The RobotCub Approach to the Development of Cognition

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This abstract elaborates on the workplan of an initiative in embodied cognition funded by the European Commission called RobotCub. We report on a multidisciplinary plan of empirical research which includes brain and robotic sciences.

Two different stances dominate the study of cognition [1]: the cognitivist and the emergent. Greatly simplifying, the cognitivist approach is forged around the physical symbol hypothesis of Newell and Simon [2] and the emergent approaches are based, to various extents, on principles of self-organization and development [3-4]. The RobotCub approach to the study of cognition falls within the latter category. Our previous work [5] developed this argument in greater detail. Cognitivist systems, because they are based on the assumption that cognition is simply the manipulation of symbols, need not be embodied: although they can benefit from the tuning of the symbolic engine by real-world learning. For emergent systems however, embodiment is fundamentally tied to the approach itself: emergence is obtained through the interaction with the environment, the shape of the body, and by means of sensorimotor coordination.

For this reason the first aim of RobotCub is to build a fully-fledged humanoid robotic platform shaped as a three and half-year-old child. The robot has 53 degrees of freedom. It has sophisticated hands to manipulate objects, an oculo-motor system, arms and legs for crawling, sitting, and interacting with the environment. The platform, both hardware and software, is distributed as Open Source under the General Public/Free Documentation License, to be shared among scientists interested in the study of embodied cognition.

The rationale is that by creating a common platform we will enable many laboratories to join this effort without having to invest themselves in developing yet another robotic platform. Our

hope is that over time the RobotCub platform will accumulate a substantial amount of different skills, learned, and implemented by different research groups.

The second aim of RobotCub is thus to investigate the development of these cognitive skills. The project carries out a plan of empirical research including neuroscience, developmental psychology, and robotics. This plan is centered on manipulation, ranging from the direct aspects of reaching and grasping of objects to the use of gestures for communication. Aspects that will be touched along the way are, for instance, looking & overt attention, reaching, the detection and discovery of affordances, learning through imitation, and interaction.

The emergent approach encompasses naturally the study of ontogenic development and, in fact, a comparatively large effort will be devoted to the study of development. A roadmap of this investigation [7] should include the study of the *starting point* in terms of core abilities, the motive of the system to explore and gather data, and a few research areas such as looking, reaching & manipulation, posture, locomotion and social interaction. For each of these areas, aspects of prospective use of information, motivation, and the mechanisms of exploration have to be experimentally investigated. The RobotCub agenda aims at covering, by targeted empirical investigation, most if not all of these aspects. The following table 1 summarizes this agenda.

Finally, we wish to emphasize again that the principal motivation for this initiative is to help fostering the study of embodied cognition throughout the global research community by making the RobotCub humanoid and cognitive software freely available. Representatives of this international community have been involved with RobotCub from the outset. Our goal is to increase this involvement as much as possible over the coming years and we welcome potential collaborators.

Acknowledgements
This work is funded by the European Commission's Unit E5 – Cognitive Systems, Interaction and Robotics, Directorate-General Information Society, as part of project no. IST-FP6-004370: RobotCub — ROBotic Open-architecture Technology for Cognition, Understanding, and Behaviour. The authors gratefully acknowledge Claes von Hofsten and Luciano Fadiga for the useful discussions about development and motor control in humans and the whole RobotCub consortium for the preparation of this research agenda.

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Development		Learning what	Perception/Action exploitation	Component of Social Interaction	Goal of system
Immediate	No reaching yet	Head-eye coordination	Gazing, smooth pursuit	Shared attention	Look around
	Pre-reaching	Approach an object	Controlling arm and hand movements in space	Pointing	Touch
Delay between action onset and consequences	Power grasp	Eye-hand coordination based on object position and object motion	Anticipatory closing of the hand	Reaching for object held by other person "I got it!"	Grasp (become "owner")
	Differentiated grasping	Adjustment to object shape and size	Eye-arm-hand coordination based on object's shape	Take and give	Grasp appropriately (geometric)
	Object manipulation	Objects' affordances	Eye-arm-hand coordination based on actions to be executed on objects	Play games	Handle objects appropriately (use)
Long delays	Imitate acts on objects	Associate what is seen with what the system can do	What I do looks like what I see	Play games	Action's interpretation
	Act to communicate	Associate what is seen (perceived) with meaning	What I do generates some reactions	Communication	Action's meaning

Table 1: the roadmap of RobotCub experimental research