# OntoClean and Ontology-driven conceptual modelling

*A new, simplified view*

Nicola Guarino

## Summary

- Ontological analysis of particulars
  - Parthood (mereology)
  - Unity (topology)
  - Dependence
- Ontological analysis of universals
  - Essence and identity
  - Different kinds of properties
  - Is-a overloading and the OntoClean methodology
- A practical example

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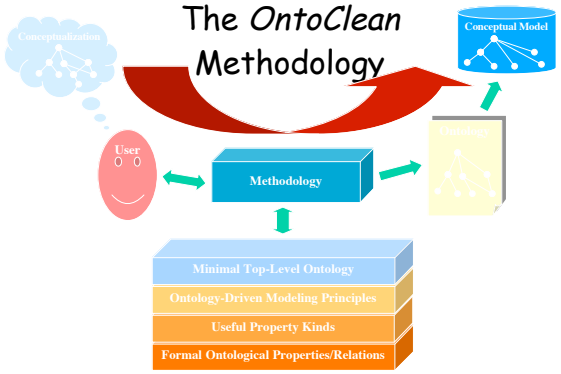
## The *OntoClean* Methodology

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## Formal Ontology

- Theory of ***formal distinctions and connections*** within:
  - entities of the world, as we perceive it (***particulars***)
  - categories we use to talk about such entities (***universals***)
- Why ***formal***?
  - Two meanings: ***rigorous*** and ***general***
  - Formal logic: connections between truths - neutral wrt ***truth***
  - Formal ontology: connections between things - neutral wrt ***reality***
- ***Goal:*** *characterizing* particulars and universals by means of formal properties and relations.

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## Essential properties

- Certain entities must have some properties in order to keep their identity;
  - John must have a brain (otherwise, he wouldn't be himself anymore)
  - John must be a person.
- A class *carries* an essential property if, for all its instances, such property is essential:
  - Every person must have a brain.

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## Mereological essential properties

- Extensionality: whenever the parts exist, *x* exists (*the whole is always the sum of its parts*)
- Mereological invariance: *x always keeps its parts*

- Examples of extensional entities:
  - Amounts of matter
  - Regions
  - Pluralities (pseudo-extensionality)
- Mereologically invariant (but non-extensional) entities:
  - A physical body (a lump of matter)

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## Unity

- A tentative formulation: *x* ***is a whole*** under ω iff there is an *equivalence relation* ω that binds together all the parts of *x*, such that, ***necessarily,***

$$P(y,x) \rightarrow (P(z,x) \leftrightarrow \omega(y,z))$$

but not

$$\omega(y,z) \leftrightarrow \exists x(P(y,x) \wedge P(z,x))$$

- P is the ***part-of*** relation
- ω can be seen as a ***generalized indirect connection***

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## Unity Refined

$$\delta_R(x) =_{df} R(x,x)$$

$$\upsilon_R(x) =_{df} \Sigma_{\delta R}(x) \wedge \forall y,z((\delta_R(y) \wedge \delta_R(z) \wedge P(y,x) \wedge P(z,x)) \rightarrow R(y,z)) \quad (x \text{ is unified by } R)$$

$$\omega_R(x) =_{df} Max_{\upsilon R}(x) \quad (x \text{ is a whole under } R)$$

$$\Sigma_\phi(x) =_{df} \forall y(P(y,x) \rightarrow \exists z(\phi(z) \wedge P(z,x) \wedge O(z,y)) \quad (\text{sum of } \phi s)$$

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## Kinds of Whole

- Depending on the ***nature of ω***, we can distinguish:
  - ***Topological wholes*** (a piece of coal, a lump of coal)
  - ***Morphological wholes*** (a constellation)
  - ***Functional wholes*** (a hammer, a bikini)
  - ***Social wholes*** (a population)

* a whole can have ***parts that are themselves wholes*** (with a different ω)

* Being a whole of a certain kind is an *essential property:* things cannot change their own unity conditions

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## Unity Disjointness Constraint

Classes with incompatible UCs are ***disjoint***

**Example: Object and Matter**

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## Essence and Rigidity

- Certain properties are essential to ***all*** their instances (compare ***being a person*** with ***having a brain***).
- These properties are ***rigid*** - if an entity is ever an instance of a rigid property, it must always be such.

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## Formal Rigidity

- $\phi$ is rigid (+R): $\forall x\ (\mathbf{pos}\ \phi(x) \rightarrow \mathbf{nec}\ \phi(x))$
  - e.g. Person, Apple
- $\phi$ is non-rigid (-R): $\exists x\ (\mathbf{pos}\ \phi(x) \wedge \neg\ \mathbf{nec}\ \phi(x))$
  - e.g. Red, Male
- $\phi$ is anti-rigid (~R): $\forall x\ (\mathbf{pos}\ \phi(x) \rightarrow \neg\ \mathbf{nec}\ \phi(x))$ e.g. Student, Agent

***Meta-properties***

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## The necessity of modality

- Consider the property *being a caterpillar*
  - Just not rigid if modality is substituted with temporal quantification
  - Anti-rigid if modality is introduced.

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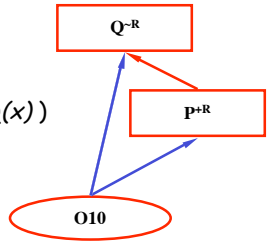
## Rigidity Constraint

**+R ⊄ ~R**

- Why?

**nec** $(\forall x\, P(x) \rightarrow Q(x))$

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## Contingency and anti-rigidity

- $\phi$ is anti-rigid (~R): $\forall x\, (\mathbf{pos}\ \phi(x) \rightarrow \neg\ \mathbf{nec}\ \phi(x))$
- $\psi$ is contingent for $\phi$: $\forall x\, (\phi(x) \rightarrow (\mathbf{pos}\ \psi(x) \wedge \neg\ \mathbf{nec}\ \psi(x)))$

- (Being a) Student is anti-rigid.
- (Being a) Student is contingent for Person
  - Student: ~R
  - Person: ~Student

- Being self-connected is contingent for amounts of matter
- Being self-connected is essential for physical objects
- Being self-connected is neither contingent nor essential for physical entities

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## Dependence

- Between particulars
  - ***Existential dependence*** (specific/generic)
    - Hole/host, person/brain, person/heart
  - Historical dependence
    - Person/parent
  - Causal dependence
    - Heat/fire
- Between universals
  - ***Definitional dependence***
    - *x* depends upon an *P* iff *P* will be **necessarily** involved in any **definition** of *x*.
    - P depends on Q iff all its instances depend on Q

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## Dependence meta-properties

- +D: all instances are definitionally dependent on a common property
- -D: no common dependence
- ~D: no dependence at all

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Essential properties are (very weak)
***Identity Conditions***
(IC)

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## Sortals and other properties

- **Sortals** (*horse, triangle, amount of matter, person, student…)*
  - Carry (non-trivial) identity conditions
  - Usually correspond to ***nouns***
  - High organizational utility
  - Main subclasses: ***types*** and ***roles***
- **Non-sortals** *(red, big, decomposable, eatable, dependent, singular…)*
  - No identity
  - Usually correspond to ***adjectives***
  - Span across different sortals
  - Limited organizational utility (but high semantic value)
- **Categories** *(universal, particular, event, substance…)*
  - No identity
  - Useful generalizations for sortals
  - Characterized by a set of (only necessary) formal properties
  - Good organizational utility

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## Carrying vs. Supplying Identity

- ***Supplying*** (global) identity (**+O**)
  - Having an IC (or essential property) that doesn't hold for *all* directly subsuming properties
- ***Carrying*** identity (**+I**)
  - Not supplying identity, while being subsumed by a property that does.
- ***Common sortal principle***: x=y -> there is a common sortal supplying their identity
- Theorem: only rigid properties supply global identity

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## *Sortal* specialization

- ***Type*** specialization (e.g. Living being → Person)
  - New features (especially essential properties) ***affect identity***
  - Both necessary and sufficient ICs can be added while specializing types
    - Polygon: same edges, same angles
      - Triangle: two edges, one angle
    - Living being: same DNA, etc…?
      - Zebra: same stripes?
- ***Role*** specialization (e.g. Person → Student)
  - New features ***don't affect identity***

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## Identity Disjointness Constraint

ICs impose ***constraints*** on sortals, making their ontological nature explicit:

Properties with incompatible ICs are ***disjoint***

Examples:
- sets vs. ordered sets
- persons and passengers
- amounts of matter vs. assemblies

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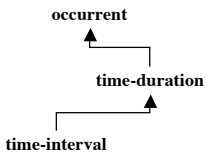
## Example - Identity

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

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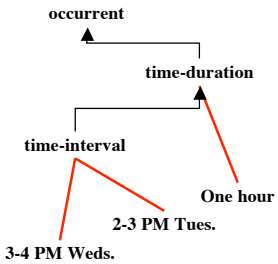
## Example - Identity

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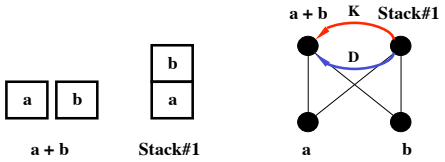
## Part, Constitution, and Identity

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

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## Ontological Levels and IC/UC Kinds

- Physical
  - Mereological *(an amount of matter, a collection)*
  - Topological *(a piece of matter)*
  - Morphological *(a cubic block, a constellation)*
- Functional *(a tool, a biological organ)*
- Biological *(a human body)*
- Cognitive/Intentional *(a person, a robot)*
- Social *(a company)*

√ Correspond to different *kinds* of IC/UC
√ All levels except the mereological one have *non-extensional* IC
√ *A generic dependence* relation links higher levels to their immediate inferior.

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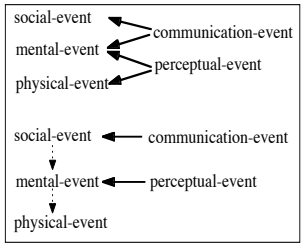
## How ontological levels simplify taxonomies

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## Why bother with this?

- ***Formal ontological analysis*** requires analyzing all properties according to their meta-properties – This is a ***lot*** of work!
- Why perform this analysis?
  - Makes ***modeling assumptions*** clear, which:
    - Helps resolving known conflicts
    - Helps recognizing unkown conflicts
  - Imposes ***constraints*** on standard modeling primitives (*generalization, aggregation, association*)
  - Elicits ***natural distinctions***
  - …results in more ***reusable ontologies***

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## Resolving Ontological Conflicts

- Two well-known ontologies define:
  - ***Physical Object is-a Amount of Matter*** (WordNet)
  - ***Amount of Matter is-a Physical Object*** (Pangloss)

- Amount of Matter
  - unstructured /scattered "stuff"
  - Identity: mereologically extensional
  - Unity: intrinsically none (anti-unity)
- Physical Object
  - Isolated material body
  - Identity - three options:
    - None
    - Non-extensional
    - Extensional
  - Unity: Topological

**Conclusion:** the two concepts are ***disjoint*** – Physical objects are ***constituted*** by amounts of matter

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## Taxonomic Constraints

- +R ⊄ ~R
- -I ⊄ +I
- -U ⊄ +U
- +U ⊄ ~U
- -D ⊄ +D

- Incompatible IC's are disjoint
- Incompatible UC's are disjoint

- Categories subsume everything
- Roles can't subsume types

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# IS-A overloading

- ***Reduction of sense:***
  1. *A physical object* is an *amount of matter* (Pangloss)
  2. An *association* is a *group* (WordNet)
- ***Overgeneralization:***
  3. An *amount of matter* is a *physical object* (WordNet)
  4. *A place* is a *physical object* (μKosmos, WordNet)
- ***Clash of senses:***
  5. *A window* is both an *artifact* and a *place* (μKosmos)
  6. *A person* is both a *physical object* and a *living thing* (Pangloss)
  7. *A communicative event* is a *physical*, a *mental*, and a *social event* (μKosmos, Pangloss)

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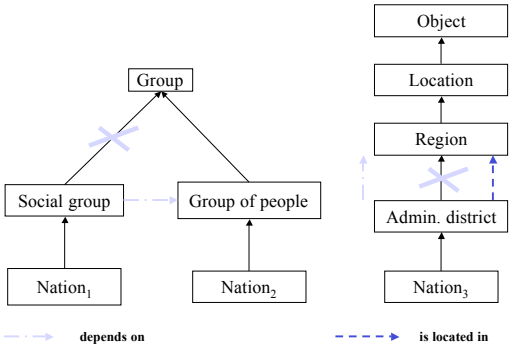
# The case of "Nation"

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# Property Dependence

- Does a property holding for *x* depend on something else besides *x*?
  - $P(x) \rightarrow \exists y\, Q(y)$
  - *y* should not be a part of *x*
- Example: Student/Teacher, customer/vendor

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## Basic Property Kinds Table

| O | I | R | D | |
|---|---|---|---|---|
| + | + | + | ± | Type |
| - | + | + | ± | Quasi-type |
| - | + | - | - | Mixin |
| - | + | ~ | + | Mat. role |
| - | + | ~ | - | Phased sortal |
| - | - | + | ± | Category |
| - | - | ~ | + | Formal role |
| - | - | - | - | Attribution |

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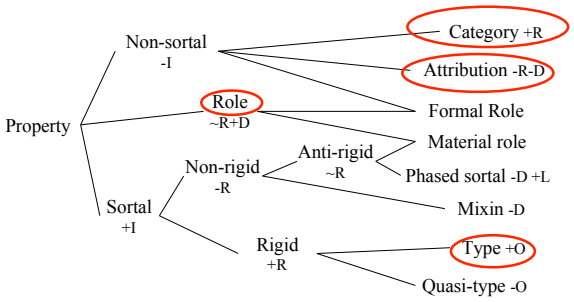
## A formal ontology of properties

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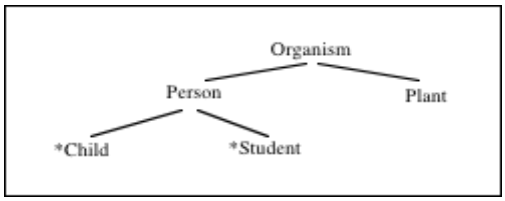
## Types, Roles, and disjointness

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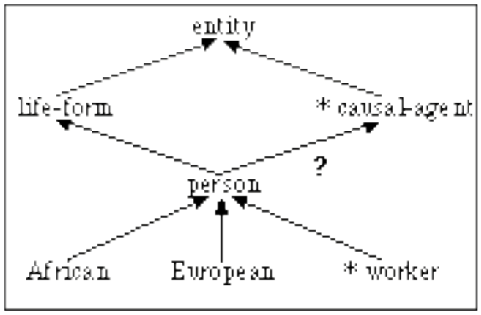
## Types and Roles

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## The *Backbone Taxonomy*

Assumption: ***no entity without identity***

- Since identity is supplied by types, every entity must instantiate a type
- The taxonomy of types spans the whole domain
- Together with categories, types form the ***backbone taxonomy***, which represents the ***invariant structure*** of a domain (rigid properties spanning the whole domain)

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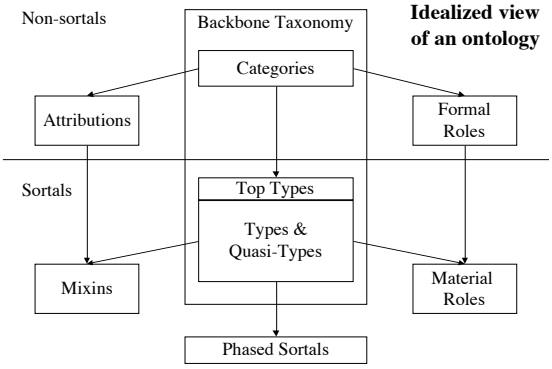


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# Well-founded ontology design

**An *ontology-cleaning* example**

## Dealing with *Ontological Relativism*

- Deciding about the meta-properties carried by a given property…

Is up to **YOU!**

- But a ***common agreement*** must be achieved about the formal meaning (and practical utility) of meta-properties

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## Property Analysis

**Entity, Location**

- Entity
  - Everything is an entity
  - -I-U-D+R
  - Category
- Location
  - A generalized region of space.
  - +O: by its parts (mereologically extensional).
  - ~U: no way to isolate a location
  - -D+R
  - Type

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## Property Analysis

### Amount of Matter, Red

- Amount of Matter
  - unstructured /scattered "stuff" as lumps of clay or some bricks
  - +O: mereologically extensional
  - ~U: intrinsically no unity
  - -D+R
  - Type
- Red
  - Really Red-thing, the set of all red-colored entities
  - -I-U-D-R
  - Formal Attribution

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## Property Analysis

### Agent, Group

- Agent
  - An entity playing a part in some event
  - -I-U: no *universal* IC/UC
  - +D: on the event/action participating in
  - ~R: no instance is necessarily an agent
  - Formal role
- Group
  - An *unstructured* collection of wholes
  - +O: same-members
  - ~U: unstructured, no unity.
  - -D+R
  - Type

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## Property Analysis

### Physical Object, Living Being

- Physical Object
  - Isolated material objects.
  - +O: same spatial location (only synchronic, no common diachronic IC).
  - +U: Topological
  - -D+R
  - Type
- Living Being
  - +O: same-DNA (only nec.)
  - +U: biological unity
  - -D+R
  - Type

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## Property Analysis

### Food, Animal

- Food
  - +I-O~U: amt. of matter
  - +D: something that eats it.
  - ~R: being food is not necessary...
  - Material Role
- Animal
  - +O: same-brain
  - +U: biological unity
  - -D+R
  - Type

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## Property Analysis

### Legal Agent, Group of People

- Legal Agent
  - A legally recognized entity
  - +L: All legal systems have a defined IC, has-same-legal-ID
  - -U: no universal unity
  - +D: on the legal body that recognizes it
  - ~R: not necessary
  - Material Role
- Group of People
  - See Group
  - +I-O~U-D+R
  - Quasi-type

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## Property Analysis

### Social Entity, Organization

- Social Entity
  - A group of people together for social reasons
  - -I: no universal IC
  - +U: social-connection
  - -D+R
  - category
- Organization
  - A group of people together, with roles that define some structure
  - +O: same-mission and way of operating
  - +U: functional
  - -D+R
  - Type

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## Property Analysis

### Fruit

- Fruit
  - An individual fruit, such as an orange or bannana
  - +O: same-plant, same-shape, etc. (only nec.)
  - +U: topological
  - -D+R
  - Type

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## Property Analysis

### Apple, Red Apple

- Apple
  - +O: shape, color, skin pattern (only nec)
  - +U: topological
  - -D+R
  - Type
- Red-Apple
  - +I-O: from Apple
  - +U: from Apple
  - -D
  - ~R: no red apple is necessarily red
  - type-attribution mixin

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## Property Analysis

### Vertebrate, Person

- Vertebrate
  - Really vertebrate-*animal*
  - A biological classification that adds new *membership* criteria (has-backbone)
  - +I-O: from animal
  - +U: from animal
  - -D+R
  - quasi-type
- Person
  - +O: same-fingerprint
  - +U: from animal
  - -D+R
  - Type

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## Property Analysis

### Butterfly, Caterpillar

- Butterfly
  - +L: same-wing-pattern
  - +U: biological
  - -D
  - ~R: the *same entity* can be something else (a caterpillar)
  - Phased sortal
- Caterpillar
  - +L: spots, legs, color
  - +U: biological
  - -D
  - ~R: caterpillars become butterflies and change their IC
  - Phased sortal

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## Property Analysis

### Country

- Country
  - A place recognized by convention as autonomous
  - +L: government, sub-regions
  - +U: countries are countable (heuristic)
  - -D
  - ~R: some countries do not exist as countries any more (e.g. Prussia) but are still places
  - Phased sortal

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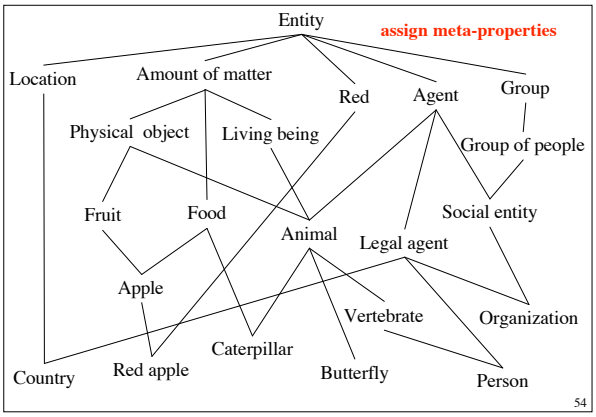


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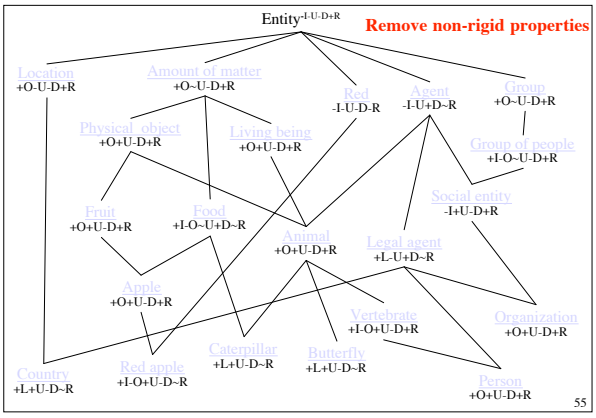
Entity-I-U-D+R
Remove non-rigid properties
Location +O-U-D+R
Amount of matter +O~U-D+R
Red -I-U-D-R
Agent -I-U+D~R
Group +O~U-D+R
Physical object +O+U-D+R
Living being +O+U-D+R
Group of people +I-O~U-D+R
Social entity -I+U-D+R
Fruit +O+U-D+R
Food +I-O~U+D~R
Animal +O+U-D+R
Legal agent +L-U+D~R
Apple +O+U-D+R
Vertebrate +I-O+U-D+R
Organization +O+U-D+R
Caterpillar +L+U-D~R
Butterfly +L+U-D~R
Country +L+U-D~R
Red apple +I-O+U-D~R
Person +O+U-D+R
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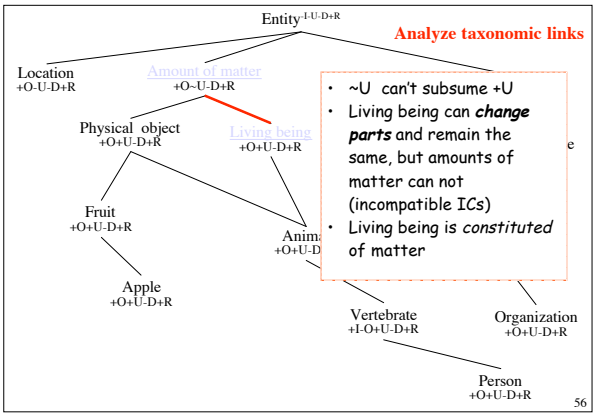
Entity-I-U-D+R
Analyze taxonomic links
Location +O-U-D+R
Amount of matter +O~U-D+R
Physical object +O+U-D+R
Living being +O+U-D+R
Fruit +O+U-D+R
Anim
+O+U-D
Apple +O+U-D+R
Vertebrate +I-O+U-D+R
Organization +O+U-D+R
Person +O+U-D+R
• ~U can't subsume +U
• Living being can change parts and remain the same, but amounts of matter can not (incompatible ICs)
• Living being is constituted of matter
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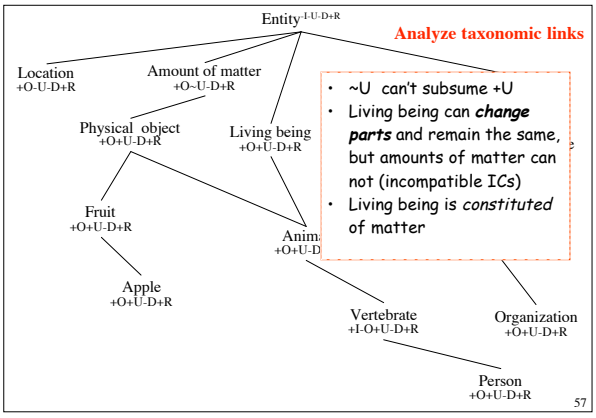
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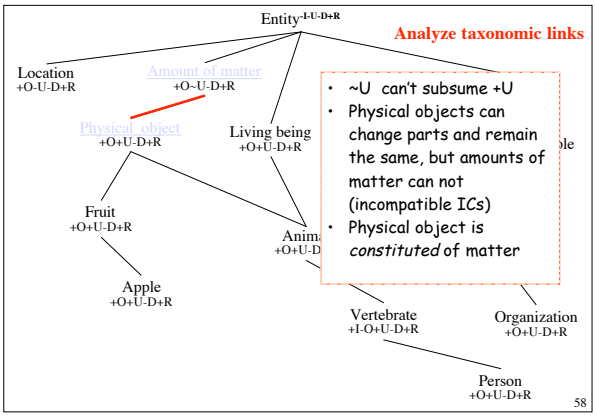
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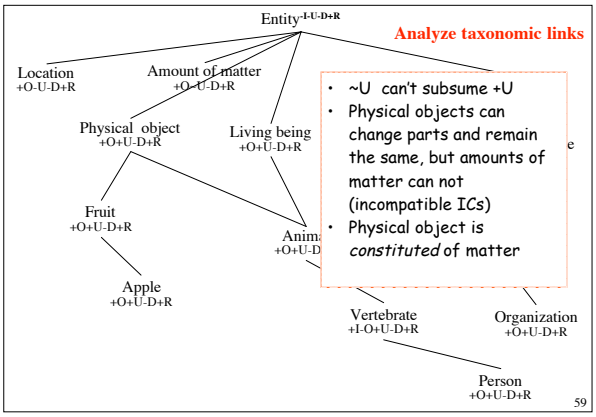
Anim +O+U-D
Apple +O+U-D+R
Vertebrate +I-O+U-D+R
Organization +O+U-D+R
Person +O+U-D+R
• ~U can't subsume +U
• Physical objects can change parts and remain the same, but amounts of matter can not (incompatible ICs)
• Physical object is constituted of matter
58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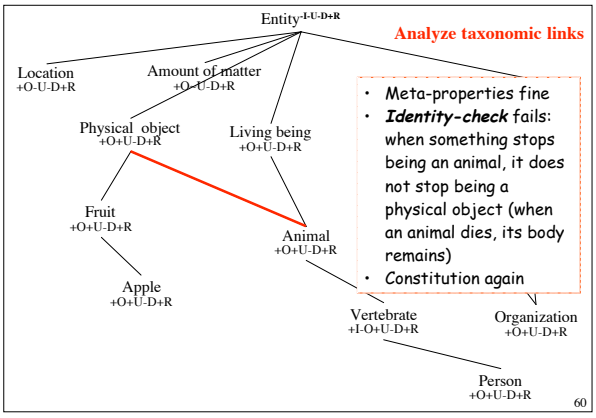
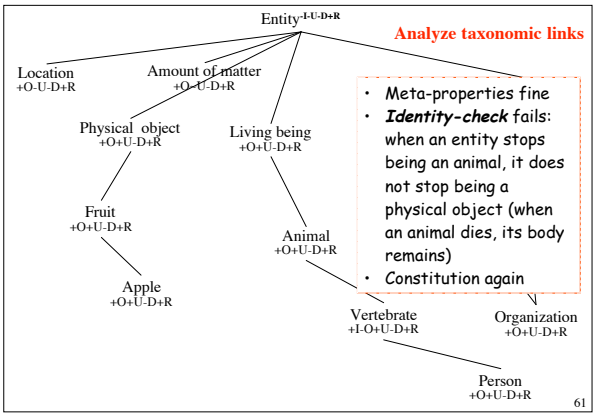
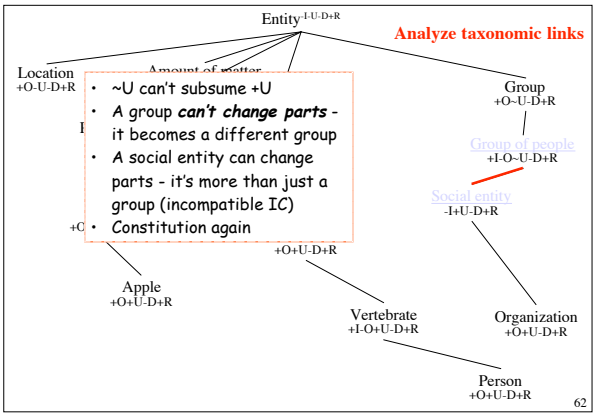
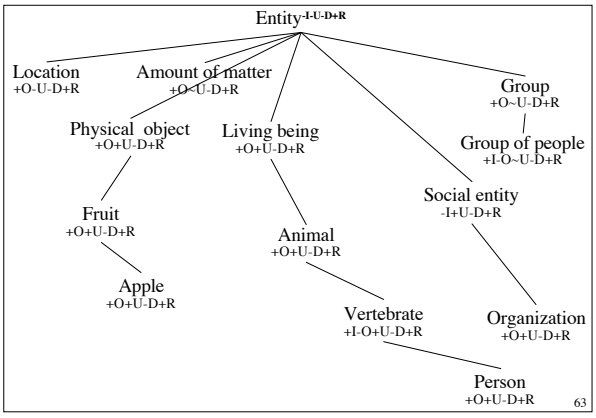
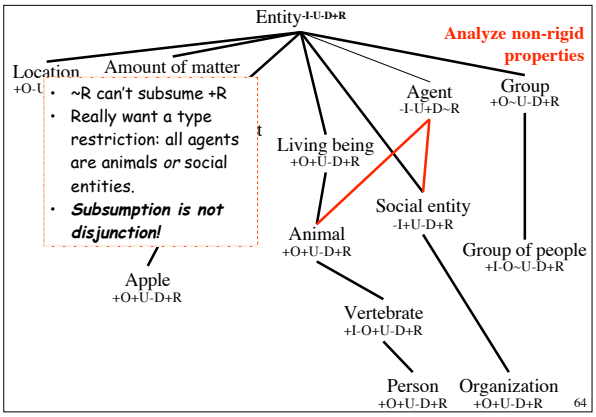
• Physical objects can change parts and remain the same, but amounts of matter can not (incompatible ICs)
• Physical object is constituted of matter
59

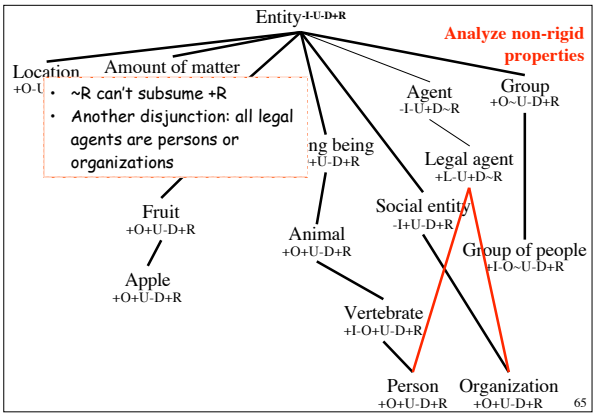

Entity I-U-D+R
Analyze taxonomic links
Location +O-U-D+R
Amount of matter +O-U-D+R
Physical object +O+U-D+R
Living being +O+U-D+R
Fruit +O+U-D+R
Animal +O+U-D+R
Apple +O+U-D+R
Vertebrate +I-O+U-D+R
Organization +O+U-D+R
Person +O+U-D+R
• Meta-properties fine
• Identity-check fails: when something stops being an animal, it does not stop being a physical object (when an animal dies, its body remains)
• Constitution again
60

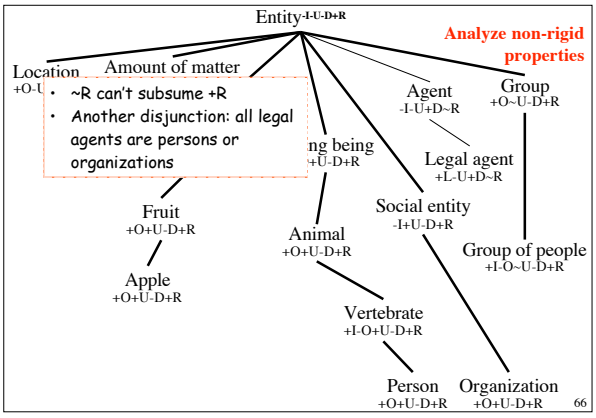

Entity I-U-D+R
Analyze taxonomic links
Location +O-U-D+R
Amount of matter +O~U-D+R
Physical object +O+U-D+R
Living being +O+U-D+R
Fruit +O+U-D+R
Animal +O+U-D+R
Apple +O+U-D+R
Vertebrate +I-O+U-D+R
Organization +O+U-D+R
Person +O+U-D+R
• Meta-properties fine
• Identity-check fails: when an entity stops being an animal, it does not stop being a physical object (when an animal dies, its body remains)
• Constitution again
61

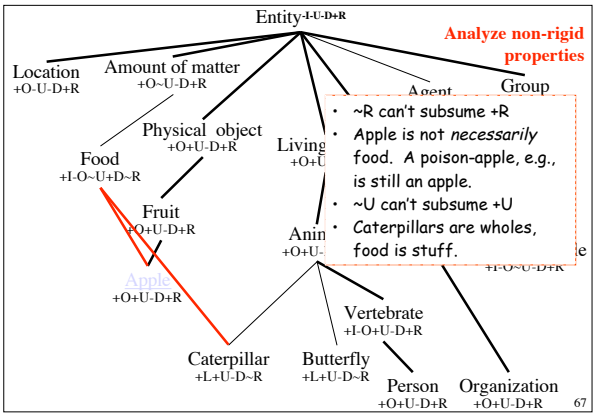

Entity I-U-D+R
Analyze taxonomic links
Location +O-U-D+R
Group +O~U-D+R
Group of people +I-O~U-D+R
Social entity -I+U-D+R
Apple +O+U-D+R
Vertebrate +I-O+U-D+R
Organization +O+U-D+R
Person +O+U-D+R
• ~U can't subsume +U
• A group can't change parts - it becomes a different group
• A social entity can change parts - it's more than just a group (incompatible IC)
• Constitution again
62

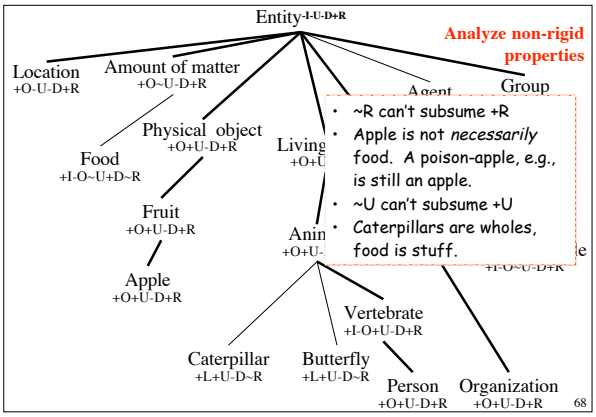

Entity I-U-D+R
Location +O-U-D+R
Amount of matter +O~U-D+R
Group +O~U-D+R
Physical object +O+U-D+R
Living being +O+U-D+R
Group of people +I-O~U-D+R
Social entity -I+U-D+R
Fruit +O+U-D+R
Animal +O+U-D+R
Apple +O+U-D+R
Vertebrate +I-O+U-D+R
Organization +O+U-D+R
Person +O+U-D+R
63

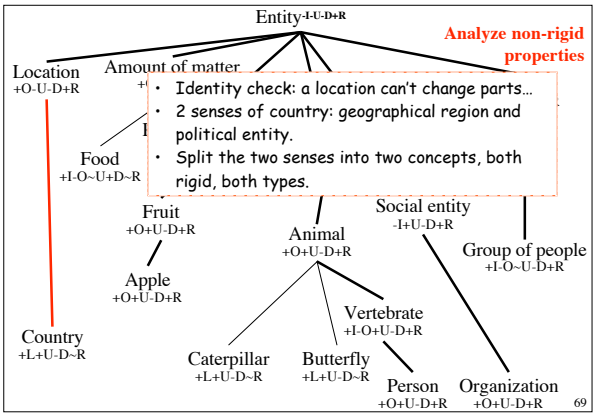

Entity-I-U-D+R
Analyze non-rigid properties
Location
+O-U
Amount of matter
• ~R can't subsume +R
• Really want a type restriction: all agents are animals *or* social entities.
• ***Subsumption is not disjunction!***
Agent
-I-U+D~R
Group
+O~U-D+R
Living being
+O+U-D+R
Social entity
-I+U-D+R
Animal
+O+U-D+R
Group of people
+I-O~U-D+R
Apple
+O+U-D+R
Vertebrate
+I-O+U-D+R
Person
+O+U-D+R
Organization
+O+U-D+R
64

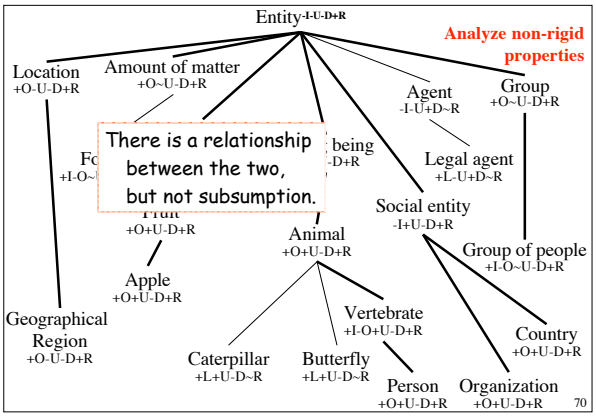

Entity-I-U-D+R
Analyze non-rigid properties
Location
+O-U
Amount of matter
• ~R can't subsume +R
• Another disjunction: all legal agents are persons or organizations
Agent
-I-U+D~R
Group
+O~U-D+R
ng being
+U-D+R
Legal agent
+L-U+D~R
Social entity
-I+U-D+R
Fruit
+O+U-D+R
Animal
+O+U-D+R
Group of people
+I-O~U-D+R
Apple
+O+U-D+R
Vertebrate
+I-O+U-D+R
Person
+O+U-D+R
Organization
+O+U-D+R
65

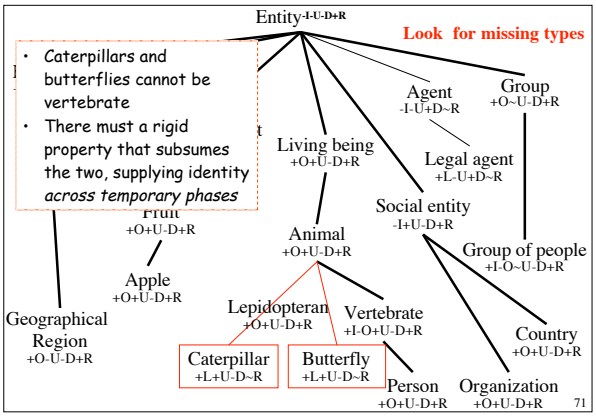

Entity-I-U-D+R
Analyze non-rigid properties
Location
+O-U
Amount of matter
• ~R can't subsume +R
• Another disjunction: all legal agents are persons or organizations
Agent
-I-U+D~R
Group
+O~U-D+R
ng being
+U-D+R
Legal agent
+L-U+D~R
Social entity
-I+U-D+R
Fruit
+O+U-D+R
Animal
+O+U-D+R
Group of people
+I-O~U-D+R
Apple
+O+U-D+R
Vertebrate
+I-O+U-D+R
Person
+O+U-D+R
Organization
+O+U-D+R
66

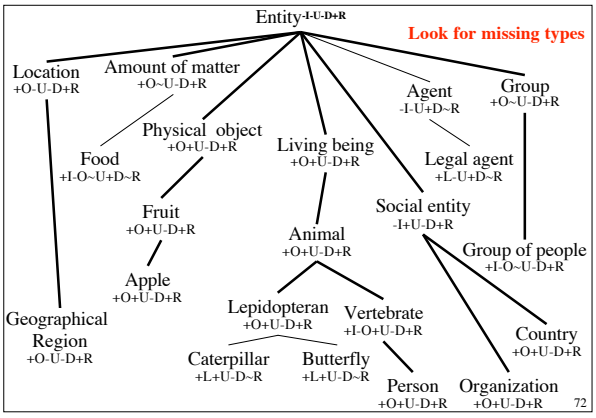

Entity I-U-D+R
Analyze non-rigid properties
Location +O-U-D+R
Amount of matter +O~U-D+R
Agent
Group
Physical object +O+U-D+R
Food +I-O~U+D~R
Fruit +O+U-D+R
Apple +O+U-D+R
Vertebrate +I-O+U-D+R
Caterpillar +L+U-D~R
Butterfly +L+U-D~R
Person +O+U-D+R
Organization +O+U-D+R
~R can't subsume +R
Apple is not necessarily food. A poison-apple, e.g., is still an apple.
~U can't subsume +U
Caterpillars are wholes, food is stuff.
67

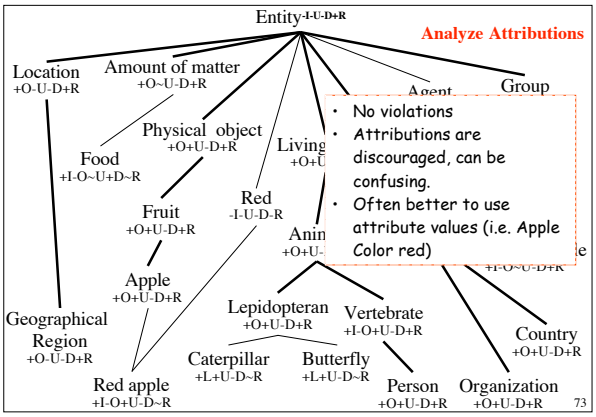

Entity I-U-D+R
Analyze non-rigid properties
Location +O-U-D+R
Amount of matter +O~U-D+R
Agent
Group
Physical object +O+U-D+R
Food +I-O~U+D~R
Fruit +O+U-D+R
Apple +O+U-D+R
Vertebrate +I-O+U-D+R
Caterpillar +L+U-D~R
Butterfly +L+U-D~R
Person +O+U-D+R
Organization +O+U-D+R
~R can't subsume +R
Apple is not necessarily food. A poison-apple, e.g., is still an apple.
~U can't subsume +U
Caterpillars are wholes, food is stuff.
68

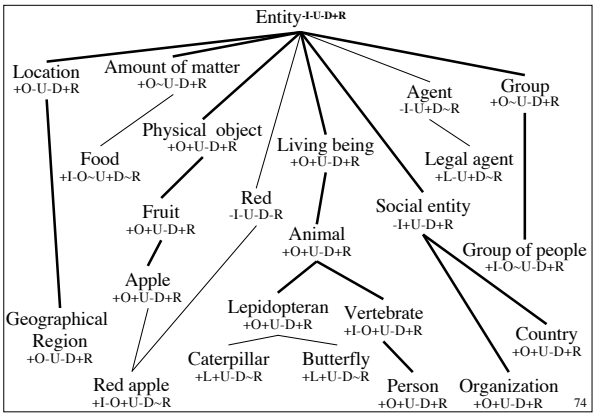

Entity I-U-D+R
Analyze non-rigid properties
Location +O-U-D+R
Food +I-O~U+D~R
Fruit +O+U-D+R
Apple +O+U-D+R
Country +L+U-D~R
Social entity -I+U-D+R
Animal +O+U-D+R
Group of people +I-O~U-D+R
Vertebrate +I-O+U-D+R
Caterpillar +L+U-D~R
Butterfly +L+U-D~R
Person +O+U-D+R
Organization +O+U-D+R
Identity check: a location can't change parts…
2 senses of country: geographical region and political entity.
Split the two senses into two concepts, both rigid, both types.
69

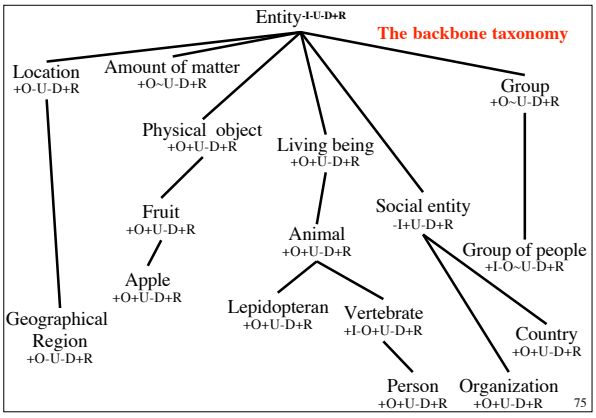

Entity-I-U-D+R
Analyze non-rigid properties
Location +O-U-D+R
Amount of matter +O~U-D+R
Agent -I-U+D~R
Group +O~U-D+R
There is a relationship between the two, but not subsumption.
Legal agent +L-U+D~R
Social entity -I+U-D+R
Fruit +O+U-D+R
Animal +O+U-D+R
Group of people +I-O~U-D+R
Apple +O+U-D+R
Vertebrate +I-O+U-D+R
Geographical Region +O-U-D+R
Country +O+U-D+R
Caterpillar +L+U-D~R
Butterfly +L+U-D~R
Person +O+U-D+R
Organization +O+U-D+R
70

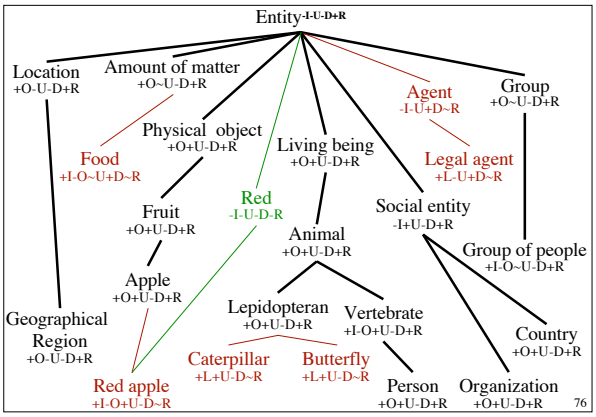

Entity-I-U-D+R
Look for missing types
Caterpillars and butterflies cannot be vertebrate
There must a rigid property that subsumes the two, supplying identity *across temporary phases*
Agent -I-U+D~R
Group +O~U-D+R
Living being +O+U-D+R
Legal agent +L-U+D~R
Social entity -I+U-D+R
Fruit +O+U-D+R
Animal +O+U-D+R
Group of people +I-O~U-D+R
Apple +O+U-D+R
Lepidopteran +O+U-D+R
Vertebrate +I-O+U-D+R
Geographical Region +O-U-D+R
Country +O+U-D+R
Caterpillar +L+U-D~R
Butterfly +L+U-D~R
Person +O+U-D+R
Organization +O+U-D+R
71

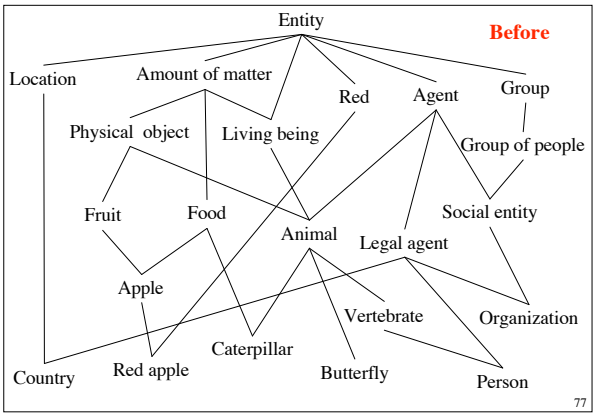

Entity-I-U-D+R
Look for missing types
Location +O-U-D+R
Amount of matter +O~U-D+R
Agent -I-U+D~R
Group +O~U-D+R
Physical object +O+U-D+R
Food +I-O~U+D~R
Living being +O+U-D+R
Legal agent +L-U+D~R
Fruit +O+U-D+R
Social entity -I+U-D+R
Animal +O+U-D+R
Group of people +I-O~U-D+R
Apple +O+U-D+R
Lepidopteran +O+U-D+R
Vertebrate +I-O+U-D+R
Geographical Region +O-U-D+R
Country +O+U-D+R
Caterpillar +L+U-D~R
Butterfly +L+U-D~R
Person +O+U-D+R
Organization +O+U-D+R
72

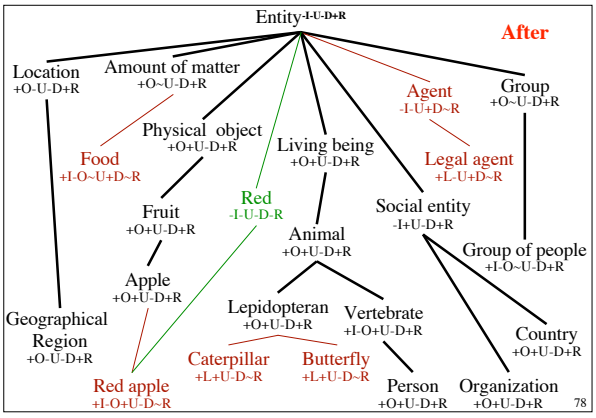

Entity-I-U-D+R
Analyze Attributions
Location +O-U-D+R
Amount of matter +O~U-D+R
Group +O~U-D+R
Physical object +O+U-D+R
Food +I-O~U+D~R
Fruit +O+U-D+R
Red -I-U-D-R
Apple +O+U-D+R
Geographical Region +O-U-D+R
Red apple +I-O+U-D~R
Lepidopteran +O+U-D+R
Caterpillar +L+U-D~R
Butterfly +L+U-D~R
Vertebrate +I-O+U-D+R
Person +O+U-D+R
Organization +O+U-D+R
Country +O+U-D+R
No violations
Attributions are discouraged, can be confusing.
Often better to use attribute values (i.e. Apple Color red)
73


Entity-I-U-D+R
Location +O-U-D+R
Amount of matter +O~U-D+R
Agent -I-U+D~R
Group +O~U-D+R
Physical object +O+U-D+R
Food +I-O~U+D~R
Living being +O+U-D+R
Legal agent +L-U+D~R
Fruit +O+U-D+R
Red -I-U-D-R
Social entity -I+U-D+R
Animal +O+U-D+R
Group of people +I-O~U-D+R
Apple +O+U-D+R
Geographical Region +O-U-D+R
Lepidopteran +O+U-D+R
Vertebrate +I-O+U-D+R
Country +O+U-D+R
Caterpillar +L+U-D~R
Butterfly +L+U-D~R
Red apple +I-O+U-D~R
Person +O+U-D+R
Organization +O+U-D+R
74


Entity-I-U-D+R
The backbone taxonomy
Location +O-U-D+R
Amount of matter +O~U-D+R
Group +O~U-D+R
Physical object +O+U-D+R
Living being +O+U-D+R
Fruit +O+U-D+R
Social entity -I+U-D+R
Animal +O+U-D+R
Group of people +I-O~U-D+R
Apple +O+U-D+R
Geographical Region +O-U-D+R
Lepidopteran +O+U-D+R
Vertebrate +I-O+U-D+R
Country +O+U-D+R
Person +O+U-D+R
Organization +O+U-D+R
75


Entity -I-U-D+R
Location +O-U-D+R
Amount of matter +O~U-D+R
Agent -I-U+D~R
Group +O~U-D+R
Physical object +O+U-D+R
Food +I-O~U+D~R
Living being +O+U-D+R
Legal agent +L-U+D~R
Red -I-U-D-R
Fruit +O+U-D+R
Social entity -I+U-D+R
Animal +O+U-D+R
Group of people +I-O~U-D+R
Apple +O+U-D+R
Lepidopteran +O+U-D+R
Vertebrate +I-O+U-D+R
Geographical Region +O-U-D+R
Country +O+U-D+R
Caterpillar +L+U-D~R
Butterfly +L+U-D~R
Red apple +I-O+U-D~R
Person +O+U-D+R
Organization +O+U-D+R
76


Before
Entity
Location
Amount of matter
Red
Agent
Group
Physical object
Living being
Group of people
Fruit
Food
Social entity
Animal
Legal agent
Apple
Vertebrate
Organization
Caterpillar
Country
Red apple
Butterfly
Person
77


After
Entity -I-U-D+R
Location +O-U-D+R
Amount of matter +O~U-D+R
Agent -I-U+D~R
Group +O~U-D+R
Physical object +O+U-D+R
Food +I-O~U+D~R
Living being +O+U-D+R
Legal agent +L-U+D~R
Red -I-U-D-R
Fruit +O+U-D+R
Social entity -I+U-D+R
Animal +O+U-D+R
Group of people +I-O~U-D+R
Apple +O+U-D+R
Lepidopteran +O+U-D+R
Vertebrate +I-O+U-D+R
Geographical Region +O-U-D+R
Country +O+U-D+R
Caterpillar +L+U-D~R
Butterfly +L+U-D~R
Red apple +I-O+U-D~R
Person +O+U-D+R
Organization +O+U-D+R
78

**Use OntoClean for all your ontology cleaning needs!**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