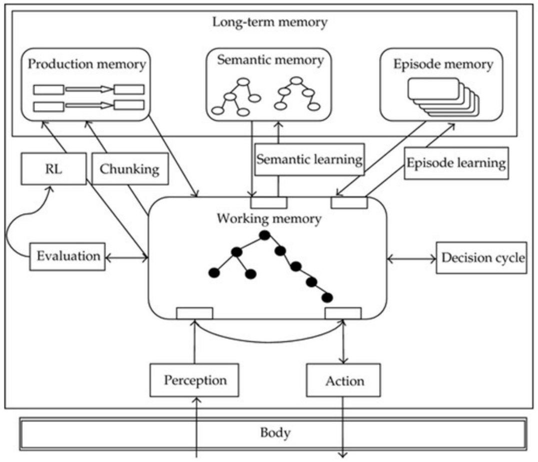
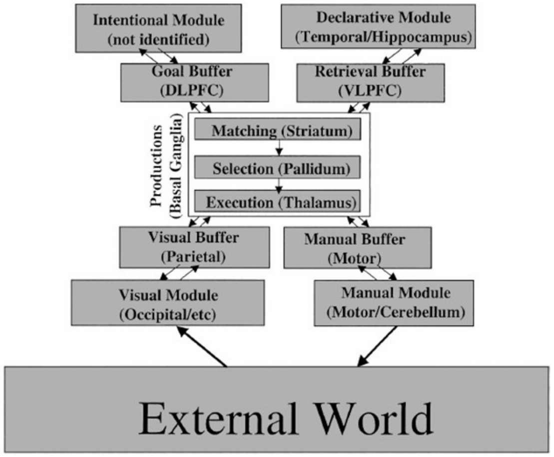
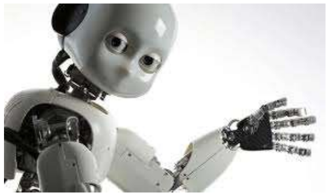
Cognitive Robotics

- Cognitive Robotics
  - Embodied AI/Embodied CS
    - Robot capable of perception, reasoning, learning, deliberation, planning, acting, interacting, etc.
  - Cognitive Architecture
    - Unified Theory of Cognition
    - Cognitive Models







Cognitive Systems and Robotics

- Since 2001: Cognitive Systems intensely funded by the EU "Robots need to be more robust, context-aware and easy-to-use. Endowing them with advanced learning, cognitive and reasoning capabilities will help them adapt to changing situations, and to carry out tasks intelligently with people"

Research Areas

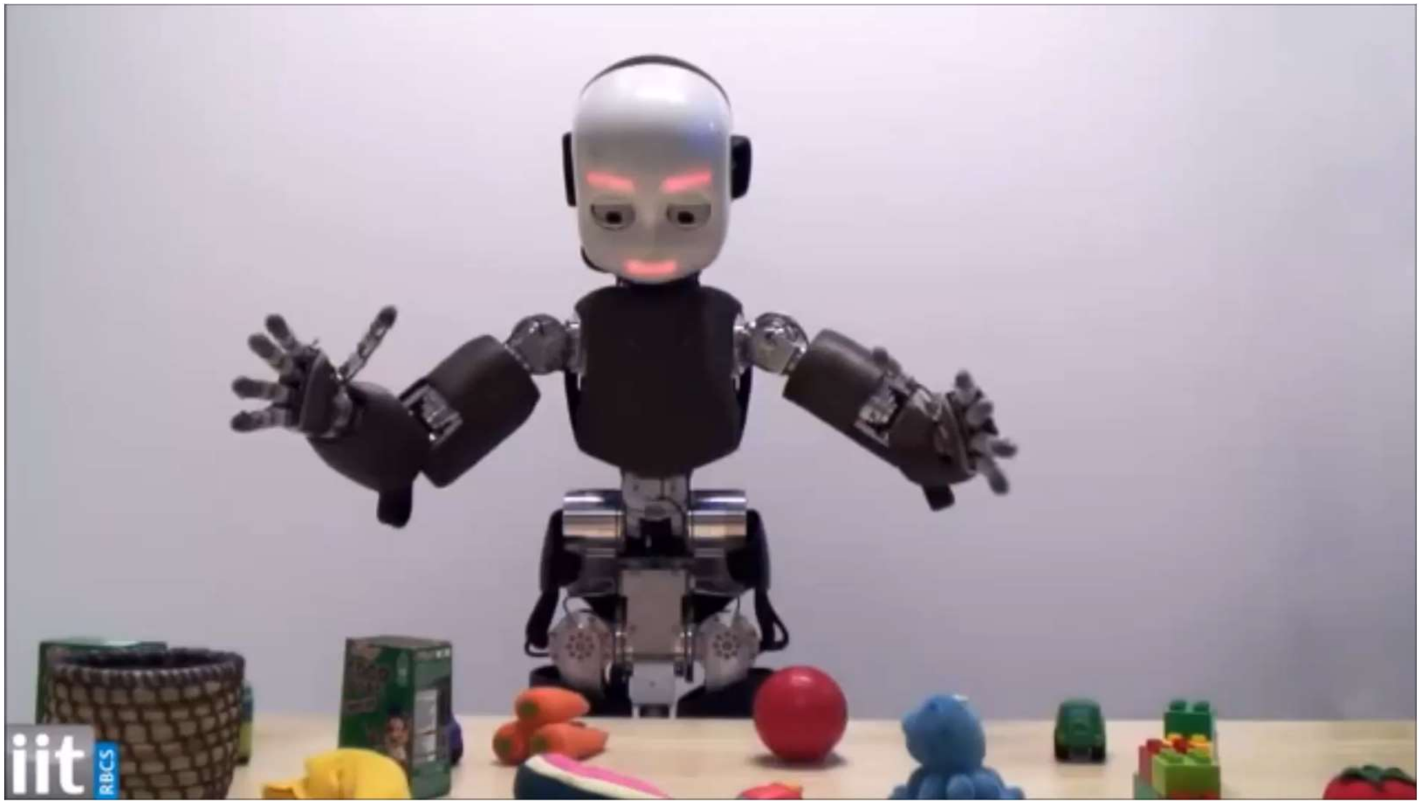
- Biorobotics
  - Bio-inspirata, biomimetica, etc.
- Enactive Robotics
  - Dynamic interaction with the environment
- Developmental Robotics (Epigenetic)
  - Robot learns as a baby
  - Incremental sensorimotor and cognitive ability [Piaget]
- Neuro-Robotics
  - Models from cognitive neuroscience
  - Prosthesis, wearable systems, BCI, etc.

icub

Cog

Developmental Robotics

- iCub Platform
  - Italian Institute of Technology
  - EU project RobotCub: *open source cognitive humanoid platf.*



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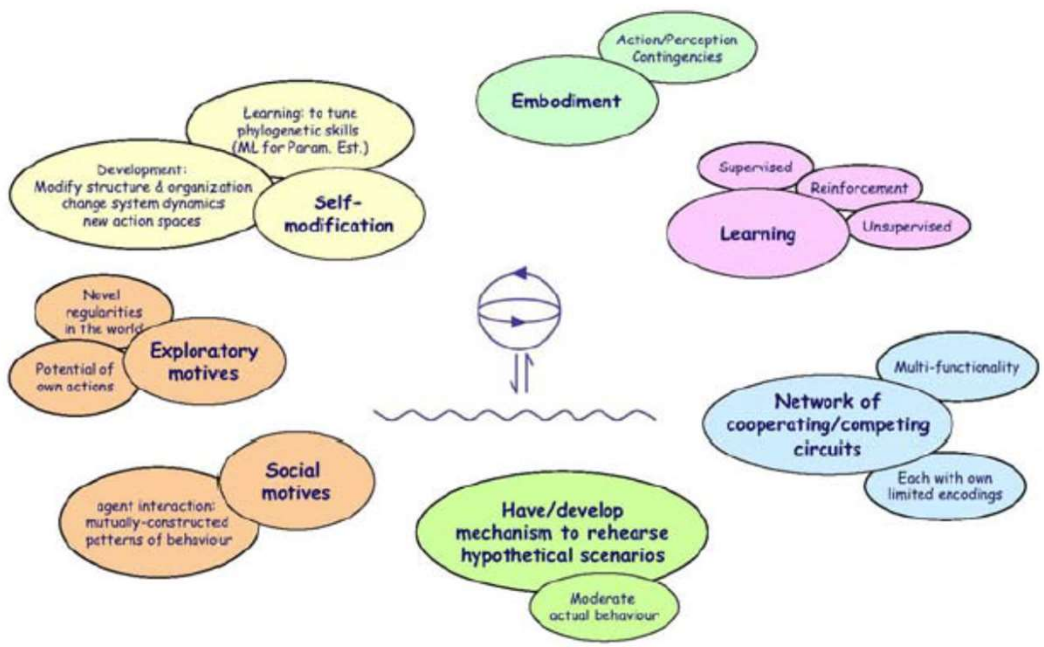
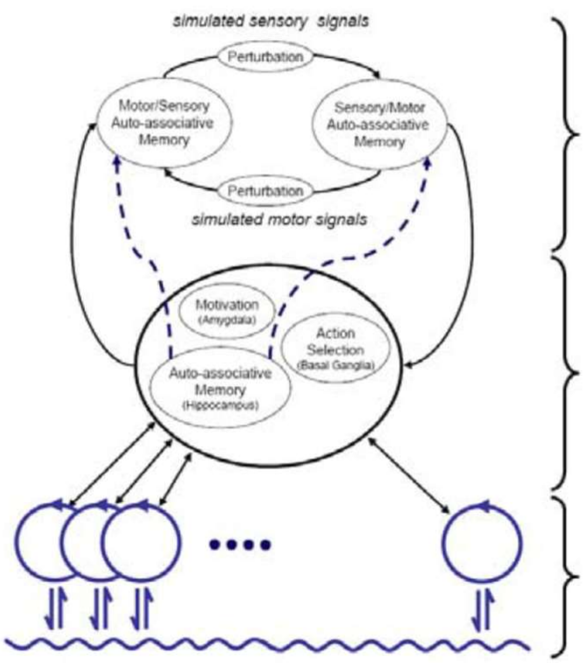


Developmental Robotics

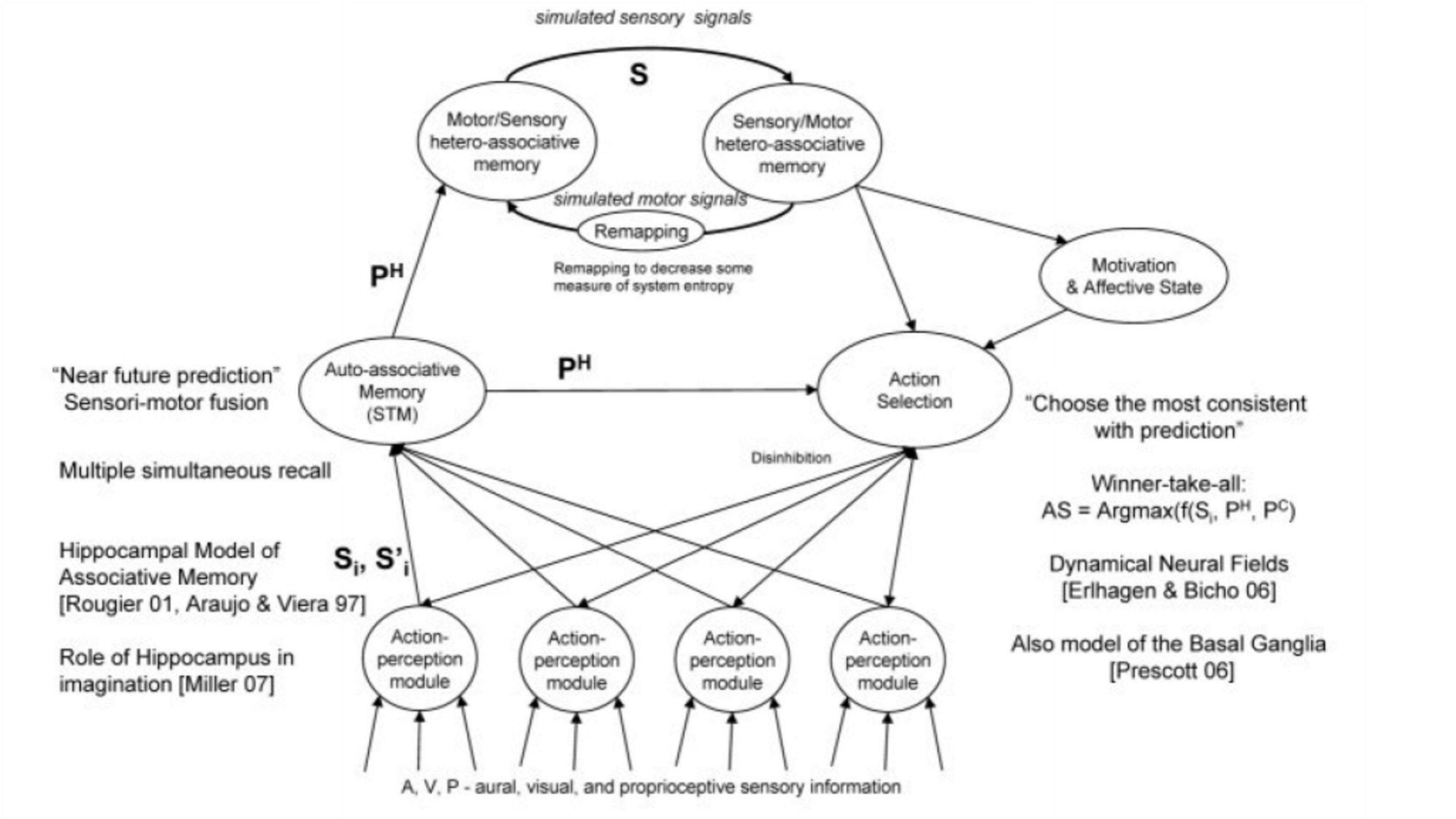
- iCub Platform



Scenario Capabilities: cognitive perception/action behaviours
Object tracking through occlusion (smooth pursuit & saccades)
Learn to coordinate VOR & tracking
Learn to reach towards a fixation point
Attention and action selection by modulation of capabilities
Conditional modulation based on anticipation
Construct sensorimotor maps & cross-modal maps
Learn by demonstration (crawling & constrained reaching)
Exploratory, curiousity-driven, action
Experience-based action selection based on interaction histories
Navigate based on local landmarks and ego-centric representations
Quasi-independent Phylogenetic Capabilities
Saccadic re-direction of gaze towards salient multi-modal events
Focus attention and direct gaze on human faces
Ocular modulation of head pose to centre eye gaze
Move the hand(s) towards the centre of the visual field
Stabilize & integrate of saccadic percepts
Stabilize gaze with respect to self-motion (VOR)
Create attention-grabbing stimuli
Gait control
Component Capabilities
Compute optical flow
Compute visual motion with ego-motion compensation
Segmentation of the flow-field based on similarity of flow parameters
Segmentation based on the presence of a temporally-persistent boundary
Fixation and vergence
Gaze control: smooth pursuit with prediction; possibly tuned by learning
Classification of groups of entities based on low numbers
Classification of groups of entities based on gross quantity
Detection of mutual gaze
Detection of biological motion

Developmental Robotics

- iCub Platform

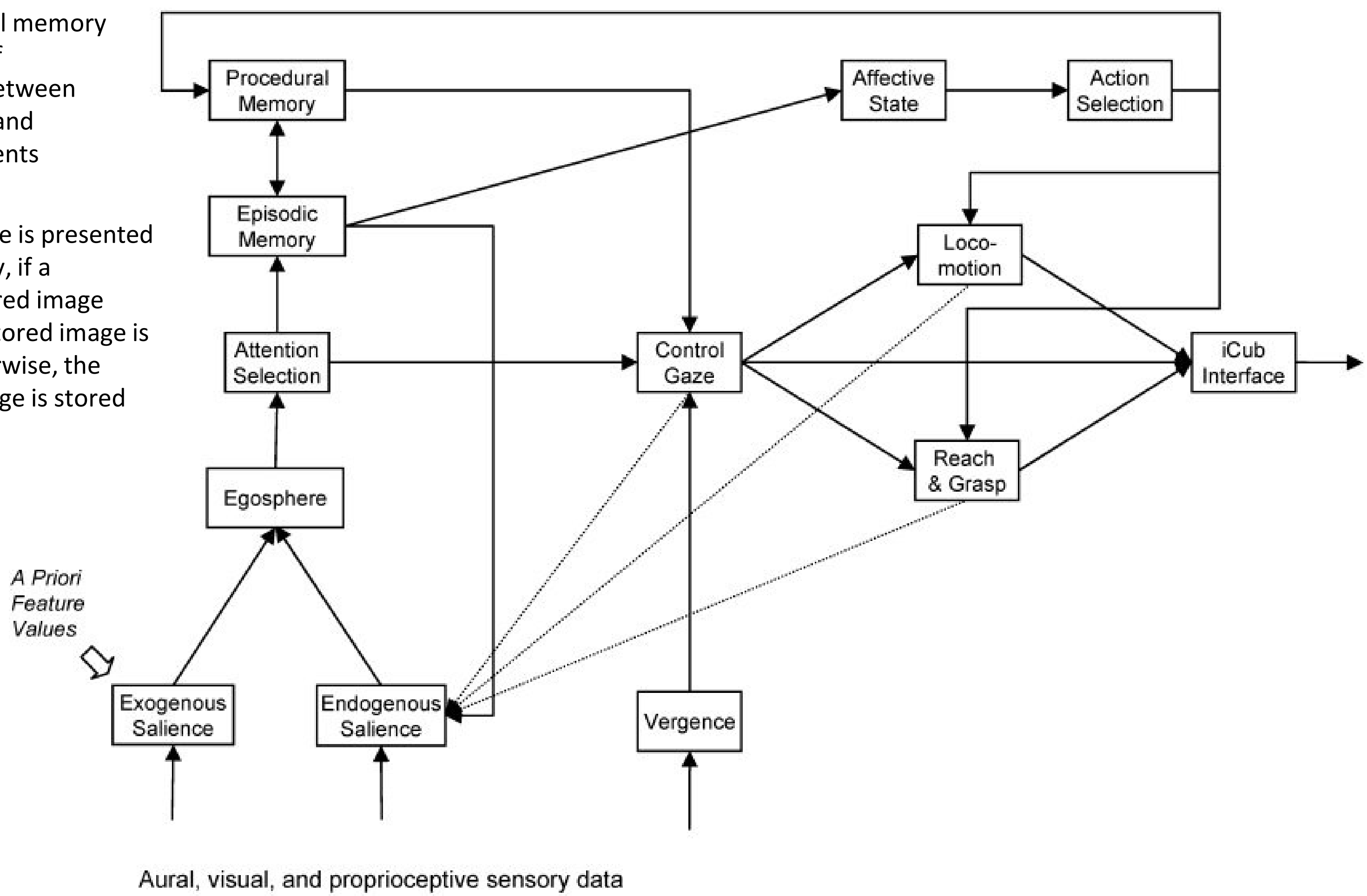


Developmental Robotics

- Cognitive Architecture:

The procedural memory is a network of associations between action events and perception events

When an image is presented to the memory, if a previously stored image matches the stored image is recalled; otherwise, the presented image is stored



Affordance

- **Affordance:** property of an object or a feature of the immediate environment, that indicates how to interface with that object or feature ("action possibilities" latent in the environment [Gibson 1966])
  - “The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill. The verb to afford is found in the dictionary, but the noun affordance is not. I have made it up. I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment.”
  - Interaction design (*The Design of Everyday Things* [Norman 1988]): concept of affordance subjective rather than objective
  - Developmental psychology:
    - Means-end behaviors, predicting effects and imitation
  - Robotics: exploration, learning, grasping [Jamone et al. 2016]
    - Learning affordance, perception of affordance

Affordance

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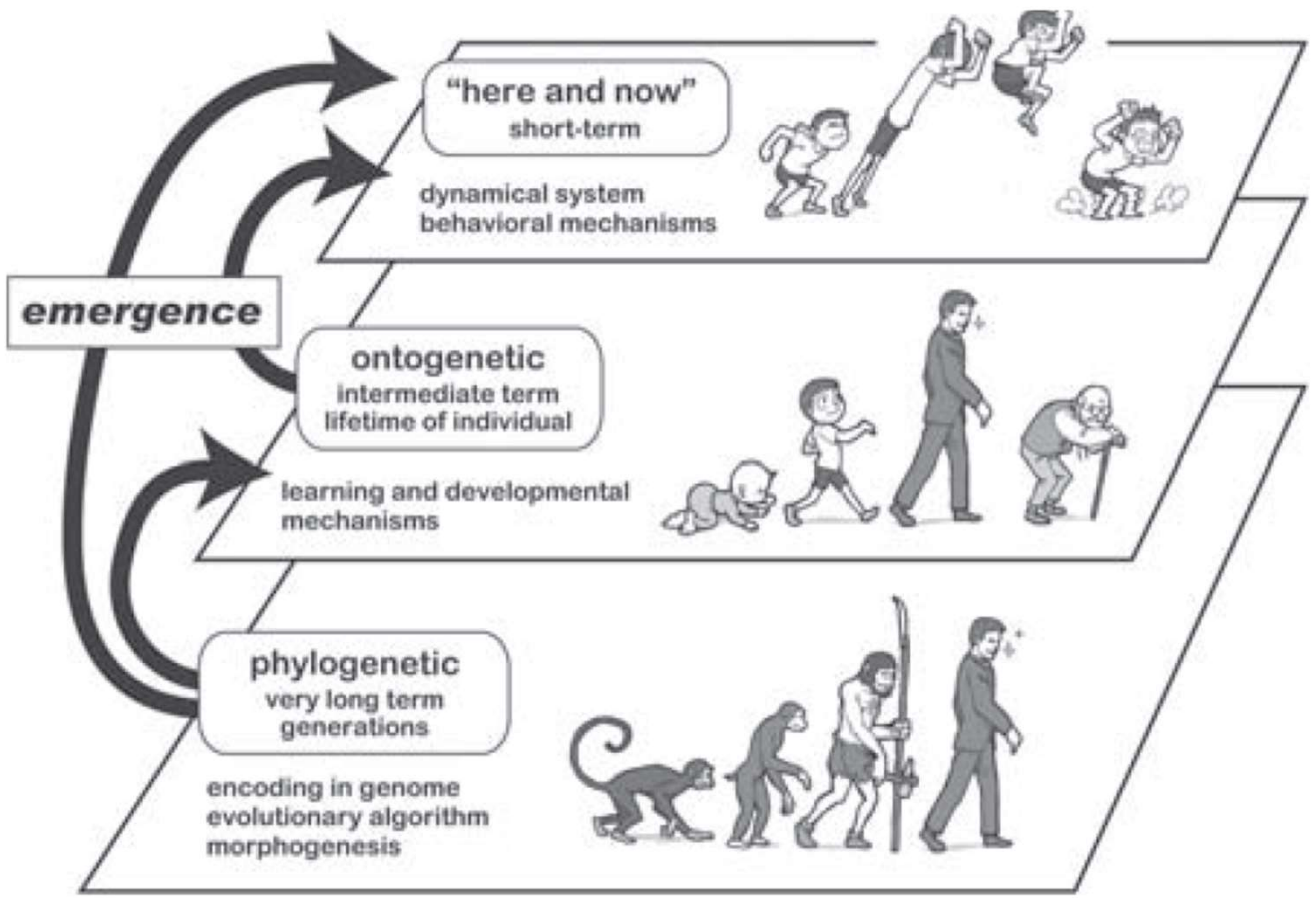
    - Learning affordance, perception of affordance

Developmental Robotics

- JST ERATO Asada Synergistic Intelligence Project:
  - Child-robot with Biomimetic Body [Asada et al. 2006]

Evolution, Development, Learning

- Phylogeny Ontogenesis



Rolf Pfeifer and Josh Bongard

Research Areas

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icub

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Cog

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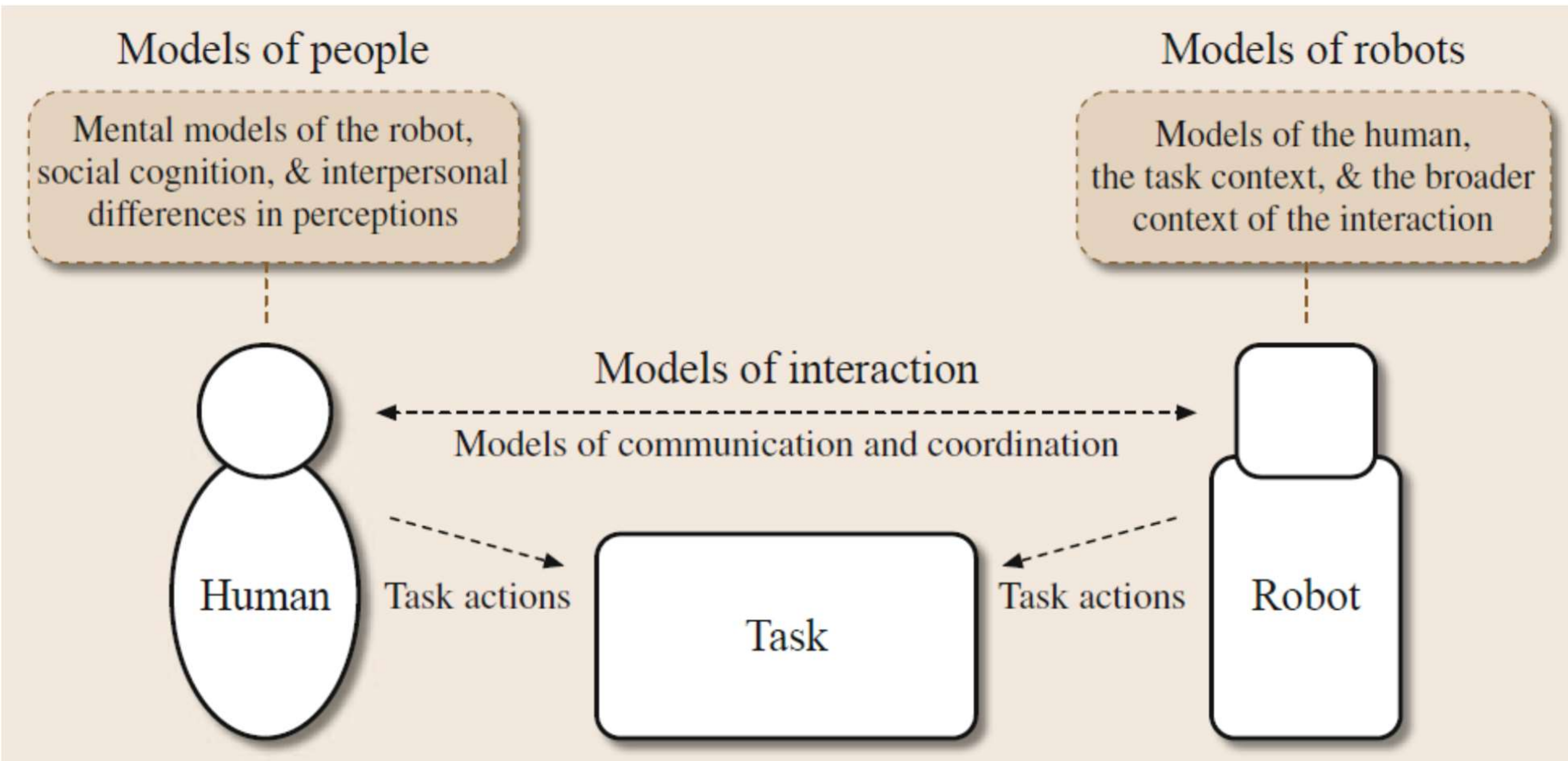
Cognitive Science as Enabler Cognitive Robotics

- Hypothesis:
  - A system using human-like representations and processes will enable better collaboration with people than a computational system that does not
    - Similar representations and reasoning mechanisms make it easier for humans to work with the system; more compatible
  - For close collaboration, systems should act "naturally"
    - i.e. not do something or say something in a way that detracts from the interaction/collaboration with the human
    - Robot should accommodate humans; not other way around
  - Solving tasks from "first principles"
    - Humans are good at solving some tasks; let's leverage human's ability

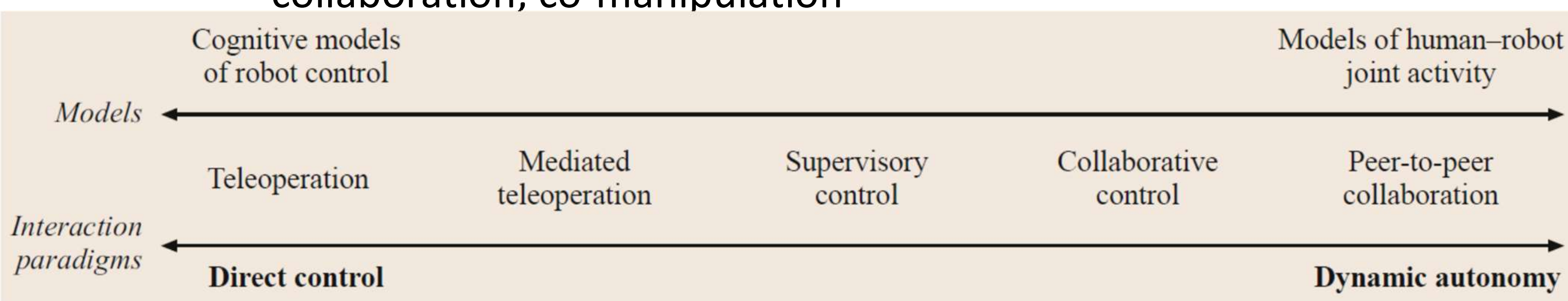
Cognitive Robotics and HRI

- Human-Robot Interaction as a uniform Cognitive System
  - Human models, Robot models, interaction models



Cognitive Robotics and HRI

- Interaction type:
  - Physical, Cognitive, Social
  - Proximity:
    - Same place, different place
  - Critical:
    - Search and Recue, Service, Entertainment, etc.
  - Autonomy:
    - Teleoperation, supervision, interaction, coordination, collaboration, co-manipulation



Human-Robot Interaction

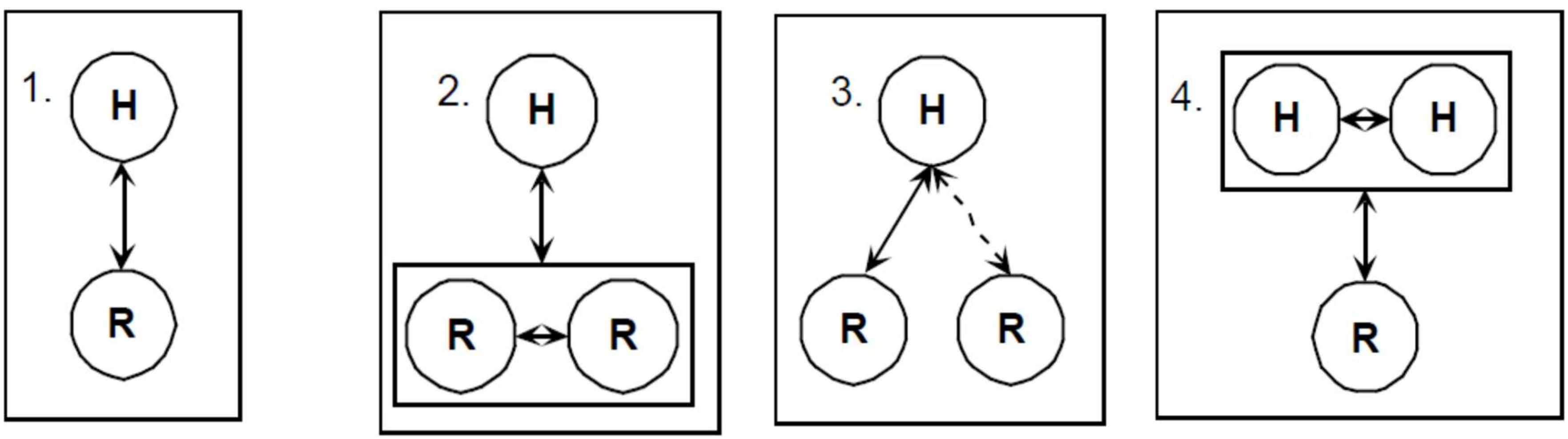
- Specific features:
  - Physical/cognitive interaction with embodied intelligence
  - Social relation between humans and robots
  - Complex, dynamic, unpredictable environment/human

Taxonomies in HRI

- Physical vs. Cognitive
- Co-located vs. Remote
- Team configurations [Yanco2002]

Taxonomies in HRI

- Team configurations [Yanco2002]

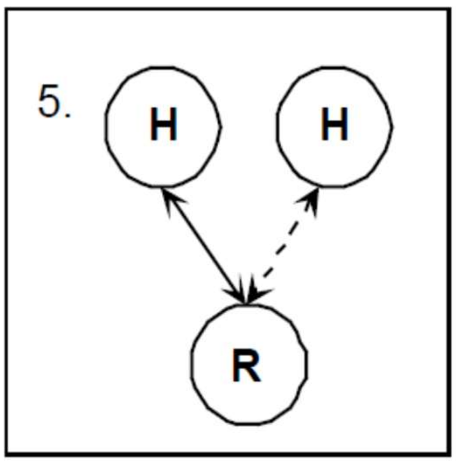


Human-Robot | Human-Team | Human-Robots | Robot-Team

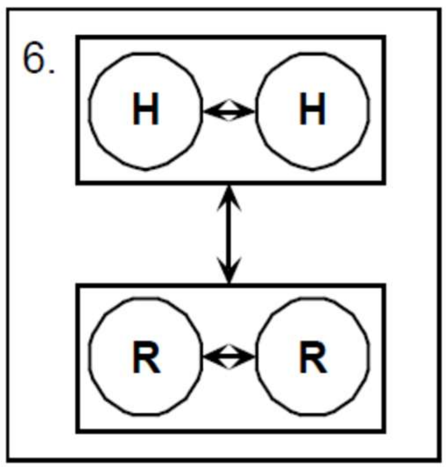
HUMAN-ROBOT-RATIO
ROBOT-TEAM-COMPOSITION
(homogeneous/heterogeneous)
ROBOT-MORPHOLOGY
(anthropomorphic,zoomorphic,functional)

Taxonomies in HRI

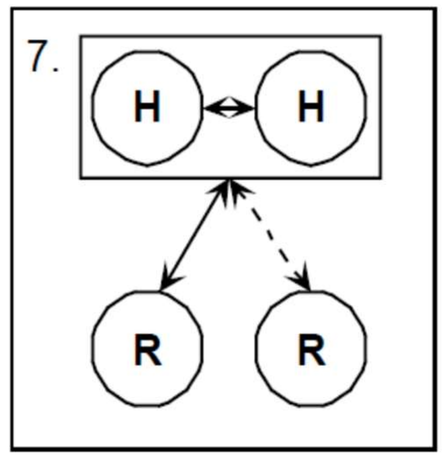
- Team configurations [Yanco2002]



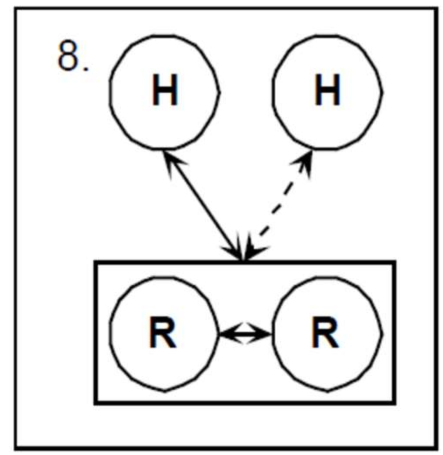
mHuman-1Robot



TeamR-TeamH



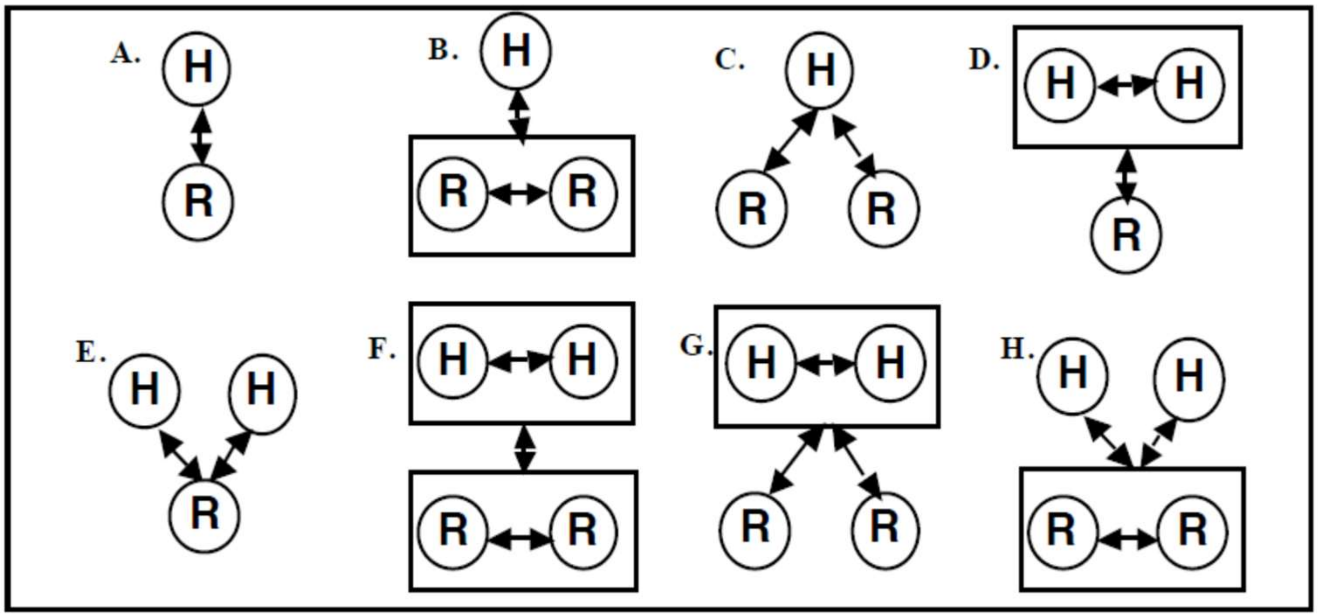
TeamH-mRobot



mHuman-TeamR

Taxonomies in HRI

- Team configurations [Yanco2002]



one human, one robot;
one human, robot team; *one human, multiple robots*;
human team, one robot; *multiple humans, one robot*;
human team, robot team; *human team, multiple robots*;
and *multiple humans, robot team*.

Taxonomies in HRI

- Space and Time:

		Time	
		Same	Different
Space	Same	Robot Wheelchair	Manufacturing robots
	Different	Urban Search and Rescue	Mars Rover

Table 1: Time-space taxonomy category, with examples.

- Criticality:
  - High: Search and Rescue
  - Medium: Service
  - Low: Game/Social

Taxonomies in HRI

- Space and Time:

		Time	
		Same	**Different**
Space	**Same**	Robot Wheelchair	Manufacturing robots
	Different	Urban Search and Rescue	Mars Rover

Table 1: Time-space taxonomy category, with examples.

- Criticality:
  – High: Search and Rescue
  – Medium: Service
  – Low: Game/Social

Taxonomies in HRI

- PHYSICAL_PROXIMITY:
  - *avoiding*, *passing*, *following*, *approaching*, and *touching*, none
- Decision Support:
  - AVAILABLE-SENSORS, PROVIDED-SENSORS,
  - SENSOR-FUSION, PRE-PROCESSING;

Taxonomies in HRI

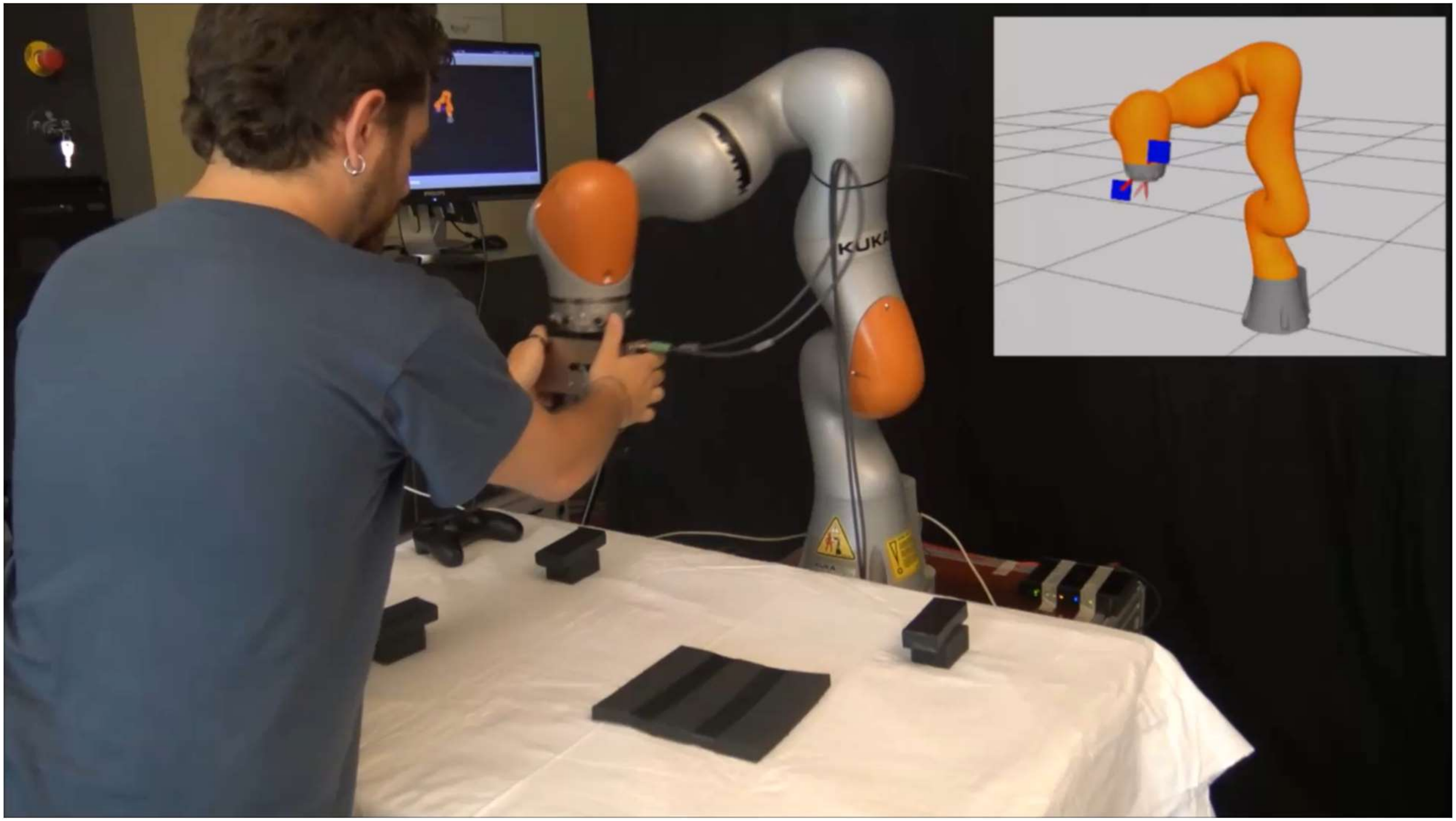
- Team hierarchy
  - Conflict resolution
  - Especially for peer-based relationships (co-X)
  - Active roles
  - Supervisor
  - Operator
  - Mechanic / Assistant
  - Peer
  - Slave
  - Passive roles
  - Patients
  - Visitors
  - Bystanders

Service Robotics

- Robot co-worker (CoBot):
  - Human monitoring
  - Intention/activity recognition
  - Physical and cognitive interaction
  - Communication and dialogue
  - Collaboration
  - Teaching

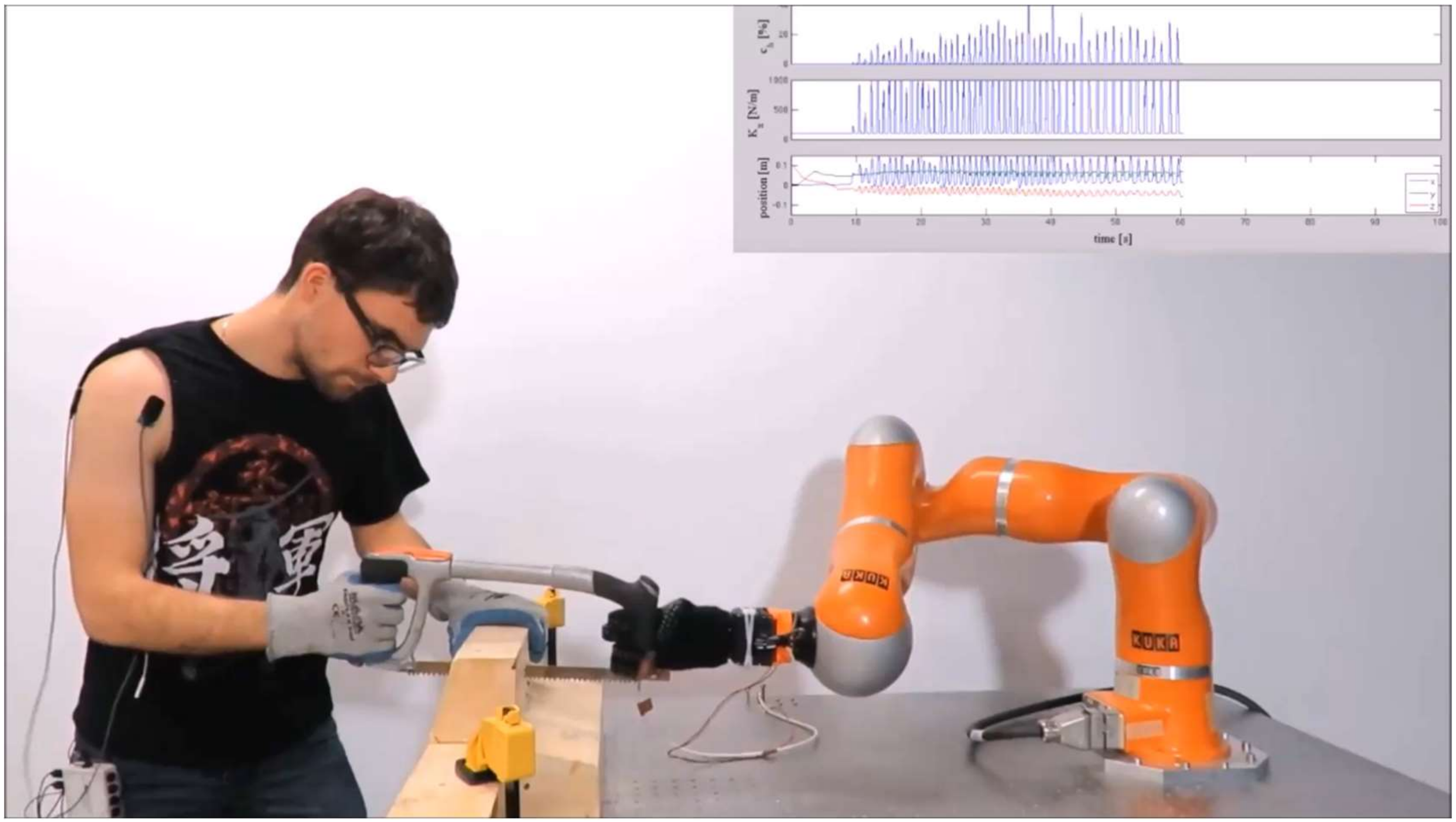
Service Robotics

- Hand guidance, co-manipulation:



Service Robotics

- Co-manipulation:
  - Physical interaction, safety, learning, adaptation



IIT [Peternel et al. 2016]

Collaborative Robotics

- **Four main categories:**
  - **Safety-rated monitored stop**
    - Robot stops when operator enters the collaborative workspace and continues when the operator has left the collaborative workspace. No physical separation is required (fences).
  - **Hand guiding**
    - Robot movements are directly guided and controlled by the operator.
  - **Speed and separation monitoring**
    - The contact between operator and moving robot is prevented by the robot by controlling the speed as a function of the separation distance.
  - **Power and force limiting**
    - Contact forces between operator and robot are technically limited to a safe level.

These basic principles of protection in HRC are in the standard EN ISO 10218 "Robots and robotic devices - Safety requirements for industrial robots" Parts 1 and 2. ISO/TS 15066 provides details

Collaborative Robotics

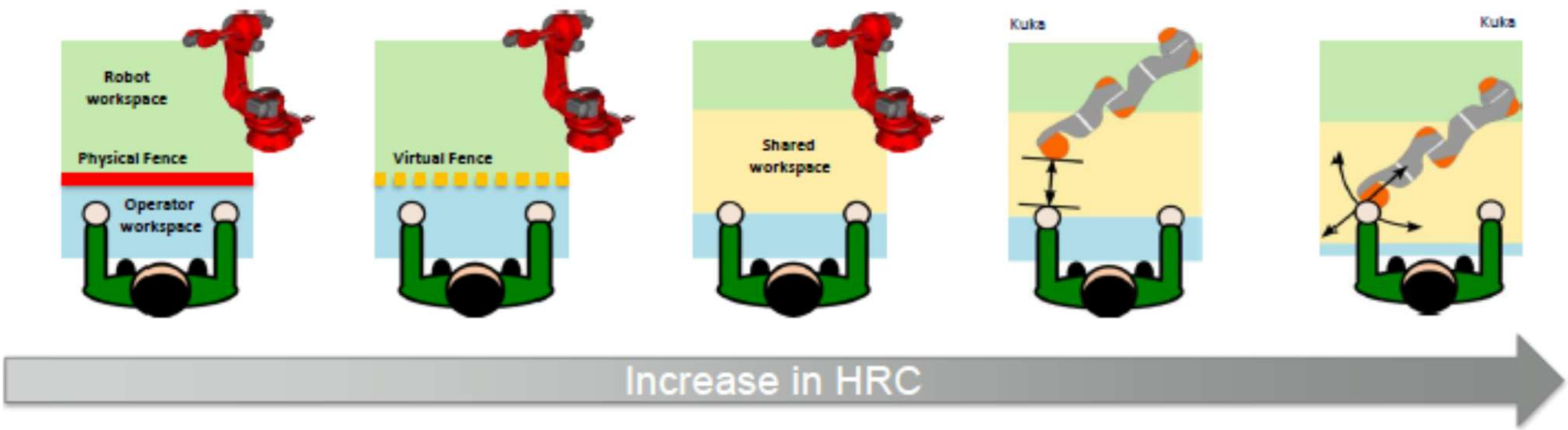
Contact not possible
→ Fixed safety fence

SMS (Safety Monitored Stop)
Contact not desired
No need to have a physical protection
→No fixed guard, virtual safety fence

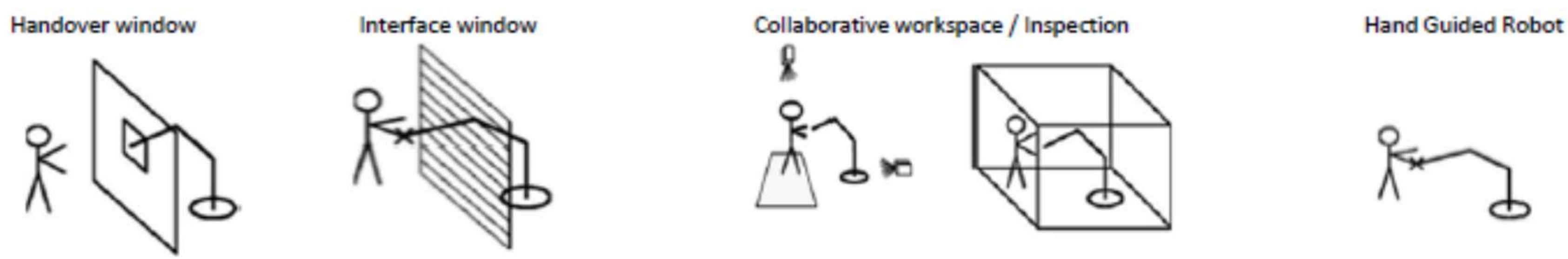
SMS Need of shared space.
Contact accepted only with stationary robot
→Shared workspace, but exclusive motion

SSM (Speed Separation Monitoring) or SMS
Need of shared space.
Contact not desired, but possible
→ Shared workspace

PFL (Power Force Limiting) or HG (Hand Guiding)
Contact desired
→ Shared workspace , simultaneous motion
e.g. manual guidance



Collaboration examples according to EN ISO 10218-2, ANNEX E



Collaborative Robotics

Origin

moving elements

Potential consequences

- crushing
- impact
- shearing

Free collision

- Dynamic due to high velocities
- Dependent on velocity, mass and shape (of robot, gripper and manipulated object)
- Risks from the end-effector and the transported part
- Collision detection must function reliably and in time (before consequential damage)

Crushing

- No high velocities, virtually static
- Max. force must be parameterizable and not exceeded

Self activation

- External approval for activation required
- Light advices prior to motion