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

Explaining the Descriptive Approach

- *Descriptive:* semantic structure of sentences is preserved (as best as possible)

- *Revisionary:* ontological eliminativism based on **paraphrasability**:

  - John gives a kiss to Mary (Mary is given a kiss by John)
  - John kisses Mary (Mary is kissed by John)

  - John gives a flower to Mary
  - *John flowers Mary

  - There is a hole in this wall
  - This wall is holed

  - This statue has a long nose
  - This statue is long-nosed

The traps of revisionism

- Is *systematic* paraphrasing really possible (also for complex sentences)?
    - There are 7 holes in this piece of cheese
- How to choose *whether* paraphrasing?
    - Mary makes a leap
    - Mary makes a cake
- Can we account for *proper inferences*?
    - There are two things John gave to Mary: a kiss and a flower

- *Where to stop* while eliminating entities?
    - Should we paraphrase everything in terms of bunches of molecules moving around?...

The rich ontology of natural language

Multiple *co-located events*

- ***John sings while taking a shower***

Multiple *co-located objects*

- I am talking here

- *This bunch of molecules is talking

- *What's here now is talking

- This statue is looking at me

- *This piece of marble is looking at me

- This statue has a strange nose

- *This piece of marble has a strange nose

Individual *qualities*

- The nurse measured the patient's temperature

- I like the color of this rose

- The color of this rose turned from red to brown in one week

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
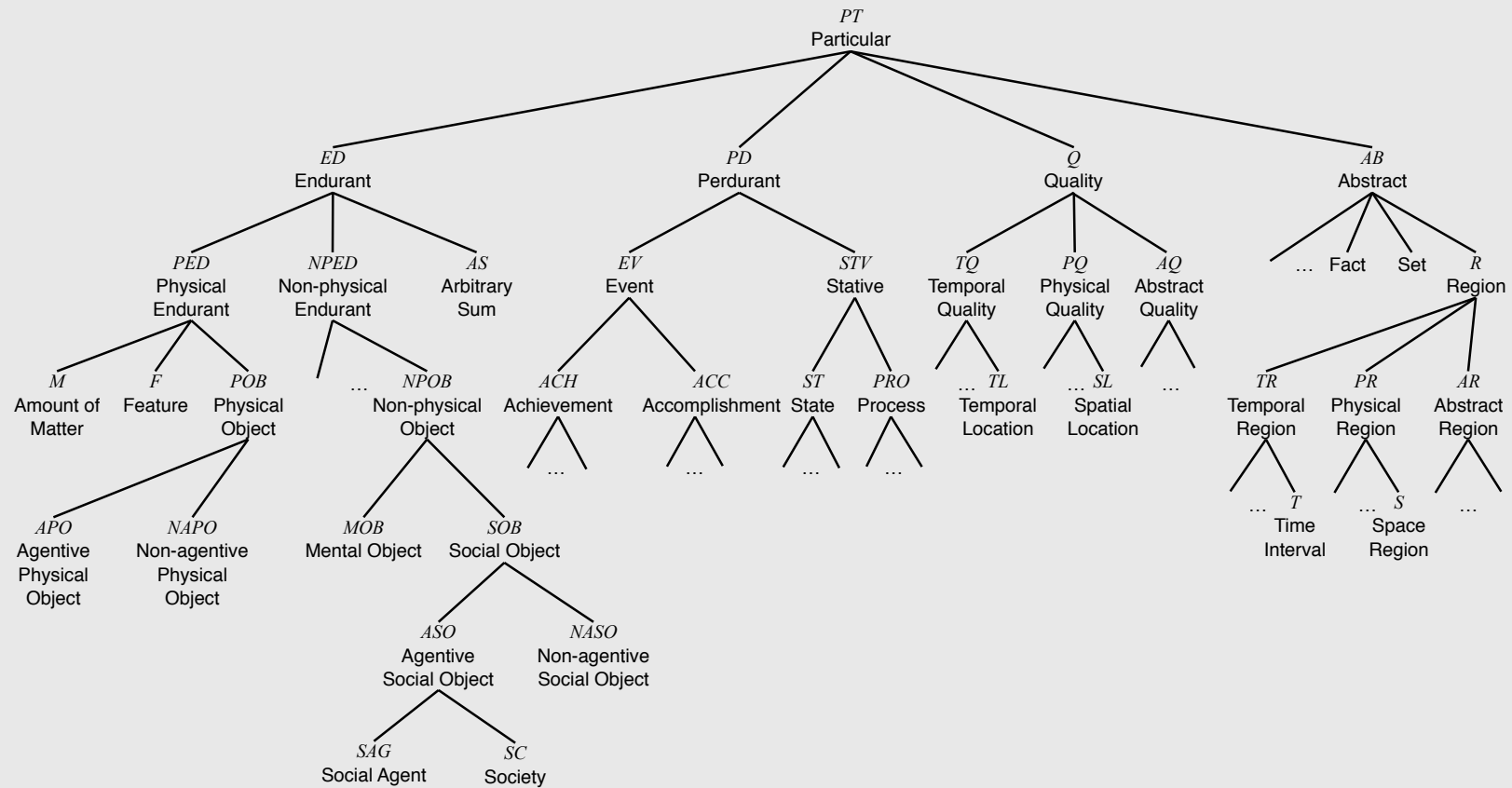   Space region
        Color region
        …
    …

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.

Some cognitive distinctions between objects and events (just intuitions!)

- Objects are *recognized,* events are just *perceived*

- Perceptions of events *accumulate in time*

- Perceptions of objects *superpose each other in time*

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

Instances, classes, and particualrs

- Being *instance-of* something vs. being an *instance*
  - Is "instancehood" a relative status?
  - Are there "ultimate instances"?
    - is the young Beethoven an instance of Beethoven?

- Instances vs. particulars
  - "instance" may be a relative notion
  - "particular" is not!
  - concrete entities are all particulars
  - so-called "temporal instances" are either *parts* of a particular or instances of an abstract *class*

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.
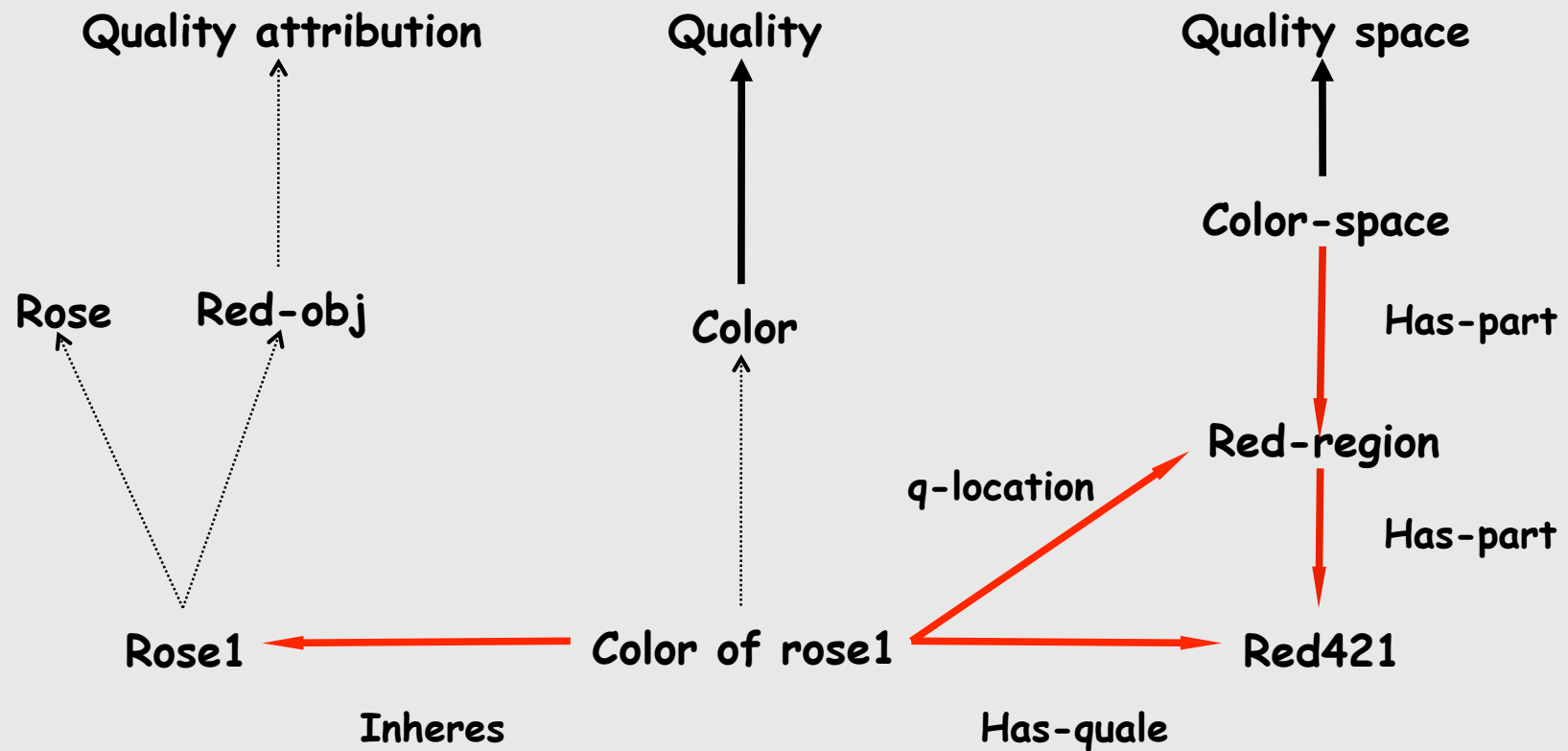- Each quality type has its own quality space

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

What's special with qualities?

- A simple attribute-value structure is not enough as a representation formalism: you need to put *individual qualities* in the domain of discourse

- Differently from instances of other ottributes, individual qualities are existentially dependent on their bearers

- The so-called *determinable/determinate issue* is not actually an issue:
  - All regions in a quality space correspond to *determinables*
  - Corresponding properties holding for objects with qualities in these spaces are *determinate*
  - Red-color vs. red-thing...

- *redness* (a quality type) is very different from *red* (a color region) and has a quality space very different from that of colors...

Qualities vs. Features

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

Open issues

- Spatial and temporal location as qualities?
- Binary quality spaces?
- Multiple quality spaces allowed for a single quality kind?
- Relationships among qualities, dimension analysis
- Measurement

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.

Mapping with lexicons: the OntoWordNet project
(Aldo Gangemi, Alessandro Oltramari, Massimiliano Ciaramita)

- 809 synsets from WordNet1.6 directly subsumed by a DOLCE+ class
  - Whole WordNet linked to DOLCE+
  - Lower WordNet levels still need revision
- Glosses being transformed into DOLCE+ axioms
  - Machine learning applied jointly with foundational ontology
- WordNet "domains" being used to create a modular, general purpose domain ontology
- Ongoing work on ontological analysis of specific WordNet domains (cognition, emotion, psychological feature)
- Ongoing cooperation with Princeton University.

The OntoWordNet methodology

1. **Populate** a general ontology (DOLCE) by adding single synsets (or whole taxonomy branches) from a c. lexicon (upon suitable classification)

2. **Restructure** a c. lexicon by checking ontological constraints (e.g. *OntoClean* meta-properties) throughout the branches

3. **Merge** an ontology and a c. lexicon (includes 1. and 2.)

4. **Enrich** the resulting structure by extracting relationships from the glosses.

Formalizing DOLCE

Basic Relations

- Parthood
    - Between quality regions (immediate)
    - Between arbitrary objects (temporary)
- Dependence
    - Specific/generic constant dependence
- Constitution
- Inherence (between a quality and its host)
- Quale
    - Between a quality and its region (immediate, for unchanging entities)
    - Between a quality and its region (temporary, for changing entities)
- Participation
- Representation

Axiomatizing basic relations

- Domain restrictions

- Ground axioms (mainly algebraic)

- Links to other relations

- Dependence on time

Domain restrictions on basic relations

Parthood: "*x is part of y*"

$P(x, y) \rightarrow (AB(x) \vee PD(x)) \wedge (AB(y) \vee PD(y))$

Temporary Parthood: "*x is part of y during t*"

$P(x, y, t) \rightarrow (ED(x) \wedge ED(y) \wedge T(t))$

Constitution: "*x constitutes y during t*"

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

Participation: "*x participates in y during t*"

$PC(x, y, t) \rightarrow (ED(x) \vee PD(y) \wedge T(t))$

Quality: "*x is a quality of y*"

$qt(x, y) \rightarrow (Q(x) \wedge (Q(y) \vee ED(y) \vee PD(y)))$

Quale: "*x is the quale of y (during t)*"

$ql(x, y) \rightarrow (TR(x) \wedge TQ(y))$

$ql(x, y, t) \rightarrow ((PR(x) \vee AR(x)) \wedge (PQ(y) \vee AQ(y)) \wedge T(t))$

Kinds of dependence

$(D1)$ $\mathsf{SD}(x, y) =_{df} o(\exists t(\mathsf{PR}(x, t)) \wedge \forall t(\mathsf{PR}(x, t) \to \mathsf{PR}(y, t)))$ (*Specific Const. Dep.*)

$(D2)$ $\mathsf{SD}(\phi, \psi) =_{df} \mathsf{DJ}(\phi, \psi) \wedge o\forall x(\phi(x) \to \exists y(\psi(y) \wedge \mathsf{SD}(x, y)))$ (*Specific Const. Dep.*)

$(D3)$ $\mathsf{GD}(\phi, \psi) =_{df} \mathsf{DJ}(\phi, \psi) \wedge o(\forall x(\phi(x) \to \exists t(\mathsf{PR}(x, t)) \wedge$
         $\forall x, t((\phi(x) \wedge \mathsf{At}(t) \wedge \mathsf{PR}(x, t)) \to \exists y(\psi(y) \wedge \mathsf{PR}(y, t))))$ (*Generic Const. Dep.*)

$(D4)$ $\mathsf{D}(\phi, \psi) =_{df} \mathsf{SD}(\phi, \psi) \vee \mathsf{GD}(\phi, \psi))$ (*Constant Dependence*)

$(D5)$ $\mathsf{OD}(\phi, \psi) =_{df} \mathsf{D}(\phi, \psi) \wedge \neg \mathsf{D}(\psi, \phi)$ (*One-sided Constant Dependence*)

$(D6)$ $\mathsf{OSD}(\phi, \psi) =_{df} \mathsf{SD}(\phi, \psi) \wedge \neg \mathsf{D}(\psi, \phi)$ (*One-sided Specific Constant Dependence*)

$(D7)$ $\mathsf{OGD}(\phi, \psi) =_{df} \mathsf{GD}(\phi, \psi) \wedge \neg \mathsf{D}(\psi, \phi)$ (*One-sided Generic Constant Dependence*)

$(D8)$ $\mathsf{MSD}(\phi, \psi) =_{df} \mathsf{SD}(\phi, \psi) \wedge \mathsf{SD}(\psi, \phi)$ (*Mutual Specific Constant Dependence*)

$(D9)$ $\mathsf{MGD}(\phi, \psi) =_{df} \mathsf{GD}(\phi, \psi) \wedge \mathsf{GD}(\psi, \phi)$ (*Mutual Generic Constant Dependence*)
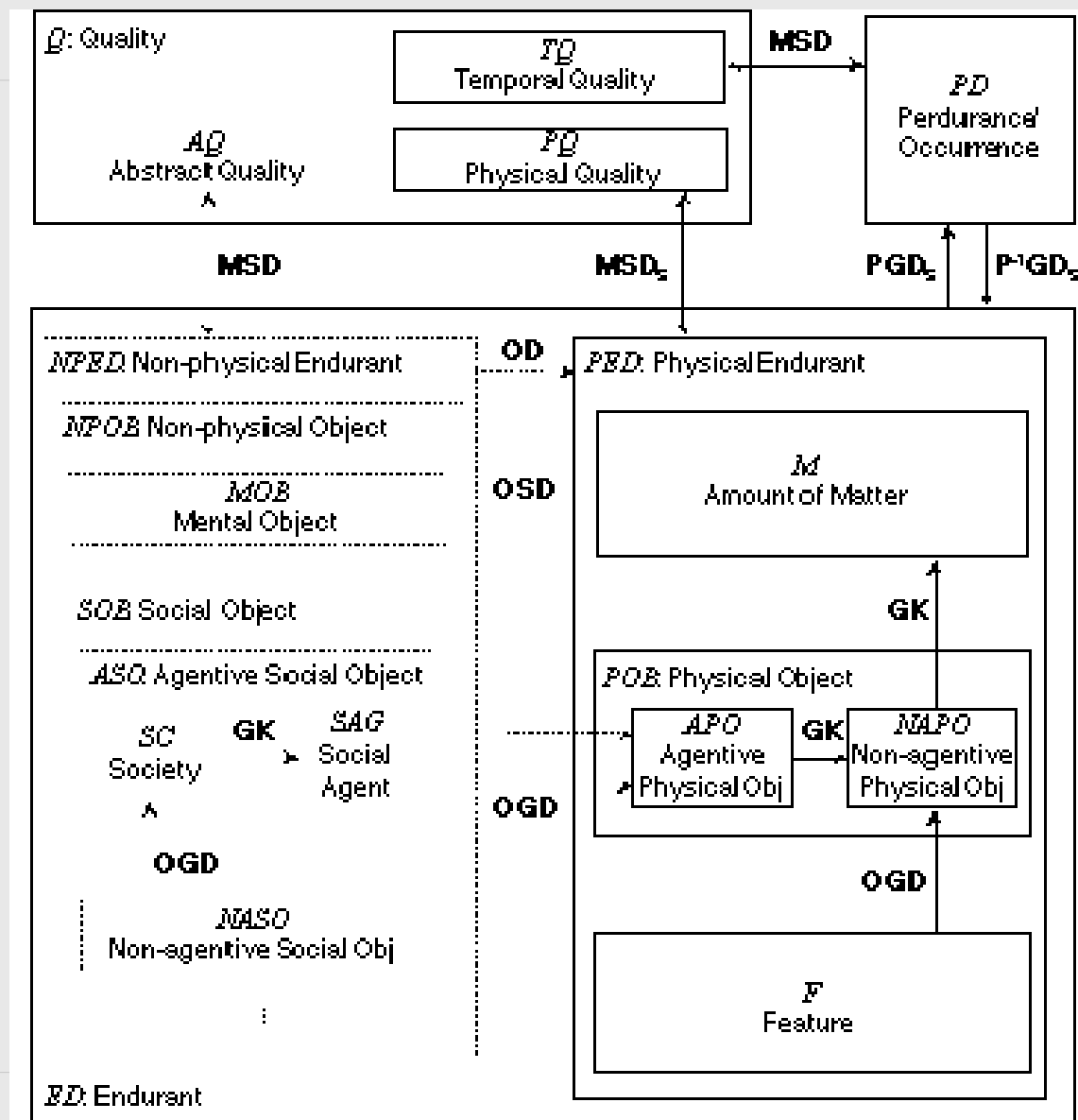
Quality relations
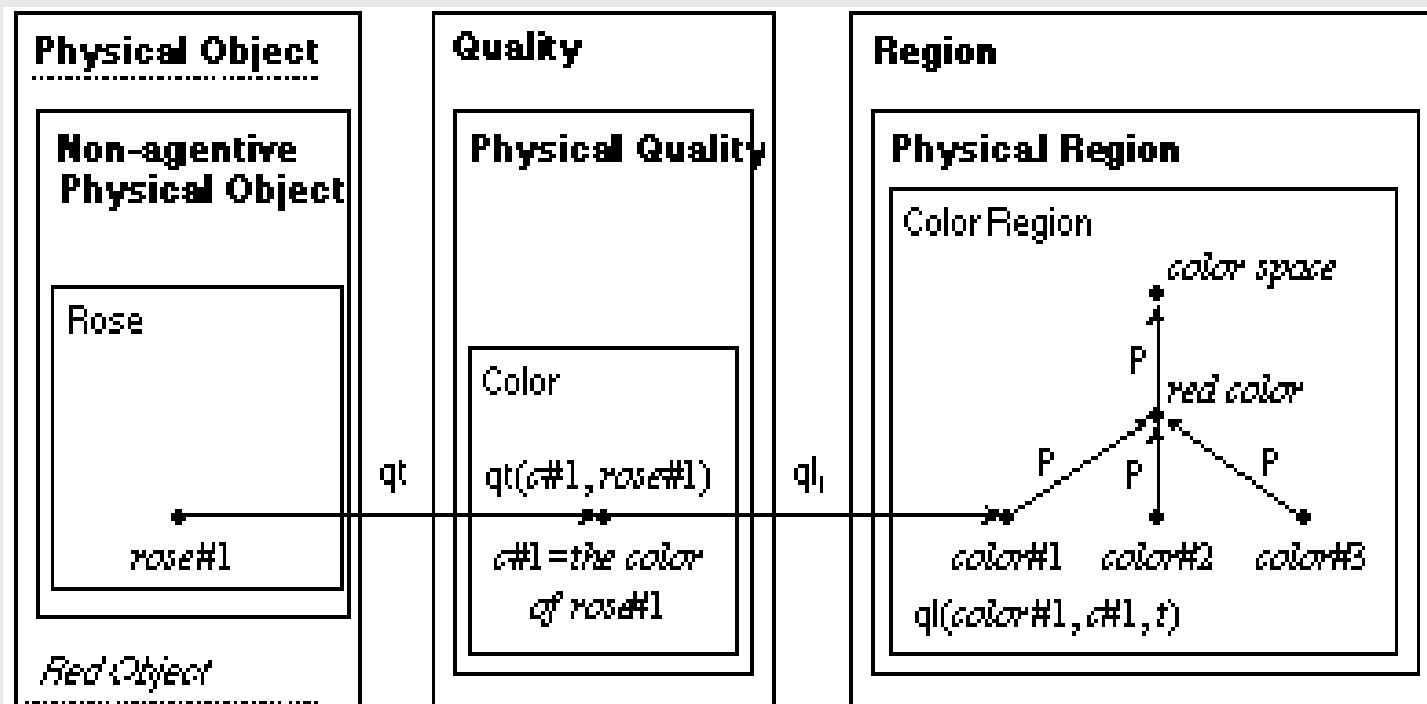
Primitive relations and basic categories
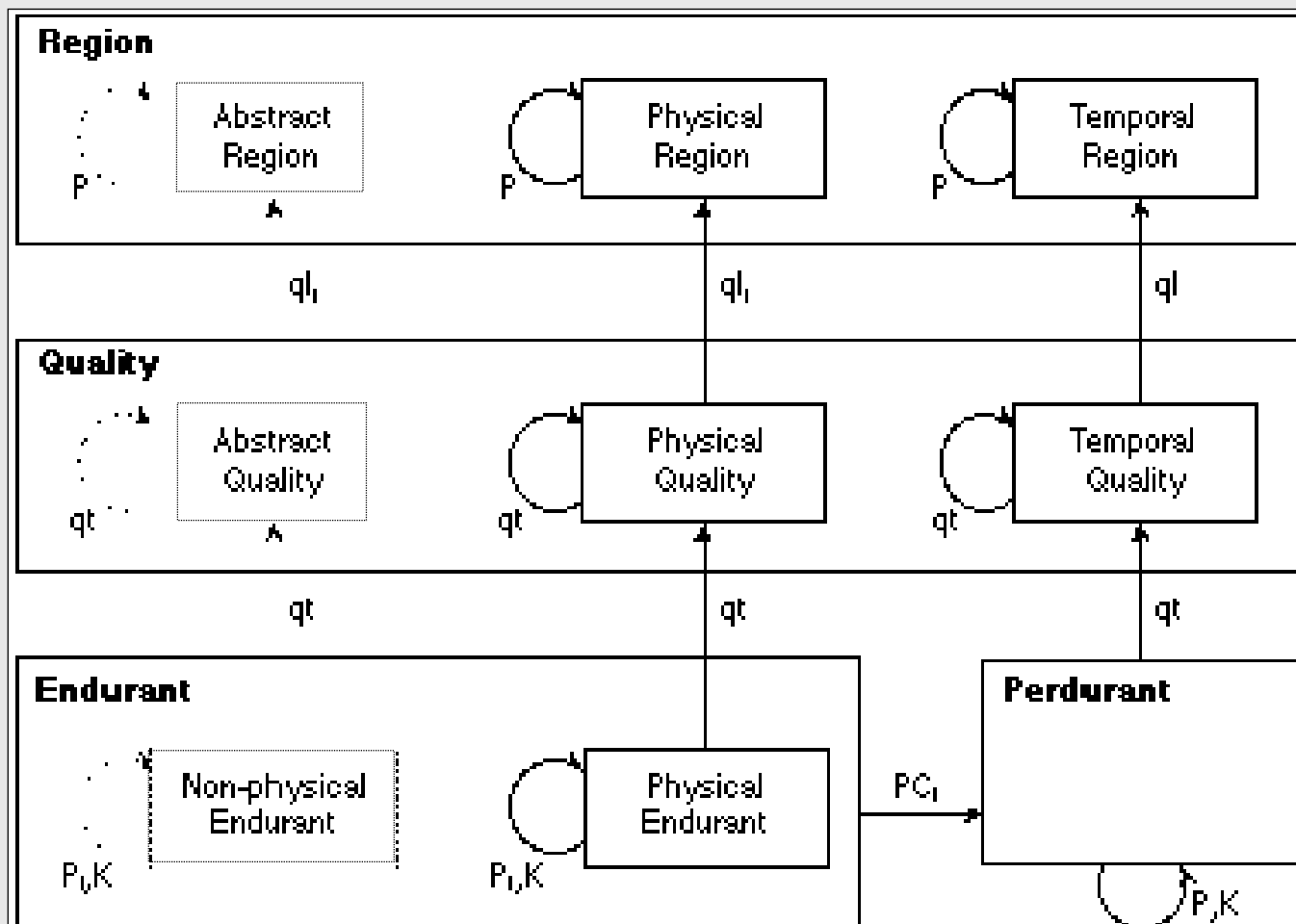
Dependence relations

Participation relations

- Hold between a perdurant and its involved endurants
- Extremely relevant for domain modelling
- Current axiomatization covers:
  - constant vs. temporary
  - complete vs. partial
- Further distinctions are currently primitive (thematic roles)
  - *Agent, Theme, Substrate, Instrument, Product*
  - More is needed on event structure, intentionality, and artifacts to produce analytic definitions

Conclusion

- Subtle meaning distinctions do matter
- Formal ontological analysis provides a rigorous methodology to obtain robust and coherent theories
- A humble interdisciplinary approach is essential

…Is this hard?

Of course yes!

(Why should it be easy??)

Ontologies should be SIMPLE...

WHY?!

- Are mobile phones simple?
- Are computers simple?
- Are nuclear plants simple?
- Are bank contracts simple?

- Bulding an ontology vs using an ontology...

- Ontology engineering **by the masses**???