Ontology Summit 2013:
Ontology Evaluation Across the Ontology Lifecycle
Virtual Panel Session 09, Track C – March 14, 2013

Developing Quality Ontologies Used for Reasoning

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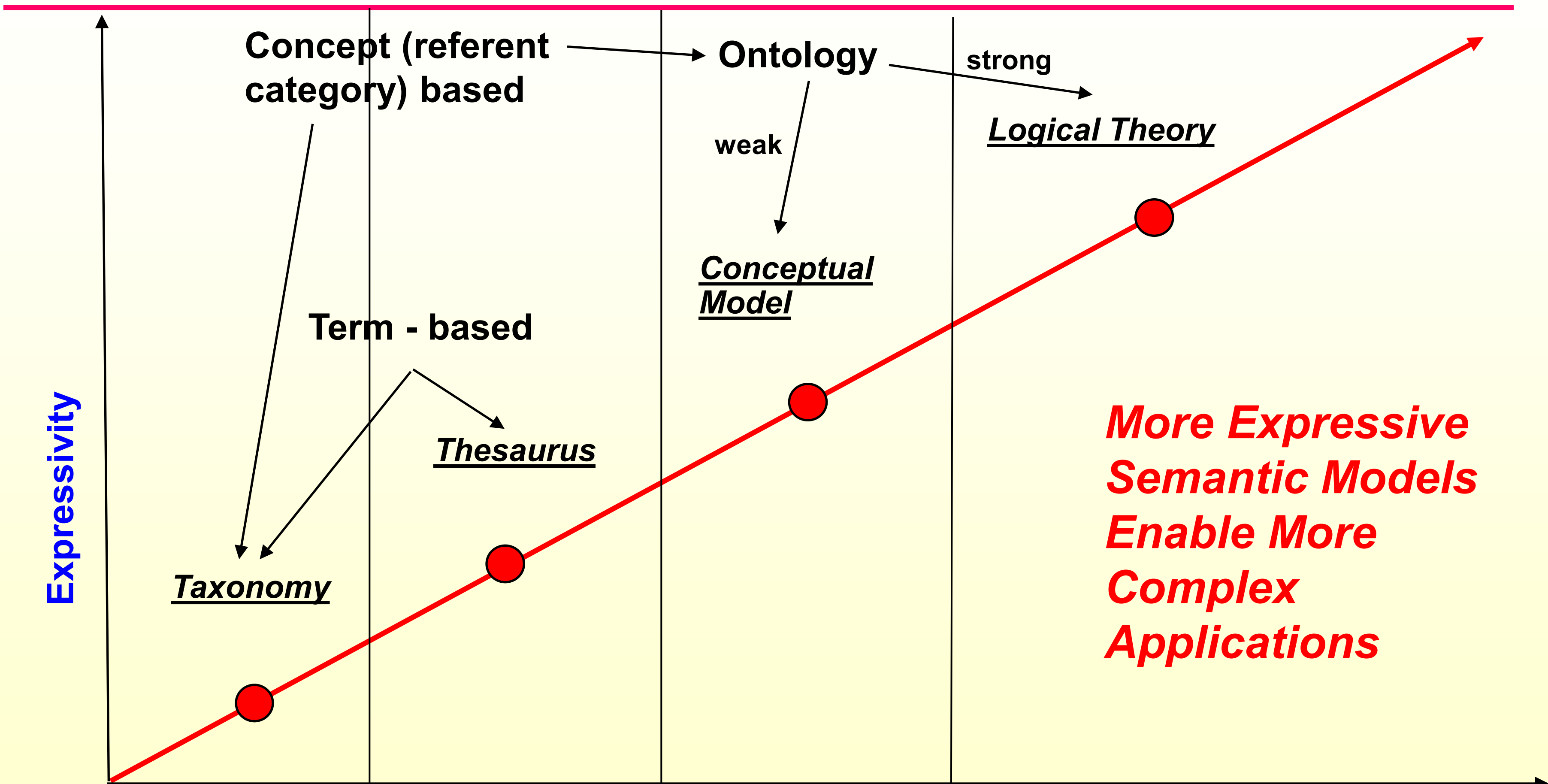
General Methodological Issues

- Assume every new ontology will be developed for automated reasoning unless explicitly ruled-out (and knowing the consequences of ruling it out)
  - This means: know the rough complexity of the semantic model you need
  - E.g., if your reasoning requirements are very large-grained (e.g., determining which topic bucket should this document be placed in) you probably don't need an ontology and the reasoning you need is minimal
- Typically you will want to reason over both the classes and the instances, i.e., what kinds of things are there, and what are the things of that kind?
  - Description Logics: T-Box vs. A-Box; but most ontology languages do not make such a hard/fast distinction
- Choose an ontology reasoning architecture: depends on the kind of reasoning you will do
  - DL classificational reasoning only?
  - Real "rule" reasoning?

Ontology Spectrum: Complexity of Applications



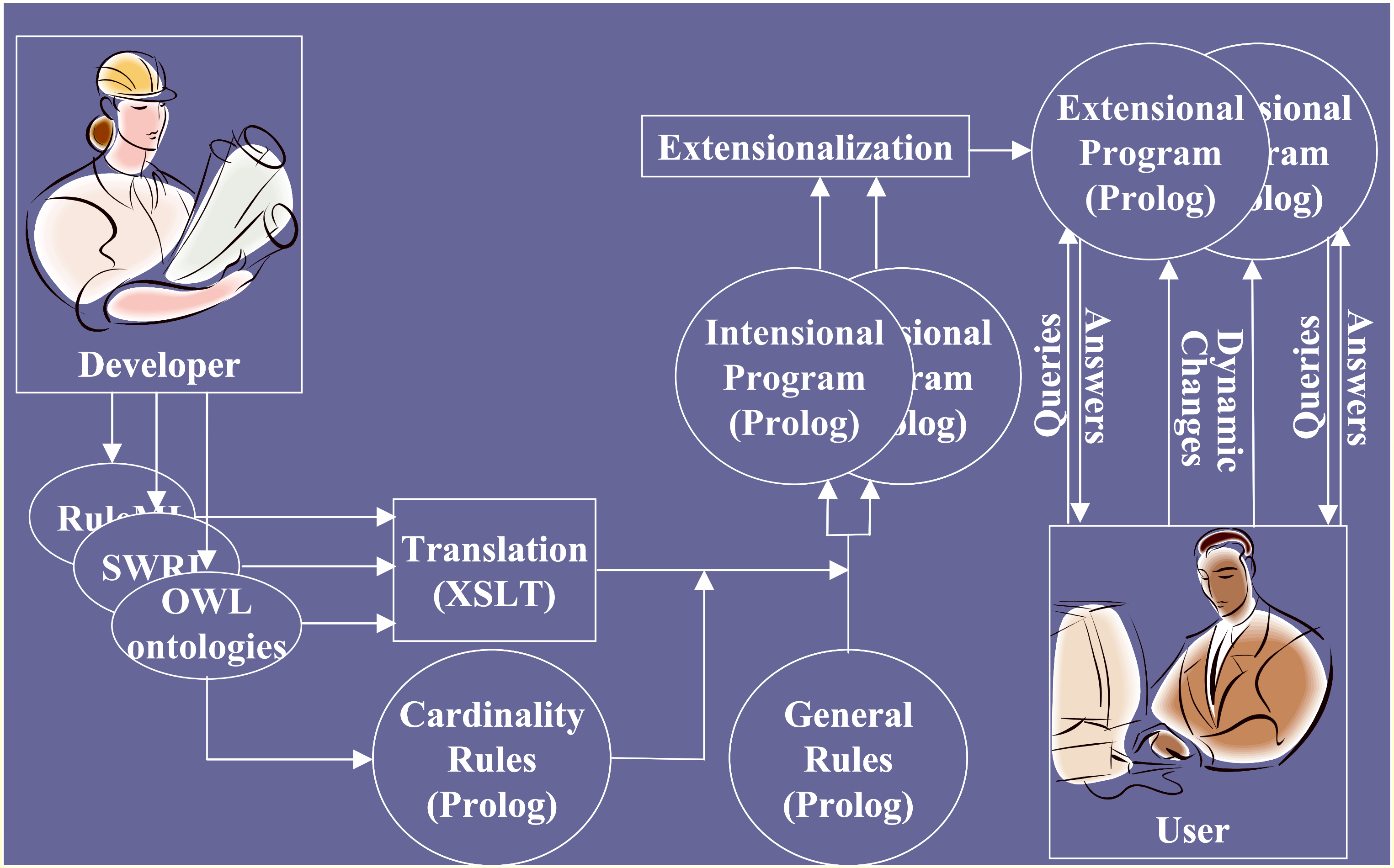
Categorization, Simple Search & Navigation, Simple Indexing	Synonyms, Enhanced Search (Improved Recall) & Navigation, Cross Indexing	Enterprise Modeling (system, service, data), Question-Answering (Improved Precision), Querying, SW Services	Real World Domain Modeling, Semantic Search (using concepts, properties, relations, rules), Machine Interpretability (M2M, M2H semantic interoperability), Automated Reasoning, SW Services

Application

What do you want to do? What kind of reasoning?

- Build an ontology, build a knowledge base
- Check consistency of your knowledge
- Check completeness of your knowledge
- I.e., Model checking, model finding
- Automatically classify new concepts, assertions
- Query the KB (search & navigation)
- Perform other inference (sometimes called rule-based reasoning)
  - Deduction
  - Induction
  - Abduction
- Add probabilistic reasoning
- Reason over beliefs (Truth Maintenance Systems), i.e., evidential reasoning
- Have built in modal operators: necessity/possibility, obligation/permission/prohibition, temporal, etc.
- **No Reasoning without Representation!**

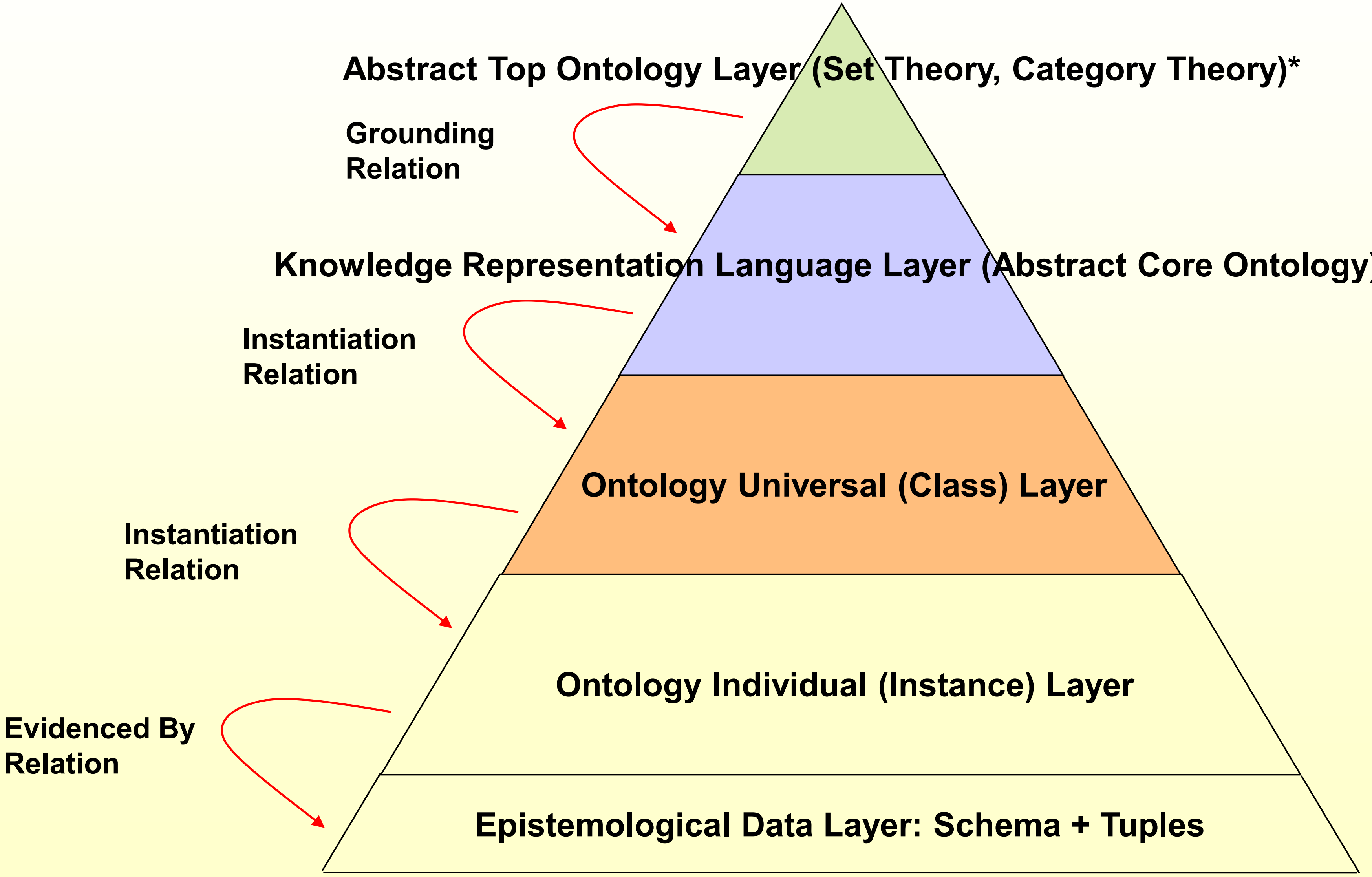
2004-2007: We had to develop our own ontology/rule reasoning system



Rules not expressible in SWRL were represented in Prolog directly

Ontology Content Architecture: You Need an Architecture!

* 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 Evaluation Criteria

- Ontology coverage of a particular domain
  - The richness, complexity and granularity of that coverage
  - The specific use cases, scenarios, requirements, applications, and data sources it was developed to address
- Formal properties of the language in which it is modeled:
  - ***Soundness*****:** any expression that can be derived from the knowledge base (KB) of the ontology and its instances is logically implied by that KB)
  - **C*ompleteness*:** any expression that is logically implied by the KB can be derived
  - ***Decidability***:being both sound and complete). All of these will correlate with the formal *complexity* (time of execution, space of memory needed to compute an answer. Decidability of a language or logic does not mean tractability of the automated reasoning on that language, but there is a relationship
  - ***Consistency:*** can contradictions be proven?
  - E.g., circularity, disjoint partition errors, incorrect classifications
- Ontology incompleteness:
  - Imprecisely defined or missing concepts, partially defined disjointness properties, redundancy of class, instance, or relation

Ontologies can be Evaluated per Questions

- Is the ontology mappable to some specific upper ontology, so that its evaluation will be at least partially dependent on the evaluation of the latter also?
- What is the ontology's underlying philosophical theory about reality?
  - ***Idealist:*** reality is dependent on mind or is ultimately mental in nature
  - ***Realist***: universals or invariant patterns really exist independently of minds (and observers)
  - **Conceptualist:** universals are neither independently existing nor just names but exist only in human and possibly other animal minds as abstractions from particulars
  - ***Nominalist***: only particulars exist and universals do not exist in reality or in our minds but only as general terms
  - ***3-dimensionalist***: space and time exist independently and material objects are extended in space and endure through time,
  - ***4-dimensionalist***: only a combined spacetime exists; etc.
- What kinds of reasoning methods can be invoked on the ontology, i.e., by the inference engine that uses it?

Additional Issues for Ontology Evaluation

- Aligning with other existing ontologies, e.g., importing OWL ontologies
  - All the entailments of the imported ontology now hold of the importing ontology
  - Establishing equivalence relations between classes/properties of the importing and imported ontologies
  - Term agreement (assuming the semantics can be read off the term name) is prone to error
- But importing ontologies may introduce inconsistencies, even or especially when equivalences are made between classes/properties of the importing and imported ontologies
- Meta-properties: Transitivity, Reflexivity, Symmetry
  - In OWL these are available axioms, i.e., in addition to Subclass (which is Transitive, Reflexive, Anti-Symmetric), you can define your own properties which have these
  - Are partOf/hasPart properties transitive? Always?
  - Maybe it's better to import an upper/foundational ontology that defines these?
- Defining additional, content-based meta-properties: e.g., OntoClean's determination of "rigidity" value correlation between a parent and a child node in the taxonomic backbone

Task-Based Evaluation of Ontologies: Requirements, etc.

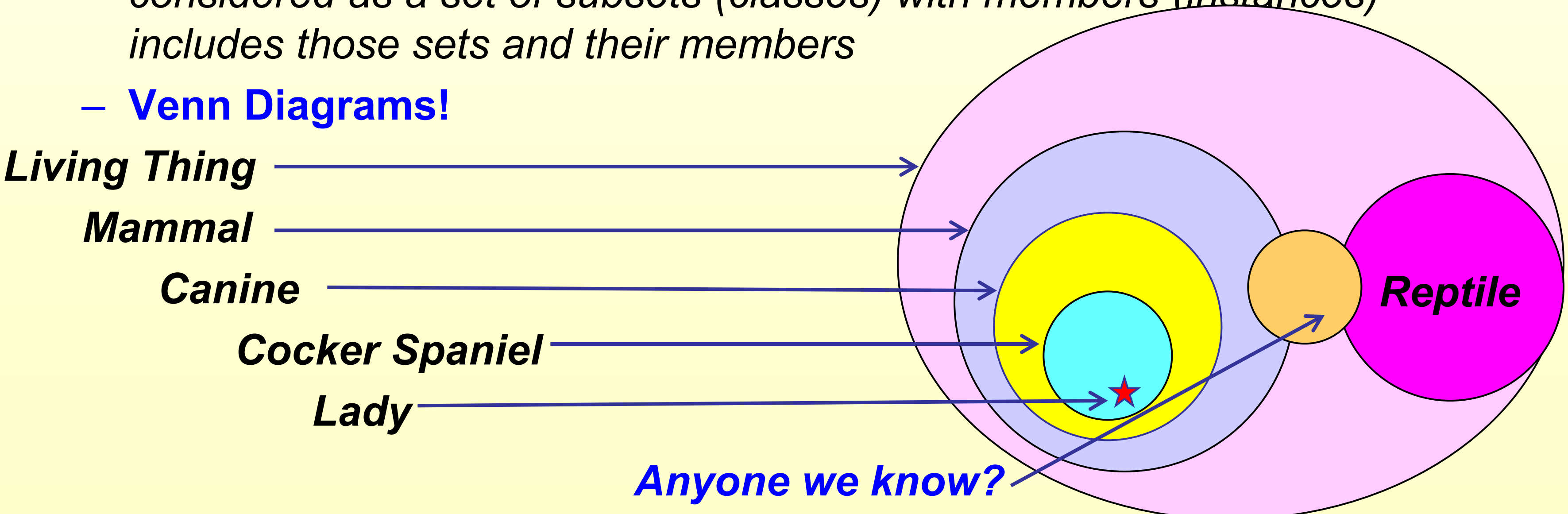
- The human ability to formulate queries using the query language provided by the ontology
- The accuracy of responses provided by the system's inferential component (and there may be more than one)
- The degree of explanation capability offered by the system
- The coverage of the ontology in terms of:
  - The degree of reuse across domains
  - The scalability of the knowledge base
  - The ease of use of the query component
- Are the constructs of the ontology (classes, properties, instances in OWL; predicates and axioms in other KR languages) annotated?
  - Descriptions, comments in natural language about intended meaning, synonyms/antonyms, examples, citations and other provenance information, i.e., alignment suggestion with other ontologies?

Collaborative Ontology Development: Evaluation Issues

- Common practice in large efforts is insulating your ontology module from other simultaneous ontology development
  - May require integrative or “overlay” ontologies that act as integration bridges between the given ontologies
  - Not only importing, but bridging
- Maintenance, redeployment, adding new applications
  - Requires Versioning of all ontologies: not just syntactic, but semantic
  - Periodic retesting of consistency of the ontology modules
  - Regression testing: queries and rules must be tested again and again, to gauge effect, evaluated

Example: 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!**



Example: Inheritance of Properties: Disjoint & Exhaustive Partitioning?

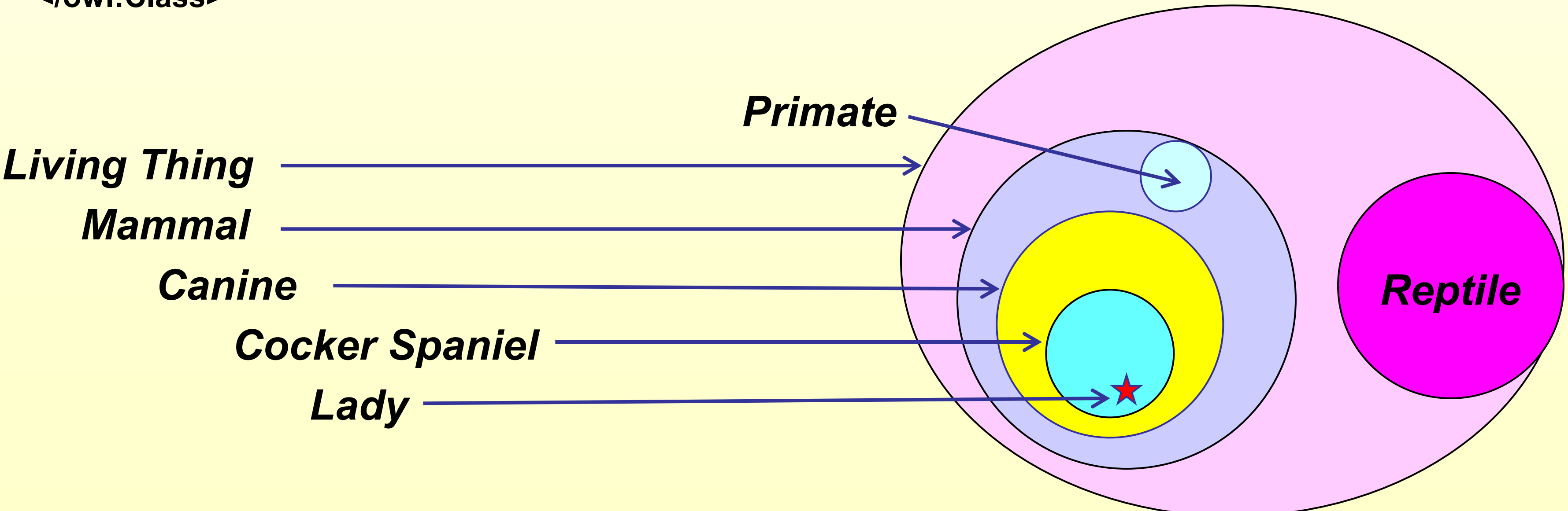
- Disjoint: We can declare by axiom that Canine is Disjoint from Reptile

```
<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>
```



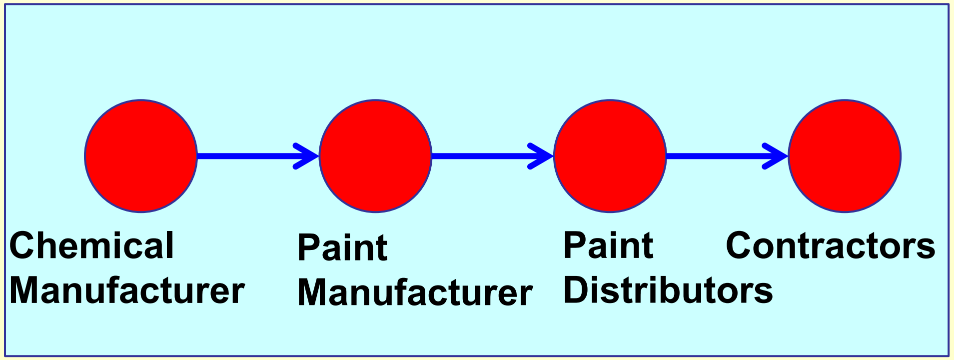
Use of Formal Ontological Analysis: OntoClean & Other Sound Approaches*

- **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 difference between a part and a whole?
  - **Theory of Essence and Identity**: what are essential, i.e., necessary, properties? If you lose a necessary property, you lose identity. If John loses an arm, he's still John. But if he loses his head? Is he John if he's dead?
  - **Theory of Dependence:** some things and properties depend on others
  - **Theory of Qualities:** features, attributes, qualia, quality spaces?
  - **Theory of Composition and Constitution**: Venus de Milo statue? Gold bar?
  - **Theory of Participation**: a conceptual framework for describing and analyzing communicative phenomena, agency, community, problem-solving, intersects formal 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.

* Adapted from Guarino, N. Multiple tutorials, 2002-2010.

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



Conclusion

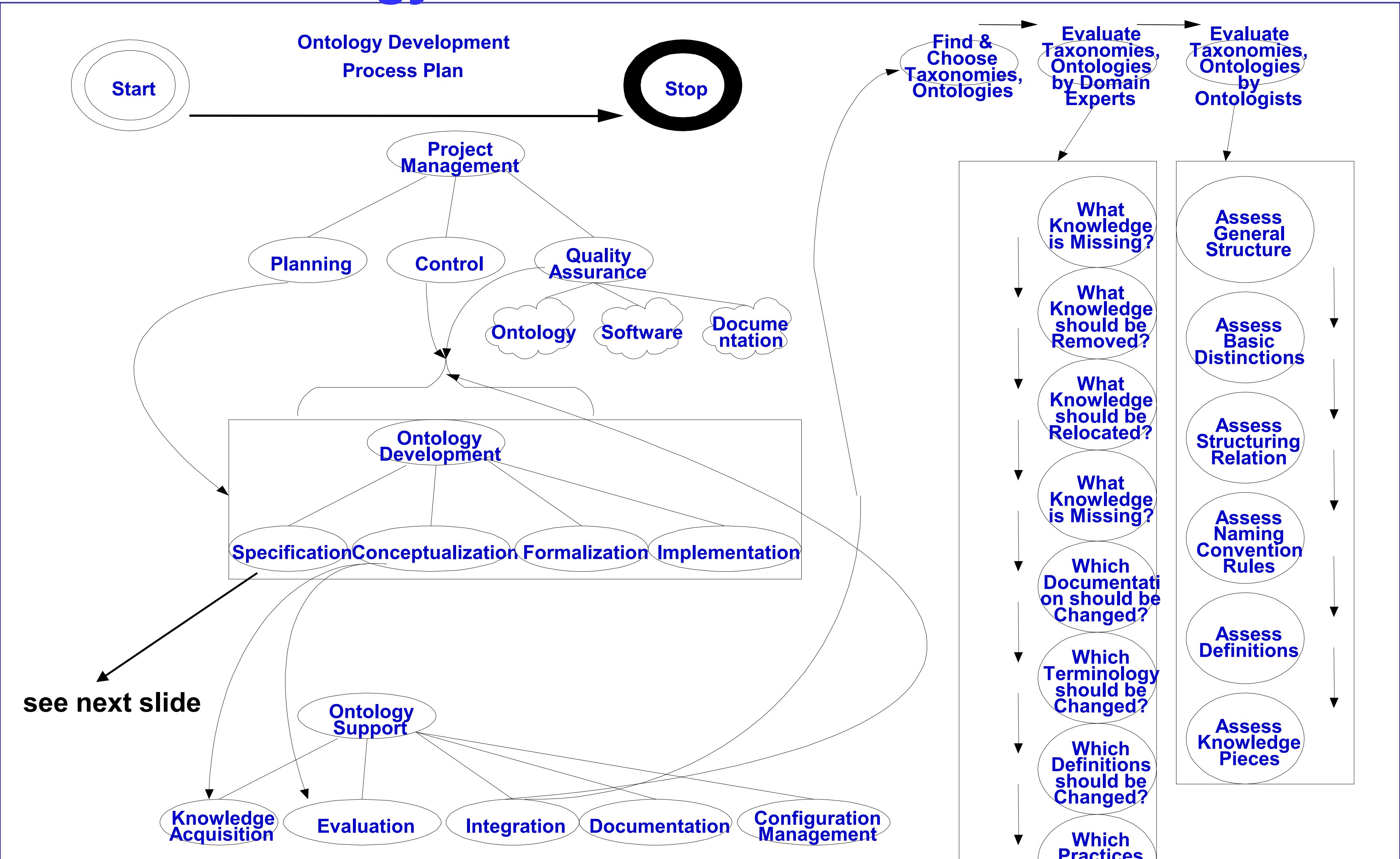
Ontology Evaluation is hard …

… because Quality Ontology Development is hard!

Thanks!

Backup

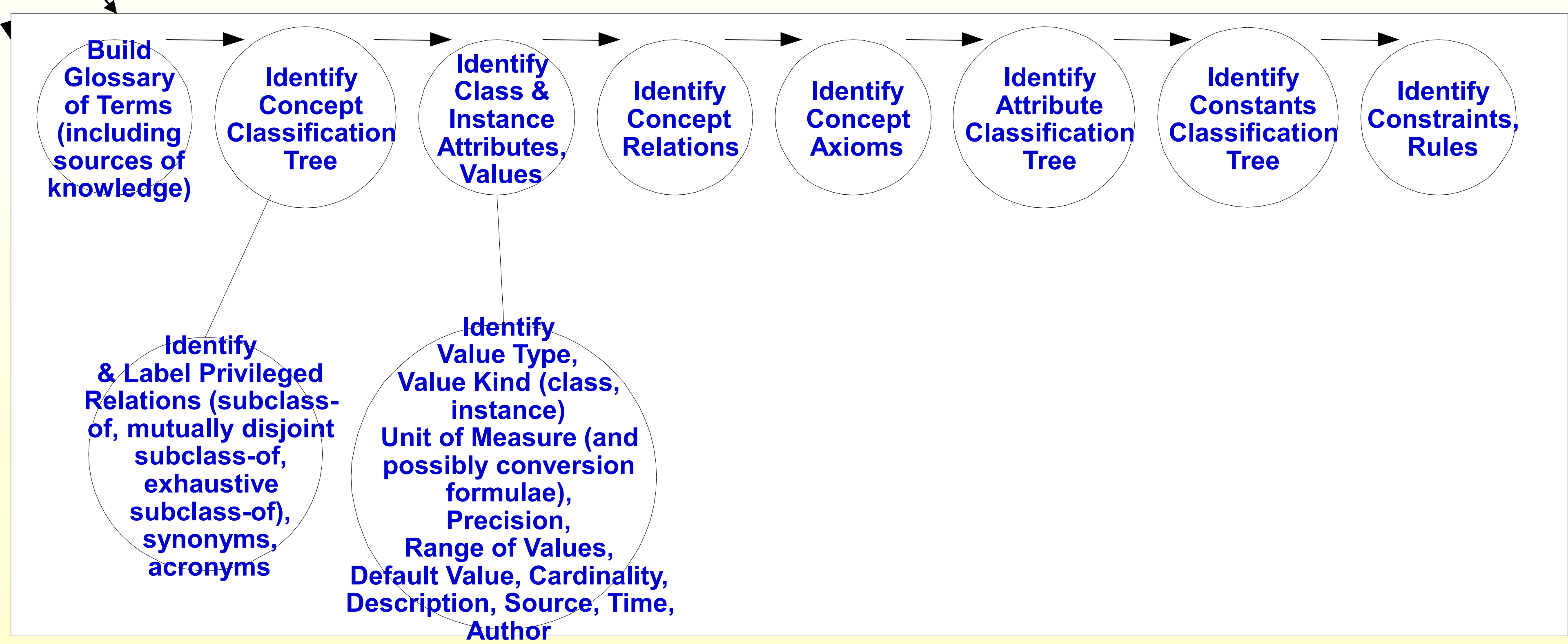
Ontology Development Process Plan: Based on MethOntology



*Fernandéz, Mariano; Gómez-Pérez, Asunción; and Juristo, Natalia. 1997. METHONTOLOGY: From Ontological Art to Ontological Engineering. Workshop on Ontological Engineering. AAAI Spring Symposium Series. Stanford University, pp. 33-40.

Ontology Development Process Plan

from previous slide



Ontology Lifecycle

1) *Rationale:* Why do you need an ontology?

2) Analysis 1 (Competency Questions)
- *Bottom-Up*: What are semantics of current data sources?
- *Top-Down:* What would you like to ask?

3) Analysis 2
- What are the referents, concepts: entities, relations, properties, rules?
- What are the terms that index the referents: terminology?

4) Analysis 3
- What are the resources available to harvest: vocabularies, schemas, taxonomies, conceptual models, ontologies?
- Are there domain standards, upper/middle ontologies to embed what we create within?

5) Design 1
- What ontology architecture do we choose?
- How expressive is the ontology language we need?
- What conceptualization?
- How do we model these entities, relations, properties, rules?
- What are the instances of these?
- What data sources mappings can link to these? How?
- What kinds of ontology tools do we need?

6) Implement 1
- Implement the ontology server we will need: periodicity, granularity, configuration management
- Implement the infrastructure, services of our architecture: enhance the server with application, SOA support

7) Design 2
- Are we done with ontology development?
- Test competency questions as queries against ontology + data: are good answers returned quickly wrt domain experts/end users?

8) Analysis 4
- Refine with domain experts, end users

9) Design 3
- Refine conceptualization

10) Implement 2
- Refine ontology

11) Deploy 1
- Provide ontology application services

12) Deploy 2
- Correct problems

13) Analysis 5
- Interrogate users
- Refine reqs
- More resources?

14) Design 4
- How can changes needed be made?
- Refine reqs

Ontology Maturity Model

Most Mature

From less to more mature

OMM Level 5

Consistent, pervasive capture of real domain semantics embedded under common middle/upper semantics (axiomatized ontologies); extensive inference

OMM Level 4

Consistent & pervasive capture of real domain semantics, represented as persistent & maintained models (frame ontologies, some axioms); some linkage to upper/middle; some inference supported;

OMM Level 3

Focus is on capture of real domain semantics, mostly represented as persistent & maintained models (frame ontologies); term resources linked to models; database and information extraction routines use some domain ontologies

OMM Level 2

Principled, consistent local semantics captured, some real domain semantics represented as persistent & maintained models (local ontologies); term & concept (referent) distinguished; databases and information extraction routines use local ontologies

OMM Level 1

Mainstream syntactic/structural DB technology (+ data warehouses + data marts), unstructured data addressed by procedural information extraction, no persistent linkage of semantics to syntax/structure, ad hoc local semantics sometimes captured in data dictionary & commented in extraneous code; no clear distinction made between term & concept (referent)

Least Mature