



The basic tools of ontological analysis

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Summary

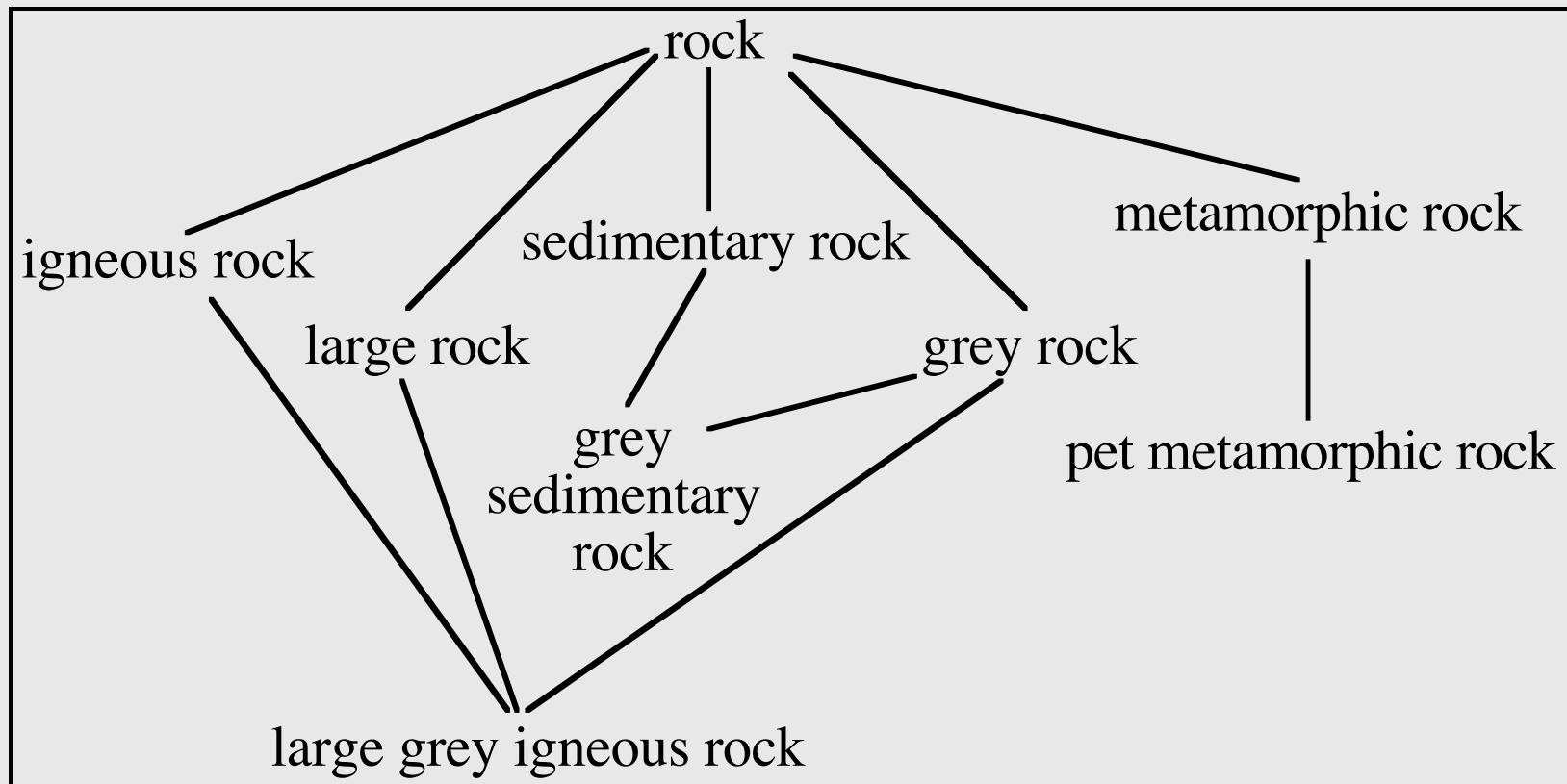
- The ontological level: which kind of *controlled language*?
- The basic tools of formal ontology
- DOLCE top-level distinctions



1. The ontological level

Kinds, roles, attributions

How many rock kinds are there?



[From Brachman, R. J., R. Fikes, et al. 1983. "Krypton: A Functional Approach to Knowledge Representation", *IEEE Computer*]



The answer

- According to Brachman & Fikes 83:
 - It's a dangerous question, only “safe” queries about analytical relationships between terms should be asked
- In a previous paper by Brachman and Levesque on *terminological competence in knowledge representation* [AAAI 82]:
 - “an *enhancement mode transistor* (which is a *kind* of transistor) should be understood as different from a *pass transistor* (which is a *role* a transistor plays in a larger circuit)”
- These issues have been simply *given up* while striving for logical simplification and computational tractability
- The OntoClean methodology, based on formal ontological analysis, allows us to conclude: *there are 3 kinds of rocks* (appearing in the figure)



A single, imperialistic ontology?

- An ontology is first of all **for understanding each other**
 - ...among people, first of all!
 - not necessarily for thinking in the same way
- A single ontology for multiple applications **is not necessary**
 - Different applications using different ontologies can co-exist and co-operate (not necessarily inter-operate)
 - ...if linked (and compared) together **by means of a general enough basic categories and relations (*primitives*)**.
- If basic assumptions are not made explicit, any imposed, common ontology risks to be
 - seriously mis-used or misunderstood
 - opaque with respect to other ontologies



Which primitives?

The role of ontological analysis

- Theory of Essence and Identity
- Theory of Parts (Mereology)
- Theory of Wholes
- Theory of Dependence
- Theory of Composition and Constitution
- Theory of Properties and Qualities

**The basis for a common ontology
vocabulary
(the “controlled vocabulary”)**

*Idea of Chris Welty, IBM Watson Research
Centre, while visiting our lab in 2000*

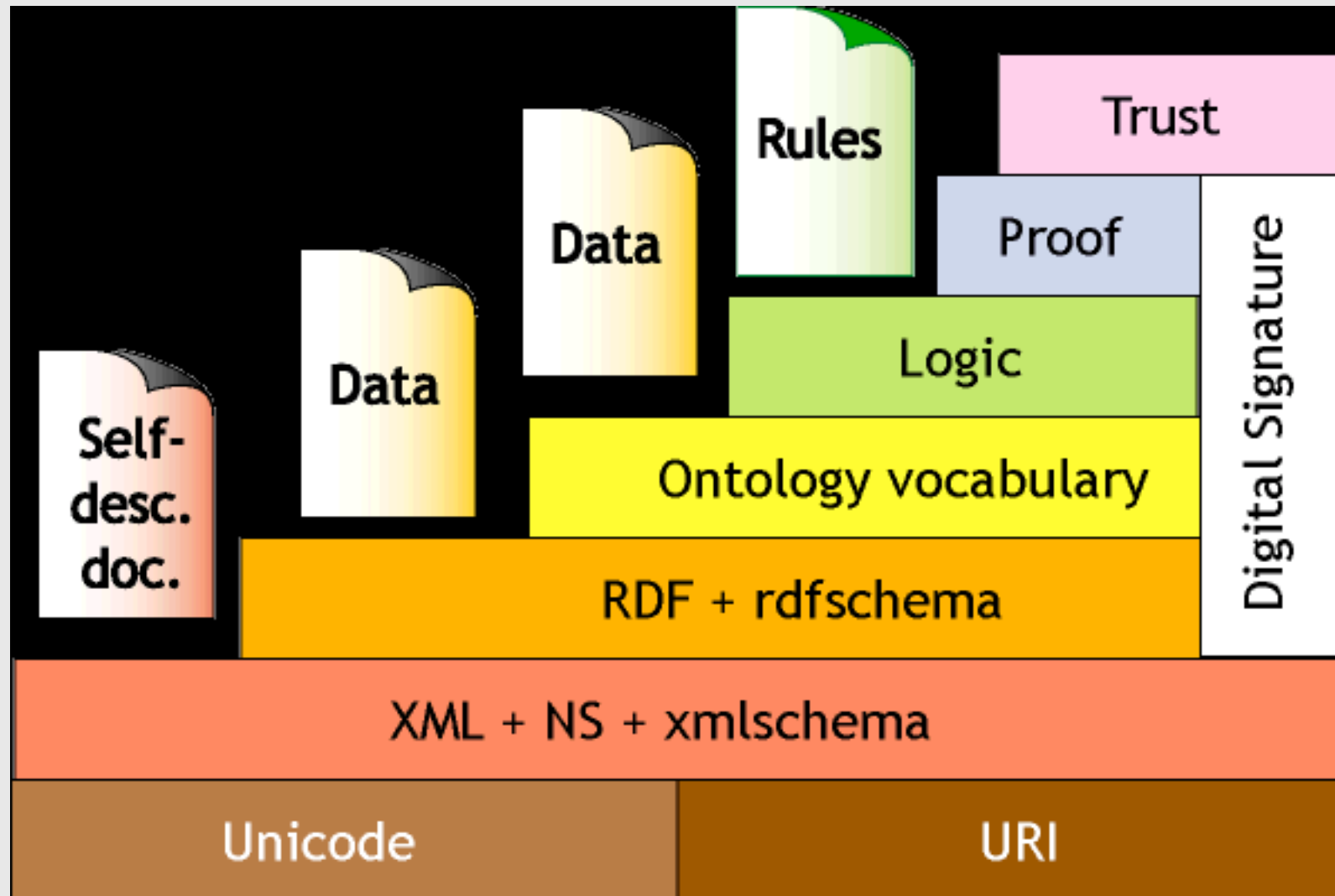


The Ontological Level

(Guarino 94)

<i>Level</i>	<i>Primitives</i>	<i>Interpretation</i>	<i>Main feature</i>
Logical	Predicates, functions	Arbitrary	Formalization
Epistemological	Structuring relations	Arbitrary	Structure
Ontological	Ontological relations	Constrained (meaning postulate s)	Meaning
Conceptual	Conceptual relations	Subjective	Conceptualization
Linguistic	Linguistic terms	Subjective	Language dependence

The semantic web architecture [Tim Berners Lee 2000]





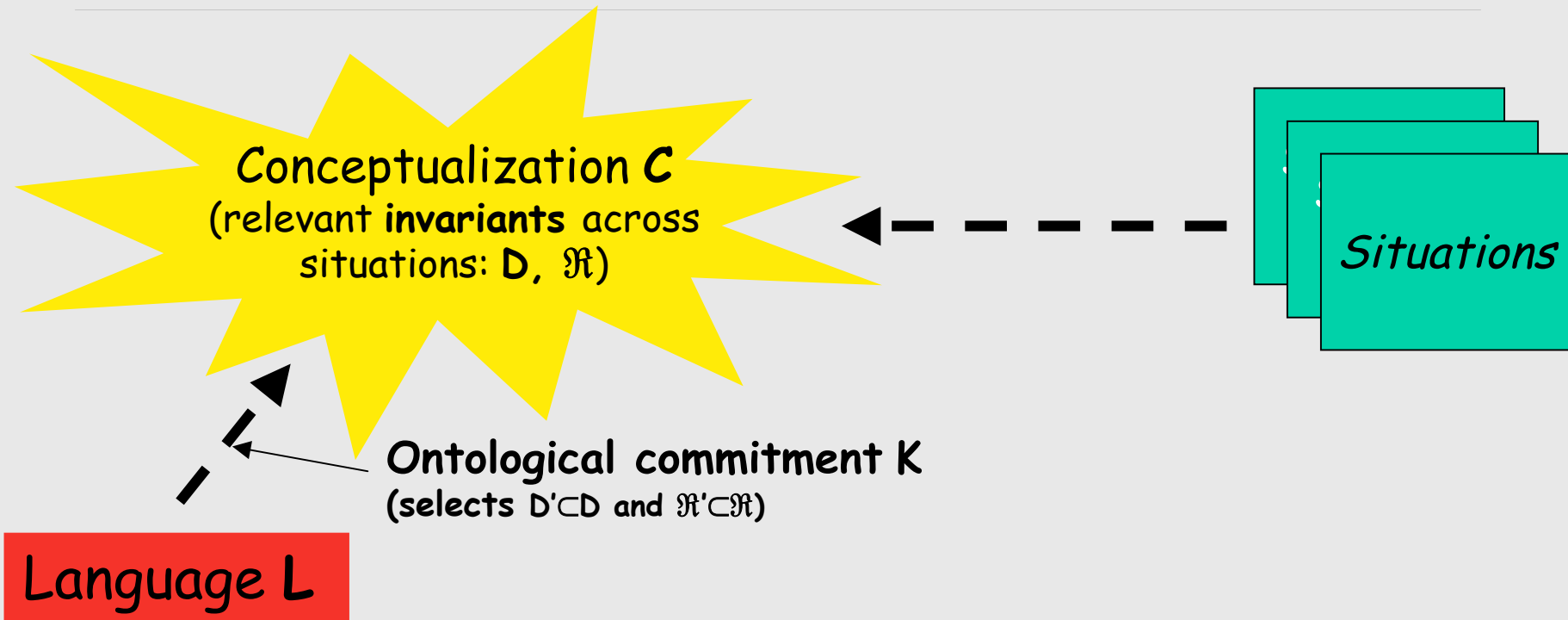
2. The tools of Formal Ontology

Formal Ontology

- Theory of **formal distinctions and connections** within:
 - entities of the world, as we perceive it (**particulars**)
 - categories we use to talk about such entities (**universals**)
- Why **formal**?
 - Two meanings: **rigorous** and **general**
 - Formal logic: connections between truths - neutral wrt **truth**
 - Formal ontology: connections between things - neutral wrt **reality**



The first steps of ontological analysis



- Be clear about the *domain of discourse* (existence...)
- Choose the relevant *concepts and conceptual relations*
- Choose the *primitive relations*
- Choose meaningful *names* for these

Essential properties

- For an individual
 - John must have a brain
 - John must be a human
 - John must be alive
- For a type
 - All human beings must have a brain
 - All human beings must be “a whole” (all of a piece)



Essential properties and rigidity

- Certain entities **must** have some properties in order to *exist*
 - John must have a brain
 - John must be a person.
- Certain properties are essential to **all** their instances (***being a person*** vs. ***being hard***).
- These properties are **rigid** - Their extension is the same in all possible worlds. If an entity is ever an instance of a rigid property, it must necessarily be such.
- By the way, what's the meaning of *exist*?
 - Being an element of the domain of discourse
 - Being present *at a certain time* (or in a certain world...)



Carrying essential properties

- A property P *carries* an **informative** essential property Q (different from P) iff Q is essential to all instances of P, **and yet Q is not rigid**:
 - Every person must have a brain.
- Compare with:
 - Every person must be a mammal.

Carrying an informative essential property implies carrying a (minimal) **identity criterion**



Identity criteria

- *Classic formulation:*

$$\phi(x) \wedge \phi(y) \rightarrow (\rho(x,y) \leftrightarrow x = y)$$

(ϕ carries the identity criterion ρ)

- *Generalization:*

$$\phi(x,t) \wedge \phi(y,t') \rightarrow (\Gamma(x,y,t,t') \leftrightarrow x = y)$$

(synchronic: $t = t'$; diachronic: $t \neq t'$)

- In most cases, Γ is based on the **sameness** of certain **characteristic features**:

$$\Gamma(x,y,t,t') = \forall z (\chi(x,z,t) \wedge \chi(y,z,t'))$$

- **Non-triviality condition:**

- $\Gamma(x,y,t,t')$ must not contain an identity statement between x and y !



Heuristics for Identity

- Finding necessary *and* sufficient ICs for a given property may be ***very hard***.
- Heuristic 1: ***at least a sufficient IC***.
- Heuristic 2: ***some essential parts or qualities***
- Heuristic 3: ***some essential (non-rigid) properties***



Carrying vs. Supplying Identity

- **Supplying** (global) identity (+O)
 - Carrying an IC (or relevant essential property) that doesn't hold for *all* directly subsuming properties
- **Carrying** identity (+I)
 - Not supplying identity, while being subsumed by a property that does.
- **Common sortal principle**: $x=y \rightarrow$ there is a common sortal supplying their identity
- Theorem: only rigid properties supply identity



Sortals and other properties

- **Sortals** (*horse, triangle, amount of matter, person, student...*)
 - Carry (non-trivial) identity conditions
 - Usually correspond to **nouns**
 - High organizational utility
- **Non-sortals** (*red, big, old, decomposable, dependent...*)
 - No identity
 - Usually correspond to **adjectives**
 - Span across different sortals
 - Limited organizational utility (but high semantic value)



Identity Disjointness Constraint

ICs impose *constraints* on sortals, making their ontological nature explicit:

Properties with incompatible ICs are *disjoint*

Examples:

- countries vs. geographical regions
- passengers vs. persons
- assemblies vs. amounts of matter
- sets vs. ordered sets



What about our rocks?

- *Igneous rock, metamorphic rock, sedimentary rock*
do supply informative essential properties.
- *Large rock, grey rock, pet rock*
DO NOT!
- Not all properties are the same...



Sortal specialization

- **Type** specialization (e.g. Living being → Person)
 - New features (especially essential properties) **affect identity**
 - ICs are added while specializing types
 - Polygon: same edges, same angles
 - Triangle: two edges, one angle
 - Living being: same DNA, etc...?
 - Zebra: same stripes?
- **Role** specialization (e.g. Person → Student)
 - New features **don't affect identity**



Roles are ‘dynamic’ and ‘antirigid’

Basic Idea (Steimann 2000): Roles have temporal/modal relations with their players

- An entity can play different roles simultaneously
 - *In 2003, B. was the Italian Prime Minister, the President of the European Union, the president of the Forza Italia party, the owner of the Mediaset company, an Italian citizen, a defendant at a legal trial.*
- An entity can cease playing a role (*antirigidity*)
 - *In 1960, B. was a piano bar singer, now he is the IPM.*
- An entity can play the same role several times, simultaneously
 - *In 2003, B. had two presidencies / was president twice.*
- A role can be played by different entities, simultaneously or at different times
 - *Today, there are 4319 Italian National Research Council researchers.*
 - *In 2000, the Italian Prime Minister was D., now it is B.*



Roles have a relational nature

- Basic Idea (Sowa)
Roles imply *patterns of relationships* (contexts), i.e., they **depend**—via these patterns—on additional ‘external’ properties

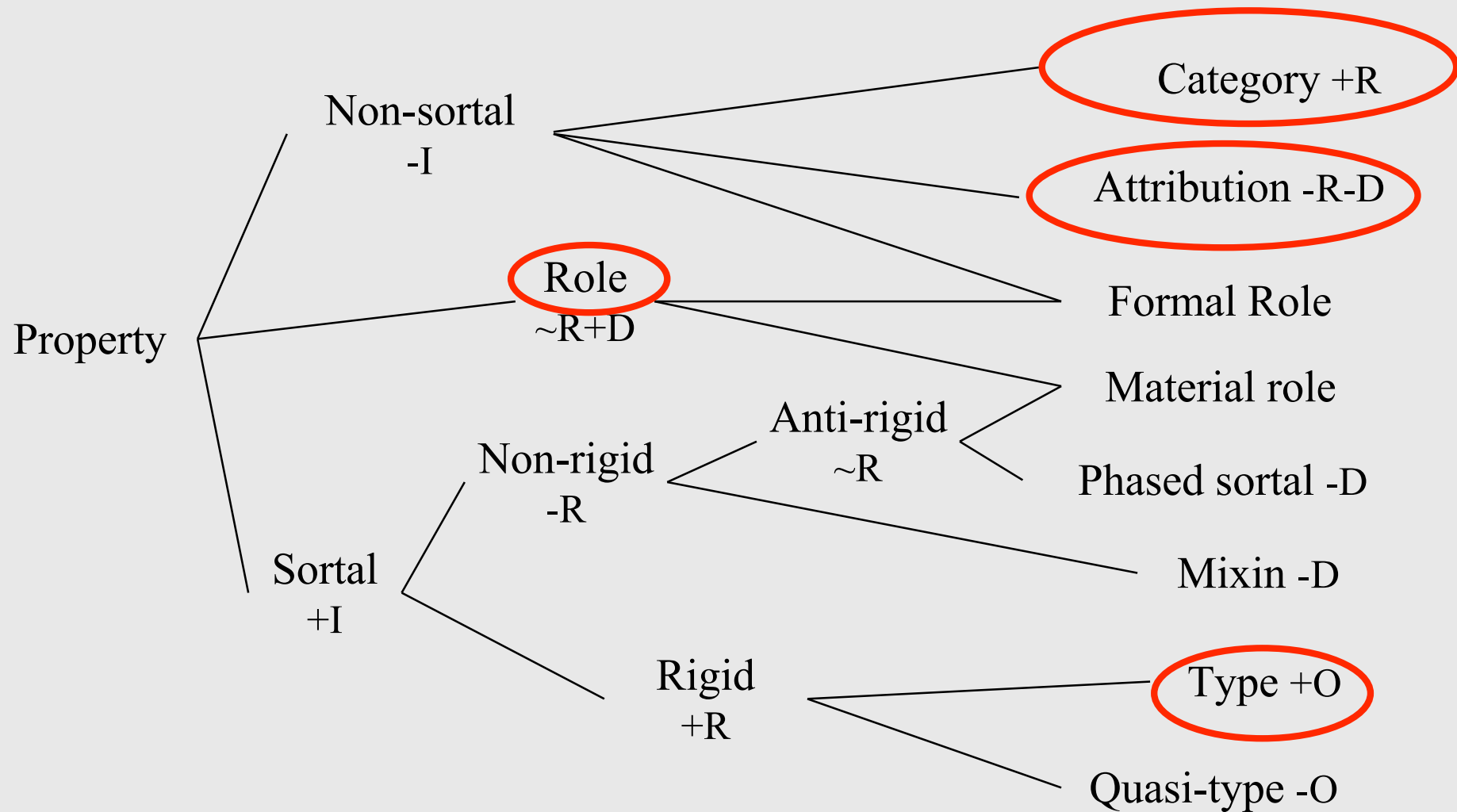


Dependence

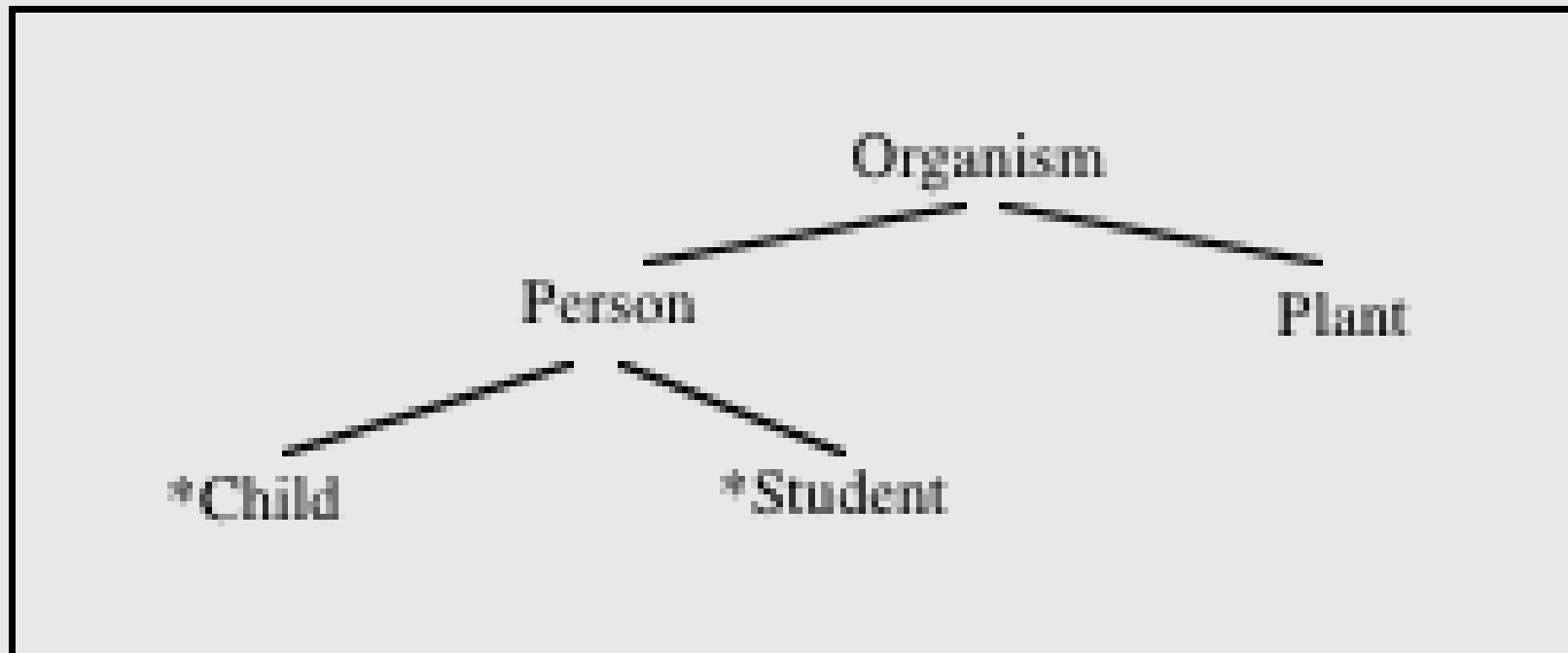
- Between particulars
 - **Existential dependence** (specific/generic) (also *constant dependence*)
 - Hole/host, person/brain, person/heart
 - Historical dependence
 - Person/parent
 - Causal dependence
 - Heat/fire
- Between universals
 - **Definitional dependence**
 - P depends on Q iff Q is involved in the **definition** of P .
 - Metaproperties: +D/-D



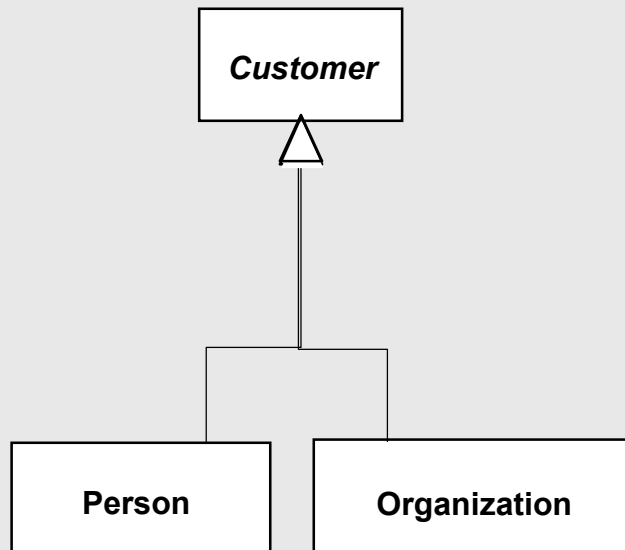
A formal ontology of properties



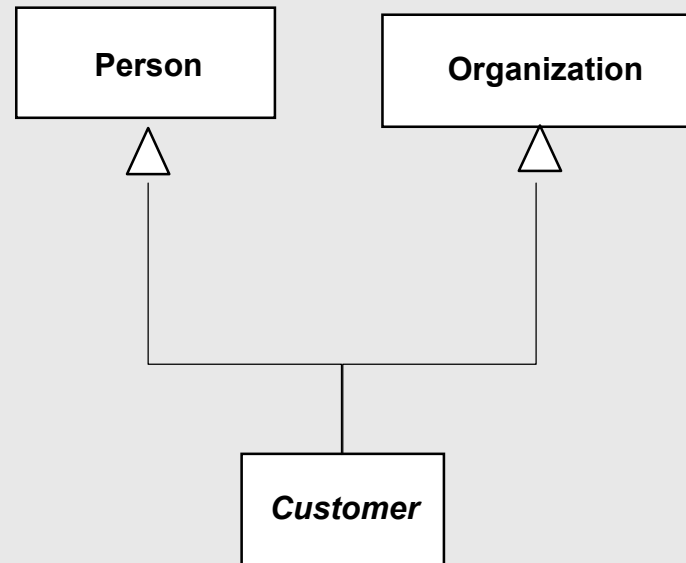
Types, Roles, and disjointness



What's the right model?



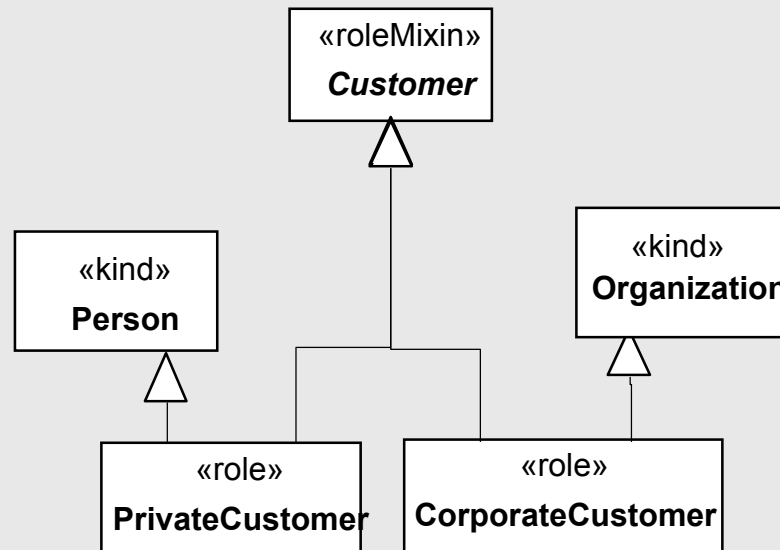
a



b

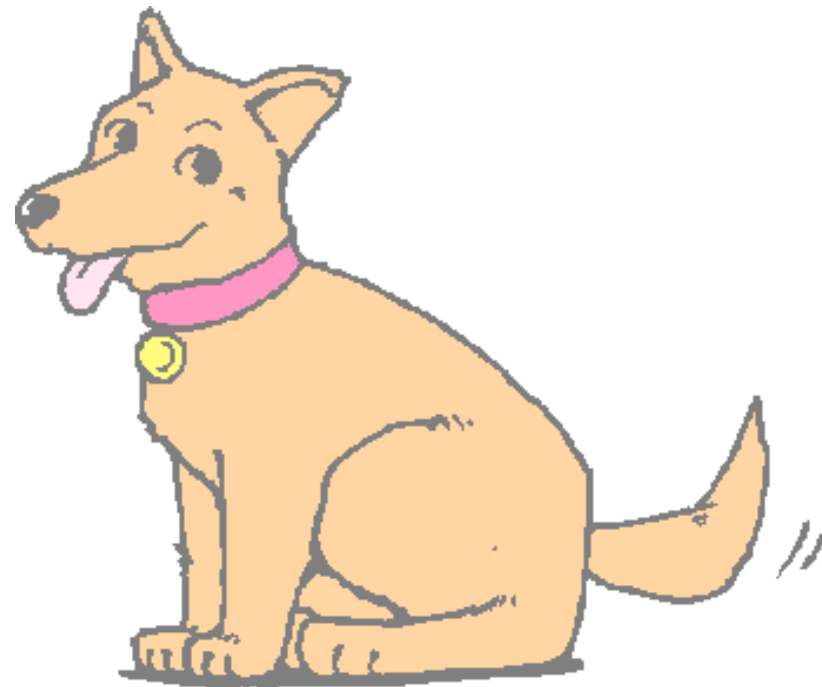


The solution [Guizzardi 2005]



Unity, Identity, and Essence

- **Unity**: is the collar part of my dog?
 - **Being a whole** (of a certain kind) is also a (relevant) essential property
- **Identity**: is this my dog?
 - Essential properties of **dogs**
 - Essential properties of **my dog**



Kinds of Whole

- Depending on the **nature of the *unifying relation***, we can distinguish:
 - ***Topological wholes*** (a piece of coal, a heap of coal)
 - ***Morphological wholes*** (a constellation)
 - ***Functional wholes*** (a hammer, a bikini)
 - ***Social wholes*** (a population)
- * a whole can have ***parts that are themselves wholes*** (with a different unifying relation)



Unity and Plurality

- *Ordinary objects: **wholes or sums of wholes***
 - *Singular: **no wholes as proper parts***
 - *Plural: **sums of wholes***
 - *Plural wholes (the sum is **also a whole**)*
 - *Collections (the sum is not a whole)*



*Dolce: motivating its
ontological distinctions*

DOLCE

a Descriptive Ontology for Linguistic and Cognitive Engineering

- Strong cognitive/linguistic bias:
 - **descriptive** (as opposite to *prescriptive*) attitude
 - Categories mirror cognition, common sense, and the lexical structure of natural language.
- Emphasis on **cognitive invariants**
- Categories as **conceptual containers**: no “deep” metaphysical implications
- Focus on **design rationale** to allow easy comparison with different ontological options
- Rigorous, systematic, interdisciplinary approach
- **Rich axiomatization**
 - *37 basic categories*
 - *7 basic relations*
 - *80 axioms, 100 definitions, 20 theorems*
- Rigorous quality criteria
- Documentation



The cognitive emergence of *objects* and *events*

- Humans isolate **relevant invariances** from physical reality (quality distributions) on the basis of:
 - Perception (as resulting from evolution)
 - Cognition and cultural experience
 - Language
- A set of **atomic stimuli** (input pattern) is associated to each situation
- Synchronic level: **spatial invariants**
 - Unity properties are **ascribed** to input patterns: topological and morphological wholes (**percepts**) emerge
- Diachronic level: **temporal invariants**
 - **Objects** : equivalence relationships among input patterns belonging to different situations
 - **Events** : unity properties are ascribed to percepts patterns belonging to different situations



DOLCE's basic taxonomy

Object (endurant)

Physical

Amount of matter

Physical object

Feature

Non-Physical

Mental object

Social object

...

Event (perdurant)

Static

State

Process

Dynamic

Achievement

Accomplishment

Quality

Physical

Spatial location

...

Temporal

Temporal location

...

Abstract

Abstract

Quality region

Time region

Space region

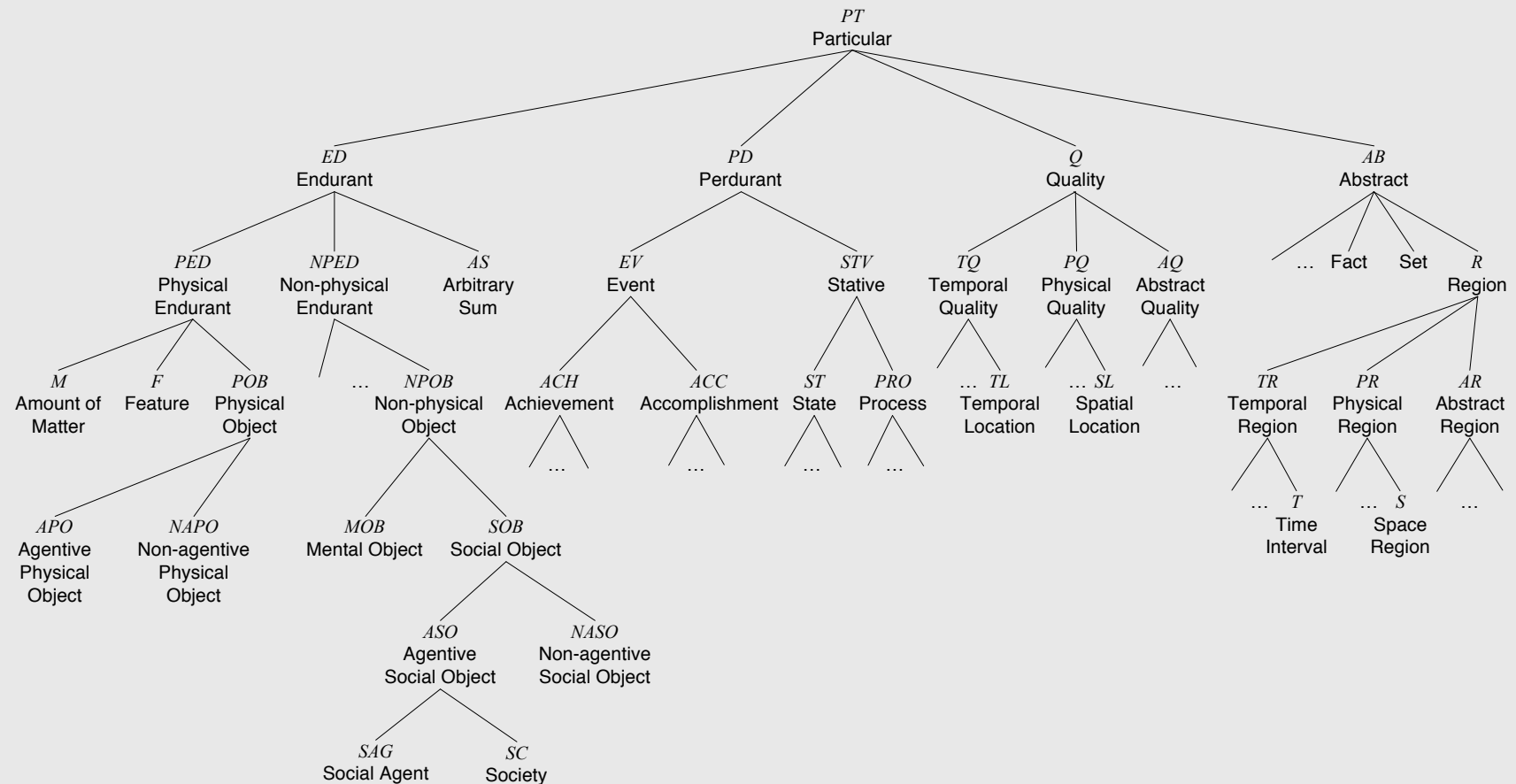
Color region

...

...



DOLCE taxonomy



DOLCE's Basic Ontological Choices

- **Objects** (aka *continuants* or *endurants*) and **Events** (aka *occurrences* or *perdurants*)
 - distinct categories connected by the relation of *participation*.
- **Qualities**
 - Individual entities *inhering in* Objects or Events
 - can live/change with the objects they inhere in
 - Instance of *quality kinds*, each associated to a **Quality Space** representing the "*values*" (*qualia*) that qualities (of that kind) can assume. Quality Spaces are neither in time nor in space.
- **Multiplicative approach**
 - Different Objects/Events can be spatio-temporally co-localized: the relation of *constitution* is considered.



Objects and Events

- Objects (3D *continuants*)
 - Need a time-indexed parthood relation
 - Exist in time
 - Can genuinely change in time
 - May have non-essential parts
 - All proper parts are present whenever they are present (wholly presence, no temporal parts)
- Events (4D *occurrences*)
 - Do not need a time-indexed parthood relation
 - Happen in time
 - Do not change in time (*as a whole...*)
 - All parts are essential
 - Only some proper parts are present whenever they are present (partial presence, temporal parts)
- Objects *participate to* Events

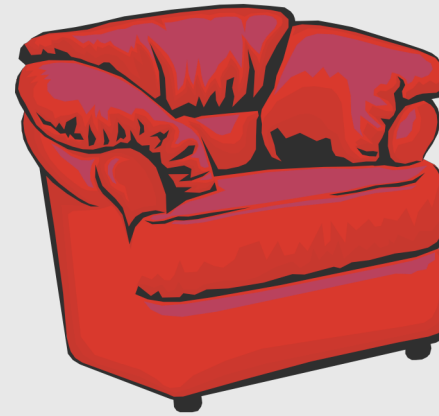


Qualities and qualia

- 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*
- Each object or 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



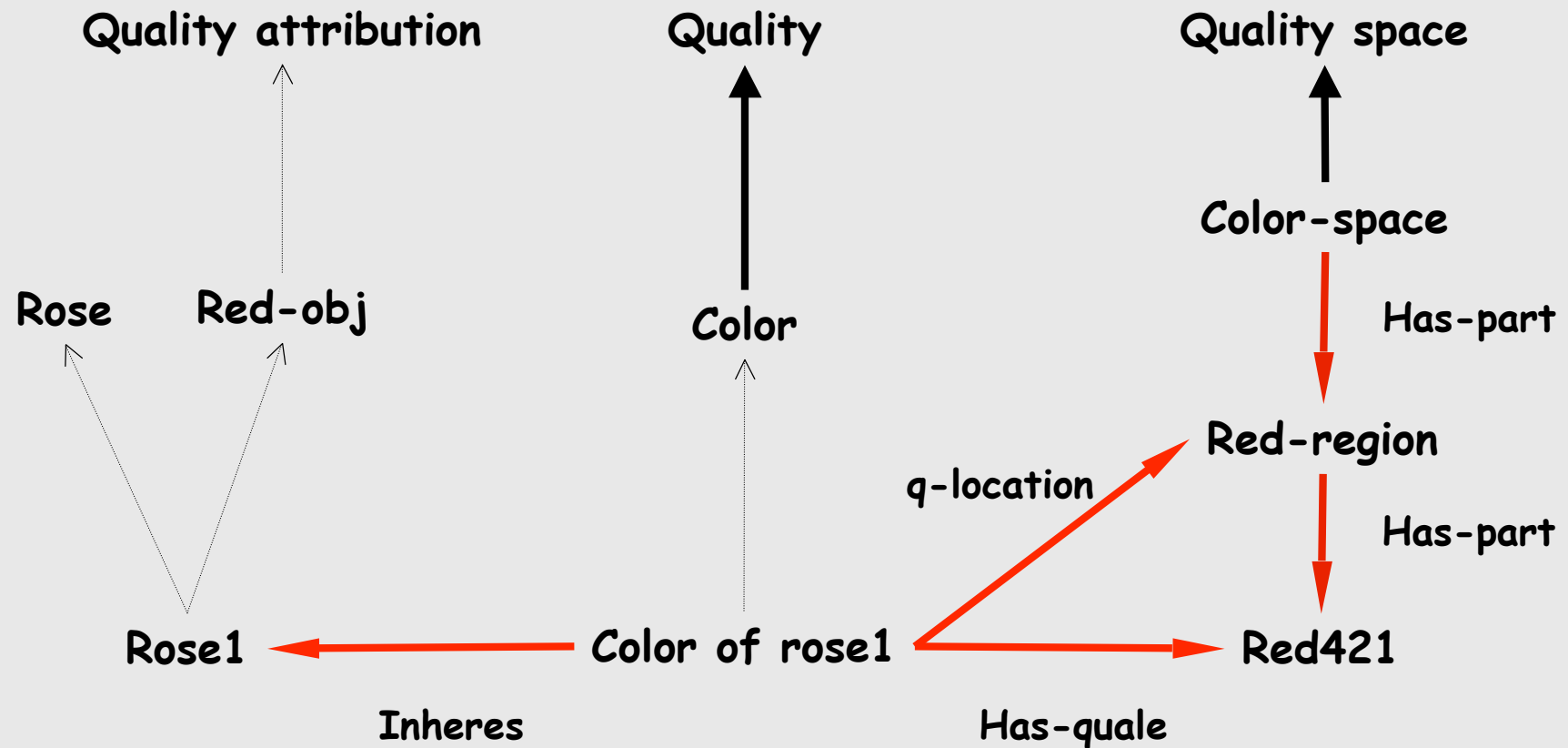
The rose and the chair have *the same color*:

- 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



Qualities



Qualities vs. Features



- **Features:** “parasitic” physical entities.
- **relevant parts** of their host...
... or **places**
- Features have qualities, qualities have no features.



Abstract vs. Concrete Entities

- Concrete:
 - located (at least) in time
- Abstract - two meanings:
 - Result of an abstraction process (something common to multiple exemplifications)
 - ☞ ***Not located in space-time*** (no inherent spatial or temporal location)
- Examples: ***propositions, sets, symbols, regions***, etc.
 - ***Quality regions*** and ***quality spaces*** are abstract entities
 - Mereological sums (of concrete entities) are concrete, the corresponding sets are abstract...



Physical vs. Non-physical Objects

- Physical objects
 - Inherent spatial localization
 - Not necessarily dependent on other objects



- Non-physical objects
 - No inherent spatial localization
 - Dependent on agents
 - mental (depending on singular agents)
 - social (depending on communities of agents)
 - Agentive: a company, an institution
 - Non-agentive: a law, the Divine Comedy, a linguistic system...
 - Descriptions, an extension of DOLCE

FIAT Co.

A new journal: *Applied Ontology*



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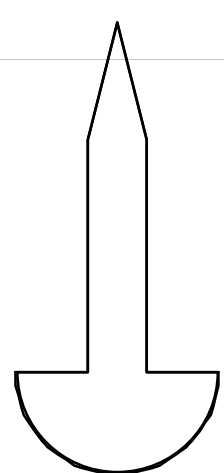
Conclusions

- Not all properties are the same
- Not all relations are the same
- Ontological distinctions *do matter*, and require to be represented *at the suitable level*
- “...*But this is hard!!*”

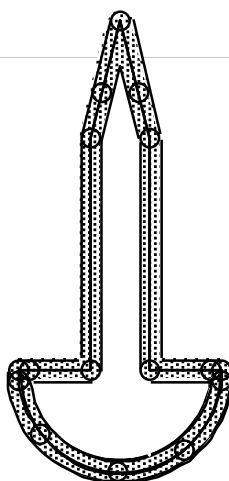
why should it be EASY?!



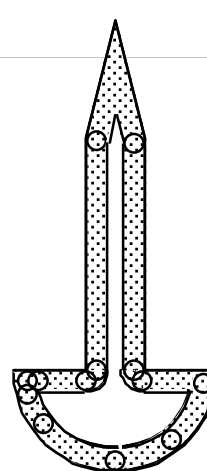
Boundaries, surfaces, and discontinuities



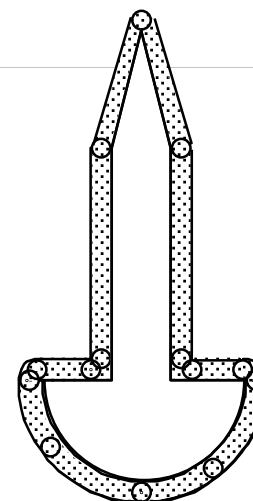
a nail



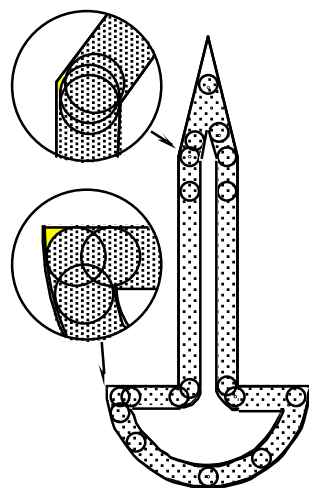
its *boundary*



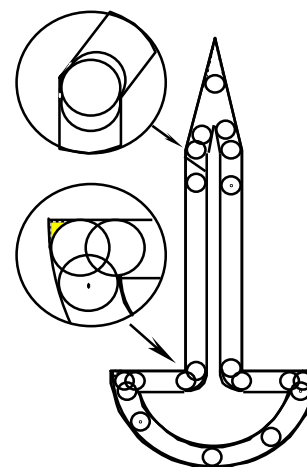
its *surface*



its *envelope*

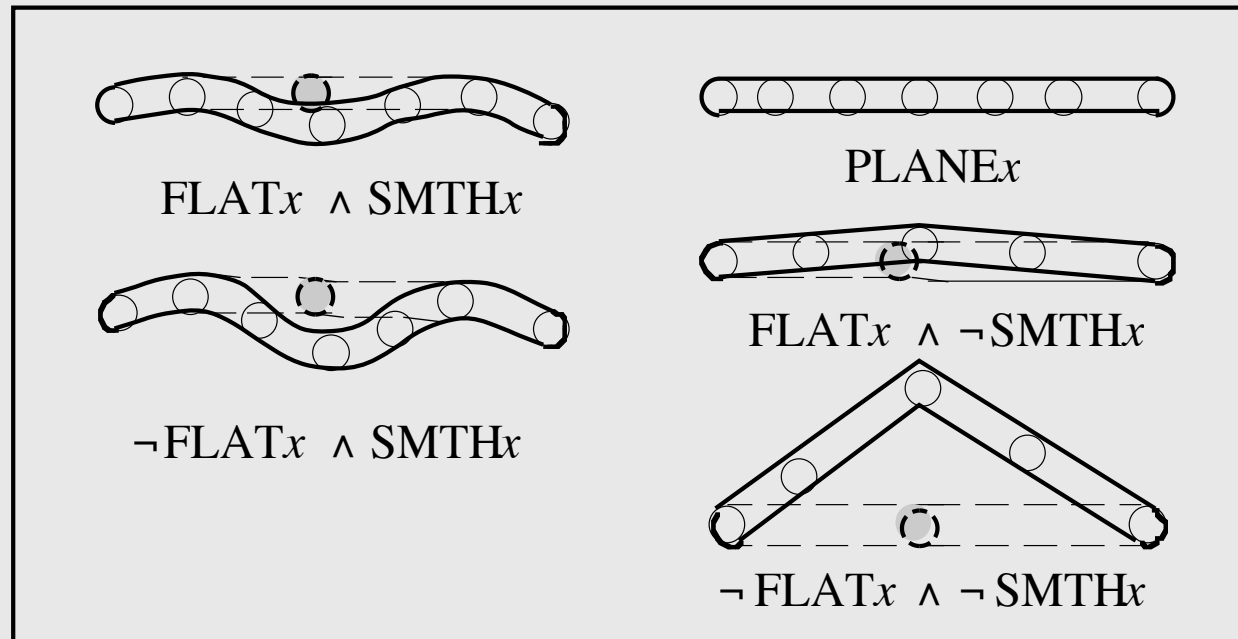


its *internal lining*



its *internal discontinuities*

Properties of boundary regions



Approximate solids

