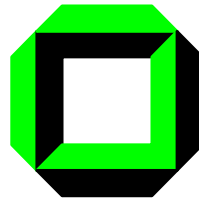# PACO-PLUS (IST-4-27657)

Perception, Action and Cognition through Learning of Object-Action Complexes

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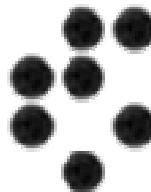Germany
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PACO+: Goal

- ➢ PACO-PLUS aims at the design of cognitive robot system capable of
  - developing perceptual, behavioural and cognitive categories in a self-emergent and a measurable way and
  - communicating and sharing these with humans and other artificial agents

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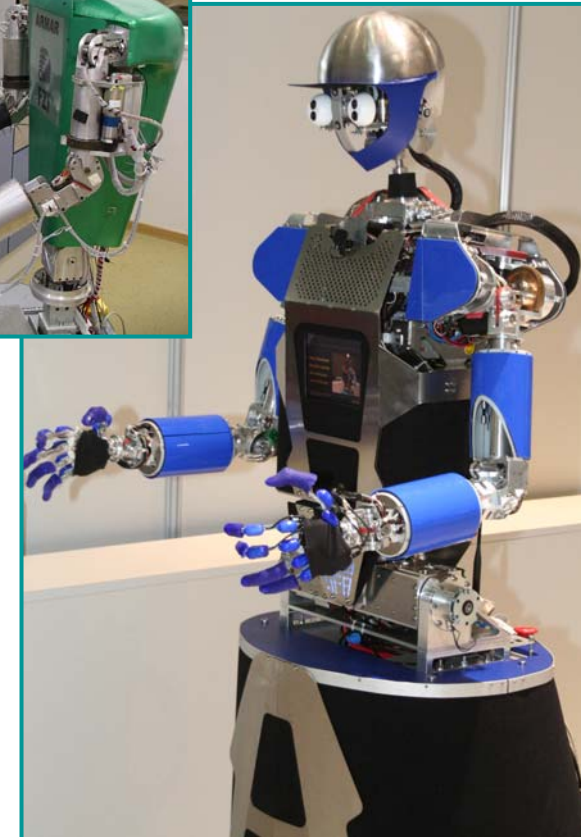
PACO+: Paradigm and guiding principles (1)

➢ Objects and Actions are inseparably intertwined

➢ Categories are determined (and also limited) by the action an agent can perform and by the attributes of the world it can perceive;

➢ the resulting, *so-called* **Object-Action Complexes (OACs)** are the entities on which cognition develops (action centred-cognition)

– Action defines the meaning of an Object

– and Objects suggest Actions

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PACO+: Paradigm and guiding principles (2)

Continuous path to cognition and language

- OACs are categories with inherent semantics
- New OACs through exploration, interaction and learning
- Combination of OACs → higher level of abstraction
- Sharing of the same OACs → mutually grounded symbols → simple language
- Shared symbols → explicit reasoning and communication
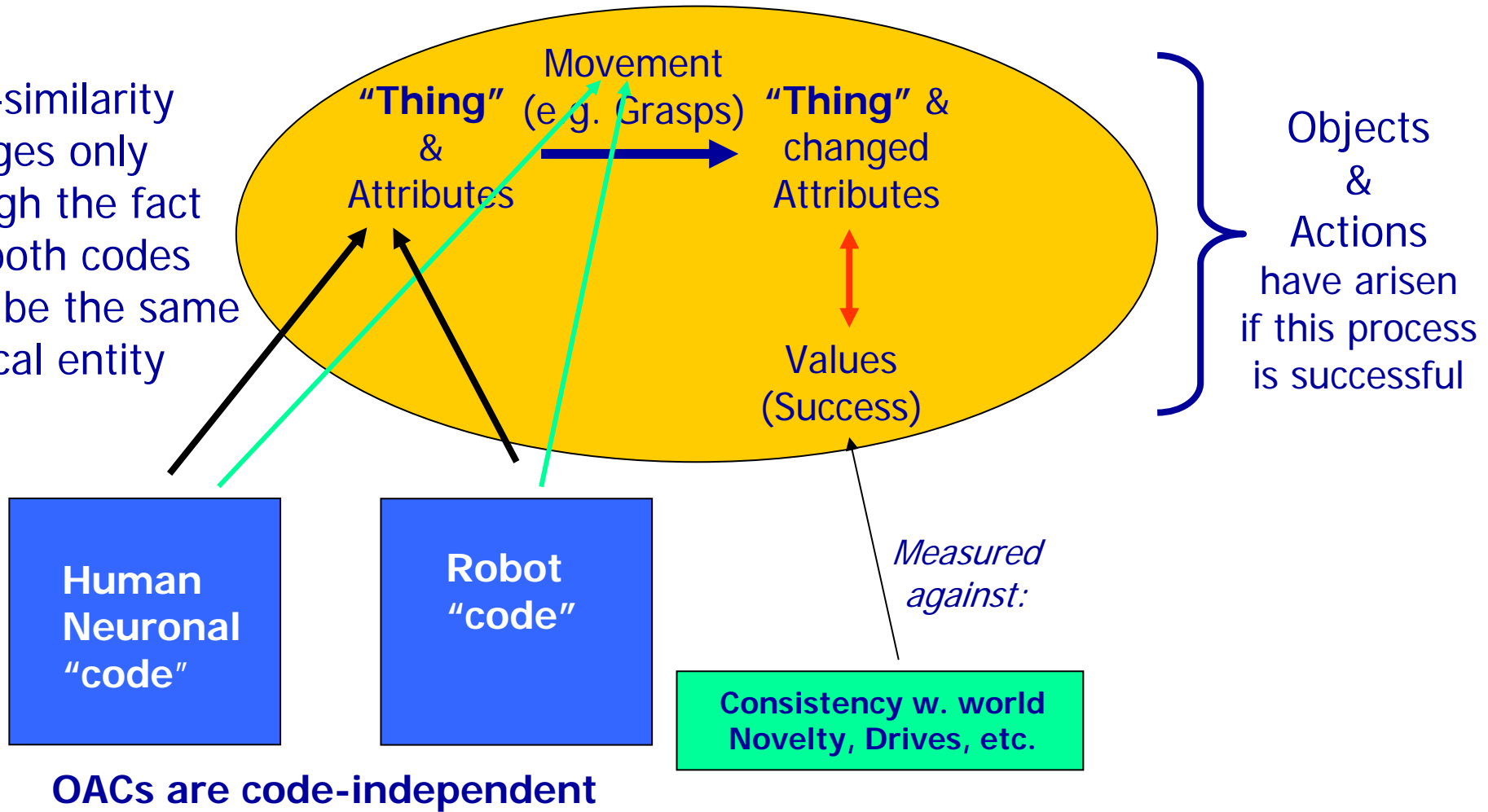
Unified measure of success and progress

- Common evaluation function for contingency minimization and reward maximization strategies
- Theoretical framework for the design of a conjoint measure for learning success

What is an OAC ?

Code-similarity emerges only through the fact that both codes describe the same physical entity

Movement (e.g. Grasps)

"Thing" & Attributes

"Thing" & changed Attributes

Values (Success)

Objects & Actions have arisen if this process is successful

Human Neuronal "code"

Robot "code"

Measured against:

Consistency w. world Novelty, Drives, etc.

OACs are code-independent

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Action centred object categorization

➤ **Visually based object recognition fails**

➤ **Visual information is sparse and limited**

➤ **Activity involving the object decreases the uncertainty about the object's nature considerably!**
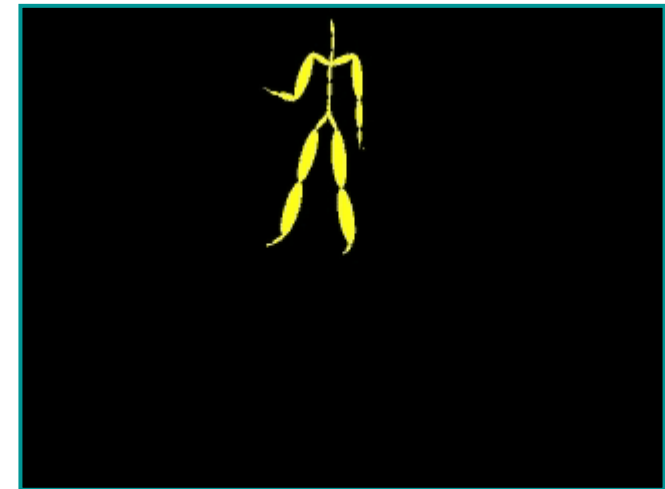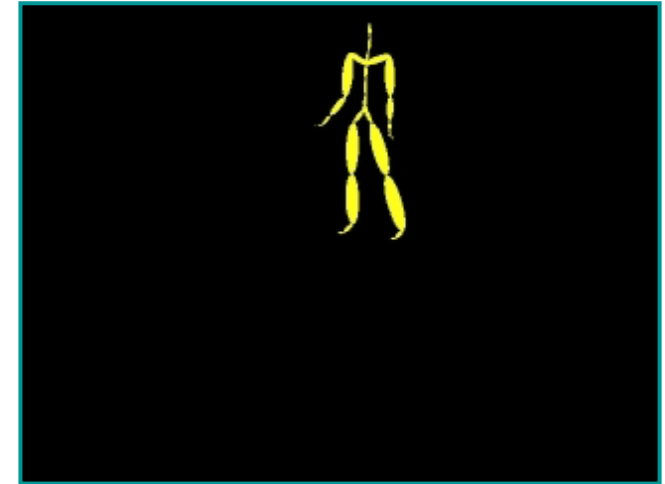
CMU Graphics Lab Motion Capture Database
http://mocap.cs.cmu.edu/

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This is another OAC

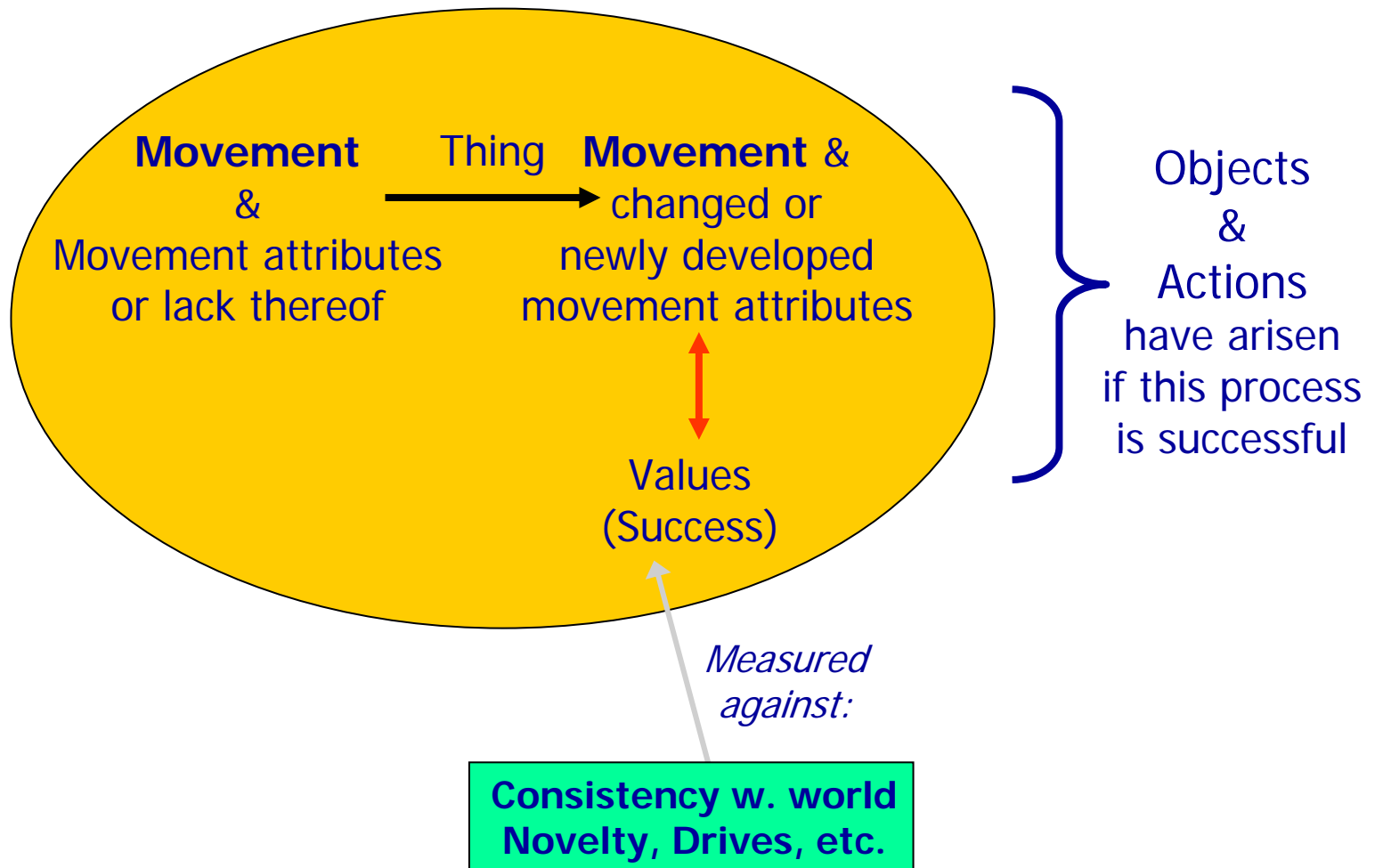**Movement**   Thing   **Movement** &
&
Movement attributes   changed or
or lack thereof   newly developed
    movement attributes

Values
(Success)

Objects
&
Actions
have arisen
if this process
is successful

*Measured
against:*

**Consistency w. world
Novelty, Drives, etc.**

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More Examples

Object Perspective

tilting

Container (full) → Container (empty)

Success?

Consistency w. world Novelty, Drives, etc.

Action Perspective

Grip — Pen → Pinch Grip

Success?

Consistency w. world Novelty, Drives, etc.

Grip — Can → Power Grip

Success?

Consistency w. world Novelty, Drives, etc.

Task Perspective

"drink"

Grip — Cup → Handle Grip

Success?

Consistency w. world Novelty, Drives, etc.

"slam on table"

Grip — Cup → From-top Grip

Success?

Consistency w. world Novelty, Drives, etc.
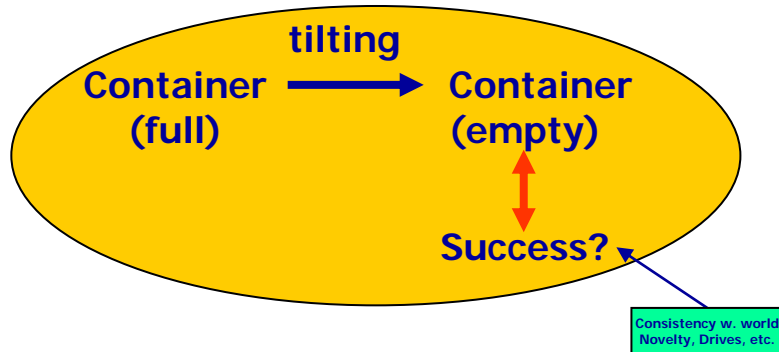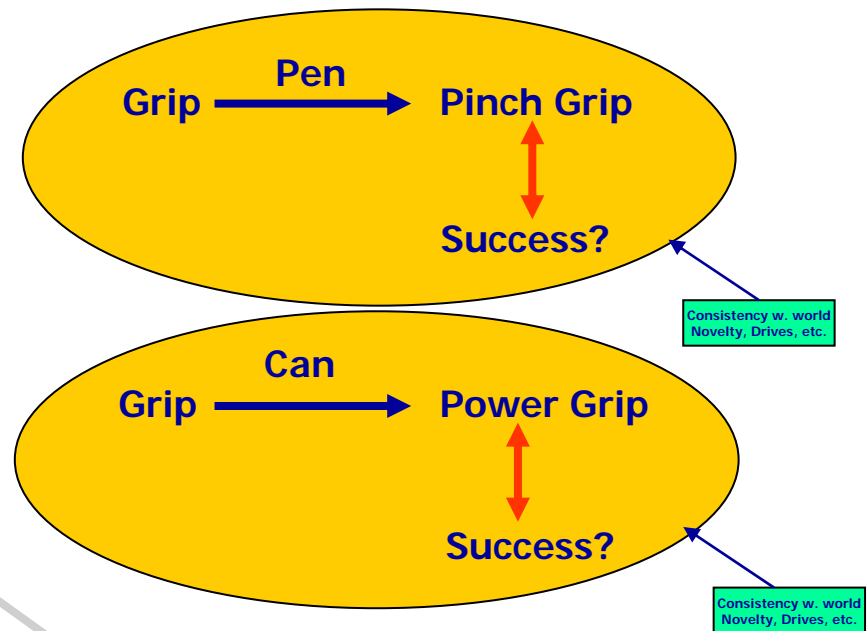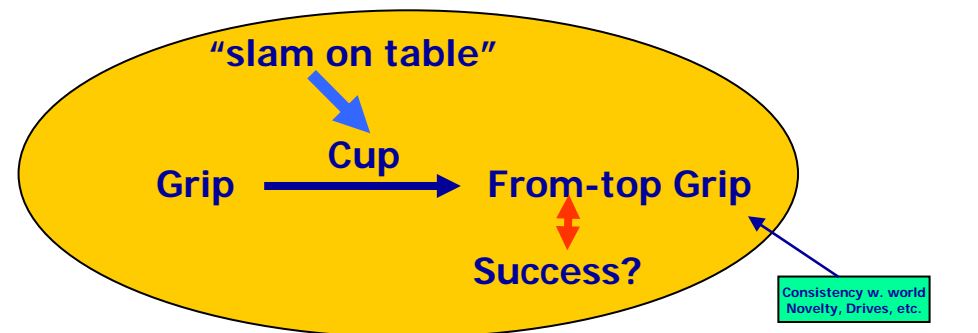
Algorithmic Framework & Architecture

Sensor Rep. of "Things"

Haptic, (Eco)-vision, MRF for neighb. relations, auditory

Motor Rep. of Actions

Stoch. Gram. → PAT —**DBN**→ Rep. Tree

Sensor Rep. of Actions

alignment

Align. Action Rep.

Kin. and dyn. motor Learning

Particle Filtering for prob. density estimation

Partly predefined + chance explorations

Guided explorations

Interaction & Communication

Learning & Predictions

Early OACs

LDEC & CCG

Learning & Predictions

OACs

LDEC & Multimodal dist.

Dec. making & Planning

OAC Categor.

Reinf. Learning
Corr. based Learning
Augmented Actor-Critics

Emergence through feedback

Stochastic state estimation techniques

Common Evaluation Function:
for strategy selection: reward max. vs. contingency min.

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Theoretical Framework

Theory of Event Coding (TEC)	Computational Theory of Mind	Language	Theory of Learning
Hommel et al. 2001 BBS	Putnam, 1961; Dennett 1984, Porr & Wörgötter 2005	Quine 1960, Siskind 1996, Villavicencio 2002 Steedman 2002	Camerer 2003 Torras 2002, Porr & Wörgötter 2003
Shared code for perception and action exists.	Solving the Frame Problem by *embodied, situated, adaptive* agents reacting to disturbances in the environment in a *proactive, anticipatory* way.	Language learning is easy. Developing the concepts that underlie it is hard.	Convergent learning arises from minimization of contingencies together with the maximization of return.
OACs: Technical version of TEC	Richly integrated robotics platform(s) process a continuum of multiple stimuli while producing meaningful behaviour	OACs will constitute shared and grounded symbols as the basis of language	Conjoint evaluation function for success of the system

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Scenario

➢ **Exploration and manipulation of a limited set of objects in a human centred environment**

– Multi-sensory and action centred object representations

– Categorising objects and recognition in terms of the actions performed on them

➢ **Imitation of human actions (on objects)**

– Learning what to imitate ➔ which aspect of an object is important

– Learning how to imitate ➔ understanding of human actions on objects

➢ **Robot coaching in the context of an integrated action-language system**

– OAC based grammar as the basis for a robot coaching system

– Communication through direct demonstration and/or verbal instructions

– Coach specifies goals and priorities, to focus attention of the learning agent, and to give feedback such as correction strategies, evaluation and success definition.

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Scenario

Cooking Scenario

Objects & Attributes → Actions (e.g. Grasps) → Objects & changed Attributes

Subproblem

Container Handling

Values (Success)

Cutting
Cucumber (whole) → Cucumber (Pieces)

"nice" Slices?

New Objects!?

| OACs from Exploration | Neuronal Learning | Grounded Symbols | Body Ego explore | Grasping + else ? |
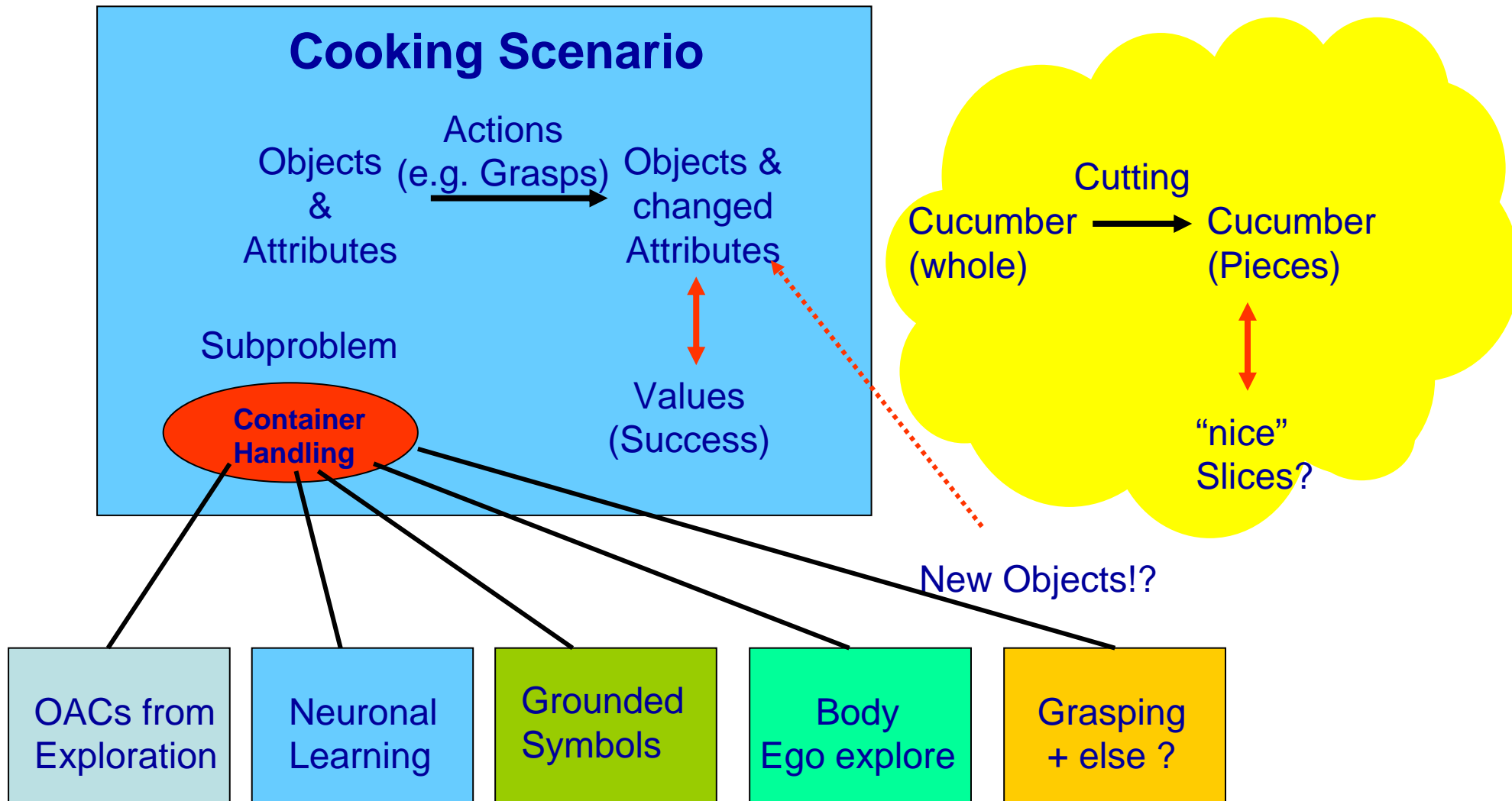
Available Humanoid Demonstrators

- 2 Humanoid robots
  - 7 DOF neck/head
  - 7-DOF arms
  - 3-DOF torso
  - Mobile platform
- Active heads
  - 2 colour cameras per eye (3 DOF)
  - 6 Microphones
- Anthropomorphic 5-Finger hands
  - 8 DOF
  - Weight: 395 g
  - Force (Finger tip: 7 N, Holding force: 35 N)
  - RS 232/Bluetooth
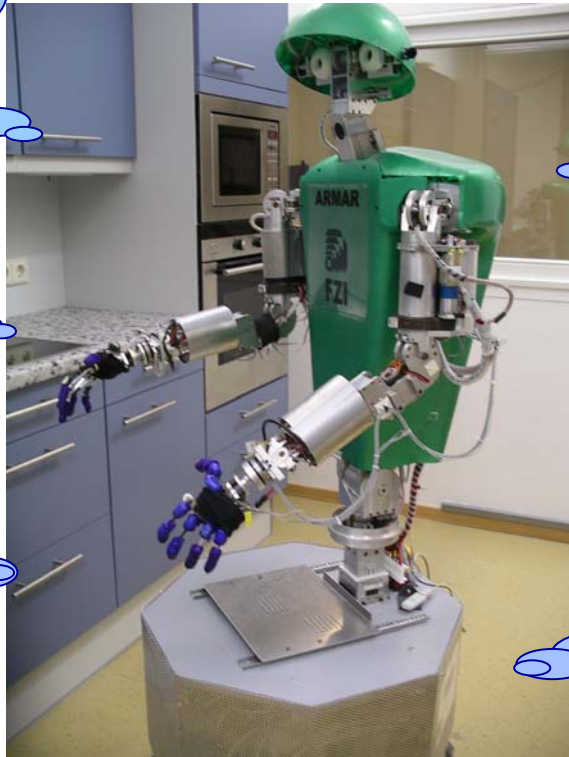 - Data glove with 14 tactile sensors (RS232/Bluetooth)

www.sfb588.uni-karlsruhe.de

PACO PLUS: Key Research Activities

Representation of "things" and actions

How OACs arise?

Novelty: How OACs evolve?
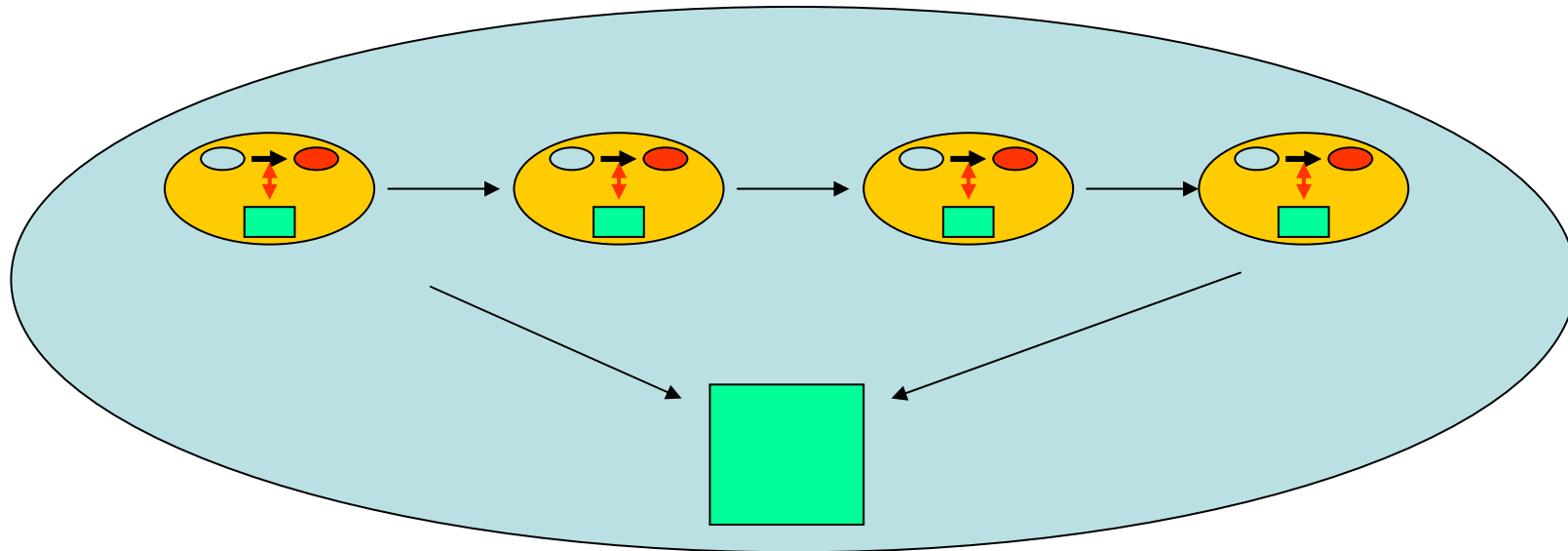
Language, Communication and Interaction

Memorization and Learning

Decision Making and Planning

Cognitive Robotics System: Integration and Architecture

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Thank you

➤ ... for your attention

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