

# Objects and their qualities

How DOLCE(-CORE) manages properties

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# 1 Ontological analysis

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

## 2 Ontology **O**ntology **o**ntology

- **O**ntology ~ realism, *the* theory of reality;
- **o**ntology ~ develop *arbitrary* models (often simple taxonomies).
- **O**ntology ~ develop a set of well founded ontologies avoiding both a *monolithic approach* and *arbitrary models*.
  - ▶ Multi-disciplinary approach to *foundational* notions.
  - ▶ No *standard* **O**ntology, rather, an integrated *library* of **O**ntologies (that reflects different commitments):
    - starting point to build new ontologies;
    - reference point to compare and integrate ontological choices;
    - framework for analyzing, harmonizing and integrating existing ontologies and metadata standards.

### 3 DOLCE

- **D**escriptive **O**ntology for **L**inguistic and **C**ognitive **E**ngineering.
  - ▶ Developed in the context of the *WonderWeb, Ontology Infrastructure for the Semantic Web* – EC project from 2002 to 2004.
  - ▶ No intended to be a standard top-level ontology: it is part of a *library* of (partially) integrated ontologies (that includes BFO).
  - ▶ *Cognitive bias*: descriptive (vs. prescriptive) attitude, categories as conceptual containers: no ‘deep’ metaphysical implications.
  - ▶ Branching points to individuate ontological options.
  - ▶ Axiomatized in FOL, DL approximations exist.
- DOLCE-CORE (2009): update of the core fragment of DOLCE.

## 4 Basic taxonomy of DOLCE

### Endurant (Object)

- Physical
  - Amount of matter
  - Physical object
- Feature
- Non-Physical
  - Mental object
  - Social object
- Arbitrary Sum

### [Individual] Quality

- Physical Quality
  - Spatial Location
  - ...
- Temporal Quality
  - Temporal Location
  - ...
- Abstract Quality

### Perdurant (Event)

- Stative
  - State
  - Process
- Event
  - Achievement
  - Accomplishment

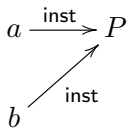
### Abstract

- Region
  - Time Region
  - Space Region
  - Color Region
  - ...

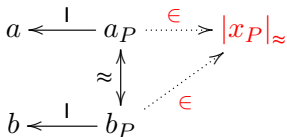
## 5 Main philosophical theories of properties

- *One over Many*: how  $a$  and  $b$  can share the property  $P$ ?

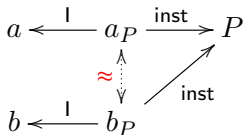
**Universalism**



**Trope Theory**

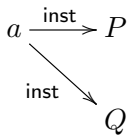


**Universals+Tropes**

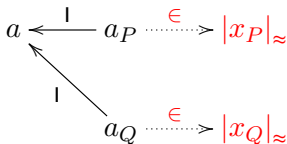


- *Many over One*: how  $a$  can have two different properties  $P$  and  $Q$ ?

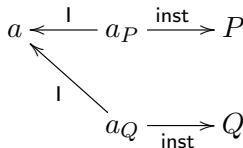
**Universalism**



**Trope Theory**



**Universals+Tropes**

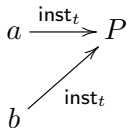


## 6 Properties and (change in) time

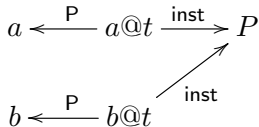
(1/2)

- “ $a$  has  $P$  at  $t$ ” and “ $b$  has  $P$  at  $t$ ”.

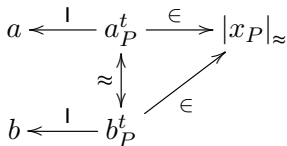
### Universalism



### Universals+Perdurantism



### Trope Theory

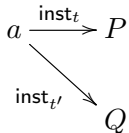


## 7 Properties and (change in) time

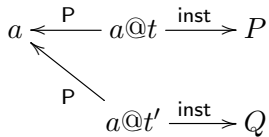
(2/2)

- “ $a$  has  $P$  at  $t$ ” and “ $a$  has  $Q$  at  $t'$ ”.

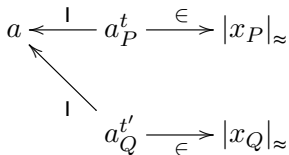
### Universalism



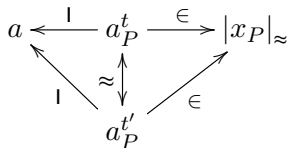
### Universals+Perdurantism



### Trope Theory



$a$  has  $P$  at both  $t, t'$  if  $t + t'$  is not convex





## 8 Representing properties and change in FOL (1/2)

- “ $a$  has the property  $P$  when  $t$  is (was, will be) present”

|1a|  $P(a, t)$

- + very simple and standard in FOL;
- extensionality | boolean combination of properties.

|2a|  $\text{inst}(a, p, t)$

- + intensionality | no boolean combination of properties;
- properties in the domain |  $\text{inst}$  to be managed.

|1b|  $P(a@t)$

- + temporal qualification not necessary;
- extensionality | existence of temporal slices | mereology.

|2b|  $\text{inst}(a@t, p)$

- + temporal qualification not necessary;
- existence of temporal slices | mereology.

## 9 Representing properties and change in FOL (2/2)

|3a|  $\exists a_P (I(a_P, a) \wedge P(a_P) \wedge \text{exists}(a_P, t))$

+ only **exists** temporally qualified;

– tropes in the domain | inheritance **I** to be managed

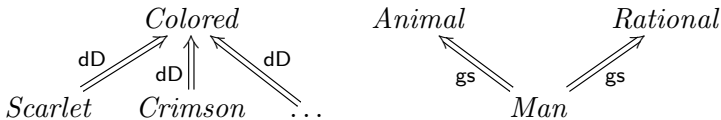
–  $\approx$  to be managed ( $P$  collects all the  $\approx$ -equivalent tropes)

■ Tropes do not change. Change is reduced to *trope substitution*.

## 10 Properties in DOLCE-CORE

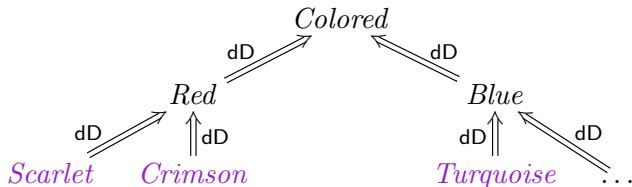
- **Predicates (1a)**. Adequate to model the *basic elements* of the user's conceptualization and the categories/primitive relations of DOLCE. The formalization of properties as extensional predicates is straightforward and requires no special formalism.
- **Concepts (2a) (new)**. Concepts are properties *reified* in the domain to consider the intensional, contextual, or dynamic aspects (roles). An instantiation relation called *classification* (CF) is added.
- **Qualities and quality spaces ~ (3a) (modified)**. In addition to the intensional, contextual, and dynamic aspects of concepts, properties are *clustered* and *structured* (relations btw properties) in spaces according to specific points of view, instruments, etc.

## 11 Taxonomies: determinate-determinable (dD)



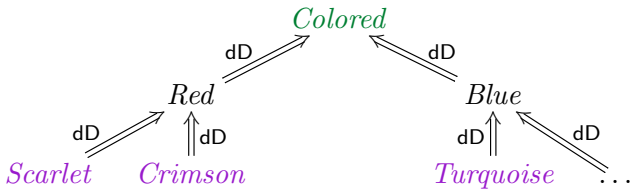
- Having a *determinate* property entails having a *determinable* property, e.g. *Scarlet* implies *Colored*.
- Having a *determinable* property entails having *one and only one* of its (full) *determinates*: no instances of both *Scarlet* and *Crimson*.
- Determinates under the same determinable are different but *comparable / similar*.
- To understand *Colored*, one needs *Scarlet*, *Crimson*, ... while for *Man* one needs *Animal* and *Rational* (genus-species) [bottom-up vs. top-down | abstraction vs. specialization]

## 12 Full determinates



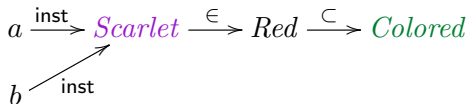
- *Full determinates* are the leaves of the dD hierarchy.
- The instances of a full color-determinate (a *color-shade*), e.g., *Scarlet*, are all the same with respect to color.
- Shades are colors, but not all colors are shades, since some colors consist of collections of shades ordered by some relation that is included in our grasp of the color (e.g. *Red* and *Blue*).

## 13 General determinables



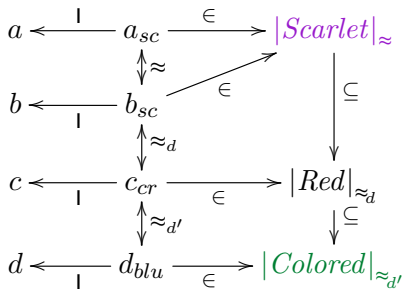
- *Incompatibility* of full determinates: having a *determinable* entails having *one and only one* of its full *determinates*.
- *Comparability*: instances of different full determinates under the same *general determinable* are (at least qualitatively) comparable.
- General determinables are maximal with respect to *comparability*: e.g. scarlet instances are more similar to crimson than to turquoise ones, but are scarlet instances more similar to 1kg than to 1m ones?

## 14 Universalism and determinables



- Full determinates correspond to universals.
- Determinables correspond to *sets* of full determinates (are they *conceptual* constructions?).
- *General* determinables collect universals that satisfy unity conditions that require additional relations:
  - ▶ resemblance/comparability (with degrees) btw universals [Church];
  - ▶ partial identity (defined on parthood) btw universals (comparability can be defined) [Armstrong].

## 15 Trope theory and determinables



- *Full determinates* correspond to classes of *exactly* resembling tropes.
- *Determinables* correspond to classes of *inexactly* (at some degree) resembling tropes.
- *General determinables* corresponds to *maximal* classes of inexactly resembling tropes.



## 16 From an empirical point of view

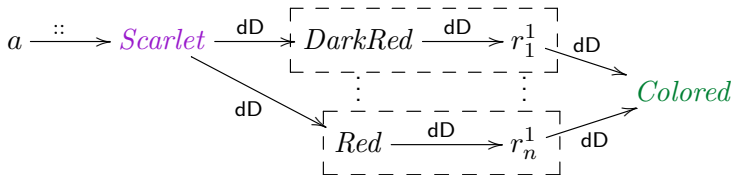
- From *ontological* full det./general det. to empirical ones:
  - ▶ abstraction from full determinates to determinables;
  - ▶ different viewpoints with different full determinates/determinables;
  - ▶ full determinates/determinables differently structured.
- *Similarity*: empirically built on experiments and it may depend on species, cultures, . . . : “judgments of similarity reveal the dimensions of our perceptions and their structures.” [Gärdenfors, 2000]
- In *science*, the analysis always is conducted at an empirical (or theoretical) level and it depends on the available information, the measurement instruments/methods, the specific theory considered, etc.

## 17 Spaces of properties

- To a general determinate can be associated more spaces that depend on culture, instruments of investigation, etc. and that have (possibly different) topological or geometrical structures.
- Spaces and concepts may have an *inter-subjective* (vs. objective) nature: they can be the product of (more or less explicit) *social conventions* or the result of some (evolutionary) *cognitive processes* typical of a kind of agents.
- Spaces and concepts may exist *in time*: they can be created, adopted, and destroyed by (communities of) intentional agents.

## 18 Spaces with the same full determinates

- Full determinates are 'objective' but they can be *contextually* organized in different spaces.

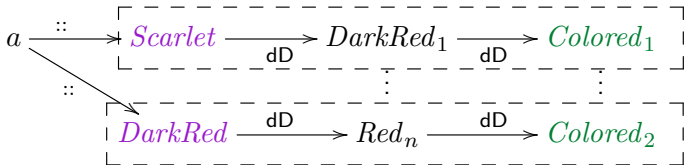


where  $::$  stands for *inst* in Universalism or for a composition of  $I$  and  $\in$  in Trope theory.

- To the same general determinate, different spaces with different (non fully) determinates can be associated, e.g. *DarkRed* is not considered in the first space.

## 19 Spaces with different full determinates

- Both full determinates and structures of spaces are *contextual*.



- If we assume that for each general determinable there is a space  $S^*$  with maximal granularity (as defined by, say, a *refinement relation*), then the atomic regions of  $S^*$  can be taken to be the the 'objective' full determinates.
- To individuate all the spaces relative to the same domain or dimension (general determinable) an additional relation is necessary.

## 20 DOLCE individual qualities

- DOLCE represents the specific aspect along with individuals are compared by introducing the *(individual) qualities*.
- We will analyze the differences between DOLCE (individual) qualities and tropes. For the moment, just note that:
  - ▶  $\sim$  to tropes, they inhere in a specific object: the 'weight of John' is different from the 'weight of Sam';
  - ▶  $\neq$  from tropes, they correspond to global determinables, not to full determinates: an individual quality (e.g. 'weight of John') can be associated to different full determinates at different times.
- The inherence relation is called *quality* (qt) in DOLCE.

## 21 DOLCE quality kinds and spaces

(1/2)

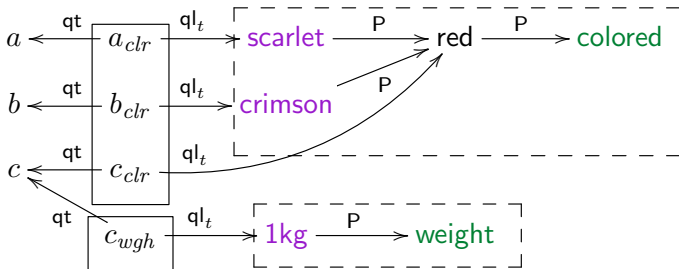
- The different dimensions of comparison are presented by  $n$  disjoint predicates  $Q_i$ , called *quality kinds*, e.g.  $Q_{color}$ ,  $Q_{weight}$ .
- Both determinables and full-determinates are represented by (*spatial*) *regions* that are in the domain of quantification.
- The *instantiation* relation is represented by the composition of
  - ▶ *quality*,  $qt(x, y)$  stands for “ $x$  is an individual quality inherent in the object  $y$ ”, and
  - ▶ *quale*,  $ql(x, y, t)$  stands for “ $x$  is the region of the individual quality  $y$  during time  $t$ ”.

## 22 DOLCE quality kinds and spaces

(2/2)

- dD is represented by *parthood simpliciter*,  $P$ , e.g.  $P(\text{crimson}, \text{red})$  and  $P(\text{red}, \text{color})$  (a *classical extensional mereology* is assumed):
  - ▶ full determinates correspond to *atomic regions* (called *qualia*);
  - ▶ general determinables correspond to *spaces*;
  - ▶ a quality kind is associated to a single space, i.e.  $ql$  is a function and spaces are regions  $x$  maximal with respect to the property:  
$$P(r, x) \wedge P(r', x) \wedge ql(r, q, t) \wedge ql(r', q', t') \wedge Q_i(q) \rightarrow Q_i(q');$$
  - ▶ structural constraints can be introduced among regions;
  - ▶ correspondence btw mereological operators and logical ones.
- Differently from the *conceptual spaces* of Gärdenfors, in DOLCE, properties do not need to correspond to self-connected regions.

## 23 General schema in DOLCE



$$\text{inst}(x, r, t) \triangleq \exists qr' (\text{qt}(q, x) \wedge \text{ql}(r', q, t) \wedge \text{P}(r', r))$$

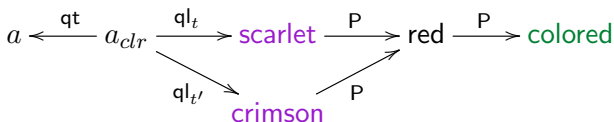
e.g.  $\text{inst}(a_{crl}, \text{scarlet}, t)$ ,  $\text{inst}(a_{crl}, \text{red}, t)$ ,  $\text{inst}(c_{crl}, \text{red}, t)$

$$\text{Color}(x, r, t) \triangleq \exists qr' (\text{qt}(q, x) \wedge \text{ql}(r', q, t) \wedge \text{P}(r', r) \wedge Q_{\text{color}}(q))$$

$$\text{Color}(x, r, t) \triangleq \text{inst}(x, r, t) \wedge \text{P}(r, \text{colored})$$



## 24 Tropes vs. individual qualities

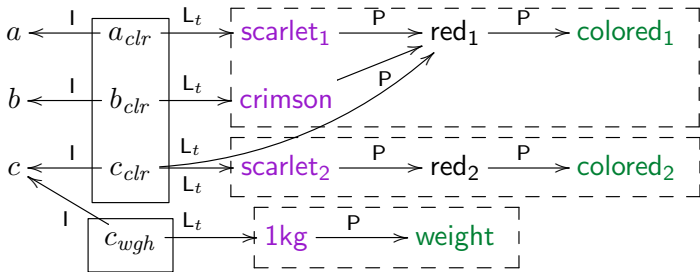


- Color-qualities persist through the change in color of the objects they inhere in, thus they can change location in the color-space(s).
- Individual qualities can be seen as the mereological sums of tropes of a given dimension that inhere in the same object, i.e. the Trope Theory can be seen as a perdurantist specialization of the theory based on individual qualities.
- DOLCE does not commit on temporal slices of objects and qualities, in this sense it can be seen as more general than pure 4d-ontologies.

## 25 DOLCE-CORE individual kinds and spaces

- More standard terminology:
  - ▶ *inherence* (I) instead of *quale* (ql);
  - ▶ *location* (L) instead of *quality* (qt).
- Cognitive/empirical bias: DOLCE-CORE modifies DOLCE to allow to associate different spaces to one quality kind  $Q_i$ .
- Different spaces correspond to different viewpoints or conventions, thus they are disjoint even when associated to the same dimension.
  - ▶ A finite set of disjoint primitive predicates  $S_1^i, \dots, S_n^i$ , corresponding to different spaces, is associated to each quality kind  $Q_i$ :  
$$S_j^i(x) \wedge P(r, x) \wedge L(r, q, t) \rightarrow Q_i(q).$$

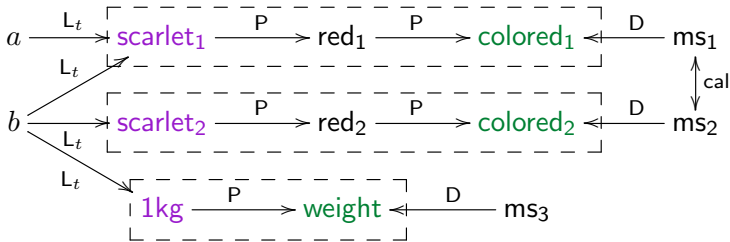
## 26 General schema in DOLCE-CORE



- Individual qualities located in different spaces of the same kind.
- Regions in different spaces can be *extensionally* compared (e.g. refinement) considering the individual qualities located in them.
- If an unique maximal refined space exists, its atoms can be seen as an empirical surrogate for objective properties.

## 27 Towards an empirical approach: measurement

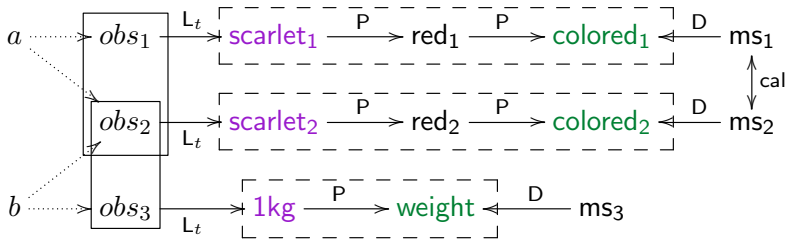
- Central role to *measurement system* (instrument, reference system, and calibration process) individual qualities are superfluous: objects are directly located in spaces.
- Measurement instruments and calibration necessary to identify spaces linked to the same dimension and to compare measures.



- *Communicability & inter-subjectivity* vs. objectivity of 'properties'.

## 28 Towards an empirical approach: data

- An *observation* is intended as a 'description' of a *datum* collected by a measurement system.
- Objects are patterns of observations.



## 29 Other DOLCE-CORE modifications

- $\text{PRE}(x, t)$ : “ $x$  is present at time  $t$ ” is now primitive.
- Parthood simpliciter is now defined on all the entities, however the existence of the mereological sums is no more guaranteed.
- Temporary parthood is now defined on all the entities that are present in time. For these entities, parthood simpliciter can be defined as *constant* temporary parthood.
- The distinction between objects and events rely now on the quality kinds that are directly (vs. indirectly, i.e. through participation) connected to them. Events are ‘primarily in time’ (they have direct temporal qualities) while objects are ‘primarily in space’ (they have direct spatial qualities).

## 30 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.istc.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.istc.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.

## 31 Other useful papers

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



## 32 *Digression*: full determinates vs. values

- What is the ontological nature of values?
  1. Can the same value be used for different attributes? For example, can '1m' be used for *height* and *length*?
  2. Do '1m' and '100cm' refer to two different values?
- Full determinates are specific properties, therefore 'being 1m high' and 'being 1m long' are just two different properties.
- The same full determinate can be 'measured' in different ways: 'being 1m high' and 'being 100cm high' refer to the same property but to different *measurement systems*.
- 'm' and 'cm' can refer to different granularities or measurement's precisions.

### 33 *Digression*: naïve linguistic evidences

- Individual qualities allow also for a more 'direct' semantics of some NL expressions.
  - This rose is red.
  - Red is a color.
  - This rose has a color.
  - The color of this rose turned to brown in one week.
  - Red is opposite to green and close to brown.
  - The patients temperature is increasing.
  - The doctor measured the patient's temperature.

## 34 *Digression*: International System of Units

- A similar approach is adopted by the SI, where:
  - ▶ quantities in the *particular* sense correspond to individual qualities;
  - ▶ quantities in the *general* sense correspond to general determinables.