DOLCE: An Upper-level Ontology

DOLCE (Descriptive Ontology for Linguistic and Cognitive Engineering)

A proposed foundational ontology, whose purpose is to negotiate meaning to enable cooperation, and to establish a consensus.

This ontology has a cognitive bias, and aims to capture ontological categories underlying natural language and commonsense.

Aims to make the rationale behind ontological modelling decisions explicit - has been used to analyse WordNet to identify conceptual errors.

Categories are descriptive notions, not attempts to capture the intrinsic nature of the world. Descriptions may be dependent on perception, cultural factors and social conventions.

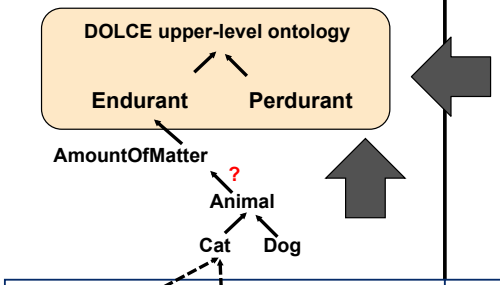
References:

Gangemi, A., Guarino, N., Masolo, C., Oltramari, A., and Schneider, L. (2002) *Sweetening ontologies with DOLCE.*

Guarino, N. and Welty, C. *An overview of OntoClean.*

DOLCE

- Particulars are instances
  - organized into categories
- Universals organize categories of particulars
  - meta-properties of unary predicates [Concepts]



essence
identity
unity
dependence

} provide guidelines for building taxonomies, and rules for checking taxonomies

Instances: cat#1 cat#2 [particulars] Assertions: cat(cat#1) owner(cat#1,person#1)	Taxonomy: animal(x) => amountOfMatter(x) [equivalently: Animal ⊑ AmountOfMatter]

Top-Level Classes

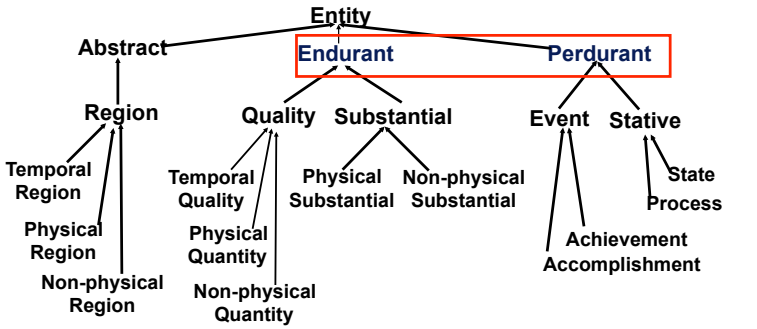
Endurants and perdurants

- Endurants (also referred to as continuants)
  - Are wholly present at any time at which they exist
  - Can change in time
  - E.g. physical objects
- Perdurants (or occurrents, occurrence)
  - Are extended in time
  - Only partially present at any time at which they exist
  - E.g. events and processes
- are related by participation:
  - An endurant 'lives' by participating in a perdurant, e.g. a person participates in a discussion, a violinist performs in a concert

Top-Level Classes

- Endurants (objects) and perdurants (events) may have constituent parts:
  - Hairs on your head
  - Chorus of a song
- Endurants (objects) may survive the loss and/or replacement of parts
  - i.e. they retain their identity
- Or, objects may just be 'the sum of their parts'
- Parts cannot be removed from perdurants (events) once the event has happened
  - Perdurants do not have temporal parts
- Connectedness: once a whole object has been delimited, we can consider connections
- Mereology and topology => next lecture

Top-Level Classes in DOLCE



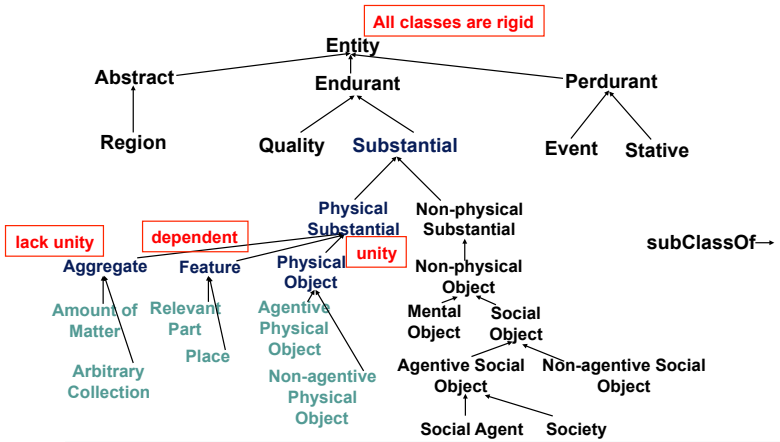
Endurant: part-of(part, whole, time)
Abstract and Perdurant: part-of(part, whole)

subClassOf ⟶

Top-Level Classes in DOLCE

- DOLCE is a top-level ontology of particulars
  - the design respects several evaluation criteria (metaproperties)
- Criteria
  - Essence (Rigidity)
    - » Properties may be essential to all instances, or only to some, e.g. being a student is not essential in this sense, but being a human is.
  - Unity
    - » Objects have unity as their parts can be recognised
    - » Amounts of matter have no unity
  - Identity
    - » How can an instance of a class be recognised, e.g. over time ?
  - Dependence
    - » Entities that are dependent for their existence on another entity, e.g. Parent - Child

Top-Level Classes in DOLCE



Top-Level Classes in DOLCE

- Physical Substantial - entities with spatial qualities
  - Physical object: has unity (may be agentive)
    - » Agentive physical object: a person
    - » Non-agentive physical object: a computer, a house
  - Aggregate: lack unity
    - » Amount of matter: some air, some gold, some cement
    - » Arbitrary collection: my foot+my car
  - Feature: are dependent on other entities for their existence (these are parasitic entities)
    - » Place: a hole, an opening
    - » Relevant part: a bump, an edge, a wart

Top-Level Classes in DOLCE

- **Objects**: are endurants with unity, different types of object have different unity criteria. Objects can change their parts over time (they can have temporary parts). Objects do not depend on other objects for their existence.
- **Aggregates**: are endurants with no unity, i.e. they change their identity when a part is removed, e.g. from a lump of cement.
  - Unity is a property that uniquely identifies the parts of an instance
- **Agentive**: objects with intentionality are Agentive (people), otherwise they are Non-agentive (house, car).
- **Non-physical objects**: are Mental or Social according to whether they are individual (e.g. an idea) or social - a social agent is the PM of UK, a law is social but non-agentive.

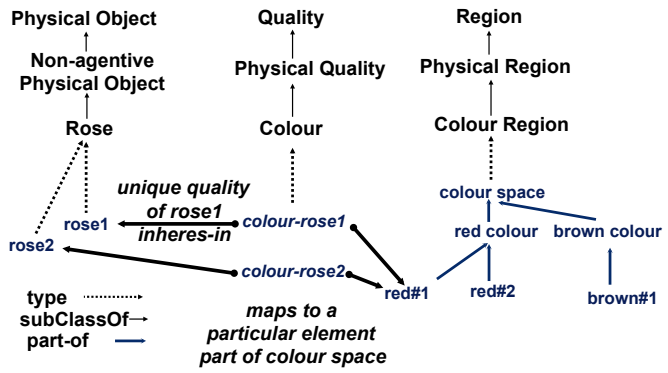
Top-Level Classes in DOLCE

Qualities and quality regions

- **Qualities are the entities we perceive or measure - shape, sound, smell, colour, mass, length, charge**
  - **These are endurants too**
  - **Quality types: colour, size *inhere in* specific individuals**
  - **All individuals have a unique quality**
  - **All qualities are specifically constantly dependent on the entity they inhere to**

Top-Level Classes in DOLCE

- **Qualities and quality regions**



Top-Level Classes in DOLCE

Thing <=inheres-in= Colour (Quality Type)
=value=> Colour Region (Region)

- **Compare with the previous approach:**
  hasColour <Thing> <ColourAttributeValue>
  ColourAttributeValue = {red,green,blue}
  BlueThings ≡ ∃hasColour.{blue}
  BlueOnlyThings ≡ ∀hasColour.{blue}

Analysing taxonomies

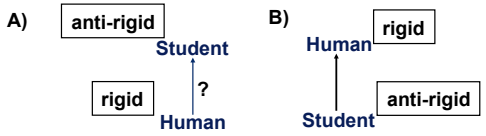
- The DOLCE top-level ontology distinguishes classes on the basis of 'metaproperties'
- A property is *essential* to an entity if it must be true of it in every possible world
  - Rigid properties are essential to all instances of a class, e.g. a human must have a brain.
  - Non-rigid properties can be acquired or lost, they are essential to some instances, e.g. some apples are always red, but being red is not essential for all apples
  - Anti-rigid properties are never essential, e.g. being a student, as any student can cease to be so
- A class C *carries* an essential property Q (different from property C) if and only if Q is essential to all instances of C, and Q is not rigid

  Every person must have a brain.

  In contrast: Every person must be a mammal.

Analysing taxonomies

- These properties are used to analyse the subclass relation
  - Anti-rigid properties cannot subsume rigid properties
  - Can Student subsume Human ?
  - On the assumption that *being-a-student* is anti-rigid: If all humans are students as in (A), and humans cannot cease to be humans, then human students cannot cease to be students, creating an inconsistency with the assumption



Analysing taxonomies

Unity and Identity

- Unity is the problem of identifying the parts of an individual entity
  - "Is the collar part of my dog?"
  - for classes whose instances are 'wholes' of some kind, there may be a unifying relation that determines the kinds of wholes (a morphological whole, e.g. a constellation, a functional whole, e.g. a car engine).
- Identity is the problem of recognizing individual entities
  - "Is that my dog?" [not: "Is that a dog?"]

    sameFingerprint is an identity criterion for the class human:

    (human(x) ∧ human(y) ⇒

    (sameFingerprint(x,y) ⇔ x=y))

Analysing taxonomies

- Identity: should TimeDuration (1hr, 2hr) subsume TimeInterval (1-2pm 1 January, 2-3pm 1 January 11)?
  - All TimeDurations of 1 hour are the same - the duration supplies identity
  - If TimeIntervals are compared according to their duration, 1-2pm 1 Jan. and 2-3pm 1 Jan. would be judged identical as both last 1hr.
  - However, identity for TimeInterval requires the instances to have the same start and end times, so 1-2pm 1 Jan. and 2-3pm 1 Jan. are not the same
  - There are 2 instances of TimeInterval and one of TimeDuration - giving an inconsistency

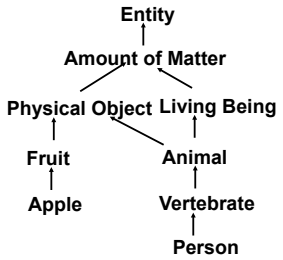
Analysing taxonomies

1. Classes in the ontology are analysed for the metaproperties, then
2. Metaproperties are checked for consistency.

- Rigidity - classes assigned anti-rigid (~R) cannot subsume rigid(+R)
  - +R :all instances of the class have an essential property
  - -R :some instance of the class has an essential property
  - ~R :class membership is never essential to any instance
- Identity - identity criteria are inherited and must be consistent
  - +O :classes that *supply* an identity criterion
    some unique identity criterion (or essential property) exists
  - +I :classes that *carry* an identity criterion
    not supplying identity, while being subsumed by a property that does.
- Unity - classes assigned anti-unity (~U) cannot subsume unity (+U)
  - +U :all instances have a common unifying criterion (e.g. an Ocean, as it is possible to tell what is and is not part of the Atlantic, Pacific etc)
  - -U :no common unity criterion (a Legal Agent class that includes people and companies, each having different unity criterion)
  - ~U :no unifying criterion, wholes cannot be recognized (e.g. an amount of water - amount of water can be scattered and mixed arbitrarily).

Analysing taxonomies

Initial taxonomy



Analysing taxonomies: Essence/Rigidity

Rigidity criteria: essential in all possible worlds?
+R :all instances of the class have an essential property
-R :some instance of the class has an essential property
~R :class membership is never essential to any instance

Entity: the class of everything

Amount of Matter: a particular clump of structured or scattered stuff, e.g. water, clay, defined by their parts (mereologically extensional)

Living Being: a whole organism, e.g. human, tree, virus.
These are necessarily living beings, ceasing to exist otherwise.

Animal: living organism, subclass of Living Being, e.g. human, spider.

Vertebrate: subclass of Animal, those with a backbone, e.g. human, dog.

Person: a human, subclass of vertebrate

Physical Object: isolated material entities. Topological wholes, i.e. the parts are connected so as to make up a recognisable whole.

Fruit

Apple

All these classes are +R

Analysing taxonomies: Identity

Identity criteria: how are instances recognized?
+I :classes that ***carry*** an identity criterion, else -I
+O :classes that ***supply*** an identity criterion

Entity: the class of everything -I

Vertebrate: +I adds the membership criteria *has-backbone to animal (a property that carries an identity criterion)*

Amount of Matter: +O supply own identity

Living Being: +O instances have some identity criterion, e.g. having the same DNA

Animal: +O (as for Living Being)

Person: +O (as for Living Being)

Physical Object: +O no two objects can be in the same place at the same time, therefore some identity criterion exists

Fruit: +O (as Physical Object)

Apple: +O (as Physical Object)

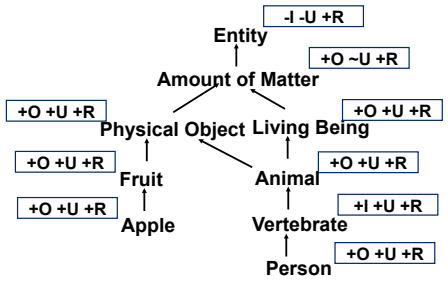
Analysing taxonomies: Unity

Unity criteria: recognizing the parts of an entity
+U :all instances have a common unifying criterion
-U :no common unity criterion
~U :no unifying criterion

Entity: **-U the class of everything**
Amount of Matter: **~U not necessarily wholes**
Living Being: **+U necessarily biological wholes**
Animal: **+U (as Living Being)**
Vertebrate: **+U (as Living Being)**
Person: **+U (as Living Being)**
Physical Object: **+U objects are topological wholes, i.e. physically distinct from other entities**
Fruit: **+U (as Physical Object)**
Apple: **+U (as Physical Object)**

Analysing taxonomies

Taxonomy with metaproperties

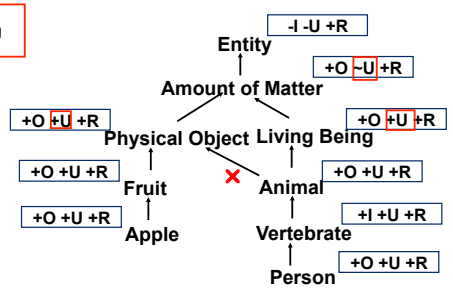


Analysing taxonomies

Taxonomy with metaproperties – check rules and criteria

~U cannot subsume +U

~R cannot subsume +R (satisfied)

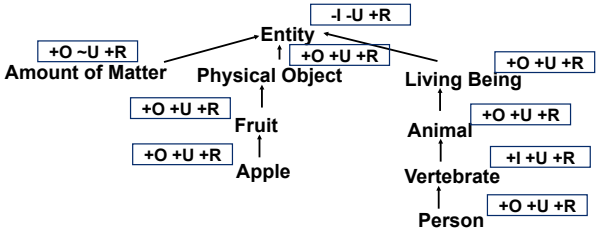


× **Identity criteria do not match.**
Animals have the essential property of being alive, but a Physical Object would be the same alive or not.

Analysing taxonomies

Cleaned taxonomy with consistent metaproperties

- **Amount of Matter no longer subsumes Physical Object or Living Being**

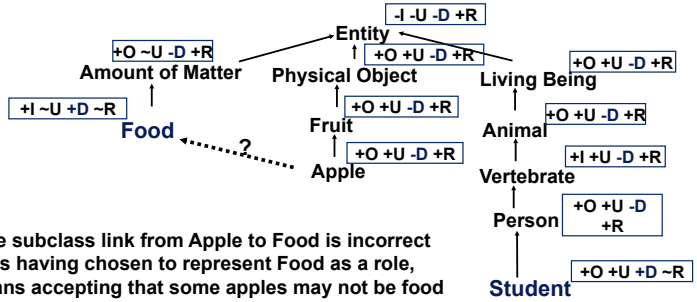


Now add non-rigid properties: roles and dependent entities

Analysing taxonomies

Roles: choose to add the term **Food** as a Role - meaning that nothing is necessarily food, but can take that role in some state.

Add the analysis of dependency **D**

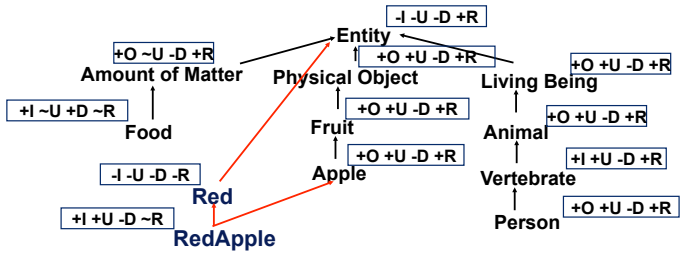


The subclass link from Apple to Food is incorrect as having chosen to represent Food as a role, means accepting that some apples may not be food (i.e. not eaten) in some state. (But clearly, some instances of Apple may be Food.)

Analysing taxonomies

Attribution: Add the terms **Red** and **RedApple**

(Note, this is a very simple solution to representing attributes, see the earlier slide.)



The term Red contributes little to the ontology.

Subclass links from RedApple and Red are not considered part of the backbone of the ontology.

Analysing taxonomies

- Once the metaproperties are assigned (manually) the conflict detection can be done automatically.
  - All of the analysis is conditional on the assignment of metaproperties
  - May not be straightforward
- Restructuring the ontology needs manual input.
- This method has been used to review ontologies and linguistic resources such as WordNet
- Addresses conceptual modelling issues, i.e. it examines the meaning of classes
  - Should A be a subclass of B?
  - If B is a role, can A be a subclass of it?

Analysing taxonomies

- Dolce has been applied to integrating geological ontologies
  - Q. Can foundational ontologies such as Dolce provide a coherent and complete conceptual basis for integrating existing ontologies?

Brodaric and Probst:

Enabling Cross-Disciplinary E-Science by Integrating Geoscience Ontologies with Dolce

http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=04763657

DOLCE ROCKS: Integrating Geoscience Ontologies with DOLCE

http://www.aaai.org/Papers/Symposia/Spring/2008/SS-08-05/SS08-05-002.pdf

Analysing taxonomies

- An existing XML schema (GeoSciML) and an ontology (SWEET) were aligned to Dolce [in OWL-DL]
  - Both are widely used in geoscience
  - The original sources were not altered in structure
  - A manual mapping of classes and relations, together with their informal definitions was performed

    EarthMaterial[GeoSciML] —subClassOf→ AmountOfMatter[Dolce]

    Substance[SWEET] == AmountOfMatter[Dolce]

    MarineAnimal[SWEET] → PhysicalObject[Dolce]

    SeaFloor[SWEET] → Feature[Dolce]
  - SWEET and GeoSciML could then be aligned, maximising reusability but leaving semantic differences unresolved

Next Lecture

- Parts and Wholes
  - An analysis of part-whole relations informed by natural language usage: English speakers use of ‘part of’ and phrases of similar meaning
  - The formal ontology view of part-of and connected-to: mereology and topology