CRAM – a Cognitive Robot Abstract Machine

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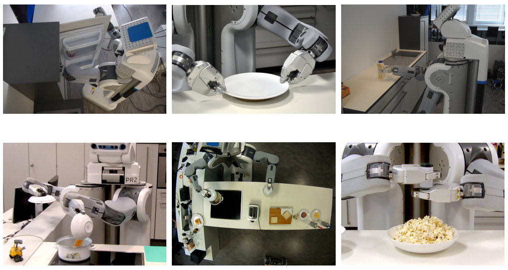
A toolbox for cognition-enabled robot control

Autonomous household robots, robot assistants and robotic co-workers become more and more available. They are supposed to understand and execute commands like "Make some pancakes" or "Set the table". In order to translate such underspecified and ambiguous instructions into executable action specifications and to execute them in realistic environments, a robot needs deep knowledge and powerful reasoning techniques.

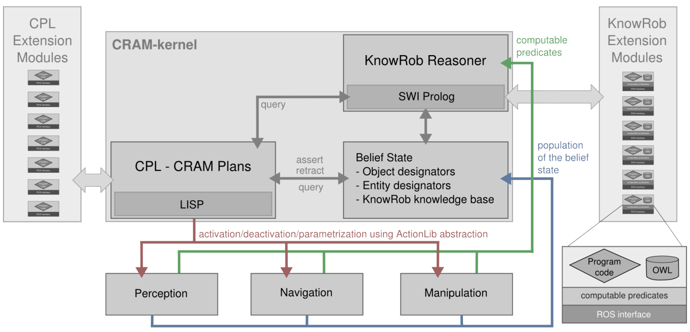
With CRAM, we propose a software toolbox for realizing cognition-enabled robot control programs. CRAM provides a rich set of components for reasoning and action execution which are the building blocks for complex robot control programs. With these components, CRAM raises the conceptual level at which service and personal robot applications can be programmed. This facilitates the creation of cognition-enabled robot control programs.

CRAM has successfully been used for realizing complex robot behavior including mobile pick-and-place tasks and the preparation of simple meals like popcorn.



CRAM is used as platform for task execution and reasoning in several EU FP7 research projects (RoboHow, Saphari, RoboEarth).

The CRAM system



The core of the CRAM system is the CRAM-kernel which consists of the CRAM Plan Language, data structures for storing and updating a belief state and the KnowRob reasoning system. The CRAM kernel communicates with the different actuators of the robot and sensors update the belief state. Control decisions in CRAM plans are made by utilizing the KnowRob reasoner and the belief state. The basic functionality of the kernel is extended by a number of extension modules, for instance semantic environment models, a plan importer to generate actions from the world wide web and a spatial reasoning system.

The KnowRob Knowledge Base

KnowRob is a knowledge processing system particularly designed for autonomous personal robots that provides CPL with the knowledge required for taking decisions. KnowRob is a first-order knowledge representation based on description logics and provides specific mechanisms and tools for action-centric representation, for the automated acquisition of grounded concepts through observation and experience, for reasoning about and managing uncertainty, and for fast inference — knowledge processing features that are particularly necessary for autonomous robot control.

The CRAM Plan Language

The CRAM Plan Language (CPL) is designed as an expressive powerful programming language. Its main features include

- full-featured programming language
- integration of KnowRob and other reasoning components
- plan parameterizations are first class objects (designators)
- transparent plans, i.e. plans cannot only be executed but also reasoned about
- recording of execution traces and reasoning about plan execution

```
(def-goal (achieve (object-in-hand ?obj))
  (with-designators
        (pickup-place ...)
        (grasp-type ...)
        (pickup-reaching-traj ...)
        (lift-trajectory ...))
    (when
      (and (holds-bel (object-in-hand ?curr-obj) now)
           (obj-equal ?curr-obj ?obj))
      (succeed (object-in-hand ?obj)))
    (at-location pickup-place
      (achieve (arm-at pickup-reaching-traj))
      (achieve (grasped grasp-type))
      (achieve (arm-at lift-trajectory))
      (succeed (object-in-hand ?obj))))
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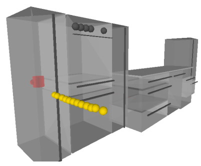
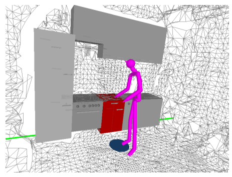
CRAM extension modules

CRAM can be equipped with a set of extension modules that provide additional cognitive capabilities for perception, learning, and adaptation.

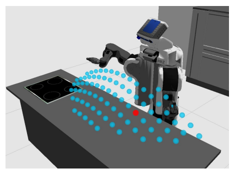


Semantic environment models



Interpretation of human activities

Knowledge acquisition from the www



Physics-based spatial and action reasoning

Open-source software toolbox

All CRAM components are available as open-source software including documentation and tutorials:

http://ias.in.tum.de/research/cram

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