Connecting knowledge-level planning and task execution on a humanoid robot using Object-Action Complexes

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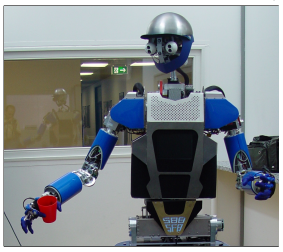
Motivation

A humanoid robot operating in a real-world domain typically requires a collection of decision making and control mechanisms, combining low-level sensorimotor systems with high-level action/reasoning engines. Building such systems requires overcoming the theoretical and practical challenges that arise from integrating such diverse components in a single framework.

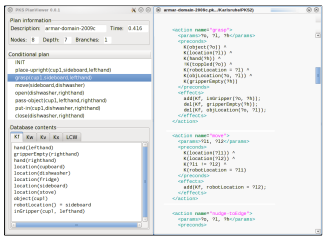
ARMAR humanoid robot platform

Our system uses the ARMAR humanoid robot platform [1] featuring a 7-degree-of-freedom (DOF) head with foveated vision, a 3-DOF torso, two 7-DOF arms, and two 5-finger hands, each with tactile sensors and 8 DOFs. ARMAR also includes a number of sensorimotor processes that enable it to act autonomously in complex environments.

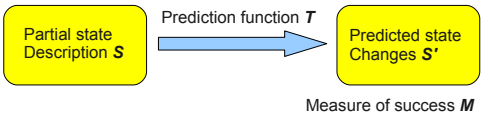


Planning with Knowledge and Sensing (PKS)

High-level plans are built using PKS [3], a conditional planner that operates with incomplete information and sensing actions. PKS operates at the "knowledge level" by explicitly modelling what the planner knows, and does not know, during plan generation.

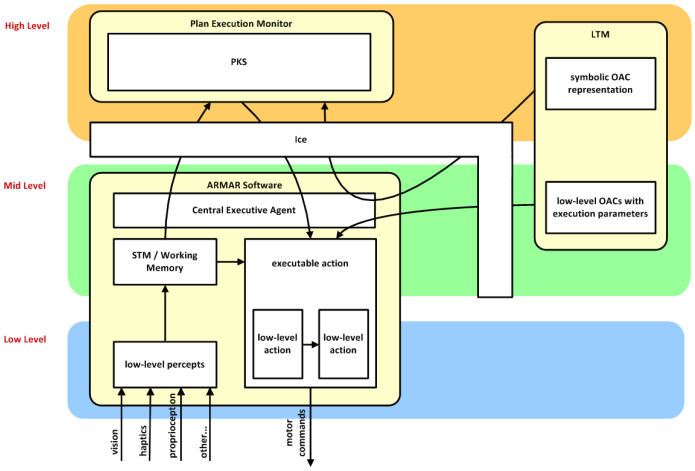


Object-Action Complexes (OACs)



Task planning and execution are connected using Object-Action Complexes (OACs) [2], a universal representation usable at all levels of a cognitive architecture. OACs combine ideas from STRIPS, the object/situation-oriented concept of affordance, and logical formalisms like the event calculus. Planning-level operators and robot-level tasks/skills are modelled using OACs.

System architecture and component interaction



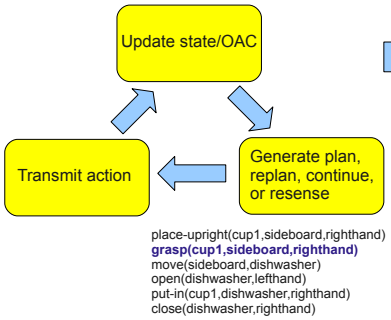
The Ice (Internet Communications Engine) middleware facilitates the exchange of information between system levels/components.

Using OACs for task planning and execution: loading the dishwasher

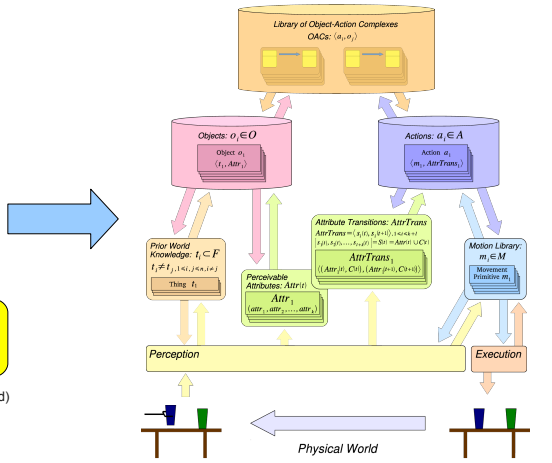
High level

Preconditions	Effects
object(?o) location(?l) hand(?h) ¬toppled(?o) robotLocation=?l objLocation(?o,?l) gripperEmpty(?h)	ingripper(?o,?h) ¬gripperEmpty(?h) ¬objLocation(?o,?l)
	Success 0.90

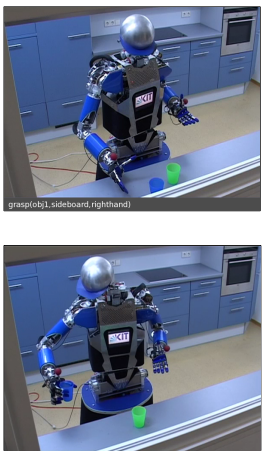
High-level OAC representation of grasp(?o,?l,?h)



Low level



Execution



References

[1] T. Asfour, K. Regenstein, P. Azad, J. Schröder, A. Bierbaum, N. Vahrenkamp, and R. Dillmann. ARMAR-III: An integrated humanoid platform for sensory-motor control, IEEE-RAS International Conference on Humanoid Robots (Humanoids 2006), pages 169-175, 2006. See **http://wwwiaim.ira.uka.de/** for more information about ARMAR.

[2] N. Krüger, J. Piater, C. Geib, R. Petrick, M. Steedman, F. Wörgötter, A. Ude, T. Asfour, D. Kraft, D. Omrcen, A. Agostini, R. Dillmann. Object-Action Complexes: Grounded abstractions of sensorimotor processes, submitted to *Robotics and Autonomous Systems*, 2009. See **http://www.paco-plus.org/** for a technical report about OACs.

[3] R. Petrick and F. Bacchus. Extending the knowledge-based approach to planning with incomplete information and sensing, *Proceedings of the International Conference on Automated Planning and Scheduling (ICAPS-04)*, pages 2-11, 2004. See **http://homepages.inf.ed.ac.uk/rpetrick/** for more information about PKS.