Ontology Engineering

Lecture 6: Top-down Ontology Development I

Maria Keet

email: mkeet@cs.uct.ac.za

home: http://www.meteck.org

Department of Computer Science
University of Cape Town, South Africa

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Outline

Introduction

- Ontology development: what to represent, and how?
  - Where do you start?
  - How can you avoid reinventing the wheel?
  - What things can guide you to make the process easier to carry out successfully?
  - How can you make the best of 'legacy' material?
  - How can you make it interoperable with other ontologies?

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  - How can you make the best of 'legacy' material?
  - How can you make it interoperable with other ontologies?
- **Foundational ontologies** provide principal categories of kinds of things and relations to give a basic structure to a domain ontology; informed by **O**ntology (analytic philosophy)
- Legacy resources can provide useful classes and properties, and possibly also constraints, for domain ontologies

Why use a foundational ontology?

- Pros:
  - don't have to 'reinvent the wheel' with respect to the basic categories and relationships to represent the subject domain
  - improves overall quality with modelling guidance
  - facilitates interoperability among ontologies
  - is useful when subtle distinctions, recognizing disagreement, rigorous referential semantics, general abstractions, careful explanation and justification of ontological commitment, and mutual understanding are important

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- Cons:
  - too abstract
  - too expressive and comprehensive for the envisioned ontology-driven information system
  - takes excessive effort to understand them in sufficient detail

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  - Properties as repeatable universals, belonging to different entities or as non-repeatable tropes, inhering only in a specific entity
  - Particulars as aggregations (collections) of properties or the properties inhere in some substrate (bare particular)

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- Persistence, principal choices:
  - How do entities persist? How do entities change in time? (Due to different phases or due to (whole) instantiation of different properties at different times?) How are change and persistence related?

General notions and principal choices

- More choices:
  - Are space and time absolute or relative, atomic or not?
  - Localization: are there entities that are not in space/time (i.e., abstract), and is it possible to have different entities spatially or spatio-temporally colocalized?

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- Principal choices, with common terminology:
  - Endurantist vs. Perdurantist
  - Universals vs. Particulars
  - Descriptive vs. Prescriptive
  - (Onto)Logical economy and multiplicative vs. reductionist

Outline

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

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  - 7 basic relations
  - 80 axioms, 100 definitions, 20 theorems

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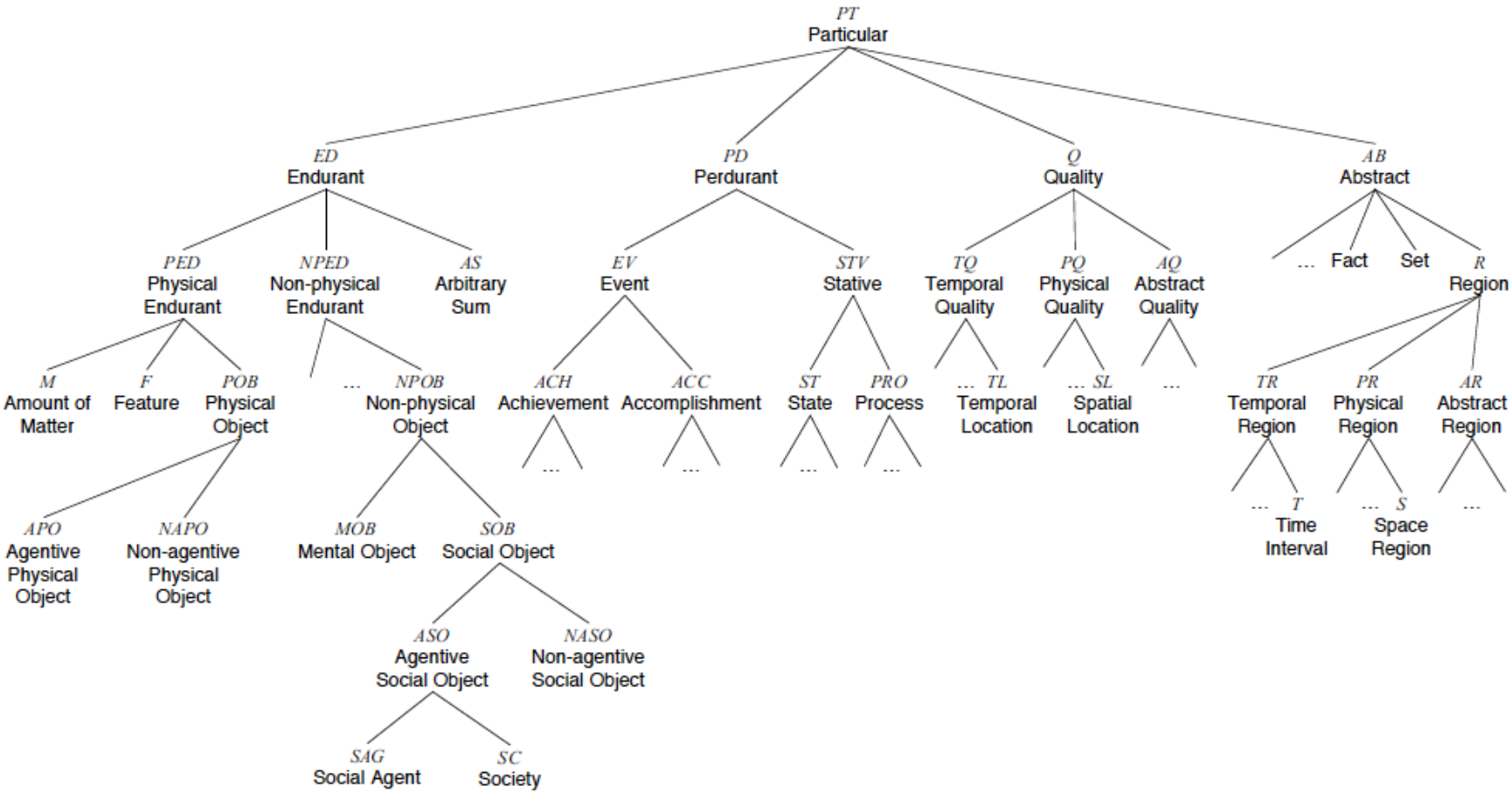
  - 80 axioms, 100 definitions, 20 theorems
- Rigorous quality criteria
- Documentation

Outline of DOLCE categories



The African Wildlife Ontology and DOLCE

- Where does `Plant` fit in DOLCE?
- Giraffes drink `Water`: where should we put `Water`?
- Impalas run (fast). Where should we put `Running`?
- Lions eat impalas, and in the process, the impalas die. Where should we put `Death`?
- Generic examples of DOLCE's 'leaf' categories: see Table 1, p21 in the D18.pdf

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  - as a subtype of Achievement...
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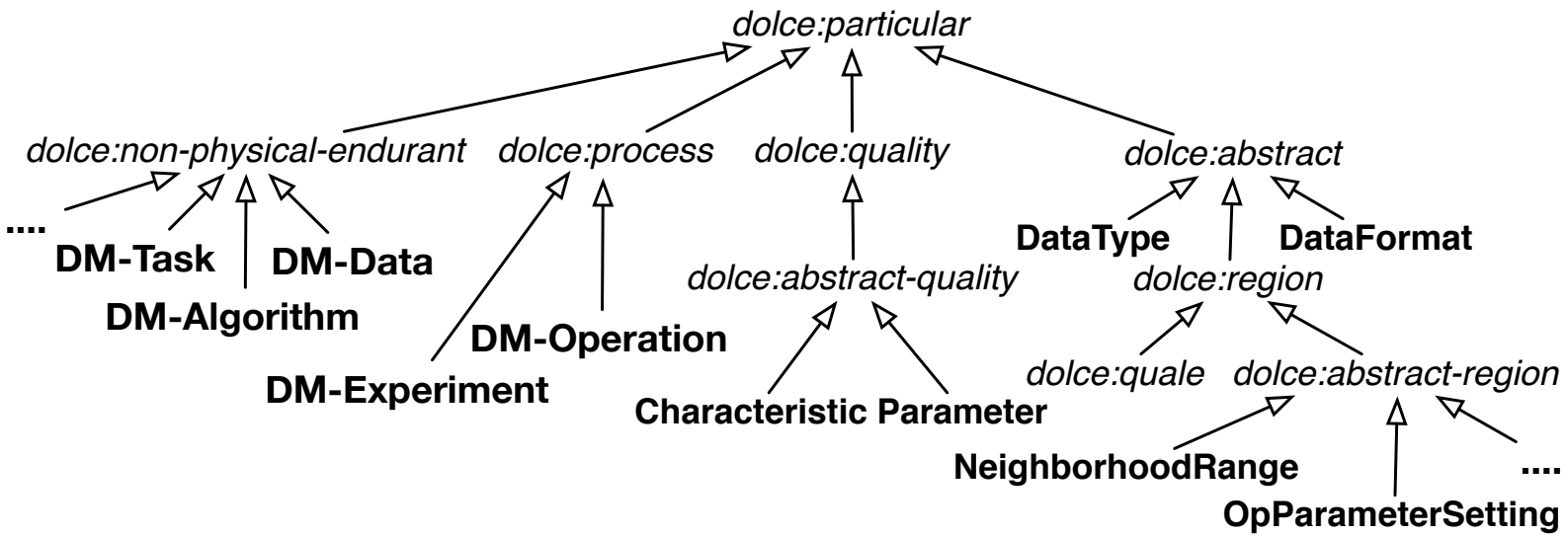
Selection of DMOP classes linked to DOLCE



DOLCE's basic relations

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  - Between quality regions (immediate)
  - Between arbitrary objects (temporary)

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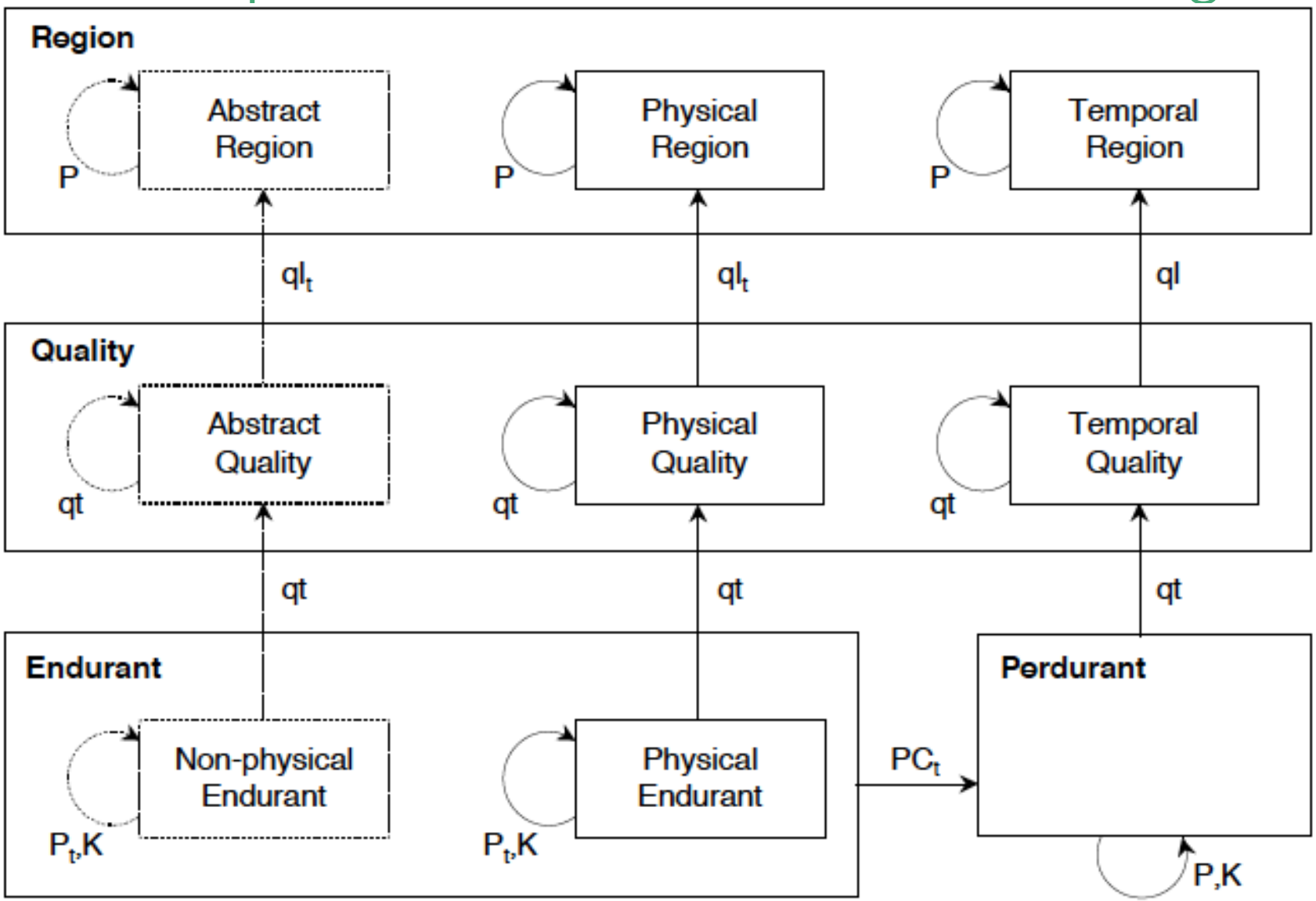
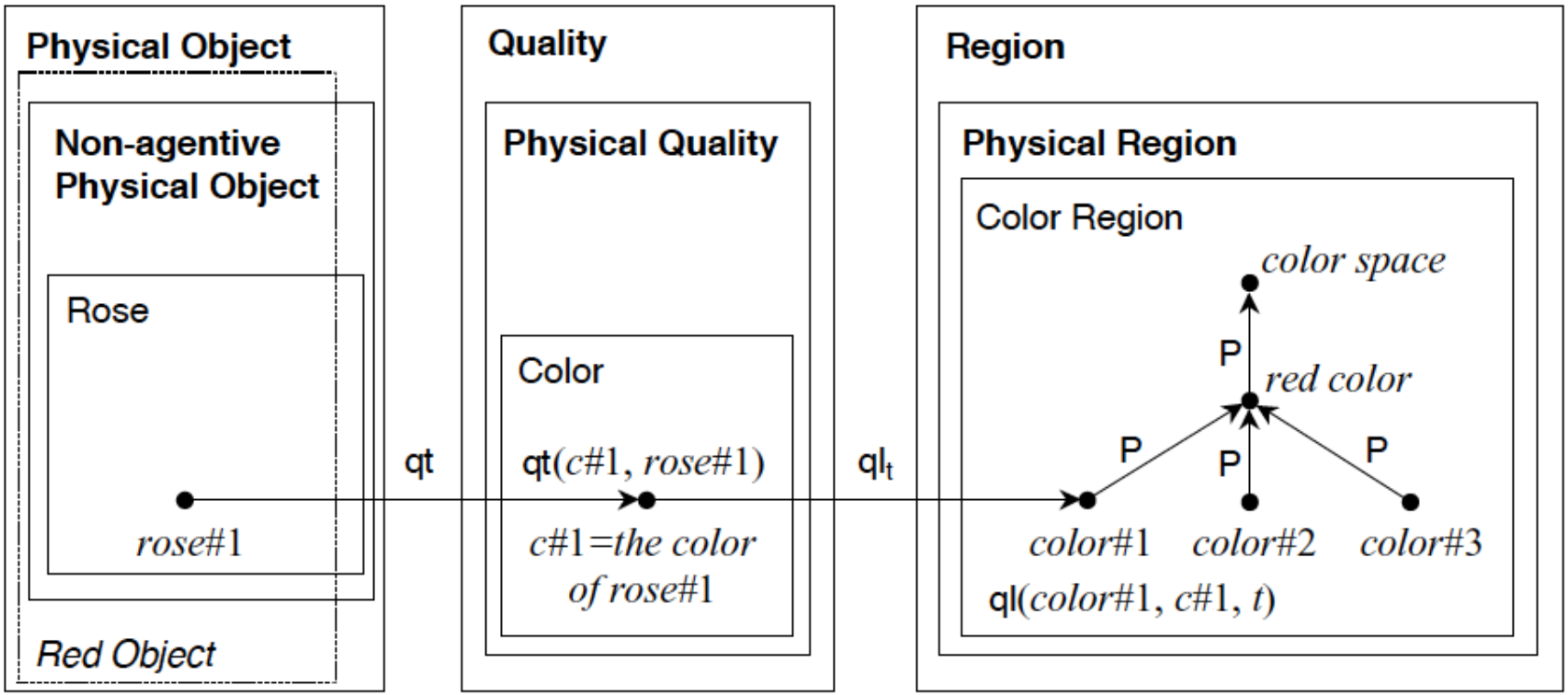
- Constitution
- Participation
- Representation
- Dependence: Specific/generic constant dependence
- Inherence (between a quality and its host)
- Quale
  - Between a quality and its region (immediate, for unchanging entities)
  - Between a quality and its region (temporary, for changing entities)

DOLCE's primitive relations between basic categories



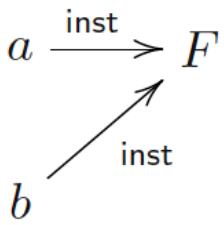
DOLCE's basic relations w.r.t. qualities



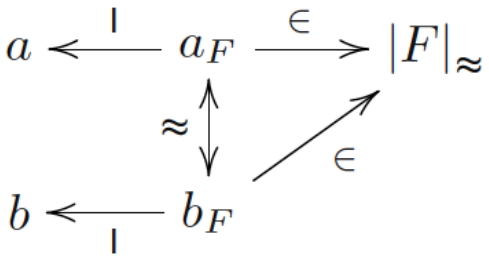
Various commitments regarding 'attributes'

- Options:

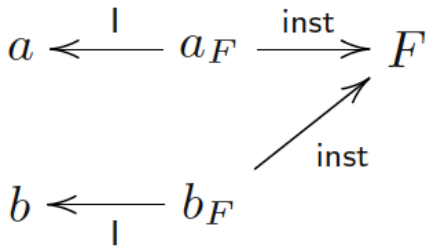
Universalism



Trope theory



Universals+Tropes



see also (Borgo and Masolo, 2009)

- DOLCE: [*PerDurant*/*EnDurant*] *–qt–* *Quality* *–ql–* *Region*: use `Quality` and `Abstract` branches with `qt` (inherence) and `ql` (quale) object properties

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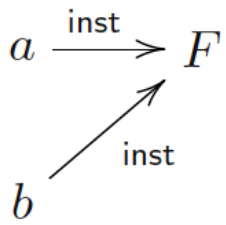

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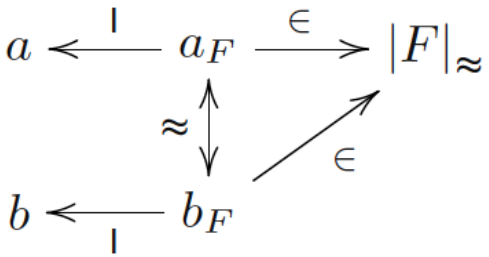

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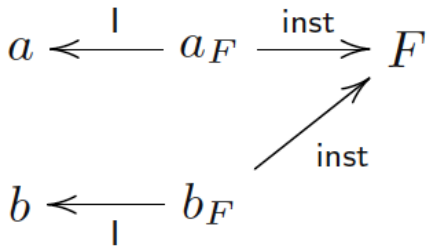

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- OWL: `DataProperty` with as domain class and range a datatype
  - More compact notation
  - But modelling based on arbitrary (and practical, application) decisions, increasing the chance of incompatibilities and less reusable

The Wildlife Ontology and DOLCE

- Giraffes eat leaves and twigs. how do `Plant` and `Twig` relate?
- The elephant's tusks (ivory) are made of apatite (calcium phosphate); which DOLCE relation can be reused?
- How would you represent the `Size` (`Height`, `Weight`, etc.) of an average adult elephant?

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  - with *quality* and *quale*
  - OWL data properties
    - What is the data type; integer, float, real, string?
    - Measure in meter, feet, kg, lb?
    - Introduce "`ElephantHeight`", and also "`LionHeight`", "`GiraffeHeight`', "`ImpalaHeight`", etc.?

DOLCE's basics on universals

(Dd1) $\mathsf{RG}(\phi) \triangleq \Box\forall x(\phi(x) \rightarrow \Box\phi(x))$ (ϕ *is Rigid*)

(Dd2) $\mathsf{NEP}(\phi) \triangleq \Box\exists x(\phi(x))$ (ϕ *is Non-Empty*)

(Dd3) $\mathsf{DJ}(\phi,\psi) \triangleq \Box\neg\exists x(\phi(x) \wedge \psi(x))$ (ϕ *and* ψ *are Disjoint*)

(Dd4) $\mathsf{SB}(\phi,\psi) \triangleq \Box\forall x(\psi(x) \rightarrow \phi(x))$ (ϕ *Subsumes* ψ)

(Dd5) $\mathsf{EQ}(\phi,\psi) \triangleq \mathsf{SB}(\phi,\psi) \wedge \mathsf{SB}(\psi,\phi)$ (ϕ *and* ψ *are Equal*)

(Dd6) $\mathsf{PSB}(\phi,\psi) \triangleq \mathsf{SB}(\phi,\psi) \wedge \neg\mathsf{SB}(\phi,\psi)$ (ϕ *Properly Subsumes* ψ)

(Dd7) $\mathsf{L}(\phi) \triangleq \Box\forall\psi(\mathsf{SB}(\phi,\psi) \rightarrow \mathsf{EQ}(\phi,\psi))$ (ϕ *is a Leaf*)

(Dd8) $\mathsf{SBL}(\phi,\psi) \triangleq \mathsf{SB}(\phi,\psi) \wedge \mathsf{L}(\psi)$ (ψ *is a Leaf Subsumed by* ϕ)

(Dd9) $\mathsf{PSBL}(\phi,\psi) \triangleq \mathsf{PSB}(\phi,\psi) \wedge \mathsf{L}(\psi)$ (ψ *is a Leaf Properly Subsumed by* ϕ)

.....

DOLCE's characterisation of categories

Physical Object

(Ad32)* $\mathsf{GK}(SC, SAG)$

(Ad30)* $\mathsf{GK}(NAPO, M)$

(Ad70)* $\mathsf{OGD}(F, NAPO)$

(Ad71)* $\mathsf{OSD}(MOB, APO)$

(Ad72)* $\mathsf{OGD}(SAG, APO)$

Feature

(Ad70)* $\mathsf{OGD}(F, NAPO)$

Non-physical Endurant

(Ad12)* $\mathsf{P}(x,y,t) \rightarrow (NPED(x) \leftrightarrow NPED(y))$

(Ad22)* $\mathsf{K}(x,y,t) \rightarrow (NPED(x) \leftrightarrow NPED(y))$

(Ad41)* $\mathsf{qt}(x,y) \rightarrow (AQ(x) \leftrightarrow (AQ(y) \vee NPED(y)))$

(Ad48)* $AQ(x) \rightarrow \exists! y(\mathsf{qt}(x,y) \wedge NPED(y))$

(Ad51)* $NPED(x) \rightarrow \exists \phi, y(\mathsf{SBL}(AQ, \phi) \wedge \mathsf{qt}(\phi, y, x))$

(Ad74)* $\mathsf{OD}(NPED, PED)$

... etc...

Can all that be used?

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- DOLCE in KIF
- DOLCE in OWL:
  - DOLCE-Lite: simplified translations of Dolce2.0
  - Does *not* consider: modality, temporal indexing, relation composition
  - Different names are adopted for relations that have the same name but different arities in the FOL version
  - Some commonsense concepts have been added as examples

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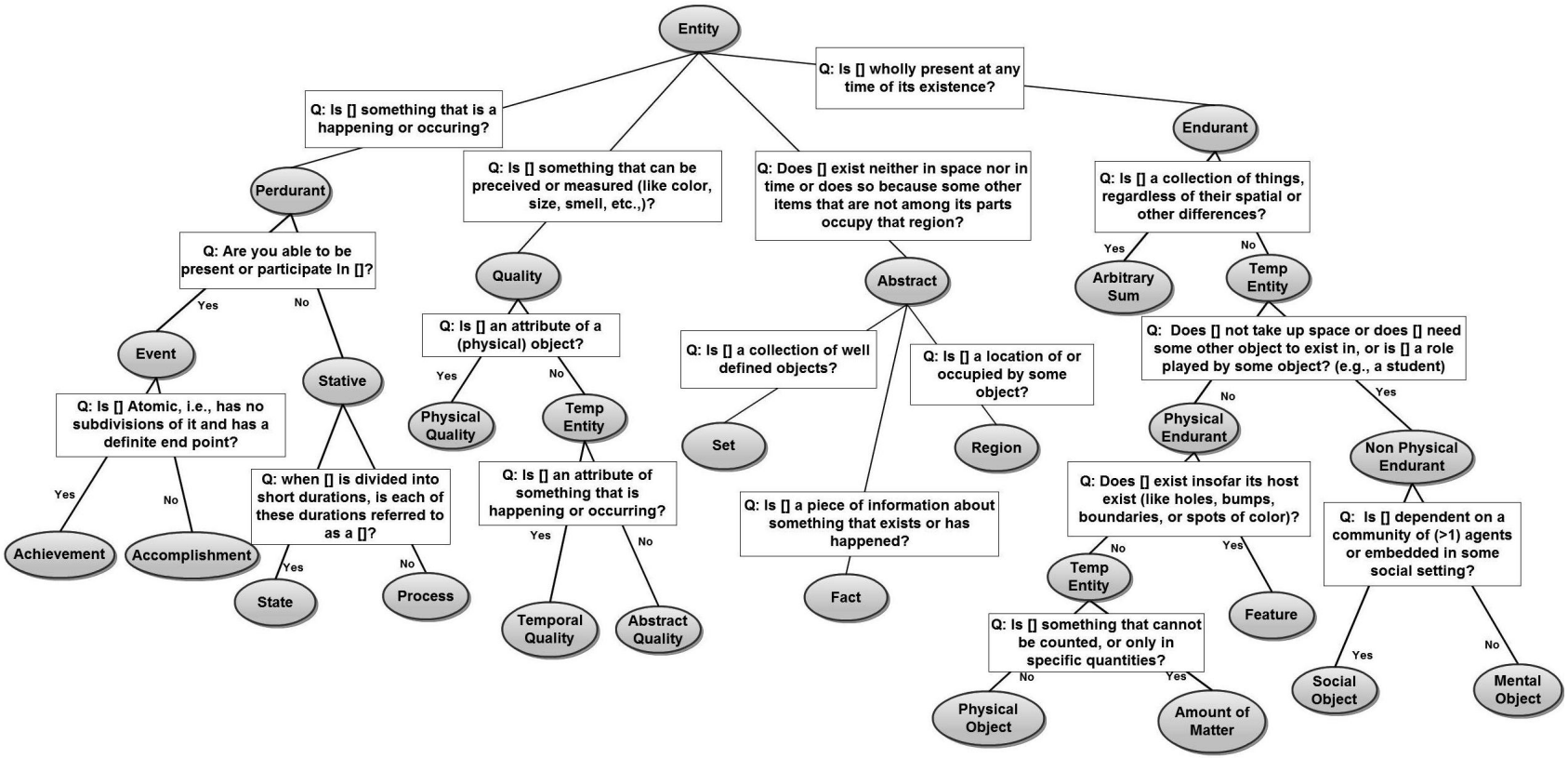
  - Different names are adopted for relations that have the same name but different arities in the FOL version
  - Some commonsense concepts have been added as examples
- DOLCE-2.1-Lite-Plus version includes some modules for Plans, Information Objects, Semiotics, Temporal relations, Social notions (collectives, organizations, etc.), a Reification vocabulary, etc.
- `http://www.loa.istc.cnr.it/old/DOLCE.html`

D3


Entity
Q: Is [] something that is a happening or occuring?
Q: Is [] something that can be preceived or measured (like color, size, smell, etc.,)?
Q: Does [] exist neither in space nor in time or does so because some other items that are not among its parts occupy that region?
Q: Is [] wholly present at any time of its existence?
Perdurant
Endurant
Q: Are you able to be present or participate In []?
Quality
Abstract
Q: Is [] a collection of things, regardless of their spatial or other differences?
Yes
No
Arbitrary Sum
Temp Entity
Event
Stative
Q: Is [] an attribute of a (physical) object?
Q: Is [] a collection of well defined objects?
Q: Is [] a location of or occupied by some object?
Q: Does [] not take up space or does [] need some other object to exist in, or is [] a role played by some object? (e.g., a student)
Q: Is [] Atomic, i.e., has no subdivisions of it and has a definite end point?
Physical Quality
Temp Entity
Set
Region
Physical Endurant
Non Physical Endurant
Achievement
Accomplishment
Q: when [] is divided into short durations, is each of these durations referred to as a []?
Q: Is [] an attribute of something that is happening or occurring?
Q: Is [] a piece of information about something that exists or has happened?
Q: Does [] exist insofar its host exist (like holes, bumps, boundaries, or spots of color)?
Q: Is [] dependent on a community of (>1) agents or embedded in some social setting?
State
Process
Temporal Quality
Abstract Quality
Fact
Temp Entity
Feature
Q: Is [] something that cannot be counted, or only in specific quantities?
Social Object
Mental Object
Physical Object
Amount of Matter

Outline

BFO Overview

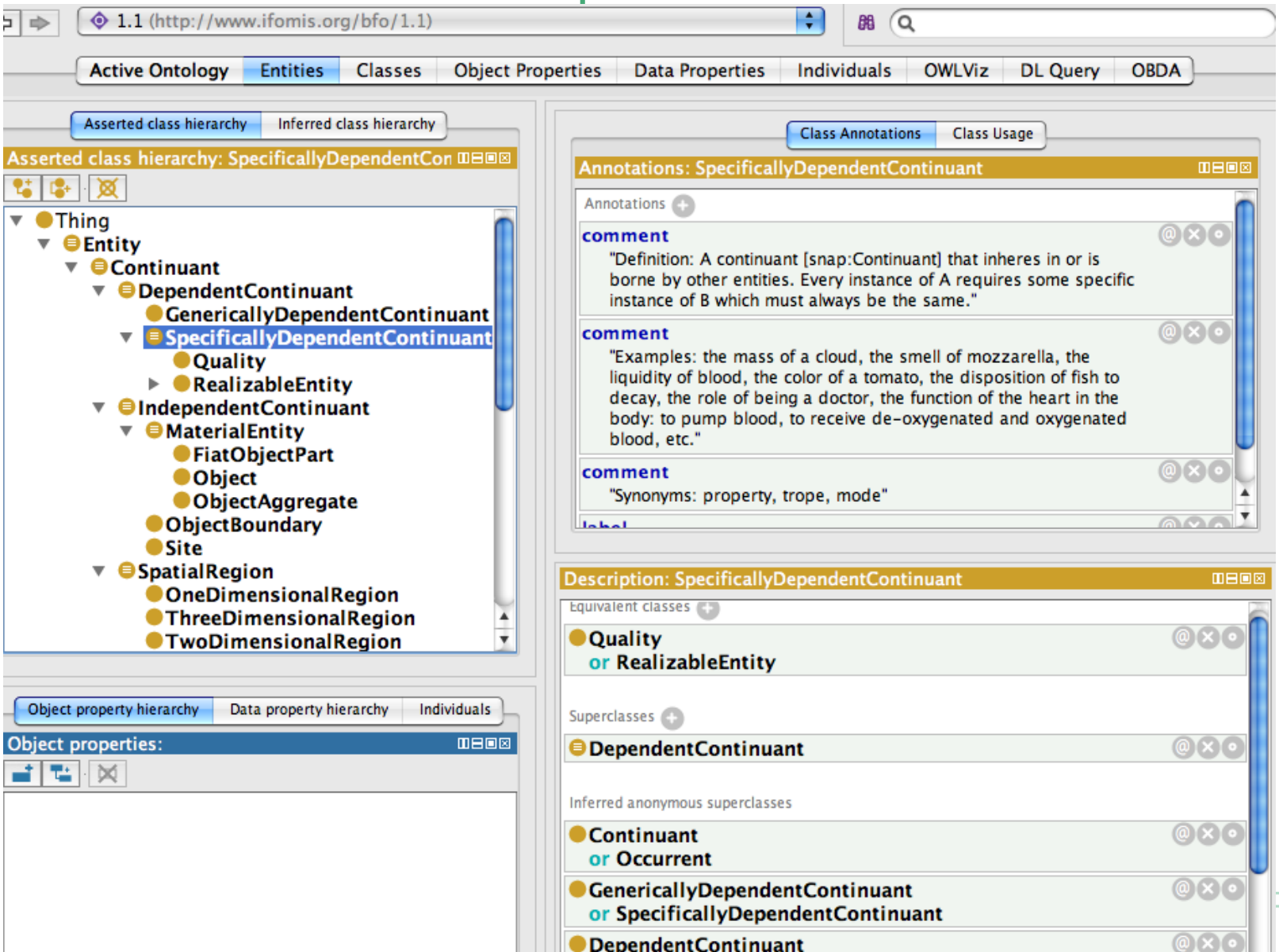
- Ontology as reality representation
- Aims at reconciling the so-called three-dimensionalist and four-dimensionalist views
  - Snap ontology of endurants which is reproduced at each moment of time and is used to characterise static views of the world
  - Span ontology of happenings and occurrents and, more generally, of entities which persist in time by perduring, or 'unfolding in time'
  - Endurants (Snap) or perdurants (Span)
- Limited granularity
- Heavily influenced by parthood relations, boundaries, dependence

BFO Taxonomy

```
bfo:Entity
  snap:Continuant
    snap:DependentContinuant
      snap:GenericalyDependentContinuant
      snap:SpecificalyDependentContinuant
        snap:Quality
        snap:RealizableEntity
          snap:Disposition
          snap:Function
          snap:Role
    snap:IndependentContinuant
      snap:MaterialEntity
          snap:Object
          snap:FiatObjectPart
          snap:ObjectAggregate
      snap:ObjectBoundary
      snap:Site
    snap:SpatialRegion
      snap:ZeroDimensionalRegion
      snap:OneDimensionalRegion
      snap:TwoDimensionalRegion
      snap:ThreeDimensionalRegion
```

```
span:Occurrent
  span:ProcessualEntity
    span:Process
    span:ProcessBoundary
    span:FiatProcessPart
    span:ProcessAggregate
    span:ProcessualContext
  span:SpatiotemporalRegion
    span:ConnectedTemporalRegion
      span:SpatiotemporalInstant
      span:SpatiotemporalInterval
    span:ScatteredSpatiotemporalRegion
  span:TemporalRegion
    span:ConnectedSpatiotemporalRegion
      span:TemporalInstant
      span:TemporalInterval
    span:ScatteredTemporalRegion
```

Example section



The Wildlife Ontology and BFO

- Exercise: revisit the Wildlife & DOLCE and find corresponding BFO categories
  - Non-Agentive Physical Object, Amount of Matter, Process, and Achievement
  - parthood, constitution, quality & quale

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- Exercise: revisit the Wildlife & DOLCE and find corresponding BFO categories
  - Non-Agentive Physical Object, Amount of Matter, Process, and Achievement
  - parthood, constitution, quality & quale
- Issues
  - Generally: to do this in a transparent and reusable way, we need a mapping between the two foundational ontologies
  - Immediacy: What with the relations?
  - There is a `bfo-ro.owl` to integrate relations of the Relation Ontology with BFO (extensions under consideration)

Overview

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Overview

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- There is a `bfo-ro.owl` to integration relations of the Relation Ontology with BFO (extensions under consideration)
- Version in Isabelle (mainly part-wholes, but not all categories)
- Version in OBO (the original Gene Ontology format, with limited, but expanding, types of relationships)
- Version in Prover9 (first order logic model checker and theorem prover)

The Relation Ontology

- Definitions for *is_a*, *part_of*, *integral_part_of*, *proper_part_of*, *located_in*, *contained_in*, *adjacent_to*, *transformation_of*, *derives_from*, *preceded_by*, *has_participant*, *has_agent*, *instance_of*

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- Proposed extensions under consideration, among others:
  - Relations between generically dependent continuants and specifically dependent continuants (a.o., concretizes, *has_quality*, *has_function*, ...)
  - A relation between a process and a process or quality (*regulates*)
  - Refinements on *derived_from*
  - Measurements (*has_value*, *of_dimension*, ...)

The Relation Ontology

- **Note**: The OBO Relation ontology is undergoing substantial changes: Core domain-independent relations will live in BFO, Biology specific relations (defined in terms of core relations) will live in RO (`http://groups.google.com/group/obo-relations/browse_thread/thread/29fc616eb570f7dc/fc0647f190b5f178`)
- BFO will likely include the follow relations:
  BFO_0000050 part of
  BFO_0000051 has part
  BFO_0000056 participates in
  BFO_0000057 has participant
  BFO_0000062 preceded by
  BFO_0000063 precedes
  BFO_0000060 immediately preceded by
  BFO_0000061 immediately precedes
- Discuss.

A relation ontology?

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- Do we need a *separate* ontology for relations, or integrated in a foundational ontology?
- Philosophers do not agree on the answers, but the modellers and engineers need agreement to facilitate interoperability among ontologies

Other relation ontologies

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- There are "**RBox**es" that can be seen as a relation ontology, e.g., containing
  - Part-whole relations (next lecture)
  - Spatial relations (RCC)
  - Temporal relations (Allen)

Outline

Ontologies and choices

- Other more or less used foundational ontologies, a.o.:
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  - SUMO
  - OCHRE
  - UFO
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- A library of foundational ontologies with mappings between them: choose your pet ontology and be interoperable with the others

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- `http://www.thezfiles.co.za/ROMULUS/` (and related papers)

Section of the content comparison

the alignments numbered in bold font can also be mapped

	Entity			Relational property	
	DOLCE-Lite	**BFORO**		**DOLCE-Lite**	**BFORO**
1.	endurant	Independent Continuant	1.	generic-location	located_in
2.	physical-endurant	MaterialEntity	2.	generic-location-of	location_of
3.	physical-object	Object	**3.**	part	has_part
4.	perdurant	Occurrent	**4.**	part-of	part_of
5.	process	Process	**5.**	proper-part	has_proper_part
6.	quality	Quality	**6.**	proper-part-of	proper_part_of
7.	spatio-temporal-region	SpatioTemporal Region	7.	participant	has_participant
8.	temporal-region	TemporalRegion	8.	participant-in	participates_in
9.	space-region	SpatialRegion			

Exercise: which FO in this scenario?

You are to develop an ontology of heart diseases. The ontology must capture the intrinsic nature of the real world only. As such, entities that are not extended in space and time must not be found in the ontology. Possible future conditions that are predicted and previous conditions of the heart must be modelled in the ontology. Since it is a biological ontology, you wish to register it with the OBO foundry to allow reuse and integration with other ontologies. This ontology must be modelled in OWL 2 EL.

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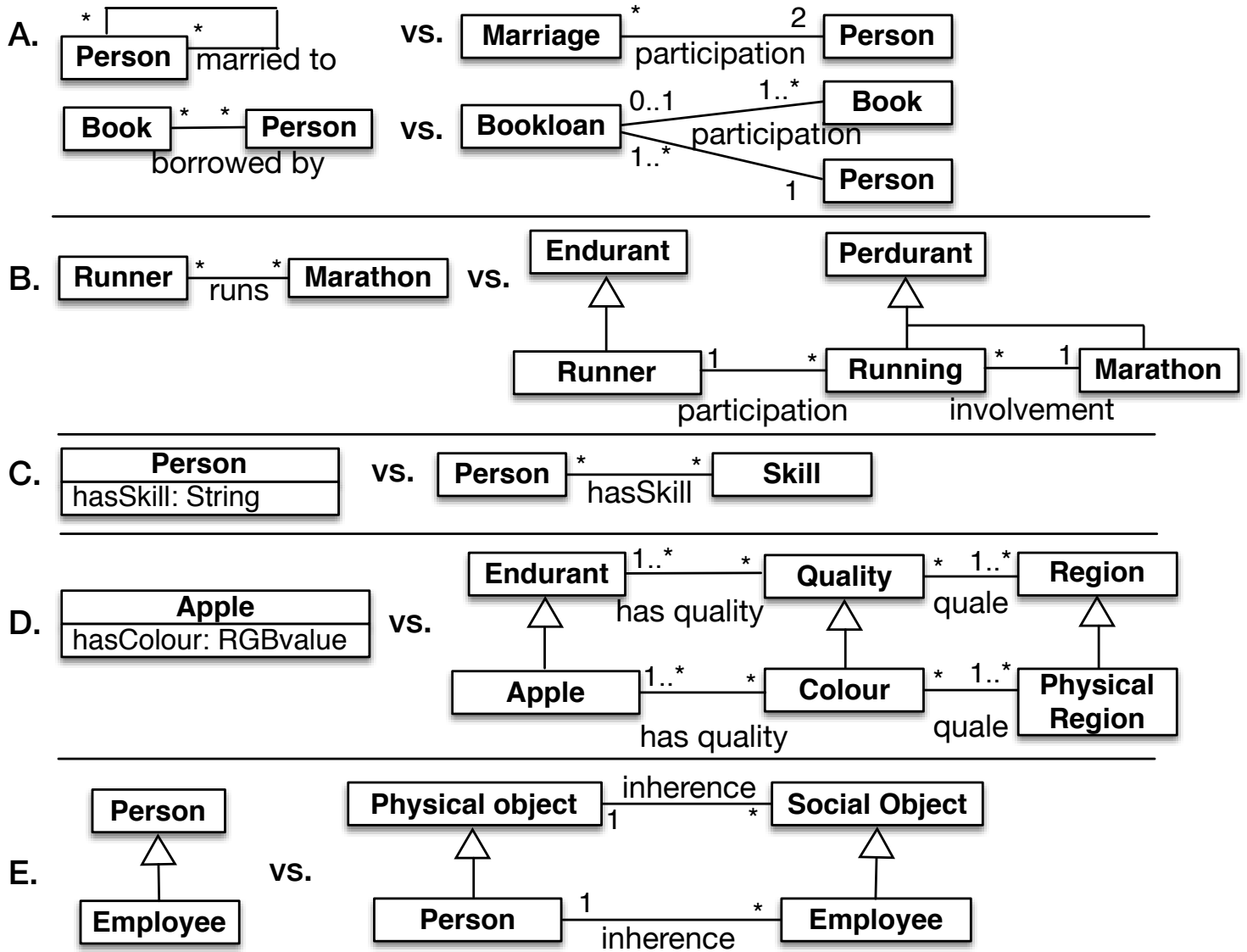
Some practical effects

- Adding DOLCE can increase reasoning time (with SUMO even much more so); not for BFO v1
- "jumping on the bandwagon" multiplier effect; e.g.:
  - Using BFO makes it easier to align with other biology ontologies in the OBO Foundry
  - There are several conceptual models that use UFO already

Modelling effects: compact vs elaborate



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- The ‘elaborate’ way captures more detail about the subject domain
- The ‘compact’ way may hamper interoperability, likely faster reasoning time
- The ‘compact’ way captures less detail, so less precise

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- When the FO doesn't have a core entity (e.g., BFO has no abstract, no stuff): complicates modelling due to lack of guidance when modeller is convinced it does exist
- Reuse well-investigated modelling decisions
- Compatibility of ontologies that use the same FO
- Integration of ontologies that are aligned to different ontologies

The General Formal Ontology

- "A Foundational Ontology for Conceptual Modelling" (Herre, 2010) [Note: actually, UFO is more so]
- **A component of an Integrated System of Foundational Ontologies**
- (3D) objects and (4D) processes
- Admitting universals, concepts, and symbol structures and their interrelations
- GFO is intended to be the basis for a novel theory of ontological modelling which combines declarative specifications with algorithmic procedures
- Module for functions and a module for roles
- GFO is designed for applications, firstly in medical, biological, and biomedical areas, but also in

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  - The entities of the world (ATO) are exhaustively divided into *categories* and *individuals*, where individuals instantiate categories, and among individuals, there is a distinction between objects and attributives
  - Basic level ontology: contains all relevant top-level distinctions and categories

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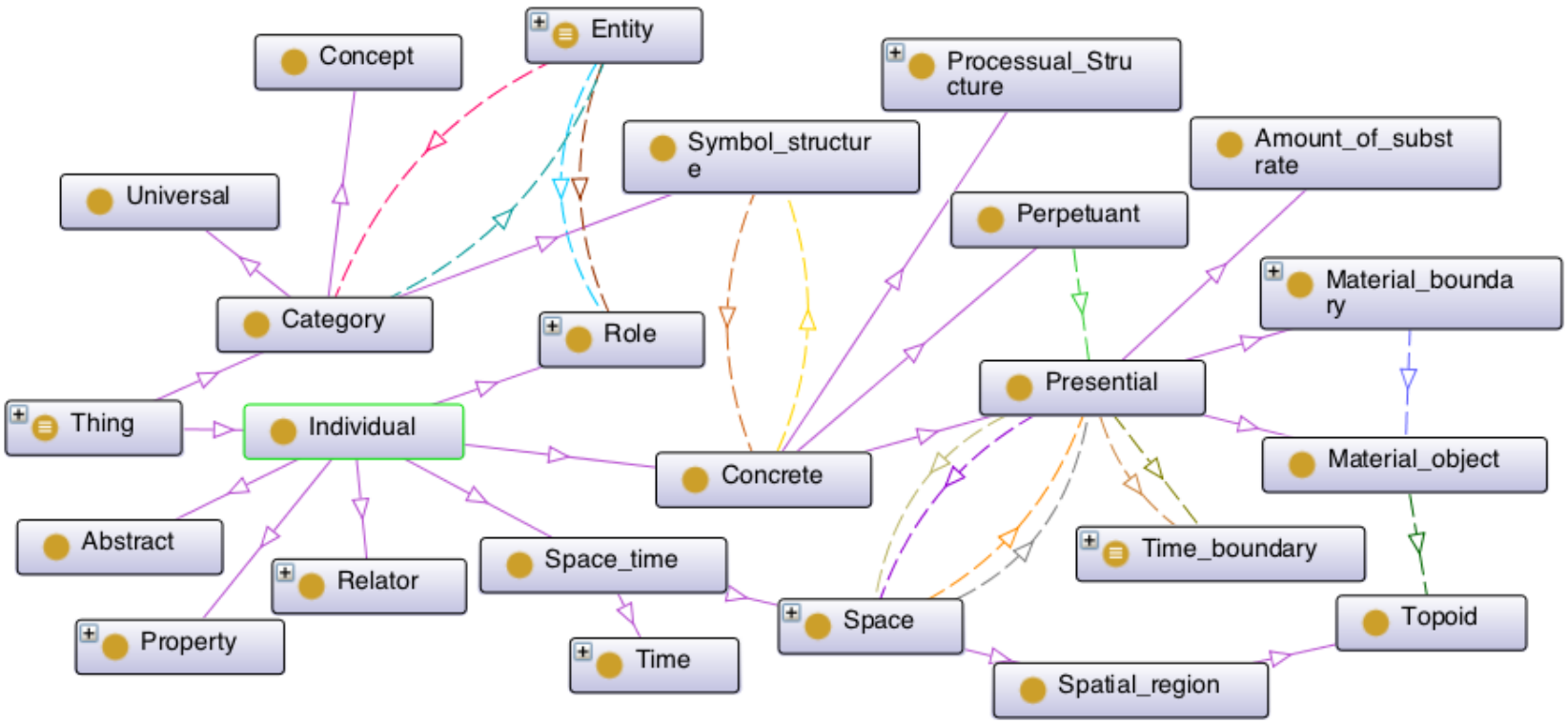
  - Attributives (a.o. properties, roles, functions, dispositions)

Basic relations

- Existential dependency
- instantiation
- parthood relations for time, space, material structures, processes
- coincidence, adjacent
- occupation
- participation
- causality

Section of GFO



Summary

1. DOLCE
   - Overview
   - Formalisations and implementations
2. BFO
   - Overview
   - Formalisations and implementations
   - Relation Ontology
3. More foundational ontologies
   - Ontologies and choices
   - Where and how does it make a difference?
   - GFO as 'super' foundational (extra slides)