Ontology Engineering and Upper Ontologies

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Outline

Ontology Engineering

Basics

Basic terms

- **Ontology Engineering** is research field that covers a set of activities appearing during conceptualization, design, implementation and deployment of ontologies. It includes topics such as philosophy, metaphysics, knowledge representation formalisms, development methodology, knowledge sharing and reuse, knowledge management, systemization of domain knowledge, standardization, evaluation etc.
- **Ontology life cycle** is the specific sequence of activities that are carried out by ontology practitioners for developing an ontology.
- **Ontology life cycle model** is a framework that provides general structure on which activities of the ontology life cycle can be mapped.

Ontology Engineering activities

List of Ontology Engineering activities :

- Ontology Conceptualization
- Ontology Integration
- Ontology Population
- Ontology Elicitation
- Ontology Learning
- Ontology Localization
- Ontology Matching
- Ontology Search
- O. Requirements Specification
- Ontology Specialization
- Ontology Diagnosis
- Ontology Repair
- Ontology Modularization
- Ontology Reengineering
- Ontology Reuse
- Ontology Versioning
- Ontology Verification
- Ontology Validation
- ...

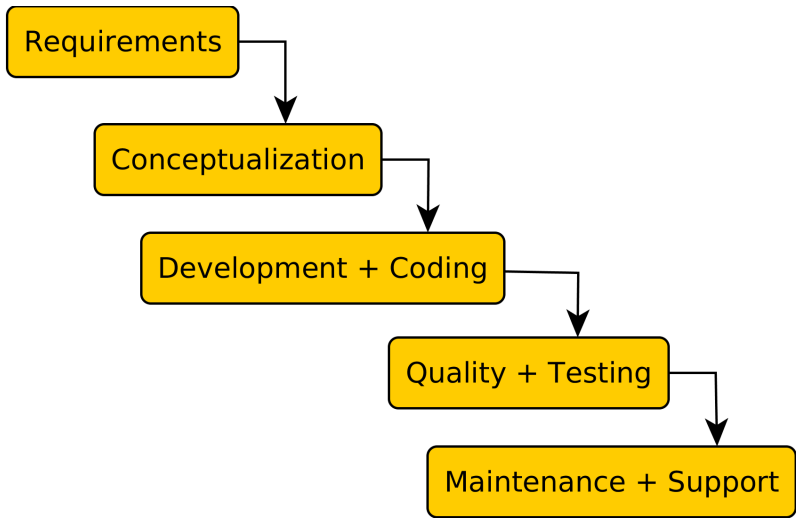
Comprehensive glossary of Ontology Engineering activities can be found at

`https://oeg.fi.upm.es/files/pdf/NeOnGlossary.pdf`

Ontology life cycle models

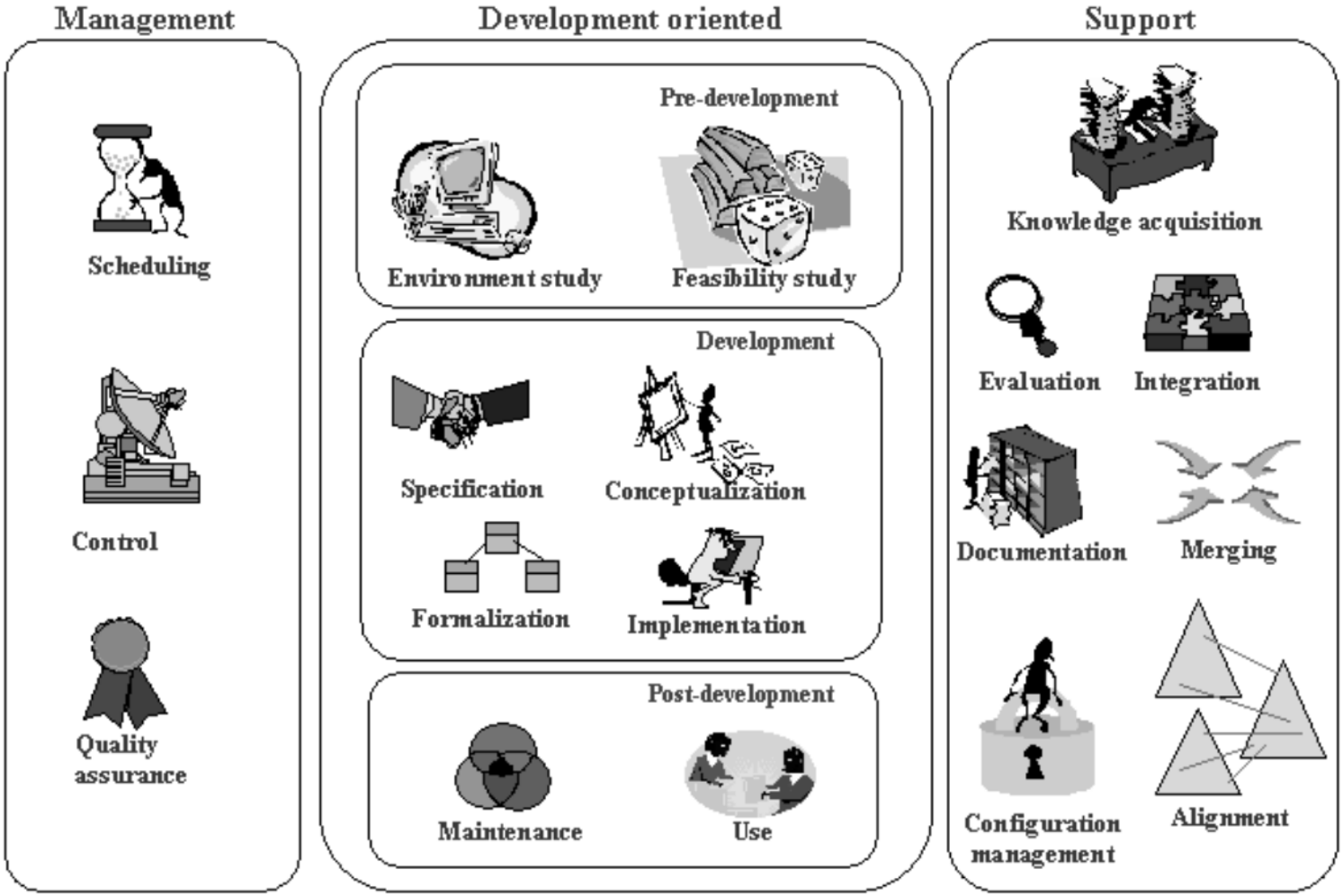
There are multiple models to sequence activities for development of ontology :

- Waterfall Model
- ”V“ Model
- Incremental Model
- Iterative Model
- Evolutionary Prototyping
- Rapid Throwaway Prototyping
- Spiral Model



Overview of methodologies

Categories of activities covered by methodologies



Taken from book Gómez-Pérez et.al, Methodologies and methods for building ontologies,2004.

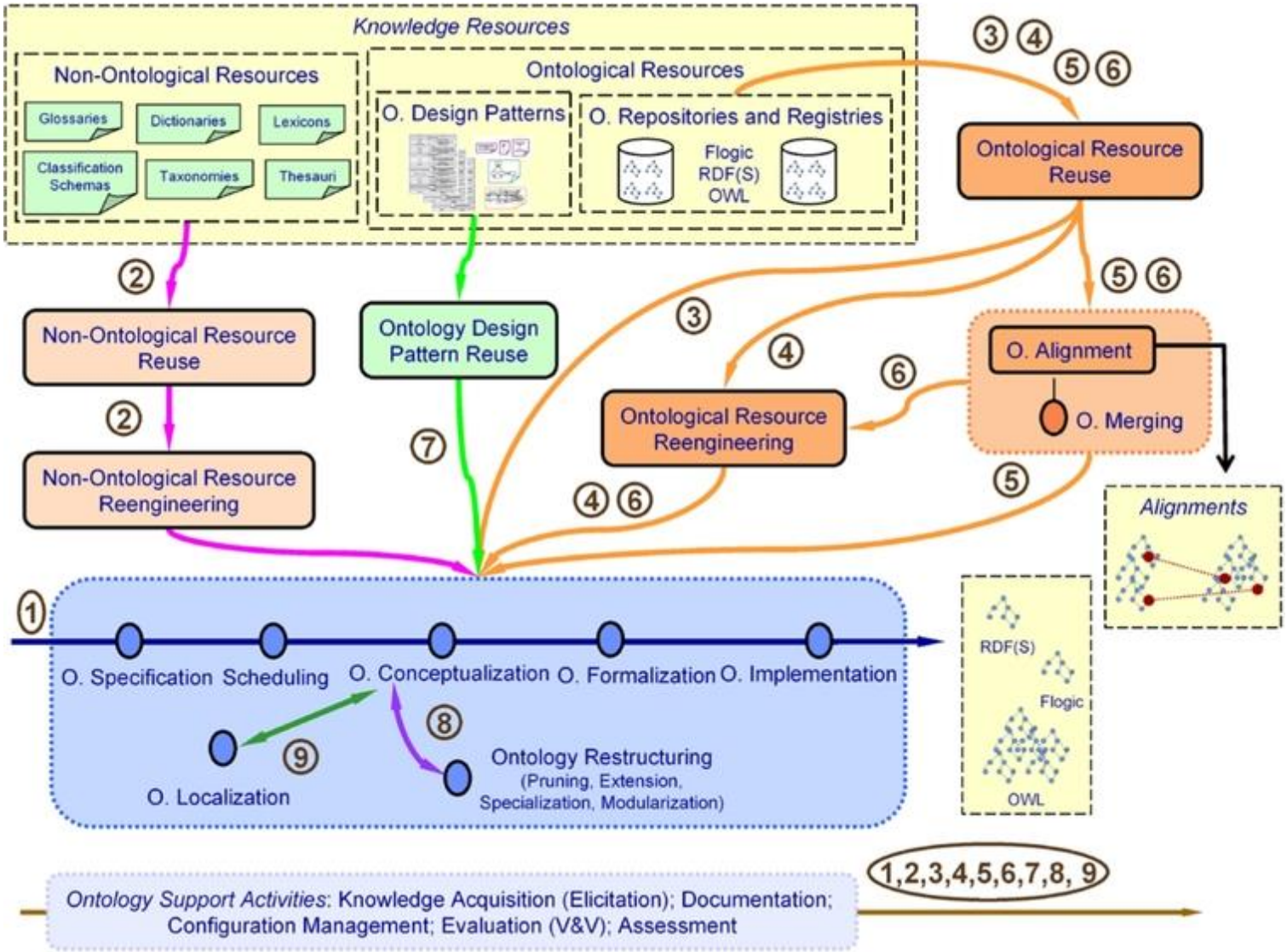
METHONDOLOGY

- **METHONDOLOGY** was developed at Polytechnic University of Madrid and is based on IEEE standards for Developing Software Life Cycle Processes.
- It provides guidelines for
  - **Project management process** – planning, project control, quality control etc.
  - **Ontology development process** – envisioned use of the ontology, explication of the envisioned users, conceptualization of target domain, formalization of ontology, implementation etc.
  - **Support activities** – knowledge acquisition, evaluation, ontology integration, documentation, version management etc.

The NeOn Methodology – introduction

- **The NeOn Methodology** [**suarez2010neon**] is scenario-based methodology with emphasis on
  - reuse and reengineering of knowledge aware resources
  - collaborative and argumentative ontology development
  - building of ontology networks, as opposed to custom-building new ontologies from scratch.
- It defines following scenarios
  1. From specification to implementation
  2. Reusing and re-engineering non-ontological resources (NORs)
  3. Reusing ontological resources
  4. Reusing and re-engineering ontological resources
  5. Reusing and merging ontological resources
  6. Reusing, merging and re-engineering ontological resources
  7. Reusing ontology design patterns (ODPs)
  8. Restructuring ontological resources
  9. Localizing ontological resources

The NeOn Methodology – overall architecture



Available at `http://mayor2.dia.fi.upm.es/oeg-upm/index.php/en/`

Other methodologies

- On-To-Knowledge
- Cyc methodology
- Grüninger and Fox's methodology
- Uschold and King's methodology
- KACTUS methodology
- SENSUS methodology
- DILIGENT methodology
- TOVE methodology
- Activity-First Method (AFM) in Hozo

Three-layer model of guidelines

An ontology engineering methodology can be composed of three-layers guidelines [**mizoguchi2004tutorial**] :

- **Top-layer** – The whole building process compliant with the conventional software development process (The methodologies described so far includes mostly only this level guidelines and partially the next level)
- **Middle-layer** – Generic constraints and guidelines which specify major steps (AFM is example of a methodology mainly concerned with this level)
- **Bottom-layer** – The most fine-grain guidelines such as those for class identification process, etc. (Ontology development tutorial by Noy [**noy2001ontology**] have few guidelines at this level)

Note

Middle-layer and bottom-layer guidelines are essential for novices to develop "correct ontology" as they directly influence the quality of the ontology developed.

Summary of methodologies

- *Cyc, Uschold and King, Grüninger and Fox, KACTUS, METHONDOLOGY, SENSUS, On-To-Knowledge* methodologies can be used to build ontologies from scratch.
- *METHONDOLOGY, On-To-Knowledge methodology* are very useful in development process management.
- *Uschold and King methodology* is useful for obtaining informal ontology in early phase of development.
- *Activity-First Method methodology* is useful for building task and domain ontologies.

Requirements engineering

Requirements engineering basics

- **Requirement engineering** is an activity in which we view ontology as black box while trying to describe requirements that the ontology should fulfill.
- Requirements are of two types :
  - **Functional requirements** describing internal structure and content
    - Query results
    - Inferences
    - Error checking
    - ...
  - **Non-functional requirements** describing overall structure, acceptance, guidelines and rules for development etc.
    - Coverage
    - Efficiency
    - Documentation
    - ...
- We will focus here rather on "computational ontologies" (as part of a software system performing some task)

Requirements engineering – Functional requirements

There are three types of functional requirements that are used within requirement engineering :

1. **Competency question** (CQ) is natural language question that the ontology should be able to answer
   - *Simple lookup queries* – Who are participant of certain event ?
   - *Queries expressing inferences and constraints* – If people have children, is a specific person grandparent or not ? Is it valid to have 3 parents ?
2. **Contextual statement** is an axiom that must hold in the ontology expressed in natural language – Every person has exactly 2 parents. Grandparent is person who has a child who has a child.
3. **Reasoning (inference) requirement** specify the input and output data for a reasoning task – we need to query directly for all the grandparents

Note

Contextual statements and reasoning requirements are used to clarify/remove complex CQs

Selected methodological guidelines

Guideline to ontology requirement specification

Based on NeOn methodology ontology requirement specification can be formed from a set of ontological needs as follows :

1. Identify the purpose, scope and implementation language
2. Identify the intended end-users
3. Identify the intended uses
4. Identify functional and non-functional requirements
5. Group requirements (the list of CQs)
6. Validate set of requirements – *if not valid jump to step 4*
7. Prioritize requirements (optional)
8. Extract terminology and its frequency

Guideline for ontology life cycle models

Based on assumption about ontology requirements we can use following ontology life cycle models :

- Ontology requirements are known from the beginning
  - Waterfall Model
  - "V" Model
  - Incremental Model
  - Iterative Model
- Ontology requirements are not known from the beginning and can change during the project
  - Evolutionary Prototyping
  - Rapid Throwaway Prototyping
- Uncertainties in the ontology requirements can derive into risks in the project
  - Spiral model

Guidelines for taxonomy construction direction

- There are three approaches to construct taxonomies :
  - top-down approach
  - bottom-up approach
  - middle-out approach
- Try to combine the approaches as much as possible !

Guideline for reusing ontological resource

- There are multiple ways how to reuse ontological resources :
  - ontologies as wholes
  - ontology modules
  - ontology design patterns
  - ontology statements
- In addition to reuse, reconstruction, re-engineering, and merging can be used.

Upper Ontologies

Motivation – Reuse of Ontological Resources

- Types of ontologies:
  - top-level (upper) ontologies
  - domain ontologies and task ontologies
  - application ontologies
- Ways to reuse ontological resources:
  - ontologies as wholes
  - syntactic/semantic ontology modules
  - ontology design patterns
  - ontology statements

Basics

What Are Upper Ontologies ?

- **Upper ontologies** (sometimes also called *top-level* or *foundational* ontologies) describe very general concepts that are independent of particular problem or domain.
- They provide categories of kinds of things and relations that can provide a basic structure for "lower-level" ontologies such as domain ontology.

Why Should We Use Upper Ontologies ?

- Pros:
  - "top-down approach" and modelling guidance for ontology development
  - basic categories and relations that we don't need to reinvent again
  - interoperability among ontologies
- Cons:
  - a lot of effort needed to understand
  - too abstract

Basic Ontological Commitments

- Universals vs. Particulars – Universals can have instances, while Particulars don't
- Descriptive vs. Realist – represent world using natural language and common sense vs. represent it as is
- Multiplicative vs. Reductionist – different objects can be co-located at the same time vs. only one object may be located at the same region at one time
- Endurantism vs. Perdurantism – an object is wholly present at all times vs. an object has temporal parts
- Actualism vs. Possibilism – everything that exists in the ontology is real vs. objects are allowed independent of their actual existence
- Concrete & Abstract entities – entities that exist in space and time & entities that exist neither in space nor time

Overview of existing Upper Ontologies

Existing Upper Ontologies

- UFO (Unified Foundational Ontology)
- BFO (Basic Formal Ontology)
- DOLCE (Descriptive Ontology for Linguistic and Cognitive Engineering)
- SUMO (Suggested Upper Merged Ontology)
- YOMATO (Yet Another More Advanced Top-level Ontology)
- GFO (General Formal Ontology)
- PROTON (PROTo ONtology)
- Cyc
- ?WordNet

Comparison of Ontological Commitments

Term and meaning	DOLCE	BFO	GFO	SUMO
Ontological Commitments				
Descriptive vs. Realist (Descriptive: represent the entities underlying natural language and human common-sense; Realist: represent the world exactly as is)	Descriptive	Realist	Descriptive and Realist	Descriptive
Universals vs. Particulars (Universals can have instances, particulars do not)	Particulars	Universals	Universals and Particulars	Universals and Particulars
Multiplicative vs. Reductionist (Multiplicative: different objects can be co-located at the same time; Reductionist: only one object may be located at the same region at one time)	Multiplicative	Reductionist	Unclear	Multiplicative
Endurantism vs. Perdurantism (Endurantism: an object is wholly present at all times; Perdurantism: an object has temporal parts)	Endurantism and Perdurantism	Endurantism and Perdurantism	Endurantism and Perdurantism	Endurantism and Perdurantism
Actualism vs. Possibilism (everything that exists in the ontology is real; Objects are allowed independent of their actual existence	Possibilism	Actualism	Unclear	Unclear
Eternalist stance (the past, present and future all exist)	Eternalist	Eternalist	Eternalist	Eternalist
Concrete & Abstract entities (Concrete: entities that exist in space and time; Abstract: entities that exist neither in space nor time)	Concrete and Abstract	Concrete	Concrete and Abstract	Concrete and Abstract
Mereology (theory of parts)	GEM	Own mereology	Own mereology	Own mereology
Temporal aspects	Provided	Not provided	Provided	Provided
Granularity (different levels of detail contained in an ontology)	High level	Sensitive	Unclear	Unclear
Properties and values ('attribute'; e.g., the colour of an apple)	Included	Some support	Included	Included
Model for space and time (Consists of time and space regions and boundaries)	Not included	Included	Not included	Not included
One-layered vs. Three-layered architecture (a basic level only; an abstract top level, abstract core level and basic level)	One-layered	One-layered	Three-layered	One-layered
Situations and situoids (Situation: an aggregate of facts that can be comprehended as a whole and satises certain conditions of unity; Situoid: is a part of the world that is a comprehensible whole and can exist independently)	Not included	Not included	Included	Not included

Comparison of ontological commitments within selected upper ontologies taken from

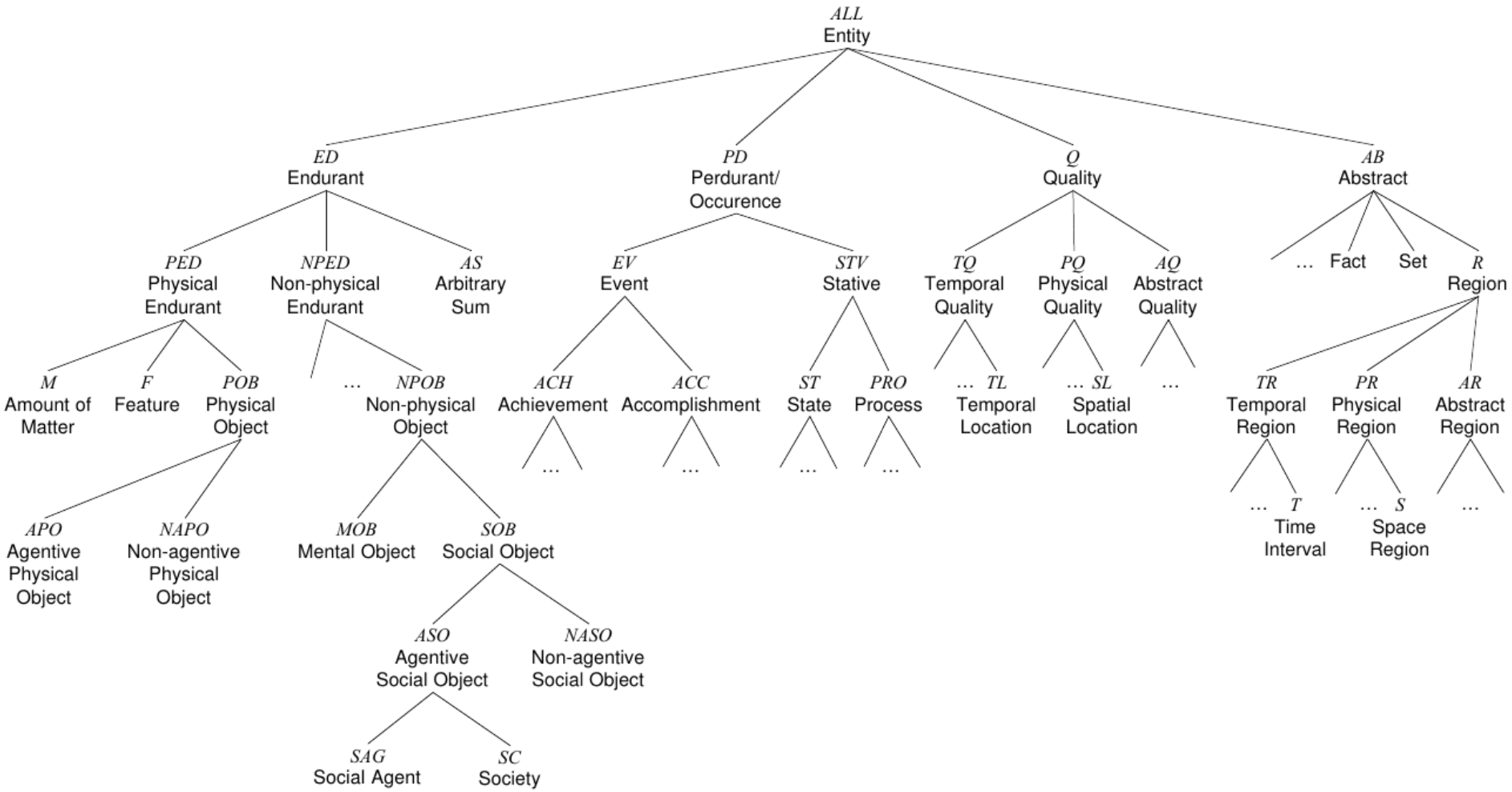
`http://www.thezfiles.co.za/ROMULUS/ontologicalCommitments.html`

DOLCE overview

- **D**escriptive **O**ntology for **L**inguistic and **C**ognitive **E**ngineering[1]
- developed by researchers from the Laboratory of Applied Ontology, headed by N. Guarino
- first module of the WonderWeb Foundational Ontologies Library
- ontology of particulars, multiplicative, possibilism
- strong cognitive/linguistic bias – descriptive attitude with categories mirroring cognition, common sense, and the lexical structure of natural language

[1] Home page – `http://www.loa.istc.cnr.it/old/DOLCE.html`, online term search – `https://www.w3.org/2001/sw/BestPractices/WNET/DLP3941_daml.html`

DOLCE's Taxonomy of Basic Categories



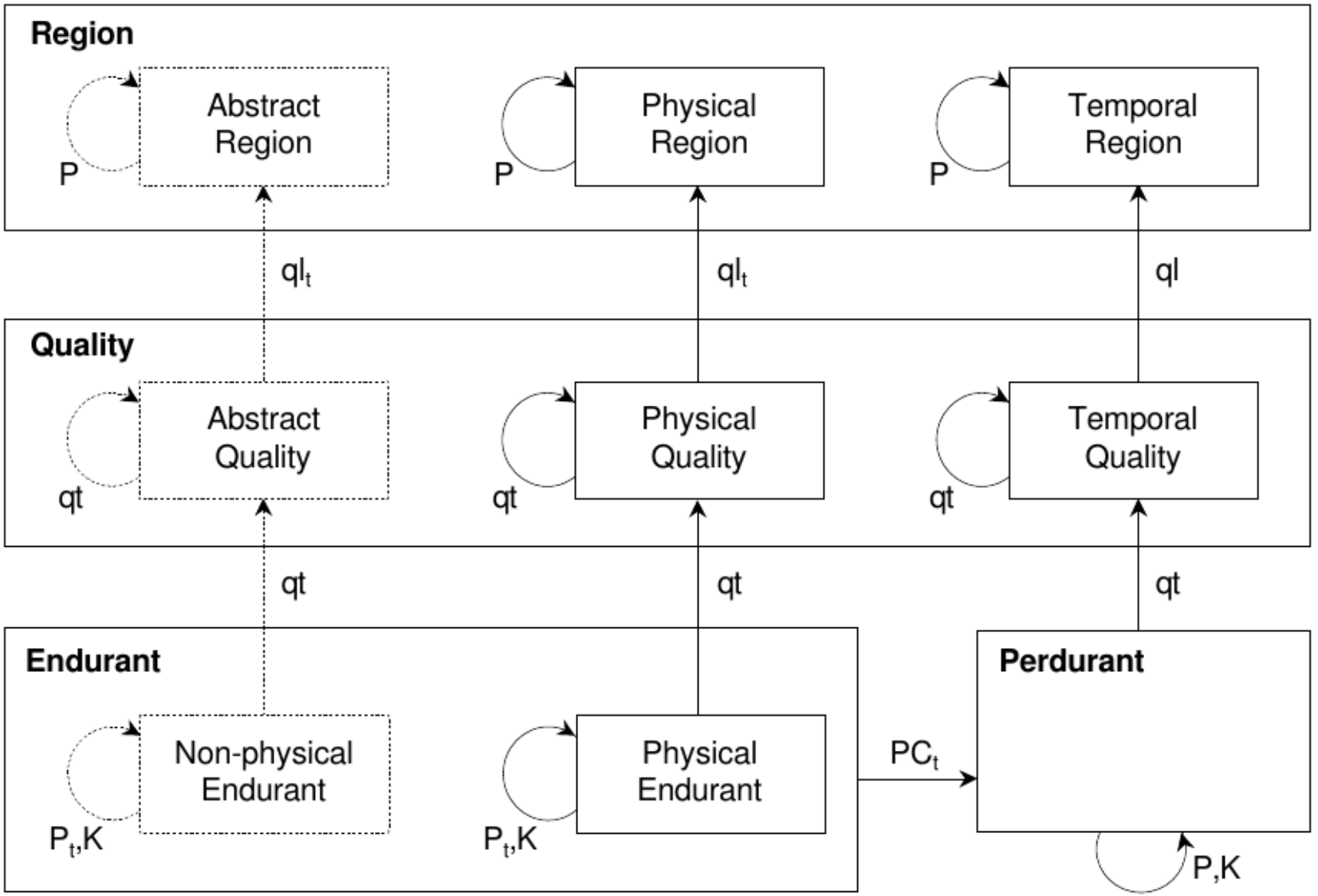
DOLCE's Examples of "Leaf" Basic Categories

"Leaf" Basic Category	**Examples**
Abstract Quality	the value of an asset
Abstract Region	the (conventional) value of 1 Euro
Accomplishment	a conference, an ascent, a performance
Achievement	reaching the summit of K2, a departure, a death
Agentive Physical Object	a human person (as opposed to legal person)
Amount of Matter	some air, some gold, some cement
Arbitrary Sum	my left foot and my car
Feature	a hole, a gulf, an opening, a boundary
Mental Object	a percept, a sense datum
Non-agentive Physical Object	a hammer, a house, a computer, a human body
Non-agentive Social Object	a law, an economic system, a currency, an asset
Physical Quality	the weight of a pen, the color of an apple
Physical Region	the physical space, an area in the color spectrum, 80Kg
Process	running, writing
Social Agent	a (legal) person, a contractant
Society	Fiat, Apple, the Bank of Italy
State	being sitting, being open, being happy, being red
Temporal Quality	the duration of World War I, the starting time of the 2000 Olympics
Temporal Region	the time axis, 22 june 2002, one second

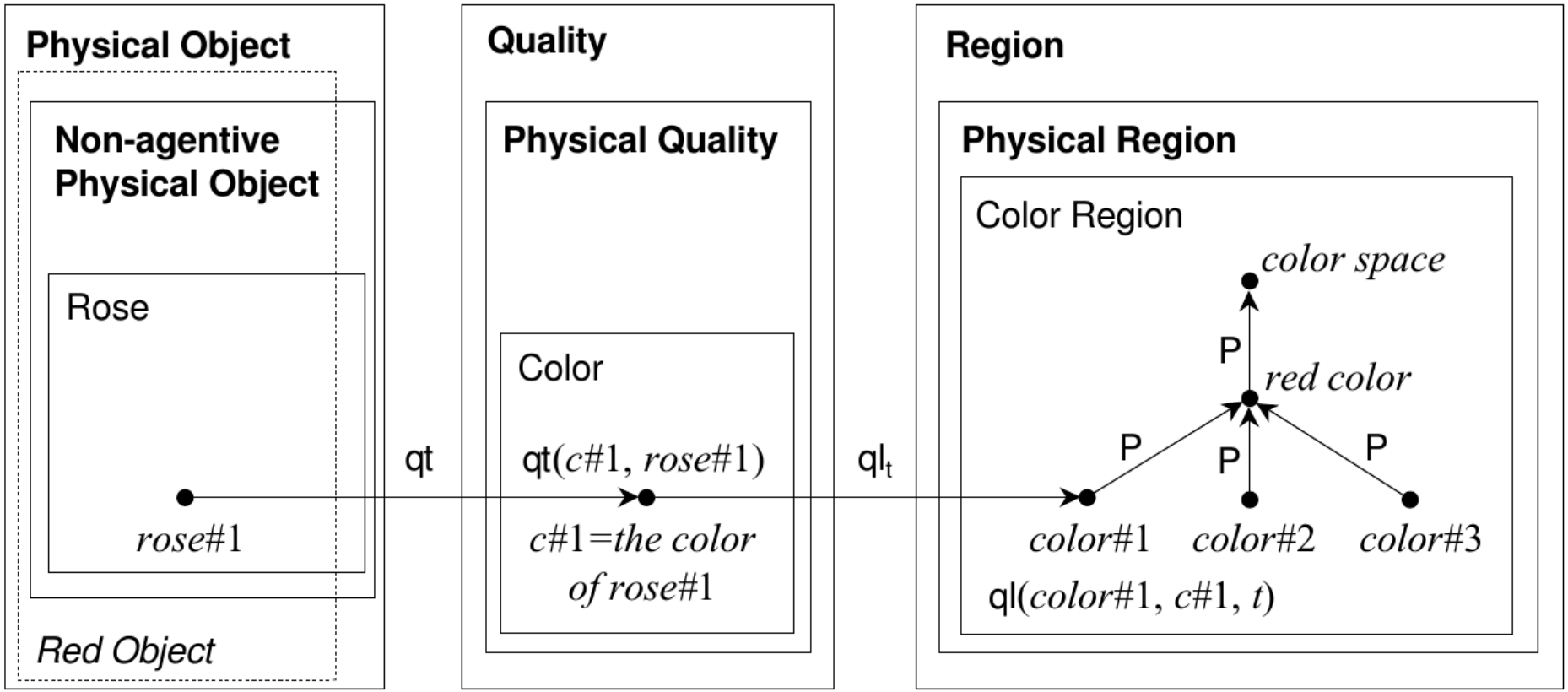
DOLCE Basic Relations

- parthood (immediate vs. temporary)
- constitution
- participation
- representation
- specific/generic constant dependence
- inherence (between a quality and its host)
- quale (immediate vs. temporary)

DOLCE's Primitive Relations Between Basic Categories



DOLCE's Relations About Qualities



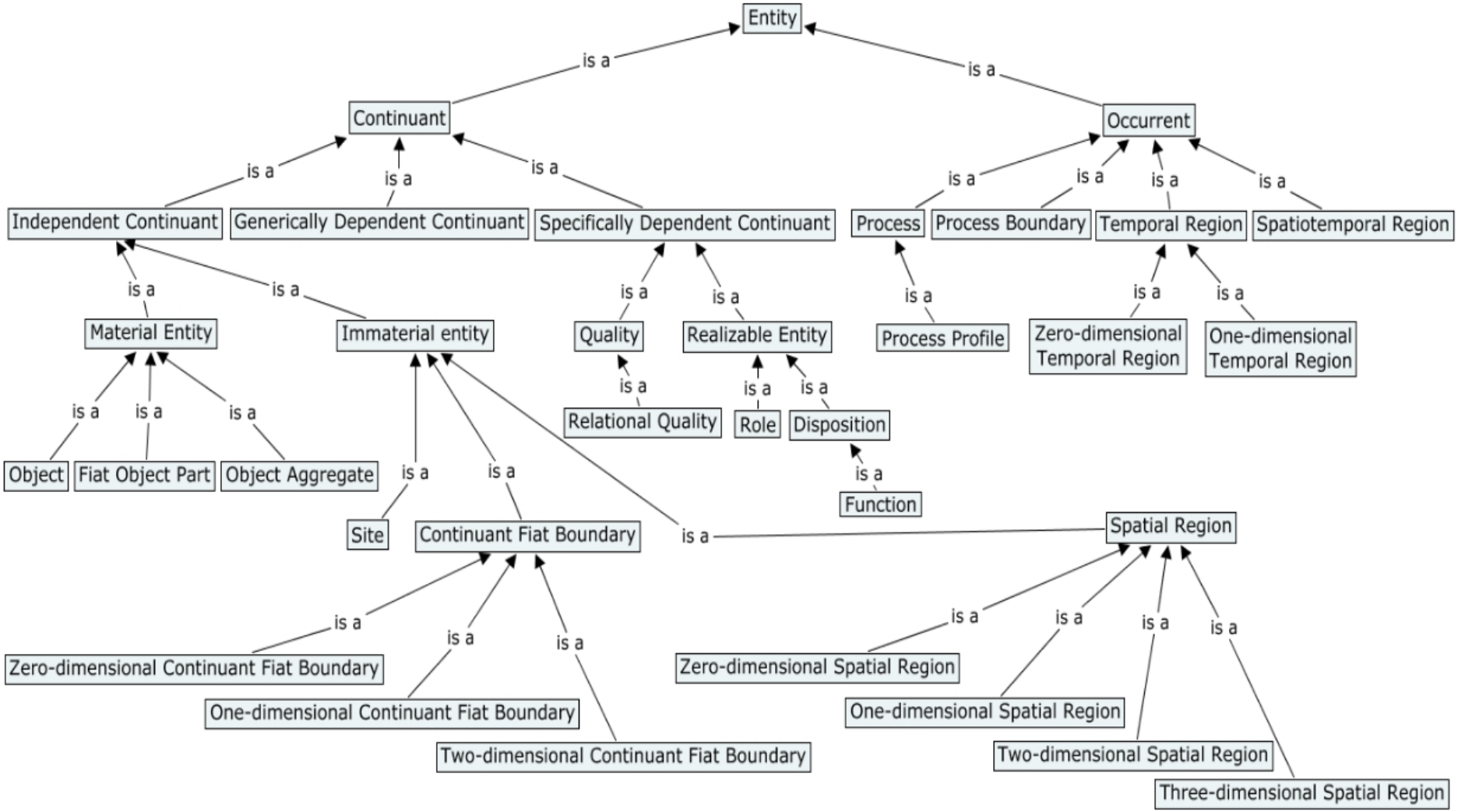
Example of quality and quality region – there is a difference between "this rose is red" (red-thing) and "the color of this rose is red" (red-color)

BFO Overview

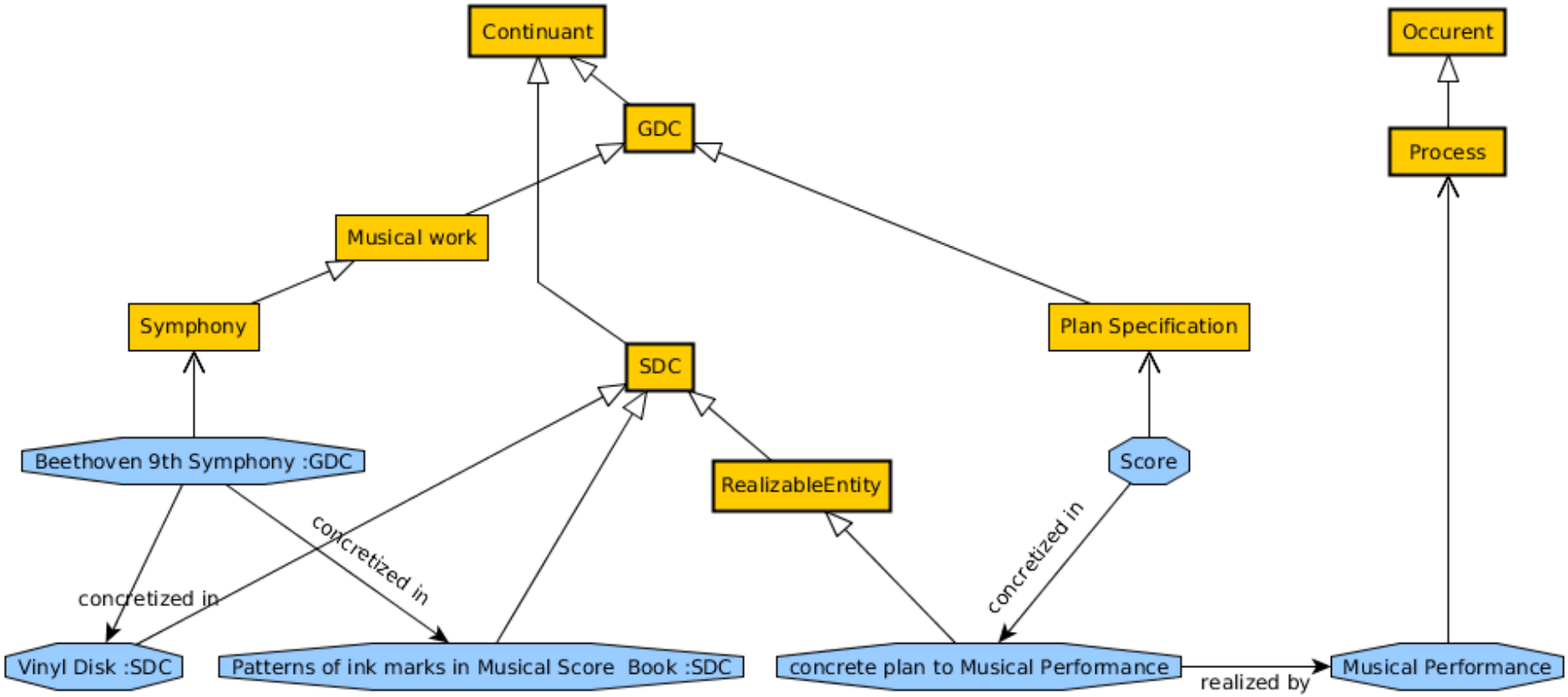
- **B**asic **F**ormal **O**ntology[2]
- developed in Saarland University mainly by B.Smith, P.Grenon
- designed for use in supporting information retrieval, analysis and integration in scientific and other domains
- realistic and reductionist view of the word, actualism
- limited granularity
- contains both SNAP (endurants) and SPAN (perdurants) sub-ontologies

[2] http://ifomis.uni-saarland.de/bfo/

BFO's Taxonomy of Basic Categories



BFO's realizable entity example



Other interesting upper ontology resources

- ONSET: the foundational ONtology Selection and Explanation Tool – `http://www.meteck.org/files/onset`
- Ontology browser integrated mainly through BFO – `http://www.ontobee.org`
- SUMO Concept hierarchy and search – `http://virtual.cvut.cz/kifb/en/toc/root.html`
- YOMATO ontology description – `http://download.hozo.jp/onto_library/YAMATO101216.pdf`
- UFO related community portal – `https://ontouml.org`
- DOLCE ontology descripton – `http://www.loa.istc.cnr.it/old/Papers/DOLCE2.1-FOL.pdf`