Laboratory for Applied Ontology

Institute of Cognitive Science and Technology
Italian National Research Council

Professional master on technologies for e-government

Conceptual modelling, ontology design, and semantic interoperability

Lecture 4
(done until slide 19)

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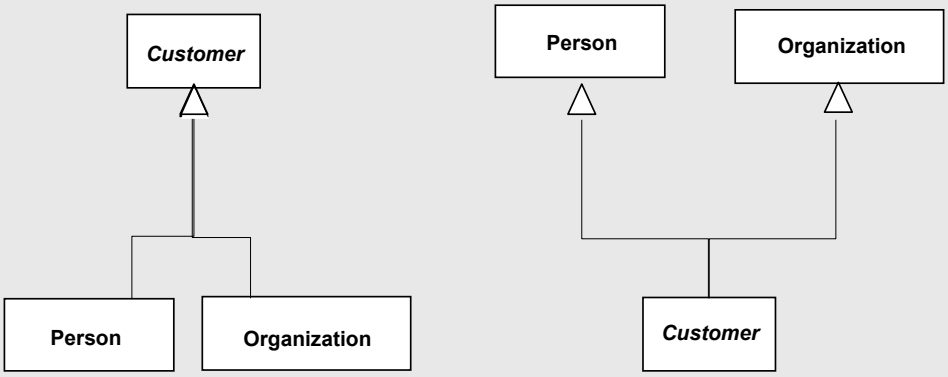
Summary

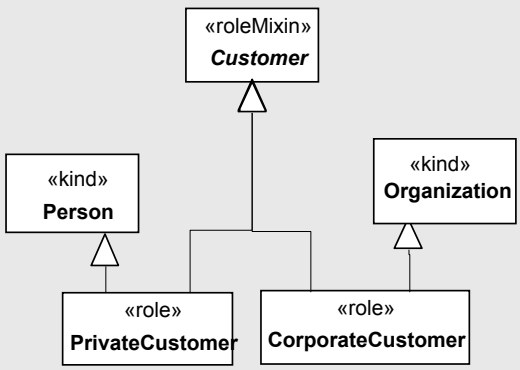
- Mastering Is-a
- The ontological level
- What are ontologies

What's the right model?



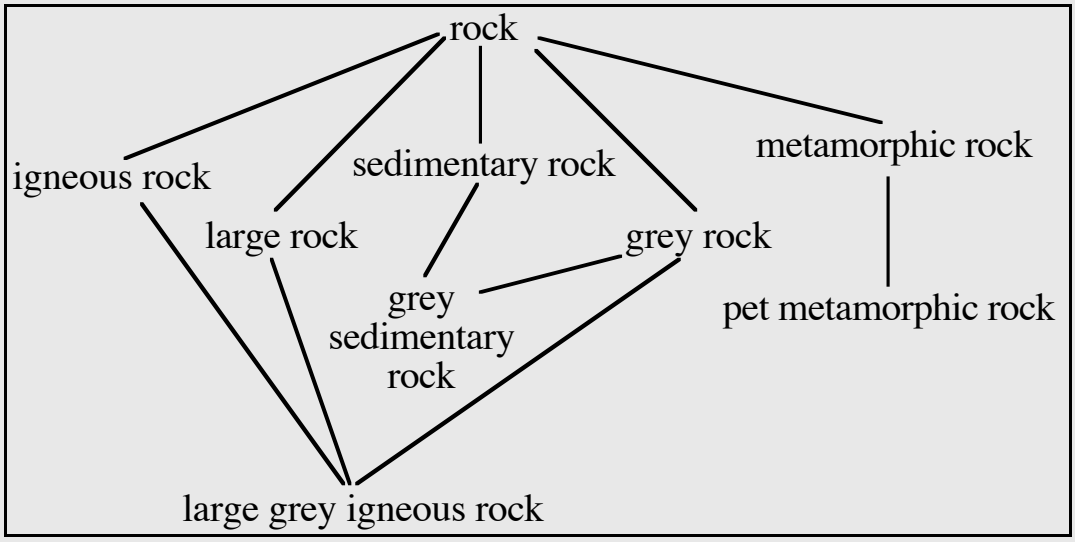
a b

The solution [Guizzardi 2005]



Kinds, roles, attributions

How many rock kinds are there?



[From Brachman, R ., R. F ikes, et al. 1983. "Krypton: A Functional Approach to Knowledge Representation", *IEEE Computer*]

The answer

- According to Brachman & Fikes 83:
  - It's a dangerous question, only "safe" queries about analytical relationships between terms should be asked
- In a previous paper by Brachman and Levesque on ***terminological competence*** *in knowledge representation* [AAAI 82]:
  - "an *enhancement mode transistor* (which is a *kind* of transistor) should be understood as different from a *pass transistor* (which is a *role* a transistor plays in a larger circuit)"
- These issues have been simply *given up* while striving for logical simplification and computational tractability
- The OntoClean methodology, based on formal ontological analysis, allows us to conclude: ***there are 3 kinds of rocks*** (appearing in the figure)

Representation levels

(Brachman 1979)

Level	*Primitives*	*Interpretation*	*Main feature*
Logical	Predicates, functions	Arbitrary	Formalization
Epistemological	**Structuring relations**	**Arbitrary**	**Structure**
Conceptual	Conceptual relations	Subjective	Conceptualization
Linguistic	Linguistic terms	Subjective	Language dependence

From the logical level to the ontological level

- Logical level *(no structure, no constrained meaning)*
  - $\exists x$ (Apple(x) $\wedge$ Red(x))
- Epistemological level *(structure, no constrained meaning)*:
  - $\exists x$:*apple* Red(x) *(many-sorted logics)*
  - ~~$\exists x$:*red* Apple(x)~~
  - a is a Apple with Color=red *(description logics)*
  - a is a ~~Red with Shape~~=apple
- Ontological level *(structure, constrained meaning)*
  - Some structuring choices are excluded because of ontological constraints: Apple carries an identiy condition, Red does not.

Ontology helps building "meaningful" representations

The Ontological Level

(Guarino 94)

Level	*Primitives*	*Interpretation*	*Main feature*
Logical	Predicates, functions	Arbitrary	Formalization
Epistemological	Structuring relations	Arbitrary	Structure
Ontological	**Ontological relations**	**Constrained** (meaning postulate s)	**Meaning**
Conceptual	Conceptual relations	Subjective	Conceptualization
Linguistic	Linguistic terms	Subjective	Language dependence

The source of all problems: different conceptualizations

- A (very simple-minded) painter may intepret the previous expression in a completely different way:
  - Three different reds on my palette:
    - Orange
    - Apple
    - Cherry
- So an expression like ∃*x:red* Apple(*x*) may mean that the painter has just picked up an "Apple" red.

- Two different ontological assumptions behind the Red predicate:
  - adjectival interpretation: *being a red thing* doesn't carry an identity criterion (uncountable)
  - nominal interpretation: *being a red color* does carry an identity criterion (countable)

Formal ontological distinctions help making a conceptualization explicit

What is an ontology

Ontology, lexicon, semantics

- Distinctions among contents: ***Ontology*** (capital ‘o’)
- Reference to content: ***Lexicon,*** via ***Semantics***

- Every organization, every computer system
  - Makes (implicit) ontologic assumptions
  - Adopt a certain lexicon, to which an ***intended semantics*** is ascribed.

Ontology and Ontologies

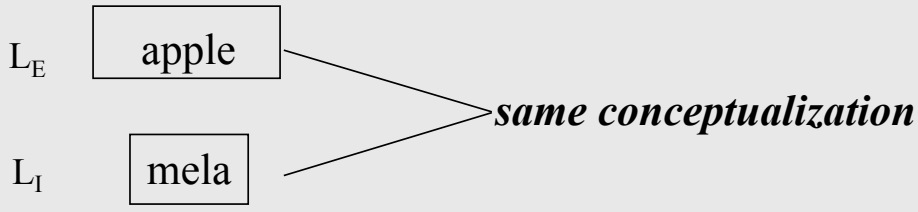
- ***Ontology***: the philosophical discipline
  - Study of ***what there is***
    (content *qua* content, even independently of its existence...)
  - Study of the ***nature*** and ***structure*** of "reality"
- ***ontologies***:

Specific (theoretical or computational) artifacts
expressing the ***intended meaning*** of a ***vocabulary***
in terms of ***primitive*** categories and relations describing
the ***nature*** and ***structure*** of a ***domain of discourse***

Gruber: "Explicit and formal specifications of a ***conceptualization***"

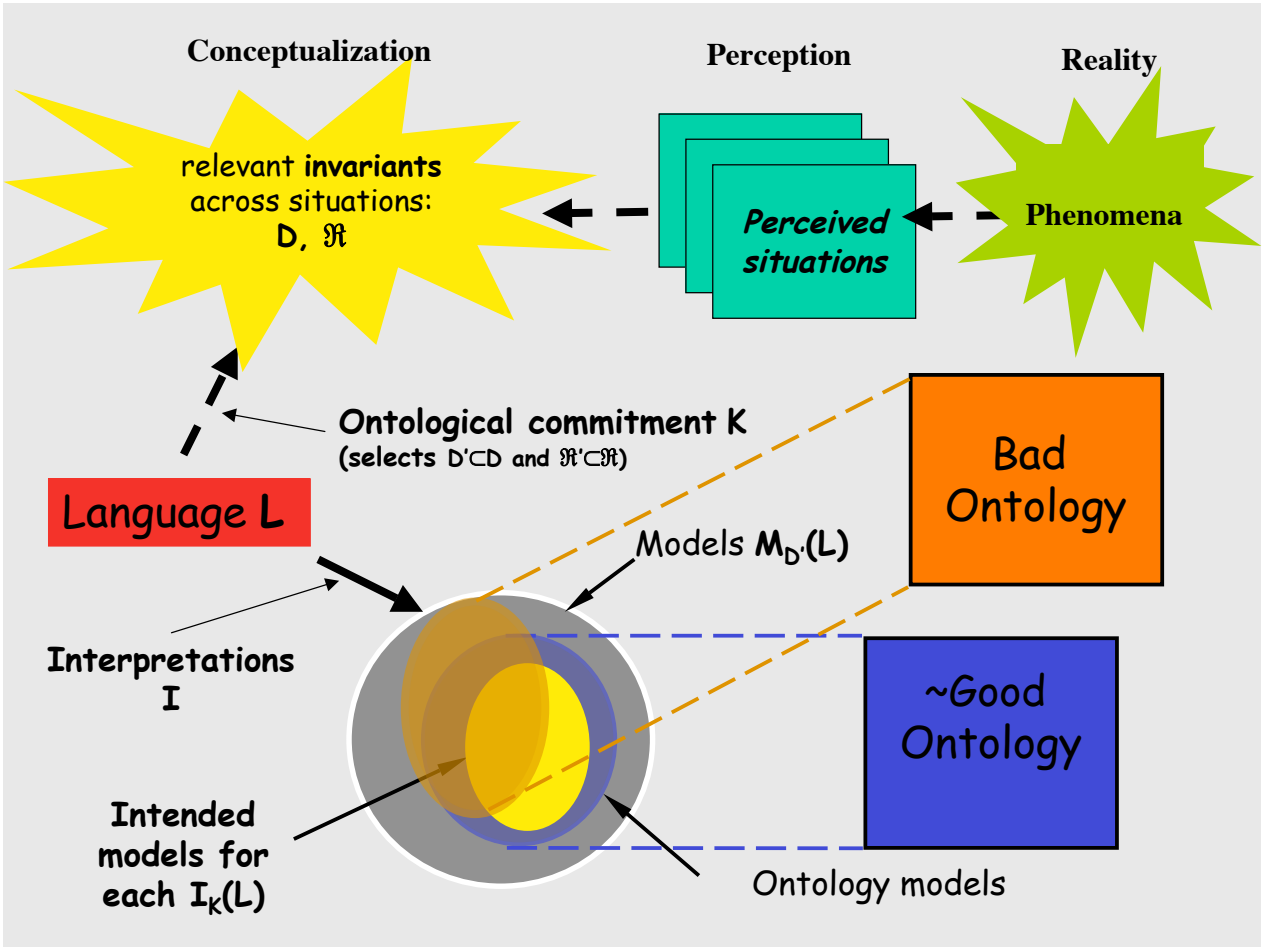
What is a conceptualization

- Formal structure of (a piece of) reality *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.

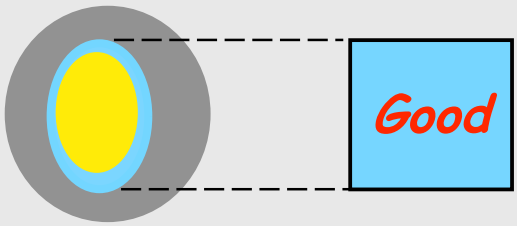


What is a *conceptualization?* A cognitive approach

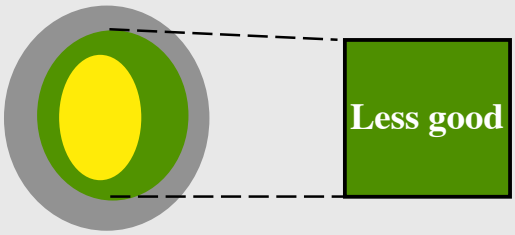
- Humans isolate ***relevant invariances*** from physical reality (quality distributions) on the basis of:
  - Perception (as resulting from evolution)
  - Cognition and cultural experience (driven by actual needs)
  - (Language)
- A set of ***atomic stimuli*** (input pattern) is received when the attention is focused on a phenomenon in a certain minimal region of spacetime (a single ***presentation****)*
- Synchronic level: topological/morphological ***invariants*** within a single presentation
  - Unity properties are *ascribed* to input patterns: topological and morphological wholes (***percepts***) emerge
- Diachronic level: ***temporal invariants*** across multiple presentations
  - ***Objects***: equivalence relationships among *percepts* belonging to different presentations
  - ***Events:*** unity properties are ascribed to *percept sequences* belonging to different presentations



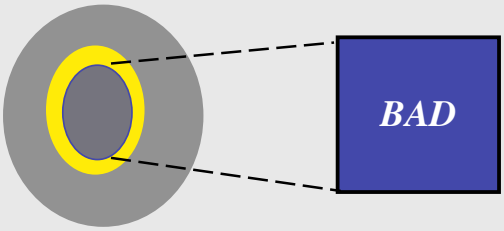
Ontology Quality: Precision and Coverage



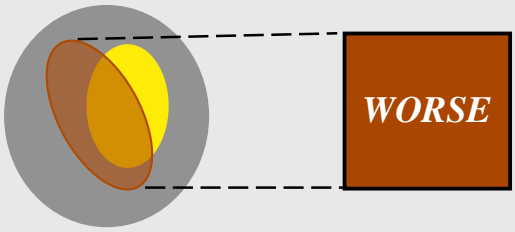
High precision, max coverage



Low precision, max coverage



Max precision, limited coverage



Low precision, limited coverage

Levels of Ontological Precision

tennis
football
game
field game
court game
athletic game
outdoor game

Glossary

Catalog

game
athletic game
court game
tennis
outdoor game
field game
football

Taxonomy

game
NT athletic game
NT court game
RT court
NT tennis
RT double fault

Thesaurus

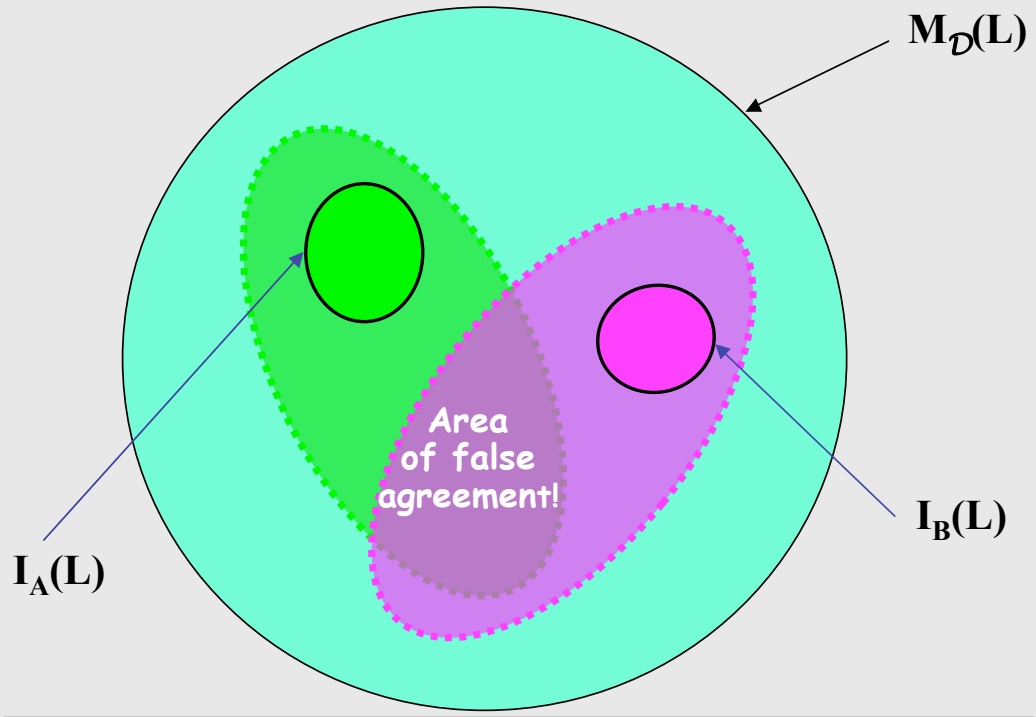
game(x) → activity(x)
athletic game(x) → game(x)
court game(x) ↔ athletic game(x) ∧ ∃y. played_in(x,y) ∧ court(y)
tennis(x) → court game(x)
double fault(x) → fault(x) ∧ ∃y. part_of(x,y) ∧ tennis(y)

DB/OO scheme

Axiomatic theory

Ontological precision

Why precision is important



When precision is not enough

Only one binary predicate in the language: on

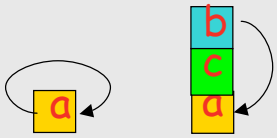
Only three blocks in the domain: a, b, c.

Axioms (for all x,y,z):

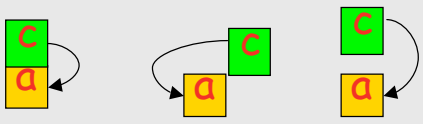
on(x,y) -> ¬on(y,x)

on(x,y) -> ¬∃z (on(x,z) ∧ on(z,y))

Non-intended *models* are excluded, but the rules for the competent usage of on in different *situations* are not captured.



Excluded conceptualizations



Indistinguishable conceptualizations

The reasons for ontology inaccuracy

- In general, a single intended ***model*** may not discriminate between positive and negative ***examples*** because of a ***mismatch*** between*:*
  - Cognitive domain and domain of discourse: lack of ***entities***
  - Conceptual relations and ontology relations: lack of ***primitives***
- Capturing all intended models is not sufficient for a “perfect” ontology

  Precision: non-intended *models* are excluded

  Accuracy: negative *examples* are excluded

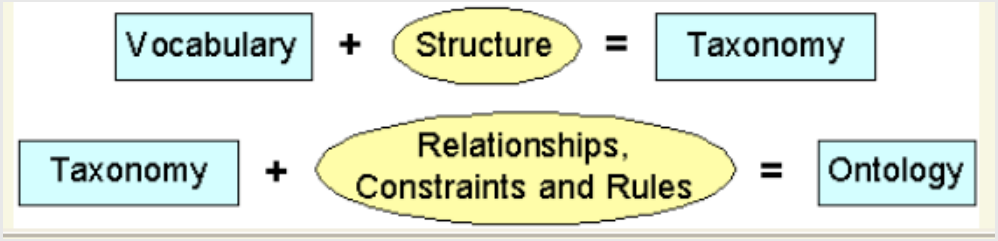
Kinds of ontology change

- Reality changes
  - Observed phenomena
- Perception system changes
  - Observed qualities (different qualia)
  - Space/time granularity
  - Quality space granularity
- Conceptualization changes
  - Changes in cognitive domain
  - Changes in conceptual relations
    - metaproperties like rigidity contribute to characterize them (OntoClean assumptions reflect a particular conceptualization)
- Logical characterization changes
  - Domain
  - Vocabulary
  - Axiomatization (Correctness, Coverage, Precision)
  - Accuracy

When is a precise (and well-founded) ontology useful?

1. When *subtle distinctions* are important
2. When *recognizing disagreement* is important
3. When *general abstractions* are important
4. When *careful explanation and justification* of ontological commitment is important
5. When ***mutual understanding*** is more important than interoperability.

Ontologies and taxonomies



Ontologies vs. classifications

- Classifications focus on:
  - ***access***, based on pre-determined criteria (encoded by ***syntactic keys***)
- Ontologies focus on:
  - ***Meaning*** of terms
  - ***Nature*** and ***structure*** of a domain

Ontologies vs. Database Schemas

- Database schemas:
  - Constraints focus on ***data integrity***
  - Relationships and attribute values out of the DoD
  - Typically ***non-executable***
- Ontologies:
  - Constraints focus on ***intended meaning***
  - Relationships and attribute values first class citizens
  - Typically ***executable***

Ontologies vs. Knowledge Bases

- Knowledge base
  - Assertional component
    - **reflects** ***specific (epistemic) states of affairs***
    - designed for ***problem-solving***
  - Terminological component (*ontology*)
    - ***independent*** of particular ***states of affairs***
    - Designed to support ***terminological services***

Ontological formulas are (assumed to be)
invariant, necessary information

Ontology-driven information systems

Ontology-Driven Information Systems

- Every IS ***has*** its own ontology (either implicit or explicit)
- The ODIS perspective: ***explicit*** ontologies play a ***central*** role, driving ***all*** aspects and components of an IS

- Two (main) dimensions to assess the role of an explicit ontology:
  - ***temporal dimension:*** development time vs. run time
  - ***structural dimension:*** impact on the various IS components:
    - ***database component***
    - ***application program***
    - ***user interface***

Temporal dimension: *development time*

- Two scenarios:
  - A pre-existing ***ontology library*** containing domain and task ontologies as "main building blocks" to be adapted and rused
    - standard IS: the ontology content is *embedded* in the standard components
    - ODIS: an *application ontology* is built by specializing domain and task ontologies taken from the library
  - Only an ***upper-level ontology*** available: not building blocks, but ***conceptual tools*** (analogous to other CASE tools)

- Two kinds of development:
  - IS ***engineering***
  - IS ***re-engineering***

Temporal dimension: *run time*

- Ontology-***aware*** IS: the IS just uses the ontology for some specific purpose
- Ontology-***driven*** IS: the ontology is a ***central component*** of the IS, cooperating at run time towards its "higher" overall goal

- Important application: ***inter-agent communication***

Structural dimension: *the database component*

- Development time:
  - support to ***requirement analysis and conceptual modelling*** (integrated with lexical resources like WordNet)
  - development of a ***global conceptual schema*** (DB integration)
- Run time:
  - mediation-based approach to ***information integration***
  - ***intensional queries***

Structural dimension: *the user-interface component*

- Development time:
  - Generation of ***form-based interfaces*** (constraints checking)
- Run time:
  - Support ***quering and browsing the ontology*** itself:
    - better understanding of the vocabulary
    - queries at the desired level of specificity
  - ***Vocabulary detaching***:
    - user free to adopt his own NL terms (mapped - after disambiguation - to the IS vocabulary with the help of the ontology)

Structural dimension: *the application program component*

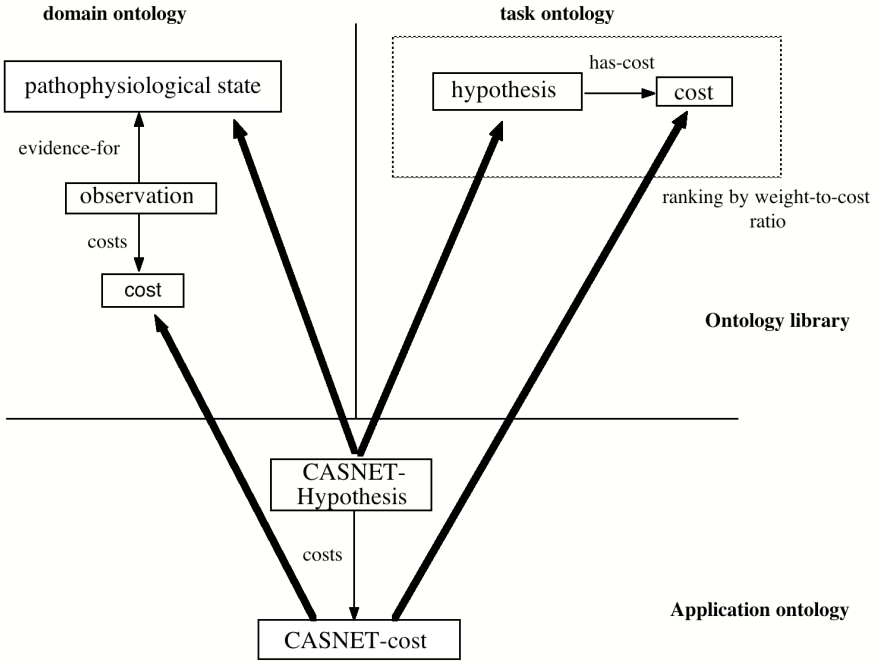
- Development time:
  - Generation of the static part of a program (type structure)
  - Support to OO design
- Run time:
  - Explicit account of the ***ontological commitment*** of an application program
  - Increase of the ***transparency*** of application software

The task dependency problem

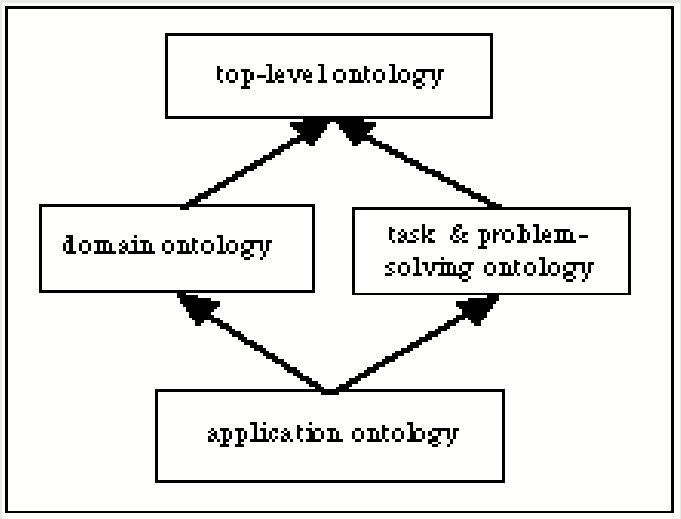
Representing knowledge for the purpose of solving some problem is strongly affected by the nature of the problem and the inference strategy to be applied to the problem.

[Bylander & Chandrasekaran 1988]

Making task dependence explicit [Guarino 97]



The role of task* ontologies



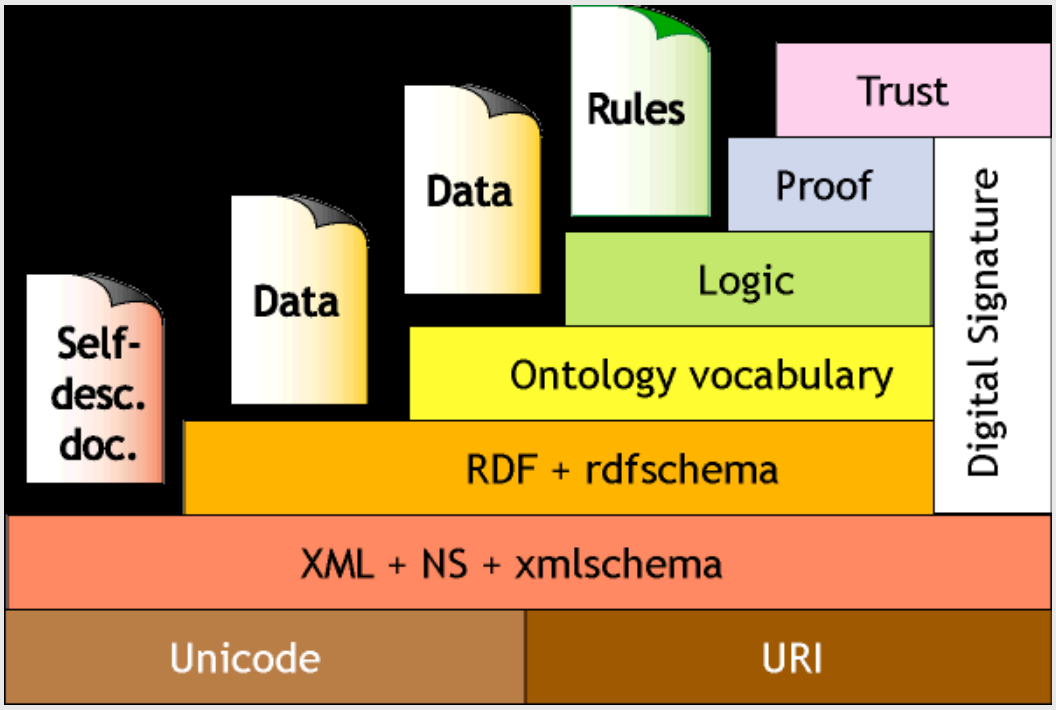
Without explicit domain and task ontologies, semantic interoperability among application ontologies is a myth!

(*) *substitute "task" with "service" if you want to be trendy…*

E il *Semantic Web?*

- Non e' l'applicazione principale delle ontologie! (Web vs. web)
- Non risolve (di per se') il problema dell'integrazione (caso mai lo amplifica)
- Semantic Web: i link hanno un interpretazione semantica, definita in modo distribuito (attraverso il riferimento a *ontologie condivise*, *piu' o meno precise*)
- L'interoperabilita' semantica dipende in modo cruciale dalla condivisione *a priori* di queste ontologie
- Le iniziative di standardizzazione del W3C non hanno purtroppo favorito l'adozione di primitive semantiche (*ontology vocabulary)* comuni

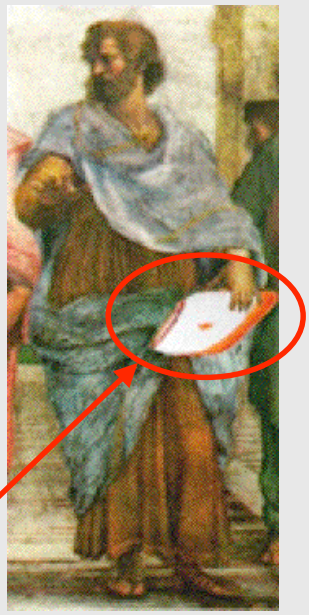
The semantic web architecture [Tim Berners Lee 2000]



Which primitives?
The role of ontological analysis

- Theory of Essence and Identity
- Theory of Parts (Mereology)
- Theory of Wholes
- Theory of Dependence
- Theory of Composition and Constitution
- Theory of Properties and Qualities

The basis for a common ontology vocabulary



Idea of Chris Welty, IBM Watson Research Centre, while visiting our lab in 2000

The problem of primitives

- Representation primitives vs. ***ontological primitives*** (against ***arbitrary*** interpretations)
- Let's aim at ***general*** primitives, similarly to what happens in mathematics: ***set, relation, transitive, symmetric…***

A single, imperialistic ontology?

- An ontology is first of all ***for understanding each other***
  - ...among people, first of all!
  - not necessarily for thinking in the same way
- A single ontology for multiple applications ***is not necessary***
  - Different applications using different ontologies can co-exist and co-operate (not necessarily inter-operate)
  - ...if linked (and compared) together **by means of a general enough basic categories and relations (*primitives*)**.
- If basic assumptions are not made explicit, any imposed, common ontology risks to be
  - seriously mis-used or misunderstood
  - opaque with respect to other ontologies