Cogn Process (2011) 12:317–318
DOI 10.1007/s10339-011-0415-y

EDITORIAL

Special corner on "cognitive robotics"

Stefan Kopp · Jochen J. Steil

Received: 1 September 2011 / Accepted: 15 September 2011 / Published online: 28 September 2011

Cognitive Robotics (CR) is a theoretical and practical approach to implement cognitive abilities for reasoning, perception and action on technical robots. It aims at robots that cognize their worlds and can reason, e.g., about goals, beliefs, actions, when to perceive and what to look for, the cognitive states of other agents, or collaborative task execution. This research line originated as a counterpart to work in classical robotics and automation that focuses on engineering tasks like sensory processing, path planning, manipulator design and control, usually with preprogrammed, task-specific models. Reminiscent of the rise of classical Artificial Intelligence, which started out from "heuristic programming" (cf. Michael 1972), CR started out as a form of "behavior programming" but has emphasized high-level primitives that rest upon principles of human-like perception and action, and which is based on internal models (e.g., representations) going beyond fixed behavior-based architectures.

In this sense, cognitive robots embody the behavior of intelligent "Cartesian agents" in the physical world (or a virtual world, in the case of simulated CR). But this calls for more than putting A.I. reasoners on robotic devices. While traditional cognitive modeling approaches have assumed complex symbolic representations as a means for capturing the world, CR can be seen as an implementation of minimal robust representationalist models of intelligence in actual embodied, technical devices. These minimal models and systems result from an amalgamation of classical representationalist Cognitive Science approaches and "new" robotics or dynamical systems approaches (Clark and Grush 1999). In this way, CR creates an opportunity for studying how Cognitive Science and A.I. accounts can (and must) be deeply grounded in real-world physical embodiment and situatedness, and—the other way around—how robots facing real-world problems can be endowed with necessary, robust cognitive skills.

S. Kopp (✉)
CITEC, Faculty of Technology,
Bielefeld University, Bielefeld, Germany
e-mail: skopp@techfak.uni-bielefeld.de

J. J. Steil
CoR-Lab, Bielefeld University, Bielefeld, Germany

With this special corner, we wish to further strengthen the interaction between Cognitive Science, Artificial Intelligence and Robotics as it figures fruitfully in the field of CR. From our point of view, CR has only begun to reveal its full potential for fertilizing work in the theoretical, technical, and empirical sciences targeting the understanding of cognition. Today's cognitive robots are still rather limited, and many challenging topics lie ahead:

- Understanding the "deep grounding" of cognitive abilities in technical bodies that are not vehicles but parts of the cognitive processes. This addresses the intersection of embodied cognition and robotics and has led, e.g., to work on compliant robots or "morphological computation" (Pfeifer et al. 2006), where constraints of biomimetic bodies provide a lot of "thinking" for the mind, but which is still to arrive at the integration of higher cognitive skills with artificial bodies.
- Exploring and exploiting further the role of learning, from learning motor skills (Rolf et al. 2010) to a principled approach for the acquisition of cognitive abilities as in the subfield of "cognitive developmental robotics" (Asada et al. 2001; Cangelosi et al. 2010).
- Incorporating language and communication by strengthening the links between linguistics, artificial

intelligence, machine learning, and robotics. Researchers have started to explore robots and agents as operational models of language development (Steels 2010) or social interaction (cf. Kopp 2010), or as systematically controllable stimuli in human–robot interaction experiments. Yet, significant progress and tangible impact on cognitive system design are still sparse.

- Increasing the incorporation of neurocognitive findings both on the level of modeling particular skills, like motor behavior or attention, and on the level of system integration, where a systematic blue-printing of architectures becomes increasingly infeasible and new paradigms of incremental, biologically motivated development needs to be explored.
- Developing architectural concepts that provide integration and organization of complex behavior on the system level. Some researchers in CR have used cognitive modeling frameworks such as ACT-R or SOAR, but only for relatively narrow control schemes and with little entrenchment in the body. In addition, the pivotal function of concepts like attention and emotions with regard to building and managing complex resource-bounded control systems need to be explored further.

The articles in this special corner provide an excellent insight into the work that is going on these topics. *Haazebroek, van Danzig, and Hommel* present an architecture (HiTEC) for embodied cognition in CR, which is based on models of human information processing and replicates respective results from behavioral studies in computational simulation. The model intertwines perception and action processes and representations, and it accounts for ideomotor learning of action control as well as the effects of task context and attention. The authors discuss implications for design of cognitive robots. *Chauhan and Lopes* investigate the role of spoken words to name objects in social interaction, for learning categories and forming concepts. They propose a learning architecture for utilizing and modeling this principle in robots, emulating the language-grounding process in children at the single-world stage. This work exemplifies the flourishing approach of using learning in cognitive robots. *Nguyen-Tuong and Peters* complement this with a survey of model learning for robotics. In contrast to classical robotics, which often relies on hand-crafted models, CR focuses on learning for automatically generating models from data streams. The authors provide an overview of the progress made in this direction, with a focus on learning models for kinematic and dynamical robot control. Using several case studies, they consider different possible learning architectures, applicable learning methods, and future directions of real-time learning. Finally, the special corner is complemented by two laboratory notes from two renowned Cognitive Science institutes, illustrating how instructive CR research can fed back into basic research on cognition. *Pezzulo, Baldassarre, Cesta, and Nolfi* report work at the Institute of Cognitive Science and Technology (ISTC-CNR), Italy. They present different lines of research, from anticipatory, goal-directed and proactive robots, to the evolution of communication in robots, to novel algorithms and architectures for robust planning and execution with explicit representations. *Quirin, Hertzberg, Kuhl, and Stephan* discuss work at the Institute of Cognitive Science at Osnabrück University, Germany, which focuses on the functional role of emotion and, more specifically, positive affect as adaptive processes to optimize cognitive behavior control. By arguing for integration of this in robot control architectures, the authors nicely illustrate how CR research grows to include many aspects of human behavior into integrated models.

Acknowledgments We thank all authors for sharing their exciting and important ideas and work. We are also very grateful to the reviewers that helped to select these papers and provided valuable comments to their authors (in alphabetical order): M. Asada, C. Becker, T. Belpaeme, J. Bonaiuto, A. Cangelosi, P. F. Dominey, C. Goerick, F. Joublin, P. Kormushev, S. Nolfi, G. Pezzulo, G. Palm, K. Prepin, K. Rohlfing, M. Rolf, G. Sandini, D. Song, T. Trappenberg, D. Vernon, T. Ziemke.

References

Asada A, MacDorman KF, Ishiguro H, Kuniyoshi Y (2001) Cognitive developmental robotics as a new paradigm for the design of humanoid robots. Robotics Auton Syst 37:185–193

Cangelosi A, Metta G, Sagerer G, Nolfi S, Nehaniv CL, Fischer K, Tani J, Belpaeme B, Sandini G, Fadiga L, Wrede B, Rohlfing K, Tuci E, Dautenhahn K, Saunders J, Zeschel A (2010) Integration of action and language knowledge: a roadmap for developmental robotics. IEEE Transact Auton Ment Dev 2(3):167–195

Clark A, Grush R (1999) Towards a cognitive robotics. Adapt Behav 7(1):5–16

Kopp S (2010) Social resonance and embodied coordination in face-to-face conversation with artificial interlocutors. Speech Commun 52:587–597

Michael GC (1972) A review of heuristic programming. Decis Sci 3(3):74–100

Pfeifer R, Iida F, Gómez G (2006) Morphological computation for adaptive behavior and cognition. Int Congr Ser 1291:22–29

Rolf M, Steil JJ, Gienger M (2010) Goal babbling permits direct learning of inverse kinematics. IEEE Trans Auton Ment Dev 2(3):216–229

Steels L (2010) Modeling the formation of language in embodied agents: methods and open challenges. In: Nolfi S, Mirolli M (eds) Evolution of communication and language in embodied agents. Springer, Berlin, pp 223–233