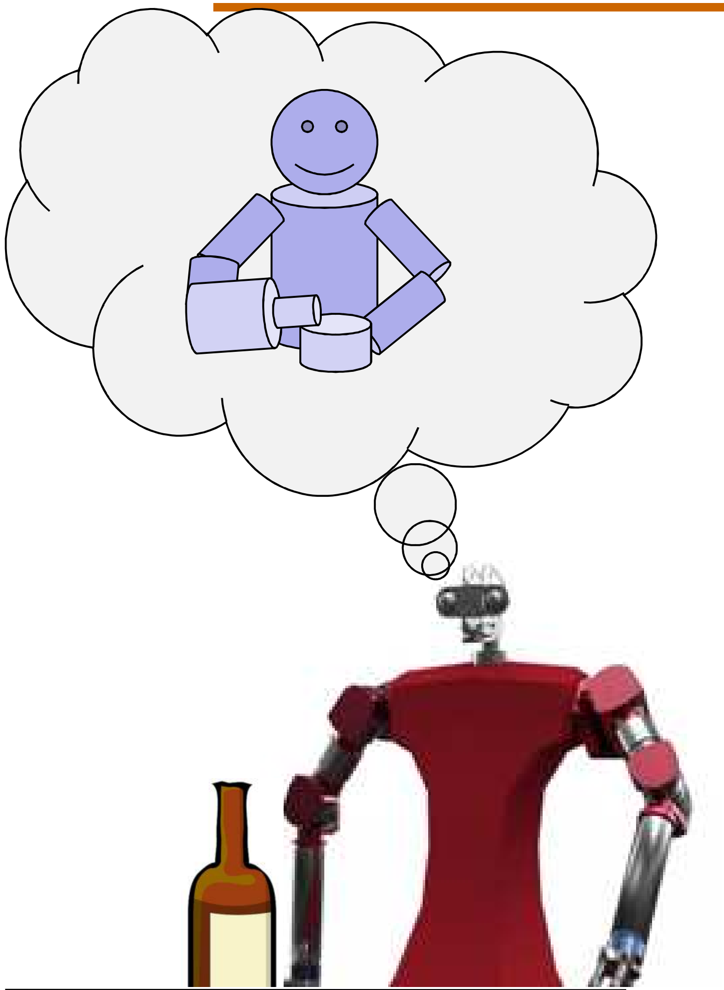


The experience of agency

- Patrick Haggard and Manos Tsakiris, 2009

- *How to proceed…*

Step-by-step!!

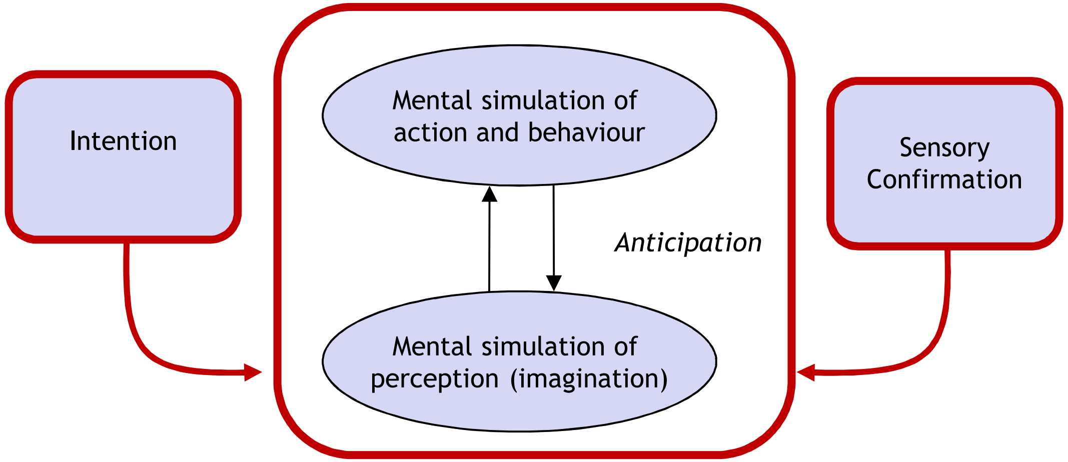


Motivation The simulation theory

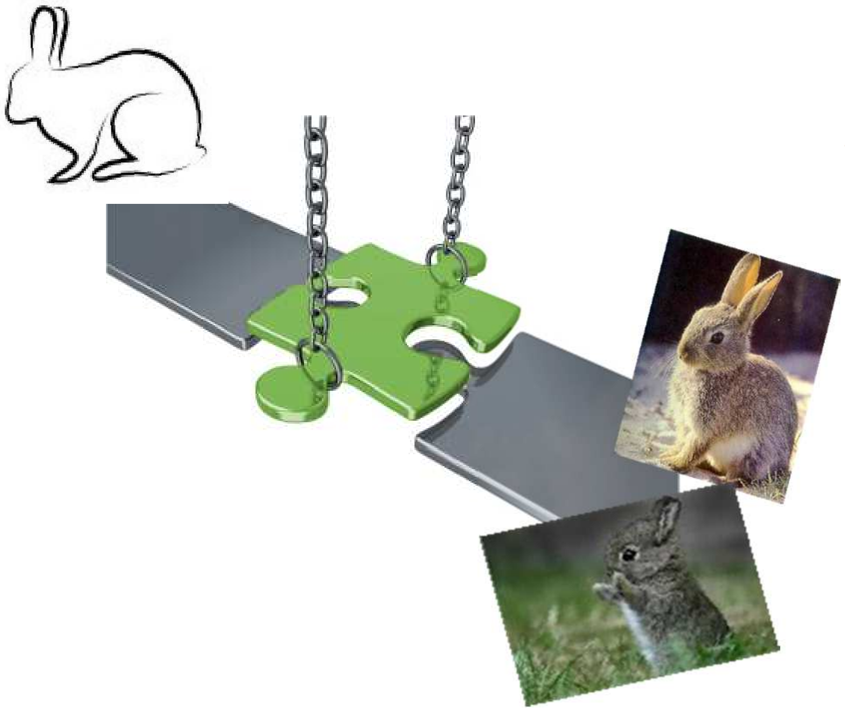
- *Open problem*

  We would like to develop a *software structure* that endows a robot with this subjective experience.

- *One possibility…*



The current status of the simulation theory of cognition, G. Hesslow, Brain Research, 2011



Goal Making robots to imagine for acting

- *Putting a virtual robot inside of a virtual world*

  The problem of *modeling itself and the outer world*

  ✓At perception level: there is a representational gap[1] between outer items and inner models

  ✓At situational level: there is a need of models and of mechanisms to drive these models

  ✓At deliberative level: the course of action should be reactively adapted to the dynamic scenario[2]

LET PUT NOW THE EMPHASIS ON A ROBOT MOVING ITS BODY AND BEING AWARE OF THE CONSEQUENCES OF ITS OWN ACTIONS

[1] *Generic model abstraction from examples*, Y. Keselman and S. Dickinson, CVPR, 1:856–863, 2001

[2] *Towards performing everyday manipulation activities*, M. Beetz et al, Robotics and Autonomous Systems, 2010

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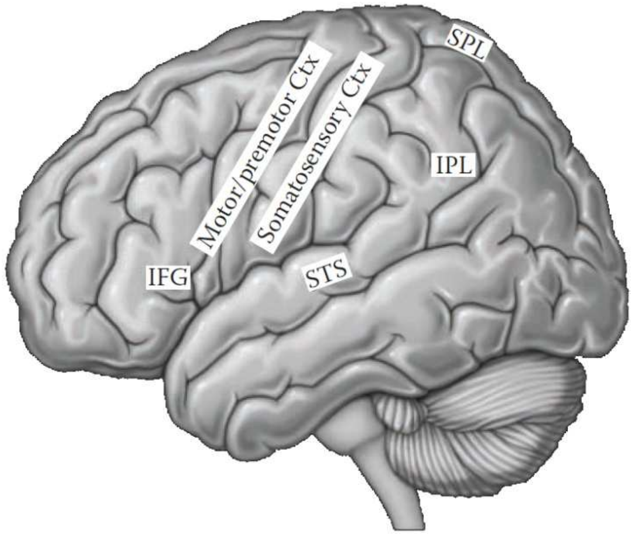
The simulation theory of cognition Foundations



'…simulation of movement precedes and plans for upcoming physical action and activates the same cortical and subcortical structures that are responsible for motor execution'

- Keith D. Markman, William M.P. Klein, and Julie A. Suhr

The common coding hypothesis[1]:

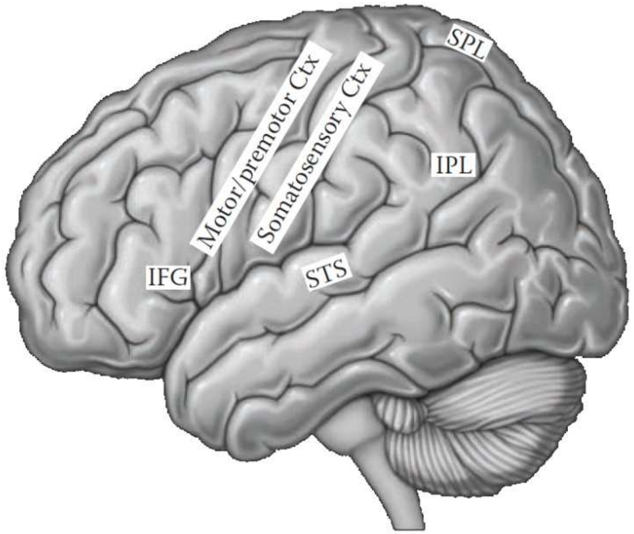
✓Actions are coded in terms of the perceivable effects they will generate

✓Associations between motor patterns and sensory effects can then be used backward to retrieve a movement by *anticipating* its effects

✓Perception-action codes are also accessible during action observation, and perception activates action representations to the degree that the *perceived and the represented actions are similar*

[1]Prinz, W. (2003). *Experimental approaches to action*. In J. Roessler & N. Eilan (Eds.), Agency and self-awareness (pp. 175–187). Oxford, England: Oxford University Press.

The simulation theory of cognition Foundations



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The 'simulation' theory of cognition[1]:

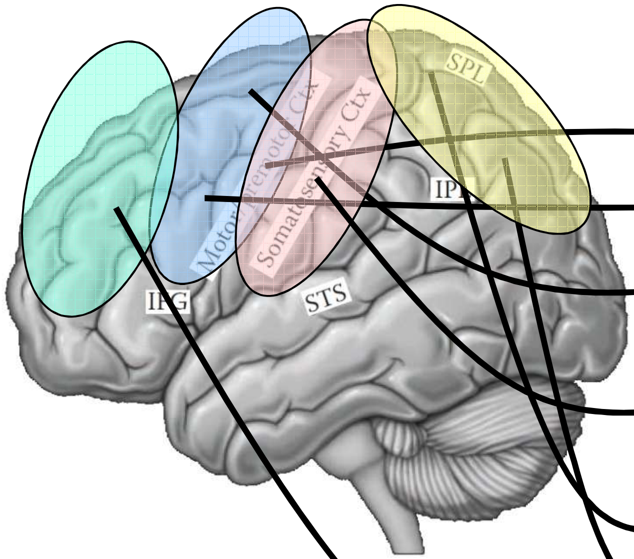
✓Motor structures are activated when *behaviours are simulated*, as during normal overt action but suppressing its execution

✓Internal activation of sensory cortex simulate perception in a way that resembles its normal activation during perception of external stimuli

✓Overt and simulated actions can elicit perceptual simulation of their most probable consequences (*anticipation*)

[1]G. Hesslow (2011) *The current status of the simulation theory of cognition,* Brain Research

The simulation theory of cognition Engineering



Body movement at the brain. The motor cortex:

Primary motor cortex (Area 4): A map of the human body muscles

Premotor cortex (Area 6): Body postures (optimal position for a movement)

Supplementary motor area (Area 6): Movement planning and initiation on the basis of past experience. **Anticipation**

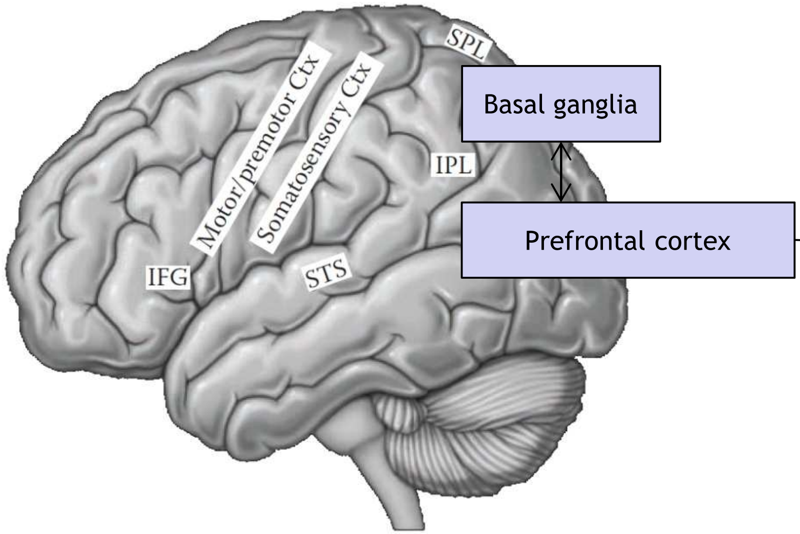
Somatosensory cortex : A map of the human body sensing

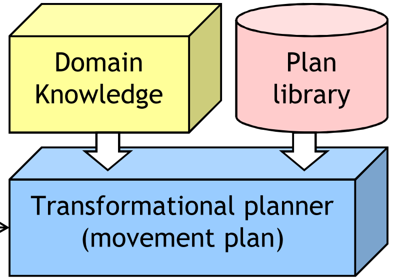
Posterior Parietal Cortex (Area 5): Coding space / spatial attention to body movements

Posterior Parietal Cortex (Area 7): Visual information (from MT or V5) integration

The parietal lobes and the prefrontal areas represent the highest level of integration in the motor control hierarchy: they take the decision of what action to accomplish.

The simulation theory of cognition Engineering





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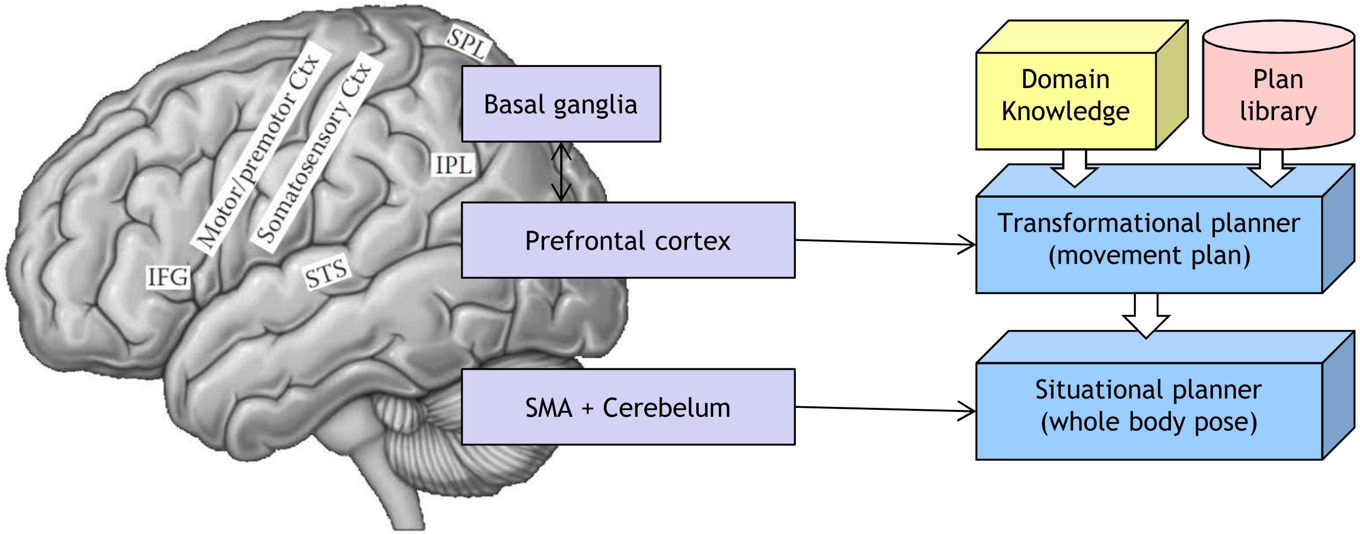

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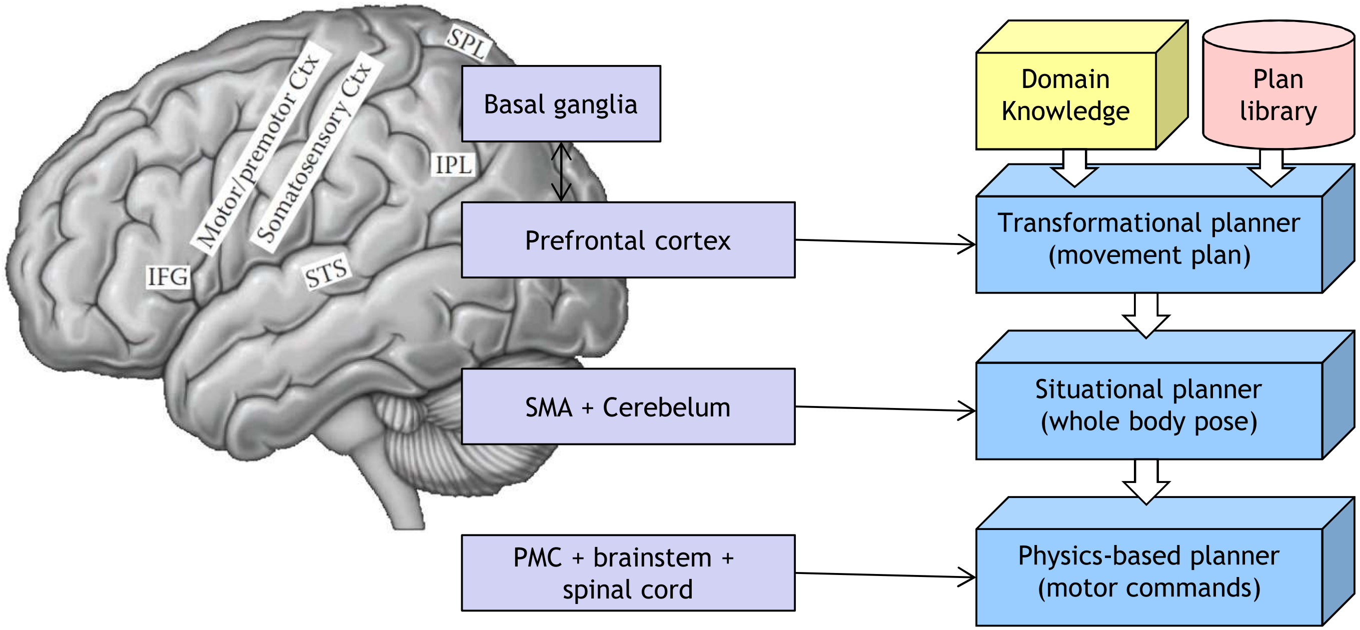

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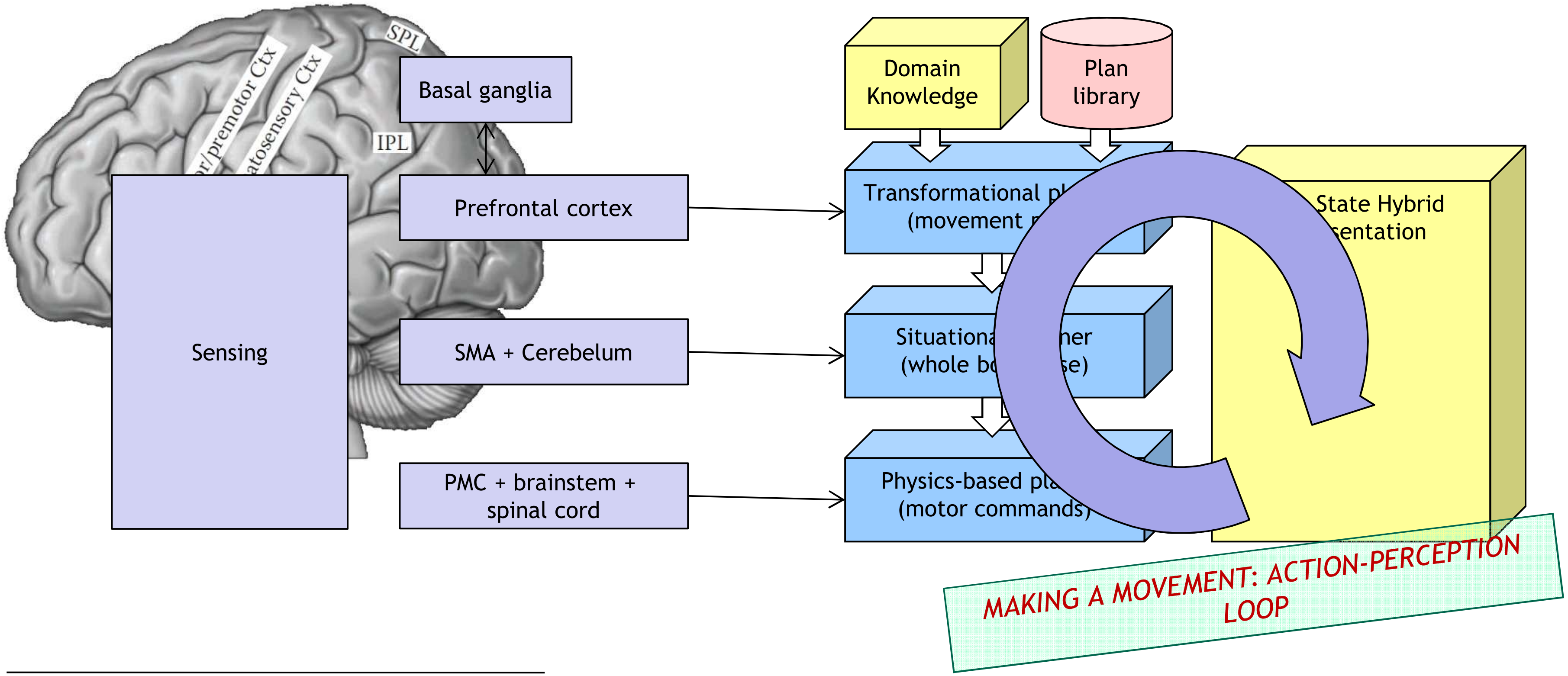
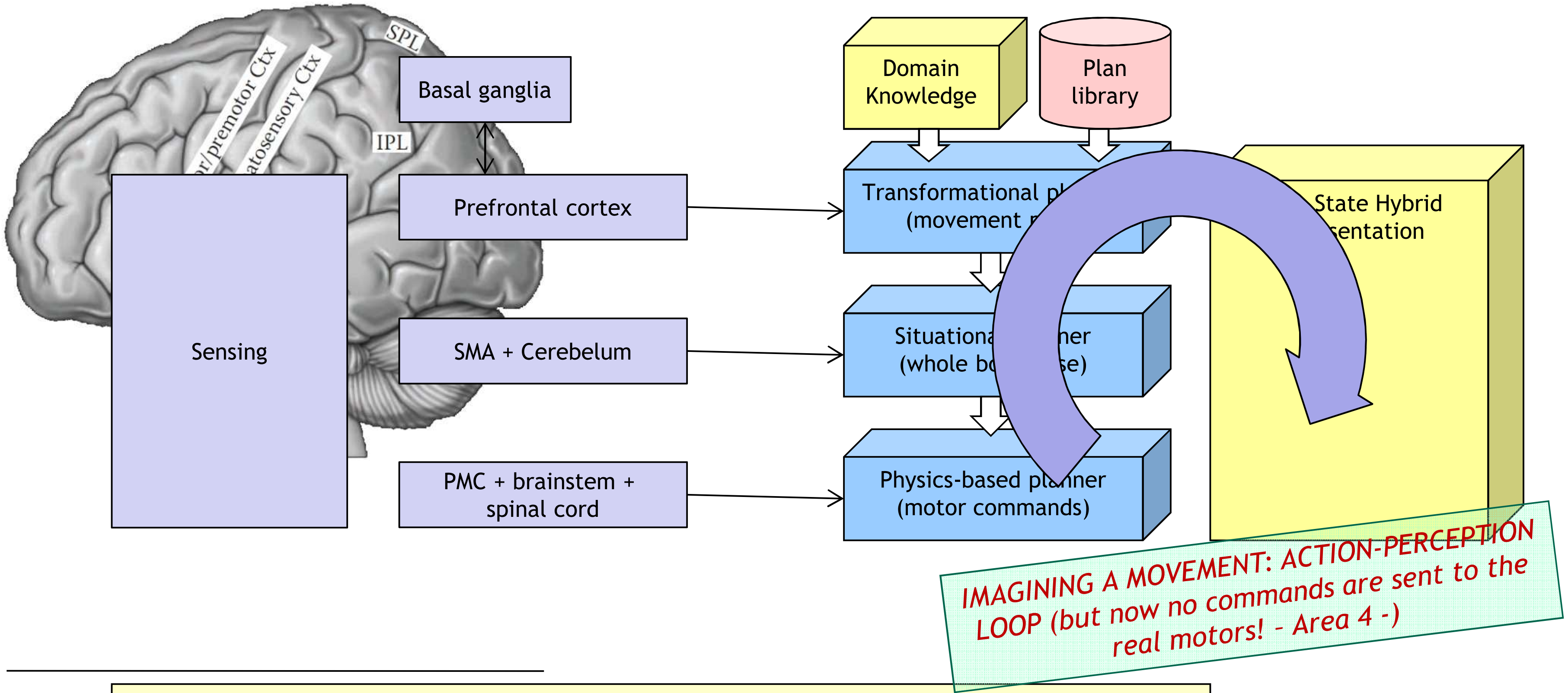


The operation of each hierarchical level in the motor control system is extremely dependent on the sensory information that it receives. It can be considered that the motor system must really be considered in sensorimotor terms.

The simulation theory of cognition Engineering



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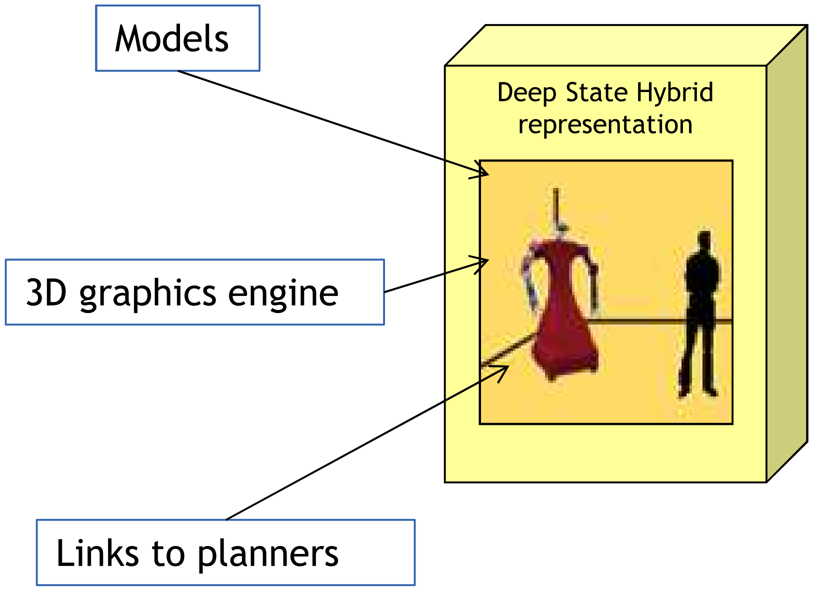
Cognitive architecture Deep State Representation



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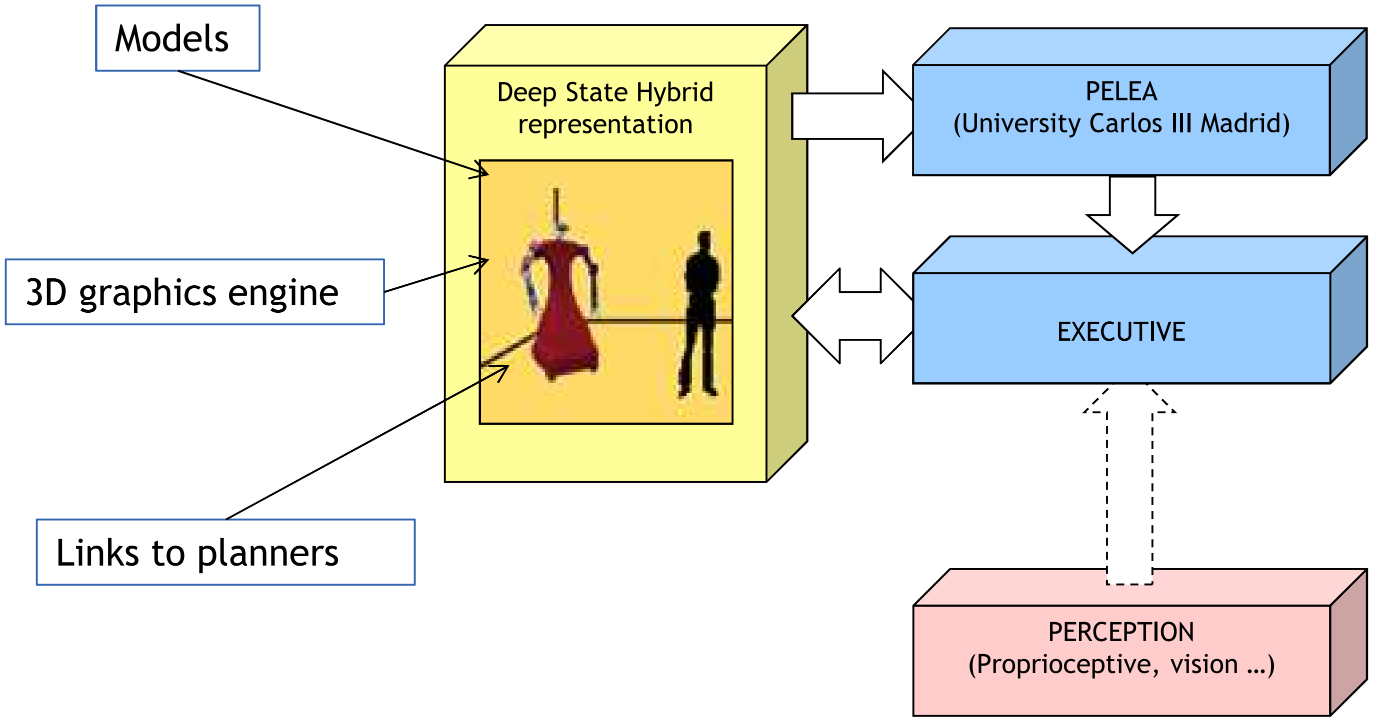
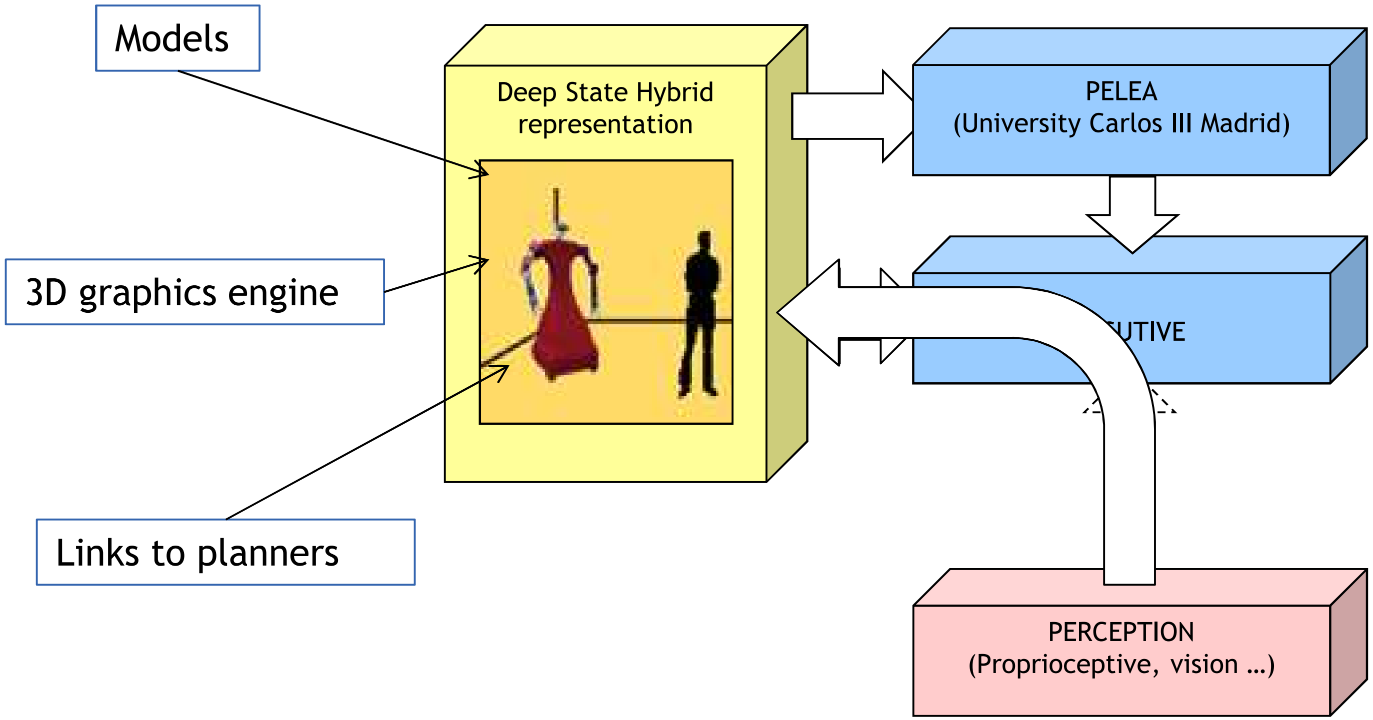
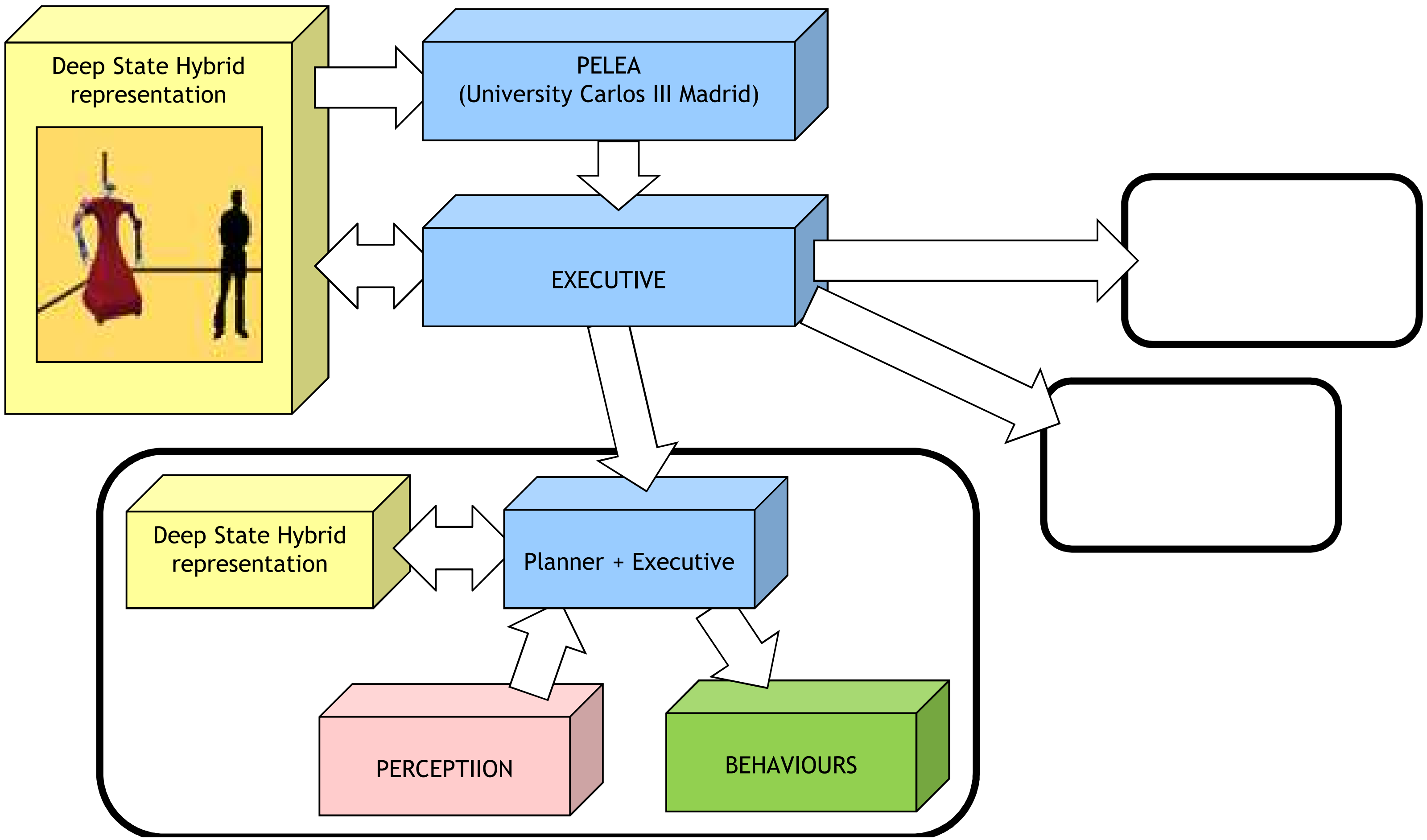


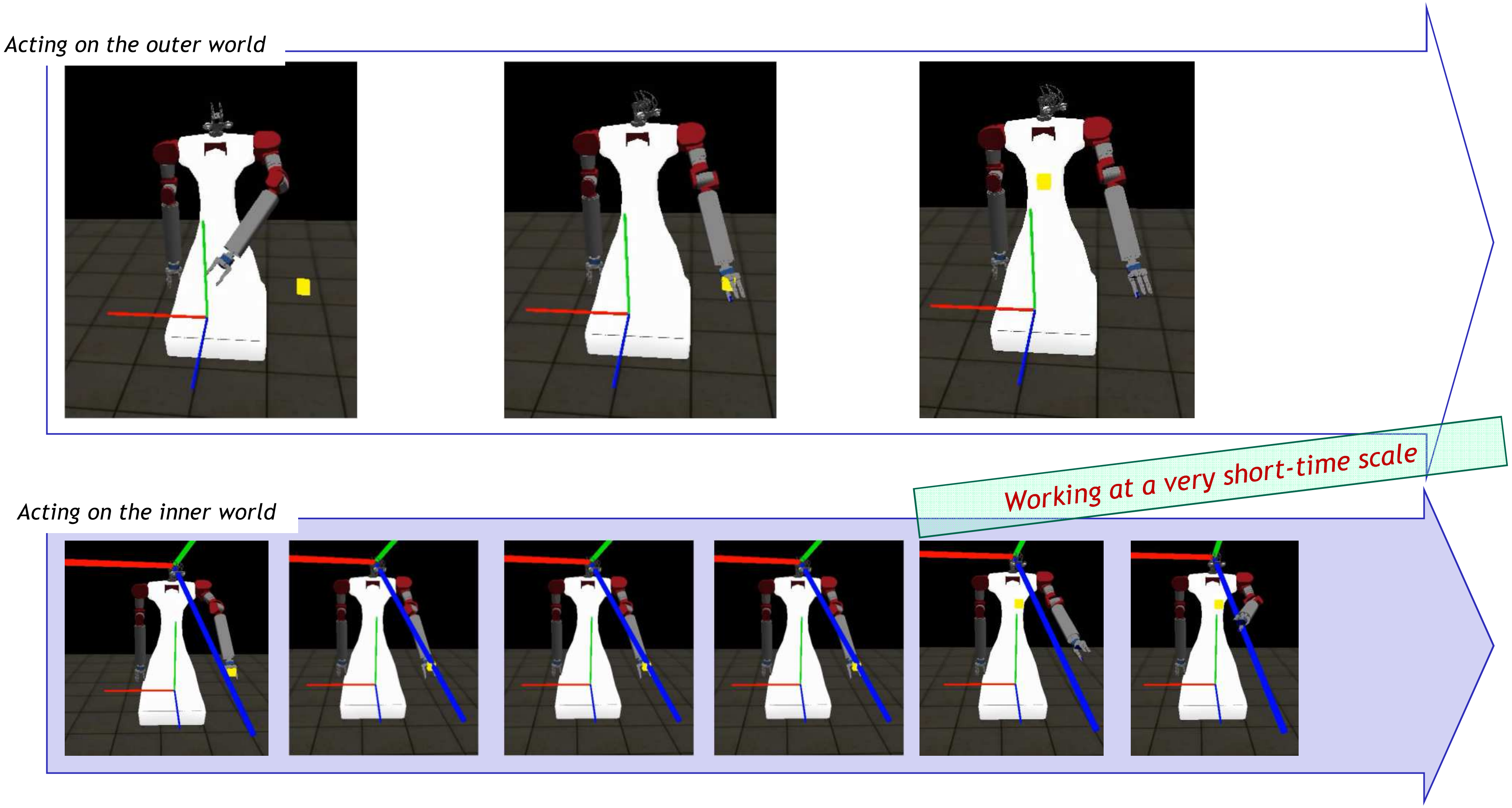
Cognitive architecture Deep State Representation



Cognitive architecture A global view



Cognitive architecture An illustrative example



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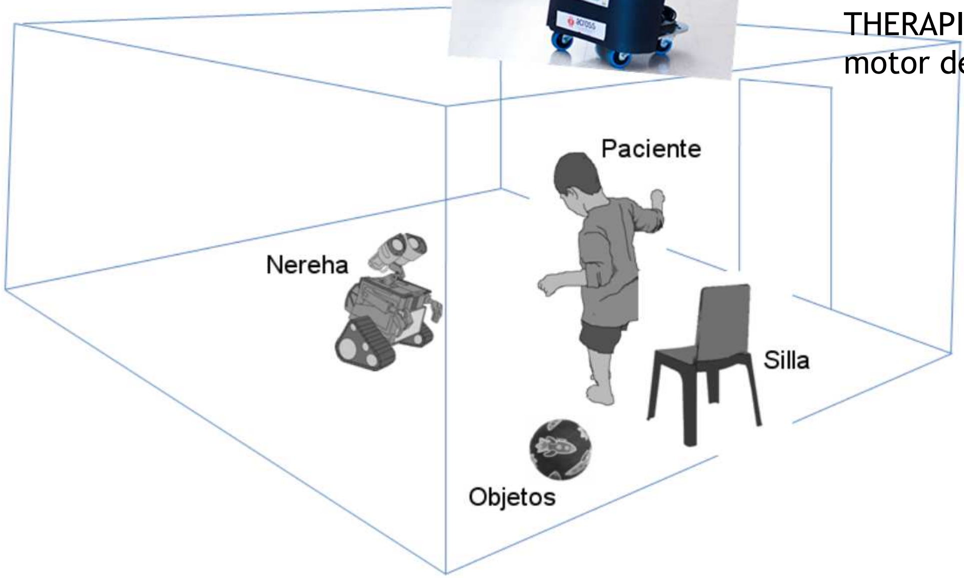
Experimental scenarios Rehabilitation robotics

URSUS, the antecessor of THERAPIST – RoboLab



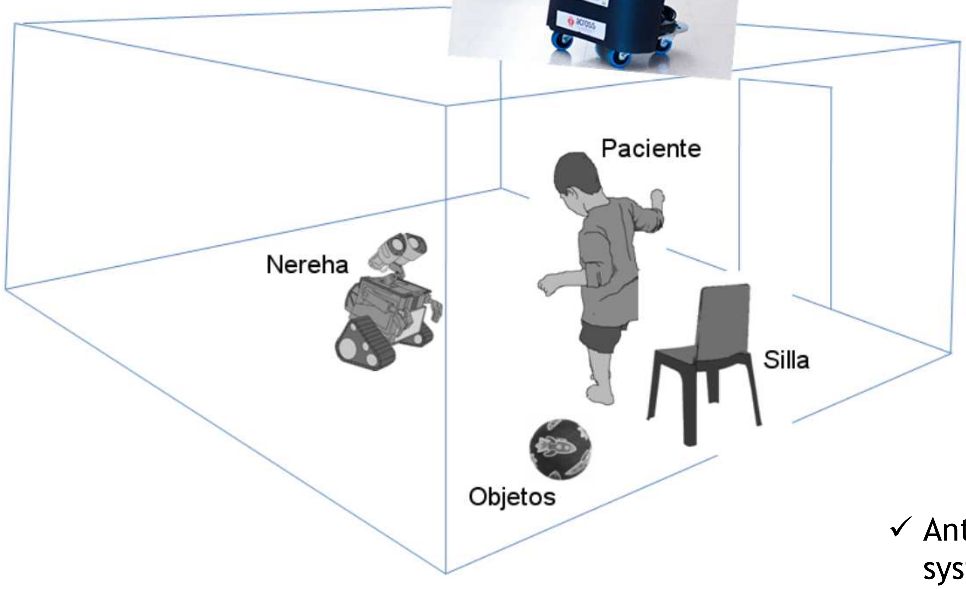
Neuro-rehabilitation therapy pursuits the recovery of damaged neuronal areas and/or muscles from the repetitive practice of certain motor or cognitive activities. The patient's recovery directly depends on the adherence to neuro-rehabilitation therapy.

Within this project, we are working on the definition of new neuro-rehabilitation therapies through the development of THERAPIST, a robot that will perform as an innovative trainer in motor deficit therapies.

Experimental scenarios Rehabilitation robotics

URSUS, the antecessor of THERAPIST – RoboLab

- ✓ In order to engage patients in social interactions, our therapist robot should be able to emanate responses at human interaction rates, and exhibit a *pro-active behaviour*
- ✓ This behaviour implies that the internal architecture of the robot should not only be able to perceive and act. It should also be able to perform *off-line reasoning*.



Perceive the outer world

Update the inner DSR

Simulate an ACTION

Simulate a PERCEPTION

ACT

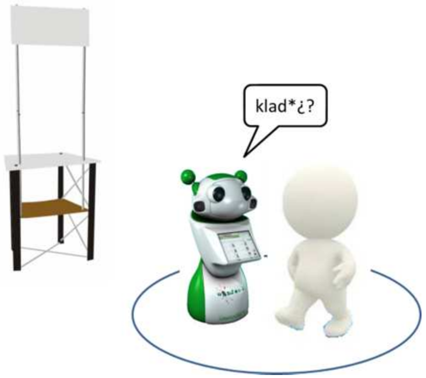
- ✓ Anticipation cancels out the inherent delays of physical systems

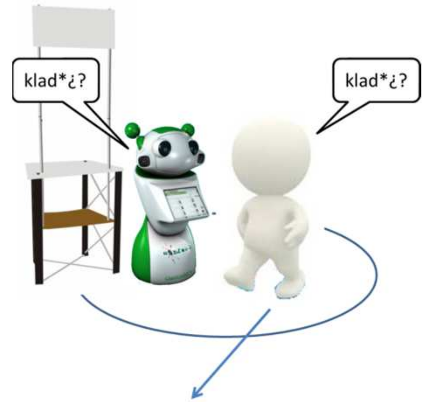
INDRA SOFTWARE LABS

Experimental scenarios Vendor robotics

Working on large environments, the goal of the Adapta project is to use interactive panel to capture the people attention and to show them publicity contents.

Our aim is to incorporate to this scenario a Gualzru, a robot that is able to engage with people through expressions, dialogue, gestures… and that tries to convince pedestrians to come to an interactive stand panel where publicity contents are shown.





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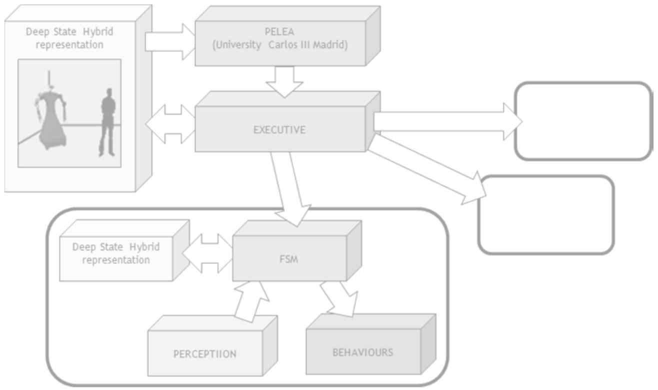
Conclusions and future work



- **Deep state representations** coupled with a hierarchy of planners could provide the necessary structure to implement internal simulation systems

- Further complexity can be achieved with a **self-similar** architecture, where low-level behaviors are themselves organized as a composition of DSR, planners and behaviors. Is there a correspondence in the brain?

- A big challenge is to handle the complexity of **very large** distributed computational systems implementing cognitive architectures. Integration of models of attention for action/perception focusing.

- New design tools working at increasing levels of abstraction are needed, i e. **domain specific languages**, specialized frameworks

- Evaluate the extension of the temporal scale of emulation (to the future an past)

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Thanks for your attention…

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