In Defense of a Trope-Based Ontology for Conceptual Modeling: An example with the foundations of Attributes, Weak Entities and Datatypes

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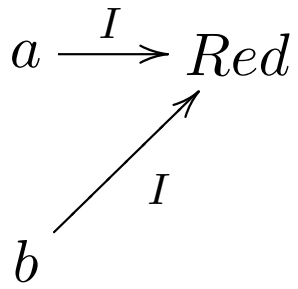
Goal

- ▷ Explore different philosophical positions on *properties* and *predication*.
- ▷ Compare the *Bunge-Wand-Weber* (BWW) position and a *trope-based* one with respect to:
  - *ontological commitment* (kinds of entities and relations);
  - *expressivity* (ontological interpretation of CM constructs);
  - *adequacy* (for some modeling tasks).

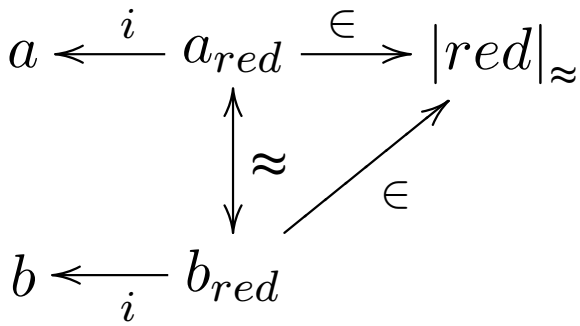
Main philosophical positions on properties

Example. The particulars a and b have the property "being red".

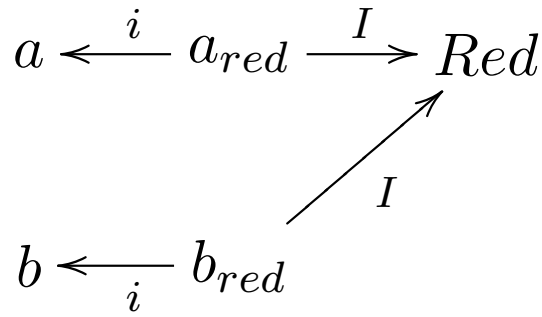
Universalism



Trope theory



Universals+Tropes



- ▷ **Natural classes**. Properties are classes of particulars, *natural* classes correspond to "universals"
- ▷ **Resemblance Nominalism**. Properties are classes of resembling particulars (resembling couples, etc.)

Things vs. Particulars

- ▷ BWW (and universalism).
  (Post 1) The world is made of *things* that possess *properties*.
- ▷ Tropes inhere in (and existentially depend on) *things* and possess *properties*.
  - Note. The difference between tropes as *members* of classes of resembling entities vs. tropes as *instances* of universals is not relevant for the following arguments.
- ▷ Therefore, *tropes* are existentially dependent particulars.
  In this sense they are conceptually similar to *weak-entities* and different from *things*.
- ▷ Can tropes inhere in tropes?

More specific goals

Show that a trope-based theory

1. can be used to provide an alternative (w.r.t. BWW) ontological interpretation of some CM fundamental constructs/notions;
2. leads to a more explicit ontological characterization of some of these CM constructs/notions;
3. allows for representing additional situations in an ontologically well founded way, e.g. change in time, properties of properties, measurement, etc.

Attribute Functions (1/5)

Alternative representations of attribute functions in UML:

▷ In UML, a *datatype* is a class whose instances are *values* not *objects*. A value does not have an identity: two occurrences of the same value cannot be differentiated:

color: Apple $\rightarrow$ *Color*

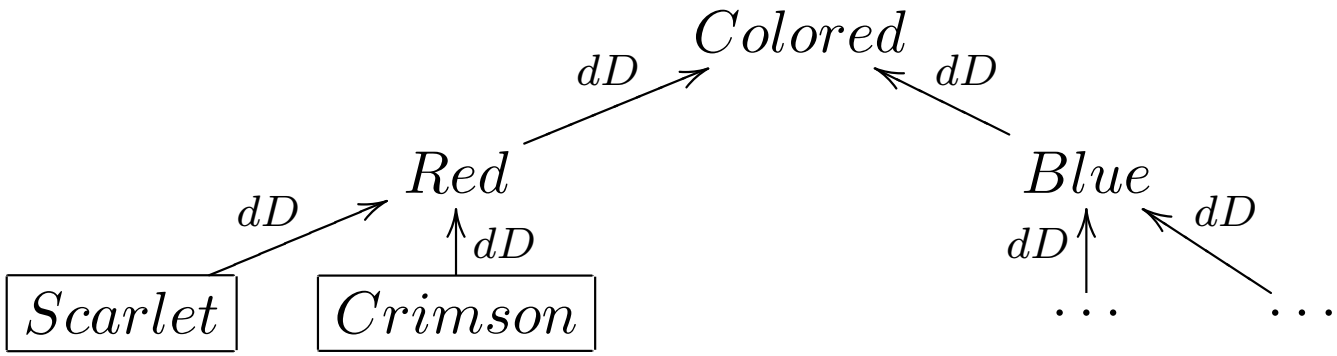
▷ In BWW, Apple is a set of things, *Color* is a set of values, and color is a property (an attribute). A set M representing the "observation conditions" (times, contexts, etc.) is added.

color: Apple $\times$ M $\rightarrow$ *Color*

Attribute Functions (2/5)

- ▷ Intuitively, "being coloured" is different from "being red" or from properties individuating a specific color shade.
- ▷ Each value in *Color* individuates a specific property, e.g. "being scarlet", "being crimson", etc.
- ▷ *Color* (and color) individuates the set of *specific properties* (by means of values) that specialize a "common aspect", a general property, of things, "being coloured" in this case.
- ▷ In trope theory, specific properties are classes of *exactly* resembling tropes.
- ▷ **(?)** How can these notions (specific vs. general properties) be characterized in a trope-based theory?

Qualia

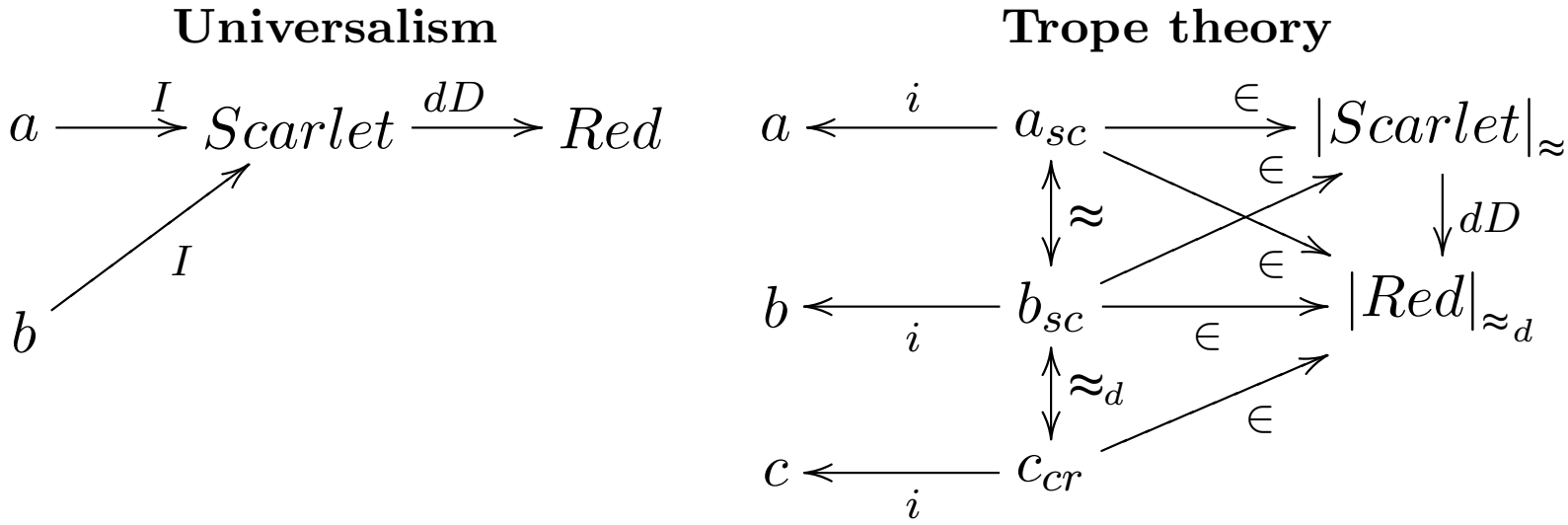


▷ $dD(p_1, p_2)$: property p_1 is a determinate of p_2 (the determinable):

- having a *determinate* property entails having a *determinable* property;
- having a *determinable* property entails having (at least) one of the properties that are its *determinates*.

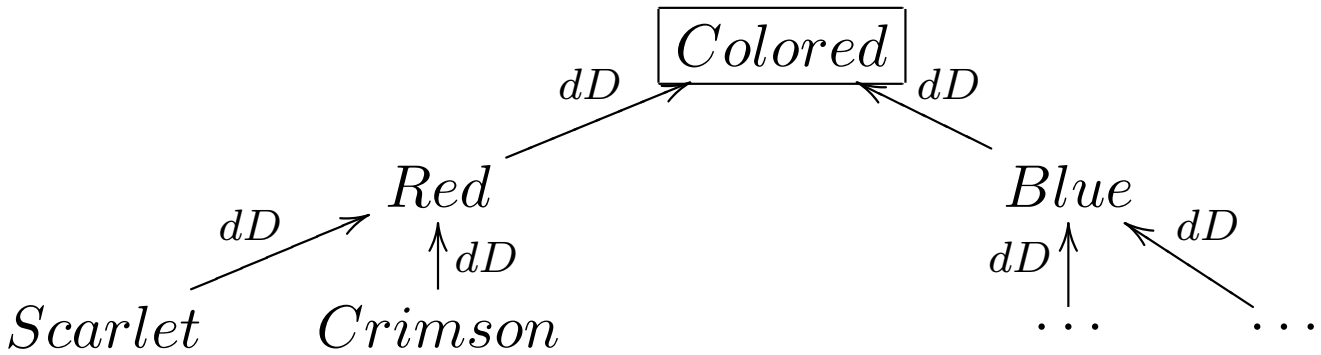
▷ **Qualia**: determinates that are not determinables, i.e. the more specific properties (that, intuitively, correspond to values).

Predication of determinables



- ▷ Universalism. *dD* is (*a*) primitive; (*b*) based on resemblance with degrees *between universals*; (*c*) based on partial identity.
- ▷ Trope theory. *dD* is based on the inexact resemblance with degree *d between tropes* ($\approx_d$): classes of exactly (inexactly) resembling tropes are qualia (determinables, resp.).

Qualia kinds



▷ *Incompatibility of qualia.* One (atomic) entity can have only a coloured-qualia (not the case of $Coloured\_OR\_Shaped$).

▷ *Comparability of qualia.* Coloured-qualia are at least qualitatively comparable (they are related). No coloured-quale resembles more closely a shaped-quale than a volume-quale.

Qualia kinds are maximal wrt incompatibility and comparability.

Attribute Functions (3/5)

Let us make use of the distinctions just introduced to interpret the attribute functions.

We introduce:

1. the set of things Apple;
2. the qualia kind (a set of inexactly resembling tropes) $\mathsf{Colored}$;
3. the (second order) axiom

   $$\mathsf{Apple}(x) \rightarrow \exists t, Q(i(t,x) \wedge Q(t) \wedge dD(Q, \mathsf{Colored}) \wedge \neg \exists Q'(dD(Q', Q)))$$

   Note. In BWW given a $m \in M$, the value of an attribute needs to be defined:

   $$(x \in \mathsf{Apple} \wedge m \in M) \rightarrow \exists v \in Color(\mathsf{color}(x, m) = v)$$

Attribute Functions (4/5)

To avoid second order quantification, we reify qualia kinds and their determinates:

- ▷ colored is the reification of the attribute (qualia kind) Colored;
- ▷ q is the reification of property Q that is a determinate of a qualia kind, in particular qualia are identified by:

  $\mathsf{Qualia}(q)$ **iff** $\neg\exists q'(dD(q', q))$

- ▷ a *classification* relation (::) between tropes and properties is introduced (a generalization of membership and instantiation).
- ▷ The previous axiom can be rewritten as:

  $\mathsf{Apple}(x) \rightarrow \exists t, q(i(t, x) \wedge \mathsf{Qualia}(q) \wedge t :: q \wedge dD(q, \mathsf{colored}))$

Attribute Functions (5/5)

▷ A function color from *things* to *qualia* can be defined as:

$\mathsf{color}(x) = q$ **iff** $\exists t(i(t,x) \wedge t :: q \wedge dD(q, \mathsf{colored}))$

assuming the incompatibility of qualia of the same quality kind:

- $(i(t,x) \wedge t :: \mathsf{colored}) \rightarrow \neg\exists t'(t \neq t' \wedge i(t',x) \wedge t' :: \mathsf{colored})$
- $t :: \mathsf{colored} \rightarrow \exists q(\mathsf{Qualia}(q) \wedge t :: q \wedge dD(q, \mathsf{colored}))$

Two basic differences with respect to the color function in BWW:

▷ the additional argument (M) is missing;

▷ color yields now "qualia" instead of "values"
(we will go back to this point).

Time and change in time

▷ One of the reason of the argument M in BWW is the encoding of the change of properties of things through time.

▷ Like other particulars, tropes can have a temporal extension.

▷ Let us suppose that the function time yields the temporal extensions of particulars, then, we can introduce a temporal argument in the previous color function:

$$\mathsf{color}(x, m) = q \textbf{ iff } \exists t(i(t, x) \wedge \mathsf{time}(t) = m \wedge t :: q \wedge dD(q, \mathsf{colored}))$$

$\Rightarrow$ change in time as *substitution* of tropes;

$\Rightarrow$ explicit recording of the "color history" of an object.

– Note. The same can be done for relationships.

Attributes of Attributes (1/2)

▷ In the previous example, the function time can be seen as an attribute of tropes that yields temporal qualia.

▷ Consequently, we admit tropes that inhere in tropes.

▷ Very useful in the case of complex tropes like *symptoms*, e.g. John's headache and influenza are tropes inhering in John and they are different from the ones inhering in another patients.

▷ Different *symptoms* can:

- occur at different times;
- have specific temporal/causation relations;

Attributes of Attributes (2/2)

Another interesting representational problem regards roles, e.g.:

- if the instances of Customer are persons (or organizations) and code is an attribute of Customer, therefore to each person it is possible to associate only one customer code.

  But, at the same time, the same person can be customer of different stores, therefore he can have a multitude of different codes, one for each store.

- ▷ A possible solution consists in introducing code as an attribute of a class of (relational) tropes that inhere in persons and stores.

Qualia vs. Values

- ▷ What is the ontological nature of values in BWW?
  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?
- ▷ Qualia are specific properties, therefore "being 1m high" and "being 1m long" are just two different properties.
- ▷ The same qualia 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.

Spaces of properties (1/3)

▷ Objects sharing a *quale* are *exactly similar* (w.r.t. some given aspect).

▷ In general, objects sharing a *determinable* are *inexactly similar*, i.e. they resemble each other with a *degree*.

But *in applications*, we find a variety of degrees of resemblance

▷ they are *empirically* determined by the chosen experiments and depend on species, culture, available information, measurement instruments and methods, etc.

▷ they furnish (roughly speaking) spaces of properties with quite different structures.

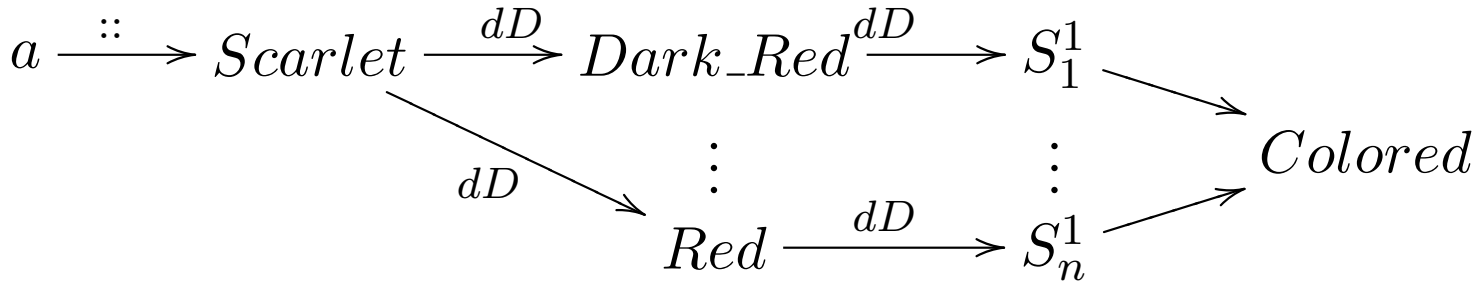
Spaces of properties (2/3)

- ▷ Resemblance with *degree* simply introduces a partial order among properties.
  - Spaces have more structure: they add further relations like those determining a topological or geometrical space.
- ▷ Each qualia kind is associated to (can be structured in) one or more spaces which depend on culture, instruments of investigation, etc.
- ▷ Spaces exist *in time*: they are created, adopted, and destroyed by (communities of) intentional agents.

Spaces of properties (3/3)

Taking exact similarity and qualia to be *objective*, they are *contextually* organized in spaces.

▷ Qualia are linked to possibly different *properties* in spaces.



▷ Structuring relations can be added into specific spaces, e.g. $\mathsf{Connected}(Brown, Red)$.

▷ Different granularities can be assumed in different spaces, e.g. $Dark\_Red$ is not considered in space S^1_n.

▷ Different measurement systems can be introduced in one space.

Multidimensional spaces (1/2)

- ▷ Simple spaces can be composed in more complex spaces by means of *existential dependences* among tropes and qualia, e.g. the color space (trope) can be seen as composed by three spaces (tropes): hue, saturation, and brightness.
- ▷ Constraints (*laws*) on qualia in the same simple space or multi-dimensional spaces, e.g. the linearity of weights, or the splinter shape of the color space, can be introduces as constraints on relations between qualia.

Multidimensional spaces (2/2)

Alternative spaces can be considered also for complex attributes like color:

- ▷ We can map the same color-quale $q = \mathsf{color}(x)$ to different *regions* (in different spaces).
- ▷ Each region of space can be the result of the composition of other regions belonging to simpler spaces, for example the hue, saturation, and brightness spaces.
- ▷ The qualia kind is associated just to one *space kind*, i.e. all the color qualia are mapped to regions in color-spaces.