CRAM — Cognitive Robot Abstract Machines

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Cognition-enabled Control for Everyday Manipulation

with compact control programs performing an open-ended set of everyday manipulation tasks like

► laying the table and
► cleaning up

in human environments in a natural, general, skillful, flexible and reliable manner.

PR2 in the Simulated Kitchen at IAS Lab

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Demonstrations

- setting the table, cleaning the table
- 2 simple meal preparation tasks

strong emphasis on

- inferring right actions and action parameterizations,
- answering queries about what the robot did and why

Examples: infer

- missing items on the table
- where objects belong
- how objects must be handled
- where to stand, how to reach, which grasp type, where to grasp, how much grasp force, etc
CRAM Perception System
Characteristics

- is **multimodal** (tilting laser, tof, stereo camera)
- is **taskable**
- based on **object descriptions**
- reasons about **object identities**
- maintains **belief state** through passive perception
- stores a **time-stamped memory** of perceptions
- computes **symbolic scene descriptions**
CRAM Perception System

PCL Contributions

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Scene Perception

Knowledge Base

\[
\begin{align*}
&\text{holds(on(o45,t2),t23)} \\
&\text{thing(o45)} \\
&\text{holds(pos(o45,\langle312,248\rangle),t23)} \\
&\text{object-data(o45,} \\
&\quad \text{)}
\end{align*}
\]
Provides the robot with abstract symbolic knowledge about the perceived scenes

Uses abstract symbolic knowledge for accomplishing perception tasks

Answers queries that require knowledge processing and perception.
missingObjects(Meal, Missing):- 
instanceOf(Table, 'table'),
in(Table, Kitchen),
primaryFunction(Table, 'HavingAMeal'),
perceivedObjectsOnPlane(Table, Perceived),
neededObjectsForMeal(Perceived, Needed),
setOf(Obj, 
  (member(Obj, Needed),
   not(member(Obj, Perceived)),
   Missing).

perceivedObjectsOnPlane(Plane, Perceived) :-
onPlane(Plane),
setOf(Obj-Hyp, 
  ( on(Obj, Plane),
    category(Obj,Cat),
    uniqueId(Id),
    objectInstance(Obj,KnownObj),
    Obj-Hyp = [Id,Obj,Cat,KnownObj],
    Perceived).
CRAM Knowledge Processing

Functionality

Object

- terminological knowledge
- pragmatic: PROLOG
- OWL: semantic map, Semantic Robot Description Language
- graphical interface
- statistical relational learning and reasoning
Architecture of the KnowRob framework.
Visualized results of queries for human poses. Objects that are considered to be missing for a complete table setup.
Positions for manipulation actions.
methods for processing and importing natural-language task instructions from web pages.

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Using the Semantic Object Map

Point cloud acquisition → Object detection and mapping → Semantic environment models

Encyclopedic knowledge → Commonsense knowledge → Action-related knowledge

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Computable predicates

- Use the environment as ’virtual knowledge base’
- Compute predicates on demand based on the belief state
- Inherently grounded, automatically updated
- Query-specific abstraction

**Symbolic knowledge representation**

- `type(Robot,'KIMP')`
- `localization(Robot,Lztn)`
- `location(Robot,Loc)`
- `not(well_localized(Robot))`

**Computables**

- `location(Robot,Loc) :- localization(Robot,Lztn), loc_estimates(Lztn,Dist), peaks(Dist, Peaks), max(Peaks, Loc).`
- `well_localized(Robot) :- localization(Robot,Lztn), loc_estimates(Lztn,Dist), peaks(Distr, Peaks), length(Peaks, 1).`

**Sub-symbolic belief state**

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Simulation is used as a tool for e.g. testing of robot’s behavior in the presence of humans.
CRAM Plan Language

- CPL = high-level programming language for autonomous robot control
- specifies how the robot is to respond to percepts, events, success and failure
- concurrent sensor-directed control with various synchronization mechanisms
- first-class objects: object descriptions, failure descriptions, (computational) control processes
robot plan = robot control program that cannot only be executed but also reasoned about and manipulated

- declarative goals for achievement, perception, prevention, maintenance (BDI)
- allows for reasoning: teleological and causal reasoning, prediction, transformational planning
Thanks

http://ias.cs.tum.edu
http://www.youtube.com/user/iasTUMUNICH
http://www.ros.org/wiki/tum-ros-pkg

THANKS

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