NIST Discussion. Tuesday 14th March 2006

SPATIAL COGNITION

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

Ontologies for spatial reasoning, action and interaction

Basic problem statement, techniques under development, and plans

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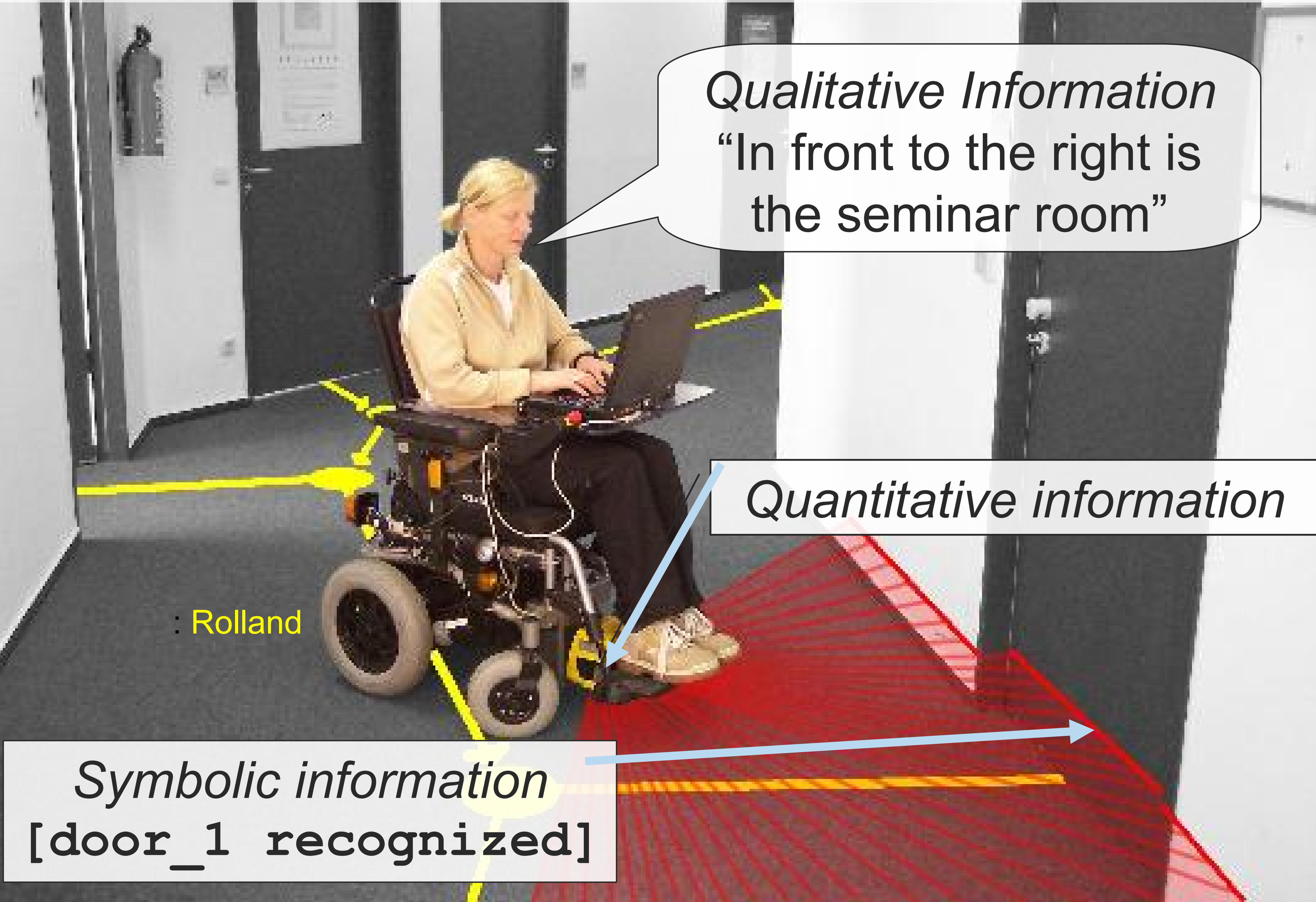
Problem focus

- Spatial assistance systems
- Route planning and navigation
- Real-world environments
  involving ‘common-sense’ entities
- Interfacing with geographic information
- Interfacing with language technology
- Interfacing with visual presentations (maps)
- Interfacing with robotic sensor data
- Embodied systems
- Human-Robot Interaction

Bremen Autonomous Wheelchair



Basis for the use of ontologies and ontological engineering

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- High degree of interoperability between diverse knowledge-rich systems
  - 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 *(Generalized Upper Model)*

Fundamental issue

- The ontologies present are diverse:
  - different methodologies
  - different motivations
  - different domains of application
  - different worlds
  - different purposes
  - different communities

Methodological starting point

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- There is no sense in which a simple ‘merging’ of the ontologies involved is a sensible strategy to follow

Many perspectives on ‘reality’: ➡ many ontologies

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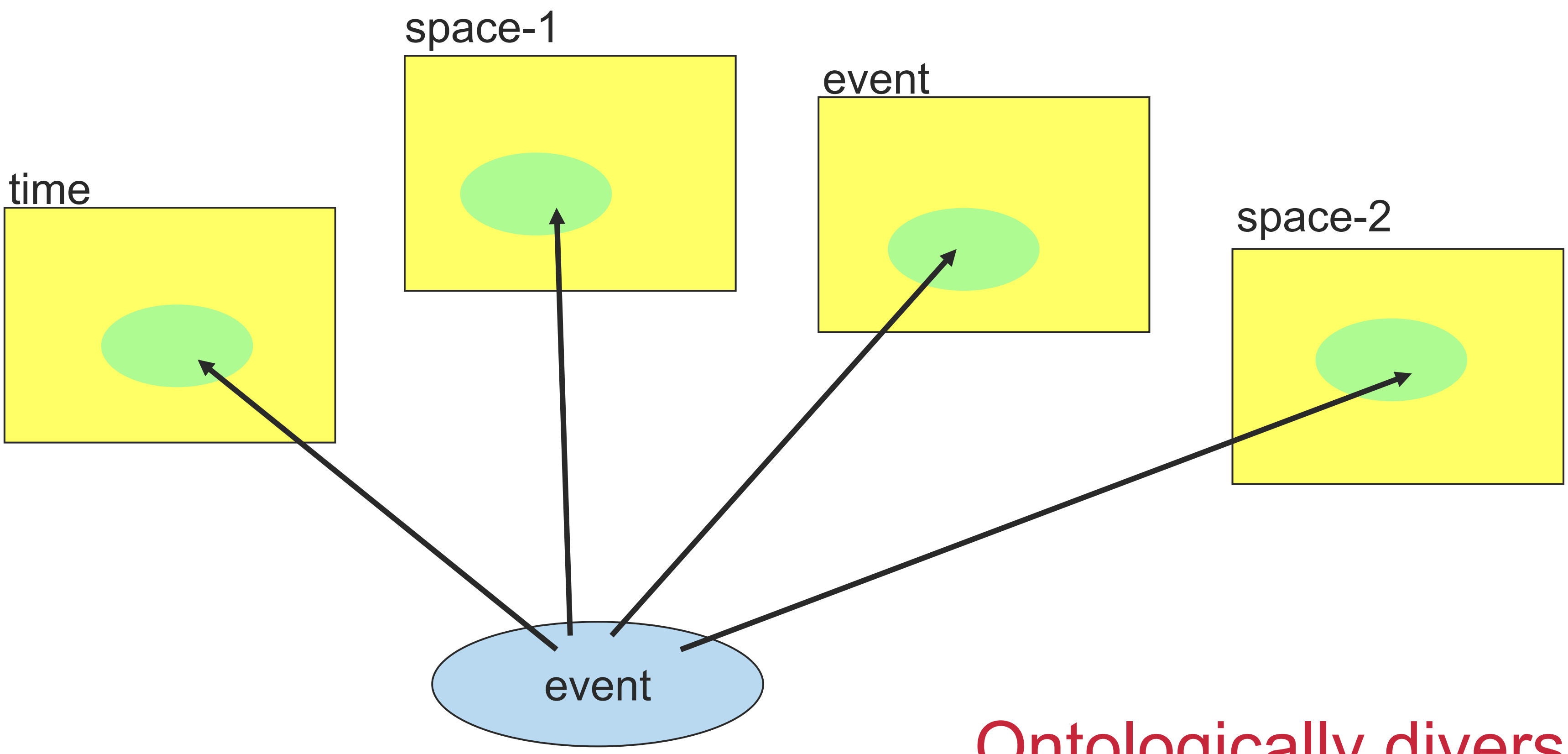

Ontologically diverse

Bateman/Mossakowski 2006

Ontological diversity
➡ inter-ontology mappings

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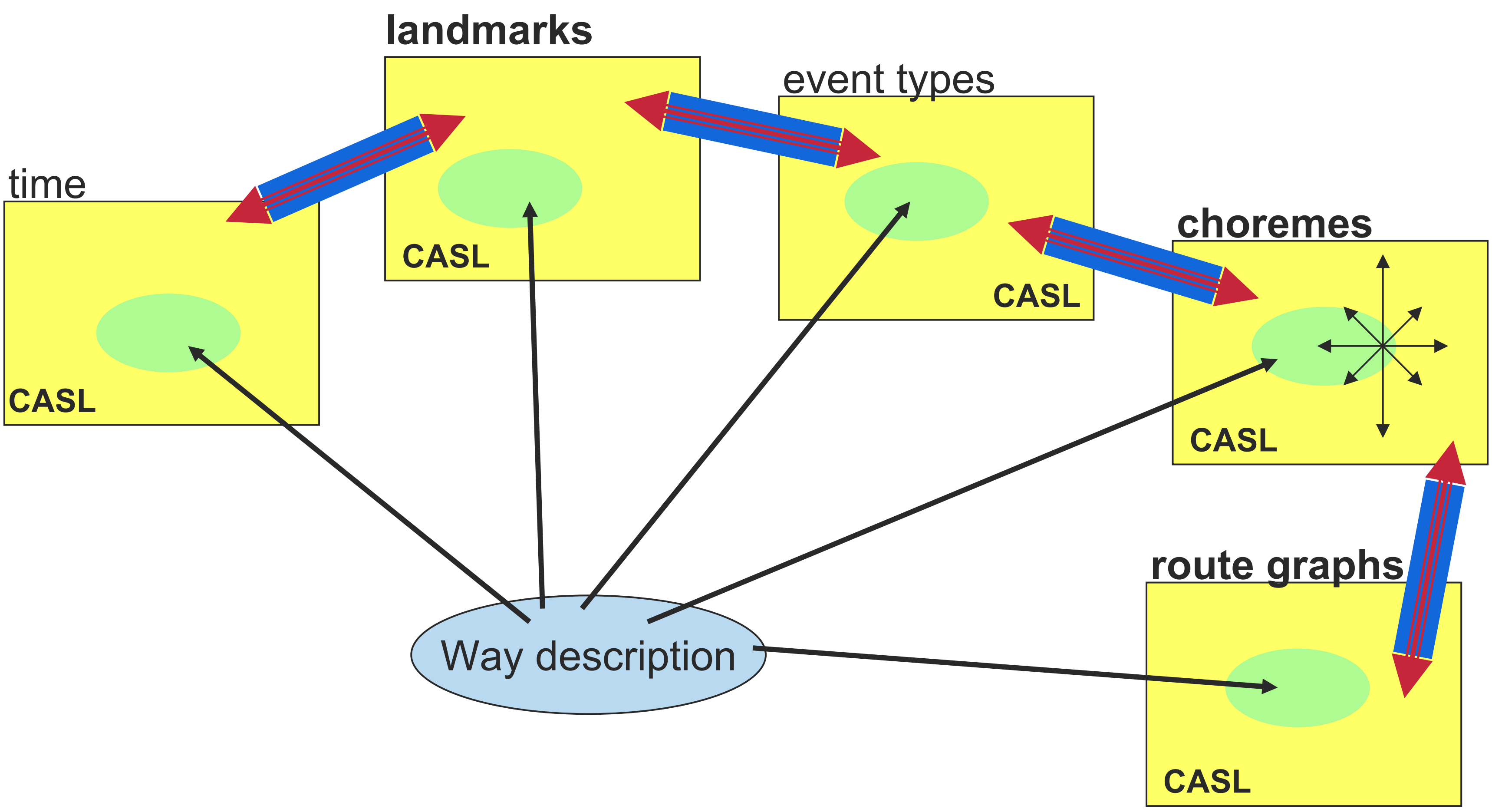

Bateman/Mossakowski 2006

Essential properties we are currently developing

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- Perspectivalism
  - Objects
  - Activities
  - Artifacts: spatial artifacts
  - Language
- Granular partitions
- Plug-and-play spatial theories

Essential ingredients we are drawing on

- *Existing ontologies*
  - DOLCE
    (for cross-category binding and axiomatization)
  - BFO
    (for sites, niches and places and for SNAP/SPAN)
  - GUM
    (generalized upper model for linguistic semantics)

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)
  - sublanguages of CASL
    (e.g., CASL-DL, modal CASL)
  - OWL-DL

Formalization choice: CASL

Common Algebraic Specification Language

- de facto standard for specification of functional requirements in software development
- developed by the “Common Framework Initiative” (COFI), an open international collaboration
- approved by IFIP WG 1.3 “Foundations of Systems Specifications”
- extensive User Manual and Reference Manual now available from Springer (LNCS 2900, LNCS 2960)

CASL language constructs

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- Basic specification: **spec** SpecName = Spec
- Extension: Spec1 **then** Spec2
- Union: Spec1 **and** Spec2
- Translations: Spec **with** SymbolMappings
- Parameterization:

  spec Spec1 [Spec2] = Spec
- Views:

view *View* **:** *Spec1* **to** *Spec2* **=** SymbolMapping

(*theory morphisms*)

Example: PSL specification ...

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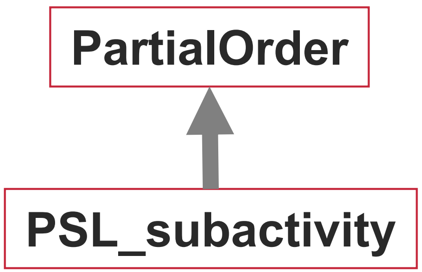


```
spec PSL_subactivity =
     PartialOrder with __<=__ → subactivity, Elem → activity
then
  ... %% axioms for discreteness
end
```

Michael Gruninger (http://www.mel.nist.gov/psl/psl-ontology/part12/subactivity.th.html)

subActivity: This relation is isomorphic to a discrete partial ordering on the set of activities.

CASL sublanguages and environment

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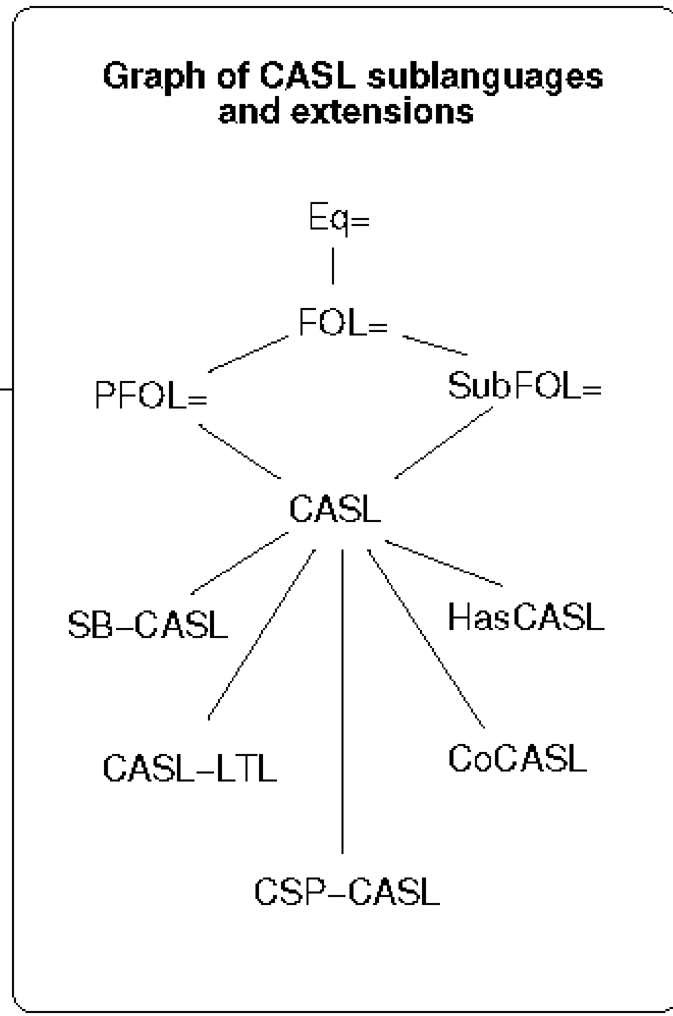
basic specs

Static Analysis
+
Tools

signatures

Theorem Provers

Isabelle
SPASS
...



architectural

Static Analysis
+
Tools

development graphs

Lüttich & Mossakowski
(FOIS 2004)

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Axiomatized Ontology in CASL

Primitives

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

DOLCE

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

GenParthood

spec GENPARTHOOD [**sort** s] =
    pred $P : s \times s$
    $\forall x, y, z: s$
    • $P(x, x)$ %(Ad11)%
    • $P(x, y) \wedge P(y, x) \Rightarrow x = y$ %(Ad12)%
    • $P(x, y) \wedge P(y, z) \Rightarrow P(x, z)$ %(Ad13)%
end

Lüttich & Mossakowski

(FOIS 2004)

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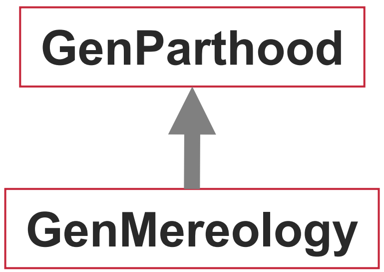
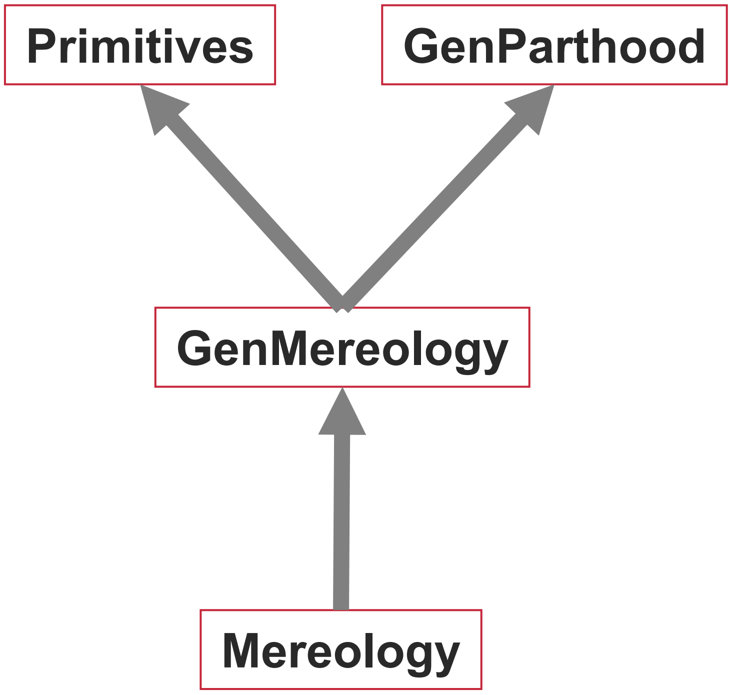


DOLCE

spec GENMEREOLOGY [**sort** s] =
GENPARTHOOD [**sort** s]
then
preds $PP(x, y{:}\ s) \Leftrightarrow P(x, y) \wedge \neg P(y, x)$; %(Dd1_Proper_Part)%
$O(x, y{:}\ s) \Leftrightarrow \exists z{:}\ s \bullet P(z, x) \wedge P(z, y)$; %(Dd2_Overlap)%
$At(x{:}\ s) \Leftrightarrow \neg \exists y{:}\ s \bullet PP(y, x)$; %(Dd3_Atom)%
then
%% Ground Axioms (2)
$\forall x, y{:}\ s$
$\bullet \neg P(x, y) \Rightarrow (\exists z{:}\ s \bullet P(z, x) \wedge \neg O(z, y))$ %(Ad14)%
$\bullet \exists z{:}\ s \bullet At(z) \wedge P(z, x)$ %(Ad18)%
then %**implies**
$\forall x, y, su, su', p, p', d, d'{:}\ s$
$\bullet (\forall z'{:}\ s \bullet At(z') \Rightarrow P(z', x) \Rightarrow P(z', y)) \Rightarrow P(x, y)$ %(Td1)%
$\bullet (\forall z{:}\ s \bullet O(z, x) \Leftrightarrow O(z, y)) \Rightarrow x = y$ %(Td3)%
end

Lüttich & Mossakowski
(FOIS 2004)



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

Lüttich & Mossakowski (FOIS 2004)

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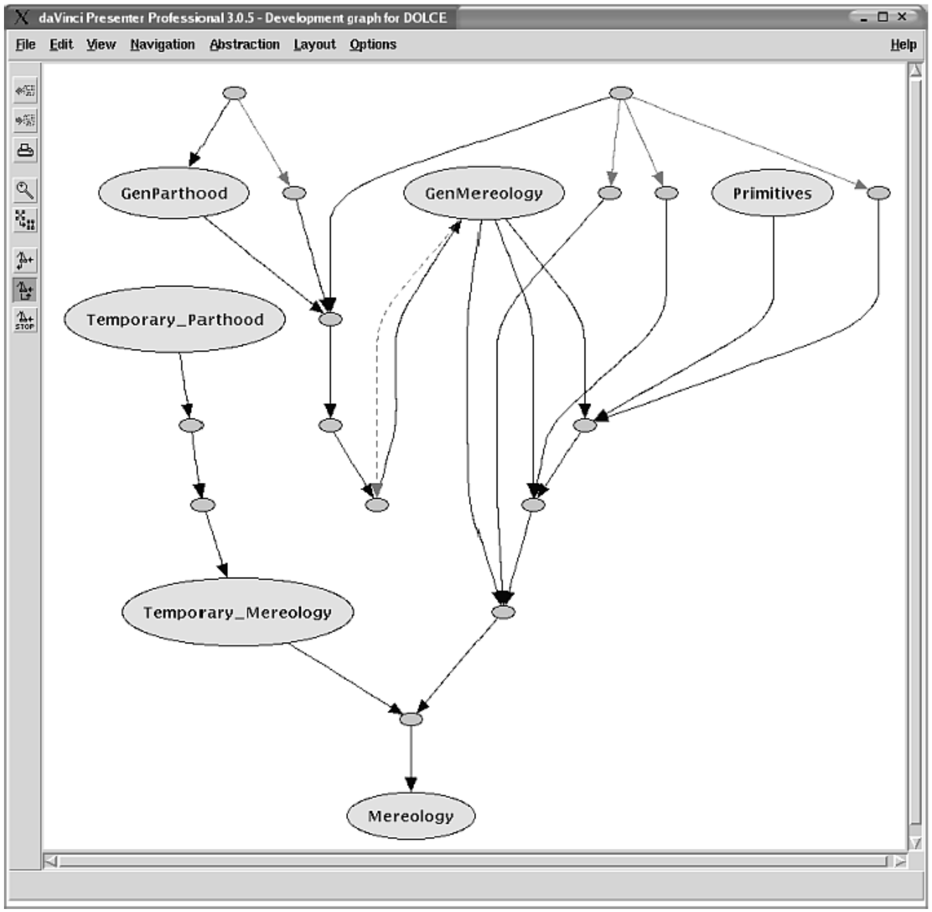

Development Graph

showing dependencies between specifications and proof obligations

The DOLCE ontology in CASL

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

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

work continuing...

Ontology construction

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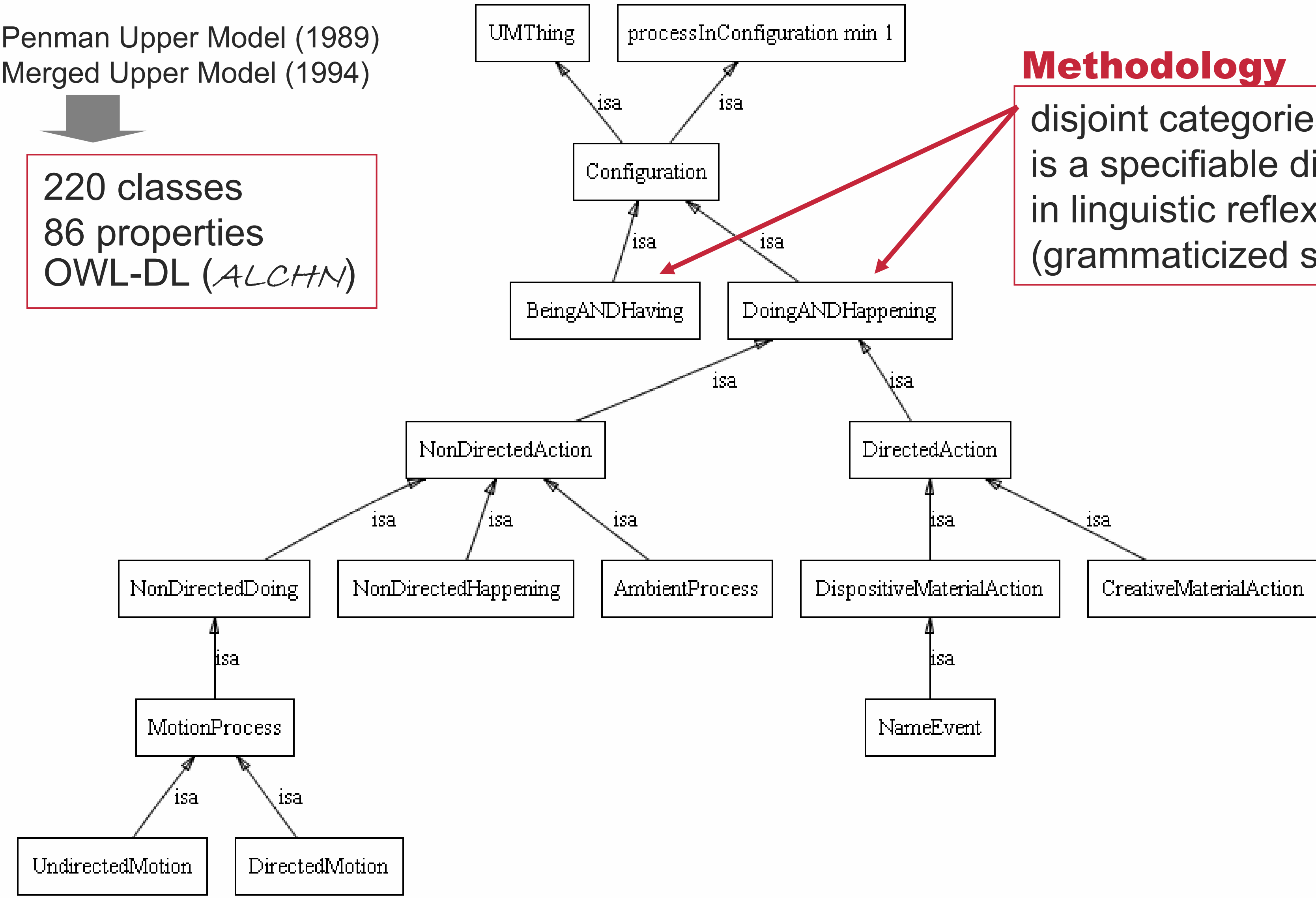
- Axioms are grouped into logically appropriate theories
- Theories may be extended via parameterization to achieve semantic re-use
- Theories may be created and related by views: theory morphisms

Only with this availability of working with meaningful interrelationships can the complexity of distinct axiomatized ontologies really be harnessed.

Generalized Upper Model : Version 3 (2004-)

Penman Upper Model (1989)
Merged Upper Model (1994)

220 classes
86 properties
OWL-DL ($\mathcal{ALCHN}$)



Methodology

disjoint categories iff there is a specifiable difference in linguistic reflexes (grammaticized semantics)

The Generalized Upper Model

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- continues to be used for interacting with our natural language components. Because of the link to language, it is relatively straightforward to understand (continuing development since 1985).
- Until the beginning of the current project in 2002, it was under seriously axiomatized.
- We are now in the middle of a complete update with axiomatization and explicit links to DOLCE (via D&S and quality spaces)
- note that this does *not* mean that it becomes **merged** with DOLCE!
- Work for next 4 years: completion of the axiomatization in the spatial area, relation to FrameNet and EuroWordNet. Perhaps to WordNet (via OntoWordNet and SUMO).

Relation to proposals for **simple** Common Subset?

Summary of work in progress:
with interest in cooperative development

- comprehensive formalization of spatial calculi
  - correctness of composition tables
  - theory morphisms among different calculi
  - inheritance of tools along theory/logic morphisms
- formal integration of ontologies
  - via colimits of theories
  - consistency of integrated ontologies
- content development and interrelation of ontologies

Approaches to ‘simplifying’ the ontologist’s life...

- Making sure that each component of a library of theories only specifies the axioms which are relevant at that point
  (cf. John Sowa: “That is the whole point of Ockham's razor: eliminate any axioms that are not absolutely essential to the task at hand.”)

- Making sure that unnecessary detail is hidden in ‘upstream’ libraries: CASL

- Possibilities for ‘common subsets’:
  - packages such as our spatial calculi
  - packages such as DOLCE’s ‘constitution’, ‘participation’, ‘quality spaces’, BFO’s ‘sites’
  - language-based generic ontology (GUM)