



Laboratory for Applied Ontology

Institute of Cognitive Science and Technology
Italian National Research Council

Ontological Distinctions among *Particulars*: *The DOLCE Experience*

Nicola Guarino

Laboratory for Applied Ontology

Institute for Cognitive Sciences and Technology,

National Research Council

Trento, Italy

Thanks to all LOA people!

www.loa-cnr.it

DOLCE: motivating its ontological distinctions

Foundational ontologies' design rationale

- Identify issues
- List possible alternatives
- Carefully *justify* and *position* the choices made with respect to possible alternatives
- **Basic options** should be clearly documented
- Clear **branching points** should allow for easy comparison of ontological options
- Tradeoffs with respect to:
 - Choice of domain
 - Choice of relevant conceptual relations
 - Choice of primitives
 - Choice of axioms

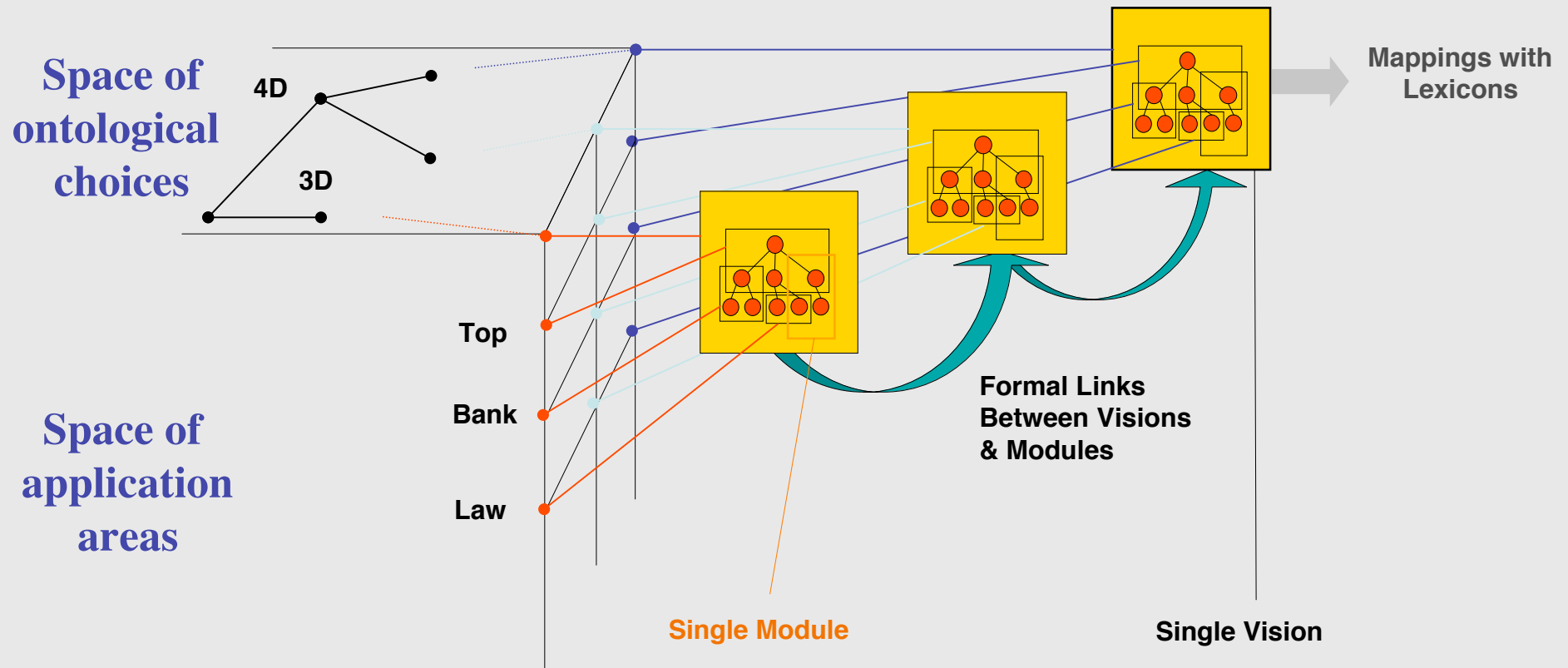


The WonderWeb Foundational Ontologies Library (WFOL)

- No single upper level
- Rather, a (small) set of **foundational ontologies** carefully **justified** and **positioned** with respect to the space of possible choices, reflecting different commitments and purposes
- **Basic issues and options** clearly documented; clear **branching points** to help ontology design in terms of *tradeoffs* with respect to:
 - Choice of domain
 - Choice of relevant conceptual relations
 - Choice of primitives
 - Choice of axioms
- A **starting point** for building new ontologies
- A **reference point** for easy and rigorous comparison among different ontological approaches
- A **common framework** for analyzing, harmonizing and integrating existing ontologies and metadata standards



The WonderWeb Library of Foundational Ontologies



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



DOLCE's basic taxonomy

Endurant

Physical

Amount of matter

Physical object

Feature

Non-Physical

Mental object

Social object

...

Perdurant

Static

State

Process

Dynamic

Achievement

Accomplishment

Quality

Physical

Spatial location

...

Temporal

Temporal location

...

Abstract

Abstract

Quality region

Time region

Space region

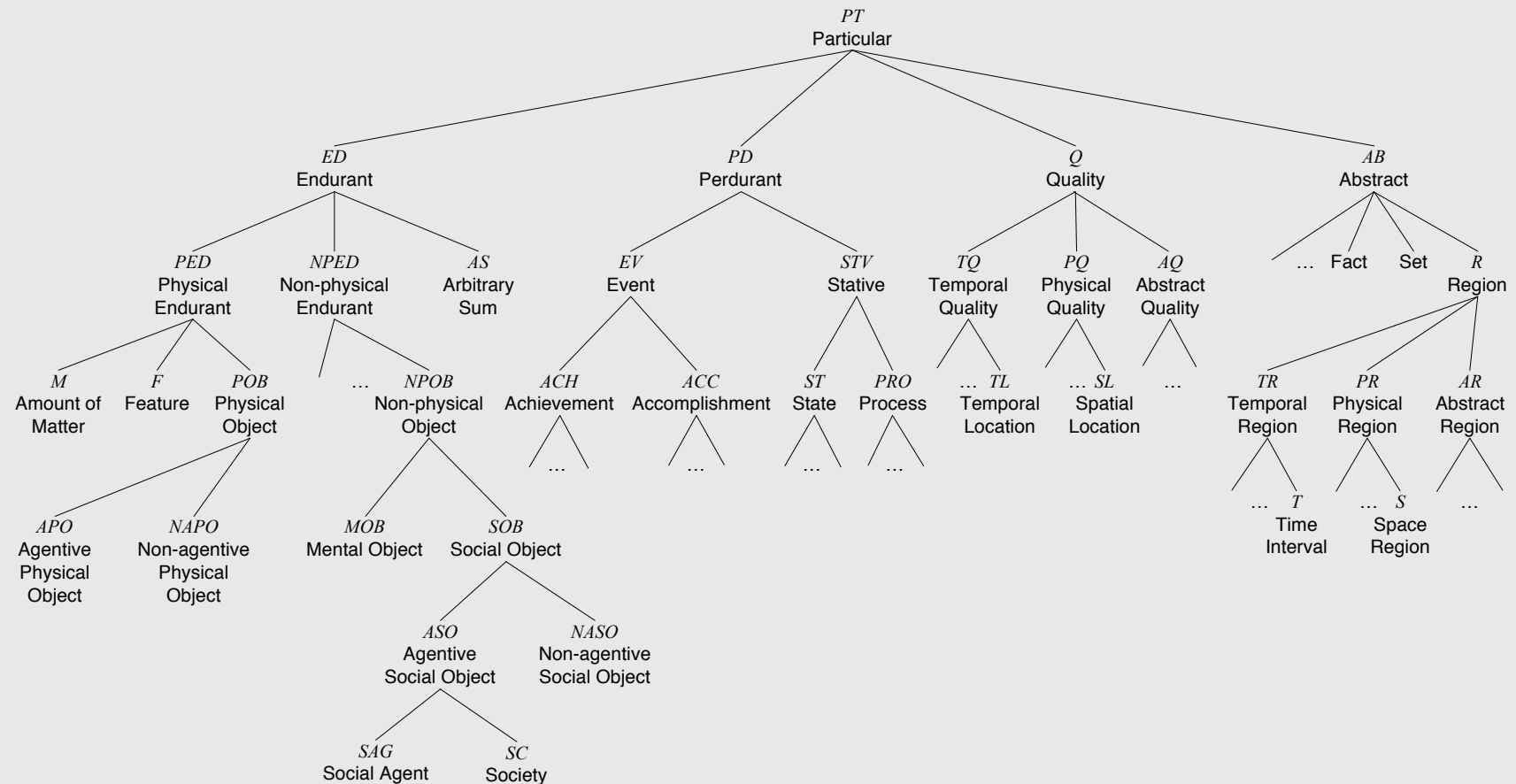
Color region

...

...



DOLCE taxonomy



DOLCE's Basic Ontological Choices

- **Endurants** (aka *continuants* or *objects*) and **Perdurants** (aka *occurrences* or *events*)
 - distinct categories connected by the relation of *participation*.
- **Qualities**
 - Individual entities *inhering in* Endurants or Perdurants
 - 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.



Endurants and Perdurants

- Endurants (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)
- Perdurants (4D *occurrences*¹) [*Occurrents* are *occurrence-types*]
 - 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)
- Endurants *participate to* Perdurants

1 - The physical view

- Basic **qualities** ascribed to atomic spacetime regions (e.g., mass, electric charge...)
- **Fields** (physical processes) are spatiotemporal distributions of qualities



2 - The *cognitive view*

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



3 - The linguistic view

and the *multiplicative choice*

substitutivity tests :

- 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

- There is a fly on the nose of this statue
- *There is a fly on the nose of this piece of marble
- There is a fly on this piece of marble

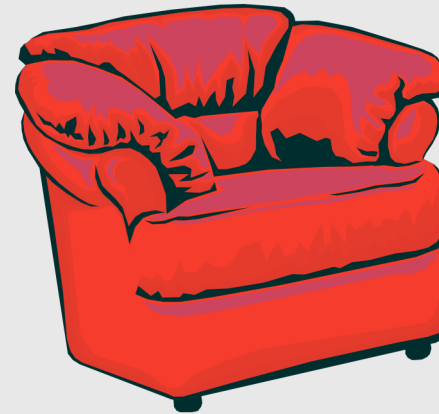


Qualities and qualia

- 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 endurant and perdurant 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

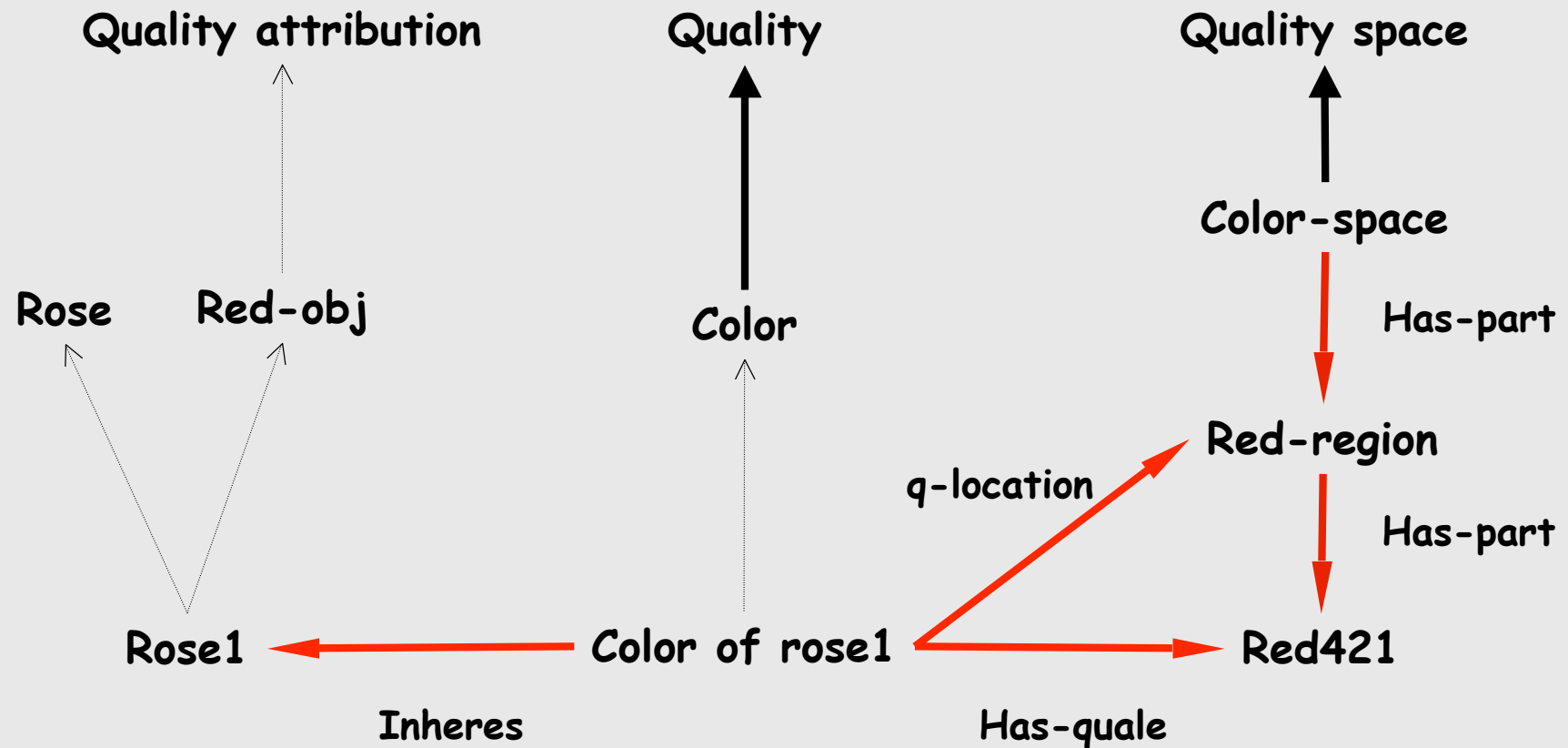


The rose and the chair have *the same color*:

- 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 Endurants

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



- Non-physical endurants
 - 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.

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)*”

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

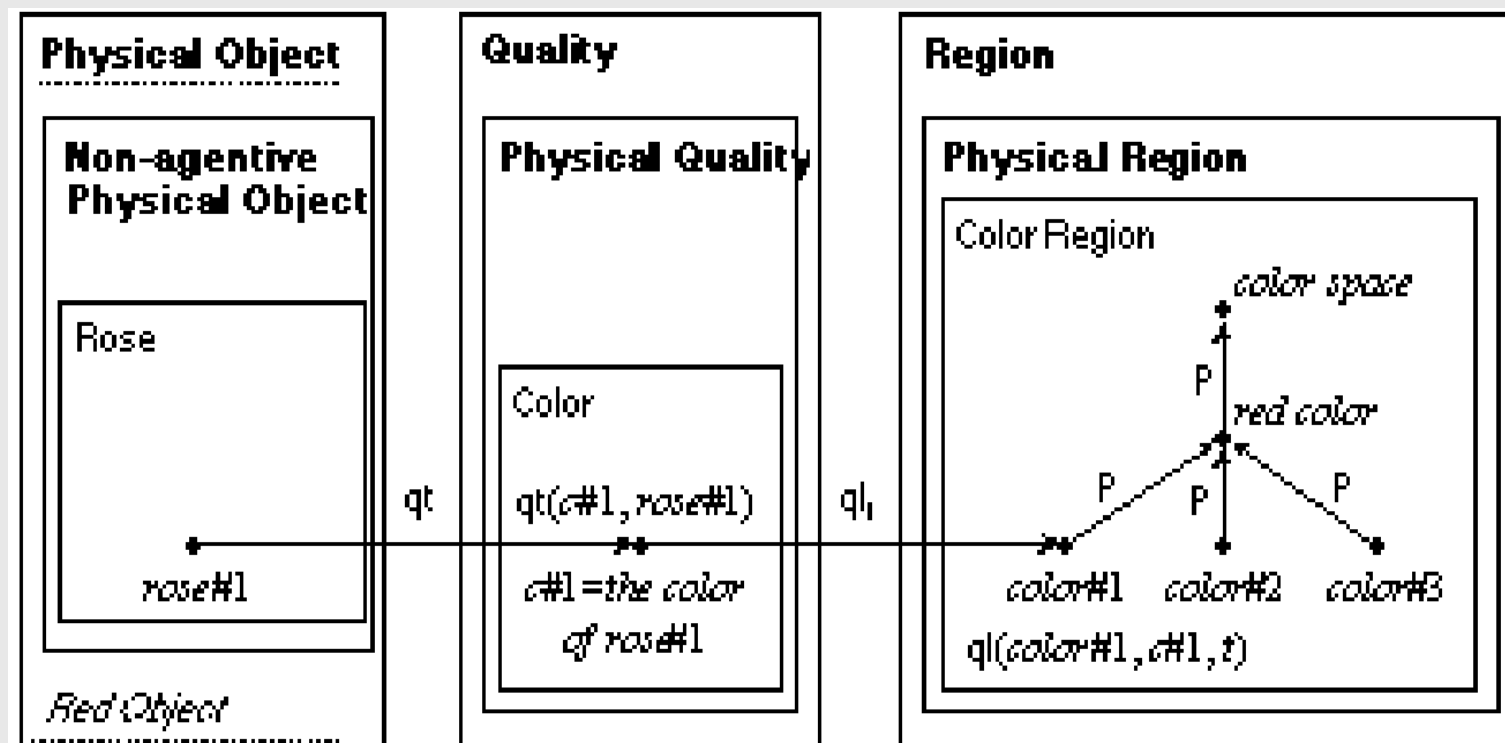
$$ql(x, y, t) \rightarrow ((PR(x) \vee AR(x)) \wedge (PQ(y) \vee AQ(y)) \wedge T(t))$$



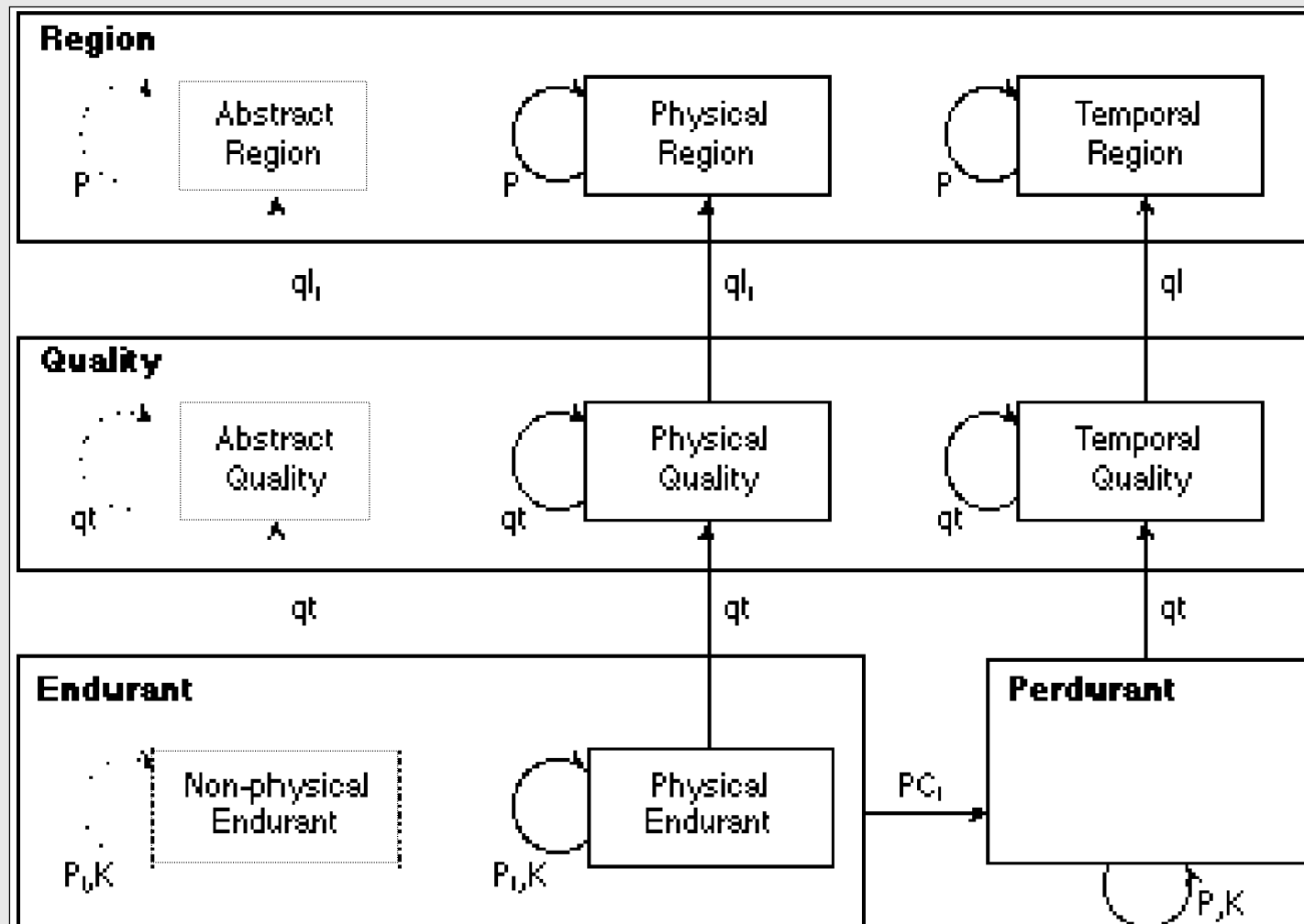
Kinds of dependence

- (D1) $SD(x, y) =_{df} o(\exists t(PR(x, t)) \wedge \forall t(PR(x, t) \rightarrow PR(y, t)))$ (Specific Const. Dep.)
- (D2) $SD(\phi, \psi) =_{df} DJ(\phi, \psi) \wedge o\forall x(\phi(x) \rightarrow \exists y(\psi(y) \wedge SD(x, y)))$ (Specific Const. Dep.)
- (D3) $GD(\phi, \psi) =_{df} DJ(\phi, \psi) \wedge o(\forall x(\phi(x) \rightarrow \exists t(PR(x, t)) \wedge \forall x, t((\phi(x) \wedge At(t) \wedge PR(x, t)) \rightarrow \exists y(\psi(y) \wedge PR(y, t))))$ (Generic Const. Dep.)
- (D4) $D(\phi, \psi) =_{df} SD(\phi, \psi) \vee GD(\phi, \psi)$ (Constant Dependence)
- (D5) $OD(\phi, \psi) =_{df} D(\phi, \psi) \wedge \neg D(\psi, \phi)$ (One-sided Constant Dependence)
- (D6) $OSD(\phi, \psi) =_{df} SD(\phi, \psi) \wedge \neg D(\psi, \phi)$ (One-sided Specific Constant Dependence)
- (D7) $OGD(\phi, \psi) =_{df} GD(\phi, \psi) \wedge \neg D(\psi, \phi)$ (One-sided Generic Constant Dependence)
- (D8) $MSD(\phi, \psi) =_{df} SD(\phi, \psi) \wedge SD(\psi, \phi)$ (Mutual Specific Constant Dependence)
- (D9) $MGD(\phi, \psi) =_{df} GD(\phi, \psi) \wedge GD(\psi, \phi)$ (Mutual Generic Constant Dependence)

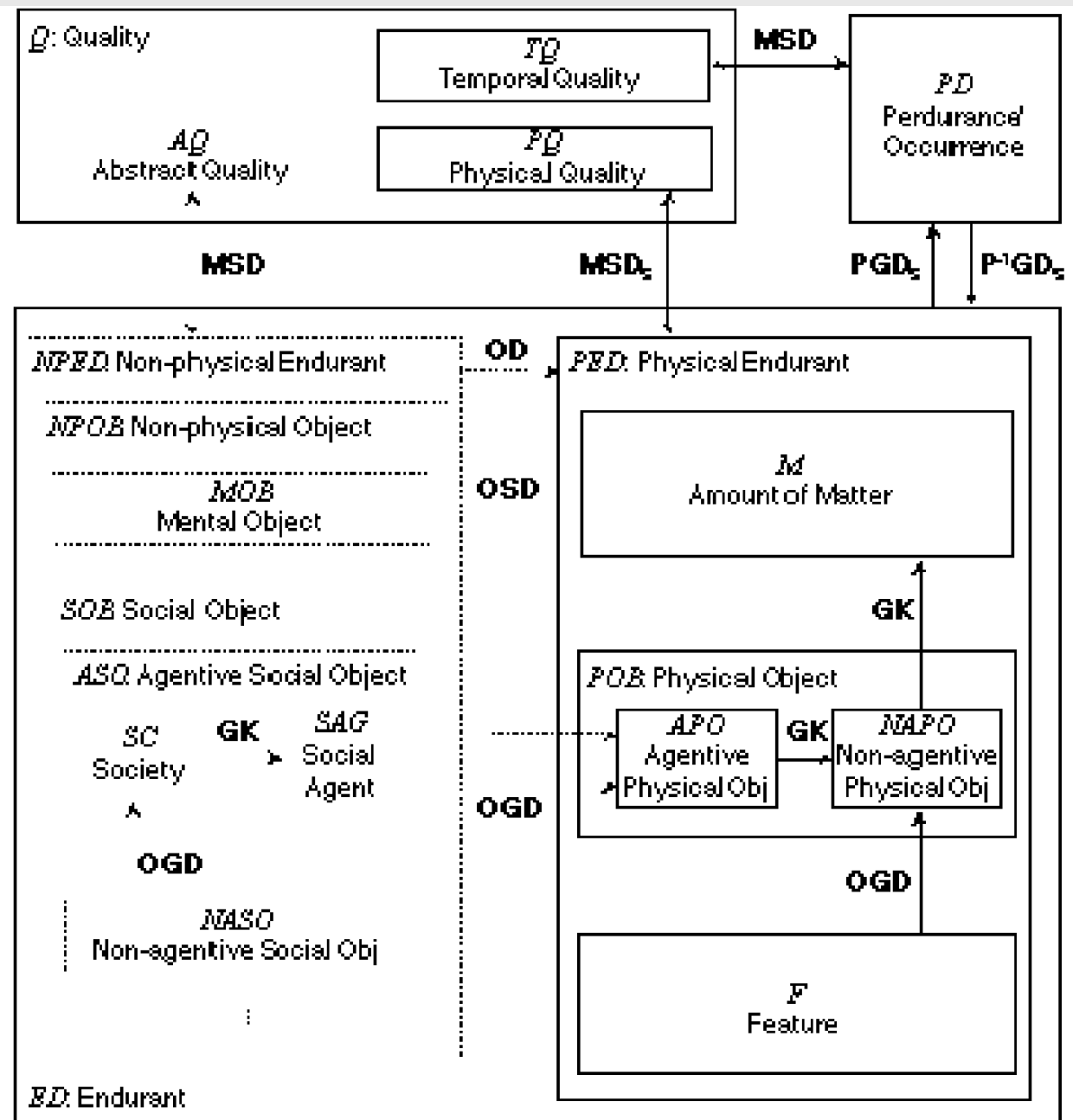
Quality relations



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



DOLCE Extensions and Applications

DOLCE Extensions

(mainly by Aldo Gangemi @LOA-RM)

- Allen-based ontology of time for events
- Ontology of common-sense locations
- Descriptions and Situations (D&S) ontology (reified relations and relationships)
- Ontology of Functional Participation (cf. *thematic roles*)
- Ontology of Plans and Tasks (DDPO) (Metokis project)
- Ontology of Information Objects (DDIO (Metokis project)
- Ontology of Knowledge Content Objects (KCO), from Metokis, for multimedia description and negotiation
- Ontology of Services, based on DDPO (with UKA, VUA)
- Ontology of Semantic Middleware (by Daniel Oberle at UKA)
- Core Legal Ontology (CLO, with ITTIG-CNR)
- Metaontology of ontology as semiotic object (O2)
- Ontology of ontology evaluation and quality (oQual)
- Ontology of design patterns
- Ontology of social entities and organizations (MOSTRO project @LOA-TN)



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.



A Selection of Most Relevant Projects (2003-2006)

- **WonderWeb** (FP5): Ontology Infrastructure for the Semantic Web (LOA: foundational ontologies for the Semantic Web)
- **OntoWeb** (FP5 - NoE): Ontology-based information exchange for knowledge management and electronic commerce (LOA: *SIG on Content Standards*)
- **METOKIS** (FP6): Methodologies and tools infrastructure for the development of multimedia knowledge units
- **SEMANTIC MINING** (FP6 - NoE): Semantic Interoperability and Data Mining in Biomedicine
- **TICCA** (PAT&CNR): Tecnologie cognitive per l'interazione e la cooperazione con agenti artificiali (LOA: ontology of social interaction)
- **MOSTRO** (PAT); Modelling Security and Trust Relationships in Organizations
- **IKF** : Intelligent Knowledge Fusion (Eureka Project)
 - *Ontology of banking transactions (with ELSAG Banklab_)*
 - *Ontology of Service-Level Agreement and IS monitoring (with SELESTA_)*
 - *Ontology of Insurance Services (with Nomos SpA)*
- **FOS** (UN/FAO): Alignment of legacy fishery ontologies
- **NEON** (FP6) - Networked Ontologies



A new journal: *Applied Ontology*



Editors in chief:

Nicola Guarino
ISTC-CNR

Mark Musen
Stanford University

IOS Press

Amsterdam, Berlin,
Washington, Tokyo, Beijing

www.applied-ontology-org

FOIS-2006

International Conference on Formal Ontology in Information Systems

<http://www.formalontology.org/>



**November 9-11, 2006
Baltimore, Maryland (USA)**

