Combining Perception and Knowledge Processing for Everyday Manipulation - K-CopMan

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Scenario/Motivation

What is missing on the table?
I. Horswill, Integrating vision and natural language without central models, in In Proc. of the AAAI Fall Symposium on Embodied Language and Action

B. Neumann and R. Möller, On Scene Interpretation with Description Logics, in Cognitive Vision Systems: Sampling the Spectrum of Approaches
Overview

- Provides the robot with abstract symbolic knowledge about the perceived scenes
- Uses abstract symbolic knowledge for accomplishing perception tasks
- Answers new types of queries that require the combination of knowledge processing and perception.
Knowrob Extensions

- provides a set of predicates that abstract away from the robot’s perceptual mechanisms and transforms the perceptual tasks and their results into a logical representation suitable for knowledge processing and decision-making

- provides a continual update mechanism for the part of the knowledge base that represents the dynamic world state

[IROS2009:] Moritz Tenorth, Knowledge Processing for Autonomous Personal Robots
interface layer to open-source SWI Prolog.

- combines fast inference and computation with declarative, logics-based semantics.
- can even run in feedback loops up to 10 Hz to make the robot action-aware.
- Prolog’s foreign language interface thereby facilitates the integration of perception routines written in other programming languages like C/C++.
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).
Perception Routines

Preprocessing:

CAD model & Chamfer & SURF matching:

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Color segmentation:

Global Radius-based Surface Descriptor (GRSD):
K-Copman Predicates

- \textit{holds(onPlane}(\textit{Obj}, \textit{Plane}),ti)
- \textit{holds(position}(\textit{Obj}, \textit{Pos}),ti)
- \textit{holds(spatial-rel}(\textit{Obj}_1, \textit{Obj}_2),ti)
- \textit{categorize}(\textit{Obj}, \textit{Cat})
- \ldots
Motivation
Overview
Perception Server
Knowledge Processing
Evaluation
Future Work

Probabilistic First-Order Reasoning

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Motivation

All Together - Missing Objects Query

K-Copman perception server

Semantic Map, Encyclopedic Knowledge

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).

K-Copman perception server
First-Order Probabilistic Reasoning

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).

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Probabilistic Query

\[
P(\text{usesAnyIn}(P, ?u, M), \text{consumesAnyIn}(P, ?f, M) \mid \text{mealT}(M) = \text{Lunch} \land \\
\text{usesAnyIn}(P, \text{Plate}, M) \land \text{usesAnyIn}(P, \text{Knife}, M) \land \\
\text{usesAnyIn}(P, \text{Fork}, M) \land \text{usesAnyIn}(P, \text{Spoon}, M) \land \\
\text{usesAnyIn}(P, \text{Napkin}, M) \land \text{consumesAnyIn}(P, \text{Salad}, M) \land \\
\text{consumesAnyIn}(P, \text{Pizza}, M) \land \text{consumesAnyIn}(P, \text{Juice}, M) \land \\
\text{consumesAnyIn}(P, \text{Water}, M) \land \text{takesPartIn}(P, M))
\]

\[
\approx \langle \langle \text{Glass: 1.00, Bowl: 0.85, Cup: 0.51, ...} \rangle, \\
\langle \text{Soup: 0.82, Coffee: 0.41, Tea: 0.14, ...} \rangle \rangle
\]
Example Scene, Breakfast

**Perceived Objects:** plate, fork, spoon, knife, napkin, salad, juice, pizza, water

![Image of breakfast scene]

**Inferred Objects:** coffee, soup, bowl, cup, glass

![Image of inferred objects]
Evaluation results

Scene 1  Scene 2  Scene 3  Scene 4  Scene 5

NB: Last row depicts inferred missing objects, hue indicates probability: Red corresponds to 1.0, with orange, yellow, green and blue denoting declining probabilities in this order.

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Future Work

- More and more specific perception routines
- Spatio-temporal reasoning
- Life-long learning using the passive perception
- Perception-to-knowledge cues
Thanks!

Available in TUM ROS Package Repository:
http://tum-ros-pkg.svn.sourceforge.net/
(knowrob, prolog_perception)

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