Objects, events, qualities

An introduction to formal ontological distinctions (in DOLCE)

Lecture 3 – Change and persistence

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Outline

- Change and puzzles about change.
- Theories of persistence.
- Perdurantism vs. endurantism: formal aspects.
- Theories of persistence and theories of properties.

1 What is change?

- In order to an object to change there must be a sense in which it remains the *same* (it *persists*, otherwise it simply ceases to exist) and a sense in which it becomes different (it *changes*).
- Most philosophers analyze change as involving (in the simplest case) four components:
  - the substratum or object changing,
  - the property (or state) the object has before the change,
  - the property (or state) the object has afterwards,
  - the time of change.
- We will see that this viewpoint is not shared by all philosophers, and that a more specific analysis is needed.

2 Time

- To analyze change, I consider a very weak theory of time:
  - time is just a non-structured set of 'indexes' called *times*;
  - no commitment to the nature of times (punctual or extended entities, primitive or builded entities, e.g. sets of simultaneous events) or to the structure of time (linear or branching, etc.).
- I will indicate times with t, t', t_i, etc.
- In addition, I will consider the predicate EX:
  - $\mathsf{EX}(x, t)$ stands for "x exists at time t".

    (in some cases, I will write $\mathsf{EX}_t x$ instead of $\mathsf{EX}(x, t)$)
- Persistence through time can be minimally characterized by:
  - $\exists t, t'(\mathsf{EX}(x, t) \wedge \mathsf{EX}(x, t') \wedge t \neq t')$

3 Puzzles about change through time

- According to Sally Haslanger these puzzles rely on general conditions that, when integrally accepted, generate a contradiction.

  1. Objects persist through change.
  2. The properties involved in a change are incompatible.
  3. Nothing can have incompatible properties.
  4. The object before the change is one and the same object after the change.
  5. The object undergoing the change is itself the proper subject of the properties involved in the change.

4 . . . for example

- A rose r persists through a change from ‘red’ to ‘brown’.
- The acceptance of all the conditions 1-5 yields a contradiction because r happens to be both ‘red’ and ‘brown’ (assuming that ‘red’ and ‘brown’ are incompatible properties).

- Three main solutions exist in the literature.
  - *Perdurantism* (four-dimensionalism) rejects condition 5.
  - *Endurantism* (three-dimensionalism) rejects condition 2.
  - *Stage Theory* rejects condition 1.
- These solutions can ‘interact’ with the underlying theories of properties.

THEORIES OF PERSISTENCE

5 Perdurantism

- All the objects persist by *perduring*, i.e. objects are extended in time in a similar way as they do in space: by having different *(temporal) parts* (*temporal slices*) at different times.
- At each time, only a part of a persisting object is present, i.e. at a given time persisting objects are only *partially present*.
- If r exists at two different times t and t' then its temporal slices r-at-t and r-at-t' exist and are different.
- r is red at t because its *temporal part* at t (r-at-t) is red.
- The fact that r-at-t is red and r-at-t' is brown is not contradictory because r-at-$t \neq r$-at-t'.

6 Endurantism

- Objects undergoing the change *endure*, i.e. they are *wholly present* at any time at which they exist, they maintain their identity through change and they are the subjects of properties, but these properties need to be *temporally qualified*.
- Usually endurantists also accept perduring objects, *events*, as opposed to *objects* (we will analyze the distinction between objects and events in the last lecture).

- At any instant objects are *wholly present* but 'being red' and 'being brown' need to be *temporally qualified* and they are incompatible only if stated at the same time (about the same object).
- The fact that r is red at t and it is brown at t' does not lead to any contradiction.

7 Stage Theory

- Stage Theory denies persistent objects: *stages*, i.e. instantaneous entities, are the only true ontological entities.
- Common-sense persisting objects are the result of a conceptual construction that collects together similar stages (*unity criteria*).
- From an ontological point of view, Perdurantism and Stage Theory have different commitments, however they both rely on the fact that the proper subjects of properties are instantaneous entities (temporal slices or stages).
- Some stagists assume stages as *static*, but not necessarily instantaneous, entities, i.e. as 'frozen' entities that can persists through time but not through change.

8 Counterpart Theory

- Theory introduced by David Lewis.
- Similarly to Stage Theory entities are (time) world bounded.
- However, world bounded entities are linked by the ontological relation of *counterpart*:
  - r exists only at t and it is red, r' exists only at t' and it is brown but they are one the *counterpart* of the other one.
- Because of the ontological nature of the counterpart relation, Counterpart Theory is often consider as a version of Perdurantism.

9 Stage Theory vs. Perdurantism

- In what follows I want to talk about persisting entities.
- For stagists these entities have a conceptual nature, while for perdurantists they are true ontological entities.
- Putting aside this difference, the two theories treat change in a very similar way and associate persisting entities with sequels of instantaneous entities.
- For this reason, in the following, I will consider only Perdurantism.

PERDURANTISM VS. ENDURANTISM: FORMAL ASPECTS

10 Perdurantism and commonsense

- I think that the initial puzzle about change is a 'commonsense' puzzle. Is the perdurantist solution incompatible with commonsense?

- The perdurantist solution is an alternative to the endurantist one. The analysis of pros and cons of these solutions is interesting to understand their adequateness to model specific domains/situations.

- In my understanding, commonsense theories need to consider mesoscopic entities, to deal with qualitative information, to be (using the word of Jerry Hobbs) "close to the intuitive theories of the world". Perdurantism does not presupposes a fine-grained level of detail nor quantitative knowledge.

11 Perdurantism: a crazy theory of the world?

- What is an "intuitive theory of the world"?
- Often one refers to *natural language*, to the theories
  "we seem to presuppose when we talk about the world, and less like those of real physics"
  "one can assume a more 'intuitive' ontology, one that is isomorphic to the language we use to talk about the world." [Jerry Hobbs]
- Perdurantism has been used as an ontological foundation to the semantics of the natural language, and this semantics solves a number of well-known semantic phenomena.
- From a different perspective, the perdurantist view is now used in applications, advocating its adequateness, conceptual simplicity and practical advantages for representing dynamic environments.

12 *Digression*: a practical usage for perdurantism

- "Sam Palmisano was named chief executive officer of the IBM Corporation effective March 1, 2002." [Welty & Fikes, 2006]
- The most common way to represent this situation is by means of a ternary predicate: $\mathsf{CEO}(\mathsf{sam}, \mathsf{ibm}, \mathsf{030102})$.
- But ternary predicates cannot be represented in OWL.
- An alternative that commits to perdurantism is possible:
  $\mathsf{CEO}(\mathsf{sam@030102}, \mathsf{ibm@030102}) \wedge$
  $\mathsf{EX}(\mathsf{sam@030102}, \mathsf{030102}) \wedge \mathsf{EX}(\mathsf{ibm@030102}, \mathsf{030102}) \wedge$
  $\mathsf{P}(\mathsf{sam@030102}, \mathsf{sam}) \wedge \mathsf{P}(\mathsf{ibm@030102}, \mathsf{ibm})$.
- This alternative uses only binary predicates (however, note that '@' does not indicate a function, but sam@030102 and ibm@030102 are just the names of two new individuals in the domain).

13 Perdurantism vs. Endurantism

- The distinction between perdurantism and endurantism is informally stated in terms of the notions of being partially/wholly present.
- While *being partially present* has been quite precisely characterized (as we will see), *being wholly present* is still quite obscure.
- The formal distinction between perdurantism and endurantism often reduces to different positions on *parthood*:
  - endurantists claim that a primitive temporally qualified parthood (*temporary parthood*) is required;
  - perdurantists assume an atemporal parthood (*parthood simpliciter*, or simply *parthood*) and they define "x is part of y at t" as "$x@t$ is part of $y@t$".

14 Parthood simpliciter and temporary parthood

- *Parthood simpliciter* and *temporary parthood* are general and foundational notions that can be used to formalize different domains;
  - e.g., endurantists often use parthood simpliciter for events or histories, therefore understanding how these notions are linked is relevant for endurantists too.
- In a perspective of integration with other systems that can be based on different ontological assumptions, the links help in understanding what perdurantists and endurantists can exchange.

  "so many researchers develop their own theories to solve a particular problem, even when similar theories already exist. The result is a large number of theories, mostly incomparable, each suited to some problem, but none suited to a broad class of problems." [Davis & Morgenstern, 'Progress in formal commonsense reasoning', 2004]

15 Perdurantism stated

- Theodore Sider introduced a formal characterization of perdurantism based on *temporary parthood* and *existence in time*.
- In this way:
  - *endurantists* can better understand the perdurantist view because it is characterized in terms of temporary parthood;
  - *perdurantists* can accept it standardly analyzing "x is part of y at t" as "$x@t$ is part of $y@t$".

16 Endurantism stated

- Endurantists do not accept the analysis of temporal parthood based on the existence of temporal parts (they refuse them in general).
- However, endurantists do not have a clear characterization of ‘being wholly present’ (even though some attempts exist): we will see that all the parts of an object at t are trivially present at t.
- It follows that the distinction between endurantists and perdurantists is basically reduced to the acceptance of temporal parts.
- Therefore, either endurantism is less constrained than perdurantism, or it still lacks a clear formal characterization [Sider, 2001].

17 Existence in time

- $\mathsf{EX}(x,t)$ is
  - a primitive relation for *endurantists*, or
  - can be reduced to $\exists s(\mathsf{TP}(s,x,t))$ for *perdurantists and stagists*

    where $\mathsf{TP}(s,x,t)$ stands for "s is the *temporal part* or *stage* of x at t" (in some case I will represent s in a functional way as $x@t$).

- Provided one does not give up on expressive power, a core theory compatible with different philosophical positions, has the advantage of providing a common framework that, when needed, can be specialized to account for specific constraints.

18 A bit of history of mereology

- **Mereology**: from the greek *meros*, 'the theory of parthood'.
- Lesniewski 1927-1931, On the Foundations of Mathematics. Alternative to Set Theory for escaping Russells paradox.
  - No null individual (no empty set).
  - No distinction between *urelements* ($\in$) and *sets* ($\subseteq$): a single relation of parthood.
- Tarski 1935. Link with algebra.
- Leonard and Goodman 1940. The calculus of individuals, nominalism.
- Contemporary studies: Peter Simons (1986), Achille Varzi (1996).

19 Why is mereology important?

- Today, the majority of ontologies use at least a parthood relation.
  - Philosophical, cognitive and linguistic relevance.
  - Spatial and temporal reasoning based on vague information: impossibility to use exact coordinates, trajectories in terms of mathematical functions, and calculus.
  - Reference to extended entities (e.g., temporal periods, spatial regions), possibly composed of parts of the same ontological or conceptual nature.
  - No calculus, yet still a rigorous formal approach: logical theories.

- No one single mereology, but a plurality of different mereologies.

20 *Digression*: extensionality

- Are statues identical to the sum of the amounts of matter that compose them?
- Is a castle identical to the sum of the bricks that compose it?
- Is a person identical to his/her body?

- If we assume Leibniz principle, these entities seem different. It is enough to consider temporal or emergent/supervenient properties.

- *Solution 1*: the castle and the sum of bricks have the same parts (the bricks) but they are different (*non-extensional mereology*).
- *Solution 2*: the bricks are not (mereologica) parts of the castle. Extensional mereology can be used at the price of introducing a new relation between the bricks and the castle (*constitution*).

21 Parthood vs. spatial inclusion

- Assuming extensionality and interpreting parthood as spatial inclusion then two objects are identical iff they have the same spatial location, i.e. it is not possible to have spatially coincident different objects.

- Particularly tricky in the case of change when objects can spatially coincide only at a specific time.

- In addition, one need to assume that parthood does not apply to
  - abstracts objects (e.g. numbers, ideas) that do not have a spatial location;
  - immaterial objects (e.g. holes, ghosts, shadows) that are not impenetrable.

22 Parthood vs. spatio-temporal inclusion

- A similar problem appears in the case of spatio-temporal coincidence.
- E.g. consider the two events
  - 'the rotating of the sphere s' and
  - 'the heating up of the sphere s'.

  or a situation in which a statue and its clay are created and destroyed at the same times.

- (Strong) perdurantism rejects spatio-temporally coincident entities (in the case of the statue and the clay, a modal dimension is added).
- I think that, Lesniewski intended mereology as a substitute of set-theory. His main focus was on how entities can be summed up without any commitment on their nature.

23 Parthood simpliciter vs. temporary parthood

Parthood simpliciter
$\mathsf{EX}xt$ "x exists at t";
$\mathsf{P}xy$ "x is part of y".

Temporary Parthood
$\mathsf{EX}xt$ "x exists at t";
$\mathsf{tP}xyt$ "x is part of y at t".

Definitions on the basis of P:

d1 $\mathsf{O}xy \triangleq \exists z(\mathsf{P}zx \wedge \mathsf{P}zy)$

d2 $\mathsf{TP}xyt \triangleq \mathsf{EX}xt \wedge \mathsf{EX}yt \wedge \neg\exists t'(\mathsf{EX}xt' \wedge t' \neq t) \wedge \mathsf{P}xy \wedge \forall z(\mathsf{P}zy \wedge \mathsf{EX}zt \rightarrow \mathsf{O}zx)$

d3 $\mathsf{tP}xyt \triangleq \exists zw(\mathsf{TP}zxt \wedge \mathsf{TP}wyt \wedge \mathsf{P}zw)$

Definitions on the basis of tP:

d4 $\mathsf{tO}xyt \triangleq \exists z(\mathsf{tP}zxt \wedge \mathsf{tP}zyt)$

d5 $\mathsf{tTP}xyt \triangleq \neg\exists t'(\mathsf{EX}xt' \wedge t' \neq t) \wedge \mathsf{tP}xyt \wedge \forall z(\mathsf{tP}zyt \rightarrow \mathsf{tO}zxt)$

d6 $\mathsf{P}xy \triangleq \forall t(\mathsf{EX}xt \rightarrow \mathsf{tP}xyt)$

24 The theories $\mathcal{T}_{\mathsf{tP}}$ and $\mathcal{T}_{\mathsf{P}}$

$\mathcal{T}_{\mathsf{tP}}$: **temporary parthood** (Sider)

- **a1** $\exists t(\mathsf{EX}xt)$
- **a2** $\mathsf{tP}xyt \rightarrow \mathsf{EX}xt \wedge \mathsf{EX}yt$
- **a3** $\mathsf{EX}xt \rightarrow \mathsf{tP}xxt$
- **a4** $\mathsf{tP}xyt \wedge \mathsf{tP}yzt \rightarrow \mathsf{tP}xzt$
- **a5** $\mathsf{EX}xt \wedge \mathsf{EX}yt \wedge \neg \mathsf{tP}xyt \rightarrow \exists z(\mathsf{tP}zxt \wedge \neg \mathsf{tO}zyt)$
- **pd** $\mathsf{EX}xt \rightarrow \exists y(\mathsf{tTP}yxt)$

$\mathcal{T}_{\mathsf{P}}$: **parthood simpliciter**

- (a1) $\exists t(\mathsf{EX}xt)$
- **a6** $\mathsf{P}xx$
- **a7** $\mathsf{P}xy \wedge \mathsf{P}yx \rightarrow x = y$
- **a8** $\mathsf{P}xy \wedge \mathsf{P}yz \rightarrow \mathsf{P}xz$
- **a9** $\neg \mathsf{P}xy \rightarrow \exists z(\mathsf{P}zx \wedge \neg \mathsf{O}zy)$
- **a10** $\mathsf{P}xy \wedge \mathsf{EX}xt \rightarrow \mathsf{EX}yt$
- **pdn** $\mathsf{EX}xt \rightarrow \exists y(\mathsf{TP}yxt)$

25 $\mathcal{T}_{\mathsf{P}}$ is strictly stronger than $\mathcal{T}_{\mathsf{tP}}$

t1 $\mathcal{T}_{\mathsf{tP}} \nvdash \mathsf{tTP}xyt \wedge \mathsf{tTP}zyt \rightarrow x = z$

t2 $\mathcal{T}_{\mathsf{tP}} \nvdash \forall t(\mathsf{EX}xt \rightarrow \mathsf{tP}xyt) \wedge \forall t(\mathsf{EX}yt \rightarrow \mathsf{tP}yxt) \rightarrow x = y$

t6 $\mathcal{T}_{\mathsf{P}} \vdash_{\text{(d3)}} \mathcal{T}_{\mathsf{tP}}$

t7 $\mathcal{T}_{\mathsf{P}} \vdash_{\text{(d3)}} \mathsf{tTP}yxt \wedge \mathsf{tTP}yzt \rightarrow y = z$

t8 $\mathcal{T}_{\mathsf{P}} \vdash_{\text{(d3)}} \forall t(\mathsf{EX}xt \rightarrow \mathsf{tP}xyt) \wedge \forall t(\mathsf{EX}yt \rightarrow \mathsf{tP}yxt) \rightarrow x = y$

(d3) $\mathsf{tP}xyt \triangleq \exists zw(\mathsf{TP}zxt \wedge \mathsf{TP}wyt \wedge \mathsf{P}zw)$

- In $\mathcal{T}_{\mathsf{tP}}$, the temporal part at a time is not unique and two different entities can be one part of the other during their whole life.

26 $\mathcal{T}_{\mathsf{P}} \smallsetminus \{(\text{a7})\}$ is equivalent to $\mathcal{T}_{\mathsf{tP}}$ via (d3)&(d6)

$\mathcal{T}_{\mathsf{P}}$ is strictly stronger than $\mathcal{T}_{\mathsf{tP}}$ because of the antisymmetry of P :

t9 $\mathcal{T}_{\mathsf{P}} \smallsetminus \{(\text{a8})\} \nvdash_{(\text{d3})} (\text{a4})$ — (a8): transitivity of P; (a4): transitivity of tP

t10 $\mathcal{T}_{\mathsf{P}} \smallsetminus \{(\text{a9})\} \nvdash_{(\text{d3})} (\text{a4})$ — (a9): extensionality of P

t11 $\mathcal{T}_{\mathsf{P}} \smallsetminus \{(\text{a10})\} \nvdash_{(\text{d3})} (\text{a4})$ — (a10): temporal monotonicity of P

t12 $\mathcal{T}_{\mathsf{P}} \smallsetminus \{(\text{a7})\} \vdash_{(\text{d3})} \mathcal{T}_{\mathsf{tP}}$ — (a7): antisymmetry of P

t14 $\mathcal{T}_{\mathsf{P}} \smallsetminus \{(\text{a7})\} \nvdash_{(\text{d3})} \mathsf{tTP}yxt \wedge \mathsf{tTP}zxt \rightarrow y = z$

t15 $\mathcal{T}_{\mathsf{P}} \smallsetminus \{(\text{a7})\} \nvdash_{(\text{d3})} \forall t(\mathsf{EX}xt \rightarrow \mathsf{tP}xyt) \wedge \forall t(\mathsf{EX}yt \rightarrow \mathsf{tP}yxt) \rightarrow x = y$

(d3) $\mathsf{tP}xyt \triangleq \exists zw(\mathsf{TP}zxt \wedge \mathsf{TP}wyt \wedge \mathsf{P}zw)$

t16 $\mathcal{T}_{\mathsf{tP}} \vdash_{(\text{d6})} \mathcal{T}_{\mathsf{P}} \smallsetminus \{(\text{a7})\}$

(d6) $\mathsf{P}xy \triangleq \forall t(\mathsf{EX}xt \rightarrow \mathsf{tP}xyt)$

27 $\mathcal{T}_{\mathsf{P}}$ is equivalent to $\mathcal{T}_{\mathsf{tP}} \cup \{(\mathrm{a11})\}$ via (d3)&(d6)

$\mathcal{T}_{\mathsf{tP}}$ can be strengthened via (a11) (that directly corresponds to the antisymmetry of P), to achieve a theory equivalent to $\mathcal{T}_{\mathsf{P}}$:

a11 $\forall t(\mathsf{EX}xt \rightarrow \mathsf{tP}xyt) \wedge \forall t(\mathsf{EX}yt \rightarrow \mathsf{tP}yxt) \rightarrow x = y$

28 Comments on the two equivalences

- $\mathcal{T}_{\mathsf{tP}}$ mainly differs from $\mathcal{T}_{\mathsf{P}}$ because of the uniqueness of the temporal parts and the acceptance of *coincident* objects (objects that are one part the other during their whole life).

- $\mathcal{T}_{\mathsf{tP}}$ shows that, even though we assume temporal parts, coincident entities can differ, e.g. the statue and the the clay can be different even though they are one part of the other during their whole life.

  - This is compatible with the endurantist view that accept coincident objects that are different because of non mereological properties.

- $\mathcal{T}_{\mathsf{P}}$ is a stronger version of perdurantism that, identifying coincidence with identity, tends to reduce differences among objects to mereological ones (in particular spatio-temporal ones).

29 Avoiding temporal parts

- It is possible to define *temporal parthood* on the basis of parthood simpliciter without rely on the existence of temporal parts.
- This definition does not commit on temporal parts but on weaker existential conditions: a sort of *extensional closure mereology* is enough.
- Because of temporal parts are nor assumed, endurantists could accept this definition of tP in terms of P.

30 Parthood in DOLCE

- DOLCE distinguishes parthood from spatial (spatio-temporal) inclusion: spatial (spatio-temporal) co-location does not imply identity.
- DOLCE distinguishes parthood simpliciter (defined on *abstracts* and *perdurants*) from temporary parthood (defined on *endurants*).
  - Temporary parthood cannot be reduced to parthood simpliciter because, in general, endurants do not have temporal parts (therefore (d3) cannot be used).
  - Parthood simpliciter cannot be reduced to temporary parthood because (a11) is not assumed (see the debatable axiom (AP=) in DOLCE).
- Actually, this choice reflects the idea that a temporally qualied parthood is required for endurants but not for perdurants.

31 Parthood in DOLCE-CORE

- DOLCE-CORE has a more formal attitude towards parthood.
- Temporary parthood is considered as 'more informative' than parthood simpliciter when temporal slices are not necessary assumed.
- Temporary parthood is defined on all entities, (a11) is accepted, and parthood simpliciter is defined by (d6).

- Entities can coincide only at some time:
  $\mathsf{CC}(x, y, t) \triangleq \mathsf{tP}(x, y, t) \wedge \mathsf{tP}(y, x, t)$

  but when they coincide they are indistinguishable, i.e. all the properties that x has at t are also properties of y and vice versa.
- In this purely formal perspective, that must not be confused with the common usage of the term 'part', extensionality (and closure with respect the sum) is no more a problem.

THEORIES OF PERSISTENCE AND THEORIES OF PROPERTIES

32 a has P at t

- Let us start from considering a general reading of the FOL formula

  $P(x, t) \wedge Q(x, t')$:

  "x exists at both t and t', it has the property P when t is (was, will be) present and the property Q when t' is (was, will be) present".

- Let us begin with a minimal condition: since x at t has a property P, x needs to exist at t, i.e. $P(x, t) \rightarrow \mathsf{EX}(x, t)$.

  (one should refrain from considering boolean combinations of predicates, like 'not being present', as possible values for P.).

- Let us analyze how $P(x, t)$ can be reduced to more basic relations according to the theories of persistence and properties considered.

33 Universalism and change (1/2)

$$\begin{tikzcd}
a \arrow[r, "\mathsf{inst}_t"] \arrow[dr, "\mathsf{inst}_{t'}"'] & \textsf{scarlet} \arrow[r, "\mathsf{dD}"] & \textsf{red} \arrow[r, "\mathsf{dD}"] & \textsf{colored} \\
& \textsf{crimson} \arrow[ur, "\mathsf{dD}"'] & &
\end{tikzcd}$$

- Different universals are wholly present in the same object at different times.
- Two ways to model property change:
  1. adding a temporal parameter to instantiation:
     $P(x,t) \wedge Q(x,t') \leftrightarrow \mathsf{inst}(x,\mathsf{p},t) \wedge \mathsf{inst}(x,\mathsf{q},t')$;
  2. applying temporal modal operators to binary instantiation:
     $P(x,t) \wedge Q(x,t) \leftrightarrow \Box_t \mathsf{inst}(x,\mathsf{p}) \wedge \Box_{t'} \mathsf{inst}(x,\mathsf{q})$.
- Both solutions are compatible with all the theories of persistence.

34 Universalism and change (2/2)

$$\begin{tikzcd} a & a@t \arrow[l, "\mathsf{P}"'] \arrow[r, "\mathsf{inst}"] & \text{scarlet} \arrow[r, "\mathsf{dD}"] & \text{red} \arrow[r, "\mathsf{dD}"] & \text{colored} \\ & a@t' \arrow[ul, "\mathsf{P}"] \arrow[r, "\mathsf{inst}"] & \text{crimson} \arrow[ur, "\mathsf{dD}"'] & & \end{tikzcd}$$

- *Committing to perdurantism*: different universals are wholly present in different temporal slices of an object.

  3 $P(x,t) \wedge Q(x,t) \leftrightarrow \mathsf{inst}(x@t, \mathsf{p}) \wedge \mathsf{inst}(x@t', \mathsf{q})$.

- Solution 3 can be seen as a specialization of solution 1 where $\mathsf{inst}(x, \mathsf{p}, t)$ is reduced to $\mathsf{inst}(x@t, \mathsf{p})$.

35 Trope Theory and change

$$
\begin{tikzcd}
a & a_c \arrow[l, "\mathsf{I}"'] \arrow[r, "\in"] \arrow[d, leftrightarrow, "\approx_d"] & {|Scarlet|_{\approx}} \arrow[r, "\subseteq"] & {|Red|_{\approx_d}} \arrow[r, "\subseteq"] & {|Colored|_{\approx_{d'}}} \\
 & a'_c \arrow[ul, "\mathsf{I}"] \arrow[r, "\in"'] & {|Crimson|_{\approx}} \arrow[ur, "\subseteq"'] & &
\end{tikzcd}
$$

- Similarly to stages, tropes do not change, they do not persist through *change* (but they can 'statically' persist through time).
- Change is reduced to *trope substitution*: an object changes along a dimension, say color, because its color-trope is *substituted* by another non-exactly resembling (but comparable) color-trope.

$$P(x,t) \wedge Q(x,t') \leftrightarrow \exists x_p x_q (\mathsf{I}(x_p, x) \wedge \mathsf{I}(x_q, x) \wedge x_p \in \mathsf{p} \wedge x_q \in \mathsf{q} \wedge \mathsf{EX}(x_p, t) \wedge \mathsf{EX}(x_q, t'))$$

(I use $\in$ to indicate that p and q stands for sets of tropes).

36 Trope Theory and persistence

- Trope Theory assumes Stage Theory for *tropes*, but, in general it is neutral wrt the persistence of the objects in which tropes inhere.

- *Tropes and endurants*:

$$\begin{tikzcd}
a & a_c \arrow[l, "\mathsf{I}"'] \arrow[r, "\in"] \arrow[d, leftrightarrow, "\approx_d"] & {|Scarlet|_\approx} \arrow[r, "\subseteq"] & {|Red|_{\approx_d}} \arrow[r, "\subseteq"] & {|Colored|_{\approx_{d'}}} \\
 & a'_c \arrow[ul, "\mathsf{I}"] \arrow[r, "\in"'] & {|Crimson|_\approx} \arrow[ur, "\subseteq"'] & &
\end{tikzcd}$$

- *Tropes and perdurants* ($a_c \neq a'_c$ even though a does not change because they inhere in different temporal slices):

$$\begin{tikzcd}
a & a@t \arrow[l, "\mathsf{P}"'] & a_c \arrow[l, "\mathsf{I}"'] \arrow[r, "\in"] \arrow[d, leftrightarrow, "\approx_d"] & {|Scarlet|_\approx} \arrow[r, "\subseteq"] & {|Red|_{\approx_d}} \arrow[r, "\subseteq"] & {|Colored|_{\approx_{d'}}} \\
 & a@t' \arrow[ul, "\mathsf{P}"] & a'_c \arrow[l, "\mathsf{I}"] \arrow[r, "\in"'] & {|Crimson|_\approx} \arrow[ur, "\subseteq"'] & &
\end{tikzcd}$$

37 Universalism + Trope Theory and change

$$\begin{tikzcd}
a & a_c \arrow[l, "\mathsf{I}"'] \arrow[r, "\mathsf{inst}"] & \textsf{scarlet} \arrow[r, "\mathsf{dD}"] & \textsf{red} \arrow[r, "\mathsf{dD}"] & \textsf{colored} \\
& a'_c \arrow[ul, "\mathsf{I}"] \arrow[r, "\mathsf{inst}"'] & \textsf{crimson} \arrow[ur, "\mathsf{dD}"'] & &
\end{tikzcd}$$

- A tropicalist that accepts (non necessarily extensional) universals:

  $$P(x,t) \wedge Q(x,t) \leftrightarrow \exists x_p x_q (\mathsf{I}(x_p, x) \wedge \mathsf{I}(x_q, x) \wedge \mathsf{inst}(x_p, \mathsf{p}) \wedge \mathsf{inst}(x_q, \mathsf{q}) \wedge \mathsf{EX}(x_p, t) \wedge \mathsf{EX}(x_q, t'))$$

- A temporal parameter in the instantiation relation is not necessary because tropes do not change.

- As in the previous case, this theory is neutral with respect to the persistence of the objects in which tropes inhere.

38 Intrinsic properties' change

- Let us suppose that P and Q are intrinsic properties.
- (Strong) Perdurantism ontologically explains change of intrinsic properties: x changes because it has temporal parts with different properties, $P(x@t) \wedge Q(x@t')$.
- Endurantists write $P(x,t) \wedge Q(x,t')$ (or use a temporal logic) without explaining what happened to x to change from P to Q.
- David Lewis noticed: either endurantists assume that P and Q are relational properties or an alternative explanation is required.
- Conceiving change as *trope* substitution is an alternative ontological explanation compatible with endurantism but maybe not so commonsensical.

39 Tropes vs. individual qualities

$$\begin{tikzcd}
a & a_c \arrow[l, "\mathsf{I}"'] \arrow[r, "\mathsf{inst}_t"] \arrow[dr, "\mathsf{inst}_{t'}"'] & \text{scarlet} \arrow[r, "\mathsf{dD}"] & \text{red} \arrow[r, "\mathsf{dD}"] & \text{colored} \\
& & \text{crimson} \arrow[ur, "\mathsf{dD}"'] & &
\end{tikzcd}$$

- Color-qualities persist through the change in color of the objects they inheres in, thus they can change location in the color-space(s).

- Individual qualities can be seen as the collection 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.
  - $P(x,t) \wedge Q(x,t) \leftrightarrow \exists x_p x_q (\mathsf{I}(x_p, x) \wedge \mathsf{I}(x_q, x) \wedge \mathsf{inst}(x_p, \mathsf{p}, t) \wedge \mathsf{inst}(x_q, \mathsf{q}, t'))$

- No commitment on the way objects and individual qualities persist.

40 Individual qualities in DOLCE

$$
\begin{tikzcd}
a & a_c \arrow[l, "\mathsf{I}"'] \arrow[r, "\mathsf{L}_t"] \arrow[dr, "\mathsf{L}_{t'}"'] & \text{scarlet} \arrow[r, "\mathsf{P}"] & \text{red} \arrow[r, "\mathsf{P}"] & \text{colored} \\
 & & \text{crimson} \arrow[ur, "\mathsf{P}"'] & &
\end{tikzcd}
$$

- Instead of instantiation, DOLCE considers *location* that needs to be extended with a temporal argument.
- dD is represented by means of parthood simpliciter (spaces and regions are static entities).
  - $P(x,t) \wedge Q(x,t) \leftrightarrow \exists x_p x_q(\mathsf{I}(x_p,x) \wedge \mathsf{I}(x_q,x) \wedge \mathsf{L}(x_p,\mathsf{p},t) \wedge \mathsf{L}(x_q,\mathsf{q},t'))$.

41 Individual qualities without universals

- Can properties been associated to sets of *exactly resembling* individual qualities (as happens in Trope Theory with tropes)?
- Differently from tropes, individual qualities can change, therefore:
  - a *resemblance simpliciter* can just collect all the individual qualities relative to a given dimension, i.e. only general determinables, but not their determinates, can be builded on the basis of it;
  - a *diachronic resemblance*, $x \approx_{tt'} y$ stands for "the individual quality x, as it is at t, exactly resembles to the individual quality y, as it is at t'" does not solve the problem:

    to which full determinate the color-quality q_1 that is crimson at t and scarlet at t' belongs?

- The introduction of stages of ind. qualities lead to Trope Theory.

42 Resemblance Nominalism

- Resemblance Nominalism refuses universals, tropes, and individual qualities. Resemblance is directly defined on objects.
- If objects can change, then Resemblance Nominalism is unable to build both general determinables and full-determinates.
- Therefore Resemblance Nominalism needs to commit to perdurantism. However, while tropes are individualizations of the most specific properties, stages/temporal slices of objects can have different properties (color, weight, shape, etc.)
- Co-extensionality of properties is then a problem for Resemblance Nominalism: e.g. all the blue temporal slices can also weight 1kg. (partially solved by committing to *possibilia*)

43 *Digression*: synchronic resemblance (1/2)

- In Trope Theory, tropes existing at different times can be directly compared by means of the resemblance relation.
- *Empirical approaches* often allow only synchronic direct comparisons: diachronic ones are the result of a more complex process.
- Properties are then build in two steps:
  1. resemblance is defined only on tropes existing at the same time; equiv. classes of resembling tropes are *localized* in single times;
  2. (time-localized) equivalence classes relative to the 'same property' are collected by means of a cross-time relation that allows to abstract from time.

- We will see that in (some) measurement theories these two steps rely on different kinds of relations.

44 *Digression*: synchronic resemblance (2/2)

- An example of this 'two-step' construction is provided by Forbes in the construction of time from punctual events.
  - In each world, times and relations on times are abstracted from (i) the set of punctual events and, (ii) the *coincidence* $(\equiv_E)$, *precedence* $(\lhd_E)$, and *distance* (d_E) relations.
  - *Branching-worlds* share an initial segment of their course of history, i.e. they share at least two (punctual) *times* that fix a common *origin* and *unit* of measure allowing for the definition of a unique d_T on times in branching worlds.
  - A correspondence between localized times in *different* branching-worlds can be established in the following way:

    $t_1 \equiv_T t_2 \quad \textit{iff} \quad \mathsf{d}_T(t_1, t) = \mathsf{d}_T(t_2, t) \wedge t \lhd_T t_1 \wedge t \lhd_T t_2.$