PACO-PLUS

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

FP6-IST-4-027657, February 1st, 2006 - January 31st, 2010, http://www.paco-plus.org/

University of Karlsruhe, Kungliga Tekniska Högskolan, Stockholm, University of Göttingen
Aalborg University, Copenhagen, Jozef Stefan Institute, Ljubljana
Consejo Superior de Investigaciones Científicas, Barcelona, Leiden University
University of Edinburgh, University of Southern Denmark, University of Liège

PACO-PLUS: The Concept

Fundamental assumptions:

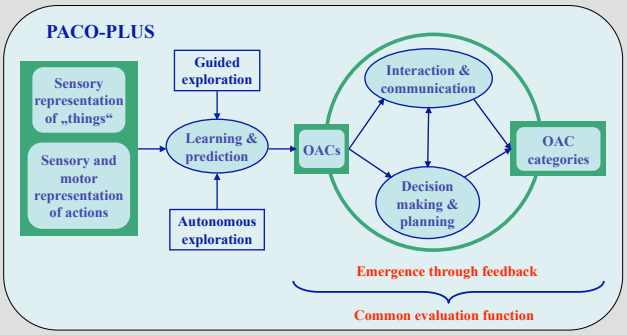
- Objects and Actions are inseparably intertwined in cognitive processing; that is "Object-Action Complexes" (OACs) are the building blocks of cognition.
- Cognition is based on reflective learning, contextualizing and then reinterpreting OACs to learn.
- The core measure of effectiveness for all learned cognitive structures is: Do they increase situation reproducibility and/or reduce situational uncertainty in ways that allow the agent to achieve its goals?

Continuous Path to Cognition and Language

- Object-Action Complexes (OACs) through exploration, interaction and learning.
- OACs are categories with *implicit* semantics.
- Sharing of the same OACs → mutually grounded symbols → language
- Shared symbols → *explicit* reasoning and communication

Unified Measure of Success and Progress

- Common evaluation function for contingency minimization and return maximization strategies.
- Exploration, imitation, SARSA like learning strategies.
- Decision making and planning → bias the evaluating functions
- Demonstration and evaluation on a humanoid robot.



Objects, Exploration, and Planning

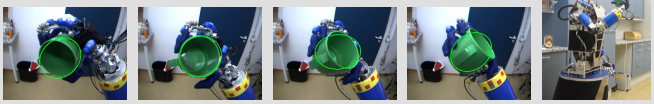
- A hierarchical architecture allows for a systematic transition of sensory information to higher semantic quality (as well as feedback processes from the higher levels to the lower levels), which generates cognitive processes on all levels.
- Our system is equipped with a well motivated amount of prior knowledge that allows for learning on all three levels of the hierarchy, such as:
  - ✓ On the sensory level, the fine tuning of prewired behaviours (grasping-reflexes, pushing actions);
  - ✓ On the mid-level, the learning of feature combinations with associated grasps and the learning of objects for recognition;
  - ✓ On the planning level, the learning of consequences of actions in abstract state spaces and the generalization of abstract rules to guide the system in further planning operations.
- We have realized grounding processes, which link high level concepts to sensory data.

Test Platform: Humanoid Robot ARMAR

- 7-DOF head with foveated stereo vision, gyro, and 6 microphones;
- 3-DOF torso, two 7-DOF arms;
- Two 5-finger hands, each with 8 DOFs and tactile sensors;
- Holonomous mobile platform;
- A number of sensori-motor processes to autonomously act in unstructured environments (kitchen).

Actions, Imitation, and Sequencing

- 3-D motion capture for reproducing and interpreting actions of human agents.
- Non-supervised generation of a grammatical representation of actions based on sensorimotor primitives. This grammatical representation will be extended to provide the necessary basis for planning and plan recognition.
- Goal-directed action synthesis using locally-weighted regression. We showed how to connect action synthesis with techniques such as coaching and imitation, which enable us to acquire example action libraries and generalize from them.
- A mechanism to select actions that reduce uncertainty for various directions in the feature space in situations with partial observability.



Processes for Acquiring OACs

Reinforcement learning:

- We developed an original approach how to introduce continuous action space that operates quickly and does not require action space sampling.
- We have started to investigate coaching procedures that are biologically grounded and physically implementable on real robots.

Symbolic processes:

- We extended the state of the art PKS planning system to allow representing various kinds of knowledge.
- We are exploring using rapid replanning to deal with uncertainty in the environment rather than probabilistic approaches.