Semantic maps - a multi-hierarchical model

64.425 Integrated Seminar: Intelligent Robotics

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Technische Aspekte Multimodaler Systeme

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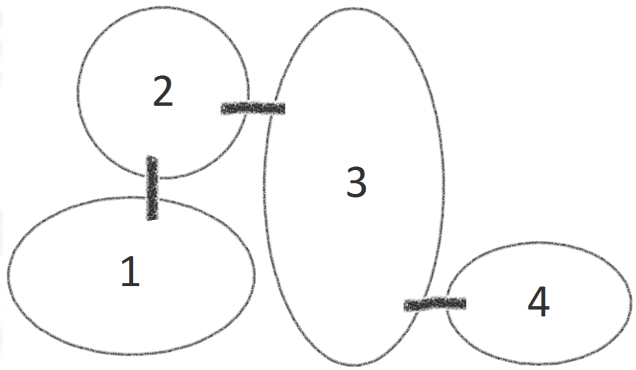
Outline

Traditional robot maps

Metric map showing lines extracted from laser range scans - [6].



Space segmented into topological nodes.

Semantic knowledge...

Empowers mobile robots

- reasoning capabilities
- autonomy
- enhanced mobility
- efficiency
- interaction
- communication skills
- ...

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Properties and challenges

- co-exist with other components
- dealing with uncertain perceptions
- real-world indoor environment:
  - dynamic
  - appearance changes
  - perception of environment
- properties of the sensors employed

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Multi-hierarchical semantic maps for mobile robotics

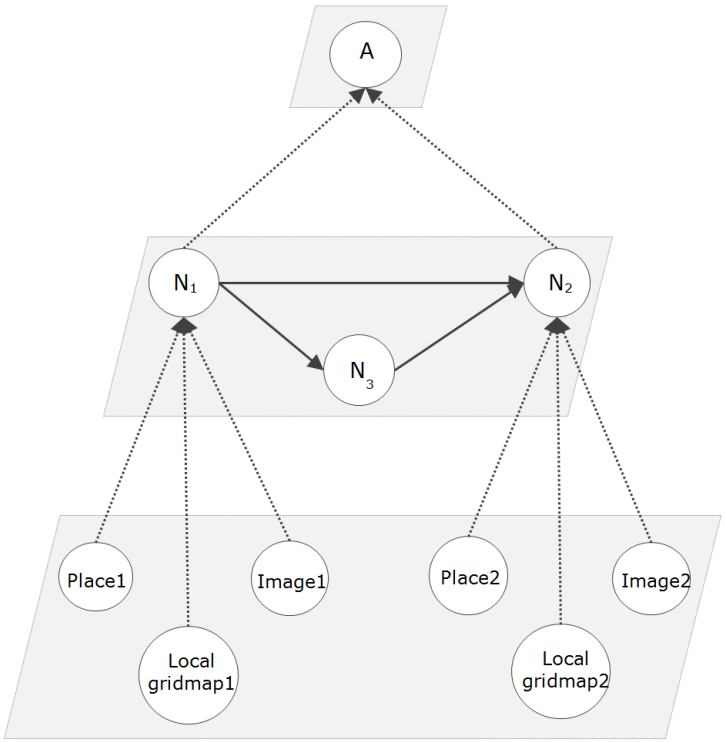
Galindo et. al.

„In this paper, we propose an approach to allow a mobile robot to build a semantic map from sensor data, and to use this semantic information in the performance of navigation tasks.“ - [3]

- Robot Task Planning using Semantic Maps [4]
- Monitoring the execution of robot plans using semantic knowledge [2]

Spatial hierarchy

Stores spatial and metric information of the environment



spatial environment

the topology of the space

images of objects and local grid maps

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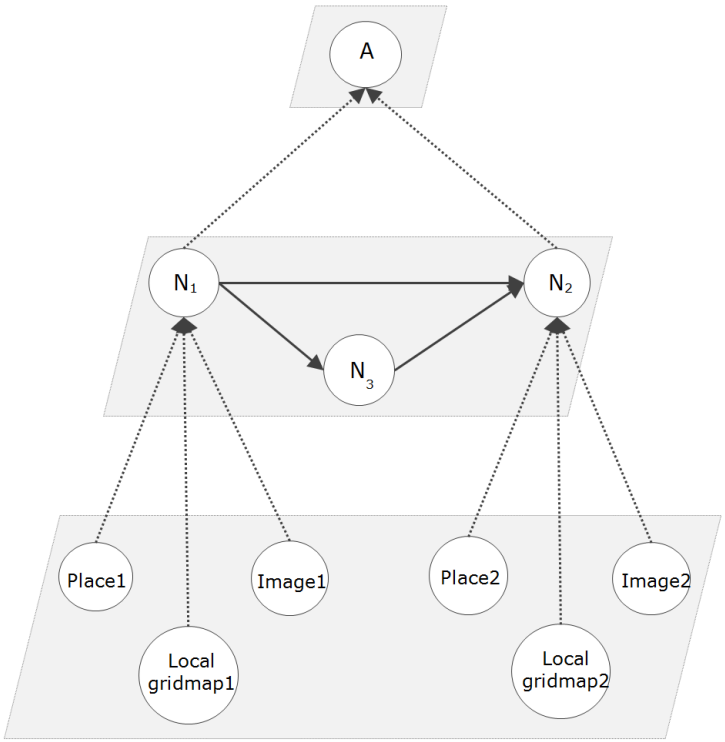

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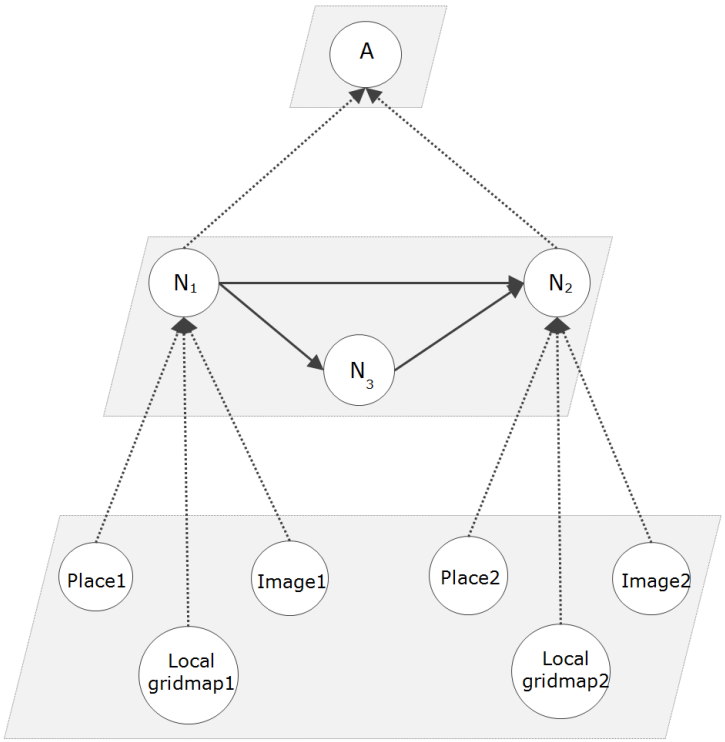

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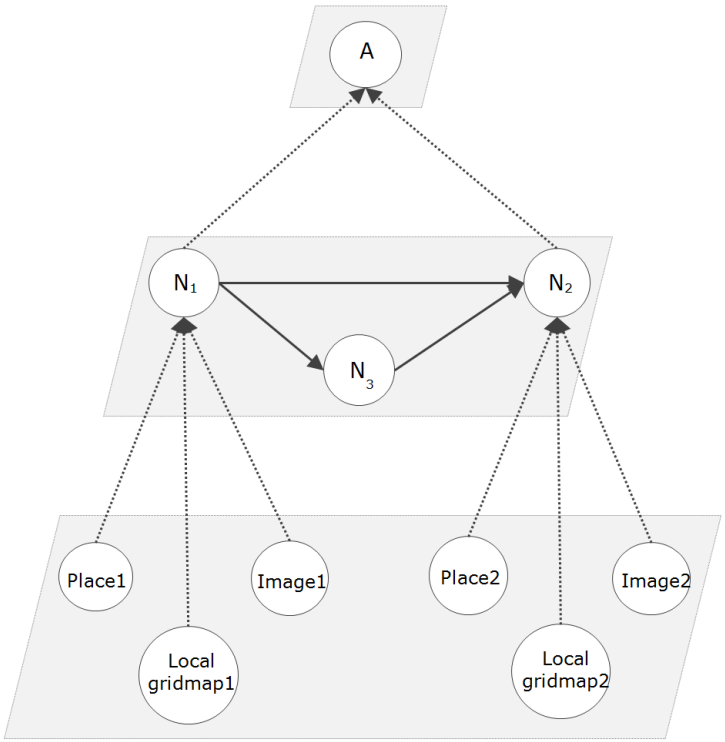

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Spatial hierarchy - [3].

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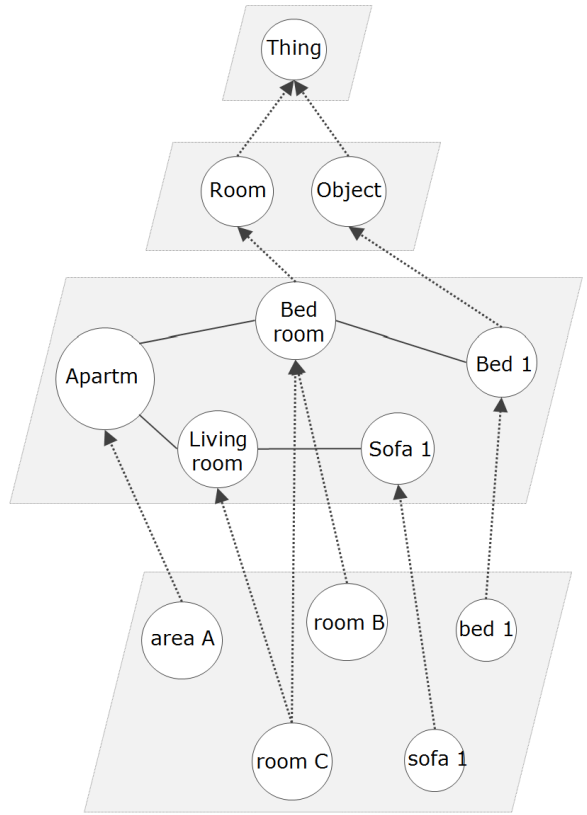
Provides modelling of semantic knowledge and human-like inference capabilities

common ancestor

general categories

specific concepts

individual instances



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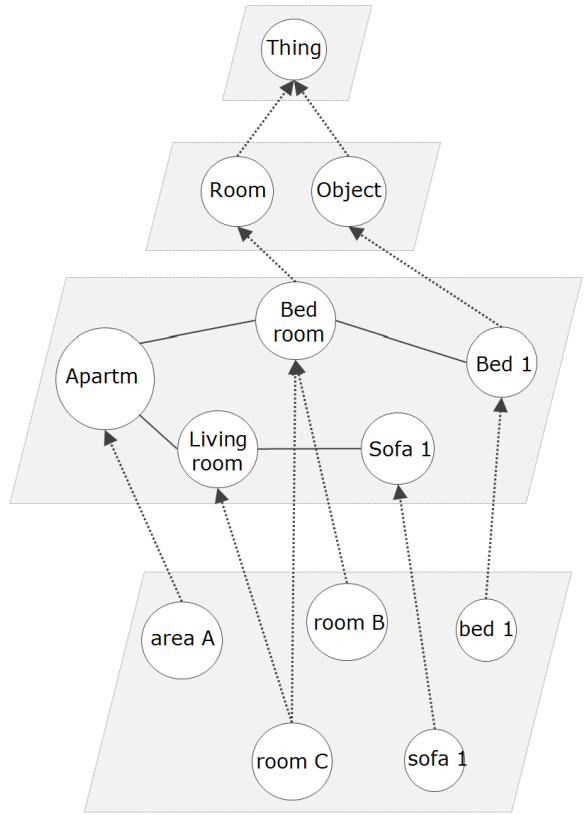

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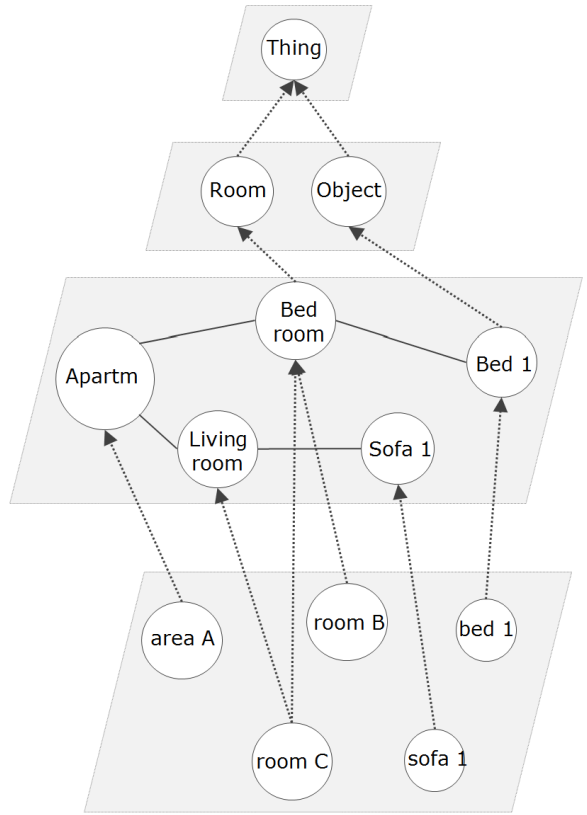

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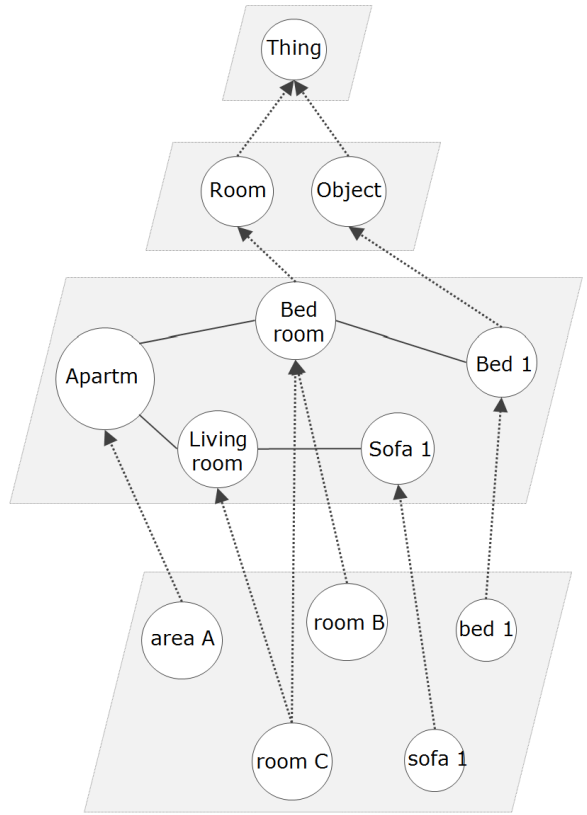

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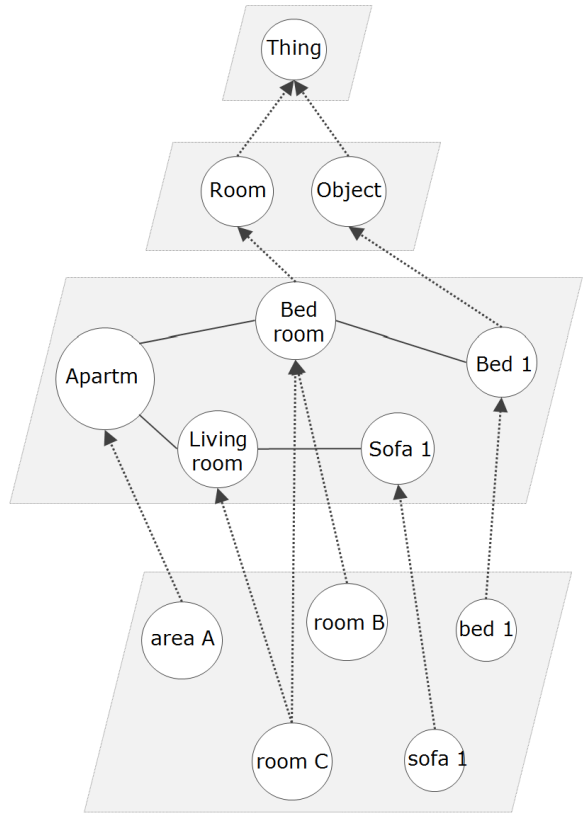
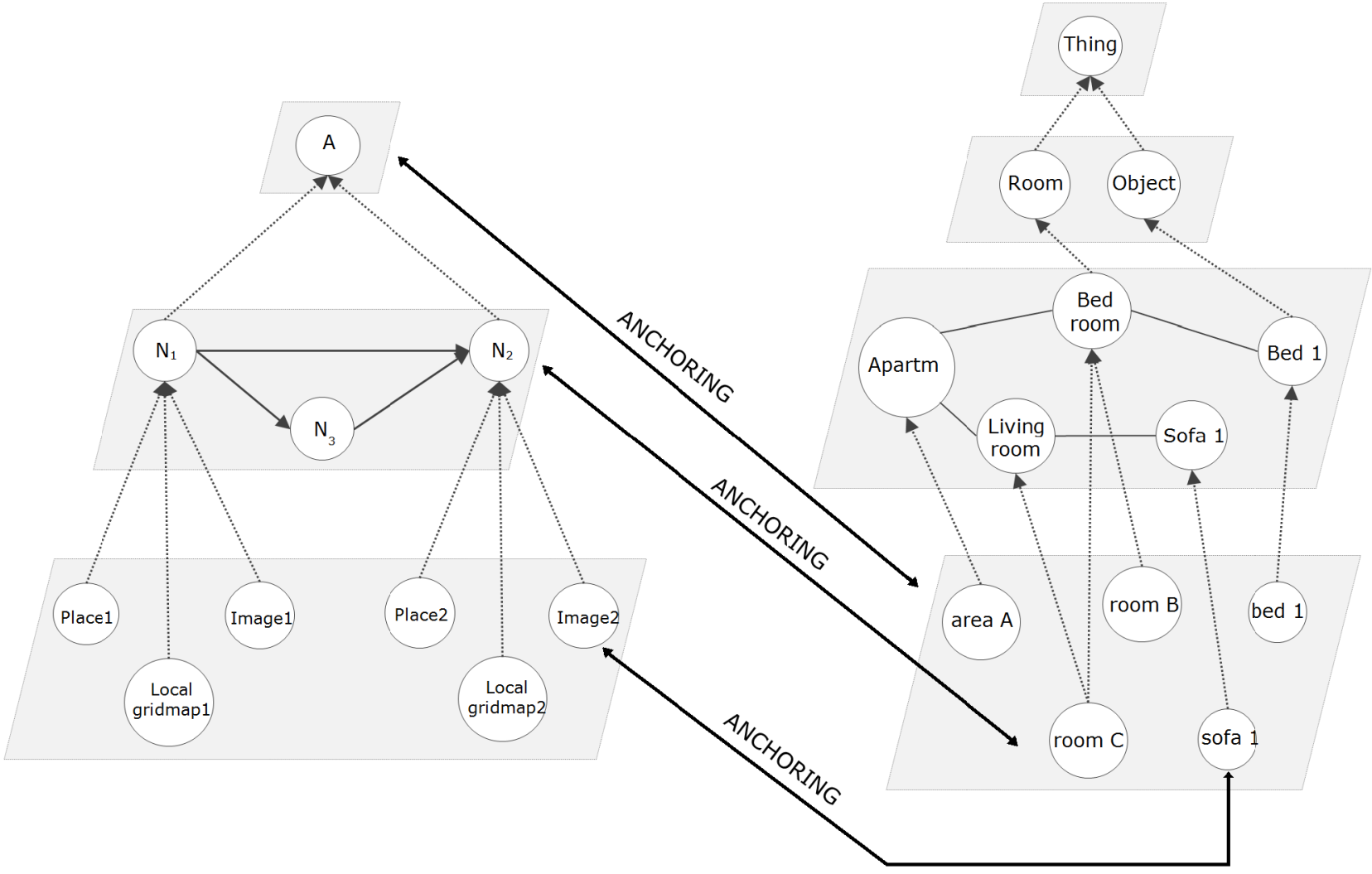


Conceptual hierarchy - [3].

Linking via anchoring



Anchoring as a technique of connecting both hierarchies - [3].

Description logics

Define the relevant concepts (terminology)

↓

Specify properties of objects and entities (description)

↓

Represent the knowledge of an application domain (the world)

Description logics (cont.)

- There are **individuals**
- Connected through **roles**
- **Concepts** are sets of individuals
  - simple concept: C
  - conjunction of concepts: $C_1 \sqcap C_2$
  - disjunction of concepts: $C_1 \sqcup C_2$
  - negation of concepts: $\neg C$
  - existential restriction: $\in R.C$
  - universal restriction: $\forall R.C$

Space

$$Area \equiv Space \sqcap (> 0 hasDoor)$$

$$Door \equiv \neg Window$$

$$\in hasBook.Bookcase$$

$$\forall hasBed.Bedroom$$

Description logics (cont.)

ABox

- individual belongs to a class:

  C(i)

- roles link individuals:

  R(i,j)

TBox

- generic/specific

  C_1 subclassOf C_2

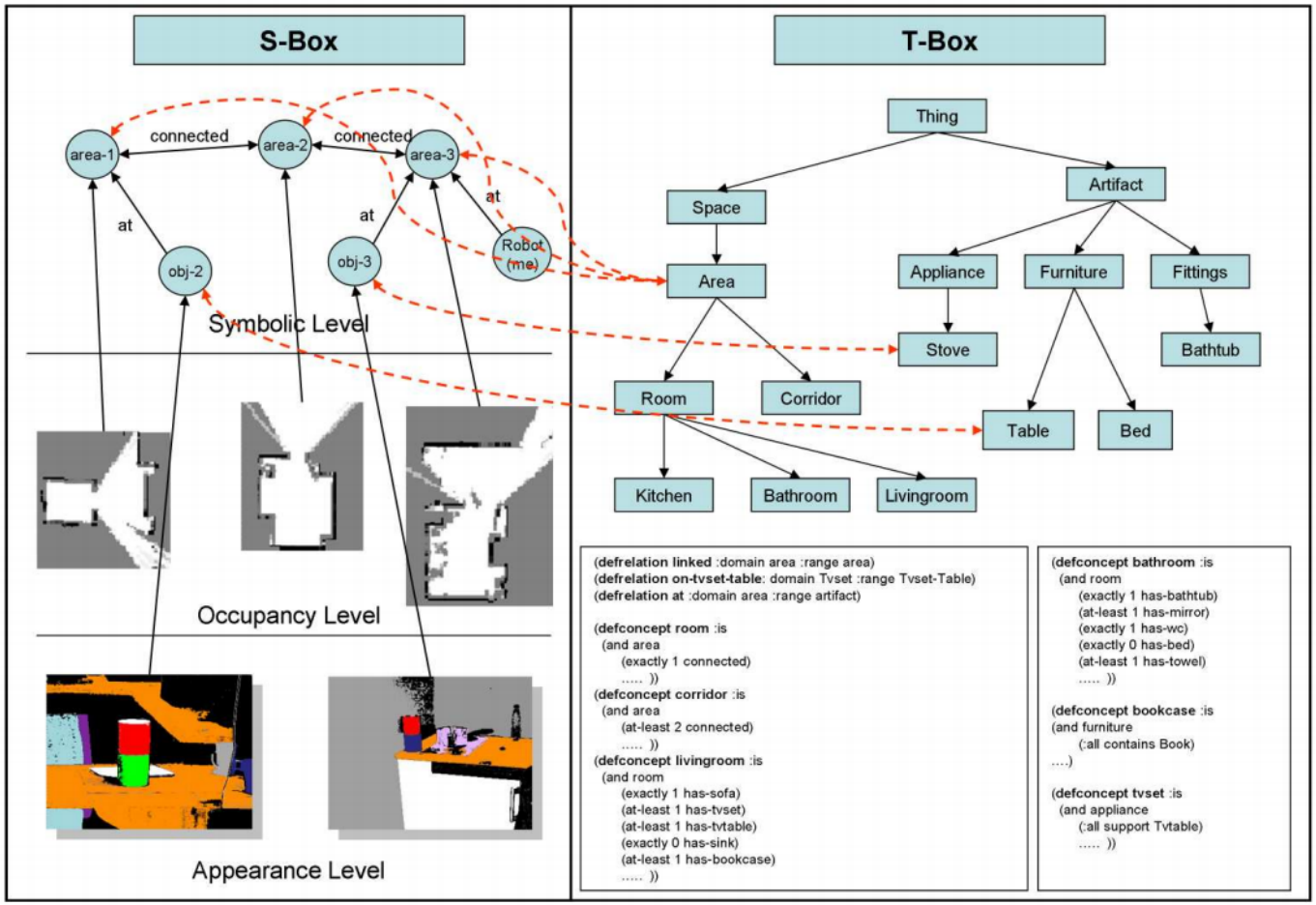
- equivalence

  C_1 equivalentClass C_2

- disjunction

  disjointWith(C_1, C_2)

Description logics (cont.)



Description Logic perspective of the semantic map - [4].

Reasoning mechanisms

- subsumption
  $KB \models C_1 \sqsubseteq C_2$
- equivalence
  $KB \models C_1 \equiv C_2$
- instance checking
  $KB \models C(i)$

Case Study

Inferring Robot Goals from Semantic Knowledge [5]

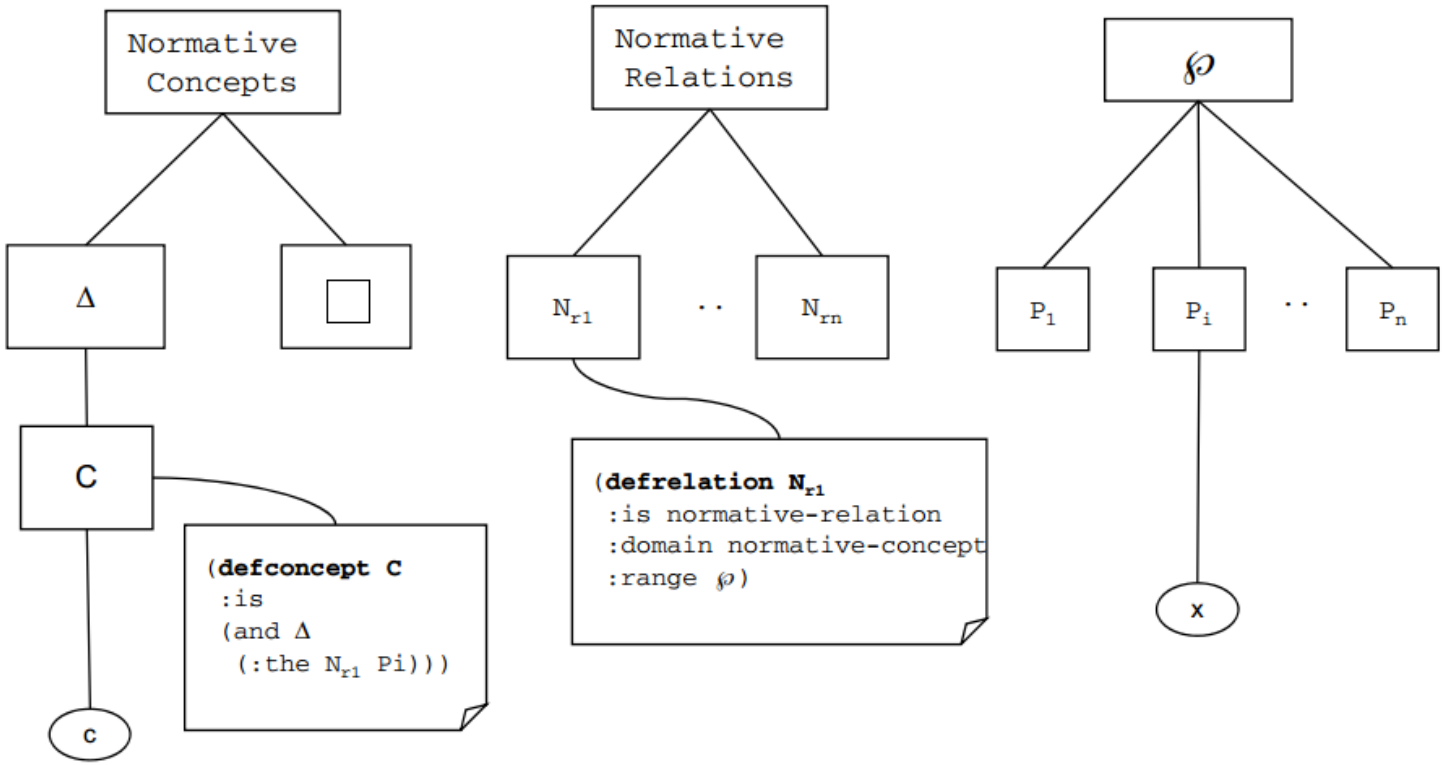
What happens if the existing knowledge turns out to be in conflict with the robot's observations?

1. update the semantic knowledge base
2. question the validity of its perceptions
3. modify the environment

Define normative relations and concepts

- Set of disjoint concepts
  $\rho = \{P_1, P_2, \ldots P_n\}, i.e., \forall a, a \sqsubseteq P_i \Rightarrow \nexists j, j \neq i, a \sqsubseteq P_j$
- Define normative relations
  $N_r : N_C \rightarrow \rho$
  $\forall b \sqsubseteq N_C \Rightarrow \exists P_j \in \rho, b \rightarrow [FILLS : N_r P_j]$
- Separate normative concepts
  $N_C = \triangle \cup \square, \triangle \cap \square = \emptyset$

Define normative relations and concepts (cont.)



Description logic interpretation of a domain[5].

Norm violation detection

if

$\exists k \sqsubseteq C, k \rightarrow [FILLS : N_r, y], y \sqsubseteq P_j \in \rho, P_j \neq P_i$

then

$y \sqsubseteq P_j \wedge y \sqsubseteq P_i$ incoherent

Critical Evaluation

Representation of spatial knowledge

Manually built ontology.
Issues: how to handle uncertainty?

Inference mechanism

Based on anchoring
[1] - probabilistic inference engine

Critical Evaluation (cont.)

Sources of semantic information

- objects
- ...

Issues: scarcity of objects, reliable object categorization
Solutions - [1]

- general appearance of places
- geometry of places
- topological structure

Questions?

Thank you for your attention :)

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