# Advanced Ontology Topics:

# Events, Roles, Artifacts

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# Overview

- An introduction to Events, Roles, and Artifacts, from an ontological and semantic view: these constructs are interrelated
- Why both ontological and semantic?
  - **Ontology:** is about the real entities, relations, and properties of the world; what are the referents?
    - **Referent:** the thing that a word or phrase denotes or stands for.
  - **Natural language semantics:** Is about the rendering in language of interpretations about the entities, relations, and properties of the world, and includes notions of sense and reference: how do we refer to the referents?
- Need both ontology and semantics: Because often our best insight into what the things of the world are is through our language, which almost by definition needs to pick out those things, for humans to communicate and think about those things
- Tutorial: informal, with formal aspects, a survey that builds a view

# Goals

1) Introduce Events, Roles, Artifacts: very general, useful, ubiquitous notions in ontology and semantics
2) Provide a relatively systematic account of these, with multiple ontological analyses
3) Enable you to begin to understand what is involved in ontological and semantic analysis, within the framework of formal ontology and logic
4) Relate these analyses to Semantic Web/OWL modeling by giving some examples

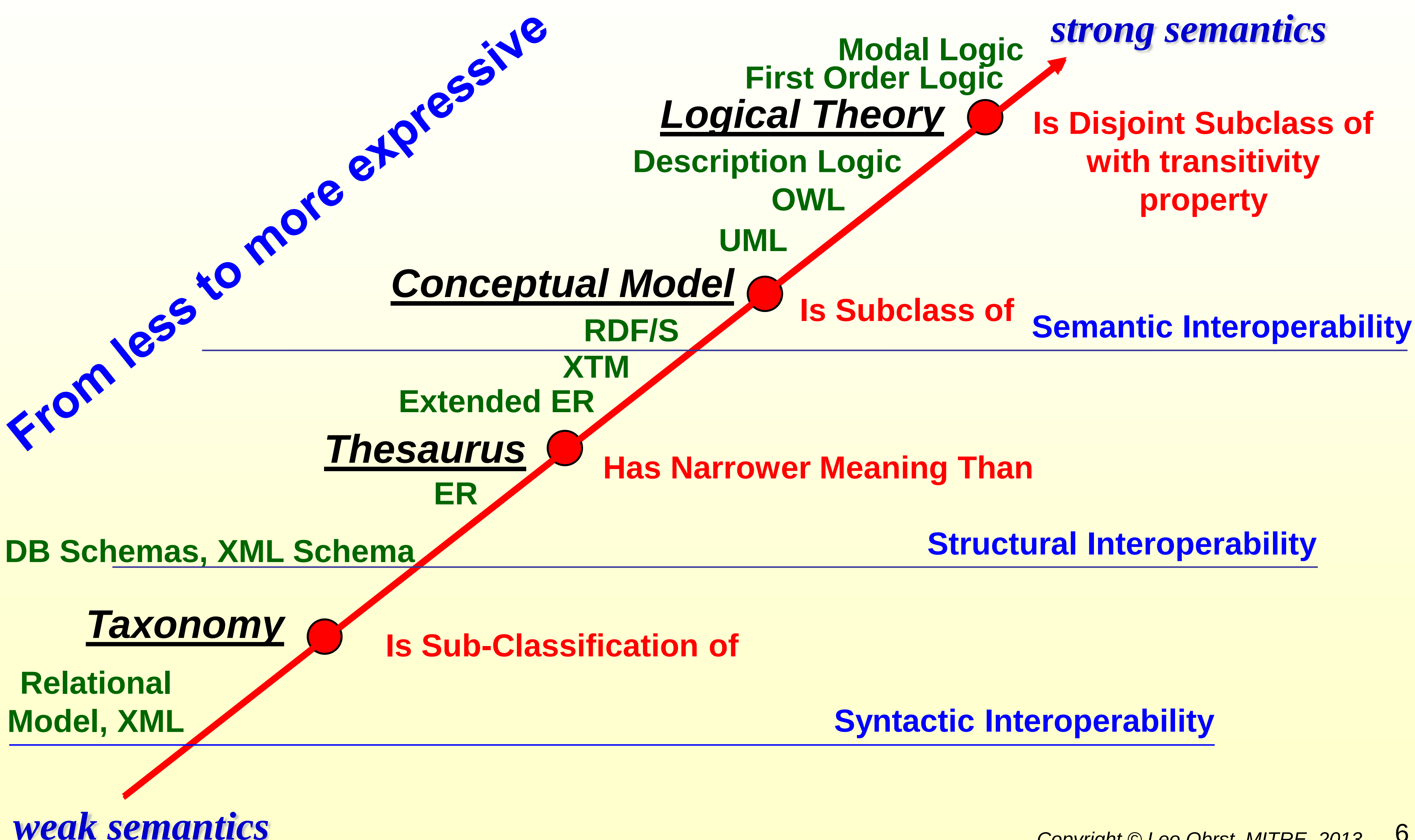
# Agenda

1) Brief Introduction to Ontologies (if needed)
2) Events: Semantics and Ontology
3) Ontologies of Verbs and Events: Thematic Roles, Verb Argument Structure, Events, and Ontology
4) Roles
5) Artifacts
6) Categorized References

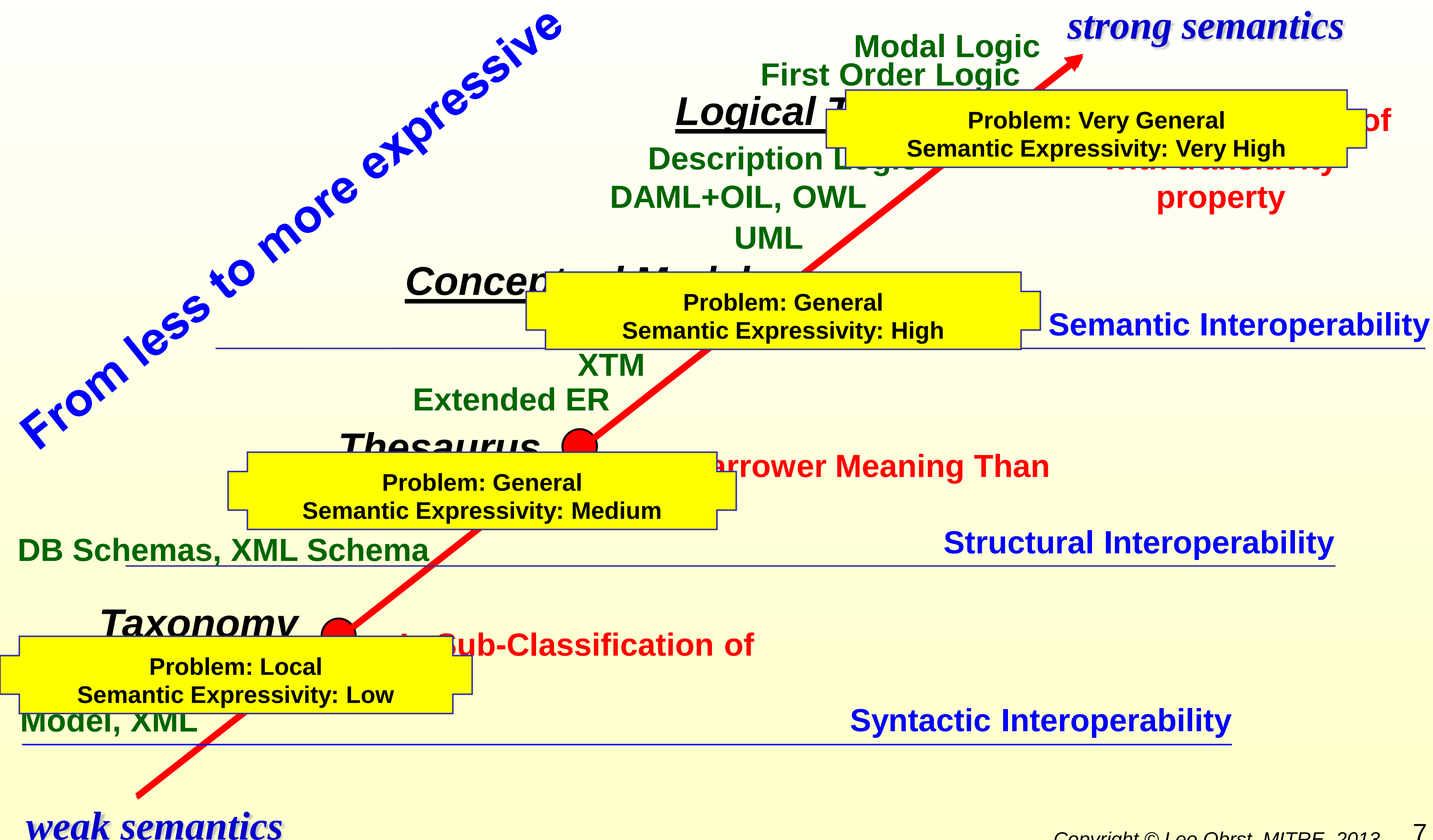
# Brief Introduction to Ontologies

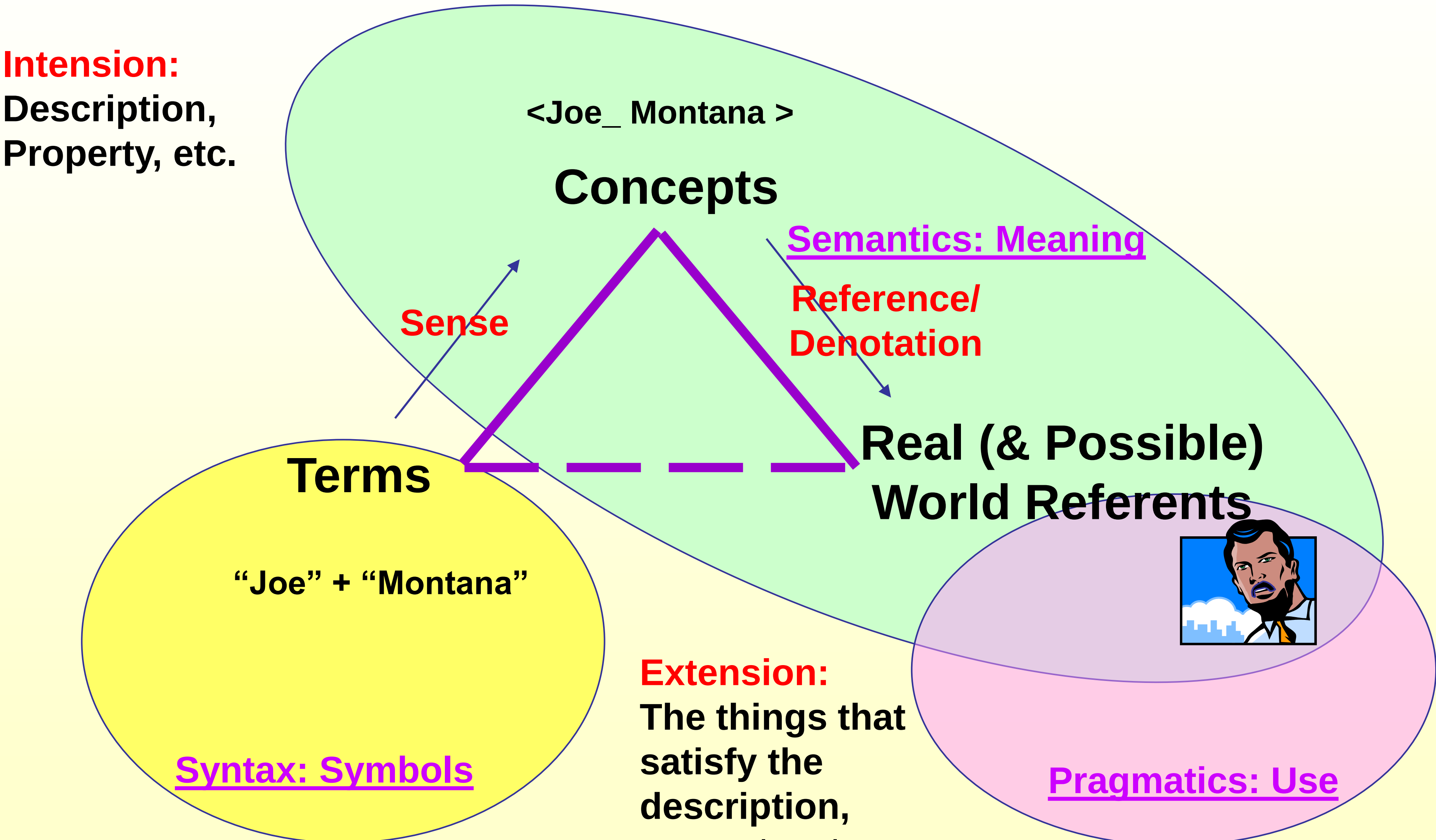
# Ontology Spectrum: One View



# Ontology Spectrum: One View

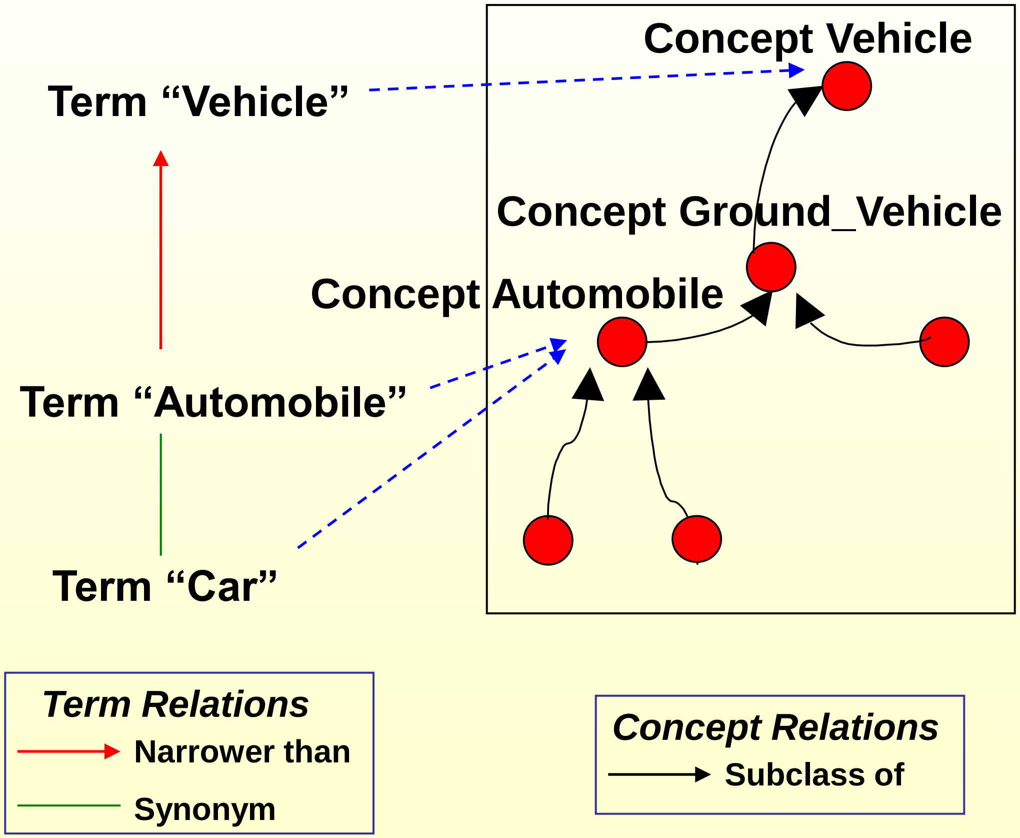


# Triangle of Signification



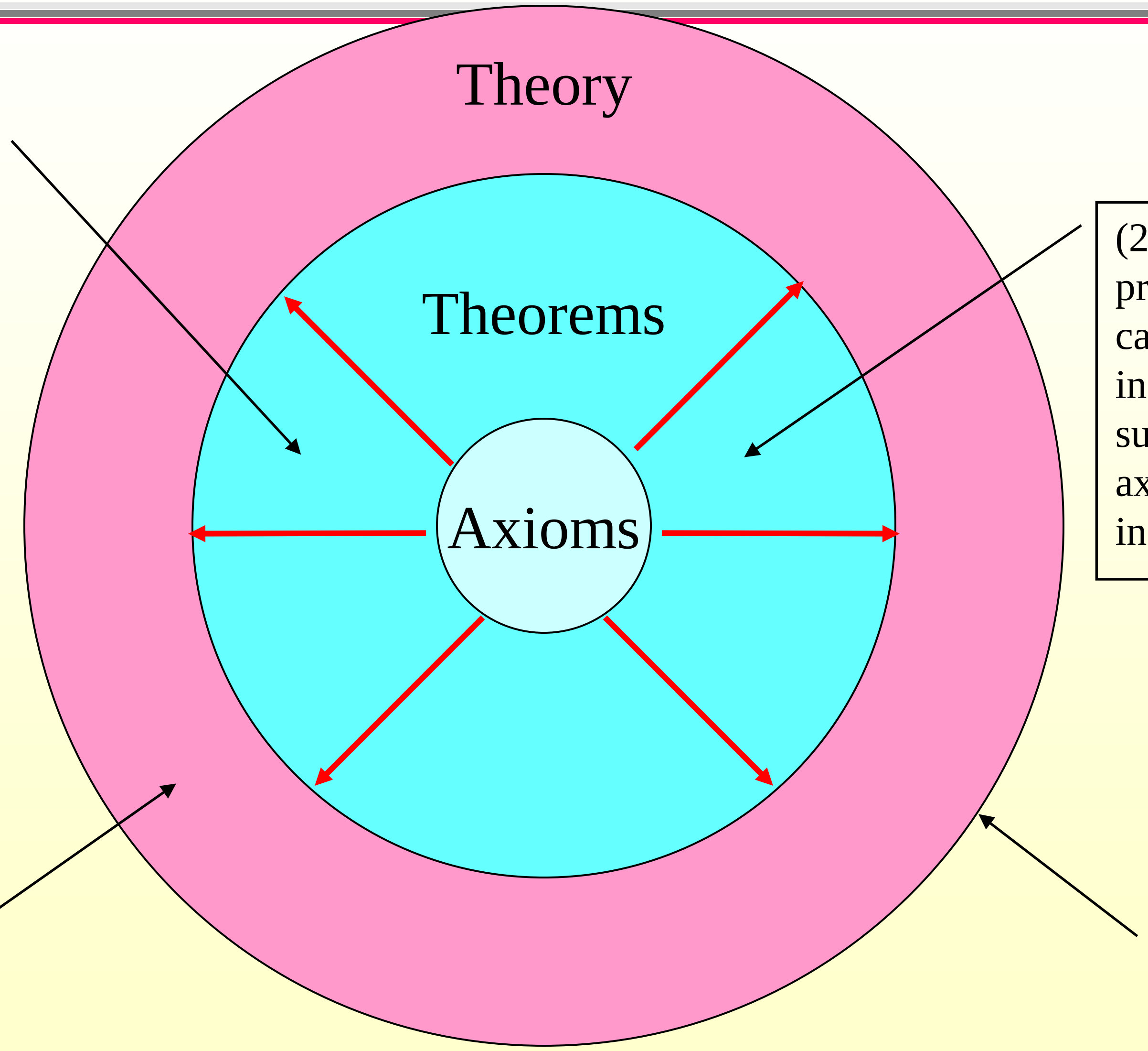
# Term vs. Concept

- **Term (terminology):**
  - Natural language words or phrases that act as indices to the underlying meaning, i.e., the concept (or composition of concepts)
  - The syntax (e.g., string) that stands in for or is used to indicate the semantics (meaning)
- **Concept:**
  - A unit of semantics (meaning), the node (entity) or link (relation) in the mental or knowledge representation model



# Logical Theory (strong ontology): Axioms, Inference Rules, Theorems, Theory

(1) Theorems are licensed by a valid proof using ***inference rules*** such as Modus Ponens




(2) Theorems proven to be true can be added back in, to be acted on subsequently like axioms by inference rules

(3) Possible other theorems (as yet unproven)

(4) Ever expanding theory

## Axioms

Class(Thing)

Class(Person)

Class(Parent)

Class(Child)

If SubClass(X, Y) then X is a subset of Y. This also means that if A is a member of Class(X), then A is a member of Class(Y)

SubClass(Person, Thing)

SubClass(Parent, Person)

SubClass(Child, Person)

ParentOf(Parent, Child)

NameOf(Person, String)

AgeOf(Person, Integer)

If X is a member of Class (Parent) and Y is a member of Class(Child), then $\neg$ (X =Y)

## Inference Rules

**And-introduction**: given P, Q, it is valid to infer $P \wedge Q$.

**Or-introduction**: given P, it is valid to infer $P \vee Q$.

**And-elimination**: given $P \wedge Q$, it is valid to infer P.

**Excluded middle**: $P \vee \neg P$ (i.e., either something is true or its negation is true)

**Modus Ponens**: given $P \rightarrow Q$, P, it is valid to infer Q

## Theorems

If $P \wedge Q$ are true, then so is $P \vee Q$.

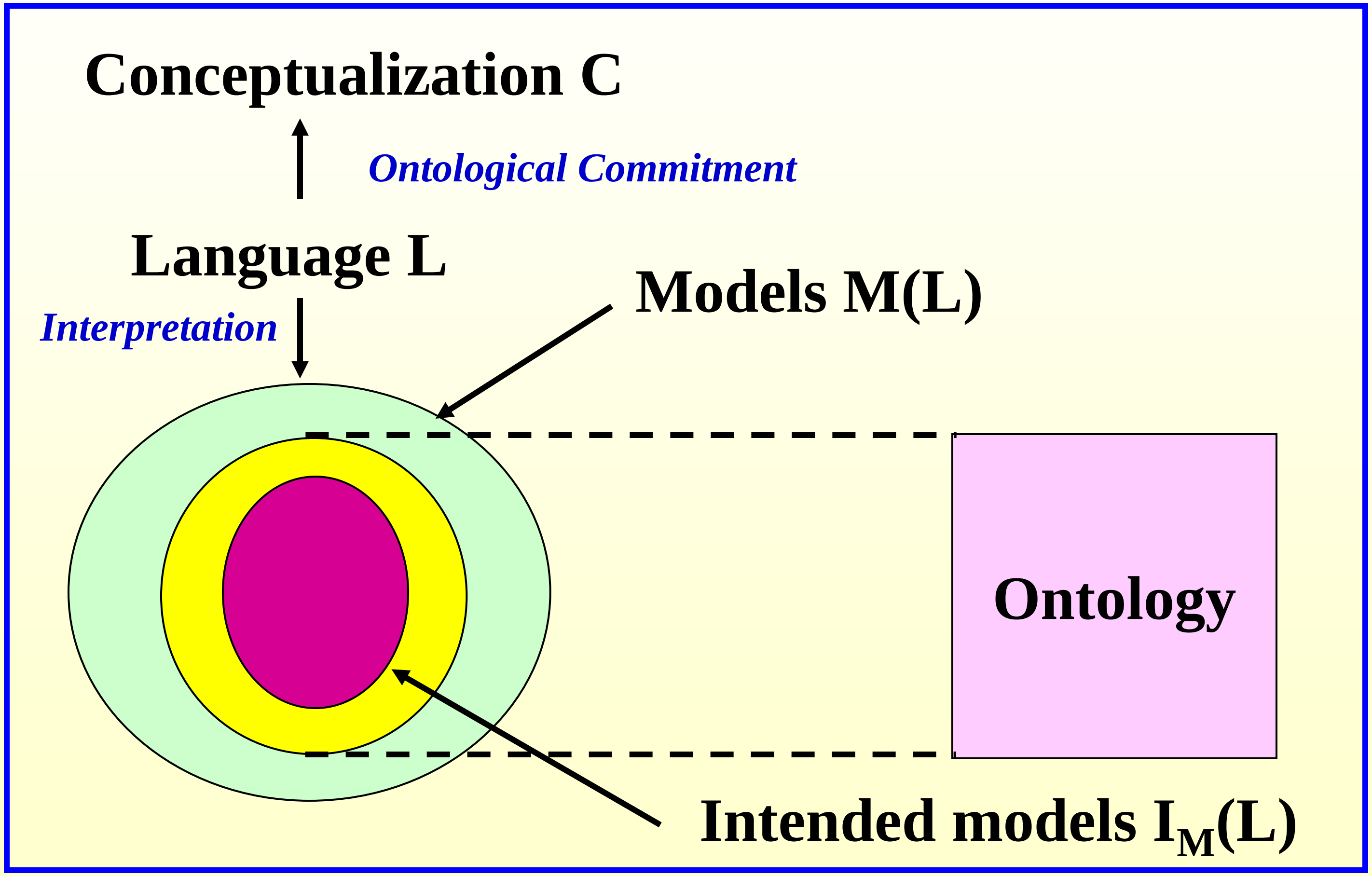
If X is a member of Class(Parent), then X is a member of Class(Person).

If X is a member of Class(Child), then X is a member of Class(Person).

If X is a member of Class(Child), then NameOf(X, Y) and Y is a String.

If Person(JohnSmith), then $\neg$ ParentOf(JohnSmith, JohnSmith).

# Logical Theories: More Formally




* N. Guarino. 1998. Formal ontology in information systems, pp. 3-15. In Formal Ontology in Information Systems, N. Guarino, ed., Amsterdam: IOS Press. Proceedings of the First International Conference (FOIS'98), June 6-8, Trent, Italy. p. 7

# Ontology Representation Levels

Meta-Level to Object-Level

| Level | Example Constructs |
|---|---|
| ***Knowledge Representation (KR) Language (Ontology Language) Level:*** **Meta Level to the Ontology Concept Level** | **Class, Relation, Instance, Function, Attribute, Property, Constraint, Axiom, Rule** |
| ***Ontology Concept (OC) Level:*** **Object Level to the KR Language Level, Meta Level to the Instance Level** | **Person, Location, Event, Parent, Hammer, River, FinancialTransaction, BuyingAHouse, Automobile, TravelPlanning, etc.** |
| ***Ontology Instance (OI) Level:*** **Object Level to the Ontology Concept Level** | **Harry X. Landsford III, Ralph Waldo Emerson, Person560234, PurchaseOrderTransactionEvent6117090, 1995-96 V-6 Ford Taurus 244/4.0 Aerostar Automatic with Block Casting # 95TM-AB and Head Casting 95TM** |

Meta-Level to Object-Level

**Language**

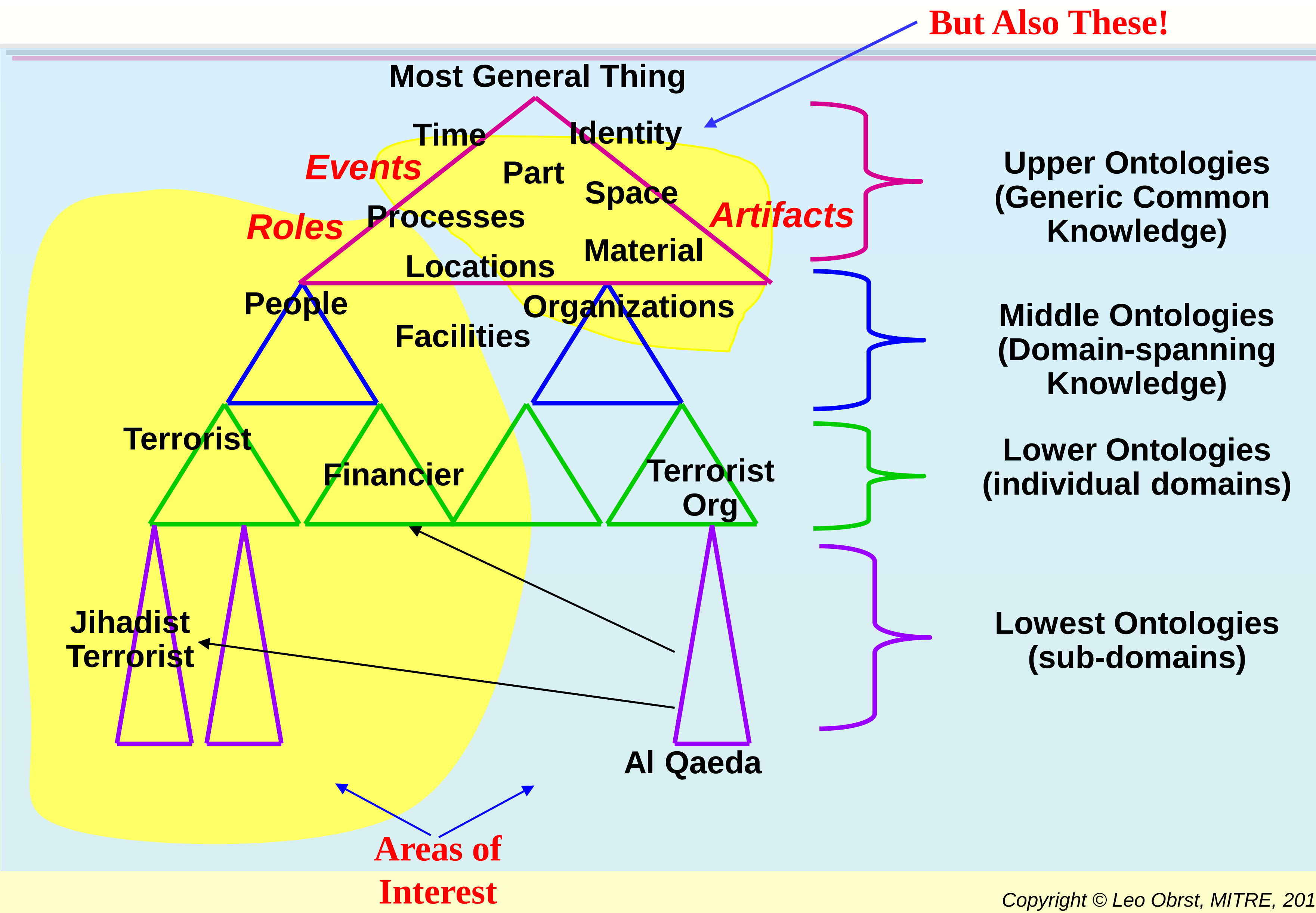
**Ontology (General)**

**Knowledge Base (Particular)**

## Ontology Example from Electronic Commerce: the general domain of machine tooling & manufacturing; note that these are expressed in English, but usually would be in expressed in a logic-based language

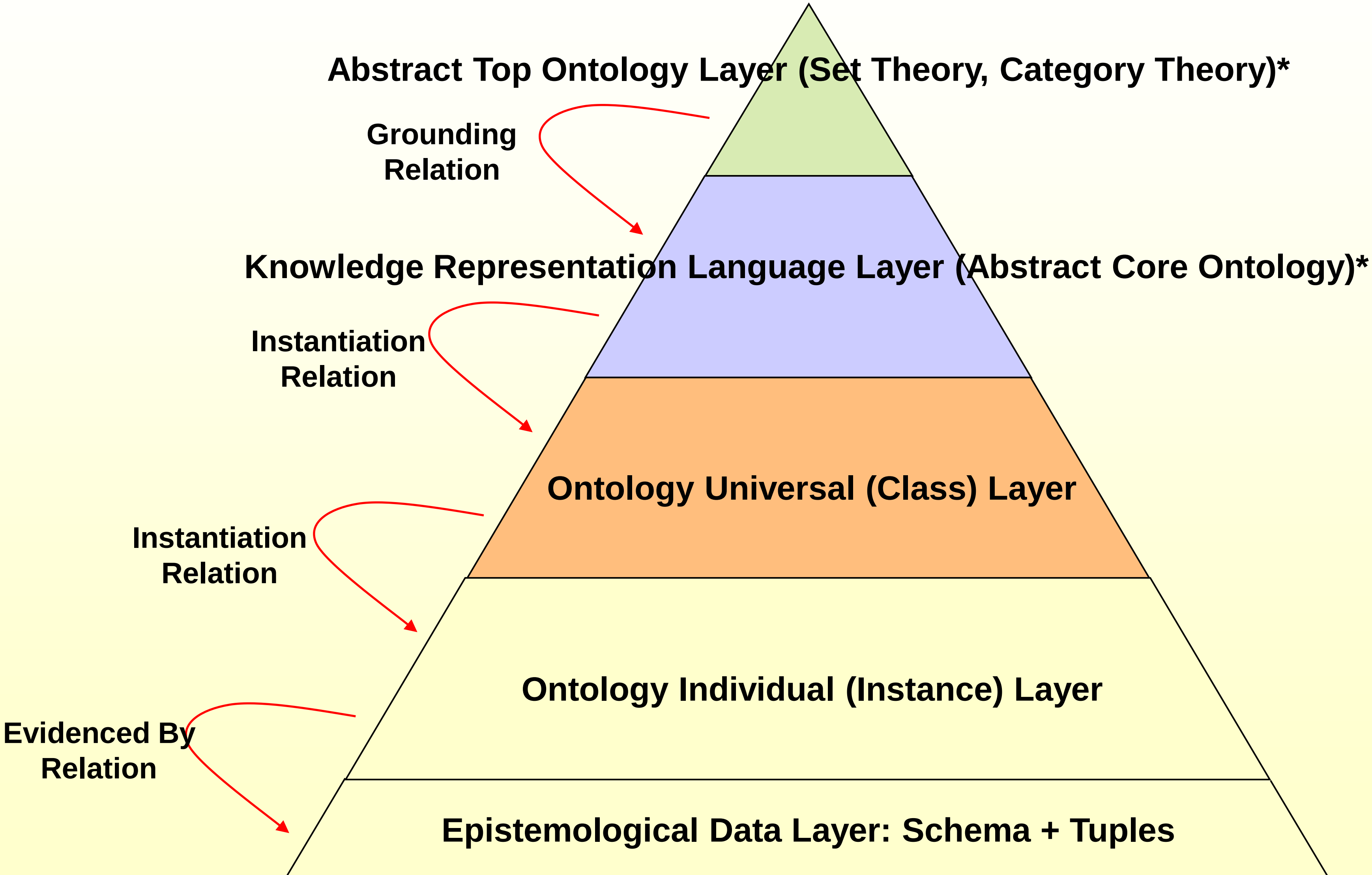
| Concept | Example |
|---|---|
| **Classes (general things)** | Metal working machinery, equipment and supplies, metal-cutting machinery, metal-turning equipment, metal-milling equipment, milling insert, turning insert, etc. |
| **Instances (particular things)** | An instance of metal-cutting machinery is the "OKK KCV 600 15L Vertical Spindle Direction, 1530x640x640mm 60.24"x25.20"x25.20 X-Y-Z Travels Coordinates, 30 Magazine Capacity, 50 Spindle Taper, 20kg 44 lbs Max Tool Weight, 1500 kg 3307 lbs Max Loadable Weight on Table, 27,600 lbs Machine Weight, CNC Vertical Machining Center" |
| **Relations: subclass-of, (kind_of), instance-of, part-of, has-geometry, performs, used-on, etc.** | A kind of metal working machinery is metal cutting machinery,<br>A kind of metal cutting machinery is milling insert. |
| **Properties** | Geometry, material, length, operation, ISO-code, etc. |
| **Values:** | 1; 2; 3; "2.5", inches"; "85-degree-diamond"; "231716"; "boring"; "drilling"; etc. |
| **Rules (constraints, axioms)** | If milling-insert(X) & operation(Y) & material(Z)=HG_Steel & performs(X, Y, Z), then has-geometry(X, 85-degree-diamond).<br>[Meaning: if you need to do milling on High Grade Steel, then you need to use a milling insert (blade) which has a 85-degree diamond shape.] |

# Upper, Middle, Domain Ontologies

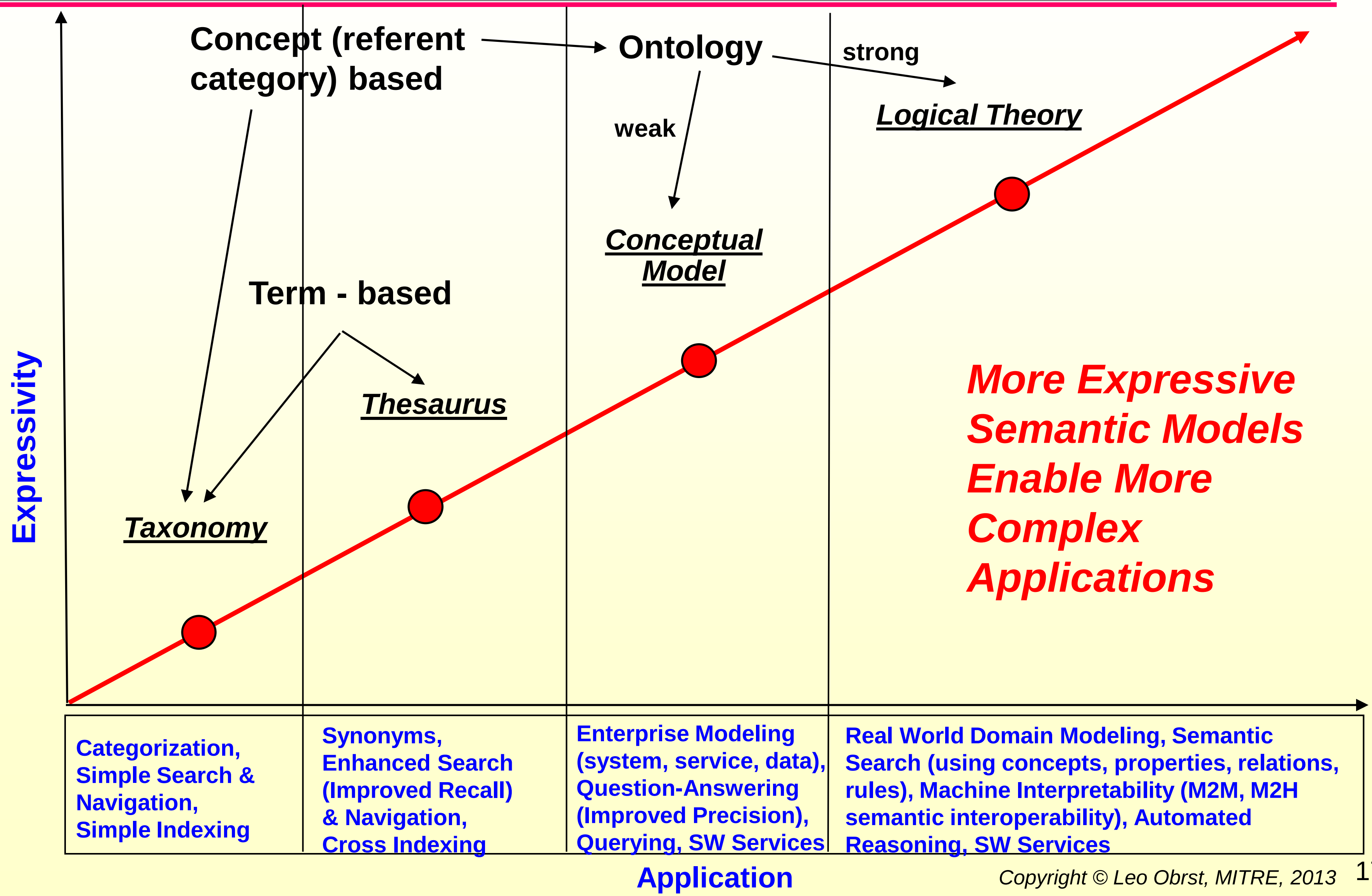


# Ontology Content Architecture: More Complex View

* Adapted from: Herre, Heinrich, and Frank Loebe. 2005. A Meta-ontological Architecture for Foundational Ontologies. In: R. Meersman and Z. Tari (Eds.): CoopIS/DOA/ODBASE 2005, LNCS 3761, pp. 1398–1415, 2005. Springer-Verlag Berlin Heidelberg.



# Ontology Spectrum: Complexity of Applications



# Ontology Modeling Issues

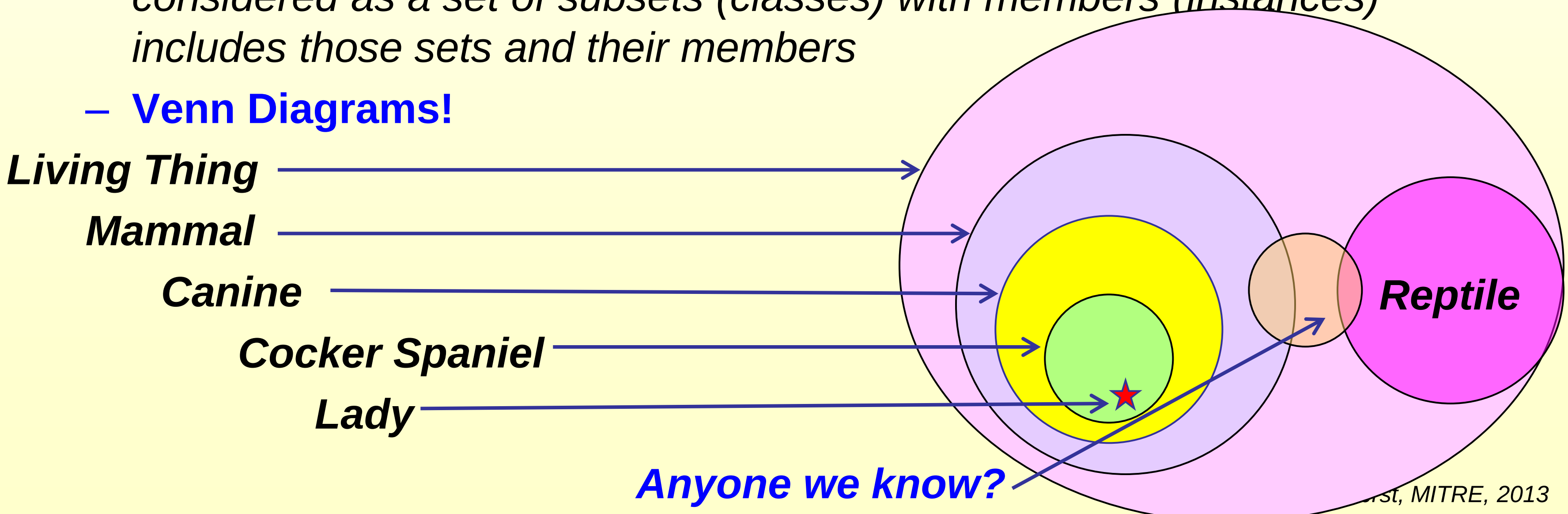
- What do you model in? **KR Language**
  - OO Frame vs. DL or FOL Axiom?
  - Currently, OWL is the de facto standard
    - Uses RDFS and also RDF for instance assertions (triples) in the RDF graph model
    - OWL $\cong$ DL, with OWL-DL 1 and OWL 2 based on different DLs
    - OWL is less expressive than Prolog (logic programming) or FOL
- What do you model? **Concepts**
- Concepts:
  - Concepts “stand in for” objects in the real world (possible world): Recall Triangle of Signification
  - Entities & relations
  - Universals & Particulars
  - Classes & Instances/Individuals
- How are Concepts modeled?
- The important point is:
  - **How do you develop a good ontology?**
  - **NOT: How do you develop a mediocre OWL ontology?**

# How are Concepts Modeled?

- Meta-class, Class, Instance
  - If have a meta-class Class, then all Classes are instances of that
  - Remember the 3 Representation Levels: Meta, Object, Instance
  - An Instance is a specific thing, a member of a Class, which is a general thing: John X. Smith is an Instance of the Class Person
- Distinguished relations: subclass/isa, instance_of, part_of (part-whole), composition_of, etc.
  - The semantics of these are defined in the meta-level or the upper ontology
- Class as unary relation: Person(X)
- Attribute as relation, reification of relations (as first class citizens, etc.)
- Domain & range of relation
  - worksAt(Person, Org) Domain: Person Range: Org
- Properties, Slots, Roles: relations "attached" to an instance
  - Properties in OWL, RDFS
  - Slots: in frame systems
  - Roles: in description logics
- Others: times, events, processes, purposes, contexts, agents, functions

# Inheritance of Properties, Subsumption

- **Developing a sound taxonomic backbone, i.e., a central subClass subsumption taxonomy is very important: $\forall x\ P(x) \rightarrow Q(x)$**
  - Nearly everything else in the ontology depends on this
  - This is the transitive, reflexive, anti-symmetric classification pipeline
  - Mathematically, it makes the core ontology a partially-ordered set
  - Parent classes subsume children classes
  - Subsumption: usually defined *extensionally, i.e., the parent class when considered as a set of subsets (classes) with members (instances) includes those sets and their members*
  - **Venn Diagrams!**



# Inheritance of Properties: Disjoint & Exhaustive Partitioning?

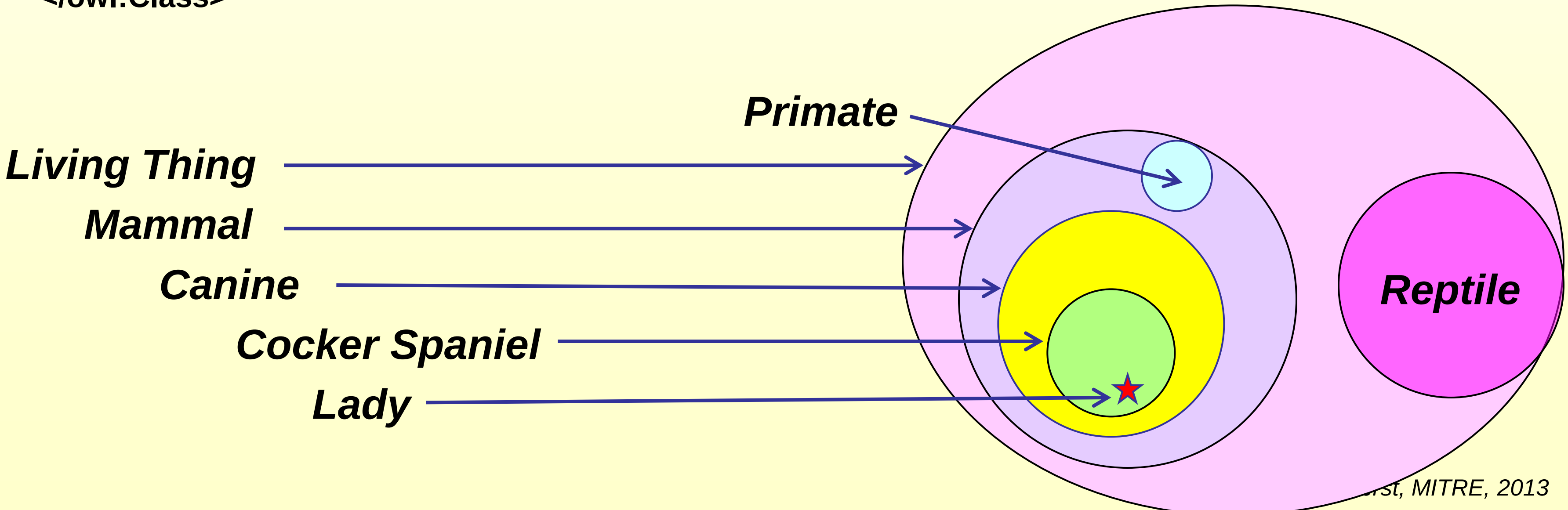
- Disjoint: We can declare by axiom that Canine is Disjoint from Reptile

```
<owl:Class rdf:about="#Canine">
  <rdfs:subClassOf rdf:resource="#Mammal"/>
</owl:Class>

<owl:Class rdf:about="#Primate">
  <rdfs:subClassOf rdf:resource="#Mammal"/>
  <owl:disjointWith rdf:resource="#Canine"/>
</owl:Class>
```

- Exhaustive Partioning: Union AND Disjoint in OWL 2 (*contrived*)

```
<owl:Class rdf:about=“#Mammal">
    <rdfs:subClassOf rdf:resource=“#LivingThing"/>
    <owl:disjointUnionOf rdf:parseType="Collection">
      <rdf:Description rdf:about=“#Canine"/>
      <rdf:Description rdf:about=“#Primate"/>
    </owl:disjointUnionOf>
  </owl:Class>
```



# Use of Formal Ontological Analysis

- **Ontology Development should be based on the following theories:**
  - **Theory of Parts**: Mereology or mereotopology? Is parthood transitive? Some, some not.
  - **Theory of Wholes**: what is the d
  - **Theory of Essence and Identit**
    you lose a necessary property, y
    But if he loses his head? Is he J
  - **Theory of Dependence:** some
  - **Theory of Qualities:** features, a
  - **Theory of Composition and C**
  - **Theory of Participation**: a con
    communicative phenomena, age
    pragmatics, speech acts, intents, etc.
  - **Theory of Representation:** how does one thing represent another? Map represent a region? Plan or specification represent real world steps? Artifact represent function?
  - **Theory of Time, Spacetime, and Events:** Events and States, bridging these.

**Do you need to know these? No, but it helps! Foundational ontologies build these theories in, but YOU have to know how to model!**

# Sounds Complicated & Theoretical?

- Actually, very concretely useful in making ontological distinctions for engineering ontologies:
  - Tools for the emerging discipline of ontological engineering
  - Goes far beyond data modeling, object modeling, and architecture model, which are concerned with local semantics, local patterns, local data access, local optimization
- Is it Hard? Yes, because Quality is Hard. Bad is Easy.
  - I can build you a bridge very quickly, vastly under budget that will collapse in a year, killing 100 people
  - Good science and engineering count!
- We'll look at OntoClean
- And MethOntology, now merged

# How To Create a Better Taxonomic Backbone to an Ontology*

- **Formal Ontological Analysis:** consider “meta” properties such as identity, rigidity, unity (whole)
- **Identity:** how does an entity change but keep its identity?
  – What are its essential properties?
  – If you change its parts, does it keep its identity?
  – Different properties/same parts, different parts/same properties
  – Persistence over time
- **Rigidity:** if having a certain property is essential for all instances
  – Having a brain is essential for a person
  – Having an arm is not essential for a person
  – Necessary and sufficient properties
  – Only rigid properties can provide identity
- **Unity:**  parts, whole, connectedness of parts, boundaries of the whole
  – Mereotopology: Parts + Connectedness
  – Collections: the sum is not a whole (five cups of coffee)
  – Plural Wholes: the sum is also a whole (ballplayers vs. team)
  – Statue of Venus vs. the clay that constitutes the statue
    - Venus de Milo: the  missing arms were part of the statue of Venus
    - The missing clay was part of the glob of clay that had been formed into the arms

*Based on OntoClean methoddology. Cf. Guarino, Nicola, and Christopher Welty. 2001. Conceptual Modeling and Ontological Analysis. http://reliant.teknowledge.com/IJCAI01/Guarino.ppt.

# Ontology Modeling Issues: Ontological Levels*, Multiple Dimensions

- Physical
  - Atomic *(a minimal grain of matter)*
  - Static *(a configuration, a situation)*
  - Mereological *(an amount of matter, a collection)*
  - Topological *(a piece of matter, something connected)*
  - Morphological *(a cubic block, a constellation)*
- Functional *(an artifact, a biological organ)*
- Biological *(a human body)*
- Intentional *(a person, a robot)*
- Social *(a company)*
- Informational *(a plan, a computer program)*

*Guarino, Nicola, and Christopher Welty. 2001. Conceptual Modeling and Ontological Analysis. http://reliant.teknowledge.com/IJCAI01/Guarino.ppt

# OntoClean: Building a Better Taxonomic Backbone

- Use meta-properties associated with the proposed classes, e.g., rigidity
  - Phased Sortals are not Subclasses of Sortals
  - Bad example:
    - Class Human: Subclasses Adult, Senior Citizen, Teenager, Toddler, Infant, Newborn, Fetus
    - These are stages (in 4D view, identifiable 4D subparts) of a Human
    - Similar: Egg, Larva, Pupa, Butterfly
- Example: Roles
  - Roles: Non-necessary, temporary (dynamic) relations: employee, carpenter, president, citizen, etc.
  - Roles are legitimate relations and even specialized role subclasses, but they are *Relations* to legitimate subclasses
- Jump to OntoClean2: next slide

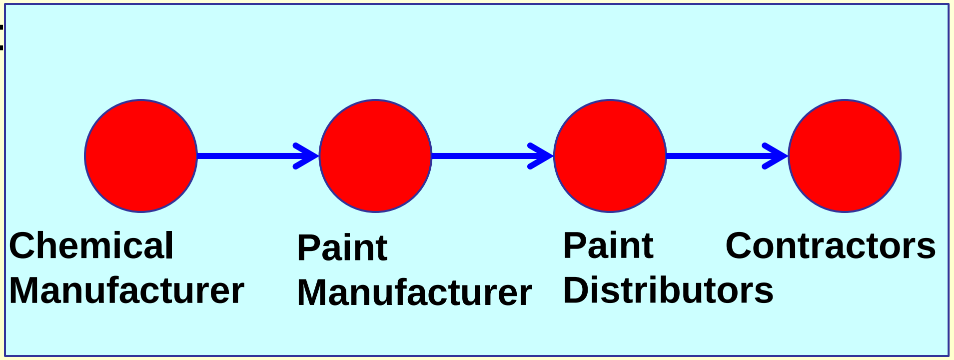
# OntoClean: Use Meta-Properties

- Assumption: no entity without identity Quine (1969)*
- Examples:
  - Computer is NOT the parent of Disk Drives & Memory
  - Computers are composed of these, have these as parts
  - Properties of Computers are not transitively inherited down to Disk Drives, Memory
  - Transitivity generally stops at Wholes: Every part of a Donut does not have a Hole, but every subclass of a Donut does have a Hole
    - Because the subclasses, if modeled right, are Wholes
- Every subclass should be thought as having a necessary property, that distinguishes it from its parents and siblings
- Nicola Guarino's & Chris Welty's Slides:
  - Jump to slide 23, then animation from slide 80+

* Quine, W. 1969, *Ontological Relativity and Other Essays*, New York: Columbia University Press, 1969.

# Real Business-to-Business E-Commerce example: Supply Chain Properties (from VerticalNet, 2000)

- Where you are in the supply chain determines the sub-ontology you need
- But you must bridge to your down/upstream supply chain partners
- **Chemical Manufacturer requires:**
  - Physical classes and properties:
    - Chemical elements, chemical compounds, chemical reactions, valency, etc.
    - Chemical processes: change or combine chemicals, chemical compounds, but also: chemical manufacturing processes (chemical engineering, etc.)
  - Purity, volatility, etc.
- **Paint Manufacturer requires:**
  - Functional classes and properties:
    - Light Reflectivity
    - Drying Time
    - Durability
    - Safety, exposure
    - Shelf life



# Ontology Modeling Issues: Well-Founded Ontologies - Some Basic Design Principles*

- *Be clear about the domain*
  - particulars (individuals)
  - universals (classes and relations)
  - linguistic entities (nouns, verbs, adjectives...)
- *Take identity seriously*
  - Different identity criteria imply ***disjoint classes***
- *Isolate a basic taxonomic structure*
  - Every entity must instantiate a rigid property with identity
  - Physical objects can change parts and remain the same, but amounts of matter cannot
  - Only *sortals* like "person" (as opposite to "red") are good candidates for being *taxons* (classes in subclass relation)
  - *Sortals:* objects which carry *identity*
  - *Categories:* objects which generalize *sortals*
- *Make an explicit distinction between types and roles (and other property kinds)*

*Guarino, Nicola, and Christopher Welty. 2001. Conceptual Modeling and Ontological Analysis. http://reliant.teknowledge.com/IJCAI01/Guarino.ppt.

# Ontology Design Patterns in OWL: Common Patterns and Problems

- Building a better Subclass Taxonomy
- Classes vs. Properties (Relations, Attributes)
- Distinguishing Properties, Relations, Attributes, Attribute Value Spaces
- Global Domain/Range vs. Local Property Restrictions
- Querying
- Rules
- OWL ontology integration strategies (patterns)
  - Import
  - Integration (Overlay) ontologies
  - Referencing other OWL ontology namespace symbols
  - Query or Rule Language: SPARQL or SWRL/RIF
- Ontology Design Patterns (odp.org): http://ontologydesignpatterns.org/wiki/Main_Page

# Events: Semantics & Ontology

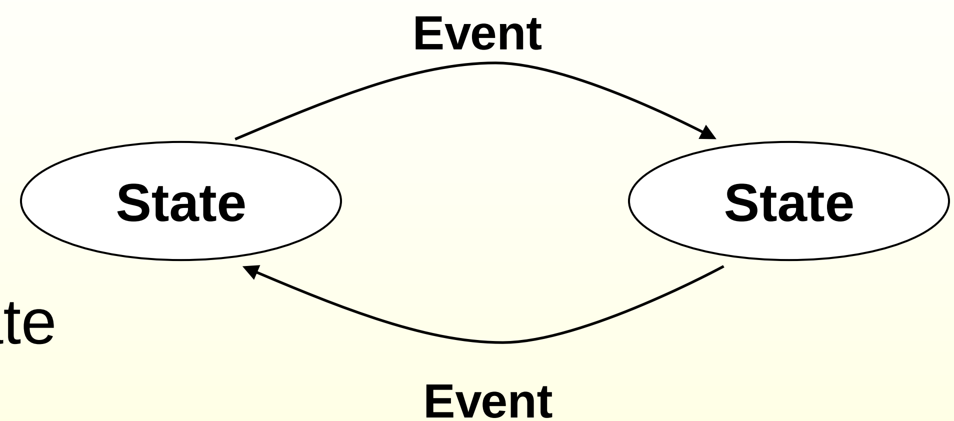
 

# Events

- What are Events?
- An Event has temporal parts or stages
  - Examples include extended events like a baseball game or a race, actions like Pursuing and Reading, and biological processes, as well as simple events (based on Cyc)
- The modern analysis of the basic structure of Events goes back to Vendler (1957)
- Events of all kinds are associated with a "preparation", or activity that brings the  event about, and a "consequent", or ensuring state, in a tripartite data structure (from Moens, 1987): preparation :: event :: consequent
- Each of the components may itself be compound
- Thus the preparation may be an iteration, the consequent state may identify a chain of consequences, and the core event may itself be a complex event, such as an accomplishment
  - Steedman, Temporality, Ch. 16, pp. 895-938 (p. 903). In: Van Benthem, Johan, and Alice ter Meulen. 1997. Handbook of Logic and Language. Cambridge, MA: The MIT Press.

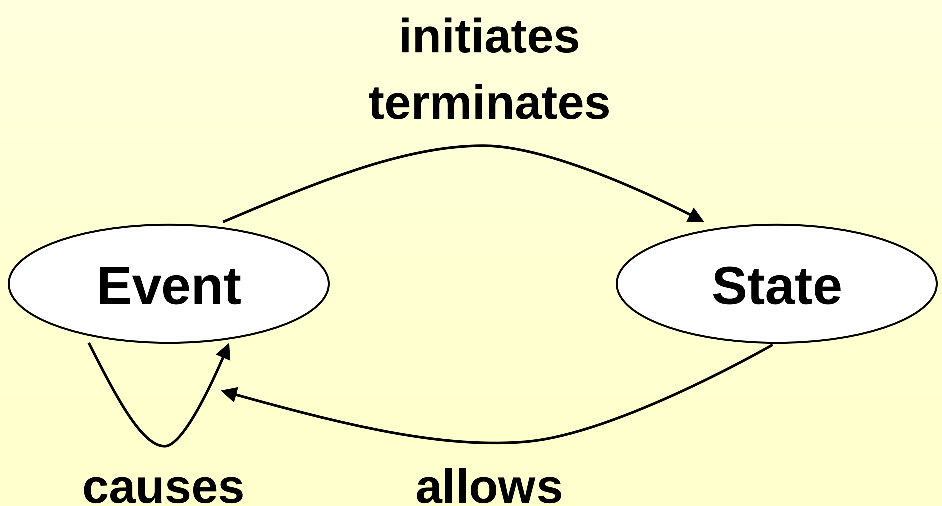
# Usual Computer Science/AI Model,

Simple Finite State Model: Event as change of State




Causal Event State Model

Galton (2012, p. 285)



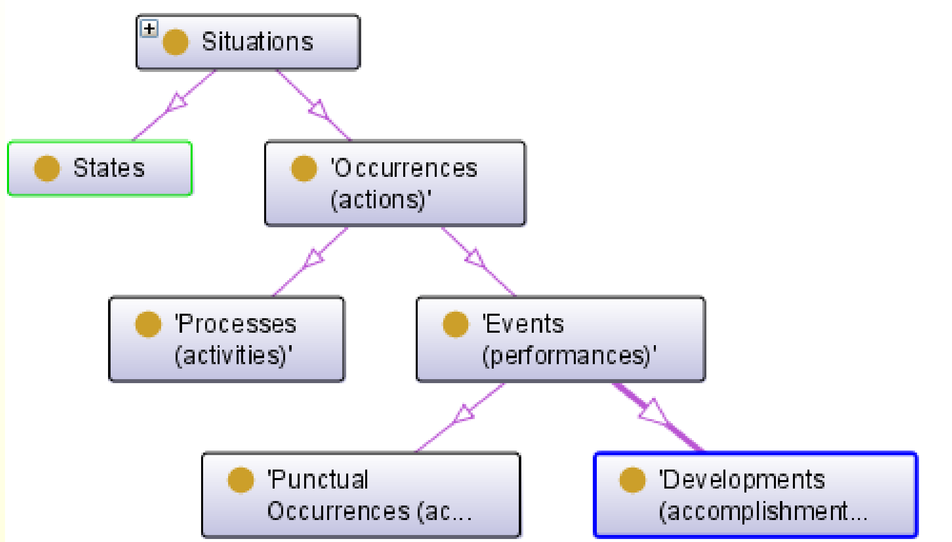
# Different Taxonomies of Events: Many initially from Linguistics: Vendler

- Vendler (1957): [from Verkuyl (1993, p. 34)]
  - ***States:*** *A loved somebody from t1 to t2* means that at **any** <u>instant</u> between t1 and t2 A loved that person
  - ***Activities*** (unbounded processes): *A was running at time t* means that time instant t is on **a** time <u>stretch</u> throughout which A was running
  - ***Accomplishments*** (bounded processes): *A was drawing a circle at t* means that t is on **the** time <u>stretch</u> in which A drew that circle
  - ***Achievements*** (point events): *A won a race between t1 and t2* means that **the** time <u>instant</u> at which A won the race is between between t1 and t2

| | **-Process** | **+Process** |
|---|---|---|
| **-Definite** | State | Activity |
| **+Definite** | Achievement | Accomplishment |

Definite: having a defined temporal unit: *a, any, the*

# Mourlatos (1978)




| | Occur (process) | Count (definite) | Punctual (momentary) |
|---|---|---|---|
| **States** | – | Ø | Ø |
| **Activities** | + | – | Ø |
| **Accomplishments** | + | + | – |
| **Achievements** | + | + | + |

# Moens (1987), Moens & Steedman (1988) Temporal Ontology 1

- **"Many of the apparent anomalies and ambiguities that plague current semantic accounts of temporal expressions in natural language stem from the assumption that a linear model of time is the one that our linguistic categories are most directly related to.**

- **A more principled semantics is possible on the assumption that the temporal categories of tense, aspect, aspectual adverbials, and of propositions themselves refer to a mental representation of events that is structured on other than purely temporal principles, and to which the notion of a nucleus, or contingently related sequence of preparatory process, goal event, and consequent state, is central." (p. 27)**

- **Note that this is "semantics", but is very relevant to "ontology"**

# Moens & Steedman (1988) 2 – Description of Model

- Initial view, similar to Vendler: events can be categorized in two dimensions (p. 3)
  - A contrast between punctuality and temporal extension
  - The association with a consequent state
- These are *typical* verbs; also need to include context
- Note that these verbs (semantically) *denote* events or states, and so offer insight into the formal semantics, but also the formal ontology

| | Events | | States |
|---|---|---|---|
| | atomic | Extended | understand, love, know, resemble |
| +conseq | **CULMINATION**<br>recognize, spot, win the race | **CULMINATED PROCESS**<br>build a house, eat a sandwich | |
| -conseq | **POINT**<br>hiccup, tap, wink | **PROCESS**<br>run, swim, walk, play the piano | |

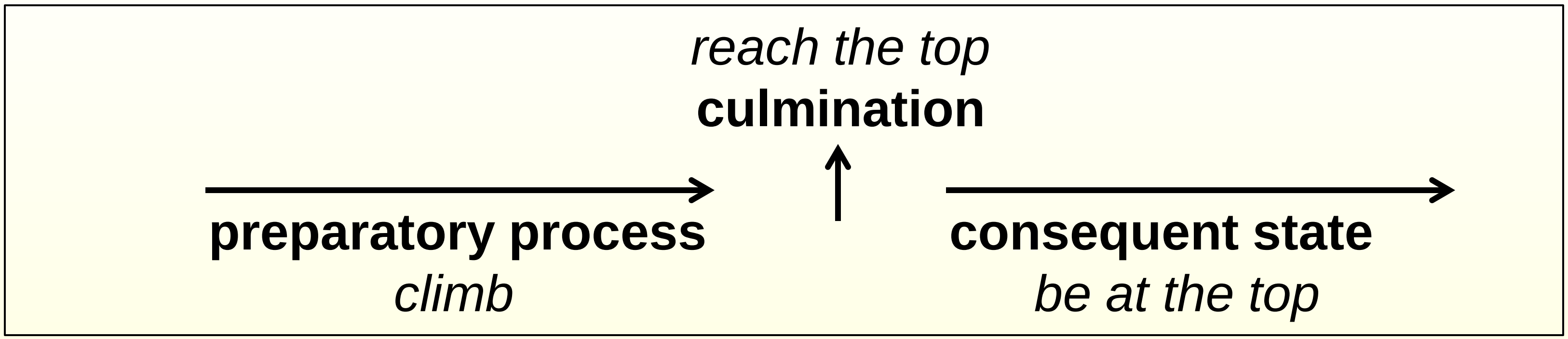
# Moens & Steedman (1988) 3 – Description of Model *

- Events have beginning and end points
- Events are punctual or extended in time
- *Event* types:
  - Culmination: instantaneous, introduces a transition from one state to another
    - Example: Harry reached the top. Harry has reached the top.
  - Point: an indivisible whole
    - Example: John hiccupped.
  - Process: has no culmination
    - Example: Harry climbed.
  - CulminatedProcess: a process that has a culmination
    - Example: Harry climbed to the top.
- *States*: indefinitely extending states of affairs

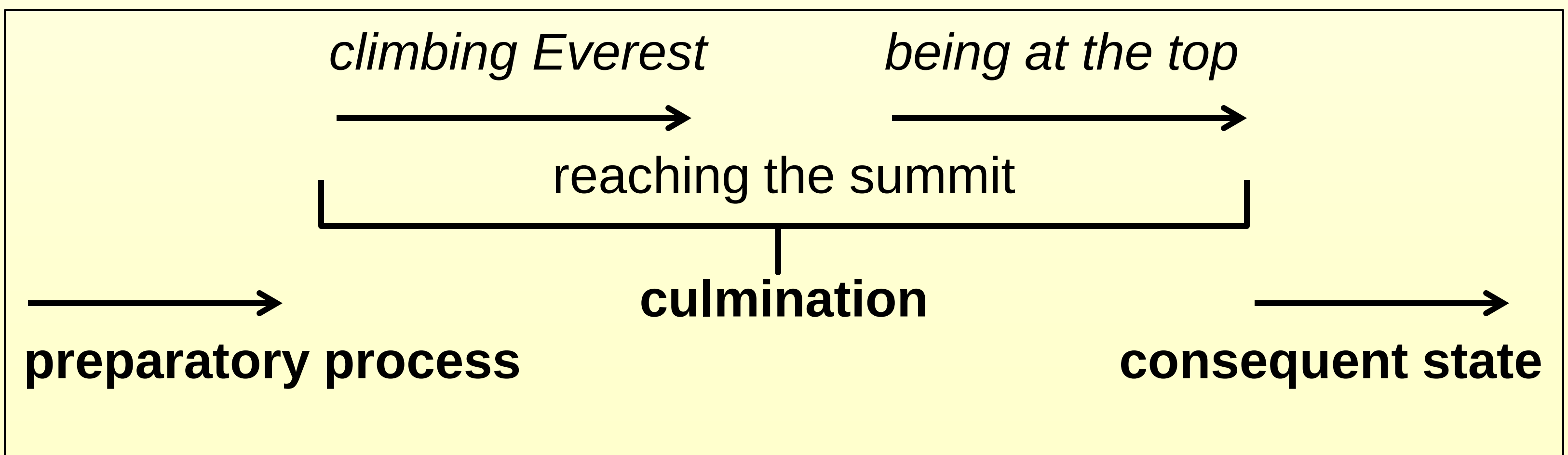
*** Also see: Brasoveanu (2008)**

# Moens & Steedman (1988) 4 – Description of Model

- Nucleus of *"climb to the top"*

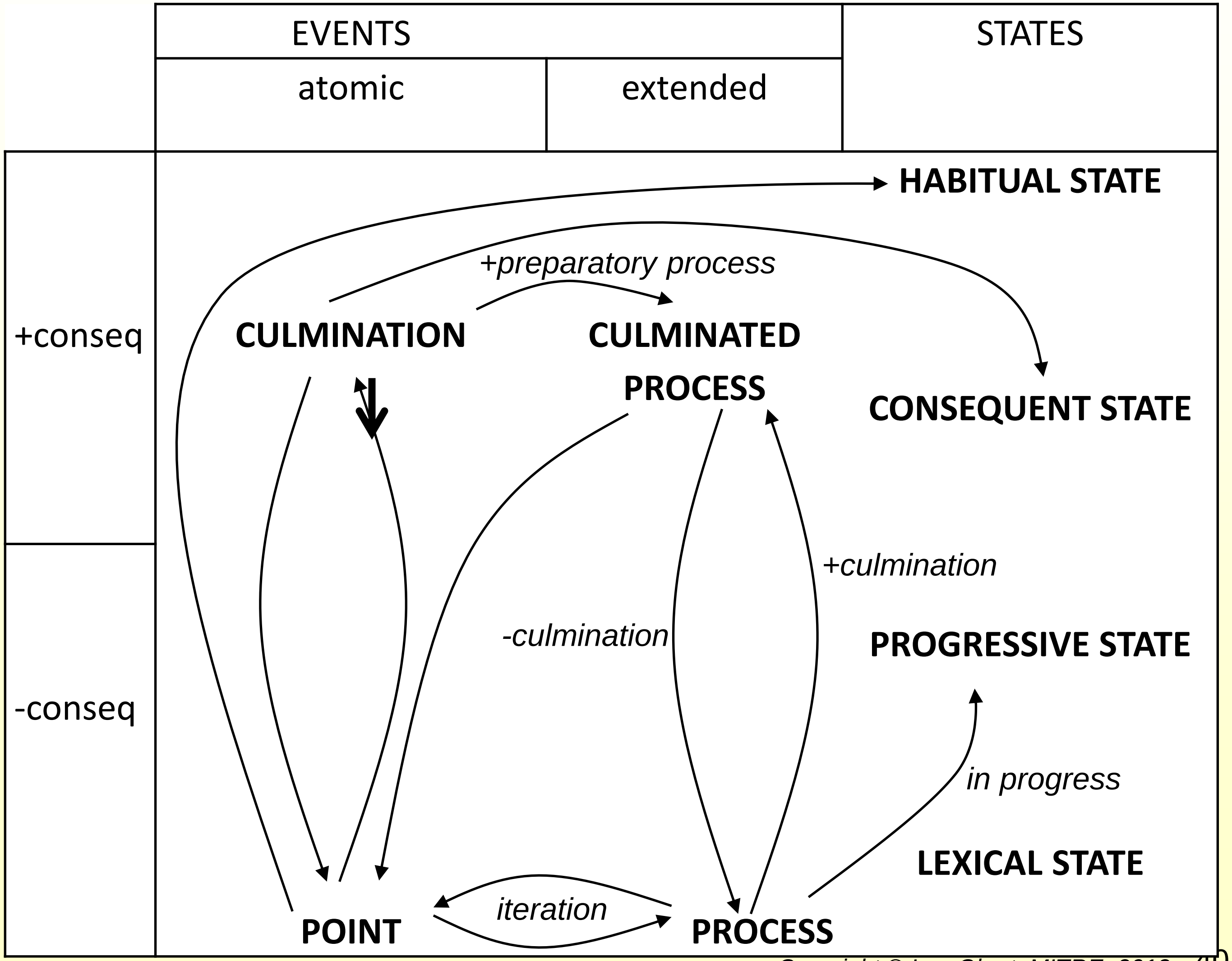



- *"Climbed Everest yet?"*



# Moens & Steedman (1988) 5 – Description of Model: Aspectual Changes

- Progressive auxiliary demands that its argument be a process
  - John was hiccupping
- Perfect auxiliary demands a culmination, predicating of the time referred
- to (Reichenbach's Reference Time) that the associated consequent state holds
  - Harry has reached the top



# Moens & Steedman (1988) 6 – Description of Model

- Combining the progressive with an expression denoting an atomic punctual event as in *Sandra was hiccupping:*
  1) The point proposition is coerced into a process of iteration of that point
  2) Then this process can be defined as ongoing, and so a progressive state:

(point *(Sandra hiccup))*

↓

(process (iteration (point *(Sandra hiccup))))*

↓

(progressive (process (iteration (point *(Sandra hiccup)))))*

# Moens & Steedman (1988. p. 12) 7 – Conclusions for Ontology

- "A principled and unified semantics of natural-language categories like tense, aspect, and aspectual/temporal adverbials requires an ontology based on contingency rather than temporality." (and contingency is weaker than usual causality notion from Allen's Interval Calculus, etc.)
- "The identification of the correct ontology is also a vital preliminary to the construction and management of temporal databases."
- "Rather than a homogeneous database of dated points or intervals, we should partition it into distinct sequences of causally or otherwise contingently related sequences of events, which we might call **episodes**, each leading to the satisfaction of a particular goal or intention.
  - This partition will quite incidentally define a partial temporal ordering on the events
  - But the primary purpose of such sequences is more related to the notion of a plan of action or an explanation of an event's occurrence than to anything to do with time itself."

# Event Calculus: Shanahan (1999) 1 – The Simple Event Calculus

- This leads us to the premise of the Event Calculus:
  - "The event calculus is an attempt to codify intuitive reasoning about action and change in such a way that the frame problem is avoided."
    - - van Lambalgen, Michiel. The Event Calculus. http://staff.science.uva.nl/~michiell/docs/SyllabusEC.
- Actions, i.e., events (or rather action or event types)
- Fluents: anything whose value is subject to change over time, i.e., quantities or propositions
  - Are first-class objects, which can be quantified over, appear as predicates arguments
- Time points
- Has all the fundamental characteristics of the full version, but easier
- Has predicates for describing:
  - What happens when
  - The initial situation
  - The effects of actions
  - What fluents hold at what times

# Event Calculus: Shanahan (1999) 2 – The Simple Event Calculus

| Formula | Meaning |
|---|---|
| Initiates(α,β,τ) | Fluent β holds after action α at time τ |
| Terminates(α,β,τ) | Fluent β does not hold after action α at time τ |
| Releases(α,β,τ) | Fluent β is not subject to the common sense law of inertia after action α at time τ |
| InitiallyP(β) | Fluent β holds from time 0 |
| InitiallyN(β) | Fluent β does not hold from time 0 |
| Happens(α,τ1,τ2) | Action α starts at time τ1 and ends at time τ2 |
| HoldsAt(β,τ) | Fluent β holds at time τ |
| Clipped(τ1,β,τ2) | Fluent β is terminated between times τ1 and τ2 |

Shanahan (1999, p. 3)

# Event Calculus: Shanahan (1999) 3 – Axioms

- A fluent holds at a time t if it held at time 0, and hasn't been terminated between 0 and t:

  $$(SC1)\ HoldsAt(f,t) \leftarrow InitiallyP(f) \land \neg\ Clipped(0,f,t)$$

- A fluent holds at time t if it was initiated at some time before t and hasn't been terminated between then and t:

  $$(SC2)\ HoldsAt(f,t2) \leftarrow Happens(a,t1) \land Initiates(a,f,t1) \land t1 < t2 \land \neg\ Clipped(t1,f,t2)$$

- A fluent is terminated between times t1 and t2 iff there is some action *a* occuring at time t, t is between t1 and t2, and the fluent terminates between *a* and time t

  $$(SC3)\ Clipped(t1,f,t2) \leftrightarrow \exists\ a,t\ [Happens(a,t) \land t1 < t < t2 \land Terminates(a,f,t)]$$

- But Frame Problem: how to represent the effects of actions, without having to explicitly represent all their non-effects? - McCarthy & Hayes (1969)
- Example: Yale shooting problem - Hanks & McDermott (1987)

# Event Calculus: Shanahan (1999) 4 – Yale Shooting Problem

- Three Actions: Load, Sneeze, Shoot
- Three Fluents: Loaded, Alive, Dead
- "The effect of a Load action is to make Loaded hold, a Shoot action makes Dead hold and Alive not hold so long as Loaded holds at the time, and a Sneeze action has no effects."
  - (Y1.1) Initiates(Load,Loaded,t)
  - (Y1.2) Initiates(Shoot,Dead,t) $\leftarrow$ HoldsAt(Loaded,t)
  - (Y1.3) Terminates(Shoot,Alive,t) $\leftarrow$ HoldsAt(Loaded,t)
- Load, Sneeze, Shoot Scenario:
  - (Y2.1) $\text{Initially}_P$(Alive)
  - (Y2.2) Happens(Load,T1))
  - (Y2.3) Happens(Sneeze,T2)
  - (Y2.4) Happens(Shoot,T3)
  - (Y2.5) T1 < T2
  - (Y2.6) T2 < T3
  - (Y2.7) T3 < T4

# Event Calculus: Shanahan (1999) 5 – Yale Shooting Problem

- Now let Σ be the conjunction of (Y1.1) to (Y1.3), and let Δ b the conjunction of (Y2.1) to (Y2.7)
- The intention is that we should have:

$$\Sigma \wedge \Delta \wedge SC \vDash \mathrm{HoldsAt}(\mathrm{Dead}, T4)$$

- But this is NOT VALID! Why? Because we haven't described the non-effects of actions
  - Sneeze action doesn't unload the gun
  - There are some models of $SC \wedge \Sigma \wedge \Delta$ in which Terminates(Sneeze,Loaded,T2) is true, Holds(Alive,T4) is true, and HoldsAt(Dead,T4) is false
- Need predicate completions
- Instead, use Circumscription – McCarthy (1980): **We won't go into this!**
- Event calculus formalizes two notions of cause:
  - Instantaneous change, e.g., when two balls collide
  - Change due to a force which exerts its influence continuously, as an activity, e.g., painting a house

# van Lambalgen & Hamm (2005): Back to the Event Calculus

- Builds on the Russell-Kamp Construction of Time from Events
- From *Precedes* and *Overlaps* using 7 Axioms, can characterize all event structures

1) $P(x, y) \rightarrow \neg P(y, x)$
2) $P(x, y) \wedge P(y, z) \rightarrow P(x, z)$
3) $O(x, x)$
4) $O(x, y) \rightarrow O(y, x)$
5) $P(x, y) \rightarrow \neg O(x, y)$
6) $P(x, y) \wedge O(y, z) \wedge P(z, v) \rightarrow p(x, v)$
7) $P(x, y) \vee O(x, y) \vee P(y, x)$

- Intuition (set-theoretic) :
  – One conceives of time as composed of instants
  – So Events must be models as particular sets of instants,
  – And Events must be composed of instants
- But there are other views of events! Richer languages. Eventually ends up with Event Calculus (with modifications)

# Kaneiwa, Iwazume, & Fukuda (2007) 1

- Statives: " ... states that are divided into states of objects and states of environments.
- As a result of this, the object state is expressed by a trinary predicate formula because the state has the three components of an object, time, and location.
- The environment state is described by a binary predicate formula that consists of the two components of time and location.
- We regard states of objects or environments as events because states are events representing the changes of objects or environments in dynamic time and location.“

# Kaneiwa, Iwazume, & Fukuda (2007) 2

- Event
  - NaturalEvent
    - Occurence1: Time, Location
    - Occurence2: Object, Time, Location
  - ArtificialEvent
    - Action1: Agent,Object, Time, Location
    - Action2: Agent, Time, Location
    - Action3: AgentGroup, Time, Location
  - DynamicState
    - ObjectChange: Object, Time, Location
    - EnvironmentChange: Time, Location
  - StaticState
    - ObjectState : Object, Time, Location
    - EnvironmentState : Time, Location

# Kaneiwa, Iwazume, & Fukuda (2007) 3

- <u>Artificial Events:</u>
  1) Actions from agents to objects or agents (e.g., murder and environmental disruption)
  2) Intransitive actions (e.g., breathing and moving)
  3) Actions with many agents (e.g., conference and discussion)

- EventSemanticFunctions
  - StateChange
  - TemporalExistenceChange
  - SpatialExistenceChange
  - CardinarityChange
  - Comparison
  - ObjectIdentificationChange

# Kaneiwa, Iwazume, & Fukuda (2007) 4 – Event Semantic Functions

- <u>Definition 1 (Activity of States):</u> A state is dynamic if the state implies the activity and dynamic change of an object or environment in time. A state is static if the state implies the static property in time.
- <u>Definition 2 (State Change):</u> An event is a state-change-event if the occurrence yields the change of states from now to the next time as follows: $F1 \rightarrow \bigcirc F2$, where the modal operator $\bigcirc F2$ implies that F2 is true at the next time.
- <u>Definition 3 (Existential Change over Time):</u> An event is a temporal-existence-change-event if its occurrence changes the existence of an object according to a change in time as follows: $\square P (\neg E(x)) \wedge E(x)$.The temporal operator $\square PF$ implies that the formula F was always true in the past. The semantic function of event e contains the existential formula $\square P (\neg E(x)) \wedge E(x)$ implying that an object x did not exist in the past but it exists now.
- <u>Definition 4 (Existential Change over Space):</u> An event is a spatial-existence-change-event if its occurrence changes the existence of an object depending on movement through space as follows: $\neg E(x) \wedge \blacklozenge E(x)$. The spatial operator $\blacklozenge F$ implies that the formula F is true in a place accessible from here. Hence, the semantic function of $\neg E(x) \wedge \blacklozenge E(x)$ indicates that an object x does not exist here, but it exists in a place accessible from here.

# Kaneiwa, Iwazume, & Fukuda (2007) 5 – Event Semantic Functions

- <u>Definition 5 (Cardinality Change):</u> An event is a cardinality-change-event if it changes the cardinality of objects as follows: $\exists ixF(x) \rightarrow \bigcirc\exists{>}ixF(x)$. Let n be a natural number. The generalized quantifier $\exists nxF(x)$ (called counting quantifier) expresses the existence of n objects x such that the formula F(x) is true. In the cardinality change, we have to introduce a variable i of natural numbers for the generalized quantifier ∃i that is more expressive than the the generalized quantifier ∃n. Hence, the semantic function of $\exists ixF(x) \rightarrow \bigcirc\exists{>}ixF(x)$ indicates that if there exist i objects x such that F(x) is true, then there exist more than i objects x such that F(x) is true the next time. This function means that the number of objects increases by the next time because of the event occurrence.
- <u>Definition 6 (Comparison):</u> An event is a comparison event if the attribute value of an object is found to change when comparing that value with the attribute value at the next time as follows: $\exists y(Value(x) = y \rightarrow \bigcirc(Value(x) > y))$. In the semantic function, Value(x) denotes the attribute value of an object x and the inequality symbol > is used to compare the value of the attribute now to that of the next time. To compare the value of x now to that of the next time, a fixed value y and the changed value Value(x) appear in the formula $\exists y(Value(x) = y \rightarrow \bigcirc(Value(x) > y))$.

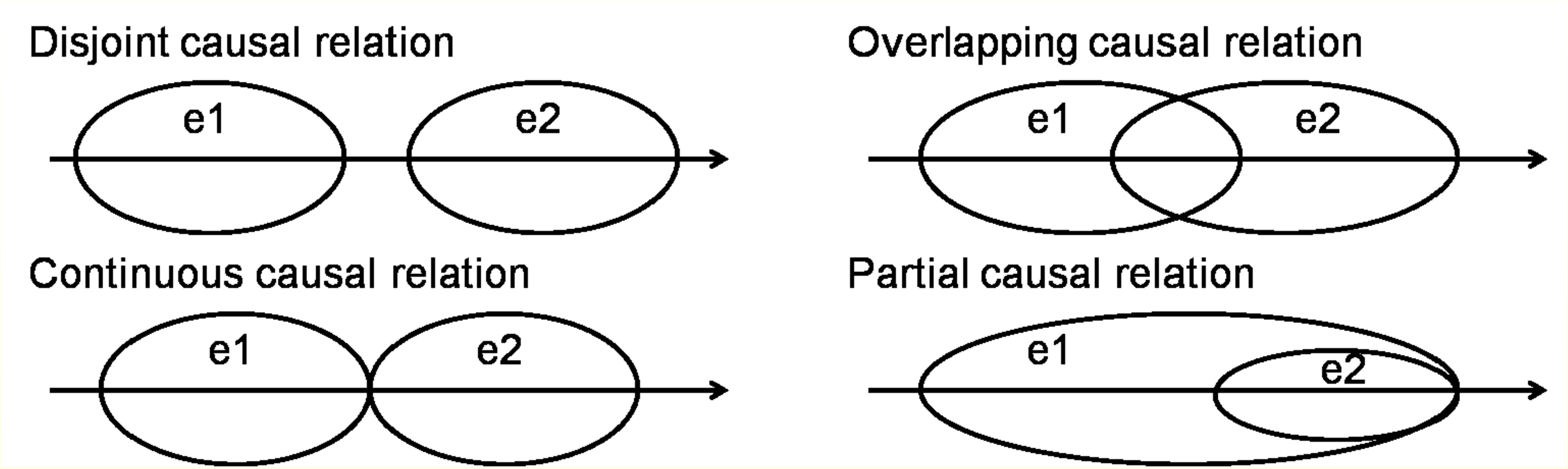
# Kaneiwa, Iwazume, & Fukuda (2007) 6 – Event Semantic Functions

- <u>Definition 7 (Object Identification Change):</u> An event is an object-identification-change-event if the essential property of an object is changed and therefore the object cannot be recognized as the former object at the next time as follows: $\exists y(x \not\equiv y \rightarrow \bigcirc(x \not\equiv y))$. The object identification is lost at the next time after the occurrence of an object-identification-change-event. Hence, the function of $\exists y(x \not\equiv y \rightarrow (x \not\equiv y))$ implies that if there exists an object y such that y is identical to object x, then the event makes them different at the next time. This means that an object x is changed into another object y.

## Kaneiwa, Iwazume, & Fukuda (2007) 7 Semantic Functions of Events

| Event predicates | Quantified modal formulas |
|---|---|
| Cure(x, y) | $\neg Healthy(y) \wedge (Act(x, y) \vee Affect(x, y)) \rightarrow \bigcirc Healthy(y)$ |
| Drink(x, y) | $(InMouth(y) \wedge Swallow(x, y) \wedge \neg Bite(x, y)) \rightarrow \bigcirc InBody(y)$ |
| Stop(x, y) | $Active(y) \wedge (Action(x, y) \vee Affect\ (x, y)) \rightarrow \bigcirc \neg Active(y)$ |
| Die(x) | $\Diamond_P (\Box_P \neg E(x) \wedge E(x)) \wedge (\neg E(x) S E(x)) \wedge \Box_F (\neg E(x))$ |
| Print(x, y) | $\exists v(Object(v) \wedge Act(x, v) \rightarrow \bigcirc \exists z(Above(z, v) \wedge Press(Mark(y), z)))$ |
| BeBorn(x) | $\Box_P (\neg E(x)) \wedge E(x)$ |
| Go(x) | $Act(x) \rightarrow \bigcirc (\neg E(x) \wedge \blacklozenge E(x))$ |
| Separate(x, y) | $Adjoint(x, y) \vee Overlap(x, y) \rightarrow \bigcirc (\neg Adjoint(x, y) \wedge Overlap(x, y))$ |
| Understand(x, y) | $\exists v((v = Fact(x) \vee v = Content(x) \vee v = Meaning(x)) \wedge Get(x, v))$ |
| Increase(x) | $\exists i(Nat(i) \wedge \exists_i x\ Countable(x) \rightarrow \bigcirc \exists_{>i} x\ Countable(x))$<br>$\exists y(Rel\ (y) \wedge Quantity(x) = y \rightarrow \bigcirc (Quantity(x) > y))$ |
| Decrease(x) | $\exists i(Nat(i) \wedge (i > 0) \wedge \exists_i x\ Countable(x) \rightarrow \bigcirc \exists_{i-1} x\ Countable(x))$<br>$\exists y(Rel\ (y) \wedge Quantity(x) = y \rightarrow \bigcirc (Quantity(x) < y))$ |
| Raise(x) | $\exists y(Location(x) = y \rightarrow \bigcirc (\neg E(x) \wedge \blacklozenge (E(x) \wedge Location(x) > y))$<br>$\exists y(Value(x) = y \rightarrow \bigcirc (Value(x) > y))$ |
| High(x, y) | $\exists r(Rel\ (r) \wedge Value(x) = r \wedge (Value(y) < r))$ |
| Change(x) | $\exists y(x \equiv y \rightarrow \bigcirc (x \not\equiv y))$ |
| Make(x, y) | $\exists z(Act(x, z) \rightarrow \bigcirc (BeBorn(y) \wedge y \not\equiv z \wedge Valuable(y)))$<br>$Act(x) \rightarrow \bigcirc BeBorn(y)$ |

# Kaneiwa, Iwazume, & Fukuda (2007) 8 – Causal Relations over Time




1) If each event instances of E1 and E2 cannot occur simultaneously, then the event disjoint relation E1||E2 holds.
2) If every instance of E1 belongs to E2, then the event-subclass relation E1 $\sqsubseteq$ E2 holds.
3) If for every event instance e of E1, there is an event instance e' of E2 such that e' <po e, then the event-class part-of relation E1 <po E2 holds.
4) If for every event instance e of E1, there is an event instance e' of E2 such that e →cause e', then the event-class causal relation E1 →cause E2 holds.

# Galton, Galton & Mizoguchi (2009)

- Two views on the relationship between objects and processes:
  - Object-centered view (going back to Aristotle)
  - Process-centered view (Heraclitus, Bergson, James, Whitehead)
- The ‘object-priority’ view: Matter and objects are prior to processes and events. Viewed as an ontological claim, the ‘object-priority’ view asserts that in some important sense matter and objects are all that there is in the world; events and processes exist solely by virtue of the distribution of matter and objects in space and time.
- The ‘process-priority’ view: Processes and events are prior to matter and objects presented as an ontological claim, that processes and events are all that there is. Matter and objects are to be analysed as in some way constructed from, or emergent from, processes and events. It is sometimes said that what we commonly call an object is in fact an event or process, although it is hard to assert this using ordinary vocabulary without courting gross categorical confusion.

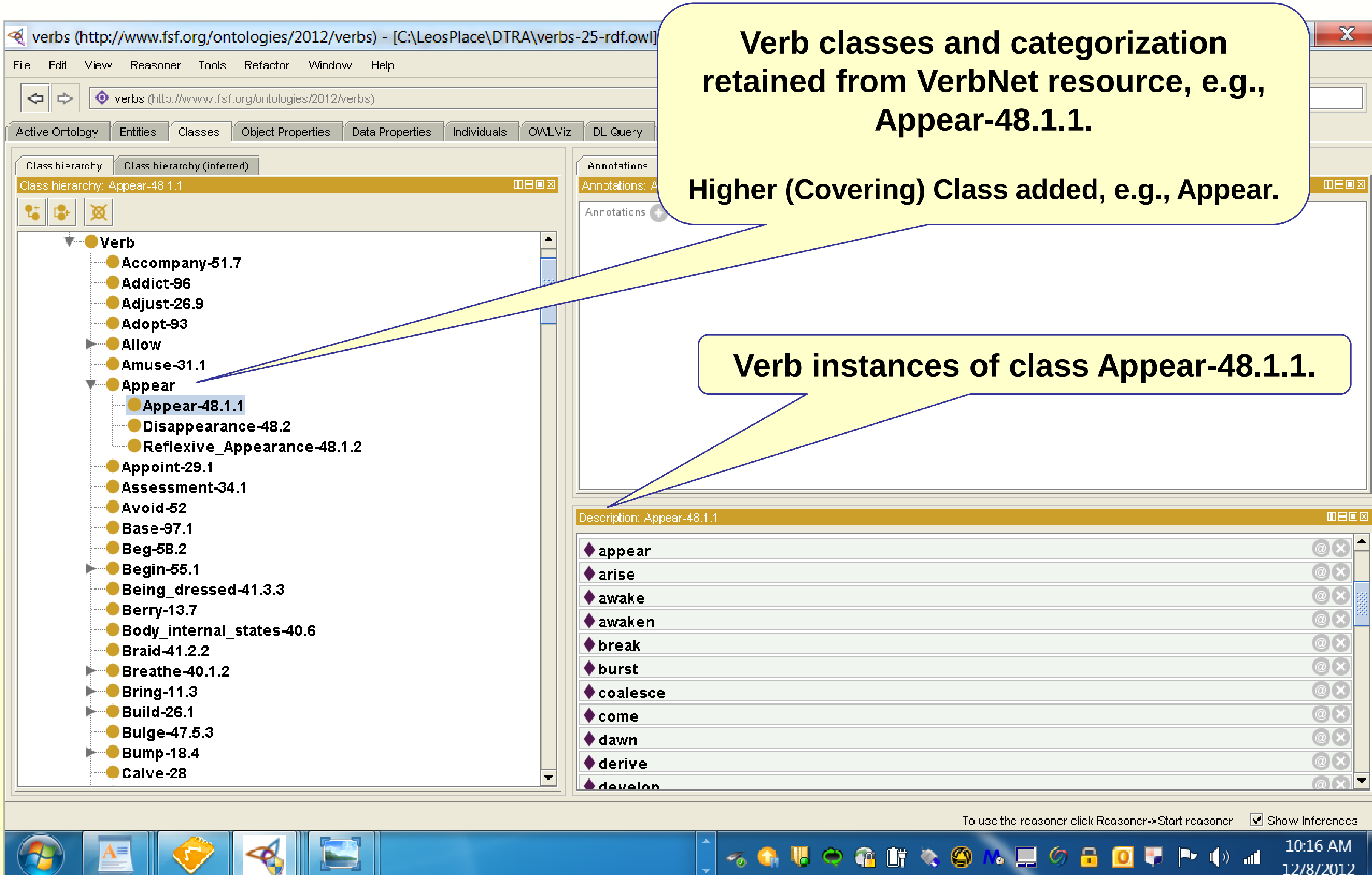
# Miscellaneous Event Models

- From DOLCE Lite Plus v397:
  - "An occurrence-type is stative or eventive according to whether it holds of the mereological sum of two of its instances, i.e. if it is cumulative or not. A sitting occurrence is stative since the sum of two sittings is still a sitting occurrence.“
- From the Event ontology:
  - States are characterized syntactically by being almost the only propositions that can be expressed in English by simple present tense; exceptions: performatives, which in all other respects are archetypal achievements): name as in "I name this ship 'The Santa Maria'." Most progressives and perfects, and predications of habitual action, are also archetypal states.
  - In the Persona ontology (from Cyc), a TemporalSituation is very close to being a Stative: An event or occurrence consisting of one or more objects playing one or more (often inter-related) roles and that has duration or other temporal properties. A TemporalSituation may be static or dynamic. (Based on Cyc.)

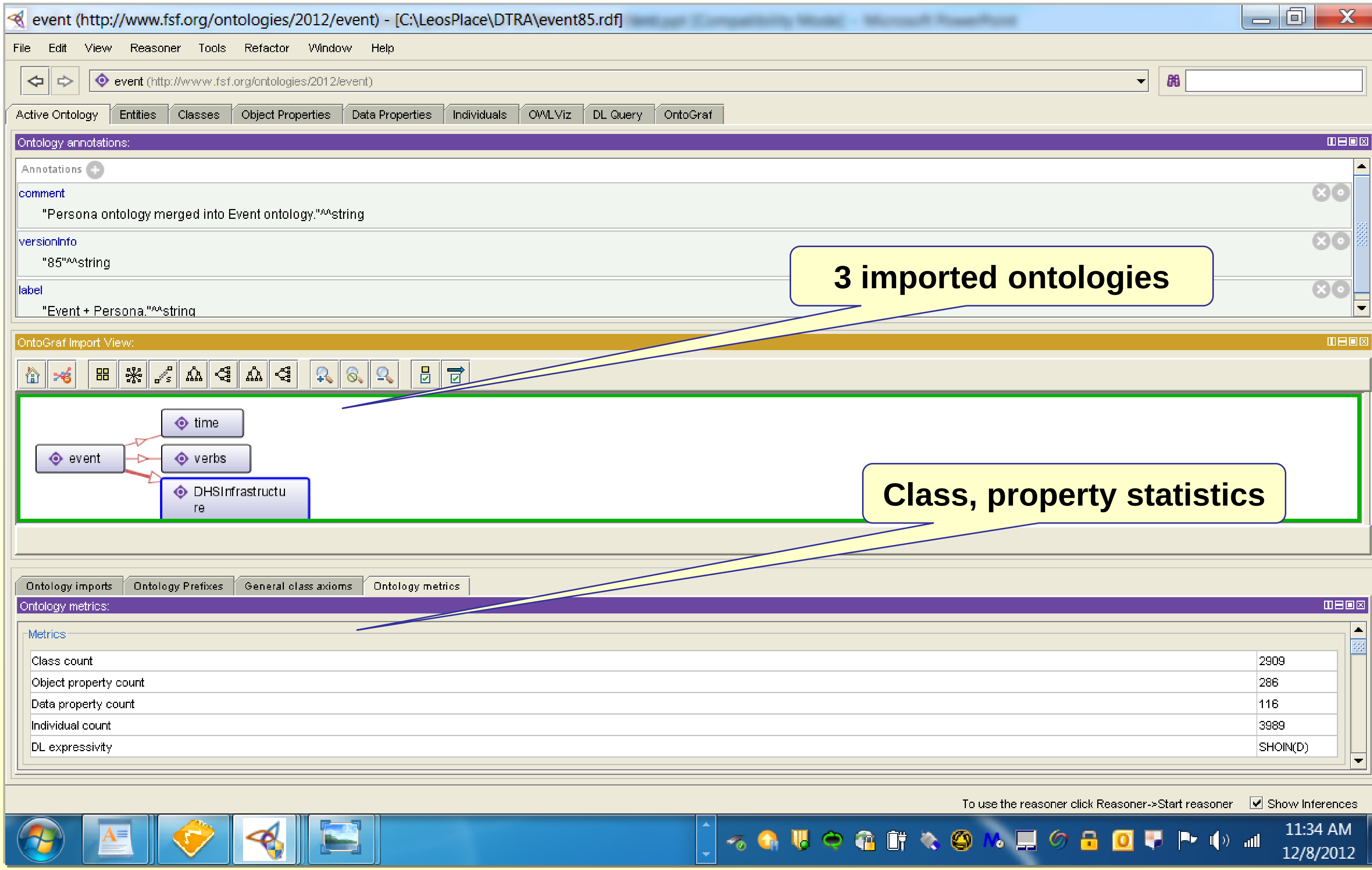
# Ontologies of Verbs and Events: Thematic Roles, Verb Argument Structure, Events, and Ontology

- Let’s look at some pictures and examples, based on the Event ontology I developed

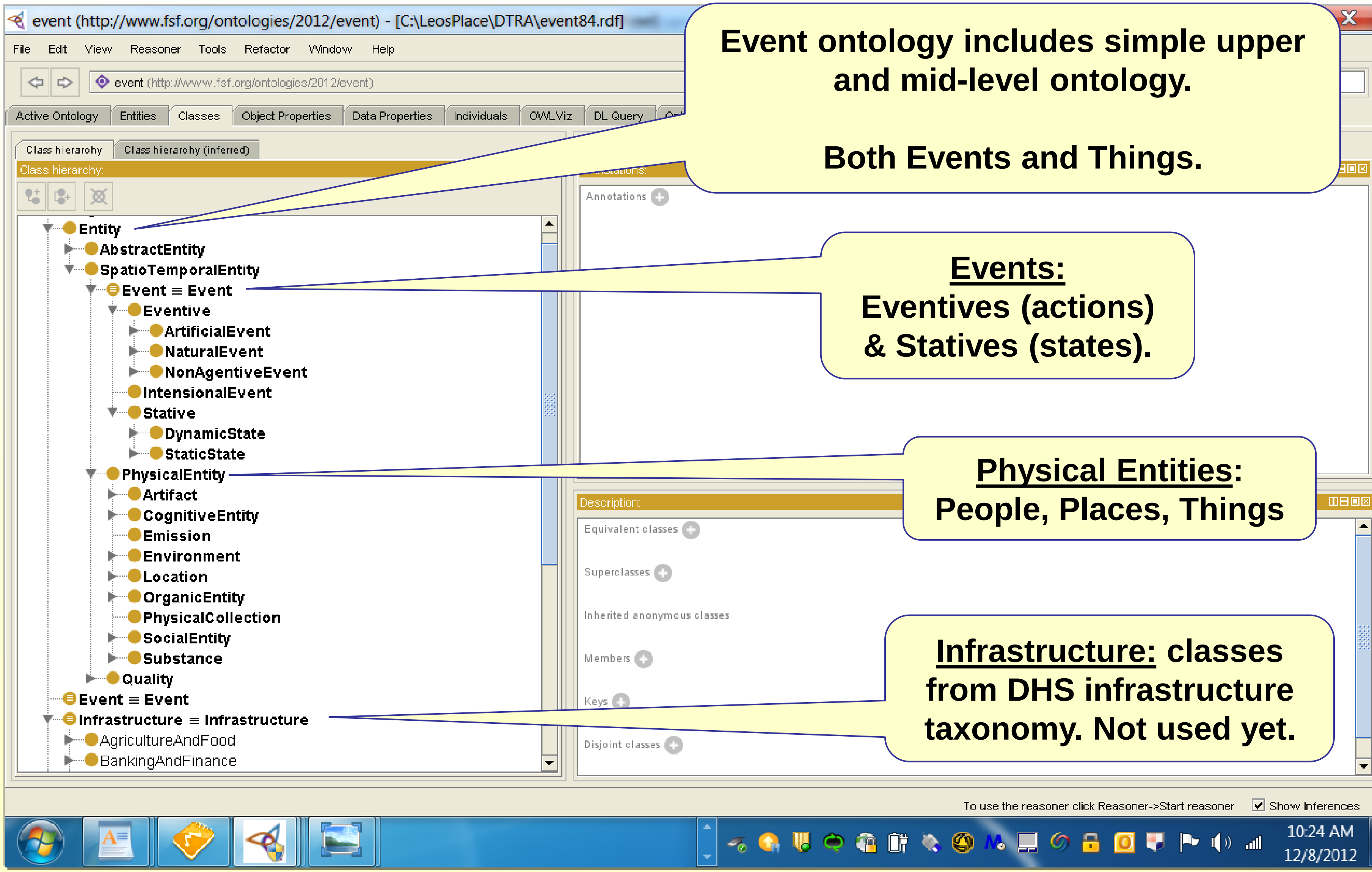
# Verbs Ontology



# Event Ontology



# Event Ontology: Events, Things, Infrastructure




Event ontology includes simple upper and mid-level ontology.

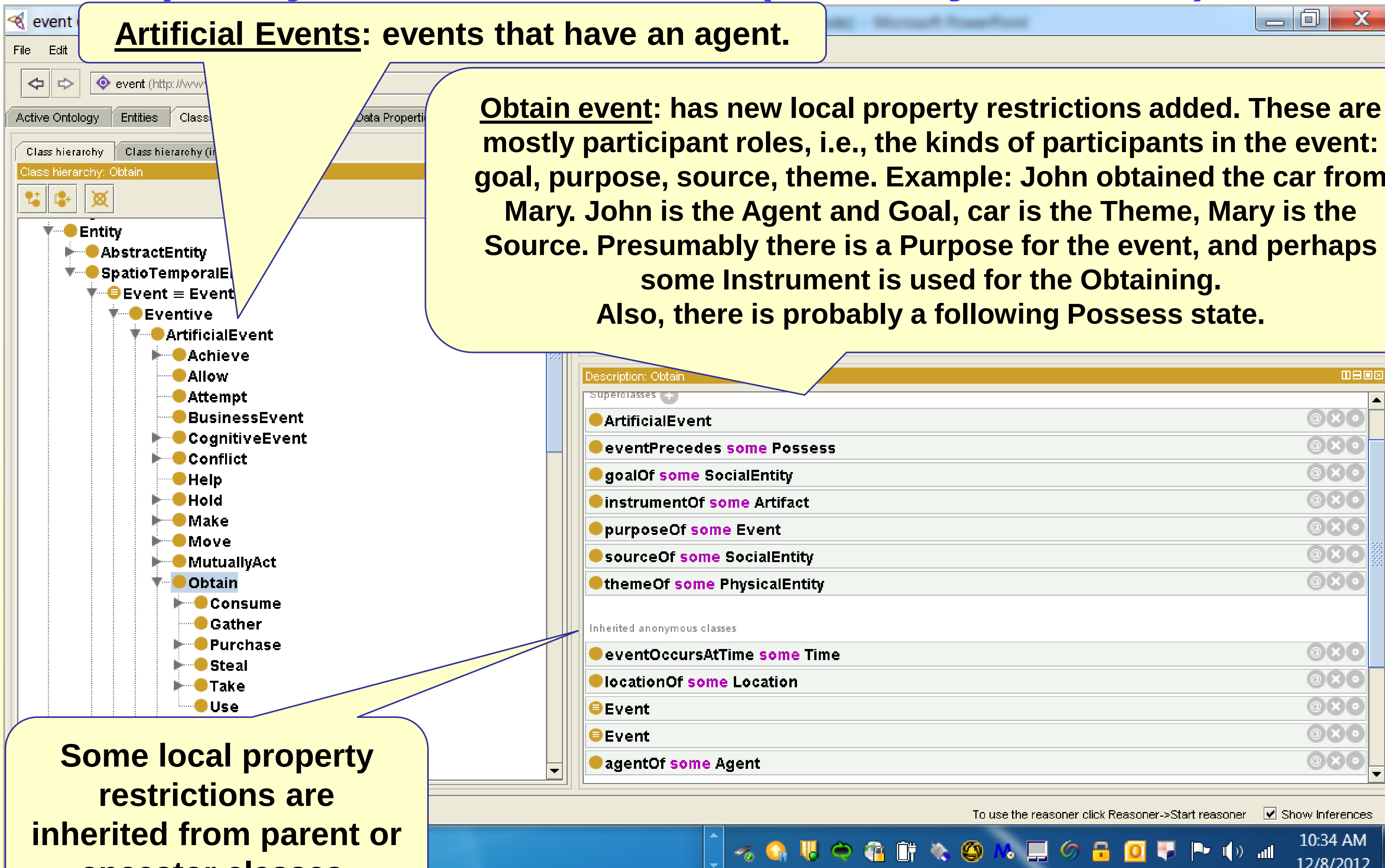
Both Events and Things.

**Events:**
Eventives (actions) & Statives (states).

**Physical Entities:**
People, Places, Things

**Infrastructure:** classes from DHS infrastructure taxonomy. Not used yet.

# Event Ontology: Artificial Events, Local Property Restrictions (mostly Roles)

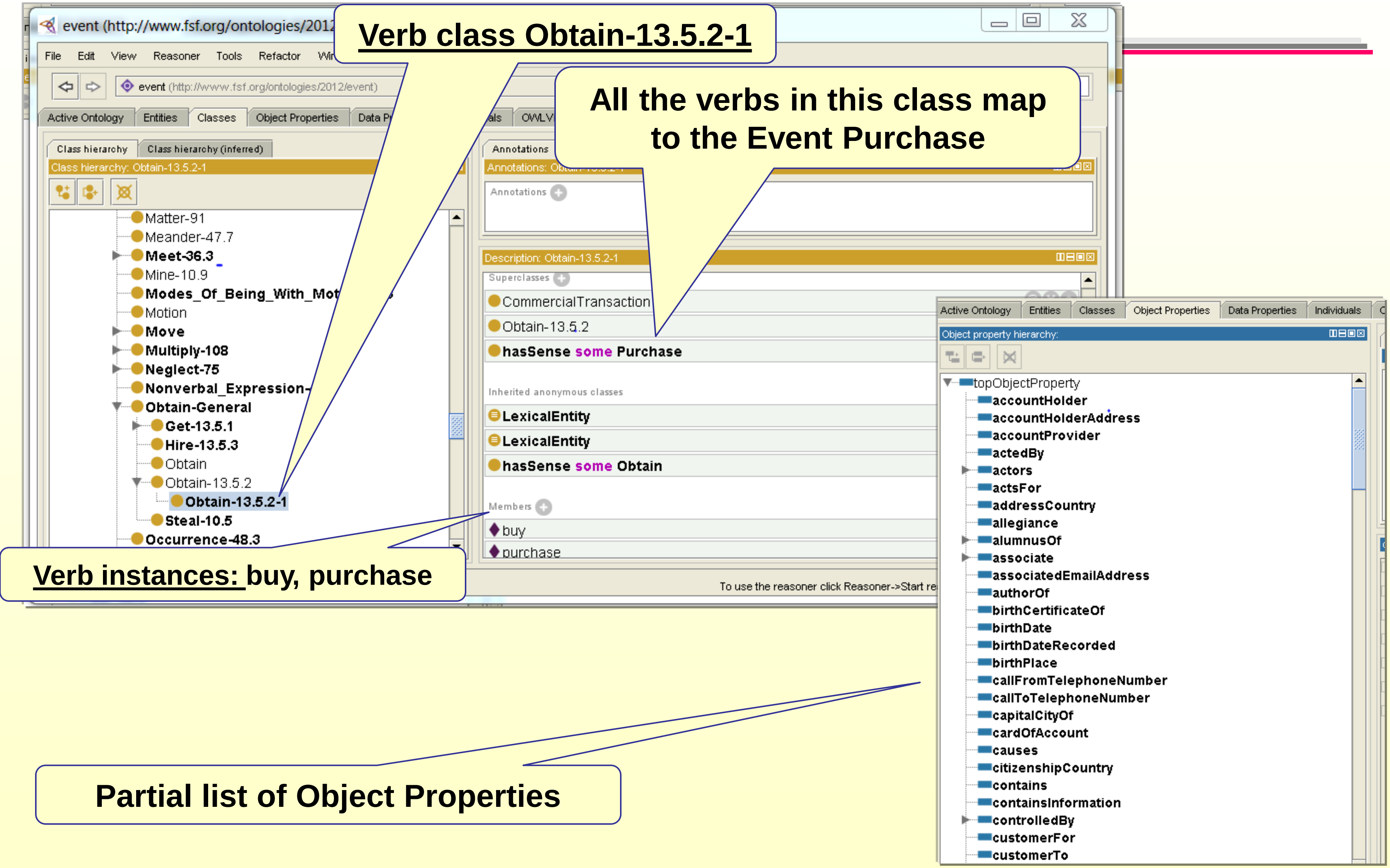



**<u>Artificial Events</u>: events that have an agent.**

**<u>Obtain event</u>: has new local property restrictions added. These are mostly participant roles, i.e., the kinds of participants in the event: goal, purpose, source, theme. Example: John obtained the car from Mary. John is the Agent and Goal, car is the Theme, Mary is the Source. Presumably there is a Purpose for the event, and perhaps some Instrument is used for the Obtaining.**
**Also, there is probably a following Possess state.**

**Some local property restrictions are inherited from parent or ancestor classes.**

# Event Ontology: Verbs map to Events



# Thematic Roles (Theta-roles) and Verbs

- A component of linguistic theory
- From Fillmore (1968), i.e., case grammar:
  - Thematic roles describe the conceptual participants in a situation in a generic way, independent from their grammatical realization
- A natural language verb has as arguments the noun phrases and prepositional phrases in a sentence
- Thematic Roles: agent, affected entity, theme, instrument, source, goal, beneficiary, experiencer, recipient, etc.
  - [John]ag gave [Sue]aff_ent [the book]theme
  - [Sue]aff_ent received [the book]theme [from John]ag
- Enables a systematic way of mapping from syntactic complements (and parts of speech) to semantic argument positions
- Verb as predicate: gave(X, Y, Z) ⇒ gave(agt(X), aff_ent(Y), theme(Z)) ⇒ gave(agt(john), aff_ent(sue), theme(book))

# Thematic Roles, Verbs, Events

- Adds selectional restrictions, constraints: e.g., Agent is animate, Source, Goal are locations, etc. These can be linked to concepts in ontologies, to provide the real world semantics, inference, etc.
- Some issues:
  - Thematic roles and assignments are relatively local and often specific to a context, e.g., commercial transaction, etc.
  - Verbs can have mandatory and optional arguments: John hit the ball. John hit the ball to Sue. John hit the ball to Sue with a bat last night in the park.
- Resources: PropBank, VerbNet, SemLink, FrameNet, Beth Levin's Verbs, OntoNotes
- Verbs (and perhaps adjectives, NPs) as Events: Davidson (1968) added event variable *e* to verbs
- shot $\Rightarrow$ $\lambda x \lambda y \lambda e.\mathit{shot}(e,x,y)$, where *shot* is a particular verb function type
  - The man shot the ambassador: Shot(e, man, ambassador)
  - The man shot the ambassador at 2 pm outside Macy's:
  - $\exists$e (shot(e, man, ambassador) $\wedge$ time(e, 2pm) $\wedge$ place(e, macy's))

# Thematic Roles, Events, Semantics, Ontology, Inference

- If we can identify verbs and their argument structure
- And provide thematic roles for the arguments
- And identify the actual roles in a sentence/clause during parsing
- Then we can link the event-indexed verbs and their arguments more easily to the ontology (which represents their real-world semantics),
- And then potentially link the events with other events and temporal information
- E1 precedes E2, E2 occurs in E3, etc.
- Person(john) $\wedge$ male(john) $\wedge$ name(john, N) $\wedge$ address(john, A) $\wedge$ wife(john, W) $\wedge$ employs(O, john) $\wedge$ ssn(john, S) … purchase(e2, john, tnt, time2, location3) …
- purchase(e2, j, t, t2, l3) $\wedge$ friend(j, harry) $\wedge$ purchase(e14, harry, timer, time44, location78) …
- Better linking the dots, providing automated inference, linking to Bayesian causal models for predicting, etc.

# Further Steps

- Nominalizations can indicate events too
  - The destruction of the temple occurred at 11 am yesterday.
  - The temple's destruction yesterday …
- Propositional reports
  - John said yesterday that Harry purchased the cell phone
  - Two events: the reporting and the reported events
  - John said today that he believed that Harry purchased the cell phone yesterday
  - Three events: the reporting, the intensional belief, the believed event
- Other natural language expressions: adjectives, etc.
  - The purchased cell phone …
  - The money from Harry for the cell phone …

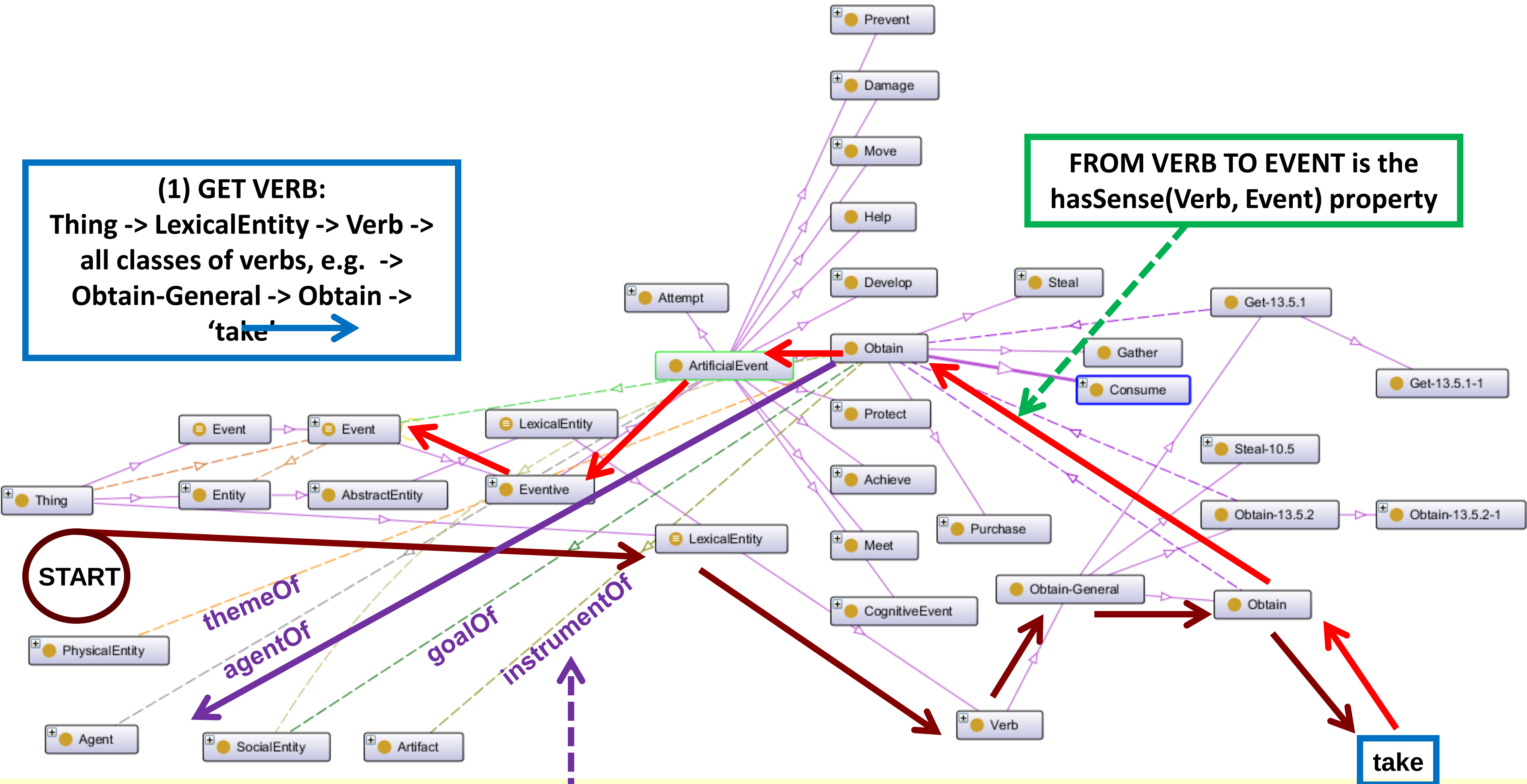
# Thematic Roles as Ontological Properties 1

- Rather than assign thematic roles (only) to the semantics of verbs, assign them as properties to the events of the ontology
- Why?
  - Avoids duplication between semantic roles and ontological participants, largely redundant since one needs these on both sides of the semantics/ontology divide
  - Representing thematic participant relations as ontological properties provides generic event-based properties that can subsequently be elaborated, as the ontology of events gets enriched
  - Since verbs, and also nouns and adjectives can indicate (denote) events, this links multiple lexical categories to a consistent ontology-based event representation
  - Nominalization: destruction, betrayal, incarceration: many productive morphology rules
  - Adjectives: nominal and verbal adjectives such as: abandoned, kidnapped, etc.

# Thematic Roles as Ontological Properties 2

- Distinction between semantics and ontology:
  - Semantics is about how one refers to the things and categories of the world [linguistic knowledge]
  - Ontology is about those real world referents, i.e., the things and categories of the world (denotations, reference) [world knowledge]
  - In between, for Fregeans are senses, which kind of correspond to concepts or ideas, i.e., placeholders for the things and categories of the real world referents
  - Of course, extension and intension complicate matters (e.g., propositional attitudes and other intensional contexts)
- Main issue is that you need participant properties that correspond to thematic roles for ontology, because participants in events are ontological
- What follows is an example that maps Verbs to Events (via a hasSense relation), and has the thematic roles as generic properties associated with the Events, rather than the Verbs

# Perspective is from Verbs ontology imported into Event ontology




(3) FROM EVENT TO ARGUMENTS: Event -> Class of argument. EVENTS have arguments (thematic roles); those arguments are instances that come from specific classes such as Artifact (human designed or built) for instrumentOf argument.

(2) FROM VERB, GET EVENT:
'take' -> Verb Obtain -> Event Obtain -> Thematic Role Properties

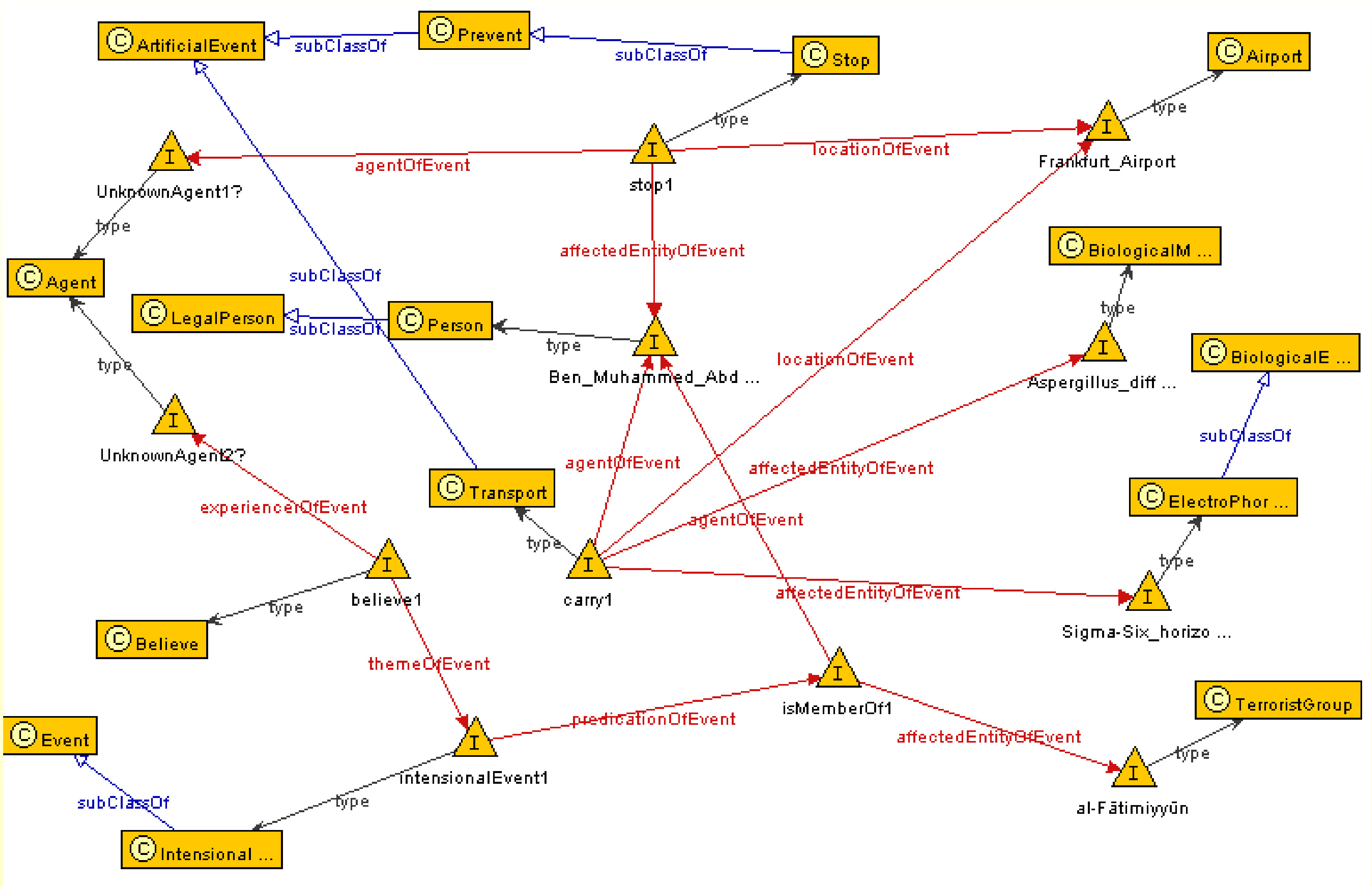
# Ways to Proceed in the Linking of Semantics and Ontology

- Push the selectional restrictions and semantic types associated with semantic thematic roles into the ontology
- Animate is ontological, mass/count is a semantic reflection of ontology
- Eventually, elaborate the ontology events beyond these generic thematic participants, as you elaborate the domains of the world
- Example: victim, perpetrator, some complex financial instrument F which is a derivative of some X instrument, financier, de facto political leader of a religious sect in geopolitical/geographical region Y, manufacturer, distributor, consumer, broker, etc.

# Natural Language Report

- Ben Muhammed Abdelaal was stopped in Frankfurt Airport carrying both Aspergillus differentiation agar and a Sigma-Six horizontal electrophoresis system.
- He is believed to be a member of al-Fāṭimiyyūn.

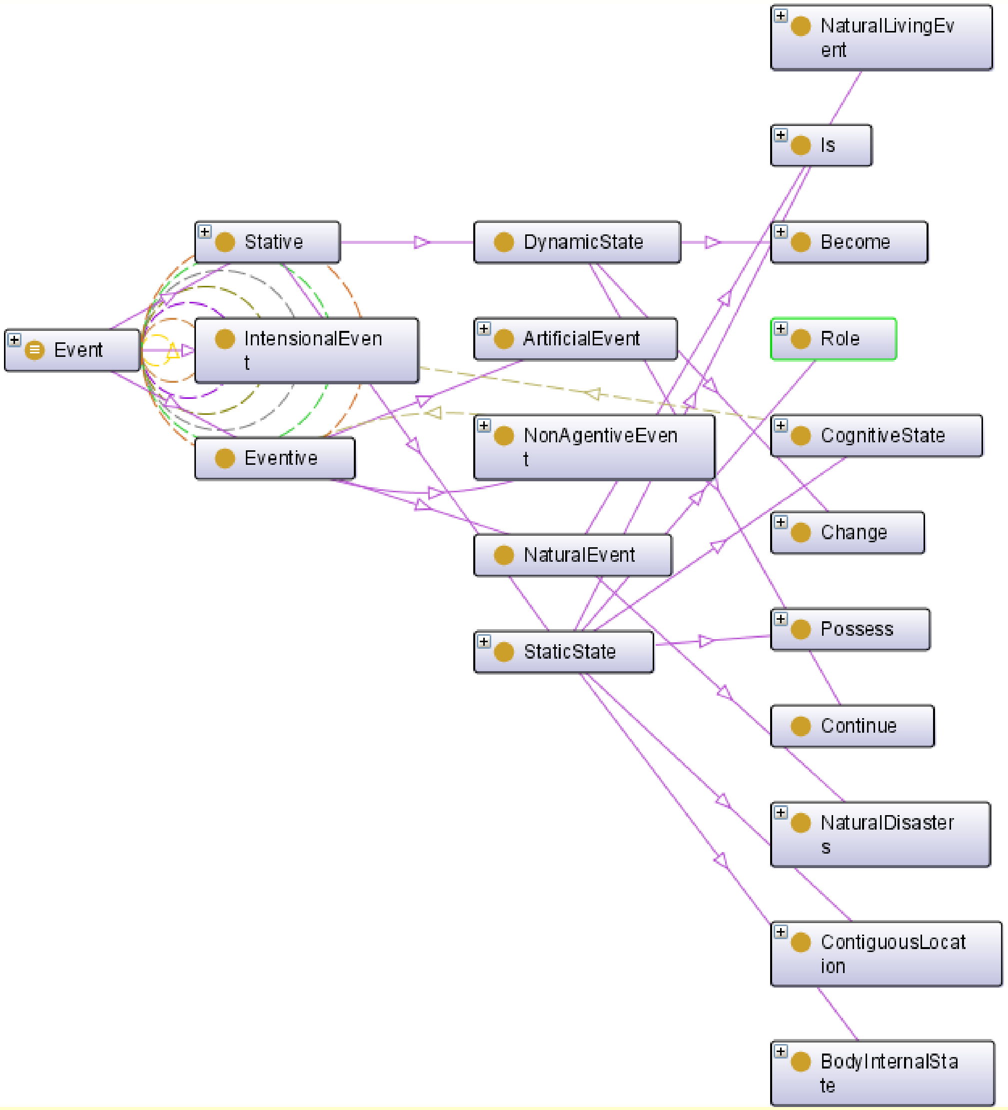
# Event Structure Example: From the Natural Language Report, a Complicated Ontology Instance (in RDF-Gravity)



# What's Involved: Linking Syntax to Semantics to Ontology

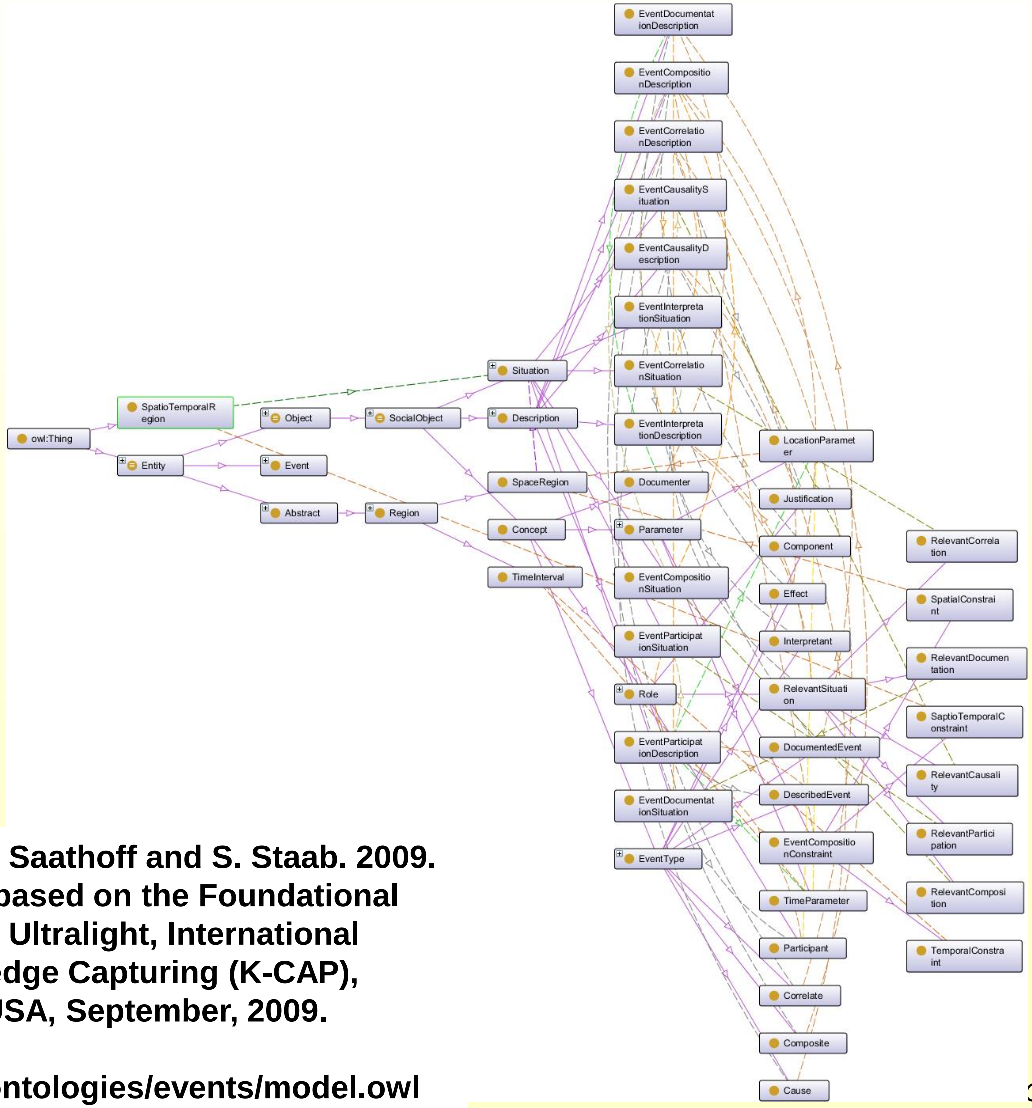
- Syntax $\rightarrow$ Semantics $\rightarrow$ Ontology
- It's long been an issue: where is the boundary between linguistic knowledge and world knowledge
- Today, we have rephrased that (in the semantic realm) as the boundary between semantics and ontology
- Now we know more and can proffer suggestions as to which side of the divide to represent notions
- The result is a smooth transition from syntax to semantics to ontology, where text can be parsed, semantically interpreted, mapped to world knowledge, automatically reasoned over at the latter level, eventually enhanced with rules

# Event Ontology



# Other Event Ontologies: F-Event Model – Based on DOLCE+DnS Ultralite




**Scherp, A., T. Franz, C. Saathoff and S. Staab. 2009. F---A Model of Events based on the Foundational Ontology DOLCE+DnS Ultralight, International Conference on Knowledge Capturing (K-CAP), Redondo Beach, CA, USA, September, 2009. http://west.uni-koblenz.de/Research/ontologies/events/model.owl**

# Roles

- Many notions of Role historically
  - Roles in linguistics: thematic roles; event participant roles
  - Roles in computer science, AI: description logic roles (relations), UML roles, intelligent agent technology roles (based on actions, plans, speech act theory)
  - Roles in philosophy, etc.: behavior of persons in contexts, rights, duties, tasks, statuses, etc.
- Many recognized issues and problems with Roles
- Many recent applied ontological analyses of social and other Roles
- We'll step through these in an abbreviated fashion, lay a basis for an extension to artifact

# Ontological Issues and Problems with Roles

- Thematic Roles
- Relational Roles
- Processual Roles
- Roles of Roles
- Figures
- Qua-individuals

# Recent Ontological Analyses of Roles

- Masolo et al (2004): Social Roles, Descriptions
- Masolo et al (2005): Relational Roles and Qua-individuals
- Loebe (2007): Abstract vs. Social Roles
- Arp & Smith (2008): Function, Role, and Disposition in BFO
- Vieu et al (2008): Artifacts and Roles

# Masolo et al (2004) 1 - Background

- Ontological background based on Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE)
- 2 senses of "sociality":
  - √ Entity is social if it is an immaterial product that depends on a community of agents (with conventions): "conventional"
  - – Stronger: entity is social if it is conventional and this involves a network of relations among social agents: collective intentionality, actions and deontic constraints, etc.
- Their intent: establish a framework for social entities and provide an ontological analysis of social roles
  - – Pull all into domain of discourse: social entities, relations, etc.
  - – Establish a "context" for all of these: Descriptions

# Masolo et al (2004) 2 - Characteristics of Roles

- Four characteristics of social roles:
  1. Roles are properties: different entities can play the same role
  2. Roles are anti-rigid and dynamic
     a. An entity can play different roles at same time
     b. An entity can change role
     c. An entity can play the same role multiple times at same time
     d. Different entities can play a role, at the same time or at different times
     e. Order of acquiring and relinquishing a role is subject to restrictions
     f. Roles are temporal

# Masolo et al (2004) 3 – Characteristics of Roles

3. Roles have a relational nature
   a. Roles depend on external properties via patterns of relationships, i.e., a *foundational dependence* (generic existential) dependence on external properties
   b. Generalize this to *definitional dependence of properties*: a given property definitionally depends on another property
4. Roles are linked to contexts
   a. Multiple definitions of context: *Metaphysical context* (states of affairs holding in the world against which sentences are interpreted), *Cognitive context* (concepts as backgrounds for interpretations of states of affairs), *Linguistic context* (semantic content and structure of the discourse against which a sentence is semantically interpreted)
   b. Their context: closest to *cognitive context*, using *definitional dependence* for defining roles

# Masolo et al (2004) 4 – Examples

1) In the second half-year of 2003,Berlusconi was simultaneously the Italian Prime Minister, the President of the European Union, the president of the Forza Italia party, the owner of the Mediaset company, an Italian citizen and a defendant at a legal trial.
2) In 1960 Berlusconi was a piano bar singer, now he is the Italian Prime Minister.
3) In the second half-year of 2003, Berlusconi had two presidencies / was president twice.
4) Today, the Italian National Research Council has 4319 researchers.
5) In 2000, the Italian Prime Minister was D'Alema, now it is Berlusconi.
6) Only Italian citizens can be Italian Prime Minister.
7) All professors have been students.
8) All Italian Prime Ministers are Prime Ministers.
9) All Italian Prime Ministers are Italian citizens.
10) Berlusconi is Prime Minister.
11) Only employees can be project leaders.
12) In France, the head of the state is the president, and currently the president is Jacques.
13) Italian Prime Minister is an Italian public office.
14) Earl is a title of nobility.

# Masolo et al (2004) 5 - Approach

- Reify social concepts, to predicate on them
- Create Concept class, with Description as a Subclass:
  - DS(x): “x is a description”
  - DF(x, y): “the concept x is defined by the description y”
- Create new temporalized classification relation to link concepts with the entities they classify:
  - CF(x, y, t): “x is classified by the concept y (satisfies all the constraints stated in the description y) at time t”, where t is the time interval of the classified entity, i.e., during which the entity satisfies the constraints of the concept definition
  - Entities can be classified by different concepts at different times
  - Concepts are static, i.e., don’t change during their (limited) life
- Example: Italian Constitution
  - A description defining the concepts of Italian President, Italian government, Italian Prime Minister, etc.

# Masolo et al (2004) 6 – Characterizing Descriptions

- Descriptions
  - Are created by intentional agents of a community on their first encoding
  - Have a unique semantic content
  - Are "encoded" on some media, including cognitive encodings
  - Exist even if no one adopts them, if an encoding exists
  - Cease to exist when their last physical encoding ceases to exist
  - Are *definitionally dependent* on their concepts
  - Can be composed of simpler descriptions, which reuse concepts, etc.

# Masolo et al (2004) 7 – Concepts, Descriptions, Entities, Roles

- All these notions are based on DOLCE, and so extend DOLCE
  - DOLCE is not strictly metaphysically referentialist, but reflects a commonsense bias
  - DOLCE categories constitute a basic conceptualization of the world that is static and context-independent
- DOLCE predicates used: endurant, perdurant, non-agentive social object (e.g., a law, asset, currency, etc.), temporal location, part of, part of at time t, present at time t
- Relations among Descriptions and Concepts:
  - Used-by: a Concept is used-by a Description
    - Descriptions must use at least one Concept, defined in itself or in another Description
  - Defined-by: a Concept is defined-by a single Description
- Descriptions may be the union of simpler Descriptions
- Descriptions defining the same Concepts are identical (extensional)
- Concepts can reuse the same concepts and still be different: concepts cannot change their definition
- Descriptions and Concepts are Endurants, and so, classifiable

# Masolo et al (2004) 8 – Formalization

- Descriptions and Concepts
  - (A1) $DS(x) \rightarrow NASO(x)$
  - (A2) $CN(x) \rightarrow NASO(x)$
  - (A3) $DS(x) \rightarrow \neg CN(x)$
- Concept Use and Definition
  - (A4) $US(x, y) \rightarrow (CN(x) \wedge DS(y))$
  - (A5) $DF(x, y) \rightarrow US(x, y)$
  - (A6) $CN(x) \rightarrow \exists y(DF(x, y))$
  - (A7) $DS(x) \rightarrow \exists y(US(y, x))$
  - (A8) $(DF(x, y) \wedge DF(x, z)) \rightarrow y = z$
  - (A9) $US(x, y) \rightarrow (PRE(y, t) \rightarrow PRE(x, t))$
  - (A10) $DF(x, y) \rightarrow (PRE(x, t) \rightarrow PRE(y, t))$
  - (T1) $DF(x, y) \rightarrow (CN(x) \wedge DS(y))$ *(A4),(A5)*
  - (T2) $CN(x) \rightarrow \exists! y(DF(x, y))$ *(A6),(A8)*
  - (T3) $DF(x, y) \rightarrow (PRE(x, t) \leftrightarrow PRE(y, t))$ *(A5),(A9),(A10)*

**AR: anti-rigid**
**CN: social concept**
**CF: classified-by concept at time**
**DF: defined-by**
**DS: description**
**ED: endurant**
**FD: founded (definition involves another external concept**
**NASO: non-agentive social object**
**P: part-of**
**PD: perdurant**
**PRE: present at time**
**SB: sub-concept of at time**
**TL: temporal location (i.e., point or interval)**
**US: used-by**

# Masolo et al (2004) 9 – Formalization

- Classification

  **(A11)** $\mathbf{CF}(x, y, t) \rightarrow (\mathbf{ED}(x) \wedge \mathbf{CN}(y) \wedge \mathbf{TL}(t))$

  **(A12)** $\mathbf{CF}(x, y, t) \rightarrow \mathbf{PRE}(x, t)$

  **(A13)** $(\mathbf{CF}(x, y, t) \wedge \mathbf{DS}(x)) \rightarrow \neg \mathbf{US}(y, x)$

  **(A14)** $\mathbf{CF}(x, y, t) \rightarrow \neg\, \mathbf{CF}(y, x, t)$

  **(A15)** $(\mathbf{CF}(x, y, t) \wedge \mathbf{CF}(y, z, t)) \rightarrow \neg \mathbf{CF}(x, z, t)$

- Anti-Rigidity

  **(D1)** $\mathbf{AR}(x) \equiv_{df} \forall y,t(\mathbf{CF}(y, x, t) \rightarrow \exists t'(\mathbf{PRE}(y, t') \wedge \neg \mathbf{CF}(y, x, t')))$

- Founded

  **(D2)** $\mathbf{FD}(x)\ ) \equiv_{df} \exists y,d(\mathbf{DF}(x, d) \wedge \mathbf{US}(y, d)$ Ÿ

  $\forall z,t(\mathbf{CF}(z, x, t) \rightarrow$

  $\exists z'(\mathbf{CF}(z', y, t) \wedge \neg \mathbf{P}(z, z', t) \wedge \neg \mathbf{P}(z', z, t)))$

- Role

  **(D3)** $\mathbf{RL}(x)\ ) \equiv_{df} \mathbf{AR}(x) \wedge \mathbf{FD}(x)$

# Masolo et al (2004) 10 – Examples Formalized [see slide 4 – Examples]

1) CF(b,IPM,6-12/2003)∧CF(b,EUPresident,6-12/2003) ∧ UNI(IPM) ∧ UNI(EUPresident)…
2) CF(b, PianoBarSinger, 1960) ∧ ÿCF(b, IPM, 1960) ∧ CF(b, IPM, td) ∧ UNI(IPM) ∧ ¬CF(b, PianoBarSinger, td)
3) ∃x,y (SP(x, President) ∧ SP(y, President) ∧ x≠y ∧ CF(b, x, 6-12/2003) ∧ CF(b, y, 6-12/2003))
4) ∃ $x_1$ $x_2$ … $x_{4319}$(CF($x_1$, CNR_Researcher, td) ∧ CF($x_2$, CNR_Researcher, td) ∧ ...)
5) CF(b, IPM, td) ∧ CF(D'Alema, IPM, 2000) ∧ UNI(IPM)
6) RQ(IPM, ItalianCitizen)
7) CF(x, Professor, t) → ∃t'(t' < t ∧ CF(x, Student, t'))
8) SP(IPM, PrimeMinister)
9) RQ(IPM, ItalianCitizen
10) CF(b, PrimeMinister, td)
11) RQ(ProjectLeader, Employee)
12) RQ(HeadFState, FPresident) ∧ UNI(HeadFState) ∧ UNI(FPresident) ∧ CF(Jacques, FPresident, td)
13) PRE(IPM, t) → CF(IPM, ItalianPublicOffice, t)
14) PRE(Earl, t) → CF(Earl, TitleOfNobility, t)

# Masolo et al (2004) 11 – Social Individuals (Figures, etc.), Qua-Individuals & the Counting Problem

**Social Individuals (e.g., Figures):**

15) From the birth of the Italian Republic, the (Italian) President/Presidency has signed three thousand laws.

16) The king never dies

- Figures as in (15-16) perhaps are a kind of mereological fusion of the player-stages of a given role, or qua-individuals?

**Qua-Individuals:**

17) In 2002, Alitalia carried a million passengers.

18) In 2002, a thousand gondolas passed under the Ponte dei Sospiri.

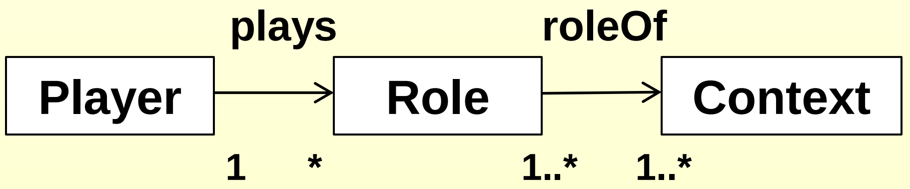
- In (17) counting passengers cannot mean counting persons who have played the Alitalia-passenger role in 2002, but persons-playing-the-Alitalia-passenger-role
- Similarly, in (18) we are counting gondola-stages, or (in a 4-D view) gondolas-passing-under-the-bridge-events
- Qua-individuals: a new kind of agentive entity created each time an entity is classified by a saturated social role, with different identity criteria than the role player entity of a role

# But: Krifka(1990)

- Example: Four thousand ships passed through the lock last year.
- Two readings for the above:
  - **Object-related:** There are four thousand ships which passed through the lock last year
  - **Event-related:** There were four thousand events of passing through the lock by a ship last year
- Krifka: measure functions on lattices
  - A measure function is a function from concrete entities to abstract entities such that certain structures of the concrete entities, the empirical relations, are preserved in certain structures of the abstract entities, normally arithmetical relations.
- **We will not go into this now!**

# Loebe (2007) 1 -- Background

- Ontological background based on General Formal Ontology (GFO): Herre etal (2006), Heller & Herre (2004)
- Both role universals and role particulars (individuals, instances)
- Simple model:
  - A player play a role in a context



# Loebe (2007) 2 -- Formalization

- One perhaps initially wants to state:

  $\forall x \mathbf{Role}(x) \leftrightarrow \exists yz(\mathbf{plays}(y, x) \wedge \mathbf{roleOf}(x, z))$

- But this does not distinguish between role universals and role individuals
- So, is actually, on the individual $\mathcal{I}$ level, rather than $\mathcal{U}$ level:

  $\forall x \mathbf{Role}^{\mathcal{I}}(x) \leftrightarrow \exists yz(\mathbf{plays}^{\mathcal{I}}(y, x) \wedge \mathbf{roleOf}^{\mathcal{I}}(x, z))$

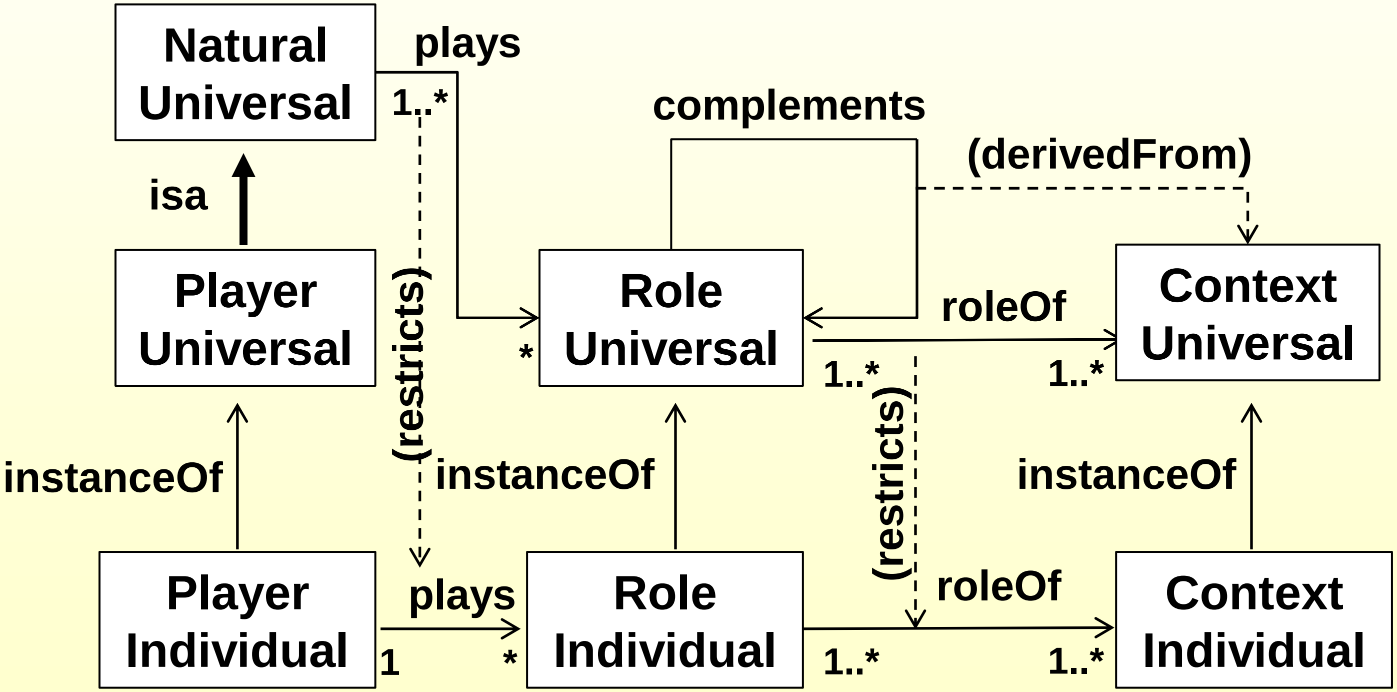
- Player, Role, and Context all have universals and individuals
- Also, distinguish between Role Universals such as Student and Natural (Kind) Universals such as Person
  - **If John plays the role of student, he is a player (of the student role)**

$\forall xy \mathbf{Role}^{\mathcal{U}}(x) \wedge \mathbf{Nat}^{\mathcal{U}}(y) \wedge \neg \mathbf{plays}^{\mathcal{U}}(y, x) \rightarrow \neg \exists uv\, u :: x \wedge v :: y \wedge \mathbf{plays}^{\mathcal{I}}(v, u)$

$\forall xy \mathbf{Role}^{\mathcal{U}}(x) \wedge \mathbf{Ctxt}^{\mathcal{U}}(y) \wedge \mathbf{roleOf}^{\mathcal{U}}(x, y) \rightarrow \forall z\, z :: y \rightarrow \exists u(u :: x \wedge \mathbf{roleOf}^{\mathcal{I}}(u, z))$

# Loebe (2007) 3 -- Formalization

- Extended Role Model



# Loebe (2007) 4 – Role Types

- Relationship between roles and players appears loose
  - Objects of unrelated types can play same role
  - Roles are part-like with respect to their contexts
  - So classify roles by their context categories
- Context of roles: relations, processes, (social) objects
  - Relational role: corresponds to the way in which an argument participates in some relation

  Example: “two is a factor of four” – factor is a relational role universal
  - Processual role: corresponds to the manner in which a single participant behaves in some process

  Example: “John’s moving a pen” – mover is a processual role universal
  - Social role: corresponds to the involvement of a social object within some society

  Example: “student” – student is a social role universal, depends on a university society

# Arp & Smith (2008): Overview

- Background: Basic Formal Ontology
- Continuants: entities that continue or persist through time
- Dependent continuants: entities dependent for their existence on some other (independent) entity's existence
- Realizable entities: entities that can be realized (manifested, actualized, executed) in occurrents of corresponding sorts
  - "In the course of their existence they contain periods of actualization, when they are manifested through processes in which their bearers participate"

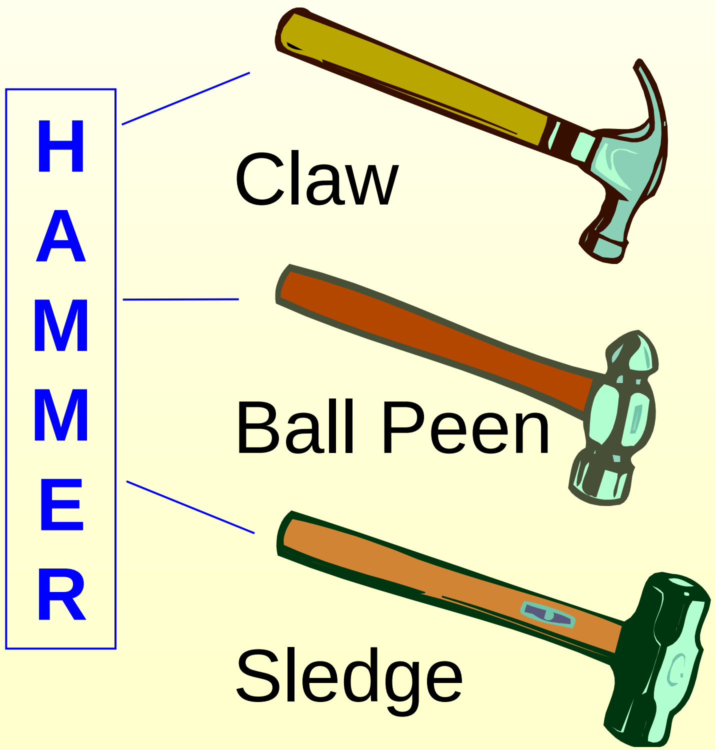
**BFO:entity**
- **continuant**
  - **independent continuant**
    - **object**
    - **object boundary**
    - **object aggregate**
    - **fiat object part**
    - **site**
  - **dependent continuant**
    - **generically dependent continuant**
    - **specifically dependent continuant**
      - **quality**
      - **realizable entity**
        - **function**
        - **role**
        - **disposition**
  - **spatial region**
    - **zero-dimensional region**
    - **one-dimensional region**
    - **two-dimensional region**
    - **three-dimensional region**

# Arp & Smith (2008, p. 3): Role

- Role: “a realizable entity whose manifestation brings about some result or end that is not typical of its bearer in virtue of the latter’s physical structure”
- “The role is *played* by an instance of the corresponding kind of continuant entity because this entity is in some special natural, social, or institutional set of circumstances”
- Examples:
  - The role of a chemical: desiccant, catalyst, etc.
  - The role of bacteria in causing infection
  - The social role of a person as employee
- Roles are typically optional, especially social roles
- Determining function vs. role:
  - “Is the realizable entity such that its typical manifestations are based upon its physical structure? If so, then it is a function.
  - Or, is the realizable entity such that its typical manifestation is a reflection of surrounding circumstances, especially those involving social ascription, which are optional? If so, then it is a role”
- Note that functions, in particular, and roles too are important for artifacts

# Artifacts

- Artifacts are objects which are human-designed or manufactured
- Artifacts thus are always focused on *function,* what the artifact is used for, which in turn depends on *intention,* i.e., intentionality, agentivity
- A seashell can be an ashtray, a pebble can be a paperweight
- **Function provides identity for an artifact**
  - **Essential properties**
- What are the *distinguishing properties* between these three hammers?
  - Form (physical property)
  - Function (functional property)
- "Purpose proposes property" (form follows function) – for human artifacts, at least



# Vieu et al (2008) 1 - Artifacts and Roles

- Artifacts seem to be related to roles, in that there is an element of dependency on other entities associated with them, i.e., the *multiplication of entities*
- This paper provides two analyses of artifacts:
  - Entity Stacking
  - Property Reification
- Begins from a particular ontological stance, that of DOLCE and is moderate mutiplicativist viewpoint
  - I.e., not reductionist, where parsimony of entities is valued over all
  - And not extreme multiplicativist, where every non-synonymous linguistic description gets a distinct entity

# Vieu et al (2008) 2 – Entity Stacking

- Entity stacking is grounded on identity (or non-identity) between entities
- Leibnitz's law, i.e., the Identity of Indiscernibles:
  - No two objects have exactly the same properties
  - If two objects have the same properties, they are identical, i.e., the same object
- Slogan of mereological extensionality: "no two things at the same place at the same time"
  - Parthood == co-located spatially
  - If something has the same proper parts, spatially co-located, that provides identity
- Historically, led to puzzles such as the statue and the clay, and Theseus's ship

# Vieu et al (2008) 3 – Entity Stacking

- Statue and clay: ***constitution*** relation
  - The statue is constituted by clay
  - Two different entities, with different identity criteria, in the same spatial region
- So, *entity stacking*: having the same proper parts is not equivalent to spatial co-location
- Recall *roles* and the notion of *qua-individuals* in the *counting problem* scenario:
  - In 2002, Alitalia carried a million passengers.
  - John qua Alitalia passenger of flight 123 on September 3, 2002 is spatially co-located with John the person
  - ***Inherence*** relation

# Vieu et al (2008) 4 – Property Reification

- Introduce properties as individuals in the domain of quantification, i.e., reify properties
- Ordinarily in FOL, predicates have sets, i.e., is *extensional*
- If want to quantify over properties, must introduce new kind of individual, that of Universal or Concept, and so a different of model than the extensionalist model
  - Similar to reifing events, as e.g., in the Davisonian semantics we saw in the Event ontology
- Intentionality is important for Artifacts
  - The seashell is intended by an agent to be used as an ashtray
- But intentionality is a property of agents
- Artifactuality is not a property that physical objects have or acquire
- Hence, prefer *entity stacking*

# Vieu et al (2008) 5 – Intentions and Capacities

- *Intention*: an agent attributes some capacities to an entity to constitute an artifact
- The artifact may not have those capacities, i.e., it's a flawed or damaged artifact, but still exists as an artifact
- *Capacity:* In DOLCE, a capacity is a *quality* possessed by the categories: Amount of Matter, Non-agentive Physical Object, and Physical Artifact
  - Qualities are mapped to values in a Quality Space
- Differentiate capacity from *attributed capacity*, i.e., capacities are physical properties, but attributed capacities are intentional properties attributed to artifacts by an agent
  - Attributed at *creation* time
  - Intentional selection:
  - IntentionalSel(e, p, x, y, q) is "e is the event of the agent p intentionally slecting the amount of matter or non-agentive physical object y and attributing to it the attributed capacity q, obtaining the artifact x"

# Vieu et al (2008) 6 – Three Layers in the Entity Stack

- Three layers of co-located objects, each with distinct identity criteria:

| | | |
|---|---|---|
| **Intentional Artifact** | Ashtray | Paperweight |
| **Shaped and structured physical object** | Shaped seashell (invertebrate exoskeleton) | Pebble |
| **Mereologically determined amount of matter** | Calcium carbonate material | Rock material |

- Identity criteria of artifacts: based on their attributed capacity, and their constituting entities
- Malfunctioning or disabled attributed capacity does not make artifact disappear
- Artifacts can be repaired or undergo parts substitution without losing identity
  – Disassemble the ship of Theseus: could argue the original ship comes back, but it is a different artifact (different creator, other attributed capacities)

# Vieu et al (2008) 7 – More Complications

- Designs: artifact types
- Prototypes: individual artifacts
- Artifacts can’t be the qua-entities generated by a role of physical objects
  - *Inherence* is different from *constitution*
  - Otherwise couldn’t account for repairing artifacts
- Not explored here: functions of artifacts vs. biological functions: see Mizoguchi (2008)
  - Teleological (purpose), i.e., intention, is not available for biological functions
  - Biological function: “the disposition of a certain entity reliably to act in such a way as to achieve a goal” [Johannson (2005)]
  - Still a bit of a mystery

# Summary and Conclusions

- We have looked at events, roles (especially social roles), and artifacts from a number of perspectives, based on various formal analyses in the ontological engineering literature
- Events, we have seen, are time-based, but then everything is time-based in a 3-D perspective, or spacetime-based in a 4-D perspective
- Upper/foundational ontologies distinguish endurants (continuants) and perdurants (occurrents), which can be considered, respectively, object-like vs. event-like
- Most events, like most objects, seem to be independent, not dependent in nature, but roles and artifacts seem to be dependent on other entities (both event-like and object-like)
- Roles seem to depend on a context for the role, and often that context is either relation-based or event-based or possibly situation-based
- Artifacts are mostly based on functions or functional properties, rather than physical properties, and are nearly always intentional in nature, i.e., an agent intends or prescribes properties to an object to make it an artifact

# Thank You! Questions? lobrst@mitre.org

Future:

Information Artifacts and Cyber Realm

# Backup

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