Ontology for computational linguists

— Introduction—

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Outline for today

(1) Justification

(2) Definitions

(3) Ontological diversity

(4) Languages for ontologies

(5) Sum-up and schedule for the class

Justification

Justification

1. Fundamental justifications
   - Interaction between ontology and NL semantics
   - Importance of ontology in linguistics
   - Importance of linguistics for ontology
2. Practical justifications
   - Ontologies and lexical resources
   - Semantic Web
   - Human computer interaction

Interaction between ontology and NL semantics

Ontology:

- Ontology is about **what there is.**
- Ontology is about general categories of entities.
- Ontology studies what are persons, processes, abstract objects...

NL semantics:

- NL semantics is about **referring** to what there is.
- NL semantics studies how NL language refers to persons, objects, abstract object...

Dependence recognized

- Ontological considerations in NL semantics
- NL semantics used as clues for ontological analysis

Importance of ontology in linguistics

- Following [Talmy, 2000] a language is composed of
  - a closed systems of grammatical features
  - an open system of lexical items
- Lexicon commits to some ontology (explicitely)
- But grammar too! But more implicitely (e.g much/many)

Ontology of NL and NL metaphysics
[Bach, 1986, Dölling, 1993]

Big question: Which ontology for NL?

- Should every common noun correspond to an ontological category?

Example

laptop vs. notebook

- Should ordinary NL language sentences be systematically reformulated into "ontologically" valid statements?

Example

Ordinary language: There is a hole in that piece of cheese.
"Valid paraphrase": That piece of cheese is perforated.

Answers: Depends on your philosophical approach.

The rich ontology of natural language

Cannot assume a simple physical ontology of what exits.
Natural language can handle sophisticated entities.

- Co-located events

Example

Nicola is singing while looking for mushrooms.

- Co-located entities

Example

- There is a fly on the nose of this statue.
- ? There is a fly on the nose of this piece of marble.
- There is a fly on this piece of marble.

Research of adequate ontological theories for linguistic problems

- Universals vs. particulars, abstract propositions [Quine, 1960]
- Time (Tense and Aspect): Events, Intervals, Instants [Davidson, 1967, Dowty, 1977]
- Mass Terms, Plurals, Generics: mereologic structures [Quine, 1960, Link, 1983]
- Plurals and Collections: mereologic structures [Link, 1983]

Importance of linguistics for ontology

(1) Difficult to escape language:
- Ontological analysis based philosophical arguments in NL
- Ontological analysis based on linguistic intuitions and philosophy of language (substitutivity tests)

(2) "We must rely on NL definitions to be sure of what something means" [Uschold, 2005]

(3) Significance of the commonsense/NL ontology (revisionary vs. descriptive metaphysics) [Strawson, 1959]

Dangerous (for philosophers) to escape from NL ordinary language?[Kripke, 1982]

Practical justifications

- Ontologies for computational linguitics
  - Lexical resources
  - Semantic web
  - Human-Computer interface
- Computational linguistics for ontologies

Ontologies and lexical resources

- Improvement of existing resources [Gangemi et al., 2003a]
  - Identifying ontological problems *(e.g hyperonymy relation)*
  - Re-structuring the resource
- Multilingual lexical resources (EuroWordNet [Vossen, 1998] , SinicaBOW [Huang et al., 2004], NEDO Project)

Semantic Web

Ontologies support semantic interoperability

- Ontologies as **shared understandings of a domain** (between systems, applications, artificial agents)
- Necessary for overcoming the terminological differences.

Ontological structuring helps for information retrieval [Welty et al., 2003]

- More accurate searches
- Easier to extend searches in case of failure

Human computer interaction

Ontology based dialogue systems

- Interpretation (Word-Sense Disambiguation)
- Models for sentence generation (Bateman)
- Dialogue management [Milward and Beveridge, 2003]
  - Use of taxonomy structure for handling question and answers (specificity)
  - Use of meronymy structure (accuracy)
  - Issue-based dialogue management for improving coherence

Examples [Milward and Beveridge, 2003]

Taxonomic structure:

Example

- **SYSTEM:** Have you had any chronic diseases?
- *System expects: cancer, hypertension, diabetes...*
- **USER:** Yes, Leukemia
- **SYSTEM:** # What kind of cancer?

Examples [Milward and Beveridge, 2003]

Meronomic structure:

Example

- **SYSTEM:** Where does it hurts?
- *System expects: elbow, wrist, shoulder...*
- **USER:** In my arm.
- **SYSTEM:** Where in your arm?
- **USER:** In my elbow.

Lexical resources and NLP for ontologies

Semi-automatic ontology creation from corpus

- Text mining: terms and relations extraction
- Tagging, Parsing, Disambiguisation
- Term grouping

Lexical Resources for:

- Checking ontologies
- Deepening the coverage of upper/mid level ontologies [Niles and Pease, 2003]

Axiomatizing lexical resources gloss (NLP techniques) ([Harabagiu et al., 1999, Gangemi et al., 2003b])

Definitions

Definitions

Ontology vs. ontologies

- Ontology
  - Philosophical discipline
  - The study of "what there is"
  - The study of nature and structure of possible entities
- ontology
  - Theoritecal or computational artifact
  - Created for expressing the intended meaning of a vocabulary

Ontology

- The study of ontological commitment
- The study of what there is
- The study of the most general features of what it is, and of relations between what it is
  - Domain of entities
  - **Categories** and **relations**
  - Characterizing **properties**

However, our main interest is not Ontology but ontologies...

An ontology (among others):

- is an explicit and formal specification of a conceptualization. [Gruber, 1995]
- is designed to account for the commitment of a vocabulary to a conceptualization.
- constrains the interpretation of a vocabulary.

Examples

- *An ontology of "Lord of the Rings" specifies and makes explicit my understanding of Tolkien "world".*
- *An ontology of digital cameras, an ontology of meteorology...*

A conceptualization is an abstraction over the reality performed by an agent.

The components of an ontology

An ontology is a **shared vocabulary** (arbitrary) plus a formal characterization of its **intended meaning**:

- Vocabulary: concepts (categories) and relations
- Characterization of meaning: axioms (logical formulas)

No axioms, no meaning.

Glosses and lexical relations may play the roles of axioms in linguistic ontologies, at the price of the formal rigor.

Example

- Vocabulary: Bird, White, Wing, Leg, Fish, Animal...
- Characterization (informal version):
  - A bird is an animal. (relational)
  - Birds have wings. (intrinsic)
  - Fish are not birds.

The content of an ontology

An ontology is a structure of **necessarily true knowledge** (or meant to be)

Example

Birds have wings.

An ontology do not icludes contingent situations or assertional data.

Example

This bird is white.

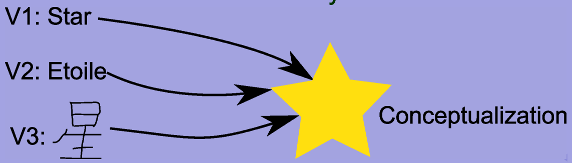
Because an ontology specifies a **conceptualization**

What is a conceptualization?

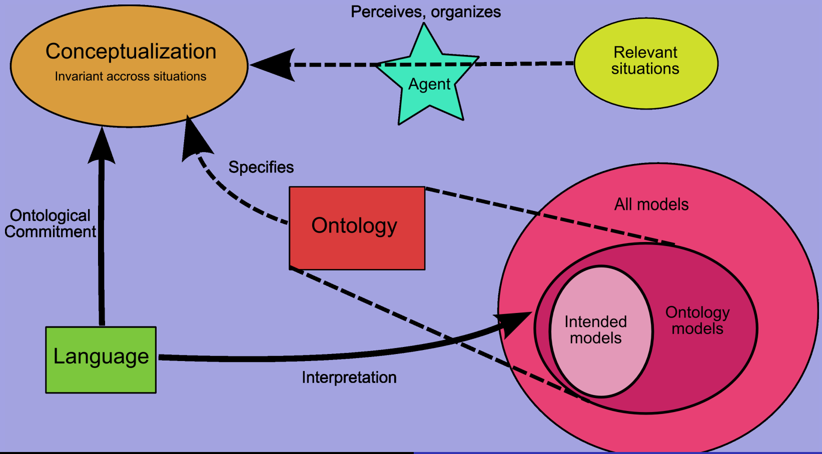
A formal structure for a piece of reality (not necessarily the true one) as perceived and organized by an agent, independently of:

- the vocabulary used
- the actual occurence of a specific situation

Different situations involving same objects, described by different vocabularies may share the same conceptualization.



Conceptualization: intended meaning



Sum-up

An ontology is a

- shared vocabulary

+ definition
    - relation with other entities
    - essential properties

Ontological diversity

Ontological diversity

Different Approaches

- Linguistic "ontologies"
  - Glossary/Lexicon
  - Controlled vocabulary
  - Taxonomy
  - Thesaurus
- Computer Science "ontologies"
  - Conceptual Schema
  - Knowledge base
- Formal ontologies
  - Domain ontology
  - Core (reference) ontology
  - Foundational ontology

Linguistic ontologies

- Word list
- Glossary: list of NL definitions
- Taxonomy: classification with a **is-a** or **is-a-kind-of** relation
- Thesaurus: Taxonomy + synonyms + related terms (generally as part as a standardization)

Important characteristics of linguistic ontologies, generally:

- Each item is generally lexicalized
- The relations and constraints are lexical ones (synonymy, antonymy, hyperonymy)

Knowledge bases

Knowledge base:

- Mainly assertions
- Reflects specific states of affair
- Use descriptors provided by the ontology

Ontology:

- Mainly definitions
- Essential properties of a domain
- Independent of particular state of affairs
- Provides vocabulary and structure for the KB
- Ontological formulas are necessarily true

Conceptual schemas

- Motivation similar to ontologies
- BUT traditionnally ad-hoc solutions (old style computer science)
- Influenced by the extension of the ontology/scheme in development framework (Programming)
- Getting ontologically better

For a in depth disscussion see [Guizzardi, 2005]

Formal ontologies

An ontology is *"'a specification of a conceptualization."*
Formal ontology requires in more:

- clear semantics for the language (formal semantics)
- clear motivations for the adopted disctinctions (philosophical analysis)
- strict rules on how to specify terms and relationships (formal language)

Approaches sum-up

- Different motivations brought different kind of ontologies
- In the course we will be mainly interested in:
  - linguistic ontologies
  - formal ontologies
  - their interface

Ontological precision: Examples, Wordlist

- football
- ping-pong
- indoor game
- ball
- chess
- go
- board game
- athletic game
- player

Glossary

- athletic game: game requiring physical effort.
- board game: game played on a board.
- chess: board game for two players.
- football: game played with a ball on a rectangular field in which two teams try to kick a ball into each other's goal
- ...

Taxonomy

- Game
  - athletic game
    - Football
    - Tennis
    - Rugby
  - board game
    - Go
    - Chess
- Sport equipment
  - paddle
  - ball

Thesaurus

chess: a game for two players who move their 16 pieces according to specific rules; the object is to checkmate the opponent's king

- synonyms: chess game
- related terms:
  - chess move - the act of moving a chess piece
  - exchange - (chess) the capture by both players of pieces of equal value
  - bishop - (chess) a piece that can be moved diagonally over unoccupied squares of the same color
  - shogi - a form of chess played on a board of 81 squares; each player has 20 pieces
- antonyms: none

Wordnet

- synset: chess, chess game
- gloss: a board game for two players [...]; the object is to checkmate the opponent's king
- Coordinate terms: [...] => backgammon – (a board game for two players; pieces move according to throws of the dice) [...]
- Hypernyms: chess, chess game => board game => parlor game, parlour game => game => activity [...]
- Hyponyms: shogi – (a form of chess played on a board of 81 squares; each player has 20 pieces)
- Topic terms: (noun) check#13, opening#12, chess opening#1, bishop#3 (verb) develop#18, promote#5

Axiomatic theory

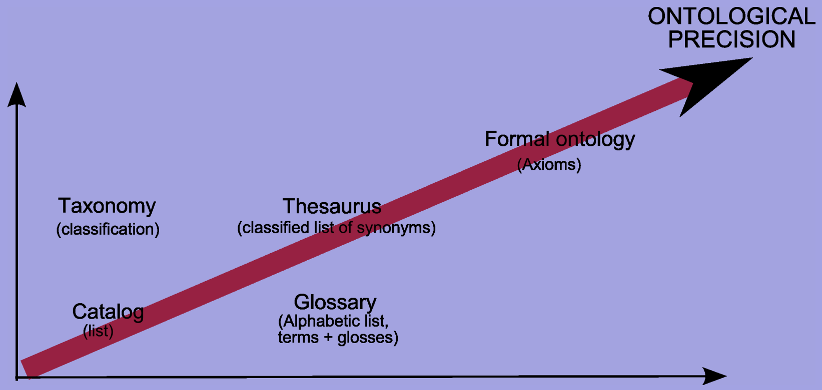
$$game(x) \rightarrow activity(x)$$

$$athleticGame(x) \rightarrow game(x)$$

$$boardGame(x) \leftrightarrow game(x) \wedge \exists y board(y) \wedge playedOn(y, x)$$

$$indoorGame(x) \leftrightarrow game(x) \wedge \exists y builing(y) \wedge playedIn(y, x)$$

Ontological precision



Domain and coverage:

- Foundational ontologies
- Core ontologies
- Domain ontologies

Foundational ontologies and upper levels

Foundational vs. upper level:

- Upper level is about the more general categories
- Foundational ontologies requires a rich characterization

Their content:

- They characterize general terms
- *e.g entity, event, process, spatial location*
- and basic relations
- *e.g part-of, quality-of, participation, constitution*

Their purpose:

- Provide a formal description of entities/relationships common to all domains
- Provide a consistent and unifying view

What a foundational ontologies can say about ping-pong?

Almost nothing! Basic entities concerned:

- NON-AGENTIVE-PHYSICAL-OBJECT
- AGENTIVE-PHYSICAL-OBJECT
- PROCESS

But very fundamental things:
PHYSICAL-OBJECT PARTICIPATES-IN PROCESS

Foundational ontologies and upper levels

Their domain:

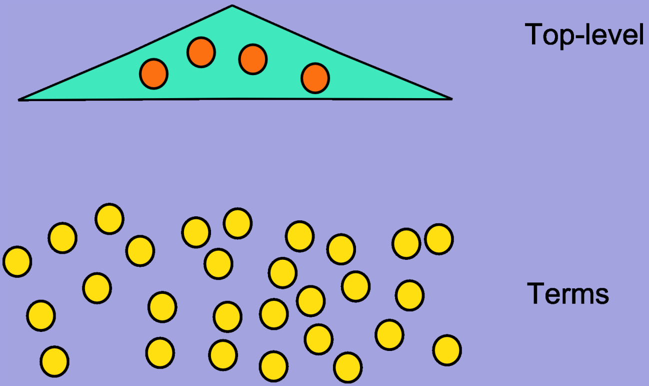
- Everything
- Common to all domains

Their coverage (the number of terms it includes):

- Extremely broad but shallow or even null
- Talk about only very general things
- Have to be mapped to get some coverage

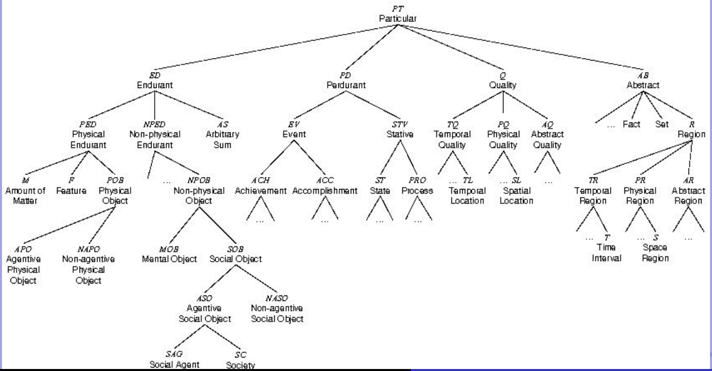
DOLCE: Roughly 40 categories, 100 relations, 80 axioms

Coverage foundational ontologies



Example, DOLCE

DOLCE taxonomy(Descriptive Ontology for Linguistic and Cognitive Engineering)[Masolo et al., 2003]



Domain ontologies

- All ontological information relevant for a given domain
- Provides a deep technical vocabulary

Their domain:

- only one
- usually not a broad one

Their coverage:

- Narrow coverage but very deep
- Ideally no gap within the domain
- Covers all the terms (and specific usage) of the domain
- It is the maximal coverage.

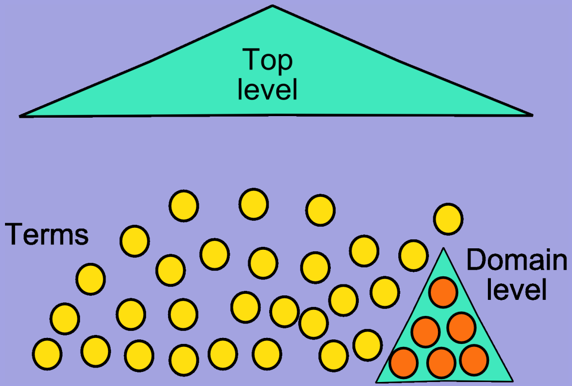
What foundtational ontology of ping-pong can say about ping-pong?

A lots of things!

- All kind of paddles: maybe the different brands and models
- All kind of ball: 1STARBALL, 2STARBALL,...
- All kind of strokes: TOPSPIN-STROKE, LIFT-STROKE

But unrelated to general things.

Coverage domain ontologies

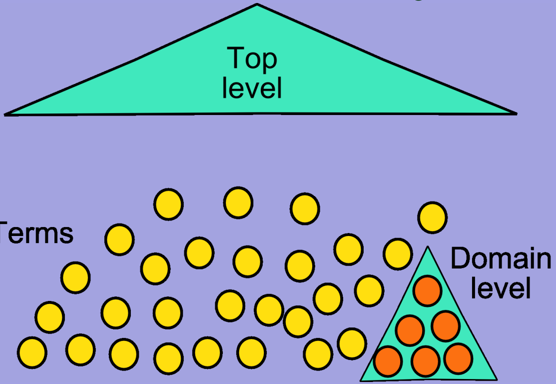


Example

- factkb:EosinophilCountProcedure
- factkb:ErosionOfStomach
- factkb:ErosiveProcess
- factkb:ErythrocyteCount
- factkb:ErythrocyteCountProcedure
- factkb:ErythrocyteSedimentation
- factkb:ErythrocyteSedimentationRate
- factkb:EsophagealPathology
- factkb:EsophagitisProcess
- factkb:EssentialHypertension
- factkb:ExactlyPairedBodyStructure
- factkb:ExcretionOfUrine
- factkb:FacultativeAerobicMetabolicProcess
- factkb:FacultativeAnaerobicMetabolicProcess
- factkb:FailedAnaesthetic
- factkb:FailureOfCellGlucoseUptake
- factkb:FailureOfCellUptakeOfBloodGlucoseDueToCellInsulinResistance
- factkb:FailureOfCellUptakeOfBloodGlucoseDueToInsulinDeficiency
- factkb:FattyDegeneration
- factkb:FattyDegenerationOfHeart

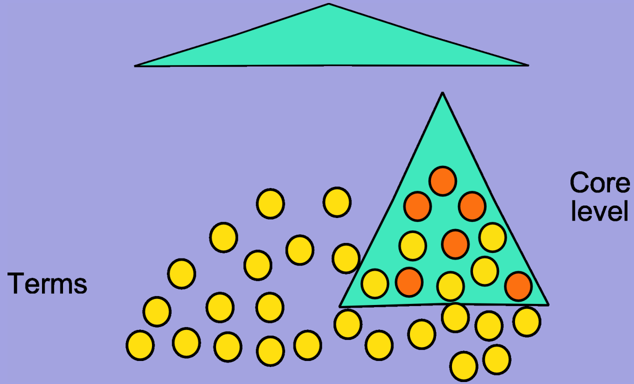
Core ontologies

Domain/foundational distance might be to big.



Core ontologies

Need an intermediate level: **Core** or **reference ontologies.**



Core ontologies

Core ontologies include:

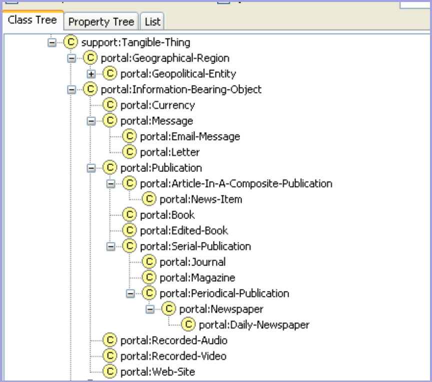
- The central concepts and relations of a domain
- Without entering into all the technical details
- May include rich conceptualization

Their coverage is balanced in scope and in depth.

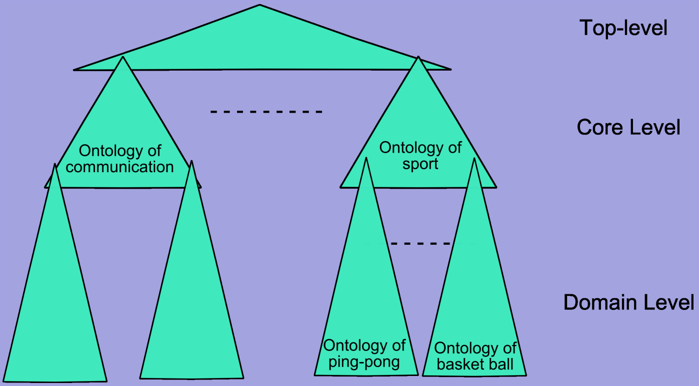
What a core ontology of sports can say about ping-pong?

- PLAYERS EXECUTE STROKES
- The SPORTEQUIPMENT used is PINGPONG-PADDLE and PINGPONG-BALL
- PLAYERS might be somehow related to AGENTIVE-PHYSICAL-OBJECT
- SPORTEQUIPMENT will be related to NON-AGENTIVE-PHYSICAL-OBJECT
- STROKES will be related to the TOPSPINSTROKE, LIFTSTROKE
- PINGPONG-BALL will be related to 1STARBALL,...

Example


Class Tree
Property Tree
List
support:Tangible-Thing
portal:Geographical-Region
portal:Geopolitical-Entity
portal:Information-Bearing-Object
portal:Currency
portal:Message
portal:Email-Message
portal:Letter
portal:Publication
portal:Article-In-A-Composite-Publication
portal:News-Item
portal:Book
portal:Edited-Book
portal:Serial-Publication
portal:Journal
portal:Magazine
portal:Periodical-Publication
portal:Newspaper
portal:Daily-Newspaper
portal:Recorded-Audio
portal:Recorded-Video
portal:Web-Site

Illustration, recap



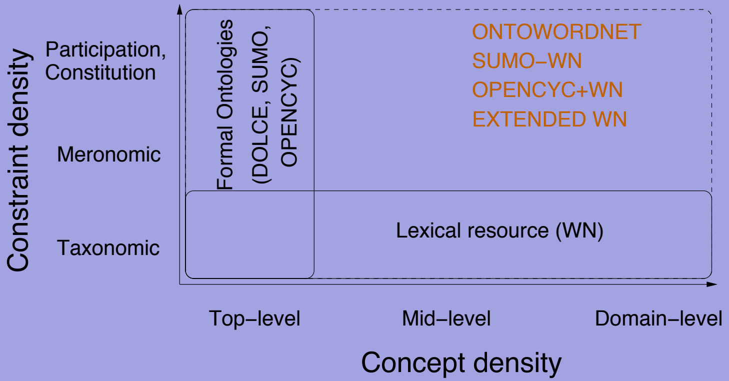
Light-weight vs. Heavy weight

- Light-weight/on-line/shared ontologies [Guarino, 1998]
  - Not a lot of constraints/relations
  - *(e.g simple taxonomies)*
  - easy to handle by programs
- Heavy-weight/off-line/reference ontologies [Guarino, 1998]
  - Rich constraints system
  - *(e.g Meronomic, Participation, Dependence, Constitution, Causal relations)*
  - Much more difficult and costly to create
  - More complex to handle (computational issue)

Light-weight vs. Heavy weight

- Concept density: number of concepts or terms for a given coverage
  - Low concept density: Upper levels, foundational ontologies
  - High concept density: Lexical resources (WN)
- Constraint density: the number or relations/constraints for a given coverage
  - Low constraint density: Taxonomies, catalogues, light-weight ontologies
  - High constraint density: Foundational and heavy-weight ontologies,

Constraint and Concept densities



Sum-up

A wide variety of ontologies
What we used greatly depends on what we use them for [Uschold, 2005]

- Reasoning
- Ontological improvement
- Using the taxonomy only

Languages for ontologies

Languages for ontologies

Languages for ontologies

Languages used

- Natural languages: philosophy sources and annotations
- First-Order Logic: Foundational works (foundational ontology)
- Description logic: More applied than FOL
- Semantic Web languages (XML, RDF, OWL): Current development of ontologies for semantic web

Examples: Natural language

The main characteristic of physical objects is that they are endurants with unity. However, they have no common unity criterion, since different subtypes of objects may have different unity criteria. Differently from aggregates, (most) physical objects change some of their parts while keeping their identity, they can have therefore temporary parts. (...)

Examples: First order logic

4.3.3 Constitution

Argument restrictions

(Ad20) $\mathsf{K}(x,y,t) \rightarrow ((ED(x) \vee PD(x)) \wedge (ED(y) \vee PD(y)) \wedge T(t))$

(Ad21) $\mathsf{K}(x,y,t) \rightarrow (PED(x) \leftrightarrow PED(y))$

(Ad22) $\mathsf{K}(x,y,t) \rightarrow (NPED(x) \leftrightarrow NPED(y))$

(Ad23) $\mathsf{K}(x,y,t) \rightarrow (PD(x) \leftrightarrow PD(y))$

Ground Axioms

(Ad24) $\mathsf{K}(x,y,t) \rightarrow \neg\mathsf{K}(y,x,t)$

(Ad25) $(\mathsf{K}(x,y,t) \wedge \mathsf{K}(y,z,t)) \rightarrow \mathsf{K}(x,z,t)$

Links with other Primitives

(Ad26) $\mathsf{K}(x,y,t) \rightarrow (\mathsf{PRE}(x,t) \wedge \mathsf{PRE}(y,t))$

(Ad27) $\mathsf{K}(x,y,t) \leftrightarrow \forall t'(\mathsf{P}(t',t) \rightarrow \mathsf{K}(x,y,t'))$

(Ad28) $(\mathsf{K}(x,y,t) \wedge PED(x)) \rightarrow x \approx_S < y,t >$

(Ad29) $(\mathsf{K}(x,y,t) \wedge \mathsf{P}(y',y,t)) \rightarrow \exists x'(\mathsf{P}(x',x,t) \wedge \mathsf{K}(x',y',t))$

Examples: KIF

```
(subclass LandArea GeographicArea)\\
(documentation LandArea "An area which is predominantly solid ground,
e.g. a &\%Nation, a mountain, a desert, etc. [...])\\
(=>
   (instance ?LAND1 LandArea)
   (exists (?LAND2)
      (and
         (part ?LAND1 ?LAND2)
         (or
            (instance ?LAND2 Continent)
            (instance ?LAND2 Island)))))
```

Examples: OWL

(Web Ontology Language)

```
<owl:Class rdf:about="#physical-object">
  <rdfs:comment rdf:datatype="&xsd;string">The main characteristic
  <rdfs:subClassOf>
    <owl:Class rdf:about="#physical-endurant">
    </owl:Class>
  </rdfs:subClassOf>
</owl:Class>
<owl:Class rdf:about="#feature">
  <owl:disjointWith>
  <owl:Class rdf:about="#physical-object">
  </owl:Class>
  </owl:disjointWith>
</owl:Class>
```

Trade off between expressivity and decidability

- First-Order Logic: expressive but undecidebale
- Description logics: Decicable fragments of FOL, KR oriented, closer to SW languages
- Semantic Web languages: Trade off between efficiency and expressivity
  - OWL-Lite: not expressive but "Lite"
  - OWL-DL: Restricted to a FOL fragment (decidable)
  - OWL-Full: Expressive but undecidable

Trade off between expressivity and decidability

- An ontology expressed in a given language can be translated in another one IF expressivity allows.
- Many important characterizations are lost when foundational ontologies are translated in less expressive language such as OWL-Lite.

Conclusion

Conclusion

13 Sum-up

14 Future courses

15 Readings and information sources

Sum-up

- Ontology vs. ontologies
- An ontology (among others) is:
  - a shared vocabulary + its characterization
- Different approaches to ontologies (Formal, Linguistic, IS)
- Different level for ontologies (Upper, Core, Domain)
- Different languages for ontologies (NL, FOL, SW)

Which approach, at which level and in which language an ontology should be choosen/developed is dictated by the main motivation for using/building the ontology.

Future courses

(1) Levels in ontologies, specially upper levels and foundational ontologies
(2) Introduction to the ontology-lexical resource interface
(3) Language and tools for ontologies
(4) Methods and tools for building ontologies
(5) Methods and tools for combining ontologies and lexical resources
(6) Maintenance and improvement methodologies
(7) Using an ontology for improving multilinguality resources
(8) Ontology and formal semantics
(9) Application: Ontology evaluation for NLP tasks
(10) Application: Ontology and the Semantic Web

Readings

For this lesson:

- Introduction, definitions: **[Guarino, 1998]**
- Philosophical background: [Quine, 1958, Quine, 1960], "Logic and Ontology" on Stanford Encyclopedia of Philosophy.
- Ontology and NL semantics: [Dölling, 1993, Carrara and Varzi, 2001]
- Ontology and NLP: [Poesio, 2005], [Bateman, 1997]
- Ontology and Information Science: [Guizzardi, 2005]

For next lesson (Foundational ontologies and upper levels): **[Masolo et al., 2003], [Niles and Pease, 2001]**

Websites

- LOA's website: http://www.loa-cnr.it/
- Wikipedia entries on ontology:
  - Computer Science: http://en.wikipedia.org/wiki/Ontology_%28computer_science%29
  - Philosophy: http://en.wikipedia.org/wiki/Ontology
- John Bateman's ontology portal: http://www.fb10.uni-bremen.de/anglistik/langpro/webspace/jb/info-pages/ontology/ontology-root.htm
- Cyc website: http://www.cyc.com/
- SUMO website: http://www.ontologyportal.org/

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