The OntoClean Methodology

- Minimal Top-Level Ontology
- Ontology-Driven Modeling Principles
- Useful Property Kinds
- Formal Ontological Properties/Relations

Conceptualization → Methodology → Ontology → Conceptual Model
Summary

• Re-visiting common conceptual modelling constructs
• Some basic ontological distinctions: the DOLCE ontology
Re-visiting conceptual modelling constructs

- Instantiation
- Generalization
- Association
- Aggregation
The Instance-of Relation

How to decide whether something is an instance?

• Properties can be instances of meta-properties
• Hence, “being an instance” may be a subjective property
• But “being a particular” IS NOT!

• Particulars are always “ultimate” instances.
• Concrete entities are always particulars.
• So-called “temporal instances” are either temporal parts of a particular or instances of an abstract class.
Particulars and Universals

• Universals
  - Have multiple exemplifications
  - All abstract
• Particulars:
  - Have no exemplifications
  - Can be either concrete or abstract

Concrete entities are all particulars
Instance-of vs. membership (1)

• The problems of logical predication
  - x is an apple → Apple(x)
  - x is red → Red(x)

• Instance-of vs. class membership
  - John is a member of “Person” → Person(John)
  - Tree1 is a member of “BlackForest” → BlackForest(Tree1) ??

(violates usual intended interpretation of unary predicates: property shared by all instances of the corresponding class. Doesn’t pass the “is-a” test)
Instance-of vs membership (2)

- **Instance-of:**
  - Particular-universal
  - Universal-universal

- **Membership:**
  - Particular-particular
Overloading Subsumption
Common modeling pitfalls

- Instantiation
- Composition
- Disjunction
- Polysemy
- Constitution
Example - Identity

• Is *time-interval* a subclass of *time-duration*?
  - Initial answer: yes
• IC for *time-duration*
  - Same-length
• IC for *time-interval*
  - Same start & end
Example - Identity

- time-duration
  - time-interval
    - 3-4 PM Weds.
    - 2-3 PM Tues.
  - One hour
  - occurrent
Does this ontology mean that *My ThinkPad is a ThinkPad Model*?

Question: What ThinkPad models do you sell?  
Answer should NOT include My ThinkPad -- nor yours.
Instantiation (2)

Notebook Computer → ThinkPad Model

My ThinkPad (s# xx123) → model → T 21

T Series
Composition (1)

- Computer
  - Disk Drive
  - Memory
  - Micro Drive

Question: What kinds of computer do you sell? Answer should NOT include Disk Drives or Memory.
Composition (2)

Computer

Has-part

Disk Drive

Memory

Micro Drive
Disjunction (1)

Unintended model: flashcard-110 is a computer-part
Disjunction (2)

Computer \(\text{has-part}\) Disk Drive \(\lor\) Memory \(\lor\) ...
Polysemy (1) 
(Mikrokosmos)

Question: How many books do you have on Hemingway?  
Answer: 5,000
Polysemy (2)
(WordNet)

Physical Object

Book
Sense 1

.....

Abstract Entity

Book
Sense 2
Biography of Hemingway
Question: What types of matter will conduct electricity? Answer should NOT include computers.
Constitution (2)

Entity

Amount of Matter

Physical Object

Metal

Clay

Computer

constituted
Part-of vs. part-whole relations

- portion/mass
- component/integral object
- member/collection
- **Member/social organization**
- stuff/object
- place/area
- feature/activity
Part, Constitution, and Identity

- *Structure* may change identity
- *Mereological extensionality* is lost
- *Constitution* links the two entities
- Constitution is asymmetric (implies *dependence*)
Attributes vs. Arbitrary Relations

• Woods’ example
  - John
    • age: 32
    • hits: Mary

• Internal vs. external relations

• Woods’ linguistic test

• The Attribute Consistency Principle:
  - Any X of Y is a X
Formal Ontological Properties/Relations

Useful Property Kinds

Ontology-Driven Modeling Principles

Minimal Top-Level Ontology

Useful Property Kinds

Formal Ontological Properties/Relations

User

Methodology

Conceptual Model

Ontology

Conceptualization
Developing foundational ontologies

- List the **basic options**
- Explore most relevant mutual **dependencies**
- Propose one preliminary upper level which is carefully **justified** and **positioned** with respect to the space of possible choices
- Add some **minimal ontologies** specifically relevant for selected domains
- Explore **alternative** upper levels
The WonderWeb Library of Foundational Ontologies

- No single upper level
- Rather, a (small) set of foundational ontologies carefully justified and positioned with respect to the space of possible choices
- Basic options clearly documented
- Clear branching points to allow for easy comparison of ontological options
The WFO architecture

Choose Vision

4D

3D

Choose Subject

Top
Bank
Law

Single Module

Single Vision

Formal Links Between Visions & Modules
DOLCE: a Descriptive Ontology for Linguistic and Cognitive Engineering

- A first reference module for the Foundational Ontology Library
- Strong cognitive bias influenced by
  - Perception
  - Culture
  - Social conventions
- Rich axiomatization
- Categories as conceptual containers: no “deep” metaphysical implications
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
  - Quality region
  - Time region
  - Space region
  - Color region
  - ...
  ...

Abstract

...
Abstract vs. Concrete Entities

- **Concrete**: located in space-time (regions of space-time are located in themselves)
- **Abstract** - two meanings:
  - Result of an abstraction process (something common to multiple exemplifications)
    - *Not located in space-time*
- Mereological sums (of concrete entities) are concrete, the corresponding sets are abstract...
Endurance vs. Perdurance

- **Endurants:**
  - All proper parts are present whenever they are present (*wholly presence*, no temporal parts)
  - Exist in time
  - Can genuinely change in time
  - Need a time-indexed parthood relation

- **Perdurants:**
  - Only some proper parts are present whenever they are present (*partial presence*, temporal parts)
  - Happen in time
  - Do not change in time
  - Do not need a time-indexed parthood relation
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
  - The room’s temperature is increasing
  - Red is opposite to green and close to brown

- Every entity comes with certain qualities that permanently \textit{inhere} to it and are \textit{unique} of it
- Qualities are perceptually mapped into \textit{qualia}, which are regions of \textit{quality spaces}.
- Properties hold because qualities have certain locations in their quality spaces.
- Each \textit{quality type} has its own quality space
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.
Aggregate vs. Object

- Both are *enduring* entities
- An object has a *unity criterion*, while an aggregate does not.
Physical vs. Non-physical Object

- Physical objects:
  - inherent spatial localization
  - not dependent on other objects (physical objects, like cars) or no inherent localization and be dependent on agents (non-physical objects, like laws and institutions).

- Non-physical objects can also be divided into mental (depending on singular agents) and social (depending on communities of agents).
Features

- **Features** are “parasitic” entities, that exist insofar their host exists.
- Features may be relevant parts of their host, or places (which are not parts of their hosts).
- All features are essential wholes, but no common unity criterion may exist for all of them (*U).
Abstracts

• **Abstracts** are entities that have no inherent spatial or temporal localization. Examples of Abstract are propositions, sets, symbols, regions, etc.
• **Quality regions** and **quality spaces** are relevant examples of abstract entities
Physical and non-physical objects
Given an entity x to be characterised as D(x), its properties are written with the following compact syntax (in the 'attribute' slot of the next UML class diagrams):

- **C** \[\forall x \, D(x) \rightarrow C(x)\]
- **NOT(C)** \[\forall x \, D(x) \rightarrow \neg C(x)\]
- **R:C** \[\forall x \, D(x) \rightarrow \exists y \, R(x,y) \land C(y)\]
- **[SOME|=|>|<]** \[\forall x \, D(x) \rightarrow \exists (n|>n|<n) (y) \, R(x,y) \land C(y)\]
- **[ALL]R:C** \[\forall x, y \, D(x) \rightarrow R(x,y) \rightarrow C(y)\]
- **NOT(R:C)** \[\forall x \, D(x) \rightarrow \neg \exists y \, R(x,y) \land C(y)\]
Endurants

Endurant
- Enduring
- [SOMExParticipatesIn:Occurrence
- [SOMExMSpeConstDep:Quality

Amount of Matter
-Mereoinvariant

Arbitrary Sum
-Pseudo-constant
- [SOMExPart:Object

Object
- Essential Whole
- Heterogeneous Unity

Physical Object
- [SOMeXHasQuality:SpatialLocation
- NOT(HasQuality:TemporalLocation)
- NOT(SpeConstDep:Object)
- [ALL]HasQuality:Physical Q

Non-physical Object
- NOT(HasQuality:SpatialLocation)
- [SOMexGenConstDep:AgentiveObj
- [ALL]HasQuality:Abstract Q

Relevant Part
- [SOMeXPartOf:*Host

Place
- NOT(PartOf:*Host)

Non-Agентive PhyObj
- [SOMeXGenKBy:AmountOfMat

Agentive PhyObj
- [SOMeXGenKBy:NonAgentPhyObj

Mental Object
- [=1]SpeConstDep:AgentPhyObj

Social Object
- [SOMeXGenConstDep:Community

Physical Body
-Mereoinvariant

Ordinary Object
-MereoVariable

Feature
- Essential Whole
- Heterogeneous Unity
- [SOMeXHost:Object
- [SOMeXGenConstDep:Object

Non-agentive SocObj
- IntentionCarrier

Agentive SocObj
- NOT(IntentionCarrier)

Community
- [SOMeXGenKBy:SocialAgent

Social Agent
- [SOMeXGenConstDep:AgentPhyObj
Perdurants

Perdurate/Occurrence

- Perdurating
  - [SOME]Participant:Endurant
  - [SOME]HasQuality:TemporalLocation
  - NOT(HasQuality:SpatialLocation)
  - [ALL]TemporalPart:Occurrence
  - [ALL]SpatialPart:Occurrence

State

- Homeomeric

Process

- Weakly-Homeomeric

Accomplishment

- NOT(Homeomeric)

Non-Relational S

- [=1]Participant:Endurant

Relational S

- [>1]Participant:Endurant

Activity

- [SOME]GenConstDep:AgentiveObj

Phenomenon

- [SOME]SpeConstDep:Endurant
Qualities

- Quality
  - [SOME]MSpeCnstDep:Entity
  - [SOME]InheresIn:Entity
  - [SOME]Quale:Region
  - [ALL]HasQuality:Quality
  - NOT(HasPart:Entity)

- Temporal Q
  - [ALL]HasQuality:Temporal Q

- Physical Q
  - [ALL]HasQuality:Physical Q

- Abstract Q
  - [ALL]HasQuality:Abstract Q

- Temporal Location

- Spatial Location

- Aesthetic Location
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 ent)
  - Between a quality and its region (temporary, for changing ent)
- Participation
- Representation
Quality relations

Physical Object

Non-agentive Physical Object

Rose

Red Object

Physical Quality

Color

qt\((c\#1, \text{rose}\#1)\)

c\#1 = \text{the color of rose}\#1

Region

Physical Region

Color Region

\(\text{color space}^{}\)

\(\text{red color}^{}\)

\(\text{color}\#1\)

\(\text{color}\#2\)

\(\text{color}\#3\)

ql\((\text{color}\#1, \text{c}\#1, t)\)
Primitive relations and basic categories

Region
- Abstract Region
- Physical Region
- Temporal Region

Quality
- Abstract Quality
- Physical Quality
- Temporal Quality

Endurant
- Non-physical Endurant
- Physical Endurant

Perdurant

ql_t
ql_t
ql
qt
qt
qt
qt

PPP

P,K

P

P

PC_t

P,K
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
Representation relations

- Ongoing axiomatization (semiotics ontology)
- Extremely relevant for domain modelling
- Concepts
  - PhysicalRepresentation vs. Expression
  - Expression vs. Content
  - Content vs. Reference
- Relations
  - Realization, Interpretant, Reference, Description
- Non-trivial dependences between use and instantiation of expressions and contents
Axiomatizing basic relations

- Ground axioms (mainly algebraic)
- Links to other relations
- Dependence on time
- FO Modal Theory (S5+Barcan)

- WonderWeb D17 v.2 for details
KIF example with PW

- \( P(w, x, y) = "x \text{ is part of } y \text{ in the possible world } w" \)
- \( P(w, x, y, t) = "x \text{ is part of } y \text{ at time } t \text{ in the possible world } w" \)

; \( O(x, y) =_{df} \exists z (P(z, x) \land P(z, y)) \) (Overlap)
(defrelation \( O(?w0 ?x ?y) := \)
(and (ENTITY ?x)
  (ENTITY ?y)
  (WORLD ?w0)
  (exists (?z) (and (ENTITY ?z)
    (P ?w0 ?z ?x)
    (P ?w0 ?z ?y)))))
Q&A for drafting the concepts

• (are the parts of the entities you're talking about all present whenever such entities are present?)
  - Yes
• (can you count these entities?)
  - uncertain
• (do they resemble a definite object rather than an indefinite amount of matter?)
  - Yes
• (are these entities an undetachable part of something else?)
  - uncertain
• (for example, are they more like a table or like its edge?)
  - a table
• (can these entities exist independently of some agent that thinks, talks, or reason about them?)
  - uncertain
• (are these entities constituted by matter?)
  - Yes
• (can these entities intend to do something, or believe, or desire something?)
  - No
• (ok, put your class in the <NonAgentivePhysicalObject> branching)
Some ongoing applications

• Ontology merging and building (e.g. fishery, bank norms)
• Catalogue creation/maintenance (e.g. portals)
• DB design and requirement analysis
• Behaviour description and detection
  – Quality/anomaly assessment from legacy DBs (money-laundering procedures)
  – Quality/anomaly assessment of runtime operations (service level agreement)