Foundational Ontologies & Their Library

Motivations and Examples

Doctorate course
Formal Ontology for Knowledge Representation and Natural Language Processing
2004-2005

“ontology” is used referring to…

Linguistic ontology (weakest semantics)
- Glossary
- Controlled vocabulary
- Taxonomy
- Thesaurus

Implementation driven ontology
- Conceptual Schema
- Knowledge Base

Formal ontology (strongest semantics)
- Domain ontology
- Core (reference) ontology
- Foundational ontology
Formal ontologies: the notion

(Starting intuition) An ontology is…

“a specification of a conceptualization of a knowledge domain” (Gruber).

Formal ontology deepens this intuition by requiring:
- clear semantics for the language (formal semantics)
- clear motivations for the adopted distinctions (philosophical analysis)
- strict rules on how to specify terms and relationships (formal language)

The complexity of a representation system splits into two distinct aspects:
- the organization of knowledge structure and
- the specific information for an application domain.

Formal ontologies look at the first issue only.

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Foundational ontologies

- Foundational ontologies
  (these are the most general formal ontologies)

They characterize general terms
e.g. entity, event, process, spatial and temporal location

and basic relations
e.g. part-of, quality-of, participation, dependence

The purpose is
(1) to provide a formal description of entities and relationships that are common in all domains and
(2) to provide a consistent and unifying view
The WonderWeb Library of Foundational Ontologies (WFOL)

- No single upper level
- Rather, a (small) set of foundational ontologies carefully justified and positioned with respect to the space of possible choices
- Basic options clearly documented
- Clear branching points to allow for easy comparison of ontological options)

Related material at: http://www.loa-cnr.it/DOLCE.html

…and from another perspective:

The WonderWeb Library

- Reflects different commitments and purposes, rather than a single monolithic view.
- Is a starting point for building new foundational or specific ontologies.
- Is a reference point for easy and rigorous comparison among different ontological approaches.
- Furnishes a common framework for analyzing, harmonizing and integrating existing ontologies and metadata standards.
The structure of the WFOL

- The modules are organized along two dimensions:
  - visions, corresponding to basic ontological choices made;
  - specificity, corresponding to the levels of generality/specific domains.

Some Ontological Choices (1)

- Universals, Particulars and Individual Properties
  - Properties are universals (repeatables), e.g. “redness”, that apply to different entities OR properties are tropes (non-repeatables), i.e. “individual” properties inhering only in a specific entity, e.g. “the red of this particular rose”?
  - Are entities the substrates of their properties or are they the aggregations of their properties?

- Persistence of entities
  - How do entities persist? What does it means for an entity to change maintaining its identity? Are entities spatio-temporal worms that change because they present different phases OR are they three-dimensional extended entities changing because they instantiate different properties at different times?
  - Is it possible to have at the same time the two kinds of entity connected by a participation relation?
Some Ontological Choices (2)

- **Space and Time**
  - Are space, time and space-time absolute (i.e. regions of space, time and space-time are assumed in the ontology) OR are they relative (i.e. we can consider only spatial, temporal and spatio-temporal relations between entities)?
  - Is space-time Newtonian, Galilean, …?

- **Localization**
  - Are all the entities localized in space (*concrete*) OR there exist entities that are not in space (*abstract*)
  - Is it possible to have different entities that are (spatially or spatio-temporally) co-localized?

Current Status of the WFOL

- 3 visions:
  - DOLCE
  - OCHRE (originally developed by Luc Schneider)
  - BFO (originally developed at the IFOMIS institute)
- 1 specialization:
  - theory of Descriptions and Situations (D&S) linked to DOLCE.
- 1 specific domain:
  - web services – using DOLCE+D&S (in cooperation with Daniel, Marta and Peter)
- 1 mapping between different visions:
  - OCHRE to DOLCE
- 1 mapping between ontology modules and lexicons:
  - DOLCE to WordNet
Current Formalization of the WFOL

- Axiomatic (FOL) characterization of the three visions (DOLCE, OCHRE, and BFO).
- KIF encoding of DOLCE and OCHRE.
- OWL encoding of (a part of) DOLCE (DOLCE-Lite).
- OWL/KIF encoding of (a part of) DOLCE+D&S (DOLCE-Lite+).
- OWL/KIF encoding of the web services “ontology”.
- Formal mapping of OCHRE into DOLCE.
- WordNet-DOLCE alignment (in KIF).
- … core ontologies extending DOLCE-Lite+ (time, plans, services, legal, finance, …)

Digging into foundational ontologies

the DOLCE ontology
Recall the underlying vision

Commitment (intended subject) → Tolkien’s world

A Language \( \mathcal{L} \)

Interpretation (formal subject) → Tarski Models for \( \mathcal{L} \)

Formal Models Tolkien would accept

The Lord of the Rings (content)

Basic Assumptions of DOLCE

- **DOLCE**: a Descriptive Ontology for Linguistic and Cognitive Engineering

- Strong Cognitive/Linguistic bias
  - Categories mirror *cognition, common sense*, and the lexical structure of *natural language*.
  - Categories as *conceptual containers*: no “deep” metaphysical implications wrt “true” reality.
  - No deep commitment on “intellectual economy” of the primitives notions adopted: focus on the simplicity of the representation primitives.
Basic Ontological Choices of DOLCE (1)

- Objects (Endurants) and Events (Perdurants)
  these are distinct categories connected by the relation of participation.

- Qualities form a category
  they inhere in Objects (Physical Qualities) or in Events (Temporal Qualities) and correspond to “individualized properties”, i.e. they inhere only in a specific entity, e.g. “the color of this particular rose”, “the velocity of this movement”, etc.
  - Physical Qualities are not instantaneous but they live with the Objects they inhere in, i.e. “the color of this particular rose” can change in time.

Basic Ontological Choices of DOLCE (2)

- Each kind of Qualities is associated to a Quality Space representing the space of the values that qualities (of a specific kind) can assume.
  Quality Spaces are neither in time nor in space, but different quality spaces associated to the same kind of Qualities are admitted.
  - Space and Time are specific quality spaces;
  - different kinds of space and time are admitted.

- Different Objects/Events can be spatio-temporally co-localized: the relation of constitution is considered.
Abstract vs. Concrete Entities

- **Concrete**: located in space-time (regions of space-time are located in themselves)

- **Abstract** (this term may have two meanings):
  - Result of an abstraction process (something common to multiple exemplifications)
    - **Not located in space-time** (this is the meaning in DOLCE)

- Mereological sums (of concrete entities) are concrete, the corresponding sets are abstract...
Endurance vs. Perdurance

- **Endurants:**
  - All their proper parts are present whenever they are present (*wholly presence*, no temporal parts)
  - They exist in time
  - They can genuinely change in time
  - They may have non-essential parts
  - The parthood relation on endurants includes a temporal argument

- **Perdurants:**
  - Only some of their proper parts are present whenever they are present (*partial presence*, temporal parts)
  - They happen in time
  - They do not change in time
  - All their parts are essential
  - The parthood relation on perdurants does not consider time

Qualities and qualia

- **Linguistic evidence**
  - *This rose is red*
  - *Red is a color*
  - *This rose has a color*
  - *The color of this rose turned to brown in one week*
  - *The room’s temperature is increasing*
  - *Red is opposite to green and close to brown*

- Every entity comes with certain qualities that permanently *inhere* to it and are *unique* of it
- Qualities are perceptually mapped into *qualia*, which are regions of *quality spaces*.
- Properties hold because qualities have certain locations in their quality spaces.
- Each *quality type* has its own quality space
Qualities

The rose and the chair have *the same color*:
- different color qualities inhere to the two objects
- they are located in the same quality region

Therefore, the same color attribute (red) is ascribed to the two objects

Individual Qualities and Quality-spaces

- **Endurant**
  - **Physical Endurant**
    - **Gripper_73**
      - Inheres
      - **Indiv. weight-quality of Gripper_73**
  - **Weight-quality**
  - **Weight-Space**
    - **Weight_421**
      - Has- quale
      - Is-part-of Endurant Quality-space
Space as a Quality
DOLCE taxonomy
(categories of interest in this example)

An endurant, its qualities (yellow boxes), and their quality-spaces (gray boxes)

Individual Shape-quality of Gripper_73

Individual Weight-quality of Gripper_73

Individual Location-quality of Gripper_73

Individual Shape-quality of Gripper_73
Going practical

- Foundational ontologies are applied

- Sample Generic Use Cases:
  - who does what, when and where?
  - what are the parts of sth?
  - what is it made of?
  - what's the place of sth?
  - what's the time frame of sth?
  - how can you do what you do?
  - does my behaviour conform to that rule?
  - what's the function of that artifact?
  - how is it built?
  - how did that phenomenon happen?
  - what's your role in that affair?
  - is my scheduling compatible with yours?
Application of DOLCE (1)
WordNet alignment and OntoWordNet

- OntoWordNet research program jointly with other institutions
- 809 synsets from WordNet1.6 directly subsumed by a DOLCE+D&S class
  - Whole WordNet linked to DOLCE+D&S
  - Lower taxonomy levels in WordNet still need revision
- Glosses being transformed into DOLCE+ axioms
  - Machine learning applied jointly with foundational ontology
- WordNet “domains” being used to create a modular, general purpose domain ontology

Applications of DOLCE (2)
Core ontologies

- DOLCE, D&S, and OntoWordNet being used to create core ontologies in various domains and applications
- Core ontology of plans and guidelines
- Core ontology of services
- Core ontology of service-level agreements
- Core ontology of transactions and anti-money-laundering gls
- Core ontology for the Italian legal lexicon
- Core ontology of regulatory compliance
- Core ontology of fishery
- Core ontology of biomedical terminologies (cf. UMLS)
Back to the Library of Foundational Ontologies

OCHRE and BFO

Basic Assumptions of OCHRE

- **OCHRE**: *the Object-Centered High-level Reference Ontology*
- Strong bias on conceptual simplicity
  - The number of basic (primitive) concepts and relations is as small as possible. This means that the theory is simpler, but the representation needs more work in translation.
  - A unique, atemporal, atomistic and extensional parthood relations defined on all the entities.
- Descriptive or intuitive adequacy
  - Models every-day applications for every-day situations.
Basic Ontological Choices of OCHRE

- **Tropes** (individualized/non-repeatable) properties are the atoms of Ochre, i.e. the simpler entities composing all other entities (all the entities are sums of Tropes).

- **Thin Objects** (corresponding to DOLCE’s *Endurants/Objects*) are non-instantaneous entities sums of “essential tropes”, i.e. properties that thin objects possess during their whole lives.

- **Thick Objects** are 3-dimensional snapshots of Thin Objects which roughly corresponds to life phases (they are sums of tropes that thin objects possess at a certain time).

- **Events+Processes**
  - these roughly correspond to DOLCE’s *Perdurants/Events*.
  - Events are sums of two directly succeeding thick objects, while processes are arbitrary sums of events.

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Basic Ontological Choices of OCHRE (2)

- No Spatial and Temporal entities are in the ontology, only spatial and temporal relations on thick objects.

- *Change* is described as the succession of thick objects (snapshots) relative to the same thin object.
Basic Assumptions of BFO

- BFO: *Basic Formal Ontology*.
- Philosophical and Realistic bias.
- *Meta-ontological* flavor

  - Originally, three-dimensional entities (called **SNAPs**) and four-dimensional entities (called **SPANs**) were considered in separate “ontologies”, i.e. in separate FOL theories. Relations involving both SNAPs and SPANs are meta-level relations.

  - In order to integrate BFO in the WFOL, SNAP and SPAN are modeled as two different categories in the same FOL theory.

Basic Ontological Choices of BFO

- SNAPs are 3-dimensional entities.
- No temporal considerations concern **SNAPs**: *presentist metaphysics*—a SNAP exists only at the present time.
- SNAPs are divided mainly into:
  - **Substantial Entities**—e.g. material objects, agents, etc.
  - **Tropes**, i.e. *individualized properties* inhering in Substantial Entities.
  - **Spatial Regions**, i.e. a Galilean space is adopted (spatial regions change through time as all other objects).
Basic Ontological Choices of BFO (2)

- SPANs entities are divided mainly into:
  - **Processual Entities**
    roughly corresponding to DOLCE Perdurants/Events.
  - **Temporal Regions**
    the whole of time and its parts.
  - **Spatio-temporal Regions**
    four dimensional regions of space-time.

From OCHRE to DOLCE

- Existential assumption in (on the domain of) OCHRE are stronger than in DOLCE:
  - OCHRE => DOLCE does not require additional existential assumptions;
  - DOLCE => OCHRE requires strong additional existential assumptions.

- OCHRE is “less expressive” than DOLCE (i.e. OCHRE contains less distinctions and less relations than DOLCE) thus only a partial mapping is possible.