Knowledge-based environment models

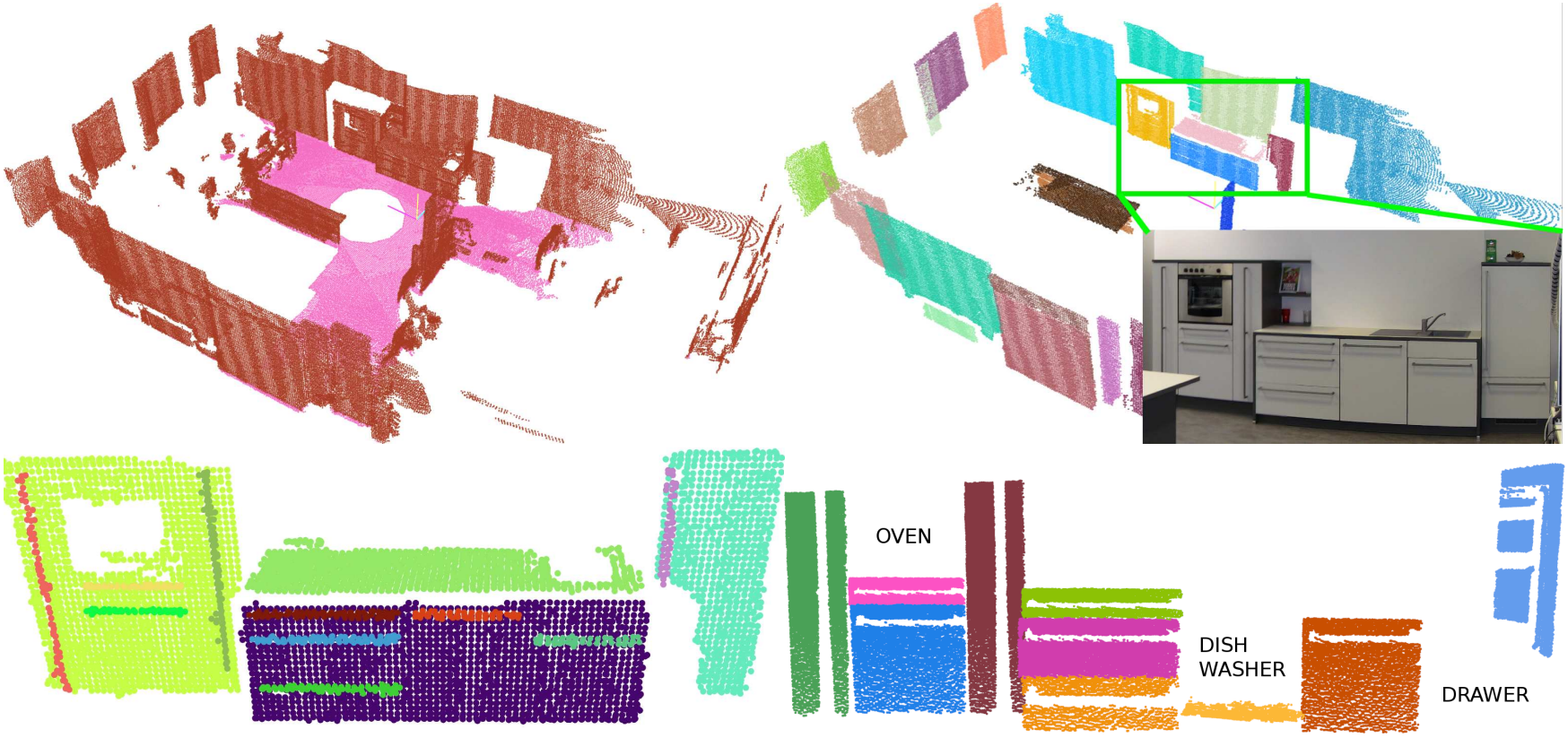
Moritz Tenorth and other members of the
Intelligent Autonomous Systems Group
Technische Universität München

robohow

A kitchen...

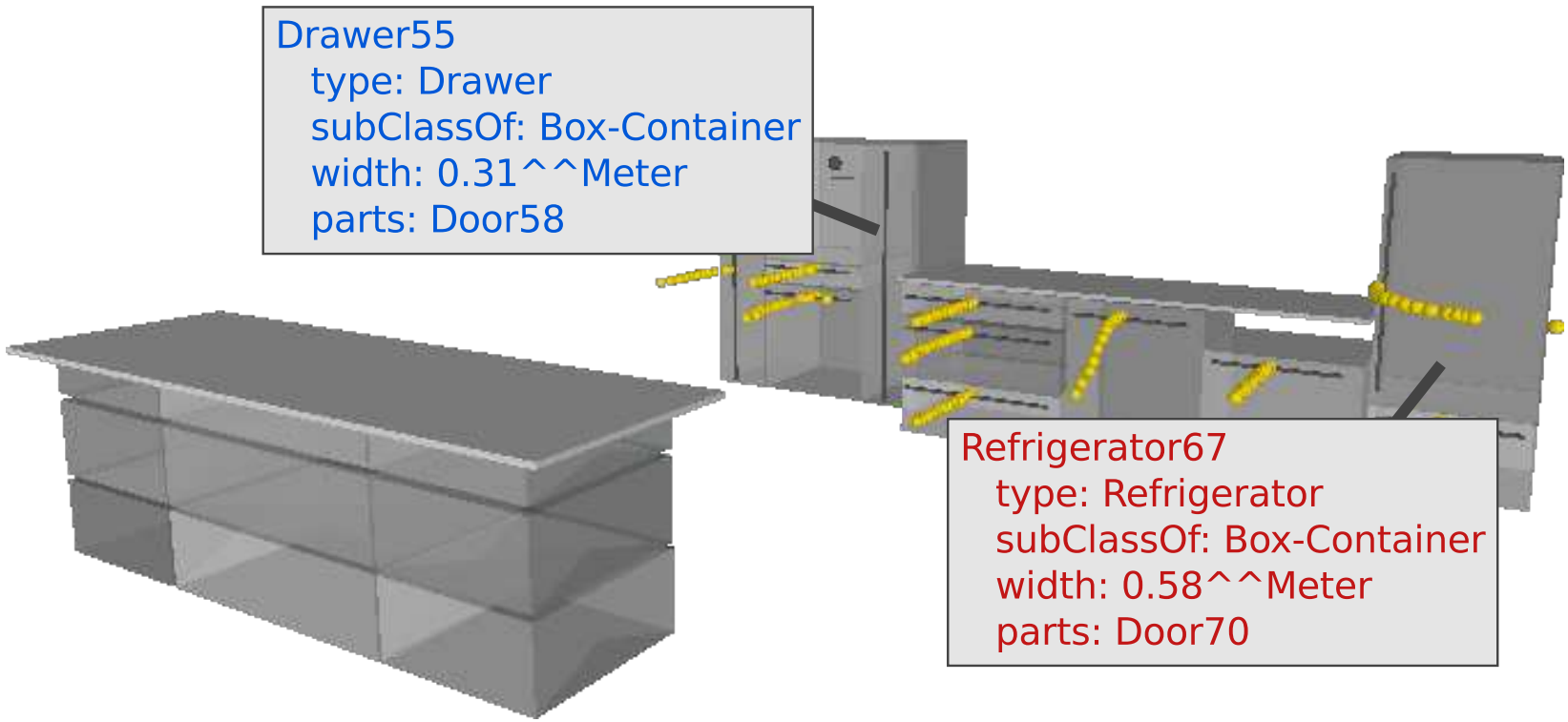
[IROS 2011]

...as segmented point cloud...



- Work by Dejan Pangercic, Nico Blodow et al.

...and its semantic environment map

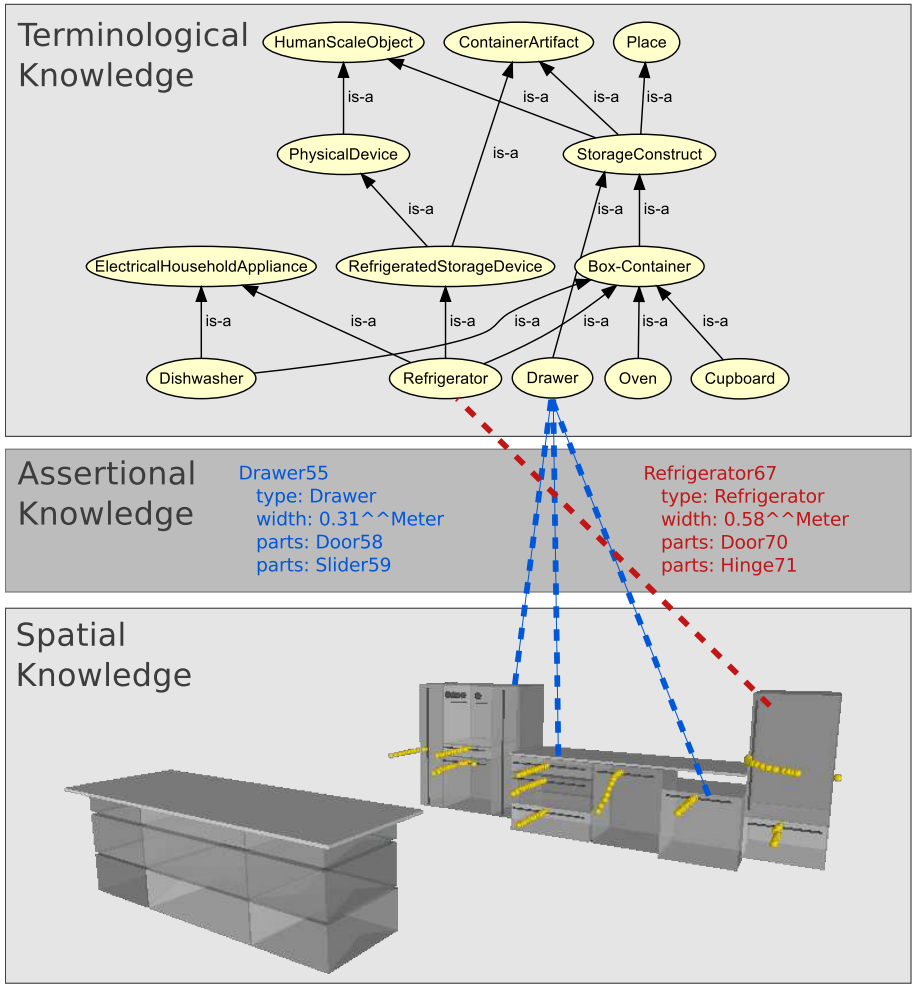


- OWL-based representation in the robot's knowledge base

Objectives

- Turn environment maps into a knowledge resource for robots
- Uniform interface for low-level information (poses, trajectories) and high-level semantics
- Facilitate integration of map information with other knowledge sources (common sense knowledge, knowledge from WWW, ...)

Semantic map representation



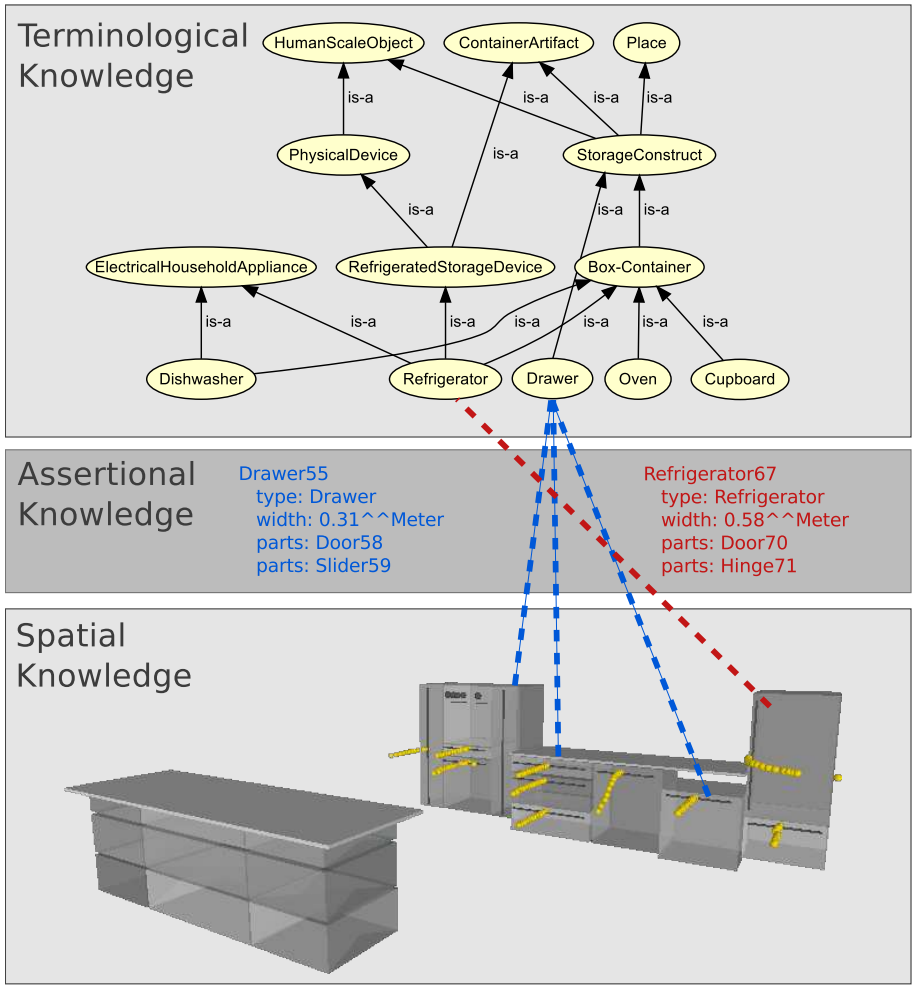
Abstract knowledge about object classes

Object instances and component hierarchy

Poses in the environment and their changes over time

Related: TBOX/SBOX, Galindo et al (RAS 2008)

Semantic map representation



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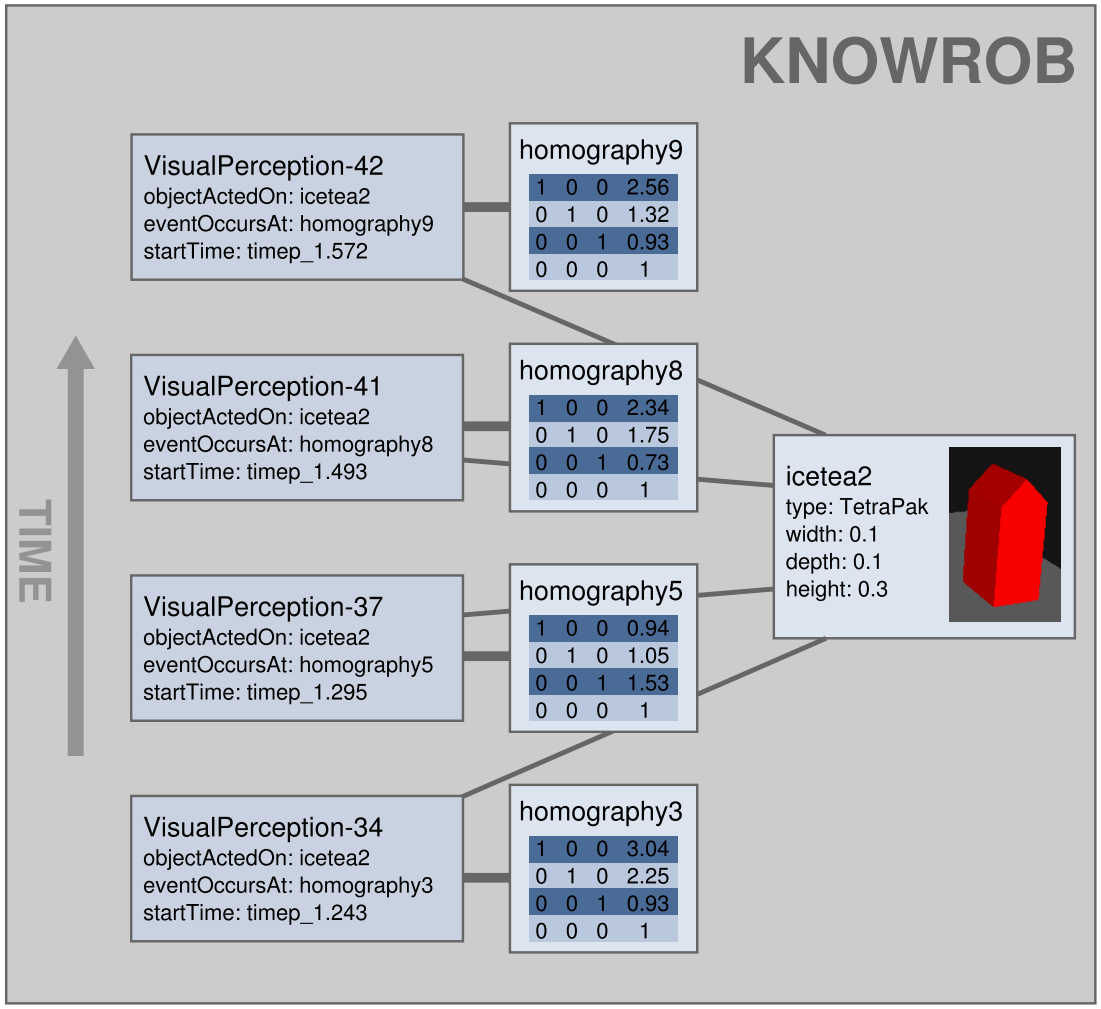
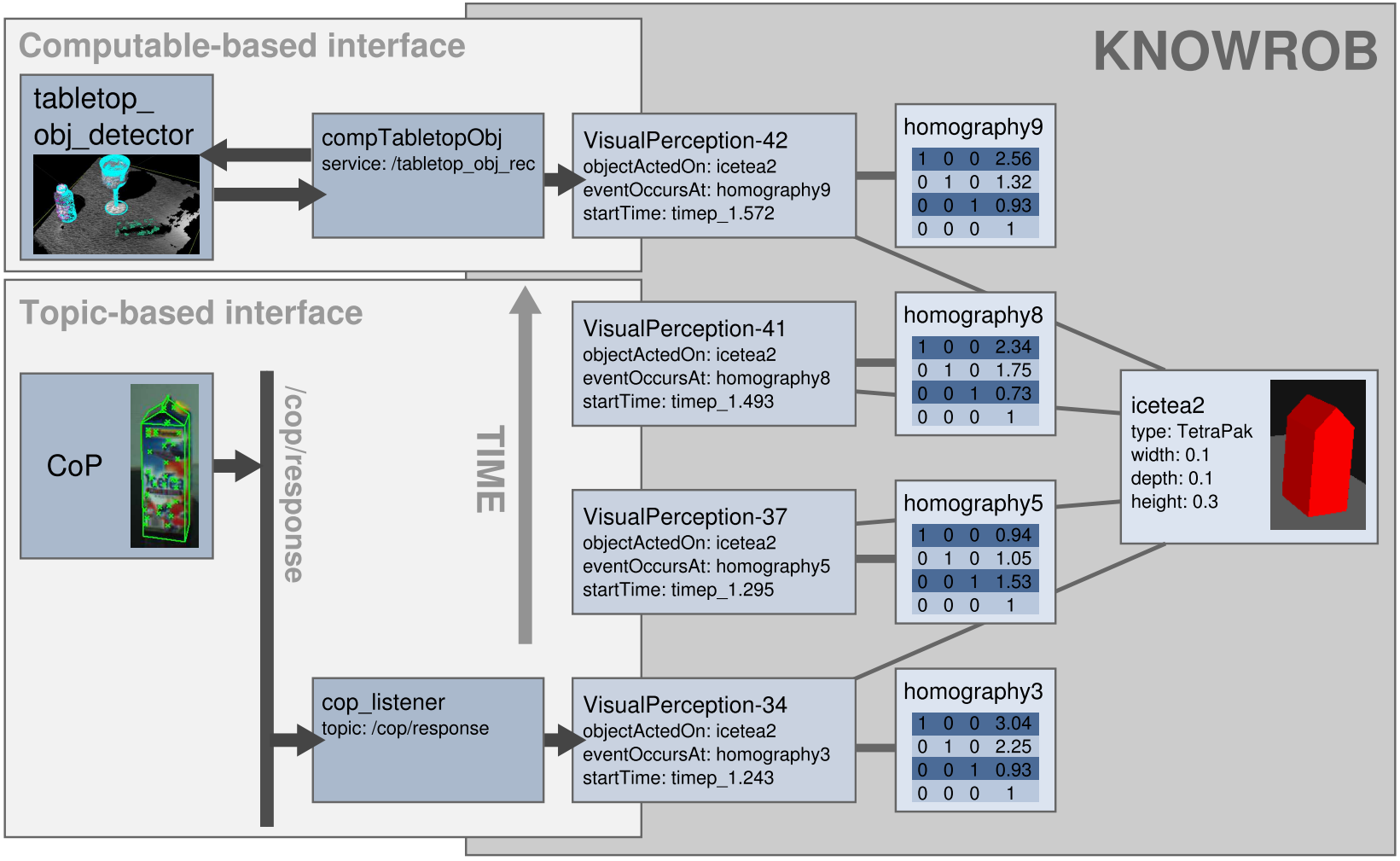
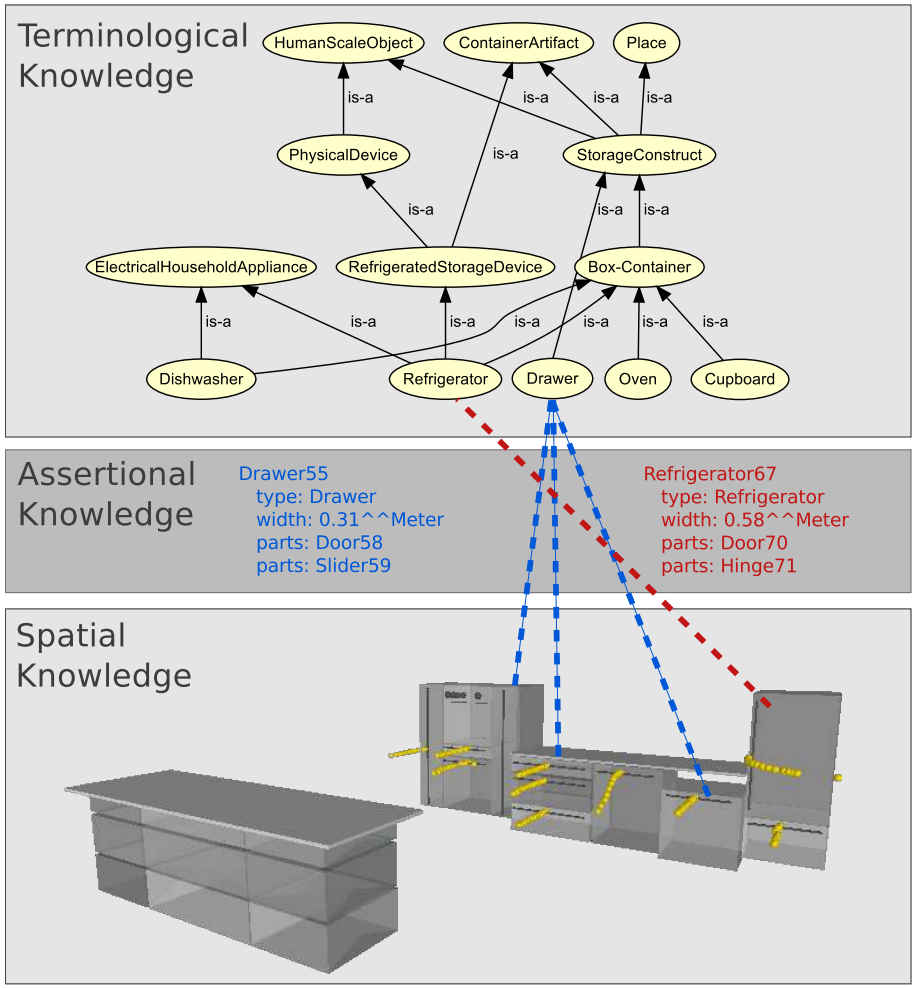
Spatio-temporal object representation



Integrating perception



Semantic map representation



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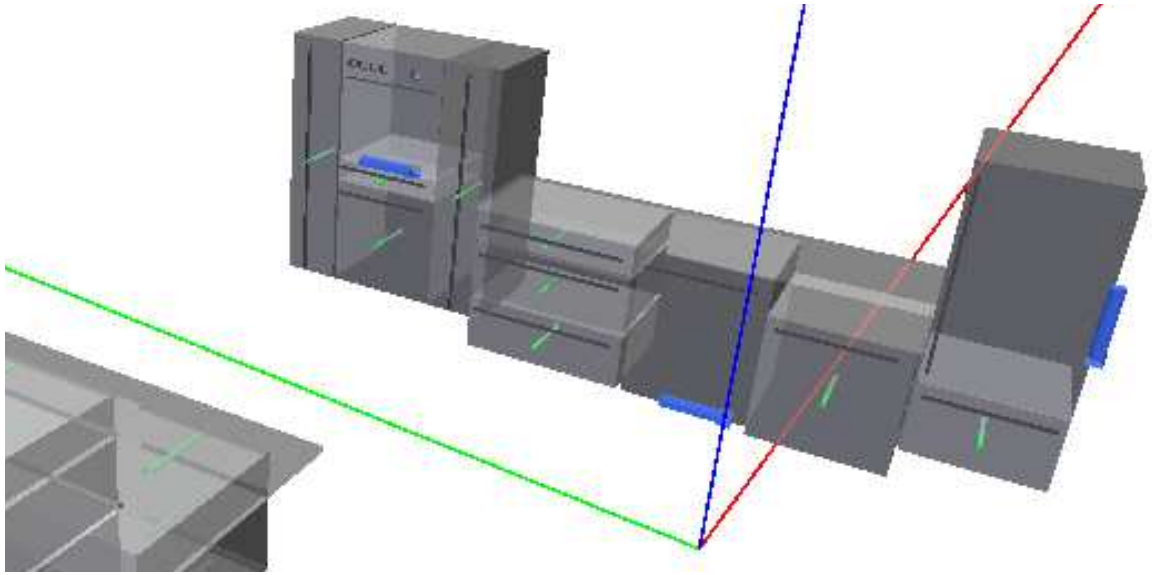
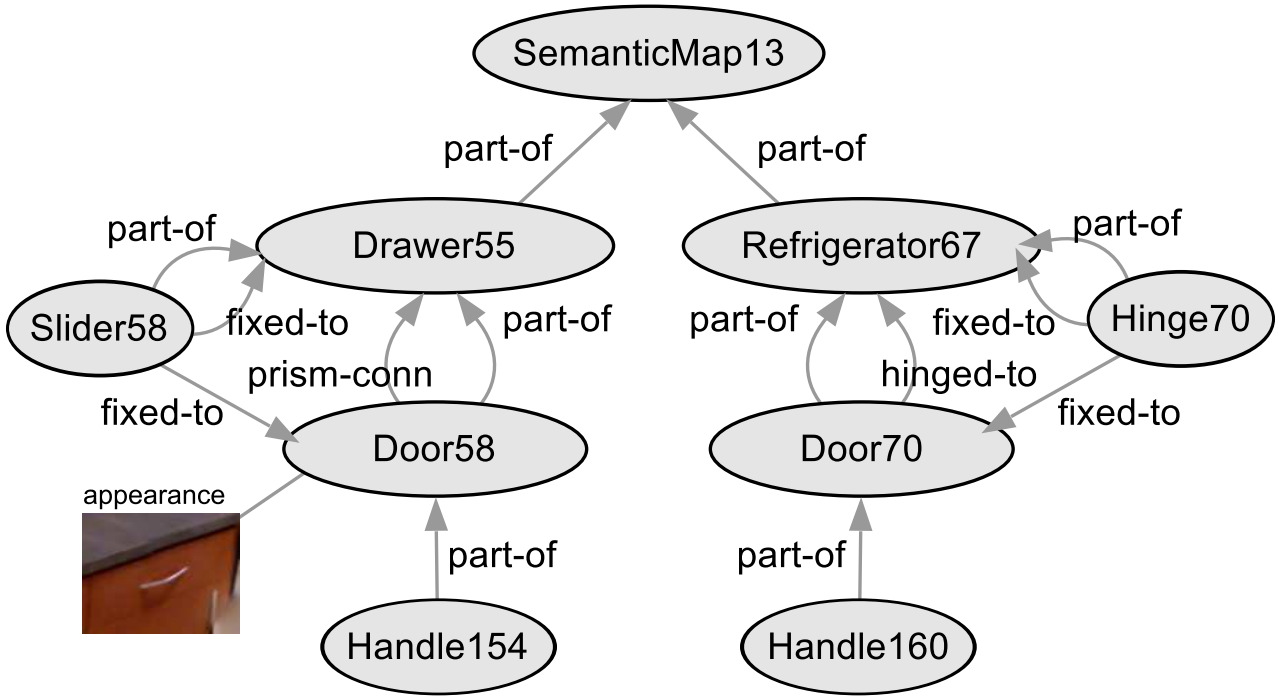
Representing articulated objects



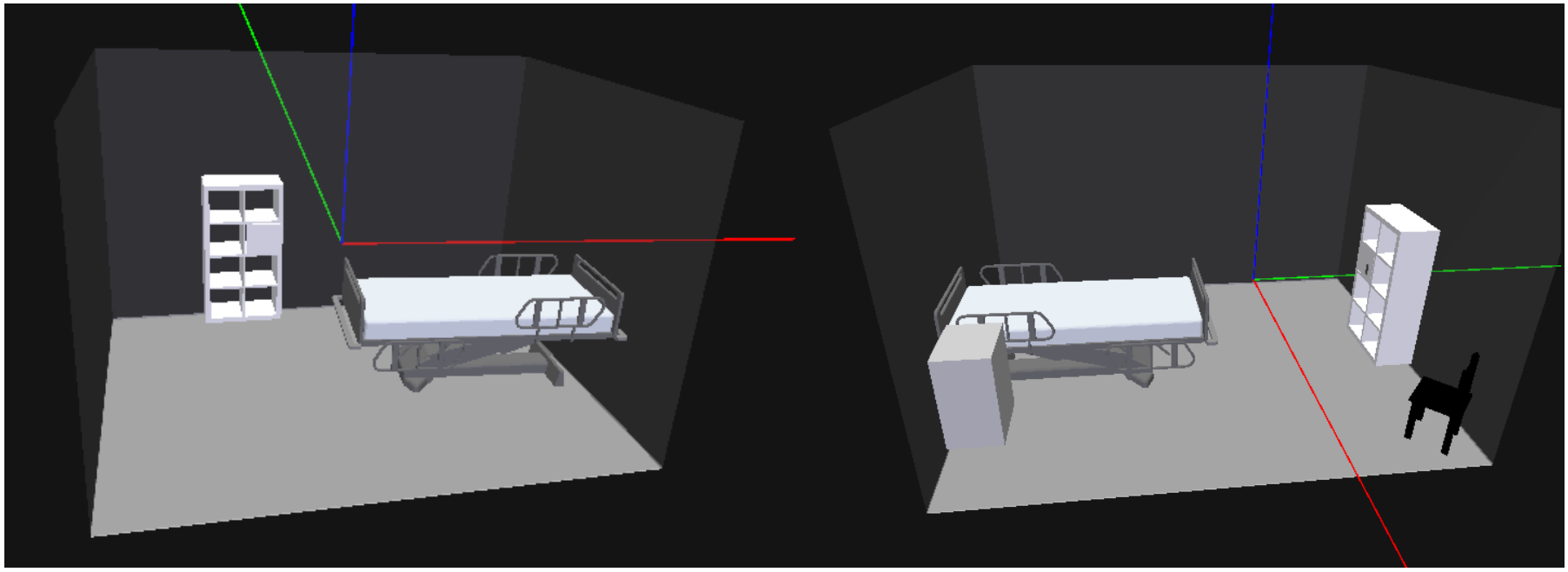
- Poses and joint limits of hinges and prismatic joints
- Enable robot to open doors and drawers

Object part composition



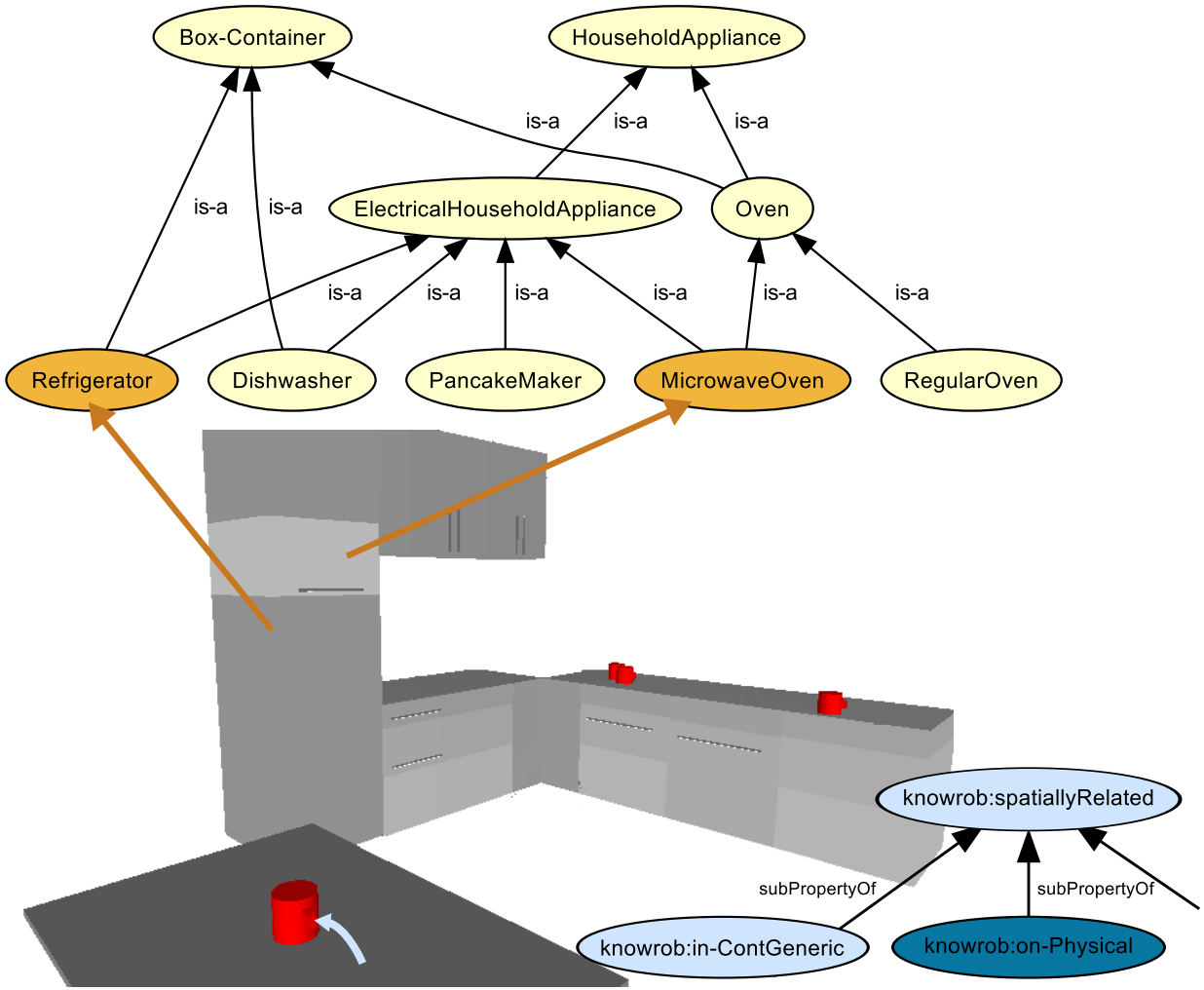
- Part-of hierarchy: composition of objects from parts
- Hinged-to/fixed-to: kinematic properties

Integrating CAD models

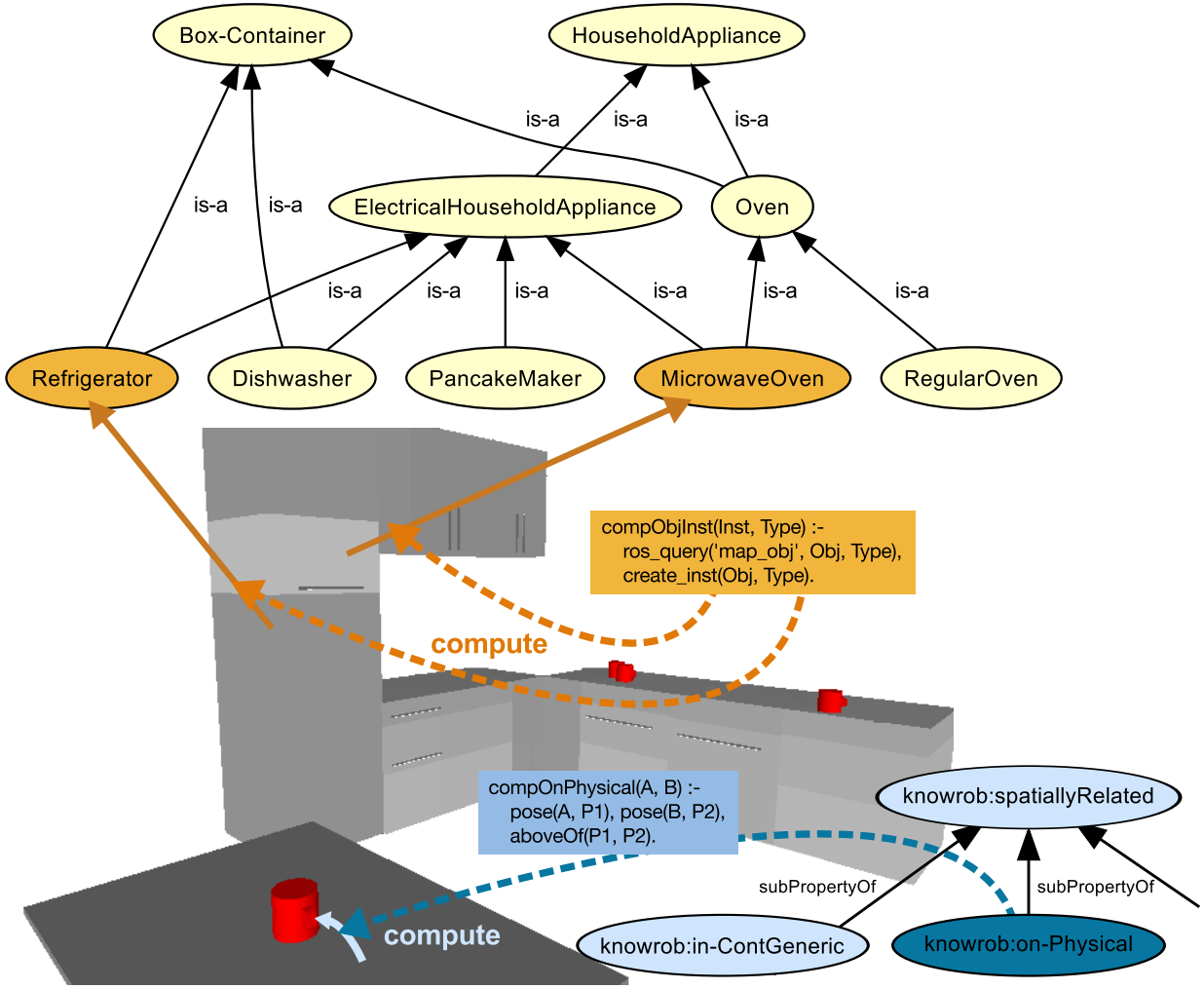


- Visualization and computation of qualitative spatial relations
- Soon: segmentation and interpretation of object parts

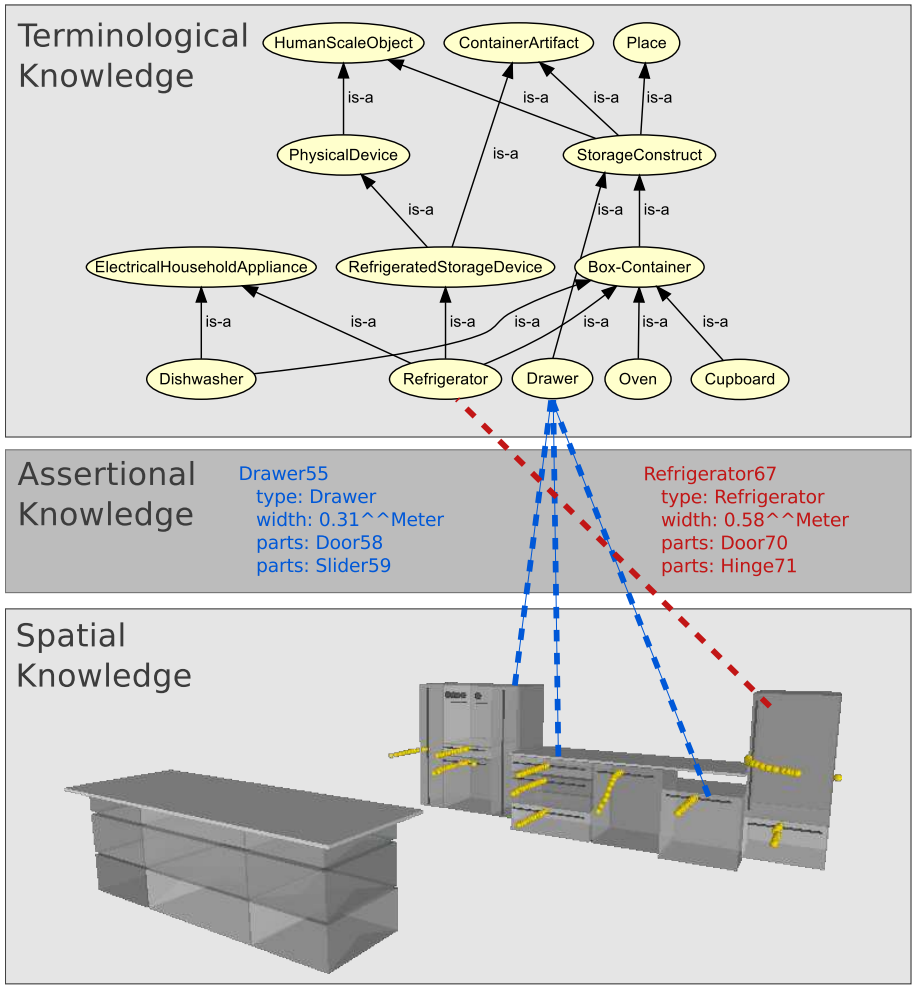
Computing qualitative spatial relations



Computing qualitative spatial relations



Semantic map representation



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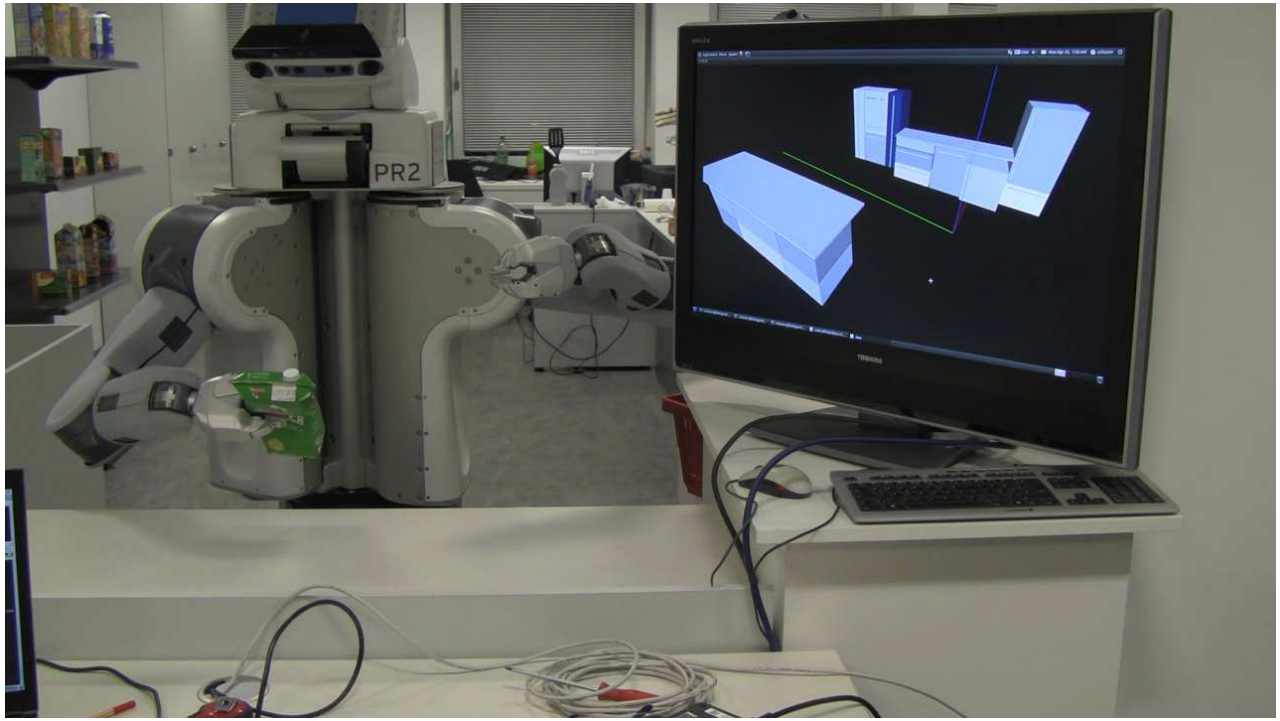
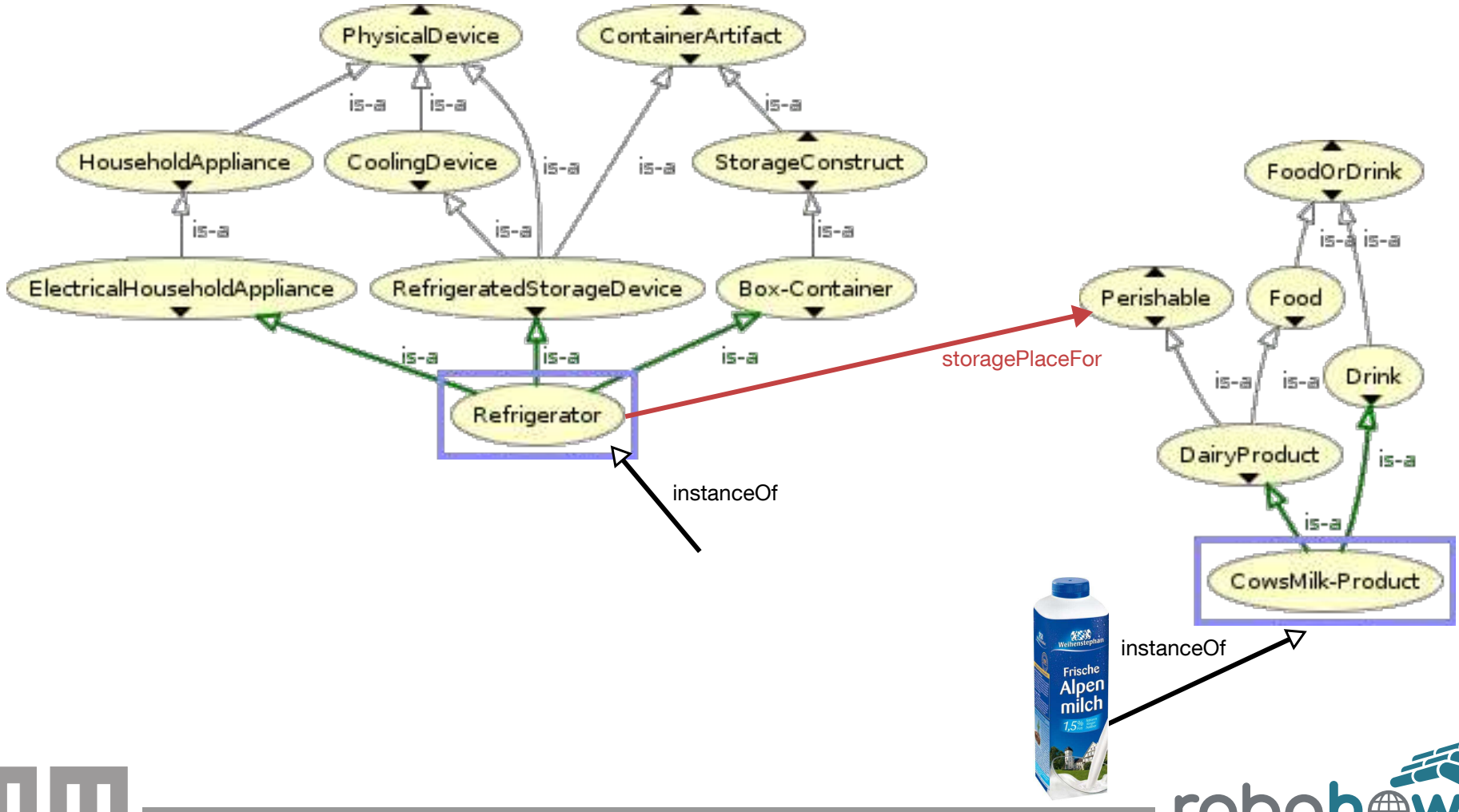
Video: Unpacking a shopping basket



Thanks to Dejan Pangercic, Máthé Koppány, Zoltan-Csaba Marton, Lucian Goron, Monica Opris and Thomas Rühr for making this live demonstration possible.

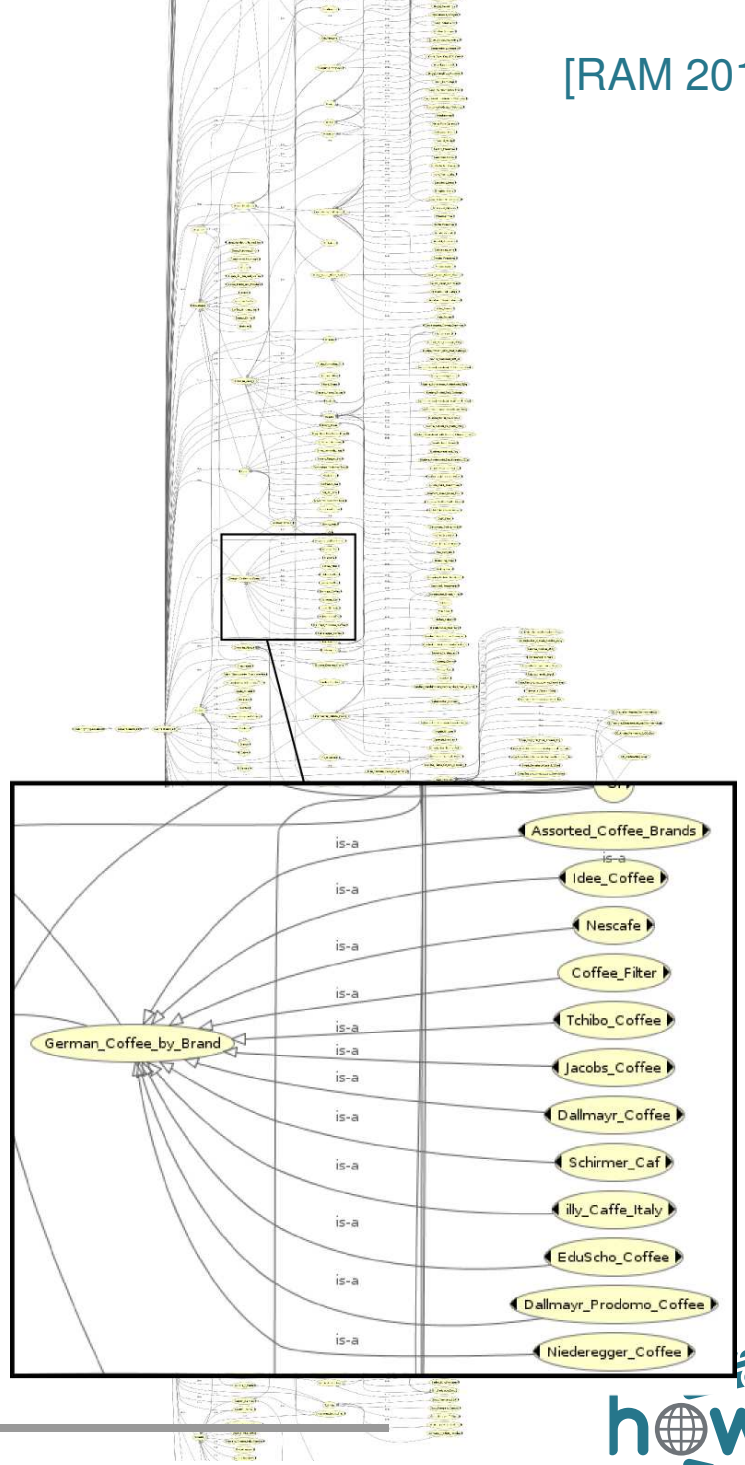
Infer storage location based on generic class knowledge



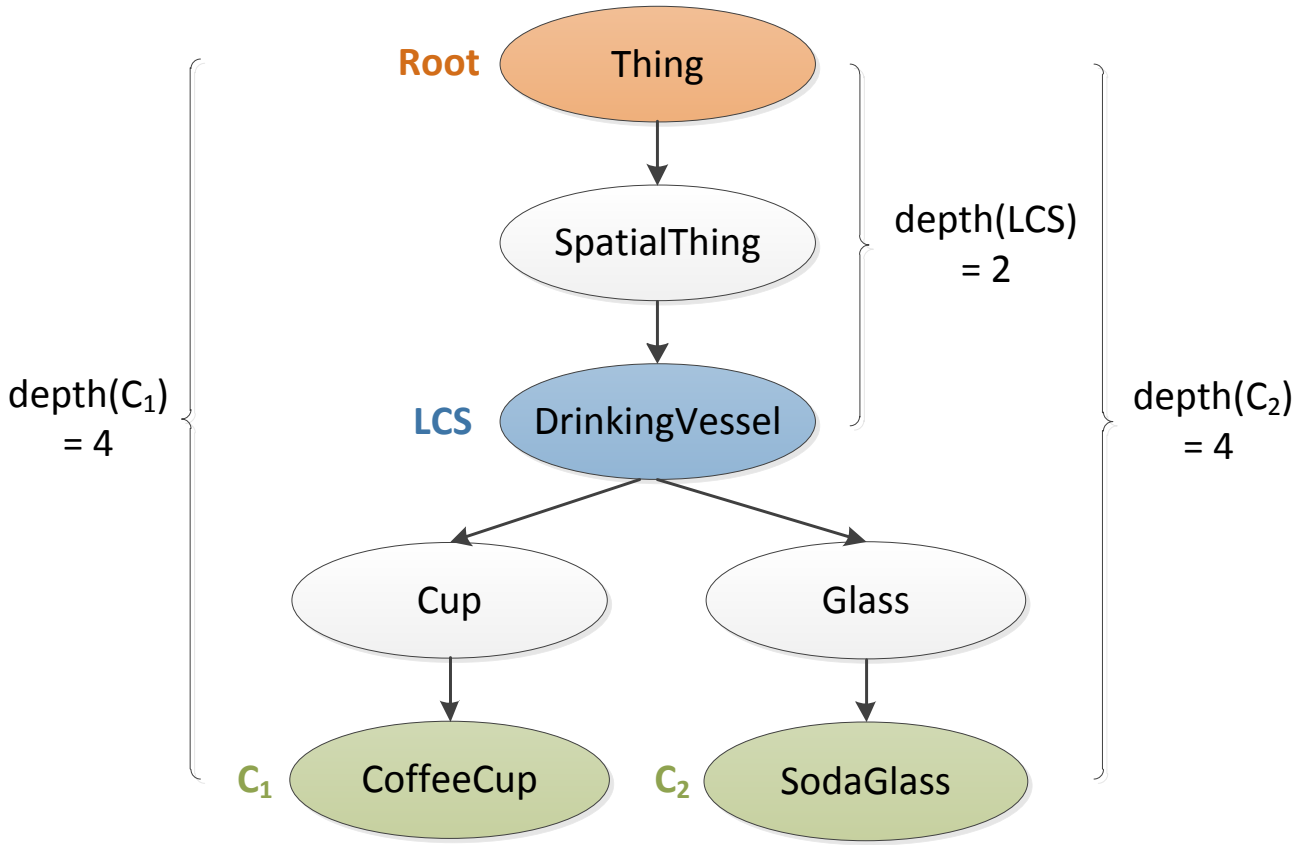
[RAM 2011a]

Object ontology

- Automatically created ontology of >7500 objects from the online shop germandeli.com
- Class hierarchy from categories + perishability, weight, price, origin, ...
- SIFT recognition models from product pictures (work by Dejan Pangercic)



Infer storage locations based on semantic object similarity



Learning Organizational Principles in Human Environments.
Martin Schuster, Dominik Jain, Moritz Tenorth and Michael Beetz. ICRA 2012

Infer storage locations based on semantic object similarity

```
?- highlight_best_location_dtree(
orgprinciples:'CoffeeFilter1', Canvas).

Best location:  knowrob:Drawer7
Objects at location knowrob:Drawer7:
WUP similarity:  object (class)
0.87500:  orgprinciples:CoffeGround1
(germandeli:Dallmayr_Classic_Ground_Coffee_250g)
0.75000:  orgprinciples:EspressoBeans1
(germandeli:illy_Espresso_Whole_Beans_88_oz)
0.70588:  orgprinciples:Sugar1
(germandeli:Nordzucker_Brauner_Teezucker_500g)
0.66667:  orgprinciples:Tea2
(germandeli:Teekanne_Rotbusch_Tee_Vanille_20_Bags)
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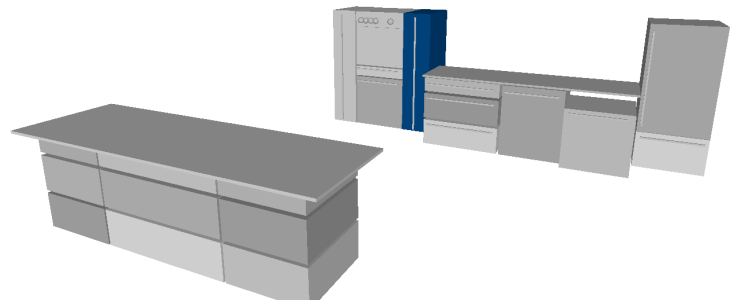
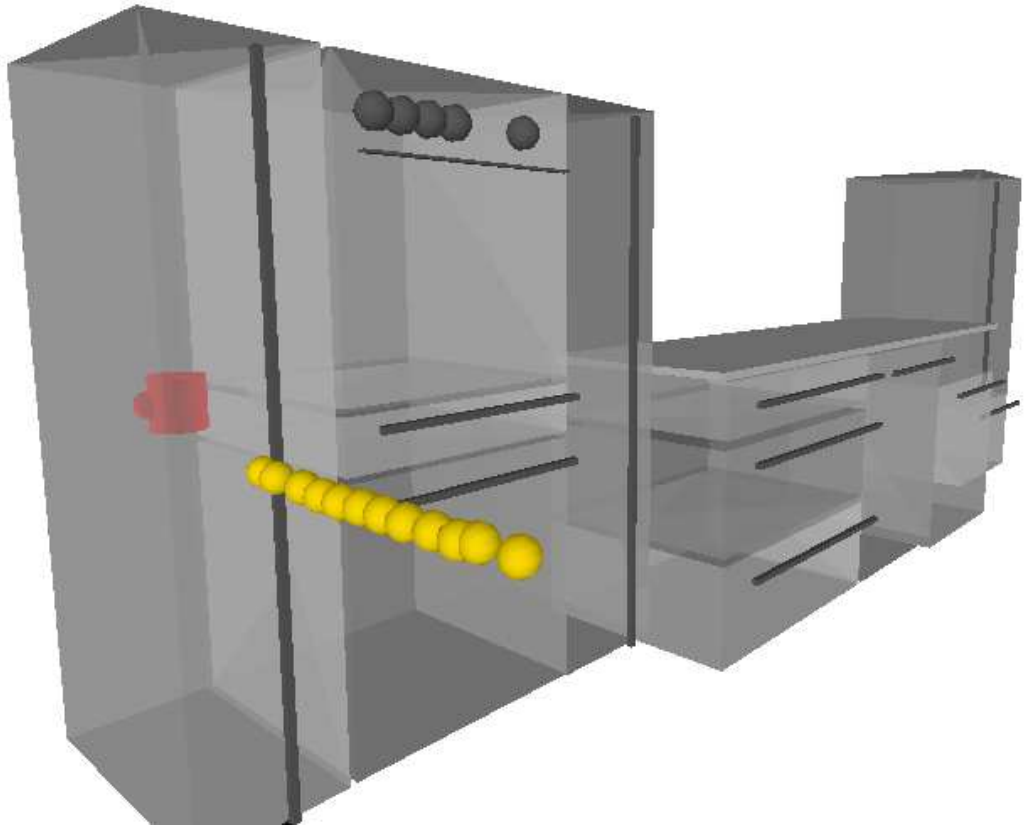
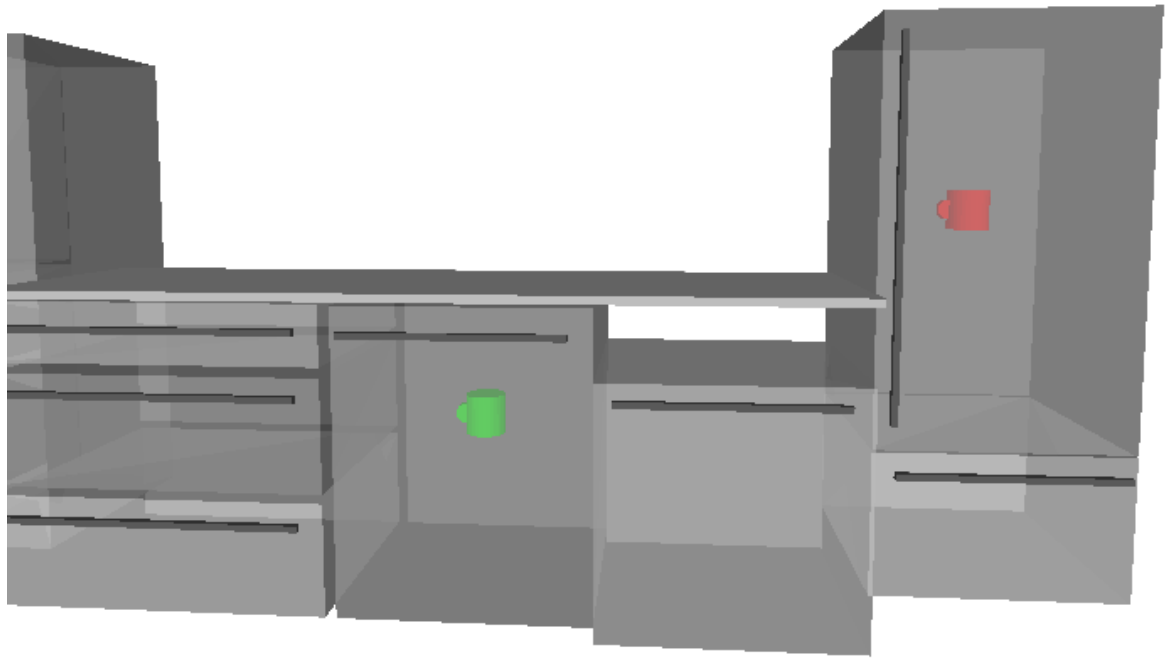


Open the drawer where cups are stored



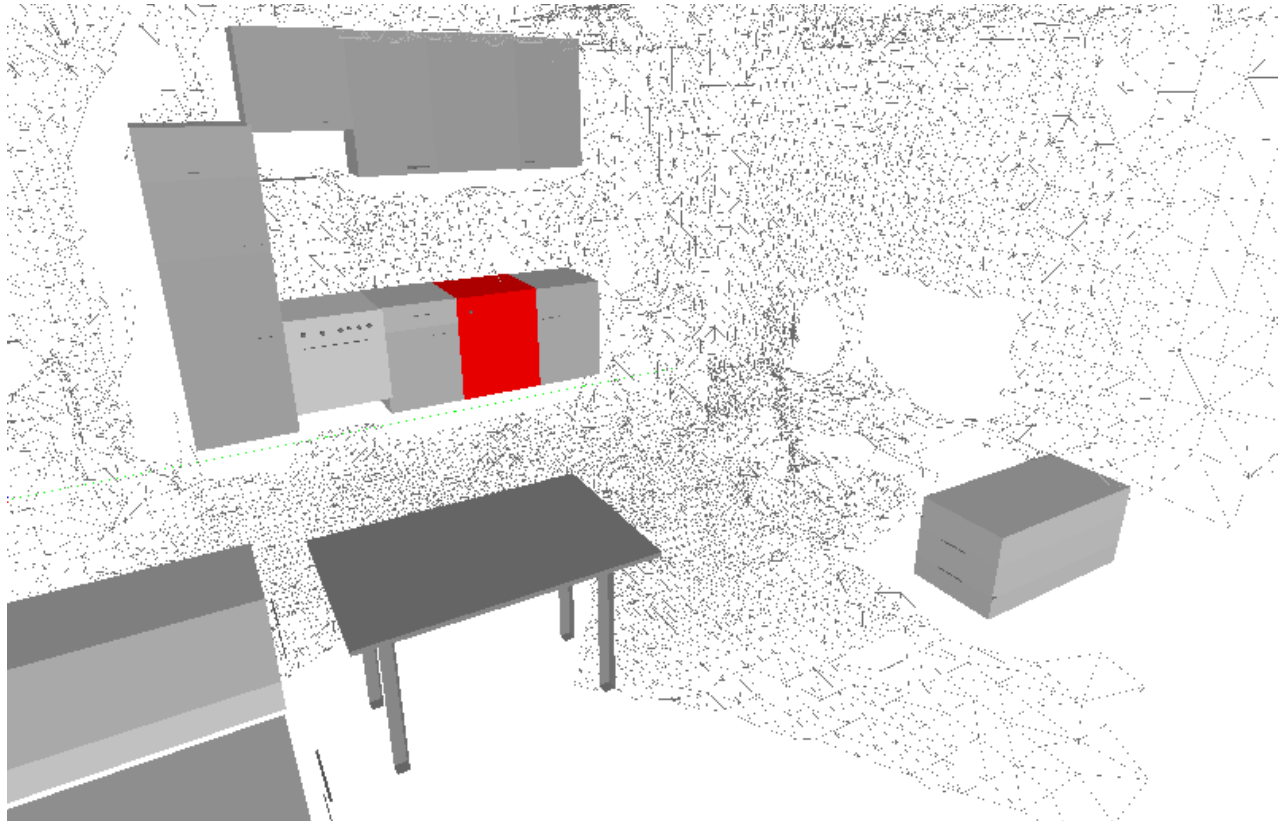
- Infer most likely storage location
- Read articulation model from semantic map

Check if objects are placed correctly



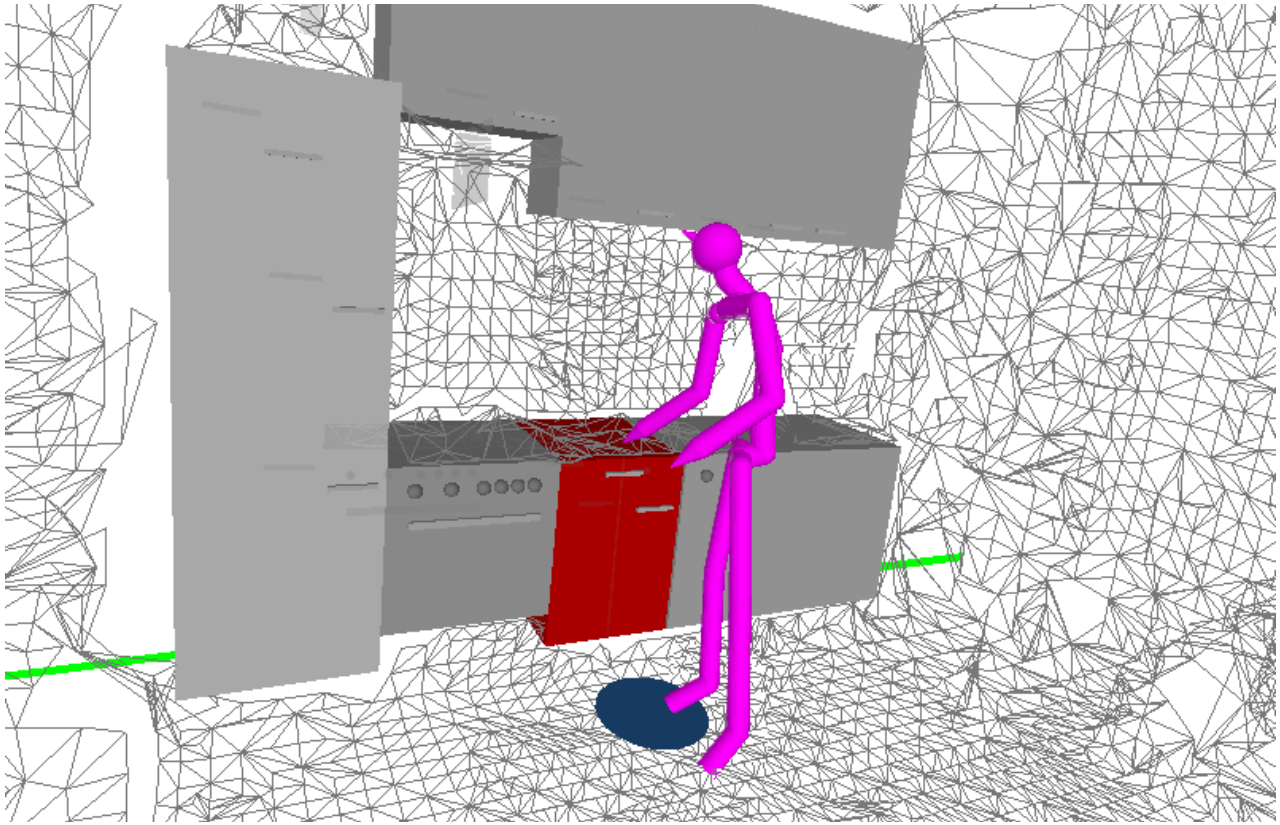
- Infer most likely storage location
- Compare with actual locations of objects

Select objects based on their purpose



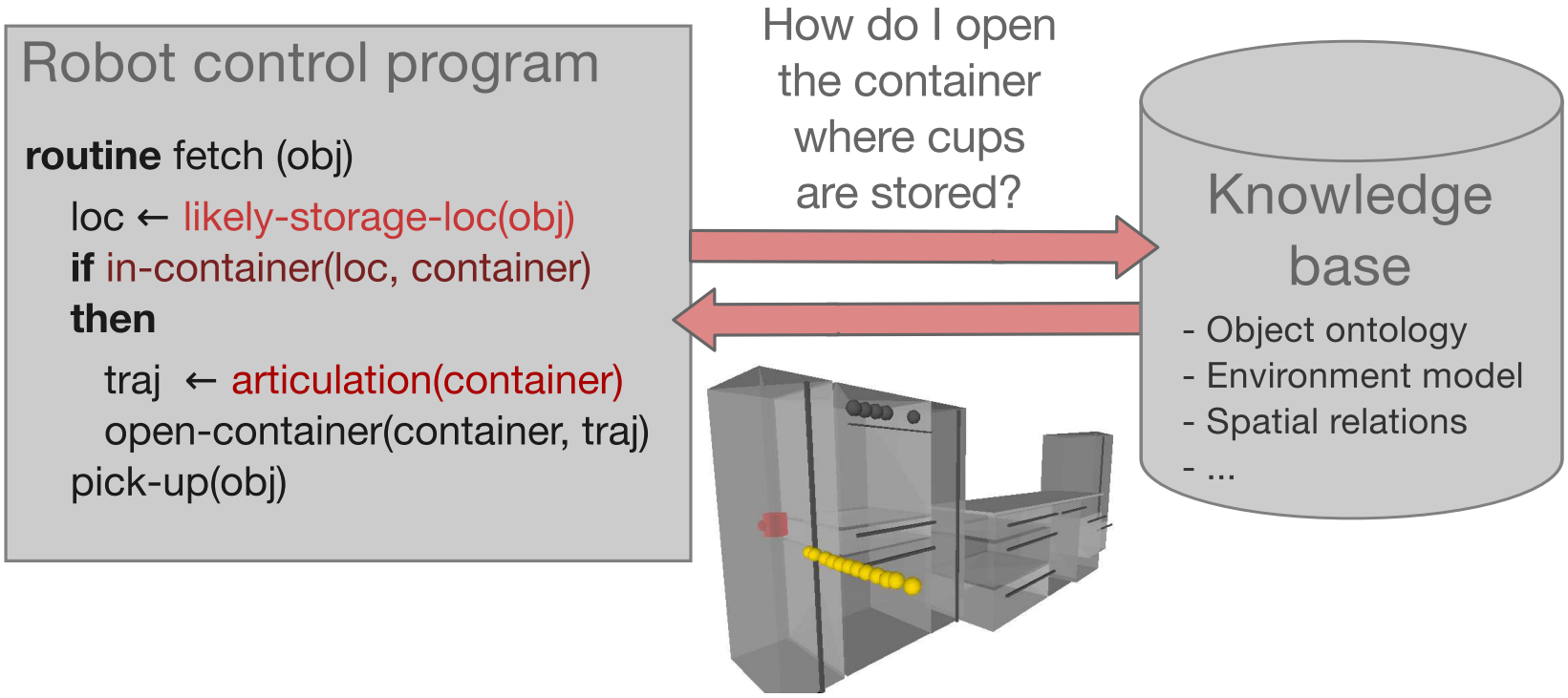
- Combine abstract object knowledge with map information
- Here: “appliance that can be used for washing dishes”

Integrate with human tracking data



- Observations of humans are represented in the KB
- Reason about their interaction with objects in the map

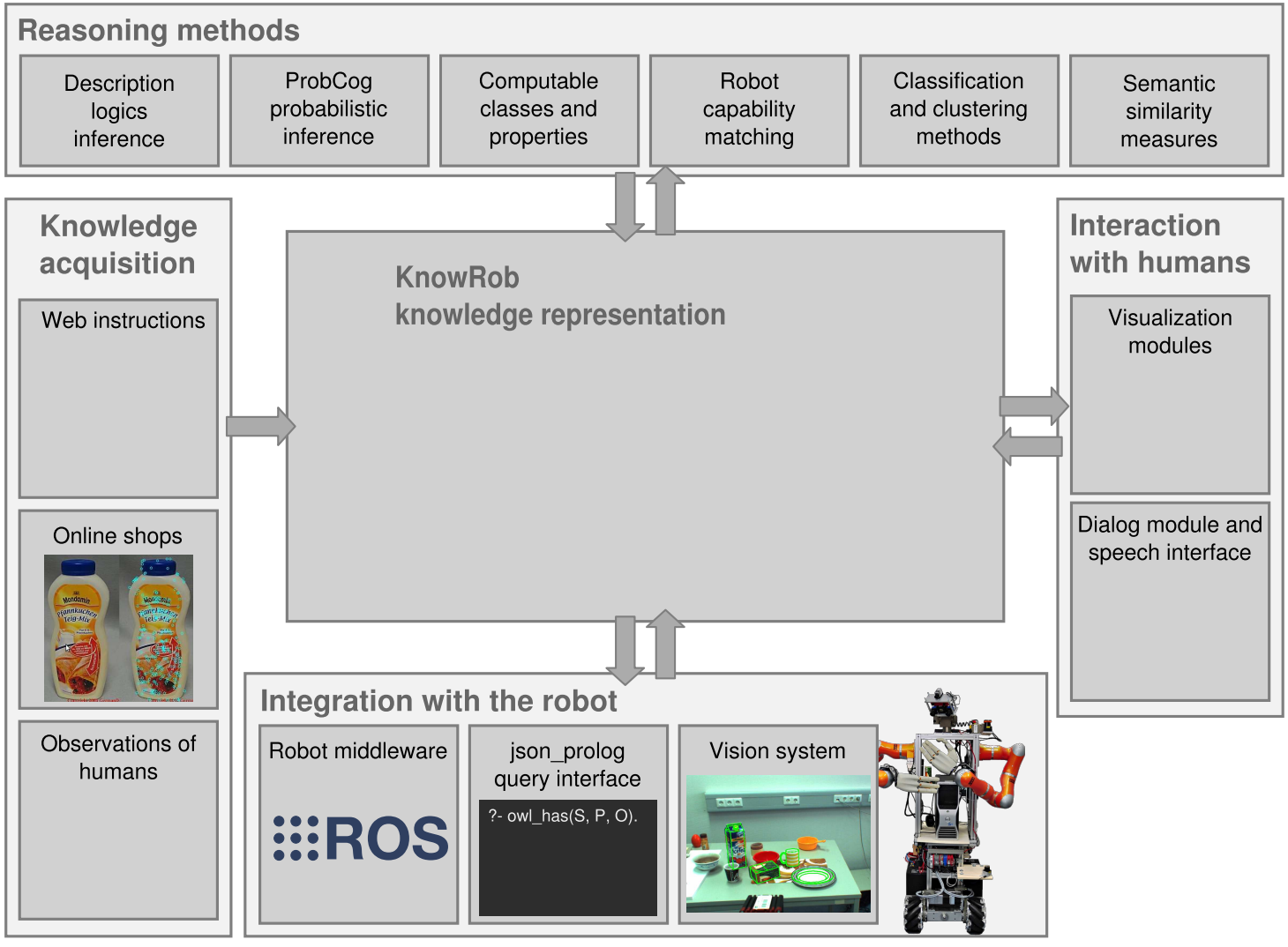
Making decisions using map knowledge



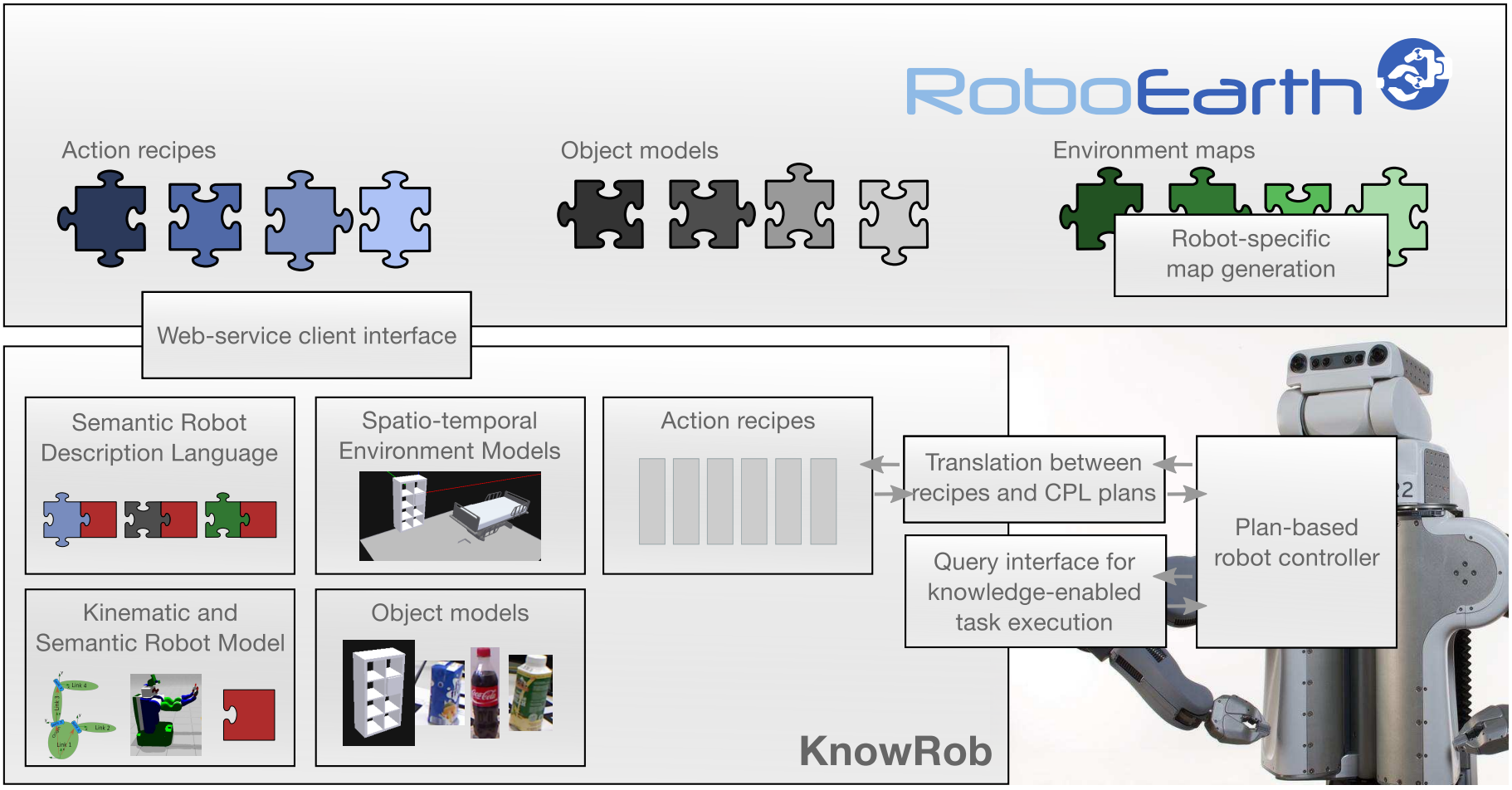
- Formulate control decisions as inference tasks
- Separate control flow from execution context
- Increase re-usability of robot plans

[IROS 2009, RAS 2010]

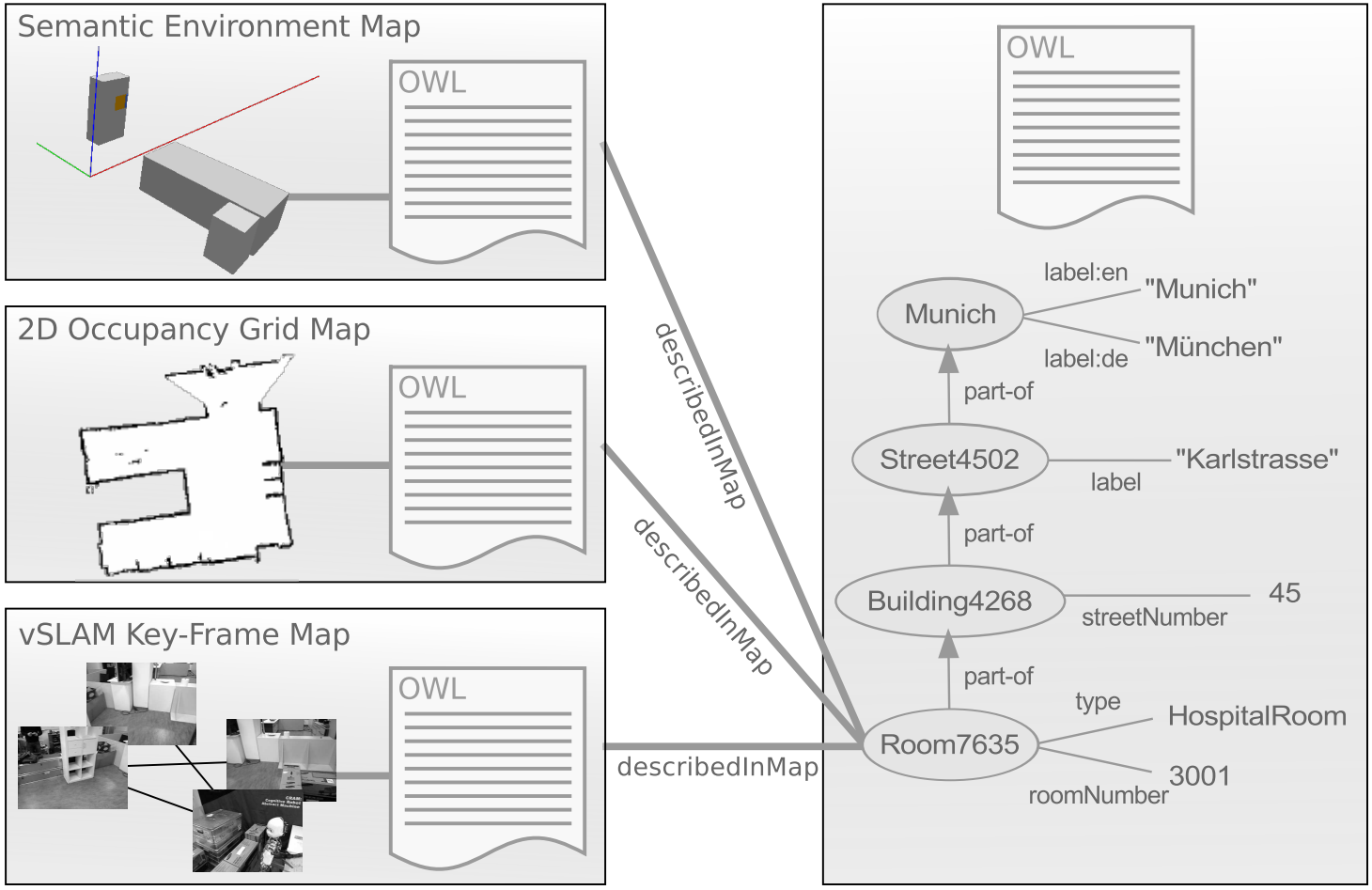
The KnowRob robot knowledge base



Exchanging maps via RoboEarth

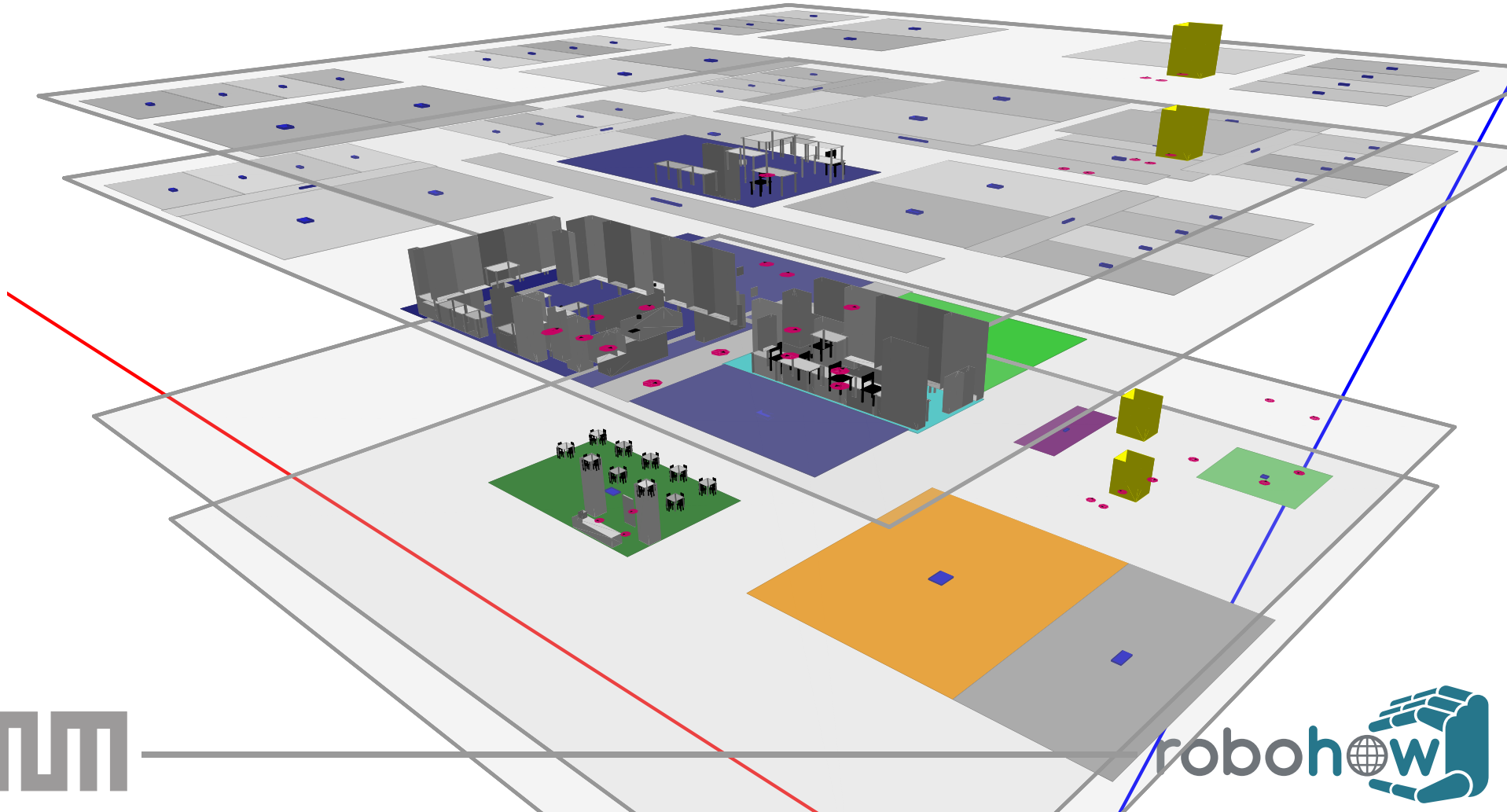


Finding maps for an environment



Scaling up to large environments

Searching Objects in Large-Scale Indoor Environments: A Decision-Theoretic Approach.
Lars Kunze, Michael Beetz, Manabu Saito, Haseru Azuma, Kei Okada, Masayuki Inaba. ICRA 2012



Conclusions

- Semantic environment maps as robot knowledge bases
- Spatio-temporal object representation
- Object composition and articulation properties
- Integration with abstract knowledge about objects
- Available as open-source ROS components incl. tutorials

http://www.ros.org/wiki/knowrob

Thank you for your attention!

Acknowledgments:

robohow

cotesys

RoboEarth