SPATIAL COGNITION

http://www.sfbtr8.uni-bremen.de
http://www.fb10.uni-bremen.de/ontology

Ontologies for spatial reasoning, action and interaction

Spatial assistance systems

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Scenario: Assistance Robotics

- Bremen / Freiburg
  - Collaborative Research Center for Spatial Cognition (SFB/TR8)
  - 12 year research program funded by the German Research Council (DFG)
- Autonomous / Partially-autonomous artificial agents for helping people deal with space

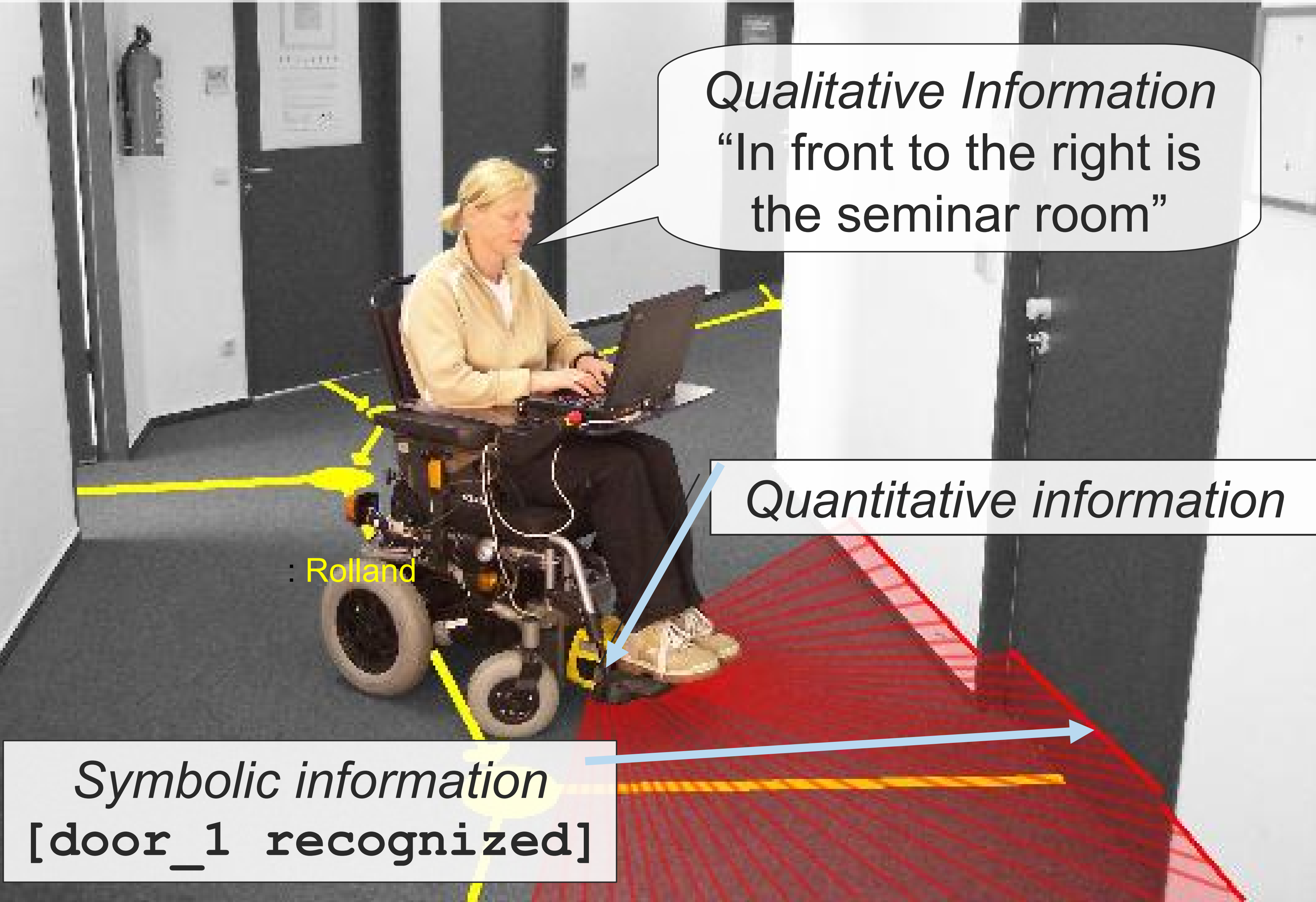
Assistance activities

- Mobility support
- Spatially-embedded tasks
- Exploration
- Navigation

Problem

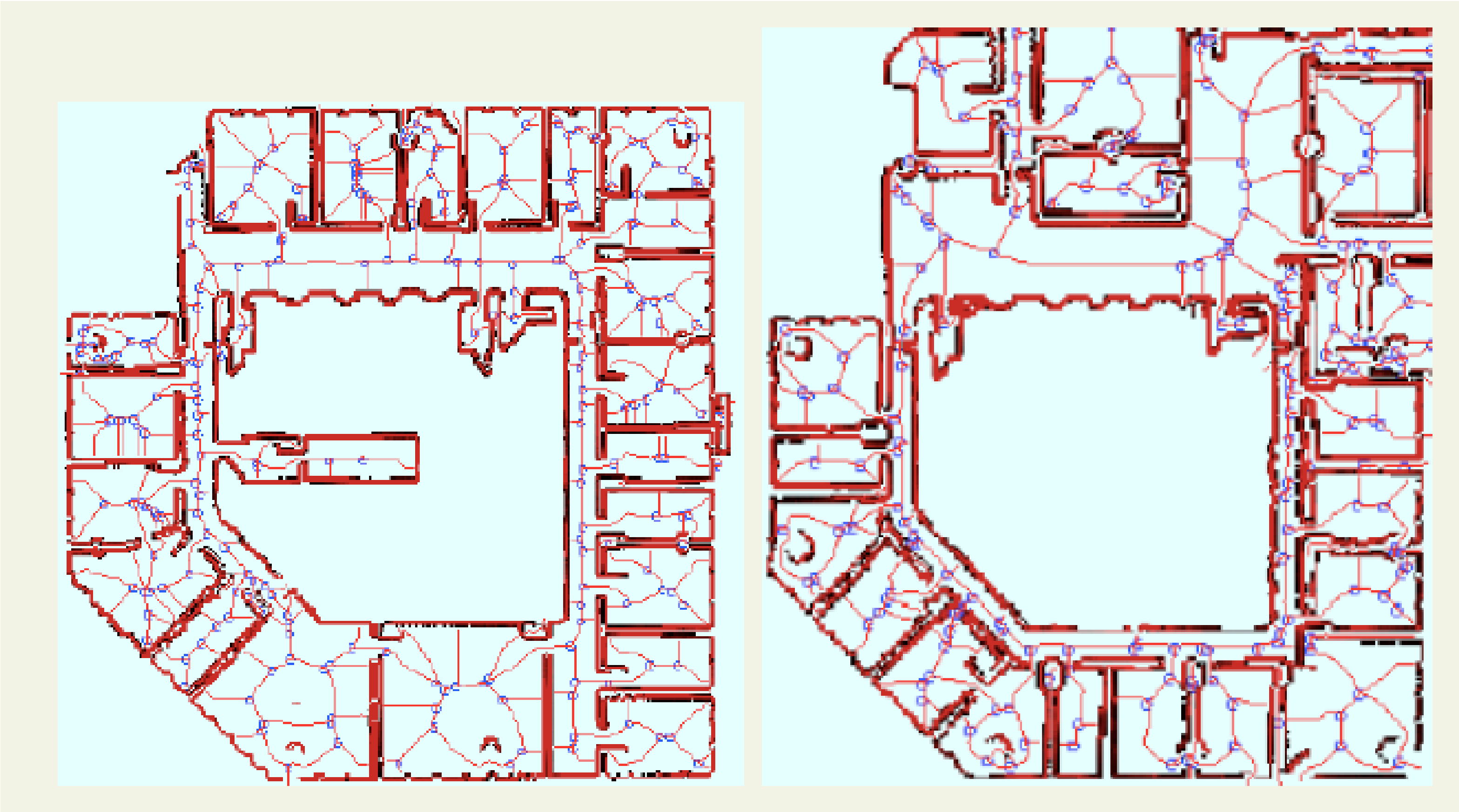
- How many different kinds of knowledge are required to get people into the loop in a way that is empowering and enriching rather than restricting?

Bremen Autonomous Wheelchair: Rolland

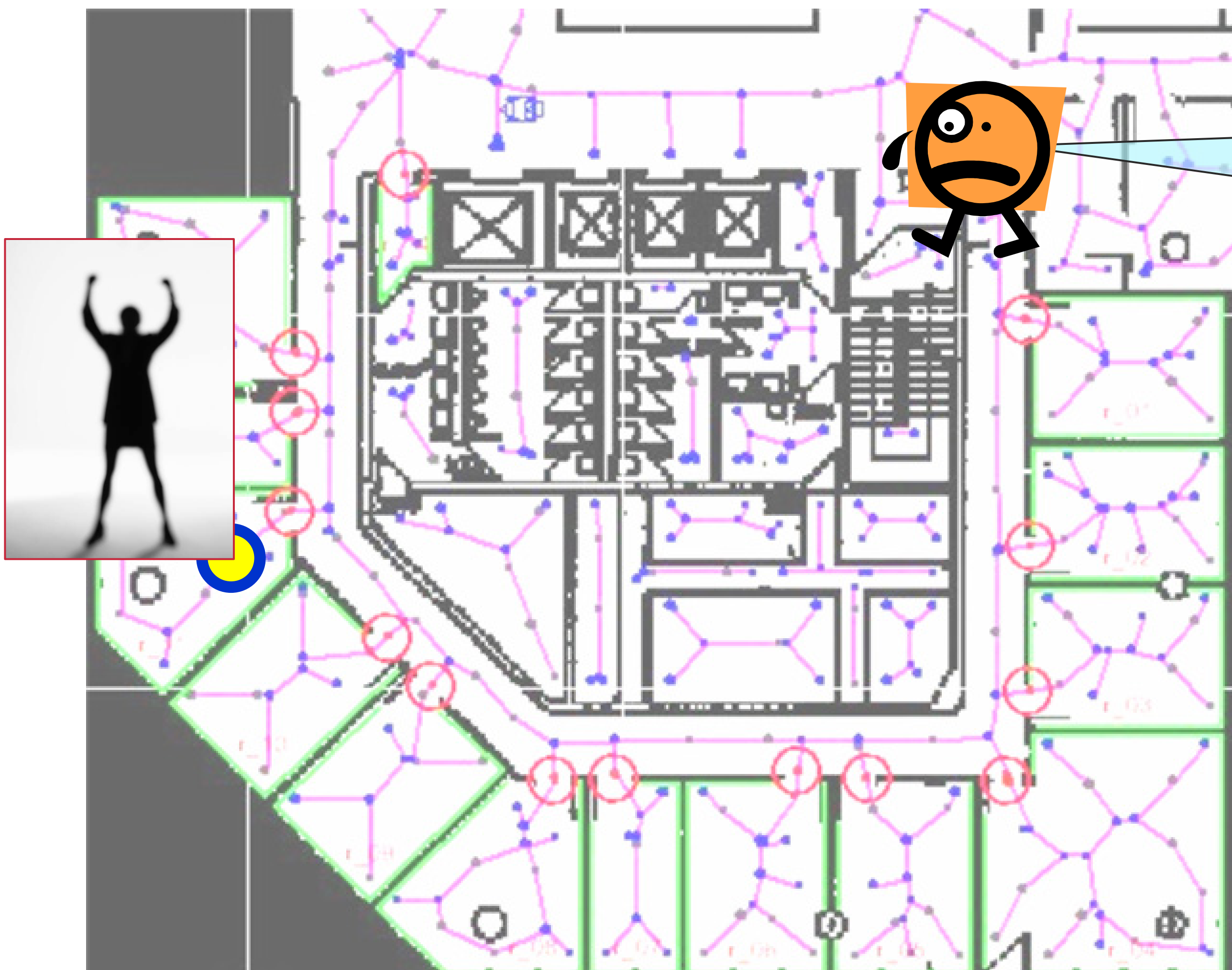


Sensor data: ‘free-space’ maps

I1-[OntoSpace]



Voronoi calculation on a scanned floor plan



Voronoi map From SFB/TR8 project: A1-[RoboMap]

Unnatural / unhelpful descriptions

- 25.4 m NW of you
- GPS: “34° 15´ N / 3° 27´ E”
- “3.45m away from edge 98 (with 80% certainty)”

Natural route descriptions

- Leave the room and turn right into the corridor.
- Go to the window and then turn left.
- Follow the corridor and I'm in the last room on the left.

Problems of semantic interpretation

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- "corridor" : what's that?
  - robot sensor map had only free space, some portions longer and narrow and others more box like...
- "leave the room" : how?
  - room's have exit points, usually found by locating doors (but maybe not when there's a fire!)
- "to the window" : how close?
  - depends on task, as landmark on path or destination (e.g., to look at the view?)
- if there is no map on board, is one downloadable from a reachable service?
- is that map in an appropriate form for communication and navigation?

Sources of relevant knowledge

Location-based services

⇕

Geographic Information Systems

⇕

Commonsense objects and activities

⇕

Spatial awareness and understanding

⇕

Natural language capabilities

⇕

Robot perception

Problem restated

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- Getting these diverse areas of expertise to talk to each other is a serious issue
  - different communities
  - different interests
  - different representations

- The kinds of knowledge maintained by such systems are very different

Solution we are pursuing

- High degree of interoperability between diverse knowledge-rich systems is to be achieved by **ontological engineering**, taking in:
  - knowledge of the human world *(commonsense)*
  - knowledge of the robot world (*programmed, emergent)*
  - geo-knowledge *(GML, other standards)*
  - spatial knowledge *(spatial calculi)*
  - knowledge of language *(linguistics)*

Ontological diversity ➡ inter-ontology mappings

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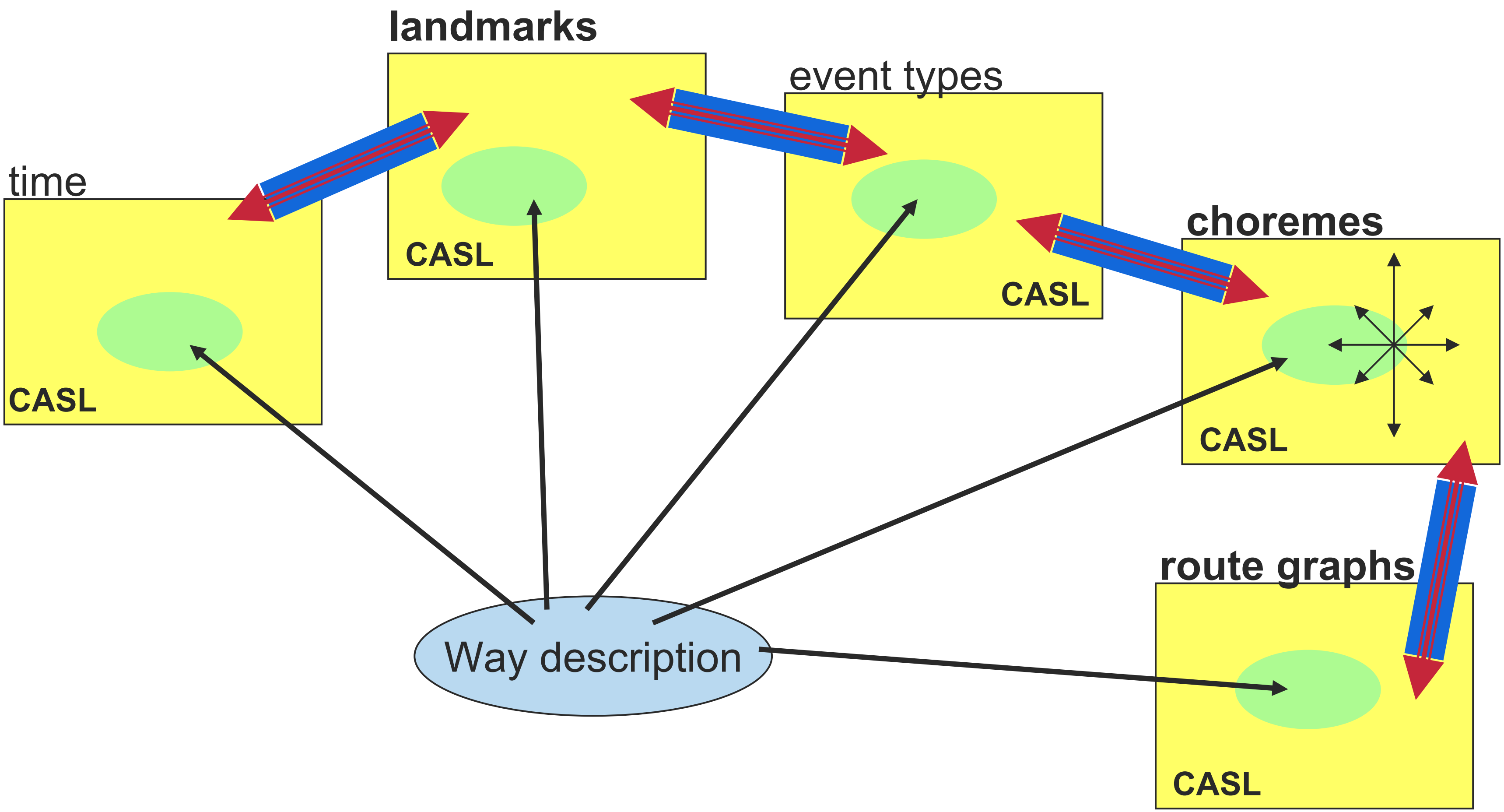

Inter-ontology mappings

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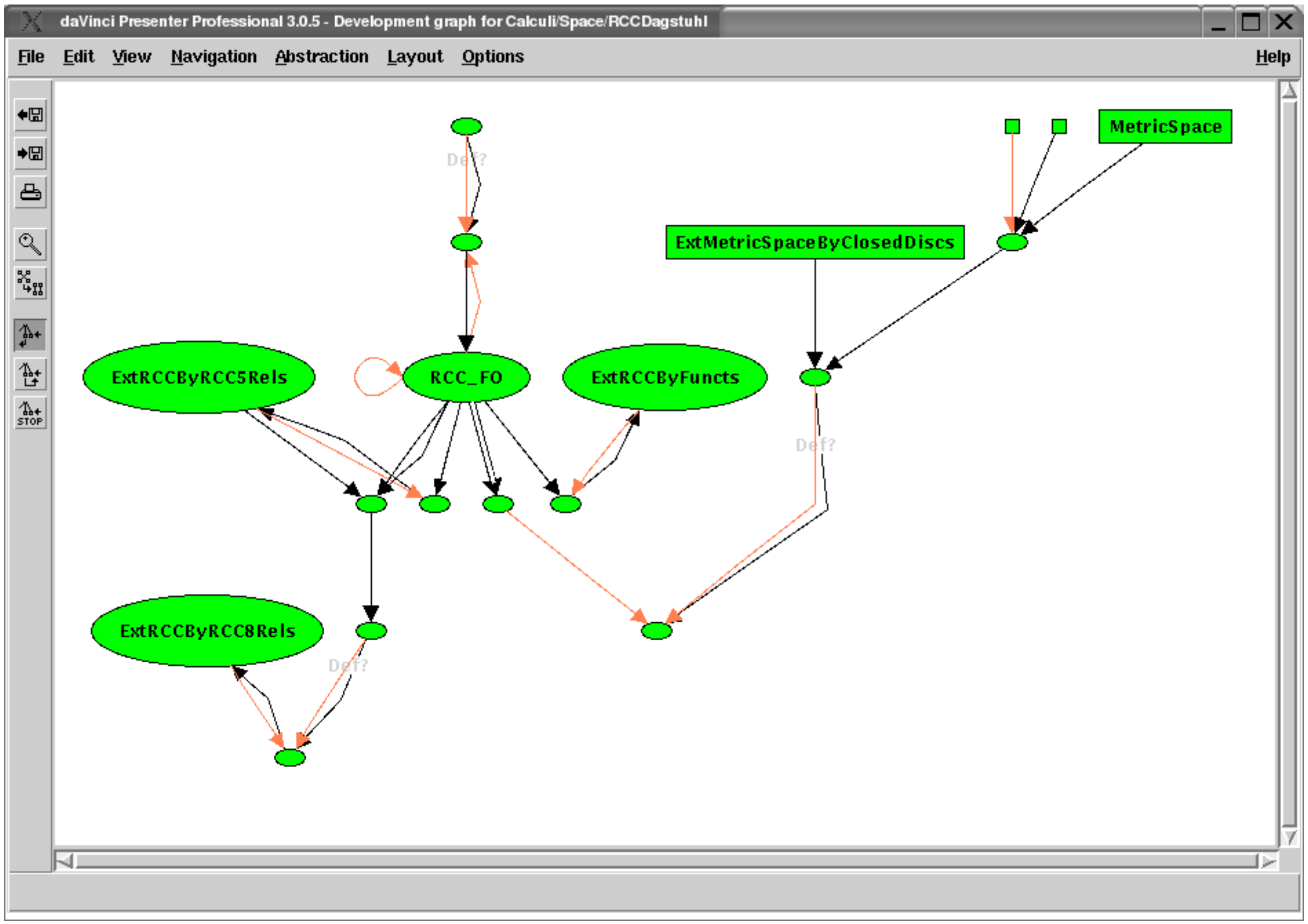
- ... can only work if there is sufficient **content** to get hold of!
- That is: not a relationship between ‘terms’ but a relationship between ‘**theories**’.
- For this, need deep ontologies, so-called ‘**axiomatized ontologies**’

Theories...

- We all have theories...
  - theories of the world
  - theories of how buildings are
  - theories of the best way to get from A to B
  - theories of how to persuade your boss for a raise
- '**A-ontologies**' set such theories out in an explicit specification.

Common Algebraic Specification Language (CASL)

development graphs



(Wölfl & Mossakowski)

CASL development graphs

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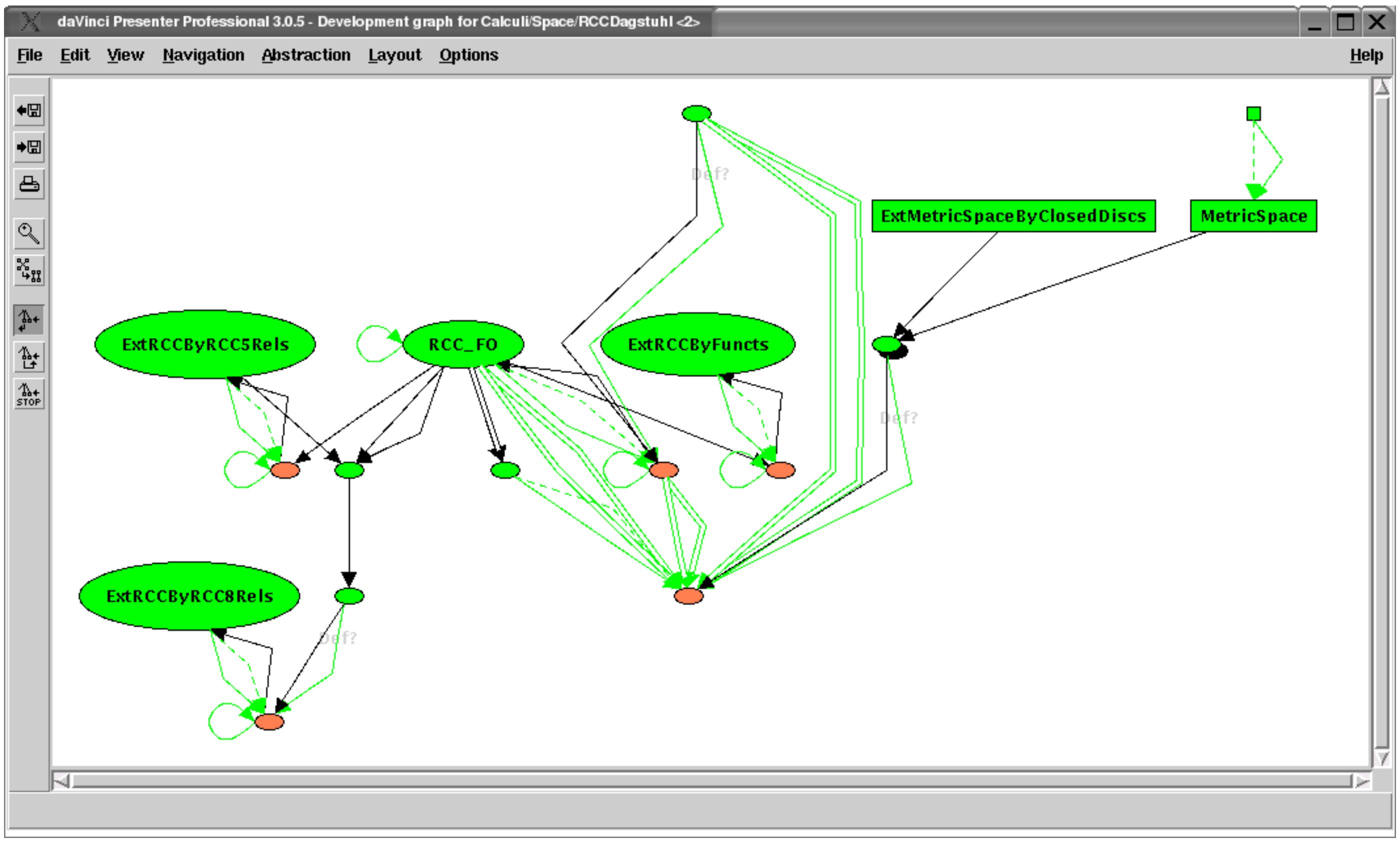

(Wölfl & Mossakowski)

Ontology construction

- Axioms are grouped into logically appropriate theories
- Theories may be extended via parameterization to achieve semantic re-use
- Theories may be created and related by views: theory morphisms

Only with this re-use factor can the complexity of distinct axiomatized ontologies really be harnessed and used to scale-up.

3 examples from current work

- Ex 1: pervasive computing
- Ex 2: pervasive computing plus navigation
- Ex 3: cross-community knowledge-rich inferencing

A problem in pervasive computing Chen / Finin / Joshi (2004)

- Example context reasoning:
  - “No agent can be physically present in two different atomic places during the same time interval.”
  - “An agent can be physically present in two different compound places during the same time interval just in case one spatially subsumes the other.”

- Sensor mismatch / inconsistency detection
  - Person X is located in Parking Lot A
  - Person X is located in Room 210

Ontological method

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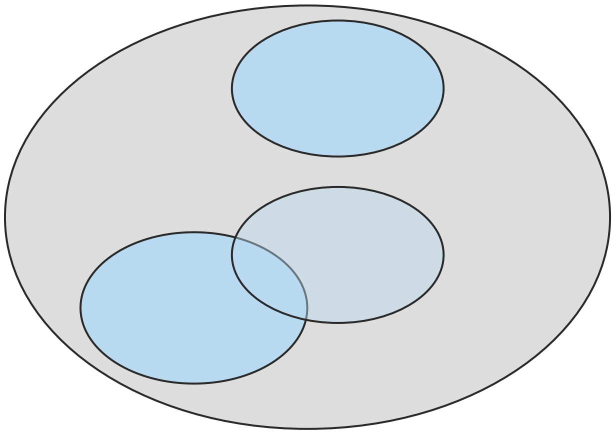
- Person X is located in Parking Lot A
- Person X is located in Room 210

Characterize the spatial task:

- spatial inclusion
- regions: parts and connections



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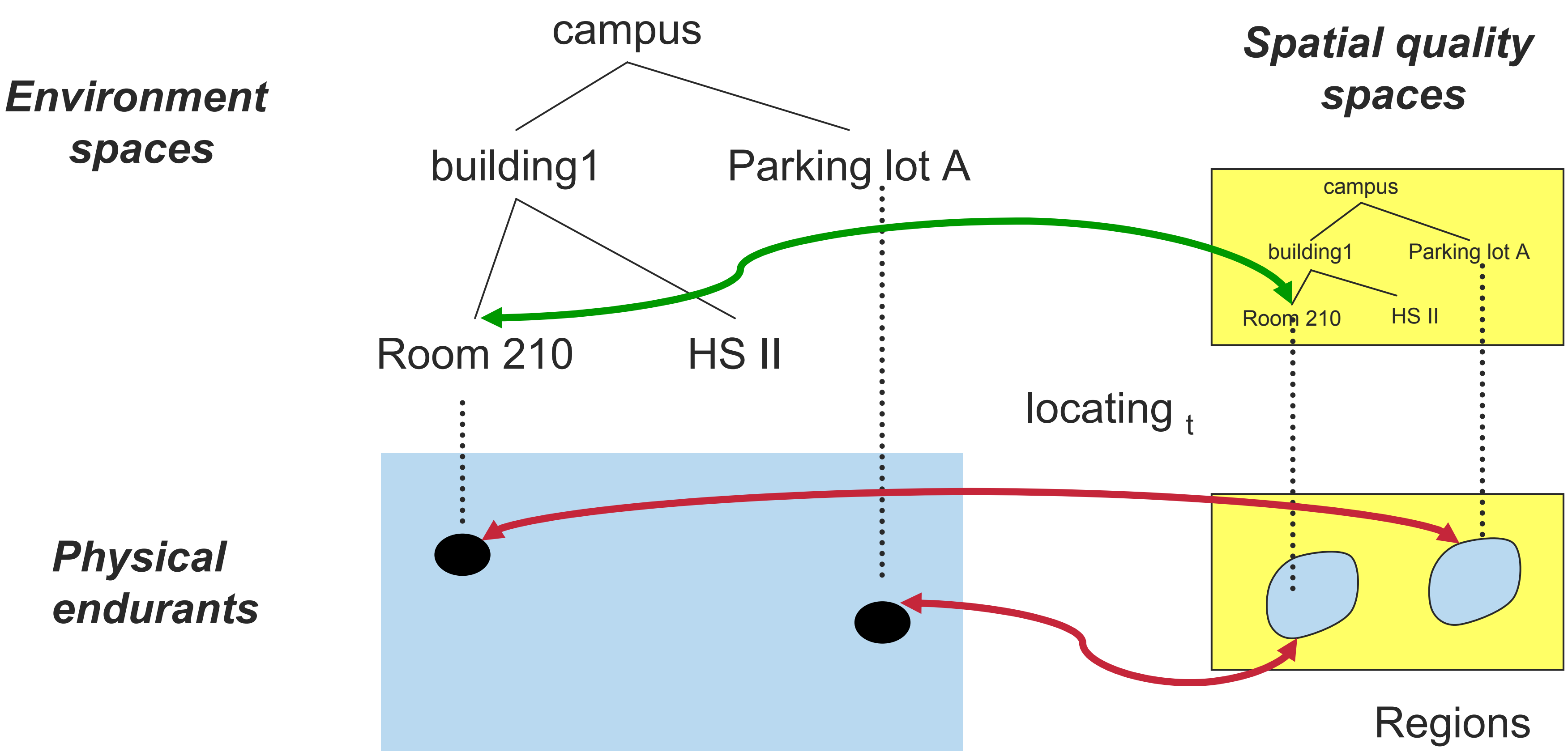
The same problem addressed with inter-ontology mappings



A related problem addressed with inter-ontology mappings

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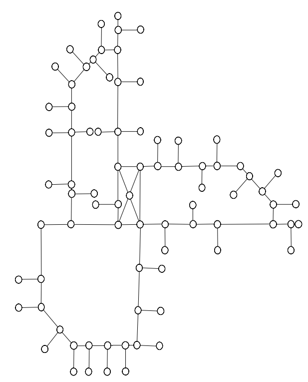
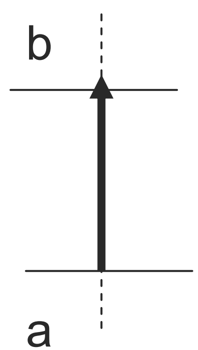
- Person X needs a **description** of how to get from Parking Lot A to Room 210

Characterize the spatial task:

- navigation
- space: supporting route planning, e.g., route graphs
- route description: linguistic expression



routes



orientation

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A related problem addressed with inter-ontology mappings

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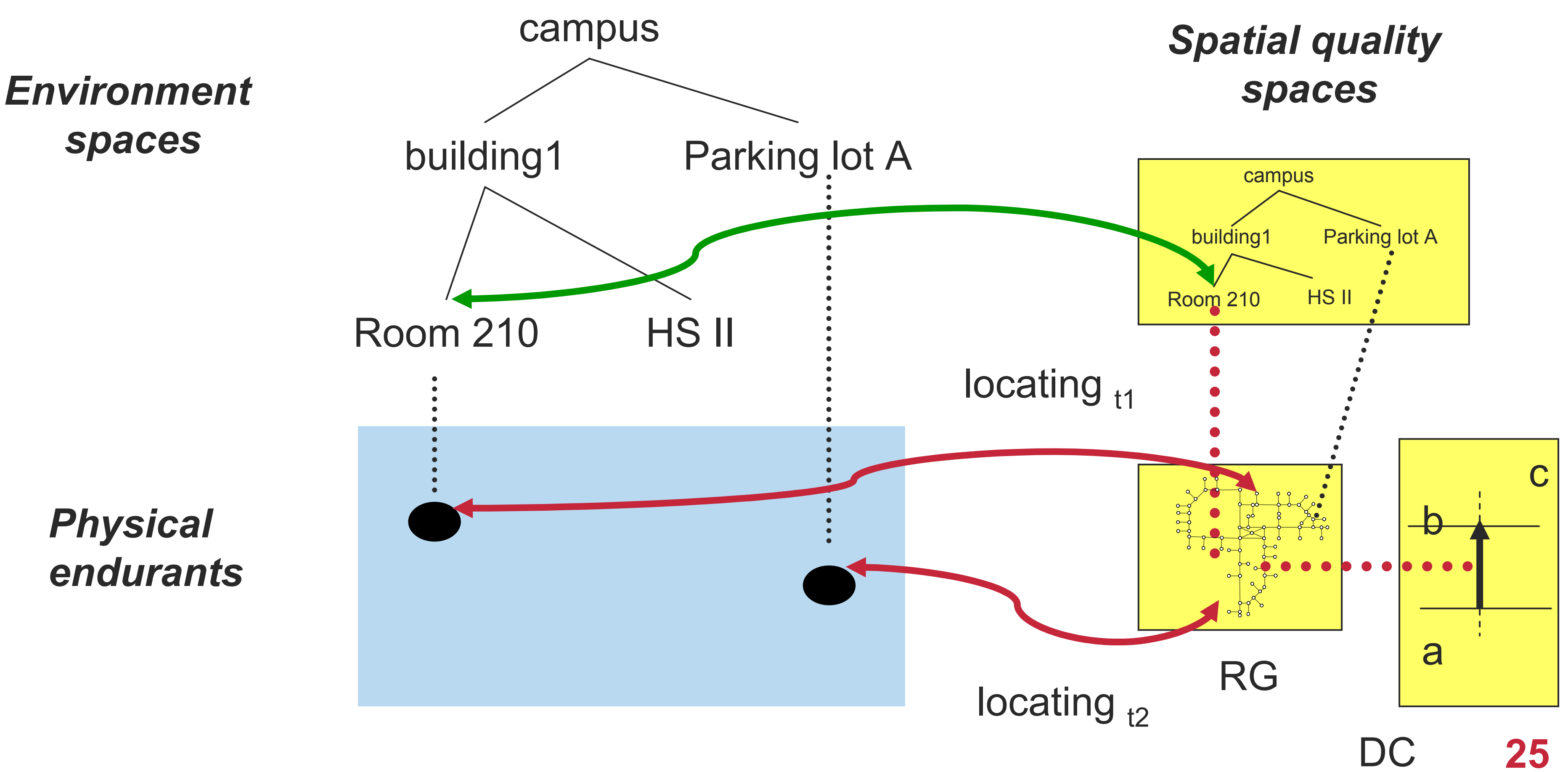

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Applications to problems of pervasive computing:

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- Definition of problematic categories:
  - CompoundPlace vs. AtomicPlace
  - Many relations: locatedInCompoundPlace, locatedInRoom, locatedInRestroom, ...
  - Specific reasoning rules

Chen / Finin / Joshi (2004)

- Most, if not all, of these are derivable from already defined foundational A-ontologies

When is a road not a road?

- Community 1:
  - transit system designers
  - roads and highways as connections between destinations (cities, towns, etc.)
- Community 2:
  - environment and wildlife department
  - species have habitats
  - habitats have divisions separating them

Ontologically mediated inter-operability

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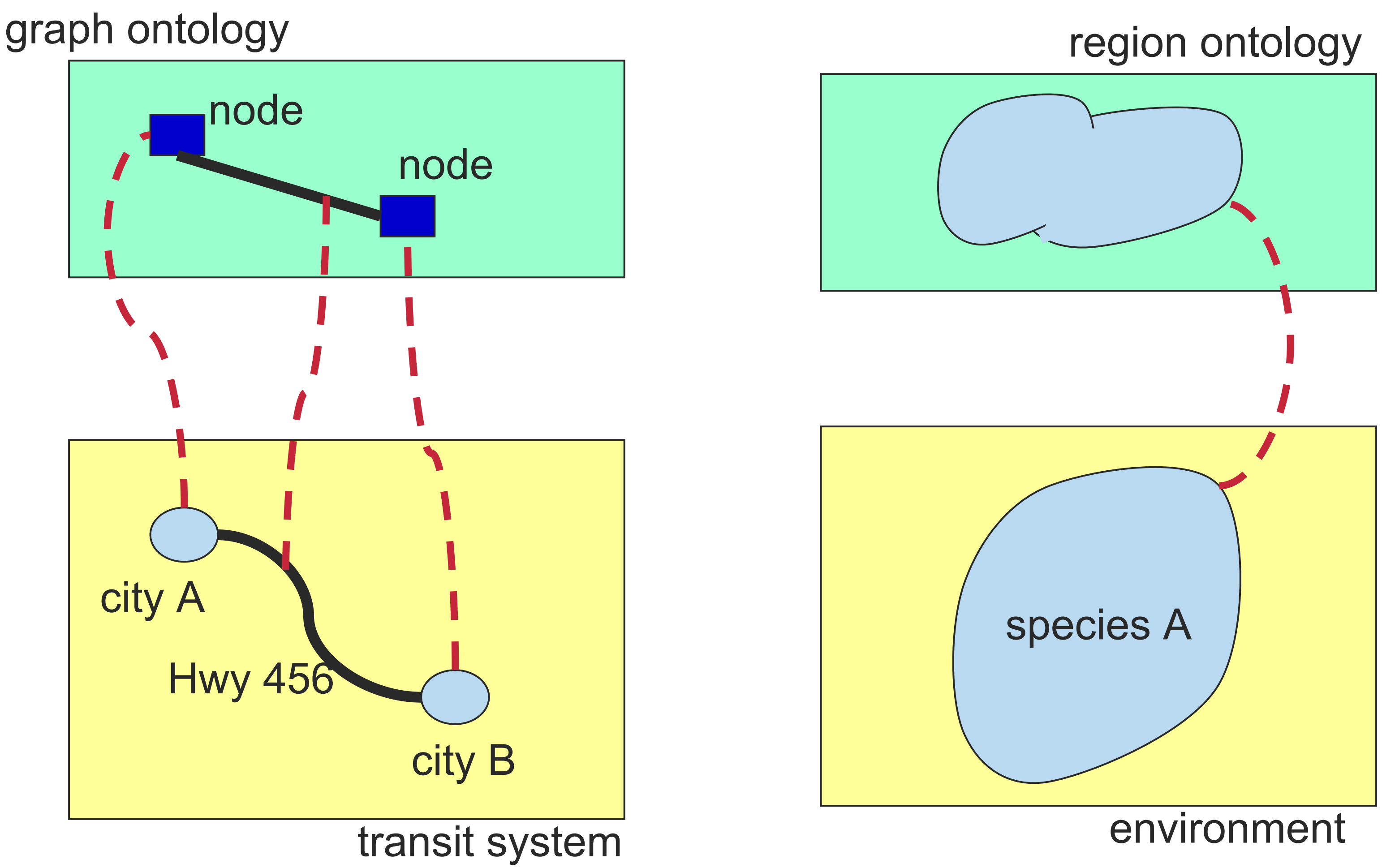
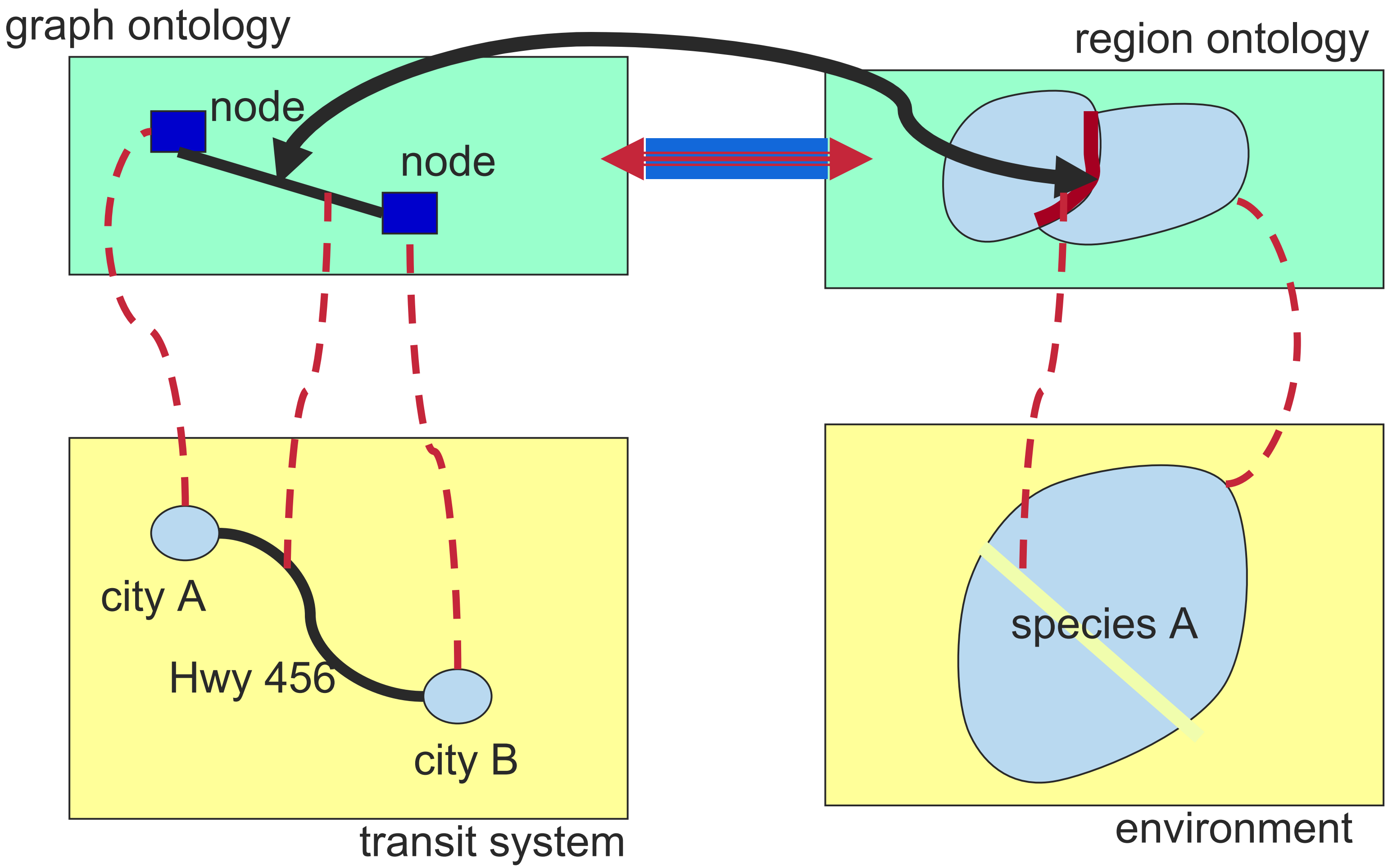


Ontologically mediated inter-operability



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Essential idea…

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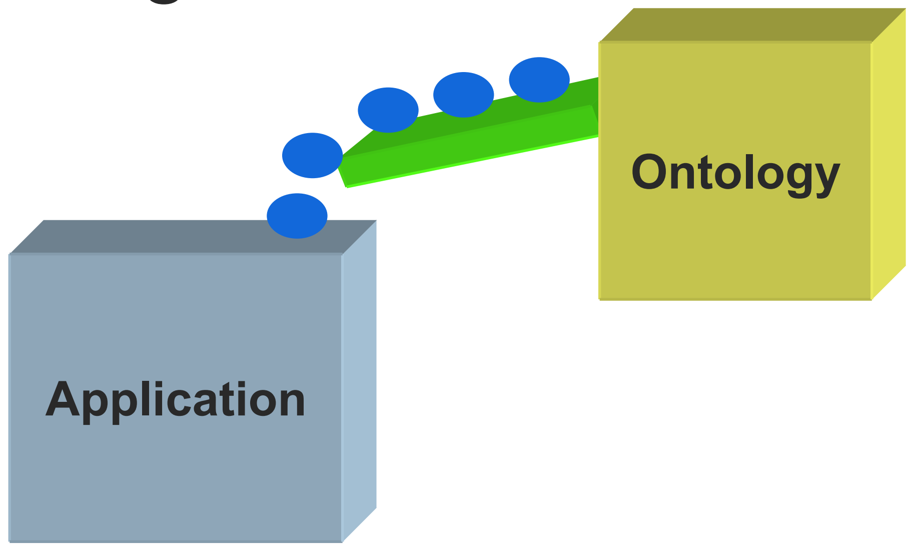
- Providing channels to ontologies provides access to detailed contextual ‘world-knowledge’ that does not then have to be worked out again…



Prerequisites for success

- unless you can reason with the axioms: non-starter → **logic**
- unless you can chunk your axioms: non-starter → **building theories**
- unless you can parameterize and re-use theories: non-starter → **structured logic support**
- unless you can state relations between the meanings of chunks: non-starter → **inter-theory mappings**

Essential ingredients we are drawing on in Bremen

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- *Existing ontologies*
  - DOLCE (Nicola Guarino)
    (for cross-category binding and axiomatization)
  - BFO (Barry Smith)
    (for sites, niches and places and for SNAP/SPAN)
  - GUM (John Bateman)
    (generalized upper model for linguistic semantics)
- *State of the art logical tools*
  - CASL