Ontological Modularity for Shared and Integrated Ontologies

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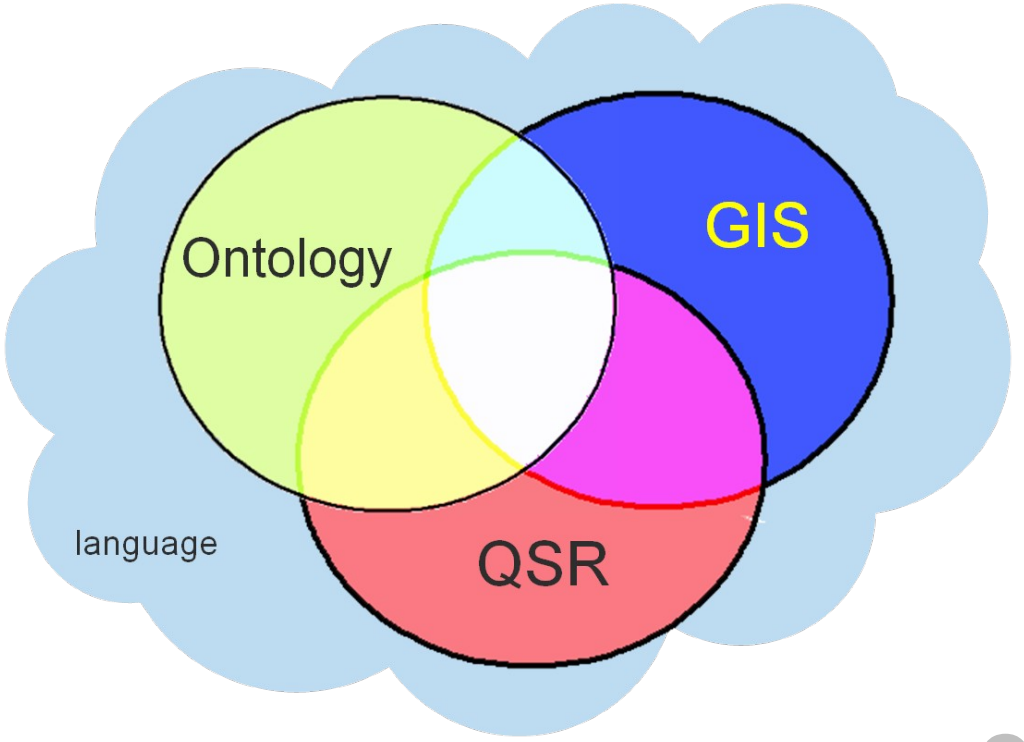
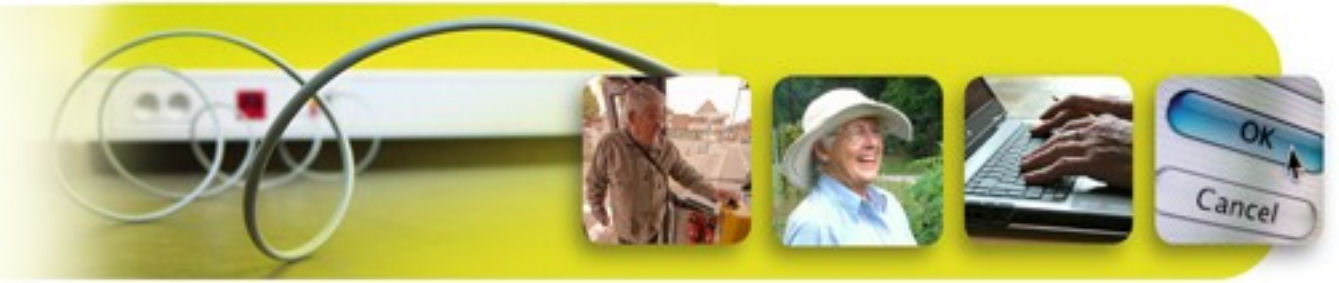
Overview

- Ongoing activities
  - within our Collaborative Research Center: “Spatial Cognition”
  - within the ontology-based EU FP7 large-scale integrating project “OASIS”
  - Proposal for standardization concerning ontology structuring principles
- Our approach to sharing and integrating ontologies
- Current plans

Triggers for our approach: Representations of Space

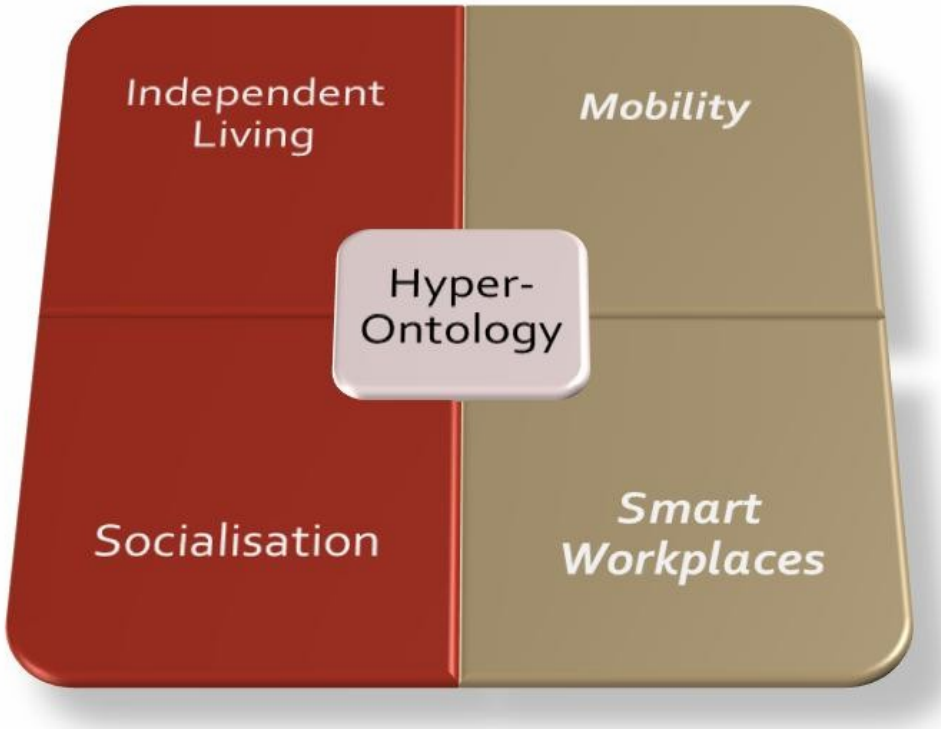
- Ontology and Space
- Qualitative Spatial Representation and Reasoning
- Language
- Geographic Information Science (GIS)





EU FP7 IP: OASIS

Open architecture for Accessible Services Integration and Standardization



OASIS targeted domains

Sharing knowledge and achieving interoperability

- Many projects, many products, many information providers now constructing ontologies
- **BUT**:
  - proliferation of unrelated designs,
  - impoverished or application-specific semantics,
  - 'roll your own' ignoring previous attempts
  - lack of **interoperability**

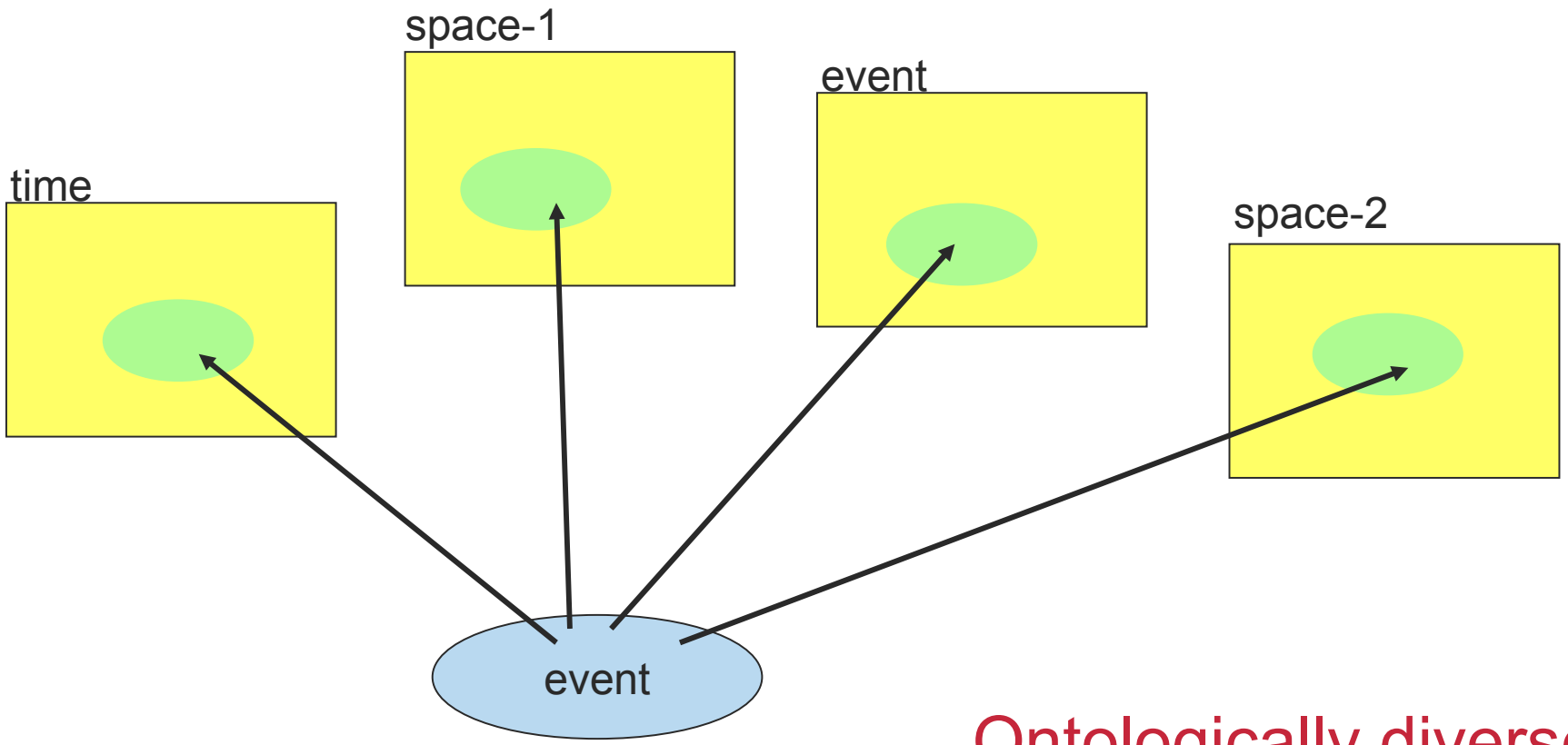
... which was precisely what ontologies were meant to provide!

How to proceed?

- High degree of interoperability between diverse knowledge-rich systems is to be achieved by **ontological engineering**
- But how to deal with the diversity?

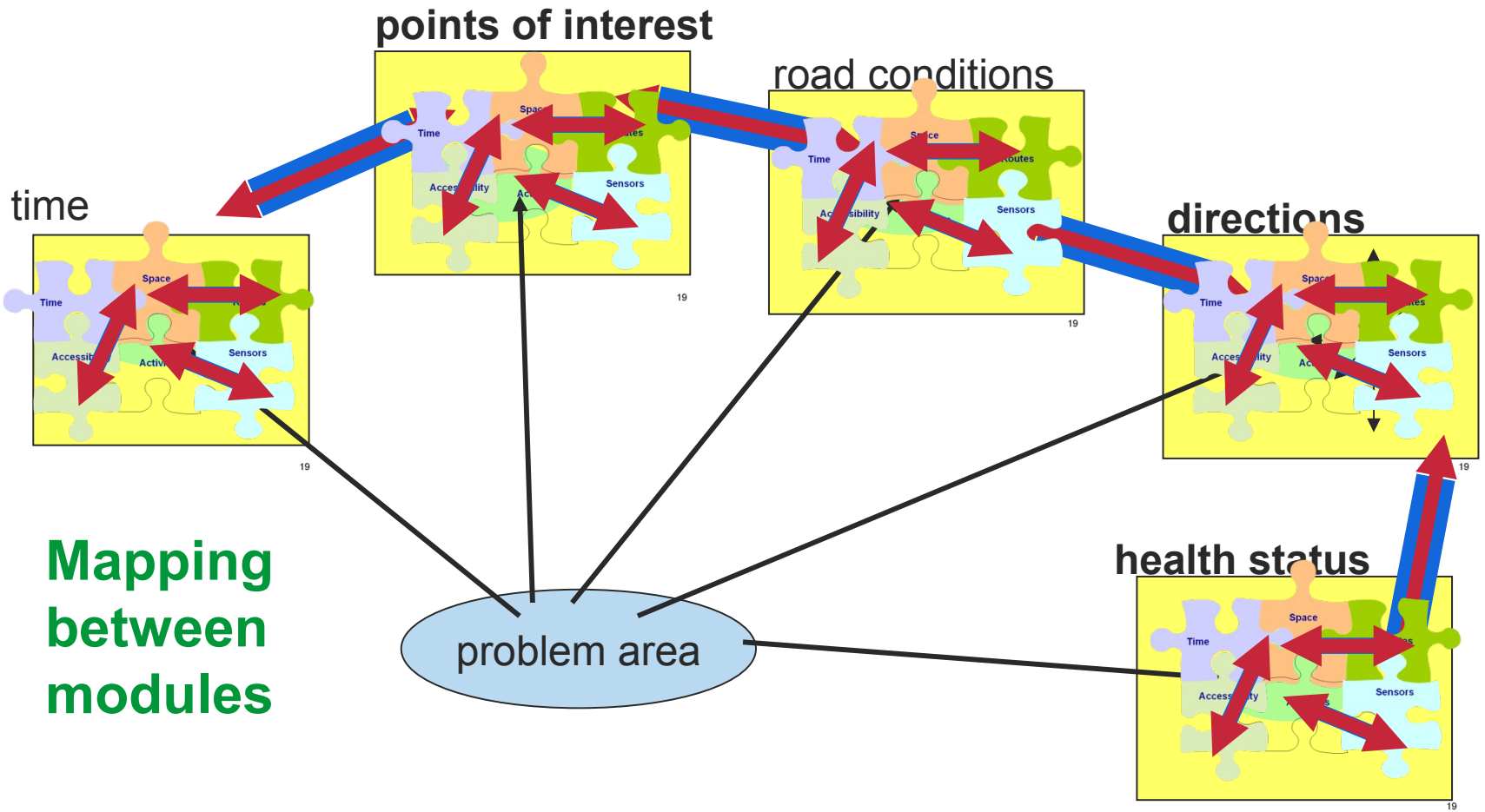
- ***Our conclusion:***
  There is no sense in which a simple ‘merging’ of all of the above is a sensible strategy to follow!

Many perspectives on ‘reality’: many ontologies



Ontologically diverse

“Hyperontology”



Our approach:

Essential ingredients we are drawing on ...

- *Formal and computational tools*

  - CASL
    Common Algebraic Specification Language
    (for specification, structuring and relating)

  - HeTS
    Heterogeneous Tool Set
    (for connecting to a range of reasoners
    and for working with structured specifications)

Lüttich & Mossakowski
(FOIS 2004)

Axiomatized Ontology in CASL: DOLCE

Primitives

GenParthood

```
spec PRIMITIVES =
    %% Basic Categories
    sorts PD, PED, S, SL, T, TL < PT
    free type PT ::= sort PD, PED, S, SL, T, TL
end

spec GENPARTHOOD [sort s] =
    pred P : s × s
    ∀ x, y, z: s
    • P(x, x)                                  %(Ad11)%
    • P(x, y) ∧ P(y, x) ⇒ x = y                %(Ad12)%
    • P(x, y) ∧ P(y, z) ⇒ P(x, z)              %(Ad13)%
end
```

DOLCE

PT	Particular
PD	Perdurant, Occurance
PED	Physical Endurant
S	Space Region
SL	Spatial Location
T	Time Interval
TL	Temporal Location

Lüttich & Mossakowski
(FOIS 2004)

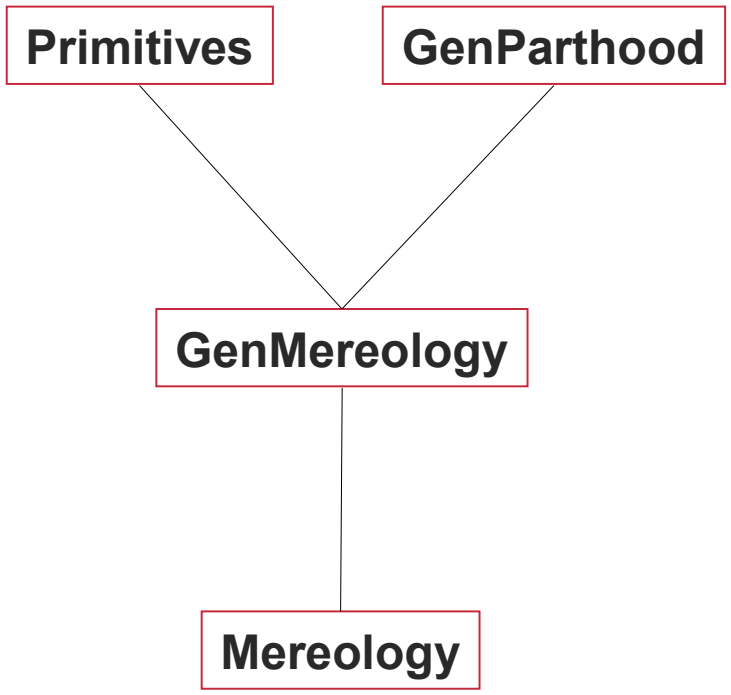
GenParthood

GenMereology

```
spec GENMEREOLOGY [sort s] =
     GENPARTHOOD [sort s]
then
     preds PP(x, y: s) ⇔ P(x, y) ∧ ¬ P(y, x);                    %(Dd1_Proper_Part)%
           O(x, y: s) ⇔ ∃ z: s • P(z, x) ∧ P(z, y);              %(Dd2_Overlap)%
           At(x: s) ⇔ ¬ ∃ y: s • PP(y, x);                       %(Dd3_Atom)%
then
%% Ground Axioms (2)
     ∀ x, y: s
     • ¬ P(x, y) ⇒ (∃ z: s • P(z, x) ∧ ¬ O(z, y))               %(Ad14)%
     • ∃ z: s • At(z) ∧ P(z, x)                                 %(Ad18)%
then %implies
     ∀ x, y, su, su', p, p', d, d': s
     • (∀ z': s • At(z') ⇒ P(z', x) ⇒ P(z', y)) ⇒ P(x, y)       %(Td1)%
     • (∀ z: s • O(z, x) ⇔ O(z, y)) ⇒ x = y                     %(Td3)%
end
```

DOLCE

Lüttich & Mossakowski
(FOIS 2004)



LATTICE OF THEORIES

spec MEREOLOGY =
PRIMITIVES
then
%%Ad7, Ad8, Ad9 and Ad10 are generated by
%% instantiation of GenMereology
GENMEREOLOGY [**sort** *T*]
then
GENMEREOLOGY [**sort** *S*]
then
GENMEREOLOGY [**sort** *PD*]
end

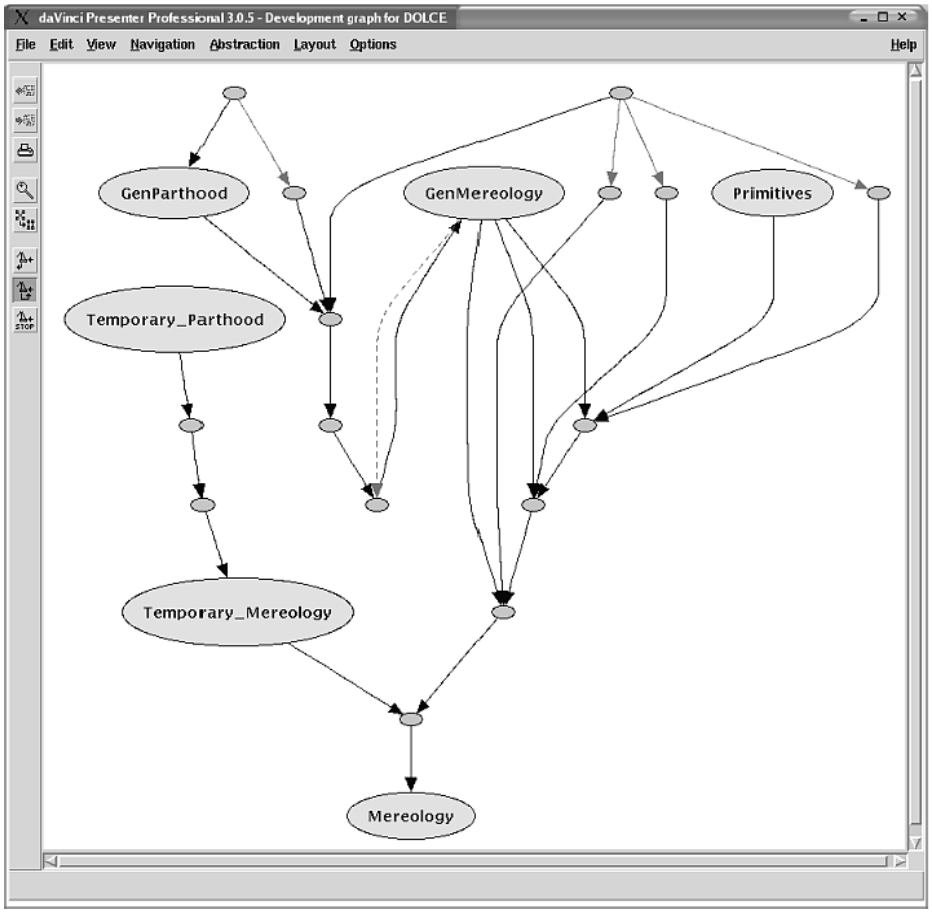
The DOLCE ontology in CASL: modularised

```
spec PreDolce =
          Mereology_and_TemporalPart
  and  Temporary_Mereology
  and  Participation
  and  Constitution
  and  Dependence
  and  Direct_Quality
  and  Temporary_Quale
  and  Immediate_Quale
end
```

LATTICE OF THEORIES

```
spec Dolce =
    PreDolce
and
    Taxonomy
end
```

Lüttich & Mossakowski (FOIS 2004)



Development Graph

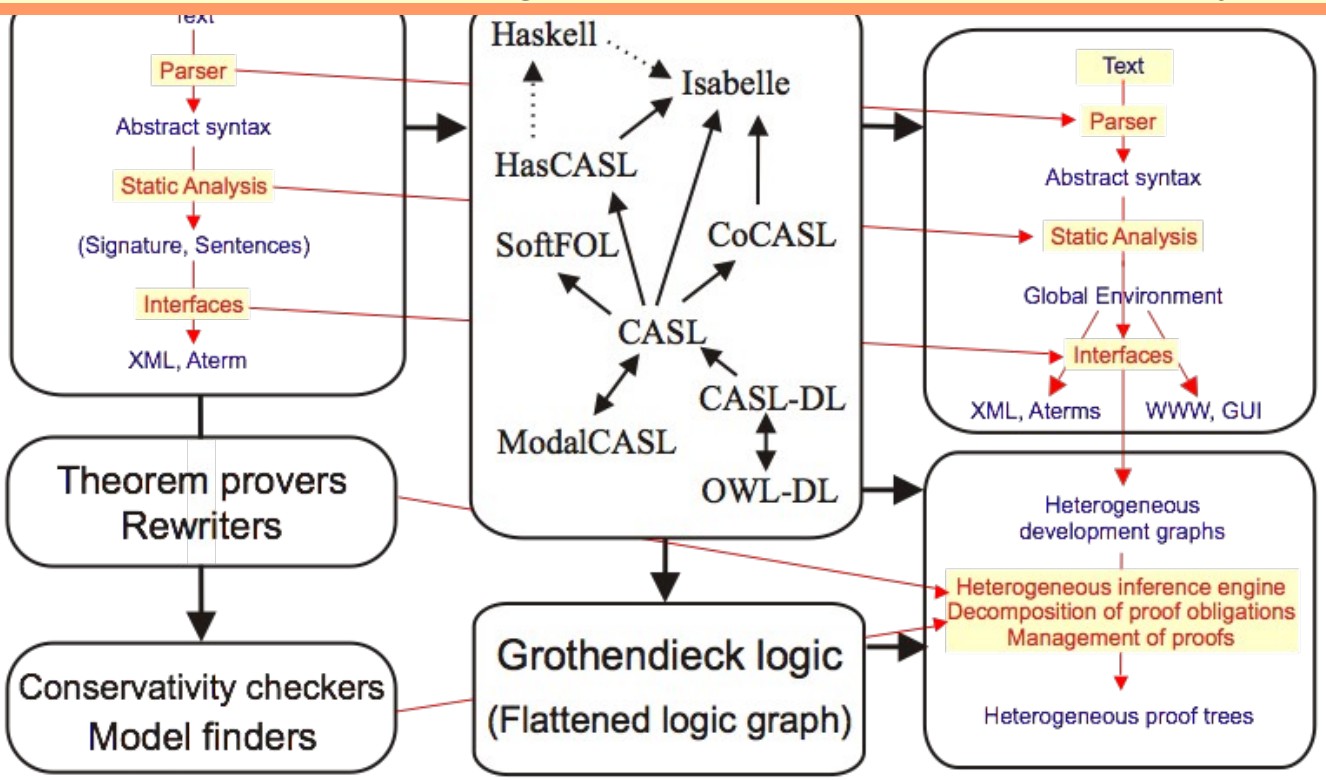
showing dependencies between specifications and proof obligations

Links: theory morphisms

- **imports of theories**
- relative interpretations of theories
  - **open**
  - **proved**

HeTS: the Heterogeneous Tool Set

Structuring mechanisms: potentially applicable to **any specification language** as an additional layer of 'meta'-organisation for semantic modularity



Institution Theory

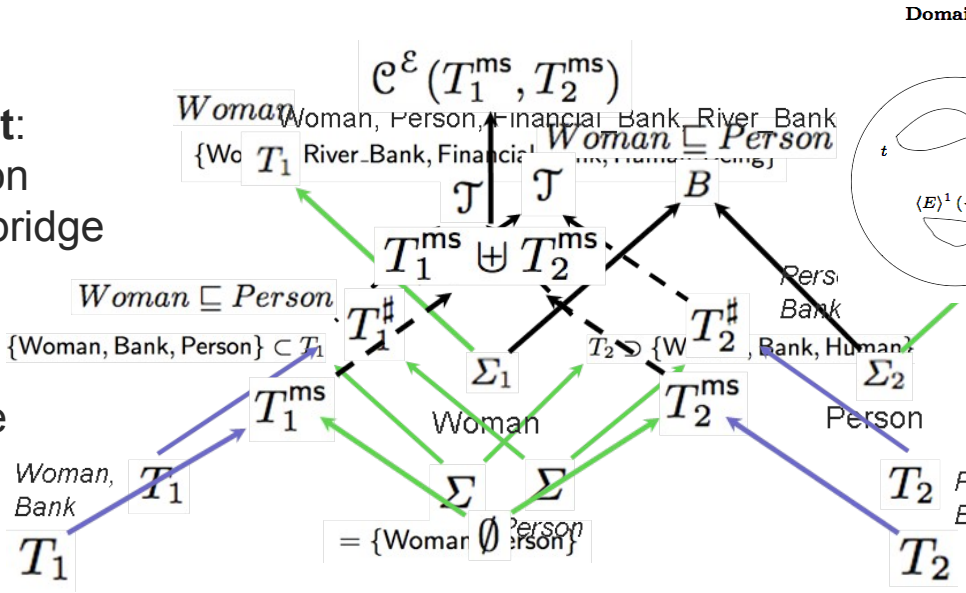
New Foundations

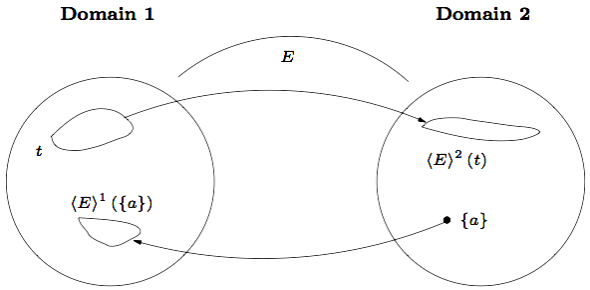
Realised through various theory morphisms

- We now have substantial results concerning a **generalised** framework for describing all kinds of inter-ontology 'relationships' that is being built into the HeTS tool

W-Alignment: integration through bridge ontology

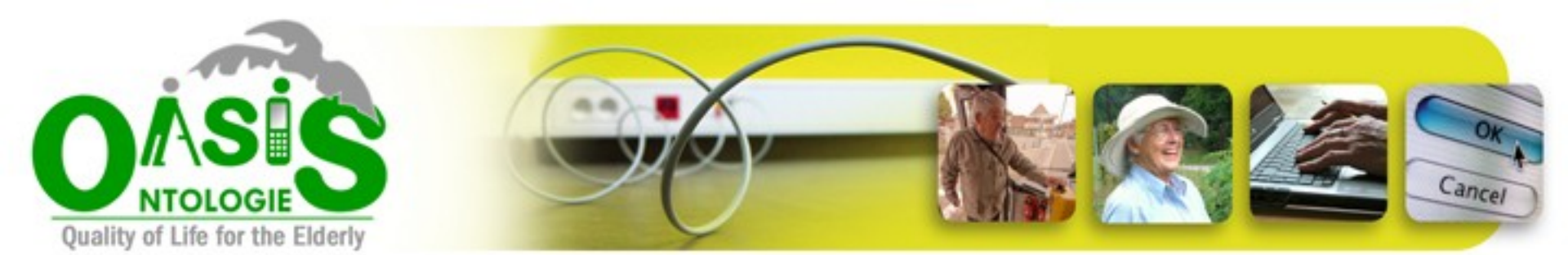
V-Alignment: cannot handle subclass assignments





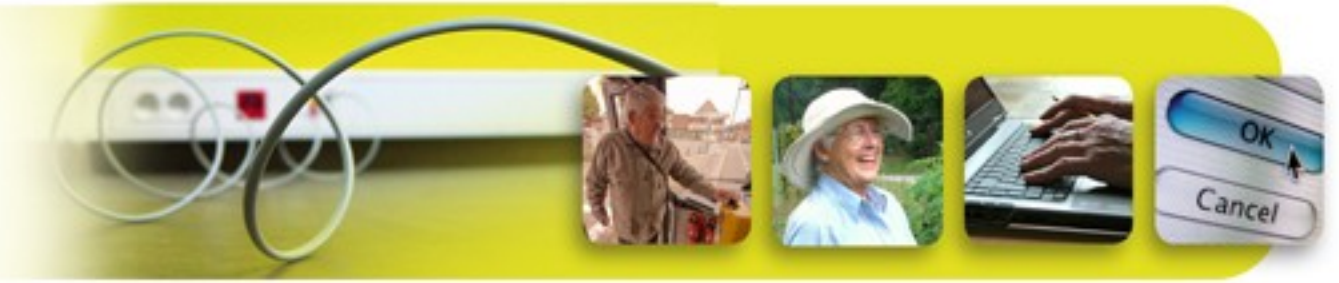
extended M-Alignment: **E-connections many sorted**

Oliver Kutz and Till Mossakowski

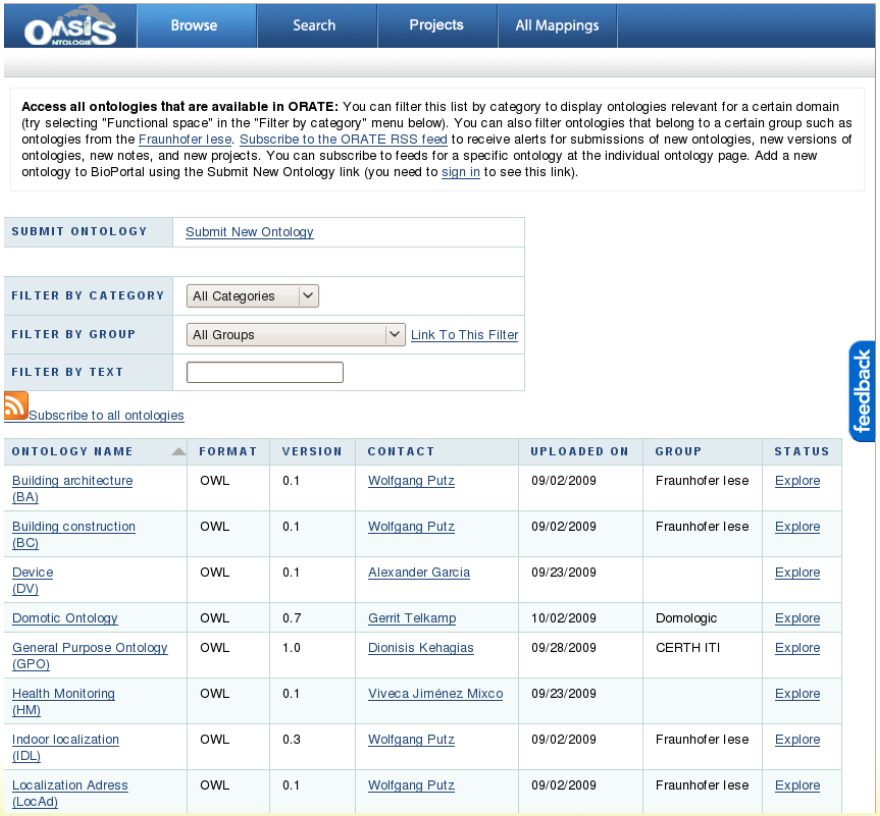


Now under development

- Selection of BioPortal (Stanford) as initial technology for open ontology repository development
  - First BioPortal instantiation in Europe and first in non-medical domain
  - Creation of OASIS Ontology Repository for Assistive Technologies
    ORATE: http://ontologies.informatik.uni-bremen.de
- Creation of Protégé plug-ins for ontology creation and manipulation in the hyper-ontology context
  - CMAPS → OWL
  - Ontology Servers: slicing import
  - Mapping/Alignment visualisation, editing, import/export



ORATE: http://ontologies.informatik.uni-bremen.de



Browse | Search | Projects | All Mappings

Access all ontologies that are available in ORATE: You can filter this list by category to display ontologies relevant for a certain domain (try selecting "Functional space" in the "Filter by category" menu below). You can also filter ontologies that belong to a certain group such as ontologies from the Fraunhofer Iese. Subscribe to the ORATE RSS feed to receive alerts for submissions of new ontologies, new versions of ontologies, new notes, and new projects. You can subscribe to feeds for a specific ontology at the individual ontology page. Add a new ontology to BioPortal using the Submit New Ontology link (you need to sign in to see this link).

SUBMIT ONTOLOGY: Submit New Ontology

FILTER BY CATEGORY: All Categories

FILTER BY GROUP: All Groups — Link To This Filter

FILTER BY TEXT:

Subscribe to all ontologies

feedback

ONTOLOGY NAME	FORMAT	VERSION	CONTACT	UPLOADED ON	GROUP	STATUS
Building architecture (BA)	OWL	0.1	Wolfgang Putz	09/02/2009	Fraunhofer Iese	Explore
Building construction (BC)	OWL	0.1	Wolfgang Putz	09/02/2009	Fraunhofer Iese	Explore
Device (DV)	OWL	0.1	Alexander Garcia	09/23/2009		Explore
Domotic Ontology	OWL	0.7	Gerrit Telkamp	10/02/2009	Domologic	Explore
General Purpose Ontology (GPO)	OWL	1.0	Dionisis Kehagias	09/28/2009	CERTH ITI	Explore
Health Monitoring (HM)	OWL	0.1	Viveca Jiménez Mixco	09/23/2009		Explore
Indoor localization (IDL)	OWL	0.3	Wolfgang Putz	09/02/2009	Fraunhofer Iese	Explore
Localization Adress (LocAd)	OWL	0.1	Wolfgang Putz	09/02/2009	Fraunhofer Iese	Explore

Currently:

- OWL ontologies
- limited versioning
- mappings of one flavour
- programmatic access for use in applications

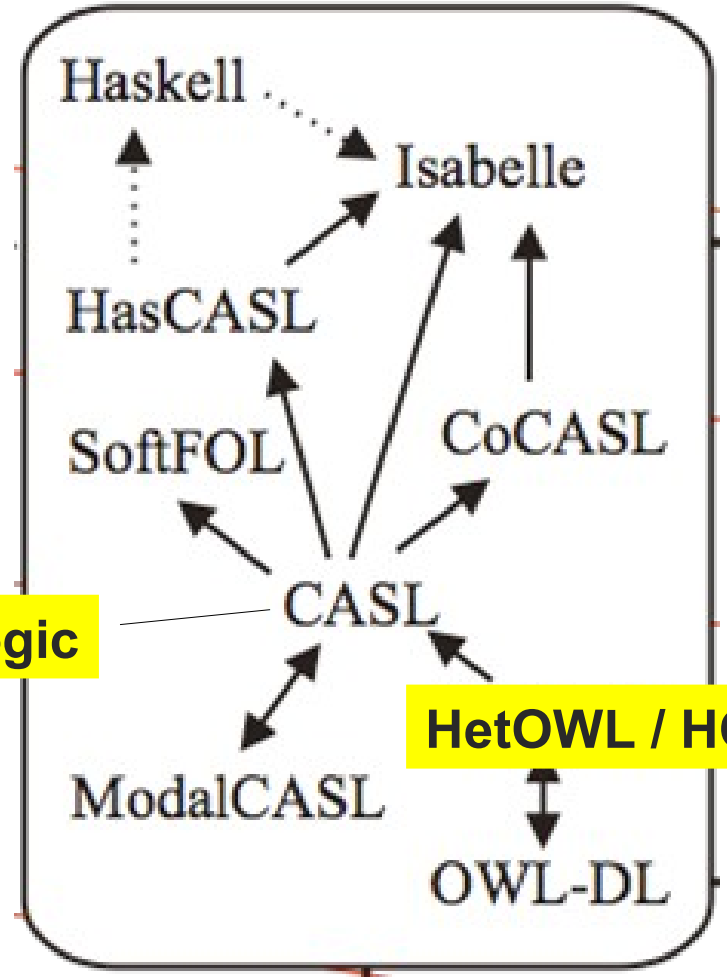
Further Steps...

- we have already added OWL-DL to the family of logics supported
- we are exploring **combining** the structuring principles of CASL and description logics

Now:

- we are planning to add Common Logic as a HETS logic node
- thereby providing access to all the tools already linked to HETS

HeTS: Continuing extension of the treated logics



CommonLogic

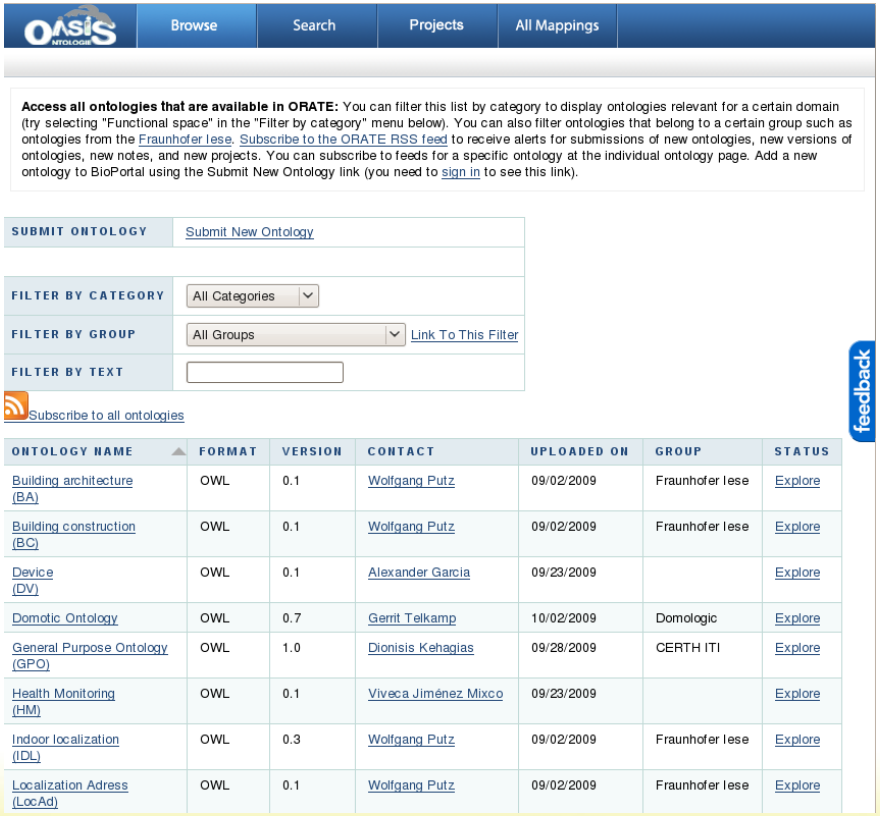
HetOWL / HOWL

```
spec LinearSpace =
    Class: LinearSpace
                SubclassOF:
                  lessThan {Maximum}
                 and greaterThan {Minimum}

    ObjectProperty: lessThan
      Domain: LinearSpace
      Range: LinearSpace

    ObjectProperty: greaterThan
      Domain: LinearSpace
      Range: LinearSpace
end
```

ORATE - OOR



Next Steps:

- integration of HeTS ‘behind the scenes’
  - access to reasoners
  - move beyond OWL
  - extension to our full complement of alignment shapes
- semantic versioning
- enforcement of design methodologies

Summary of the approach

- Applying a strong theoretical foundation, formal specification, practical implementations and tools developed for heterogeneous algebraic specifications in software engineering
- Allowing formally connected lattices of fully heterogeneous specifications
- Supporting reasoning and semantic interoperability across distinct ‘world views’
- Packaging within already established tools
  - HETS backend, Protégé, BioPortal
  - Reasoners
- Developing methodologies for distributed ontology development

Currently Proposed:

CEN Standardisation Workshop under review

- Multi-pronged approach
  - broad discussion of "**Institution"-based structuring mechanisms** for ontology languages in general, drawing on the mature implementation of the ***Heterogeneous Tool Set:*** involving stakeholders in ontology design
  - provision of **methodological guidelines** for constructing ontologies according to the principles of strong modularity
  - **worked test-bed** with a selection of committed partners in the **Ambient Assisted Living** domain, including a broad range of devices and requirements.
    - AAL working group in Germany
    - OASIS partners

Acknowledgements

- *The Bremen Ontology Research Group*
  - Oliver Kutz, Joana Hois, Till Mossakowski, Immanuel Normann, Alexander Garcia Castro, Bernd Krieg-Brückner, Mehul Bhatt

  - http://www.sfbtr8.uni-bremen.de
  - http://ontologies.informatik.uni-bremen.de
  - HETS: http://www.informatik.uni-bremen.de/agbkb/forschung/formal_methods/CoFI/hets/index_e.htm