

Objects, events, qualities

An introduction to formal ontological distinctions (in DOLCE)

Lecture 1 – Introduction

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Essli 2010 – Copenhagen, August 16-20

Summary of the course

- 1 · Introduction to formal ontology.
- 2 · How to represent and to structure properties in FOL.
- 3 · Time, change, and roles.
- 4 · Constitution and ontological levels.
- 5 · Objects vs. Events.

1 Two Slogans

- ★ **Ontological analysis:** study of *content qua content*.
What must be modeled needs to be studied, understood, and analyzed *as such*, independently of the way it will be represented.
- ★ **No ontology without ontological analysis!**
First ontological analysis, *then* knowledge representation.

2 Ontological analysis: from form to content

- *Content qua content* vs. *being qua being*.
Philosophers focus more on the nature and structure of *reality* than on (different) models of reality.
- Computer scientists focus more on the nature of reasoning than on modeling and modeling is leaved to the user.

Essential ontological promiscuity of AI: any agent creates its own ontology based on its usefulness for the task at hand (Genesereth and Nilsson 1987).

...just talking of whatever we like?

3 Ontology vs. Ontology vs. ontology

- Trend:
 - ▶ **O**ntology ~ realism;
 - ▶ **o**ntology ~ develop arbitrary models (often simple taxonomies).
- In this course:
 - ▶ **O**ntology ~ develop a set of well founded ontologies avoiding both a *monolithic approach* and *arbitrary models*.
- ★ Two achieve this, one needs to shift the way of thinking ontologies.

4 First shift

- *Logic*. From **L**ogic to **l**ogics.
No absolute *truth*: different truths underly different reasoning mechanisms that make sense in specific *contexts*.
- *Philosophy*. From **O**ntology to **O**ntologies.
No absolute *reality*: different realities (categories and relations) are useful to account for natural language, common sense, etc.
- *KR*. From **o**ntologies to **O**ntologies.
The ontological analysis contributes to the solution of some key problems, e.g. *semantic matching* and *semantic integration*.

5 Avoid a monolithic approach

- An **O**ntology is first of all for understanding each other but not necessarily for thinking in the same way: help recognizing and understanding disagreements as well as agreements.
- In an **O**ntology, basic assumptions must be characterized in an explicit way
 - ▶ to avoid mis-using and misunderstandings,
 - ▶ to be semantically transparent with respect to ontological commitment.
- A *standard ontology* is not necessary: applications based on different ontologies can co-exist and cooperate (not necessarily inter-operate) if linked and compared together.

6 Library of Ontologies

- No standard Ontology, rather, a (small) set of Ontologies (that reflects different commitments) carefully linked, justified, documented, and positioned with respect to the space of possible choices.
- ▶ Starting point for building new ontologies.
⇒ *Re-using & modularization.*
- ▶ Reference point for easy and rigorous comparison among different ontological choices.
⇒ *Semantic integration.*
- ▶ Furnishes a common framework for analyzing, harmonizing and integrating existing ontologies and metadata standards.
⇒ *Trust*

7 Avoid arbitrary models

- *Foundational ontologies* are ontologies that:
 - ▶ have a large scope,
 - ▶ can be highly reusable in different modeling scenarios,
 - ▶ are philosophically and conceptually well founded, and
 - ▶ are semantically transparent (richly axiomatized).
- Foundational ontologies provide *conceptual handles* to carry out a coherent and structured analysis of the domains of interest.
- Formalization requires to chose the *primitives* (categories and relations) and the *axioms* that characterize them.
- To have non arbitrary fondational ontologies a second shift is needed.

8 Second shift

- **Generality** (Husserl's formal ontology). Focus on very basic categories (e.g. *object, event, time, quality*) and relations (e.g. *identity, parthood, dependence, constitution, participation*), that are not specific to particular domains but can be suitably refined to match specific requirements.
- **Multi-disciplinarity**. *Philosophy, linguistic, cognitive science, and mathematics* have deeply investigated these general notions.
- Even though foundational ontologies assume a practical and engineering perspective, one can *reuse* and *rely* on these studies for the construction, comparison, organization, and assessment of ontologies.

9 Examples: theories of space and mereologies

- Is space absolute or relative (i.e. the result of relations holding between entities)?
- Is space atomic or atomless?
 - ▶ Are atoms extended or not?
- Which geometry does it satisfy?
- Is parthood transitive?
- Is parthood extensional?
- Is parthood closed under summation and difference?

10 Notions considered in the course

- Theories of properties, qualities, and measurement.
- Theories of persistence and change.
- Theories of dependence and ontological levels.
- I will not consider only DOLCE; DOLCE will be a 'running example'.

11 Appl 1: ontology-driven conceptual modeling

- Clarify the semantics of conceptual modeling languages (e.g. UML).
- Extend conceptual modeling languages by introducing ontologically well founded primitives.
- Introduce some (ontological) 'design-patterns' (e.g. in terms of UML profiles) that assure well founded solutions to recurring modeling problems.

12 Appl 2: computational lexicons

- The *alignment* of ontologies with computational lexicons (e.g. WordNet) allows to
 - ▶ improve the ontological foundation of the lexicon and its semantic transparency;
 - ▶ linguistically found the ontology;
 - ▶ use the ontological information in NLP;
 - ▶ use the linguistic information in the lexicon to ‘populate’ ontologies.
- OntoWordNet: alignment between DOLCE and WordNet + learning from the glosses of Wordnet.
(<http://www.loa-cnr.it/DOLCE.html#OntoWordNet>)

13 Which formal language?

(1/2)

- The idea is to *separate* the conceptual/ontological analysis from the implementation under specific applicative constraints.
- However, one specific concern about 'implementation' is the *formal language* used to characterize/represent the chosen primitives.
- Ontological analysis can be carried out in a *precise* but not necessarily *formal* way (as often happens in analytic philosophy).
- However, from my point of view, formalization can be extremely useful to:
 - ▶ take into account very subtle distinctions, compare them, and check what are the consequences of specific choices;
 - ▶ to make explicit, objective, and communicable the analysis.

14 Which formal language?

(2/2)

- In particular, in a more engineering perspective where ontologies are *computational ontologies*, i.e.
 - 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,

the choice of the formal language used to express and conduct the ontological analysis becomes an important aspect.

15 Expressive power vs. efficiency

- To better characterize the primitives a highly expressive language is desirable.
- High expressive power compromises computational efficiency (no automatic inference and classification in reasonable time) .
 - ▶ High order logics.
 - ▶ First order logics.
 - ▶ Modal logics and description logics.
 - ▶ Taxonomies.
 - ▶ ER and UML.

16 Analysis vs. implementation language

- Is it possible to *separate* the language used in the analysis from the language used in the implementation?
- ▶ Starting from an expressive language allowing for good characterization of primitives (e.g. FOL), one has the problem of *approximate* the theory in a less expressive language with better computational behavior (e.g. OWL), but:
 - approximations depend on external knowledge/requirements,
 - automatic translators are very difficult,
 - approximations change the (meaning of) primitives.
- ▶ Vice versa, starting from a very poor language, one is often unable to characterize the primitives in a satisfactory way.

17 Working assumptions

- ★ I will use FOL because:
 - ▶ I will focus more on ontological analysis than on efficiency;
 - ▶ it is a well known language accessible to and understandable by a 'large public' (a 'common' language?);
 - ▶ one can at least try to approximate FOL theories in DLs.
- ★ In what follows, an ontology will be then a FOL theory intended to semantically characterize the primitives and the structure of the domain by ruling out as much as possible non-intended models.

18 Formal language and ontological choices

- The choice of the language, the simplicity and the efficiency of the theory, has some impact in the technics used in order to represent and characterize the ontological analysis.
- From the applicative/engineering point of view, these technics are quite important, therefore I will address this topic in the course.
- Some ontological choices can solve specific expressive limitations or just simplify the cognitive understanding of the theory (e.g. the n -ary relations in OWL, *reification*, *multiplicativism*).
- This way of seeing things requires also a weak ontological commitment about the entities in the domain of quantification.

19 Modelling strategies

- Context: expanding an existing foundational ontology
- What modelling choices are available when analyzing a new notion?
 - ▶ Are we talking of *something* new or not?
 - introduce new individuals (of a new category), or
 - introduce a new property of existing individuals.
 - ▶ If a property is enough, which theory of properties to use, and which formal account?
 - standard predicative approach,
 - universals: new individuals + new relations, or
 - tropes: new individuals + new relation.
- How to chose among these modelling options?

20 Decision is not so obvious

- Let us consider the following three (well known) puzzling examples:
 - ▶ spatial coincidence;
 - ▶ counting problem;
 - ▶ conflicting properties paradox.

21 Spatial coincidence

A sculptor creates the statue of the infant Goliath by sculpting the lump of clay Lumpl.

- Lumpl, but not Goliath, would survive a squeezing while Goliath, but not Lumpl, would survive the loss of some parts.
- Goliath, by a continuous and complete renovation of the clay it is made of, could survive the destruction of all parts of Lumpl.
- Lumpl already existed before the sculptor bought it, while Goliath comes into existence only once the sculptor has completed her work.
- Goliath, but not Lumpl, has been created by an artist, it costs 2000 euros, it causes you to pay a ticket to see it.

22 Counting problem

In 2009, Alitalia carried a million passengers. If, in 2009, some persons flew Alitalia more than once then Alitalia served less than a million persons (similarly for roles in general).

- To count the passengers of an airline one cannot simply count the persons that flew it.
- Passengers but not persons have a flight number and specific rights and obligations.
- A person can fly different airlines or she can fly several times the same airline with different destinations or simply in different days.

23 Conflict properties paradox

Luc as passenger of Air France has the right of checking in online, while, as passenger of Alitalia, has the obligation of checking in at the airport.

- If passengers reduce to persons then one obtains a contradiction: Luc cannot have both the right of checking in online and the obligation of checking in at the airport (assuming a standard view on rights and obligations).

24 Questions

- Are *Goliath* and *Lumpl* the same individual?
 - ▶ If yes, 'being a statue' is a property instantiated by lumps of clay, but in this case how is it possible to account for the differences?
 - ▶ If not, what makes the difference?
- Are *passenger* just persons?
 - ▶ If yes, what sort of property is 'being a passenger' and how do we solve the previous problems?
 - ▶ If not, what is the difference between *Luc* and *Luc qua passenger*?

25 Principles

- Two entities are distinct if they have different *identity criteria*.
 - But *parsimony* should control the proliferation of entities.
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- ▶ Tension between ‘unifiers’ and ‘multipliers’, between applying Okham’s razor and accounting for subtle phenomena.
 - Solved in a variety of ways by different philosophers.

26 A solution: multiplicativism

Co-location doesn't imply identity.

- Lumpl *constitutes*, but it is different from, Goliath.
 - ▶ Constitution is a factive (asymmetric) relation that does not reduce to parthood or co-location; it just allows the *inheritance* of some properties, i.e. it provides a sort of *unity*.
- Luc qua passenger *inheres in*, but he is different from, Luc.
 - ▶ During its whole existence, a qua-entity inheres in the same *host* (the player of the role passenger in the example).

27 Why multiplicativism?

- *Multiplicativism* seems to imply a stronger ontological commitment.
- *Reductionism* seems more cautious, more parsimonious, more attractive.

28 The traps of reductionism/revisionism

- Is systematic paraphrasing (of complex sentences) really possible?
 - ▶ There are 7 holes in this piece of cheese.
- How to choose whether paraphrasing?
 - ▶ Mary makes a leap.
 - ▶ Mary makes a cake.
- Can we account for proper inferences?
 - ▶ There are two things John gave to Mary: a kiss and a flower.
- Where to stop while eliminating entities, and how much cognitively complex paraphrasing are acceptable?
 - ▶ Should we paraphrase everything in terms of bunches of molecules moving around?

29 Some 'linguistic evidences'

(1/2)

- Multiple co-located events.
 - ▶ John sings while taking a shower.
- Multiple co-located objects.
 - ▶ I am talking here
 - ▶ *This bunch of molecules is talking.
 - ▶ * What's here now is talking.

 - ▶ This statue is looking at me.
 - ▶ *This piece of marble is looking at me.
 - ▶ This statue has a strange nose.
 - ▶ *This piece of marble has a strange nose.

30 Some 'linguistic evidences'

(2/2)

- Individual qualities.
 - ▶ The nurse measured the patient's temperature.
 - ▶ I like the color of this rose.
 - ▶ The color of this rose turned from red to brown in one week.

31 Reductionism and ontological relativity

- To express the reduction of a kind of entities to another kind of entities expressive languages are often needed, e.g. to reduce regions to points, second order is necessary.
- On the other hand, points can be reduced to regions using a second order construction.
- What are the 'real' spatial entities? Points or regions?
 - ▶ In the absence of empirical facts, we cannot answer the question: *Quine's ontological relativity*.
- Let us suppose to have empirical evidences that show that points are just abstractions from regions.
 - ▶ Without a 2ord logic, why not consider both points and regions in the domain of quantification with some links between them?

32 Why not multiplicativism?

- *Quine*: “to be is to be a value of a variable” .
⇒ something exists *iff* it is in the domain of quantification.
- ▶ Does Goliath *really* exist or it is the result of a *conceptual* construction that collects different amounts of clay on the basis of cognitive criteria that can be founded on shape, continuity, etc.?
- ▶ If Goliath is not real, then it cannot be included in the domain of quantification of an ontology, one has just to use paraphrases.

33 Ontology and semantics

- Strictly intertwined: ontology is about *what there is*, semantics is about *referring* to what there is.
- Structural semantics vs. referential semantics.
 - ▶ Referential semantics requires a representation of the world.
 - ▶ Choice of a *descriptive attitude*: language-dependent world for being faithful to linguistic behaviour and or a cognitive conceptualization of reality.
 - ▶ Analyzing the ontological commitment of NL, i.e., doing “natural-language metaphysics” [Bach, 1986]

34 Agnosticism

- In philosophy the *ontological/conceptual* distinction is fundamental.
- In KR, I think that, if *multiplications are well justified* (maybe by expressivity issues), a more agnostic approach, a more relaxed attitude towards the entities in the domain of quantification is possible:
 - ▶ ontologies are not necessary about entities that exist in *reality* but about entities that exist in *realities*, even though these realities are cognitive or conceptual.
- On the other hand, the general (and foundational) point of view of philosophers is a very important input to avoid ad-hoc solutions that are difficult to generalize, re-use, and share.

35 A note on parsimony

- Two different interpretations of parsimony:
 - ▶ the price one “must pay for the elimination of events is the proliferation of logical connectives [or operators] – special, non-truthfunctional connectives [or relations/predicates];
 - ▶ the price eventists must pay is the proliferation of entities in the domain – whence an increase in the number of categories” [Casati&Varvi, 1996].
- This is a trend known in modal logics.

36 Modal logics and ontologies

(1/2)

- What is the ontological commitment of modal logics?
 - ▶ Standard modal logic (possible world).
 - ▶ Epistemic logics (agent, belief, desire, intentions).
 - ▶ Temporal and spatial logics (time, space).
 - ▶ Deontic logics (right, obligation, permission).
 - ▶ Dynamic and action logics (action, state of affair, causation).
- Modal logics too carry ontological assumptions – mostly hidden in the semantics of operators.
- Are they ontologically uncommitted just because they do not have these entities in the domain or is it just a technical question?
 - There are translations of modal logics in FOL theories.

37 Modal logics and ontologies

(2/2)

- No reason for considering modal logics and FOL theories as competing, I think they are just different technical tools.
 - ▶ If one wants to focus on ontology issues, before dealing with reasoning, it is maybe easier and clearer to do it in a FOL framework.
 - ▶ On the other hand, modal logics have better computational behavior and are very effective to express 'recursive applications' of operators, e.g.

$\text{Bel}_i \text{Bel}_j \text{Des}_i \phi$

is very difficult to be expressed in FOL.

38 Working assumptions again

- ★ An ontology is a FOL theory intended to semantically characterize the primitives and the structure of the domain by ruling out as much as possible non-intended models

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and aiming at parsimony about the entities included in the domain even though there is no strong ontological commitment on their existence in reality.

39 The DOLCE ontology

- DOLCE:
a **D**escriptive **O**ntology for **L**inguistic and **C**ognitive **E**ngineering.
 - ▶ Foundational ontology developed in the context of the *Wonder-Web, Ontology Infrastructure for the Semantic Web* – EC project from 2002 to 2004.
 - ▶ Part of a *library* of partially integrated ontologies (no intended to be a standard top-level ontology).
 - ▶ Developed in FOL but some DL approximations exist.
- DOLCE-CORE:
 - ▶ A recent (2009) update of the core fragment (the most general categories) of DOLCE.
 - During the course we will see the main differences wrt DOLCE.

40 General assumptions of DOLCE

- Cognitive bias: descriptive (as opposite to prescriptive) attitude.
- Emphasis on cognitive invariants.
- Categories as conceptual containers: no 'deep' metaphysical implications.
- Clear branching points to allow easy comparison with different ontological options.
- Rich axiomatization.

41 Basic taxonomy of DOLCE

Endurant (Object)

Physical

Amount of matter

Physical object

Feature

Non-Physical

Mental object

Social object

Quality

Physical Quality

Spatial Location

...

Temporal Quality

Temporal Location

...

Abstract Quality

Perdurant (Event)

Static

State

Process

Dynamic

Achievement

Accomplishment

Abstract

Quality Region (Region)

Time Region

Space Region

Color Region

...

42 Primitives of DOLCE

- *Parthood simpliciter*: $P(x, y)$ – “ x is part of y ”.
- *Temporary parthood*: $tP(x, y, t)$ – “ x is part of y at time t ”.
- *Constitution*: $K(x, y, t)$ – “ x constitutes y at time t ”.
- *Participation*: $PC(x, y, t)$ – “object x participates in event y at t ”.
- *Quality*: $qt(x, y)$ – “individual quality x inheres in y ”.
- *Quale*: $qt(x, y, t)$ – “region x is the quale of individual quality y at t ”.

43 Documentation about DOLCE

- The whole documentation about DOLCE as well as its approximations and translations in KIF and OWL are available at
<http://www.loa-cnr.it/DOLCE.html>.
- The reference paper about DOLCE (and WonderWeb library) is:
WonderWeb Deliverable D18: Ontology Library (final)
Masolo, C., Borgo, S., Gangemi, A., Guarino, N., Oltramari, A.
<http://www.loa-cnr.it/Papers/D18.pdf>
- The reference paper about DOLCE-CORE is:
Ontological Foundations of DOLCE
Borgo, S., Masolo, C.
In Staab, S., Studer, R. (eds.), *Handbook on Ontologies* (Second Edition), Springer Verlag, 2009, p. 361-382.

44 Other papers I will refer to during the course

- “Social Roles and their Descriptions” is main reference about the extension of DOLCE with the *reification of properties and roles*.
<http://www.loa-cnr.it/Papers/KR04MasoloC.pdf>
- “Founding Properties on Measurement” gives an empirical foundation to the theory of qualities of DOLCE.
<http://www.loa-cnr.it/Papers/fois2010qualV0.5.pdf>
- “Understanding Ontological Levels” develops a theory of levels that abstract from *constitution*, *inherence*, and *abstraction*.
<http://www.loa-cnr.it/Papers/fois2010qualV0.5.pdf>
- “Parthood Simpliciter vs. Temporary Parthood” compares the 3d and 4d theories of persistence through time.
<http://www.loa-cnr.it/Papers/commsense09v0.3.pdf>