Ontology Design

Aldo Gangemi
Laboratory for Applied Ontology
ISTC-CNR, Rome, Italy
aldo.gangemi@istc.cnr.it

Thanks to: Valentina Presutti and the members of LOA

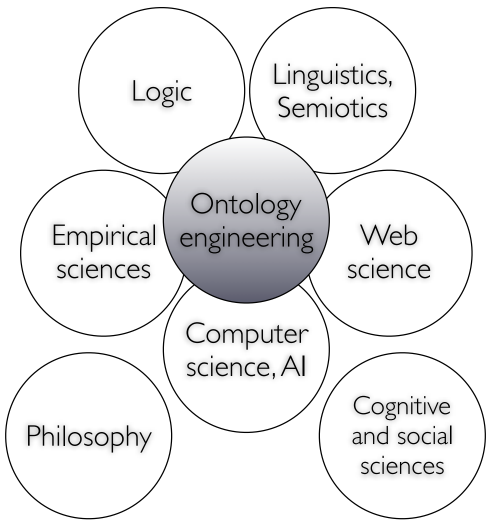
Outline

- The world of ontology design
- Ontologies and language
- Ontology design components
- Ontology design patterns
- The SWC ontology
- Summary

An ontology designer's world

- Requirements
- Logical constructs
- Existing ontologies
- Informal knowledge resources
- Conventions and practices
- Tools (editors, reasoners, translators, ...)

The cultural context of ontologies



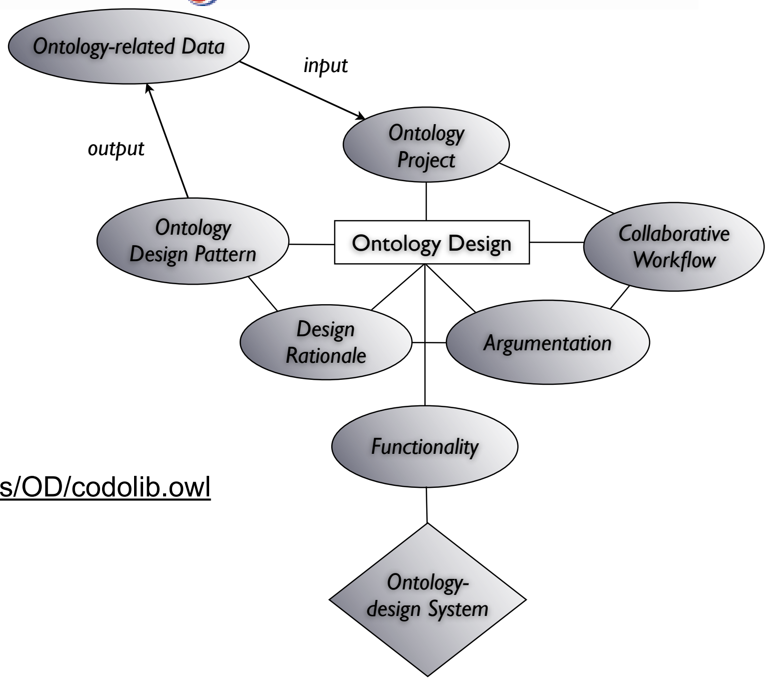
A well-designed ontology ...

- Obeys to “capital questions”:
  - What are we talking about?
  - Why do we want to talk about it?
  - Where to find reusable knowledge?
- Whats, whys and wheres constitute the **Problem Space** of an ontology project
- Ontology designers need to find solutions from a **Solution Space**
- Matching problems to solutions is not trivial

What is ontology design?

- Ontologies are artifacts
  - Have a structure (linguistic, “taxonomical”, logical)
  - Their function is to “encode” a description of the world (actual, possible, counterfactual, impossible, desired, etc.) for some purpose, e.g. the world of Semantic Web conferences
- Ontologies must match both domain and task
  - Allow the description of the entities (“domain”) whose attributes and relations are concerned by some purpose, e.g. *research topics as entities that are dealt with by a project, worked on by academic staff, and can be topic of documents, events, etc.*
  - Serve a purpose (“task”), e.g. *finding persons that work on a same topic, matching project topics to staff competencies, time left, available funds*, etc.
- Ontologies have a lifecycle
  - Are created, evaluated, fixed, and exploited just like any artifact
  - Their lifecycle has some original characteristics regarding:
    - *Data, Project* and *Workflow Types, Argumentation Structures,* ***Design Patterns***

The modular architecture of (collaborative) ontology design



The NeOn C-ODO approach
http://www.loa-cnr.it/ontologies/OD/codolib.owl

Ontologies and language

- Ontologies describe some domain (for some purpose)
- But also natural language can do it
- Ok, but natural languages are appropriate for humans, not for machines
- What's the difference?
  - Humans share tacit knowledge ("presuppositions") that provides the context for interpreting natural language utterances and texts
  - Some tacit knowledge is general
    - "US Army auditor who attacked Halliburton deal is fired"
    - ↳ auditor is a role played by persons within organizations
    - ↳ persons can "attack" others by denouncing something (e.g. a deal)
    - ↳ persons can be "fired" from a position (role)
  - Some is local
    - "US Army auditor who attacked Halliburton deal is fired"
    - ↳ denounced the decision to give billions of dollars in Iraq reconstruction contracts to a subsidiary of Vice-President Dick Cheney's old company Halliburton
    - ↳ "She told a congressional hearing that the decision was "the most blatant and improper abuse I have witnessed" in 20 years as a government contract supervisor"

Ontologies = controlled terminologies?

- Beware the mismatch between language and conceptualization!
- An ontology may not just be a controlled terminology
- We may have to capture the conceptual schema (or pattern) underlying the use of a certain terminology, in order to make it reusable for design, interoperability, meaning negotiation, etc.
- Should ontologies be considered reference conceptual schemas?
- Indeed, that was the original motivation for ontologies. Cf. Ontolingua library, 1992
  - http://www-ksl-svc.stanford.edu:5915
- Nowadays, it’s pretty different
  - Thousands of ontologies, many different uses, the most successful are very simple (DublinCore, FOAF, WSGeo, ...), huge uptake on folksonomies
- Need for simple schemas, which are close to users’ way of thinking

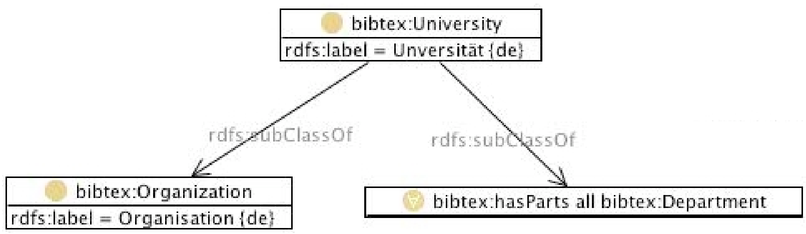
Pattern-based matching

- Ontology design is presented here as the activity of searching, selecting, and composing different patterns
  - *Logical, Reasoning, Architectural, Naming, Reengineering, Content*
  - Common framework to understand modelling choices (the "solution space") wrt task- and domain-oriented requirements (the "problem space")
  - They are being collected in the NeOn catalogue that will be available at the beginning of 2008

Logical patterns (LPs). Definition

- Logical constructs or composition of them
- LPs are content-independent structures expressed only by means of a logical vocabulary (plus possible primitives, e.g. “owl:Thing”)
- They can be applied more than once in the same ontology in order to solve similar modeling problems
- Logical patterns presented here are specific to OWL (DL)

Some LPs: *Subsumption Macros*



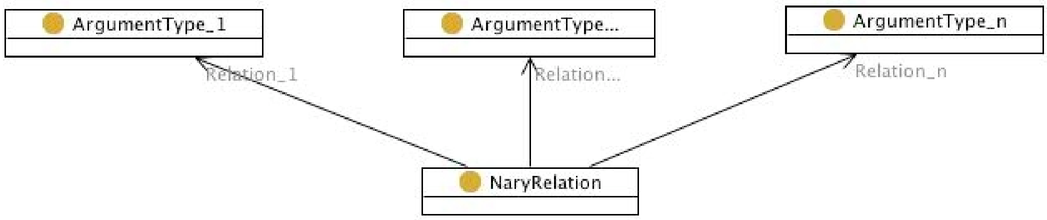
subsumption by class: *bibtex:University instances are also bibtex:Organization instances*

subsumption by restriction: *bibtex:University instances can only have bibtex:Department instances as Parts (!)*

equivalence by intersection: *European universities are universities that are located in Europe*

Some LPs: *N-ary relation*

- How to represent a relation with n arguments

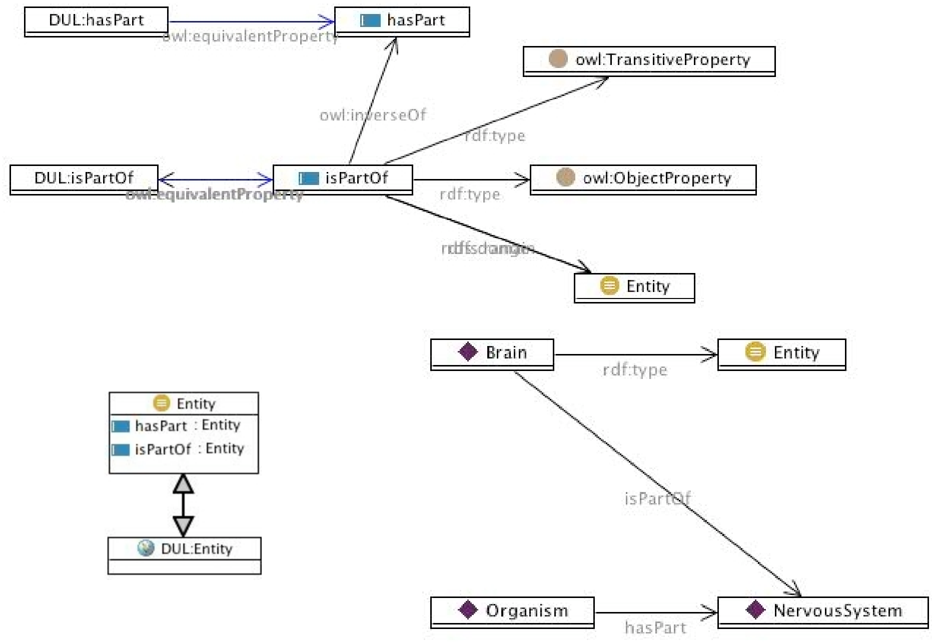


- Cf. W3C SWBPD, logical reification, DLR, UML association class

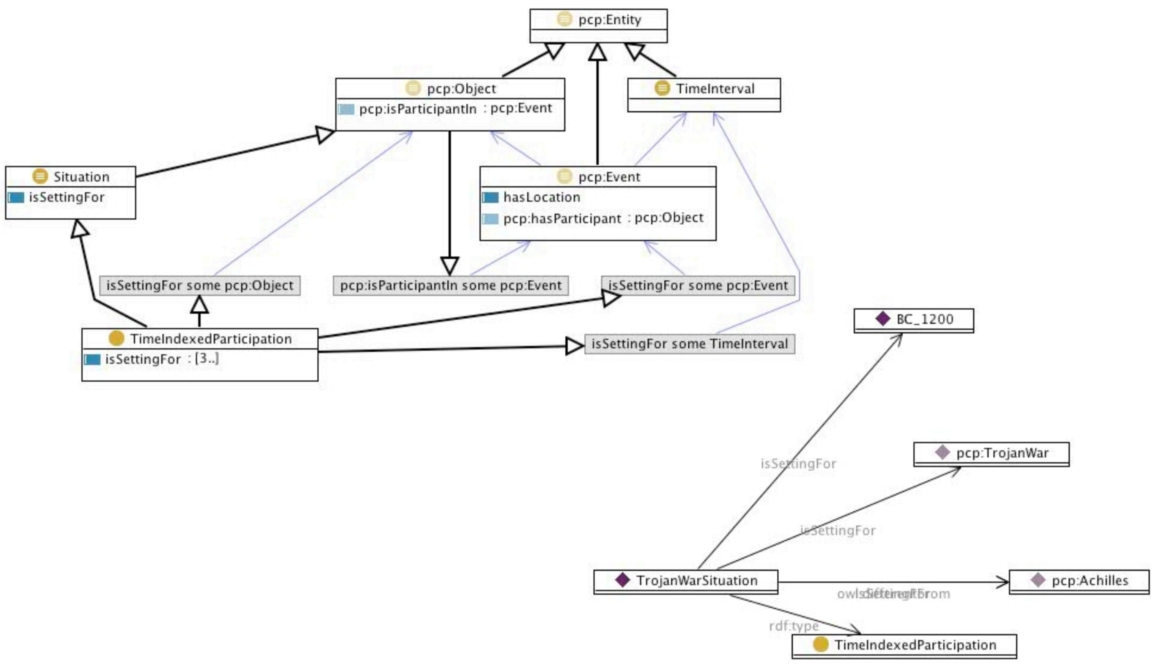
Content Patterns (CPs): Definition

- Instances of LPs or compositions of LPs.
- Domain-dependent
  - Expressed with a domain specific (non-logical) vocabulary
- Solve domain modelling problems
- Affect the specific part of the ontology dealing with the related domain modelling problem
- Examples:
  - *PartOf, Participation, Plans, Medical Guidelines, Sales Order, Research Topic, Legal Contract, Inflammation, Identity on the web*, etc.

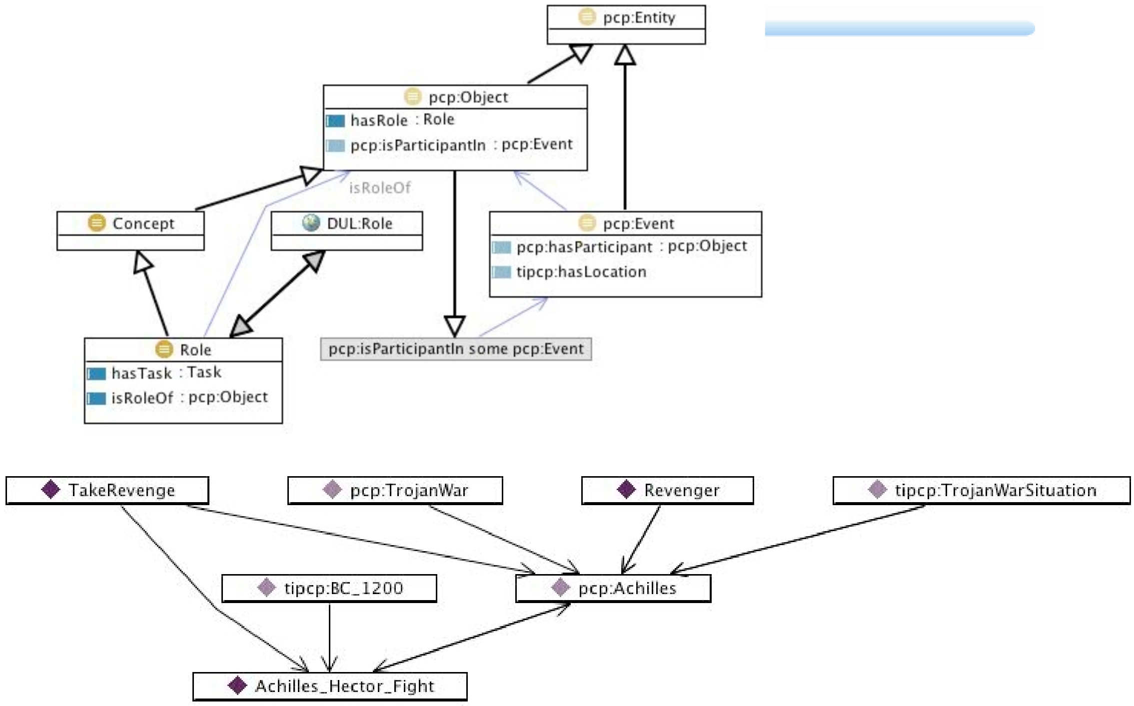
Some CPs: *PartOf*



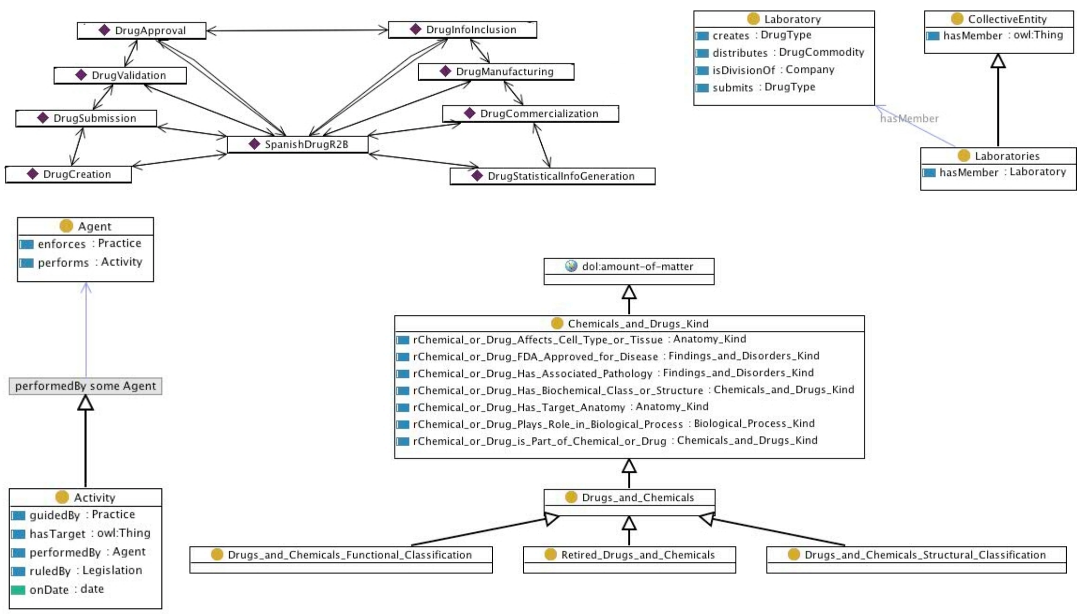
Time-indexed Participation



Role-based Participation



Other applied CPs



Specializing patterns

- Same structure down the taxonomy hierarchy
- A CP p_2 specializes another p_1 when at least one of the classes or properties from p_2 is a sub-class or a sub-property of some class or property from p_1, while the remainder of the CP is identical.
- Participation (of an object in an event)
  - Taking part in a public enterprise activities
    - Giving a grant to a Semantic Web project
- Co-participation
  - Having a social relationship
    - Being bunkmates
- Renaming elements of an imported patterns is a bad practice
  - Specializing is the way of using CPs

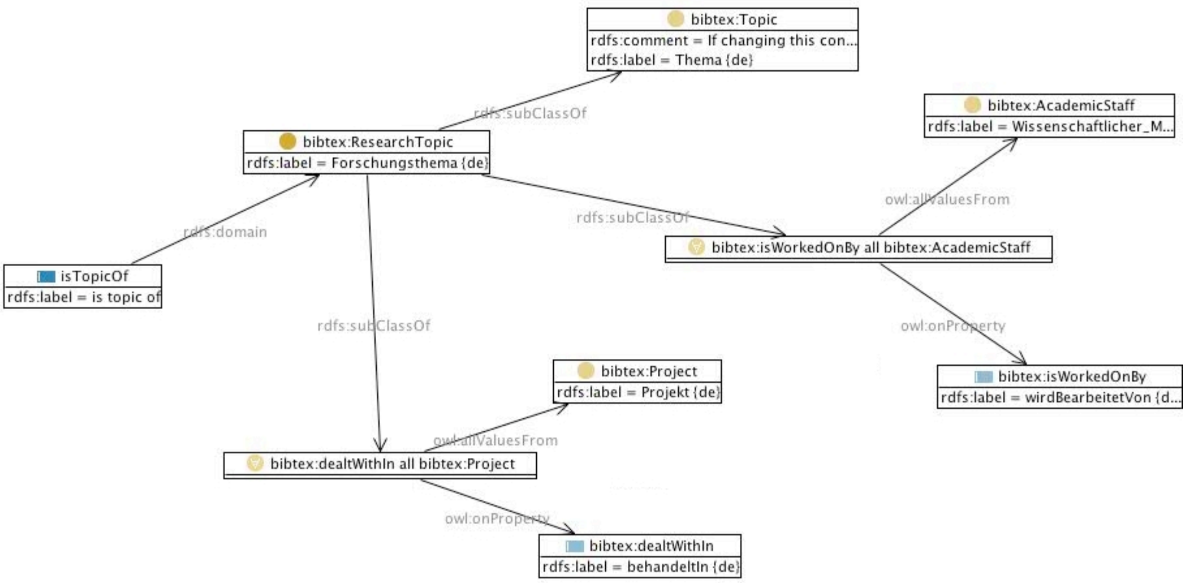
Composing patterns

- Linking sensible classes on the background of a common (or integrated) reference ontology
- A CP p_2 extends p_1 when p_2 contains p_1, while adding some other class, property, or axiom
- A CP p_3 integrates p_1 and p_2 when p_3 contains both p_1 and p_2
- A CP p_3 merges p_1 and p_2 when p_3 contains both p_1 and p_2, and there exist explicit links between at least two classes or properties from both p_1 and p_2
- *BiochemicalTreatment* → (*Role*⇔*Task* ° *Description*⇔*Situation* ° *Substance*⇔*Agent* ° *Time-indexedParticipation*)

A quick test: the SWC ontology

- Patterns used
  - Logical patterns
    - N-ary: as in *Product*
  - Content patterns
    - *Topic* pattern: obeys some tasks, generic coverage
  - Architectural patterns: *Alignment without import* to schemas used in applications: FOAF, SWRC, iCAL, WordNet1.6
  - Naming patterns

The "topic" content pattern as extracted from the SWRC ontology



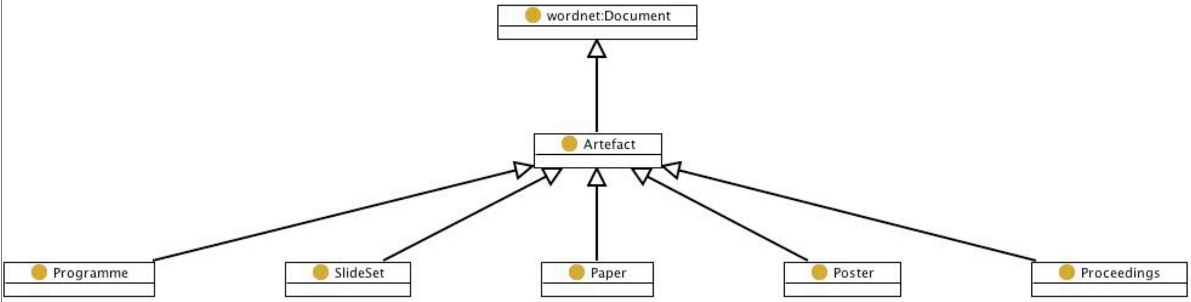
Design evaluation

- Coverage: *topics, staff, projects, dealt with by, worked on by, being a topic of*
- Task: *reasoning on semantic web entities*
- Does athe *topic* pattern satisfy coverage and task requirements?

Best practice check

- *Check that names are intuitive*
  - Antipattern: using a generic name for a subclass of class that have a specific name:
    - *Artefact subClassOf wn:Document*

Counterintuitive naming



Task-based unit test 1

– *Finding what documents have a same topic*
  - Impossible: hasTopic not an inverse of isTopicOf (!),
  - Workaround: use SPARQL query
  - Also: Document class detached from the pattern
  - Minor problem for task, but implies design “sparseness”
  - Also: topics related to papers are instances of DBpedia:Topic, not from the list of individuals from swrc:ResearchTopic
  - Fix: equivalence axiom between swrc:ResearchTopic and DBpedia:topic

Task-based unit test 2

– *Checking that only events can be sub-events* (“atEvent”) *of other events* (universal restriction)
  - Impossible: Event is not disjoint from e.g. Document
  - Consequence: e.g. a document that is said “atEvent” of an event, will be an event as well

Task-based unit test 3

– *Finding all parts of the proceedings*
  - Impossible: swc:hasPart and swc:isPartOf are not Transitive (and not Inverses)
  - Consequence: e.g. a paper that is part of a section of the proceedings will not be part of the proceedings; a laboratory that is part of a department of a university will not be part of the university; that department will not be asserted to have the laboratory as part
  - Also: no relation between transitive part for events (swc:subEvent), and the generic hasPart
  - Fix: apply *partOf* patterns (e.g. SWBPD, DOLCE-Ultralite patterns), with *Transitive Reduction* pattern: transitive property as the more generic

Appendix:
Other types of ontology design patterns

Naming Patterns (NPs): Definition

- Conventions about how to create names for namespaces, files and ontology elements in general (classes, properties, etc.)
- Good practices that boost ontology readability and understanding by humans, by supporting homogeneity in naming procedures

Examples of NPs

- Class and property names
  - A good practice for naming classes and properties is to give them a readable name either directly to the class, or to its label (this allows tools to visualize hierarchies and diagrams with readable names)
  - Usually class names start with a capital letter, and if a class name is composed of more than one terms, they are concatenated without special characters between such terms and with each term starting with capital letter
    - e.g., Person, Car, PersonalComputer
  - Classes representing elements that are single should not contain plurals. If the class name contains plurals, it should represent elements that are collections
    - e.g., Nurses, Shoes, etc.
  - Usually property names does not start with capital letter, and if a property name is composed of more than one terms, they are concatenated without special characters between such terms and with each term but the first starting with capital letter
    - e.g., hasFriend, hasChild, reads, etc.

Reasoning Patterns (RPs): Definition

- Application of LPs oriented to obtain certain inferencing results, based on the behavior implemented in a reasoning engine
- They are inference schemas, depending on the inference rules defined for a language
- Examples: Classification, Subsumption, Inheritance, Materialization, Query result construction

Classification and Subsumption RPs

- Automatic classification
  - Yes-Man(x) =df Man(x) $\wedge$ $\exists$y(hasFiancee(x,y))
  - Man(John)
  - hasFiancee(John,Mary)
  - $\therefore$ Yes-Man(John)
- Automatic subsumption
  - Yes-Man(x) =df Man(x) $\wedge$ $\exists$y(hasFiancee(x,y))
  - ItalianMan(x) $\Rightarrow$ Man(x)
  - hasFrenchFiancee(x,y) $\Rightarrow$ hasFiancee(x,y)
  - $\therefore$ ((ItalianMan(x) $\wedge$ $\exists$y(hasFrenchFiancee(x,y)) $\Rightarrow$ Yes-Man(x))

Inheritance and Materialization RPs

- Inheritance
  - Man(x) $\Rightarrow$ Human(x)
  - Yes-Man(x) $\Rightarrow$ Man(x)
  - $\therefore$ (Yes-Man(x) $\Rightarrow$ Human(x))
- Materialization
  - hasFiancee(x,y) $\Leftrightarrow$ hasFiance(y,x)
  - hasFiancee(John,Mary)
  - $\therefore$ hasFiance(Mary,John)

Architectural Patterns (APs): Definition

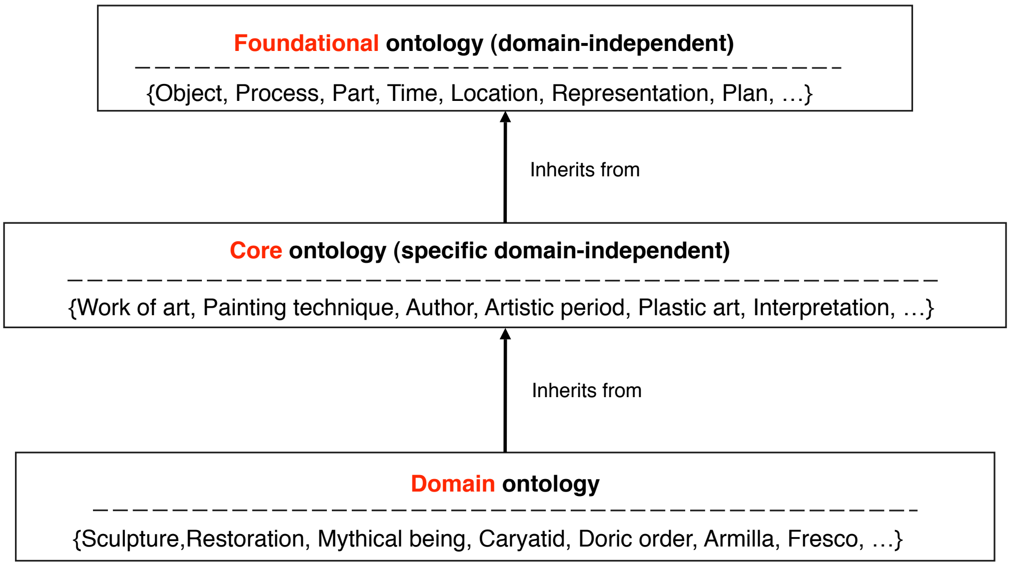
- Equivalent to LPs (or compositions of them) that are used exclusively in the design of an ontology
- An AP is a content-independent structure
- It is supposed to characterize the overall structure of an ontology
- An AP dictates how the ontology should look like

Examples of APs

- Taxonomy
  - A hierarchical structure of classes only related by subsumption relations.
- Lightweight ontology. Taxonomy + other features, e.g.:
  - A class can be related to other classes through the disjointWith relation.
  - Object and datatype properties can be defined and used to relate classes.
  - A specific domain and range can be associated with defined object and datatype properties.
- Modular architecture
  - Structuring an ontology as a configuration of components, each having its own identity based on some design criteria
  - When an ontology is committed to a huge domain of knowledge, a good practice is to decompose the domain into smaller subdomains which address simpler tasks
  - Each subdomain can be then encoded in an ontology module, in order to provide the whole ontology with a modular architecture.

Stratified MP

- To create a layering of modules, according to some criterion



Re-engineering Patterns (RePs): Definition

- Transformation rules to be applied in order to map elements of a source model (i.e. knowledge resource) to elements of a target model.
- The target model is an ontology, while the source model can be either an ontology, a thesaurus, a DB schema, a UML model, etc.

Knowledge resource types

- Modeling Languages:
  - E/R, UML, XSD, Petri Nets, ebXML, BPEL4WS
- Conceptual models:
  - Database schemas, UML diagrams, XSD schemas, etc.
- Informal Data Structures
  - Spreadsheets, tables, etc.
- Lexical resources:
  - WordNet, FrameNet, Oxford Dictionary, etc.
- Concept Schemes
  - Thesauri, classifications, nomenclatures, etc.
- Web 2.0 resources:
  - Wikipedia, Flickr, de.li.ci.o.us, etc.
- Natural Language documents

Example of ReP: from thesauri to ontologies in SKOS

- KOS ⇒ skos:ConceptSchema
- Descriptor ⇒ skos:Concept
- Broader Term ⇒ skos:broader
- Related Term ⇒ skos:related

Summary

- Interdisciplinary character of ontology design
- Ontology design and ontology evaluation
- Problem space vs. Solution space
  - The issue of matching problems to solutions
- Ontology design patterns
  - Ontology building blocks
  - Allow design by re-engineering, specialization and composition
  - Support ontology evaluation

Contribute to the collaborative design effort!

- http://www.ontologydesignpatterns.org
- http://www.neon-project.org
- http://www.w3.org/2001/sw/BestPractices/

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