

PACO-PLUS

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

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PACO-PLUS aims at the design of a cognitive robot that is able to develop perceptual, behavioural and cognitive categories in a measurable way and communicate and share these with humans and other artificial agents. The main paradigm of the project is that *Objects and Actions are inseparably intertwined* and that categories are therefore 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). Entities (“things”) in the world of a robot (or human) will only become semantically useful “objects” through the action that the agent can/will perform on them. This paradigm of OACs offers two novel key issues which will assure that a system with advanced cognitive properties can be developed.

Key issue 1: Continuous path to cognition and language: We will demonstrate that the concept of OACs leads to a natural and uninterrupted (continuous) path from early perception-action events towards complex cognitive properties as well as to the development of language by the following, here abbreviated steps. 1) As explained above, Object-Action complexes are categories with inherent semantics. The modification of OACs through exploration, interaction and learning leads to new OACs (novelty, creativity). 2) The combination of OACs to more complex ones can be seen as an internal, implicit reasoning process leading to higher levels of abstraction and more abstract categories. 3) The sharing of the same OACs between human and agent through their interaction will set the basis for the development of shared, hence mutually grounded, symbols (e.g.; replacing an action on an object with a “pointer” to it that both understand. 4) The making-explicit of these symbols will create a simple language (ranging from signs to verbal). 5) Shared language developed from shared symbols which came from shared OACs will allow for explicit reasoning and communication; creating an advanced cognitive human-robot interaction system. We believe that this path will allow us to approach the signal-symbol problem in a rather fundamental way (how to arrive at meaningful symbols from bare signals).

Key issue 2: A unified measure of success and progress: As opposed to all existing other approaches the concept of OACs (and their natural extension into the symbol/language domain) offers the advantage to formalize a general measure of success. Following their drive/motivation, agents will either seek to minimize disturbances which arrive at them from their environment, or they will actively seek to maximize some kind of reward. PACO-PLUS will develop a measure to quantify the success in disturbance minimization and/or reward maximization using the same evaluative functions at all stages 1-5 above. The process of decision making and planning, which is vital to cognition, can now be phrased in terms of how to bias the evaluating functions with respect to the context provided by environment and internal states (intentions, drives) of the agent. The design and construction of cognitive systems that can perceive and interact with their environment is an extremely challenging task. The goal of the

The central assumption behind our approach is that the conjoint application of Key Issues 1 and 2 will lead to a gradual, continuous and controlled emergence of cognitive properties in a process of interactions with objects and other cognitive agents by means of shared categories. Since these categories are limited by the action of agents, it is of central importance for the project to investigate how they can develop on a sufficiently complex anthropomorphic robot. Anthropomorphism is desirable because it makes interaction easier and also supports the transfer of ideas from psychology and neuroscience to robotics.

PACO-PLUS brings together an interdisciplinary research team to design and build cognitive robots capable of developing perceptual, behavioural and cognitive categories that can be used, communicated and shared with other humans and artificial agents. To demonstrate our approach we are building robot systems that will display increasingly advanced cognitive capabilities over the course of the programme. They will learn to operate in the real world and to interact and communicate with humans. To do this they must model and reflectively reason about their perceptions and actions in order to learn, act and react appropriately. We hypothesize that such understanding can only be attained by embodied agents and requires the simultaneous consideration of perception and action.

Our approach rests on three foundational 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 more abstract OACs, through a grounded sensing and action cycle.
- 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?