Laboratory for Applied Ontology
Institute of Cognitive Science and Technology
Italian National Research Council

Conceptual Modeling, Ontology Design, and Semantic Interoperability
Lecture 8, part II

Professional Master in Technologies for E-Government

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Outline of the lecture

- The “space” of ontological choices

- We will use the foundational ontology DOLCE as driving example

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- Space and Location

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- Space and Location
- Co-localization
- Constitution
- A hint to Qualities

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Formal Ontology as a Space of Choices

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- Are they atomic or atomless?
- Which geometry do they satisfy?

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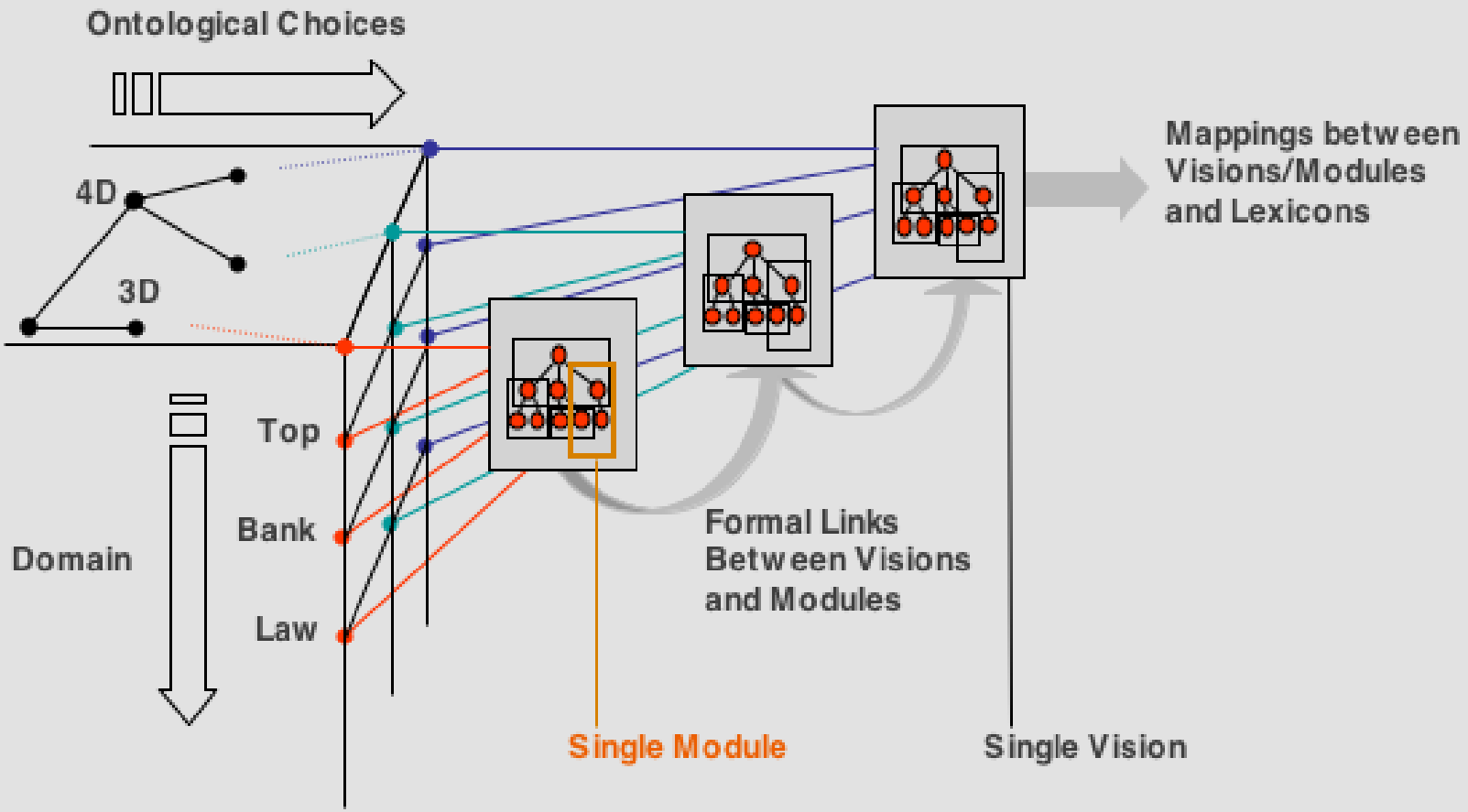
- Are entities spatio-temporal worms going through different phases? are they three-dimensional entities instantiating different properties at different times?

Space of Ontological Choices (3)

Two dimensions:

- *visions*, corresponding to basic ontological choices;
- *specificity*, corresponding to the domains



One Example: DOLCE's main assumptions

DOLCE (a Descriptive Ontology for Linguistic and Cognitive Engineering) is the first module of a foundational ontologies library

- Cognitive bias (vs. revisionary approach): DOLCE does not commit to a strictly realistic metaphysics: the categories introduced are cognitive boxes ultimately depending on human perception, cultural imprints, and social conventions (the deep background - Searle 1983, "Intentionality").
- Ontology of particulars (vs. of universals): particulars are entities which cannot have instances; of course, universals do appear in this ontology, insofar they are used to organize and characterize particulars, but they are not included in the domain.

One Example: DOLCE's main assumptions (2)

- Multiplicative approach (vs. reductionist approach): different entities can be co-located in the space-time, since DOLCE can ascribe to them incompatible essential properties. Reducible categories (points/regions) are treated similarly.

On Location

Structures of space

Spaces without points

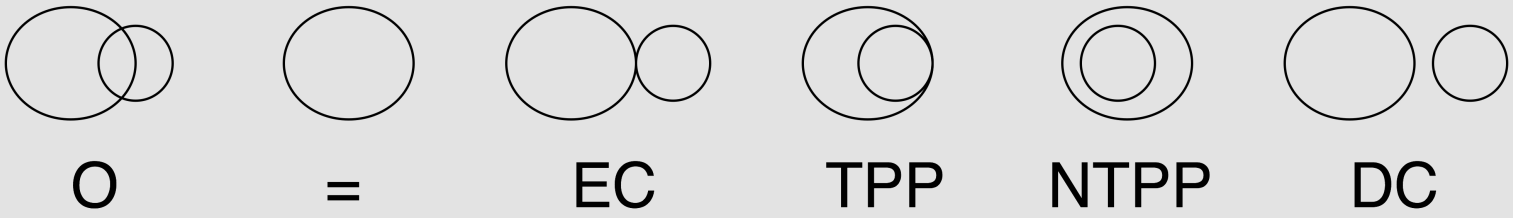
- Space of regions, i.e., extended primitive entities
- Modern accounts based on mereology
- First step: adding topological concepts, “mereotopology”
- Primitive relation of “connection” (Whitehead)
  intended semantics: at least a *point* in common
  what happens at the boundaries is taken into account

Basic Mereotopology

- Mereology
  - P1 $P(x, x)$
  - P2 $(P(x, y) \wedge P(y, x)) \rightarrow x = y$
  - P3 $(P(x, y) \wedge P(y, z)) \rightarrow P(x, z)$
- Connection
  - C1 $C(x, x)$
  - C2 $C(x, y) \rightarrow C(y, x)$
  - C3 $P(x, y) \rightarrow \forall z\,(C(z, x) \rightarrow C(z, y))$
- Strong basic mereotopology
  - C4 $\forall z\,(C(z, x) \rightarrow C(z, y)) \rightarrow P(x, y)$
  - $P(x, y) =_d \forall z\,(C(z, x) \rightarrow C(z, y))$

Eight possible relations

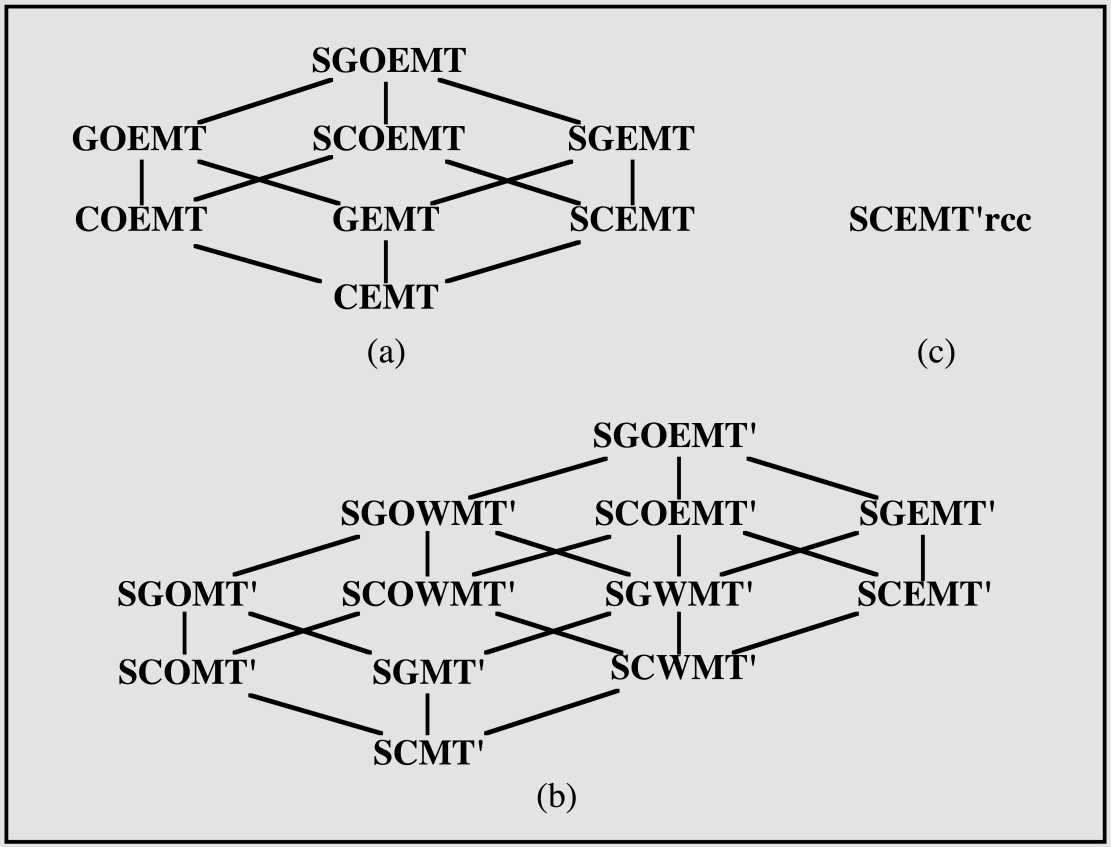
- Mutually exhaustive, pairwise disjoint
  - O $\exists z\ P(z,x) \wedge P(z,y)$
  - =
  - EC $EC(x,y) =_d C(x,y) \wedge \neg O(x,y)$
  - TPP $TPP(x,y) =_d PP(x,y) \wedge \exists z\ (C(z,x) \wedge C(z,y))$
  - NTPP $NTPP(x,y) =_d PP(x,y) \wedge \neg\exists z\ (C(z,x) \wedge C(z,y))$
  - DC $DC(x,y) =_d \neg C(x,y)$



Closed / General Mereotopology: operators

- Which extensionality?
  - important identity criteria
  - basis for definition of operators of sum, difference and fusion
- Mereology
  - O: strong supplementation
  - $\forall z\,(O(z,x) \leftrightarrow O(z,y)) \rightarrow x = y$
- Mereotopology
  - Choice of O (strong supplementation) or
  - C: strong mereotopology (C4)
  - $\forall z\,(C(z,x) \leftrightarrow C(z,y)) \rightarrow x = y$
- Topological operators
  - Interior: fusion of all the NTPP
  - Closure: complement of the interior of the complement

Families of mereotopologies



What about relative space?

- Like for event and interval temporal theories, spatial relative theories are very similar to those we have just seen
- Possible co-localization requires:
  - Part-of relation replaced by spatial inclusion
  - Identity replaced by “spatial equivalence”
- Connection replaced? Yes, if interpretation more than spatial, e.g., other unity criteria

What about space-time?

- A single domain of primitive entities: space-time “worms”
- Primitive relations: spatio-temporal ones and purely temporal ones
  - P and C with spatio-temporal interpretation
  - precedence and temporal connection
- Definition of temporal inclusion, temporal equivalence, temporal part, “temporal slice” operator
- Characterization of spatio-temporal “continuity”
- Characterization of motion

Location

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Note that we take mereology and topology as basic theories for modelling space.

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Source
R. Casati and A. Varzi “Parts and Places”, MIT Press, 1999 (Chp. 7)

Location: why?

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- Location and topological connection...

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(we put no restriction on the ‘dimension’ of the entities...)

Location: axioms (1)

$L(x,y) \wedge L(x,z) \rightarrow y = z$ (functionality)

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- what about the domain of the theory? Think of $L(x,x)$...

Location: doubts

Do we want the followings?

$\forall x \exists y \, L(x, y)$ (everything is localized)

$\forall x \, (L(x, x) \rightarrow \exists y \, (x \neq y \wedge L(y, x)))$

(every region is the location of something)

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e.g. Italy is wholly located in (the location of) Europe

$GL(x, y) =_d \exists z, w\,(P(z, x) \wedge P(w, y) \wedge L(z, w))$ (generic location)
e.g. Museums are generically located in Berlin
(i.e. some museums, although perhaps not all, are located in Berlin)

Exact and Broad Locations (2)

...and other notions can be captured with the help of topology!
Let $C(x, y)$ be the connection relation "x is connected to y" (reflexive and symmetric). Let $TP(x, y)$ be the tangential part relation "x is tangential part of y" (definable in terms of P and C).

Then, we can write

$$TWL(x, y) =_d \exists z\,(TP(z, y) \wedge L(x, z)) \qquad \text{(tangential WL)}$$

e.g. Italy is tangentially wholly located in Europe.

On Co-localization

Temporal and Spatial Co-localization

It is quite natural to admit :

- **Temporally co-localized objects**: John and the book he's reading, a person and his life...
- **Spatially co-localized objects**: a hole and the region of space it occupies, a statue and the clay it is made of...

Spatio-temporal Co-localization

It is problematic to justify the existence of spatio-temporally co-localized objects:

- Are there holes or only holed objects?
- Are there statues or only statue-shaped stuff?

These questions raise a lot of issues: identity through time, material constitution, essentiality, modality...

On Co-localization again

- If one adopts a multiplicative approach (like in the DOLCE ontology), one can also admit spatio-temporal co-localization of (even material) objects, like in the case of the statue and the clay.
- Statue and clay are supposed to be different, as they have different properties.
- But, what kind of relation do they have with each other?

On Constitution

Some quotations

"x constitutes y at time t iff x could be a substratum of y's destruction." [Doepke]

"When x constitutes y, there are certain properties of x which are *accidental* to x, but essential to y." [Simon]

Constitution is not Identity: an example

- I buy a portion of clay at 9 am
- I build a statue at 2 pm
- I substitute a hand of the statue at 3 pm and I throw away the old one.

Are the portion of clay and the statue the same entity?

Constitution is not Identity: an example (2)

NO, because:

(1) They are different in history (the clay was present at 9 am, the statue wasn't).

(2) They are different in persistence conditions (At 3 pm the statue is wholly present, while the portion of clay is not, all parts of the portion of clays are essential, while the parts of the statue are not, the clay can survive a change of shape, the statue cannot).

(3) They have different relational properties (the clay exists irrespective of the artist's intention, the statue does not).

What is constitution

- Constitution links the two entities
- It is asymmetric, as it implies dependence

Argument restriction:
$K(x,y,t) \rightarrow ((ED(x) \vee PD(x)) \wedge (ED(y) \vee PD(y)) \wedge T(t)$

On Qualities

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Source

D. M. Armstrong “Four disputes about properties”, Synthese (2005) 144: 309-320

Qualities

Let's concentrate on *qualities* !

On this topic we follow the DOLCE ontology.

Source
http://www.loa-cnr.it/DOLCE.html

See also
C. Masolo and S. Borgo "Qualities in Formal Ontology" in Foundational Aspects of Ontologies (Ws Font 2005)

Qualities (2)

- Qualities can be seen as the basic entities we perceive and measure: shapes, colours, sizes, smells, as well as weights, lengths, electrical charges;
- Qualities inhere to entities: every entity comes with certain qualities, which exist as long as the entity exists;
- We assume that these qualities belong to a finite set of quality types (like color,size, smell. . . corresponding to the leaves of the quality taxonomy). They are characteristic of specific individuals, so they are specifically constantly dependent on the entity they inhere in.

Qualities (3)

- The value of a quality is different from the quality itself: we call it **quale**, and it describes the position of an individual quality within a certain **quality space**. The structure of these quality spaces reflect our everyday experience. Quality regions roughly correspond to qualitative sensorial experiences of humans, even if we talk also about non-sensorial qualia, such as ‘1euro value’ (fixed by social conventions);
- Space and Time are considered qualities;
- Qualities can be direct (i.e.space and color for objects) or indirect (i.e. space for events or qualities of qualities, like ‘luminosity’, for objects);

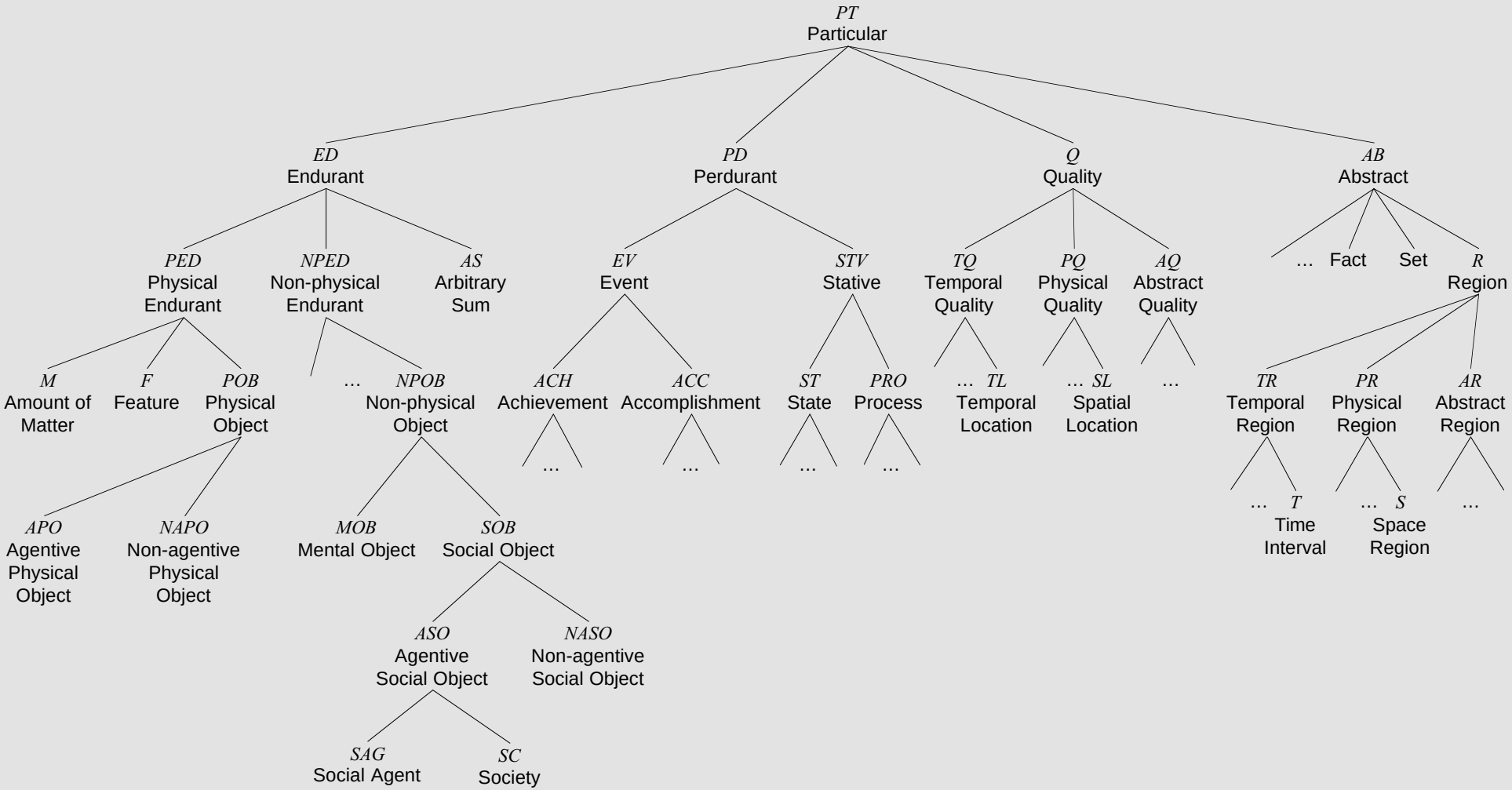
Qualities (4)

- No parthood defined
- Qualities are disjoint from objects and events;
- There are temporal qualities (direct qualities of events), spatial qualities (direct qualities of objects) and abstract qualities (qualities of abstract entities)

Qualities vs. Features

- Features are “parasitic” entities, that exist insofar their host exists.
- Features may be relevant parts of their host, like a bump in a road, or dependent places, such as a hole in a piece of cheese, the underneath of a table, or the shadow of a tree (which are not parts of their hosts).
- All features are essential wholes, but no common unity criterion may exist for all of them (*U).
- Features have qualities, qualities have no features.

Qualities: DOLCE Taxonomy



Qualities and qualia: some 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
- Red is opposite to green and close to brown
- The patient's temperature is increasing
- The doctor measured the patient's temperature

Qualities, quality regions and qualia

- Each object and event 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, an example

A rose and a flag can 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