Pattern-based design, part I

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From “raw” data to patterns

- Moving from “raw” knowledge resources to networked ontologies require: [*cf. C-ODO*]
  - Ontology requirement analysis (domain(s), task(s), and sustainability constraints for ontologies to be built/managed)
  - Tool/resource requirement analysis (functionalities to be covered by tools, and competences needed)
  - Project planning (deciding on knowledge resources, economic resources, team composition and responsibilities, data copyright management, tools)
  - Workflow decision making (specially for reengineering and argumentation)
  - Rationale elicitation (“critiquing” the reengineered data)
  - Providing solutions (e.g. based on design patterns, or conveying new ones)
- Not one, “best” methodology
  - A project can start spontaneously to solve a rationale elicitation problem, can be planned in order to reengineer knowledge resources, or to reuse existing ontologies or patterns, etc.
  - A project can be started either with or without requirement analyses
  - Even the solutions can consist only of a “bulk” reengineering process, without explicit patterns
  - eXtreme Design?
- In this tutorial, I concentrate on solutions based on ontology design patterns

OPs and patterns in other disciplines 1/3

- One might expect OPs to be easily comparable to software engineering design patterns.
- The same analogy has been done with architecture, linguistics, and other disciplines.
- **Ontology engineering and software engineering show many similarities from the pragmatic viewpoint, but they are quite different from the theoretical viewpoint.**

OPs and patterns in other disciplines 2/3

- We use comparisons between ontology engineering and software engineering for clarifying concepts and intuitions behind the definitions.

- **We do not take theoretical aspects of OP as dependent on those of software engineering (or other fields).**

OPs and patterns in other disciplines 3/3

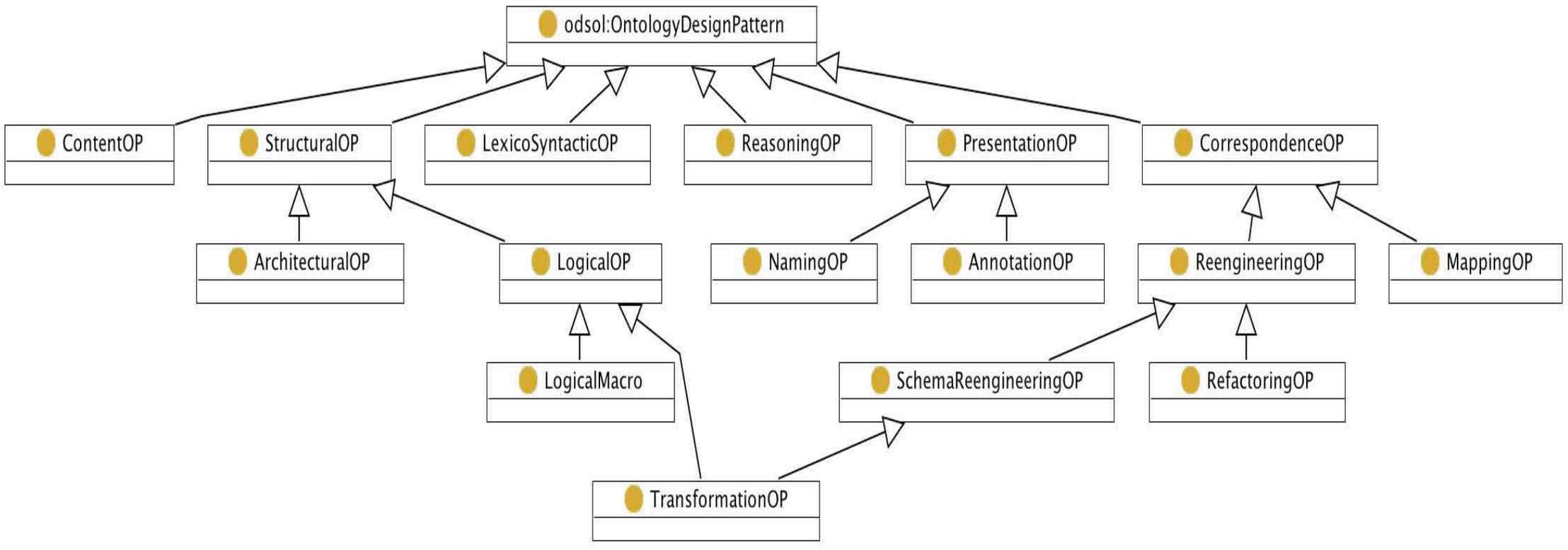
- Our concept of “pattern” is associable with the wider “good/best practice” of software engineering.

- It includes a wider range of solution types. For example:
  - naming conventions in software engineering are considered good practices, they are not design patterns.
  - In ontology engineering “naming” is an important design activity (it can have a strong impact on the usage of the ontology e.g., for selection, mapping, etc.).
  - We classify ontology naming conventions as OPs.

- We distinguish the different types of OPs by grouping them into six families.

- Each family addresses different kinds of problems, and can be represented with different levels of formality.

Types of Ontology Design Patterns (OPs)



- We also distinguish between ontological resources that are not OPs and Ontology Design Anti-Patterns (AntiOPs)

Presentation OPs

Definition

- Presentation OPs deal with usability and readability of ontologies from a user perspective.

- They are meant as good practices that support the reuse of patterns by facilitating their evaluation and selection.

- Two types:
  - Naming OPs
  - Annotation OPs

Naming OPs

Definition

- Naming OPs are conventions on how to create names for namespaces, files, and ontology elements in general (classes, properties, etc.).

- Naming OPs are good practices that boost ontology readability and understanding by humans, by supporting homogeneity in naming procedures.

Examples of Naming OPs 1/2

- Namespace declared for ontologies.
- It is recommended to use the base URI of the organization that publishes the ontology
  - e.g. http://www.w3.org for the W3C, http://www.fao.org for the FAO, http://www.loa-cnr.it for the Laboratory for Applied Ontologies (LOA) etc.)
- followed by a reference directory for the ontologies
  - e.g. http://www.loa-cnr.it/ontologies/
- It is also important to choose an approach for encoding versioning, either on the name, or on the reference directory

Examples of Naming OPs 2/2

- Class names
- They should not contain plurals, unless explicitly required by the context
  - Names like Areas is considered bad practice, if e.g. an instance of the class Areas is a single area, not a collection of areas
- It is also recommended to use readable names instead of e.g. alphanumerical codes
  - Non-readable name can be used (even if not recommended) if associated to proper annotations (see Annotation OPs)
- It is useful to include the name of the parent class as a suffix of the class name
  - e.g. MarineArea rdfs:subClassOf Area
- Class names conventionally start with a capital letter
  - e.g. Area instead of area

Annotation OPs

- Annotation OPs provide annotation properties or annotation property schemas that are meant to improve the understandability of ontologies and their elements

Examples of Annotation OPs

- RDF Schema labels and comments (crucial for manual selection and evaluation)
- Each class and property should be annotated with meaningful labels
  - i.e., by means of the annotation property rdfs:label, with also translations in different languages.
- Each ontology and ontology element should be annotated with the rationale they are based on
  - i.e., by means of the annotation property rdfs:comment

Reasoning OPs

Definition

- Reasoning OPs are applications of Logical OPs oriented to obtain certain reasoning results, based on the behavior implemented in a reasoning engine

Examples of Reasoning OPs

- Precise
  - Classification
  - Subsumption
  - Inheritance
  - Materialization
  - De-anonymizing
  - Normalization [6]
- Approximate
  - Approximate classification
  - Similarity induction
  - Taxonomy induction
  - Relevance detection
  - Latent semantic indexing
  - Automatic alignment

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) ⇒ Human(x)
  - Yes-Man(x) ⇒ Man(x)
  - ∴ (Yes-Man(x) ⇒ Human(x))
- *Materialization*
  - hasFiancee(x,y) ⇔ hasFiance(y,x)
  - hasFiancee(John,Mary)
  - ∴ hasFiance(Mary,John)

Construction RP

- *Query result construction*
  - *CONSTRUCT { ?x insanelyDesires ?z }*
    WHERE {
    ?x hasFiancee ?y .
    ?y hasFemaleFriend ?z . }
  - hasFiancee(John,Mary)
  - hasFemaleFriend(Mary,Pamela)
  - ∴ insanelyDesires(John,Pamela)

Rule firing RP

- *SWRL rule firing*
  - (hasFiancee(*x,y*) ∧ hasFemaleFriend(*y,z*)) ⇒ insanelyDesires(*x,z*)
  - hasFiancee(John,Mary)
  - hasFemaleFriend(Mary,Pamela)
  - ∴ insanelyDesires(John,Pamela)

Normalization

- Normalizations [5,6]:
  - Name all relevant classes, so that no anonymous complex class descriptions are left (restriction de-anonymizing)
  - Name anonymous individuals (skolem de-anonymizing)
  - Materialize the subsumption hierarchy (automatic subsumption) and normalize names
  - Instantiate the deepest possible class or property (“leaf”)
  - Normalize property instances (property value materialization)

Common misconceptions

- Disjointness of primitives
- Interpreting domain and range
- And and Or
- Quantification
- Closed and Open Worlds

Disjointness

- By default, primitive classes are not disjoint.
- Unless we explicitly say so, the description (Animal and Vegetable) is not inconsistent.
- Similarly with individuals -- the so-called Unique Name
- Assumption (often present in DL languages) does not hold, and individuals are not considered to be distinct unless explicitly asserted to be so.

Domain and Range

- OWL allows us to specify the domain and range of properties.
- Note that this is not interpreted as a constraint as you might expect.
- Rather, the domain and range assertions allow us to make inferences about individuals.
- Consider the following:
  - ObjectProperty(employs domain(Company) range(Person))
  - Individual(IBM value(employs Jim))
- If we haven't said anything else about IBM or Jim, this is not an error.

However, we can now infer that IBM is a Company and Jim is a Person.

And/Or and quantification

- The logical connectives And and Or often cause confusion
  - Tea or Coffee?
  - Milk and Sugar?
- Quantification can also be contrary to our intuition.
  - Universal quantification over an empty set is true.
  - Aldo is a member of restriction(insanelyDesires allValuesFrom beetle)
- Existential quantification may imply the existence of an individual that we don't know the name of.
  - Aldo is a member of restriction(insanelyDesires someValuesFrom FemaleFriend)

Close and Open World assumptions

- The standard semantics of OWL makes an Open World Assumption (OWA).
  - We cannot assume that all information is known about all the individuals in a domain.
  - Negation as contradiction
    - Anything might be true unless it can be proven false

- Closed World Assumption (CWA)
  - Named individuals are the only individuals in the domain
  - Negation as failure.
    - If we can't deduce that x is an A, then we know it must be a (¬ A).
    - Facilitate reasoning about a particular state of affairs.

Correspondence OPs

Definition

- Correspondence OPs include Reengineering OPs and Mapping OPs.

- *Reengineering* OPs provide designers with solutions to the problem of **transforming** a conceptual model, which can even be a non-ontological resource, into a new ontology.

- *Mapping* OPs are patterns for **creating semantic associations** between two existing ontologies.

Reengineering OPs

Definition

- Reengineering OPs are transformation rules applied in order to create a new ontology (target model) starting from elements of a source model

- The target model is an ontology, while the source model can be either an ontology, or a non-ontological resource
  - e.g., a thesaurus concept, a data model pattern, a UML model, a linguistic structure, etc.

- Two types:
  - Schema reengineering OPs are rules for transforming a non-OWL DL metamodel into an OWL DL ontology

  - Refactoring OPs provide designers with rules for transforming, i.e. “refactoring”, an existing OWL DL “source” ontology into a new OWL DL “target” ontology
    - E.g. a guideline to reengineer a piece of an OWL ontology in presence of a requirement change, as when moving from individuals to classes, or from object properties to classes. See also N-ary relation tranformation pattern

Schema Reengineering OP example: kos2skosABox

$$\text{KOS} \mapsto \texttt{skos:ConceptSchema} \quad (2.1)$$

$$\text{Descriptor} \mapsto \texttt{skos:Concept} \quad (2.2)$$

$$\text{Broader Term} \mapsto \texttt{skos:broader} \quad (2.3)$$

$$\text{Related Term} \mapsto \texttt{skos:related} \quad (2.4)$$

- The rule (2.1) states that, given a KOS, it maps to an instance of the class skos:ConceptSchema
- The rule (2.2) maps each “Descriptor” from a KOS to a specific instance of the class skos:Concept
- The rule (2.3) relates to the case of having two “Descriptors” d1 and d2 in a KOS, where d1 has “Broader Term” d2. Given the corresponding instances of skos:Concept skos:c1 and skos:c2, the broader term relationship between d1 and d2 maps to an object property value having the subject skos:c1, the object property skos:broader, and the object skos:c2
- The rule (2.4) relates to the case of having two “Descriptors” d1 and d2 in the KOS that are “Related Terms”. Given the corresponding instances of skos:Concept skos:c1 and skos:c2, the related term relationship between d1 and d2 maps to a (symmetric) object property value having the subject skos:c1, the object property skos:related, and the object skos:c2

Mapping OPs

Definition

- Mapping OPs refer to the semantic relations between mappable elements:
  - equivalent to, (not equivalent to)
    - foaf:Agent ≡ wn16:Agent-3
  - contained in, (not contained in)
    - foaf:Person ⊑ geo:SpatialThing
  - overlap with
    - foaf:Person ⊓ dul:Person
  - disjoint with
    - (dul:PhysicalPerson ⊓ dul:SocialPerson) = ∅

- Also called “correspondence patterns” in [16]
- We also consider an additional semantic relation that we call *cloned from*
  - ontology element oe_1 in one ontology is the clone of an ontology element oe_2 in another ontology
  - this relation is put in place when extracting a Content Ontology Design Pattern (see later)

Structural OPs

- Structural OPs includes Logical OPs and Architectural OPs.
- Architectural OPs affect the overall shape of the ontology either internally or externally.
  - i.e., an internal Architectural OP identifies a composition of Logical OPs that are to be exclusively used in the design of an ontology.
- Logical OPs are compositions of logical constructs that solve a problem of expressivity.

Architectural OPs

Definition

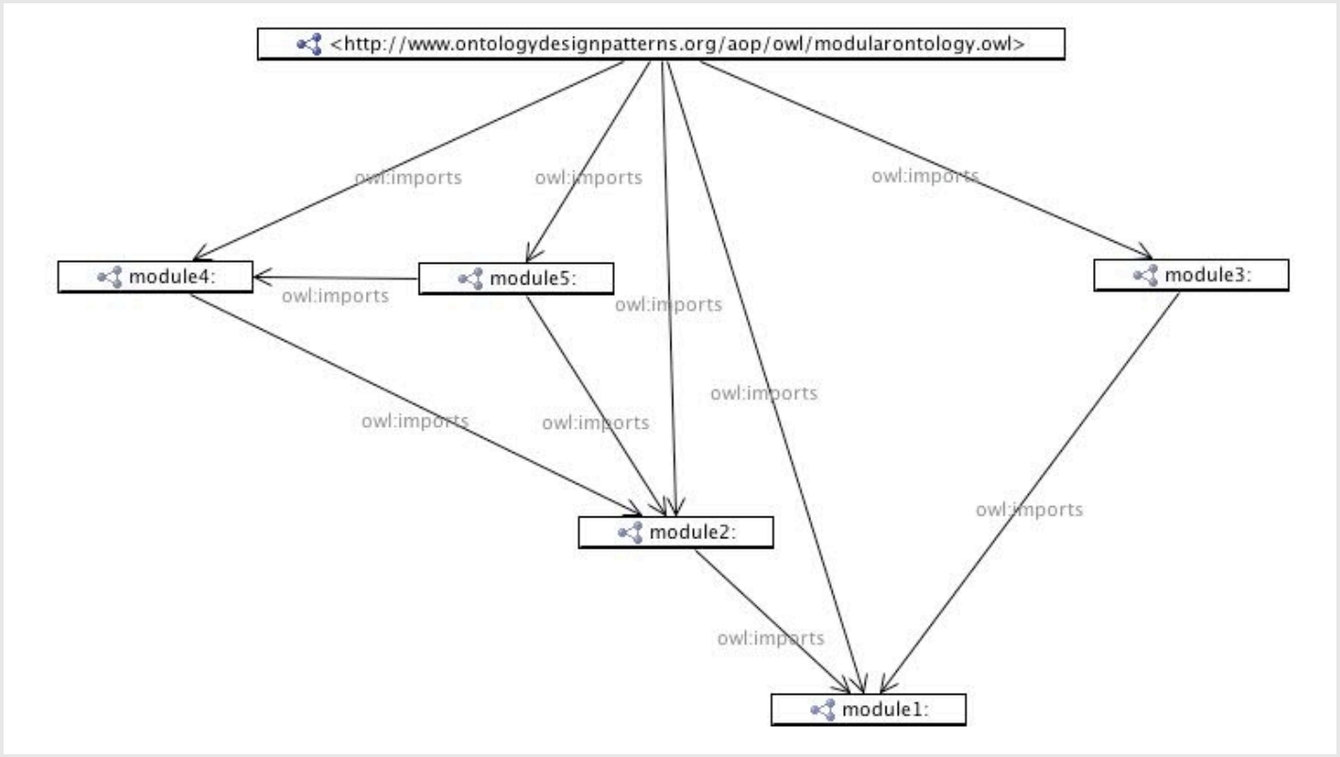
- Architectural OPs affect the overall shape of the ontology: their aim is to constrain ‘how the ontology should look like’

- Architectural OPs emerged as design choices motivated by specific needs
  - e.g., computational complexity constraints.

- They are useful as reference documentation for those initially approaching the design of an ontology

Architectural OPs

- Architectural OPs can be of two types: *internal APs* and *external APs*
- Internal APs are defined in terms of collections of Logical OPs that have to be exclusively employed when designing an ontology
  - e.g., an OWL species, or the varieties of description logics: http://www.cs.man.ac.uk/~ezolin/dl/
- External APs are defined in terms of meta-level constructs
  - e.g., the modular architecture consists of an ontology network, where the involved ontologies play the role of modules. The modules are connected by the import operation.

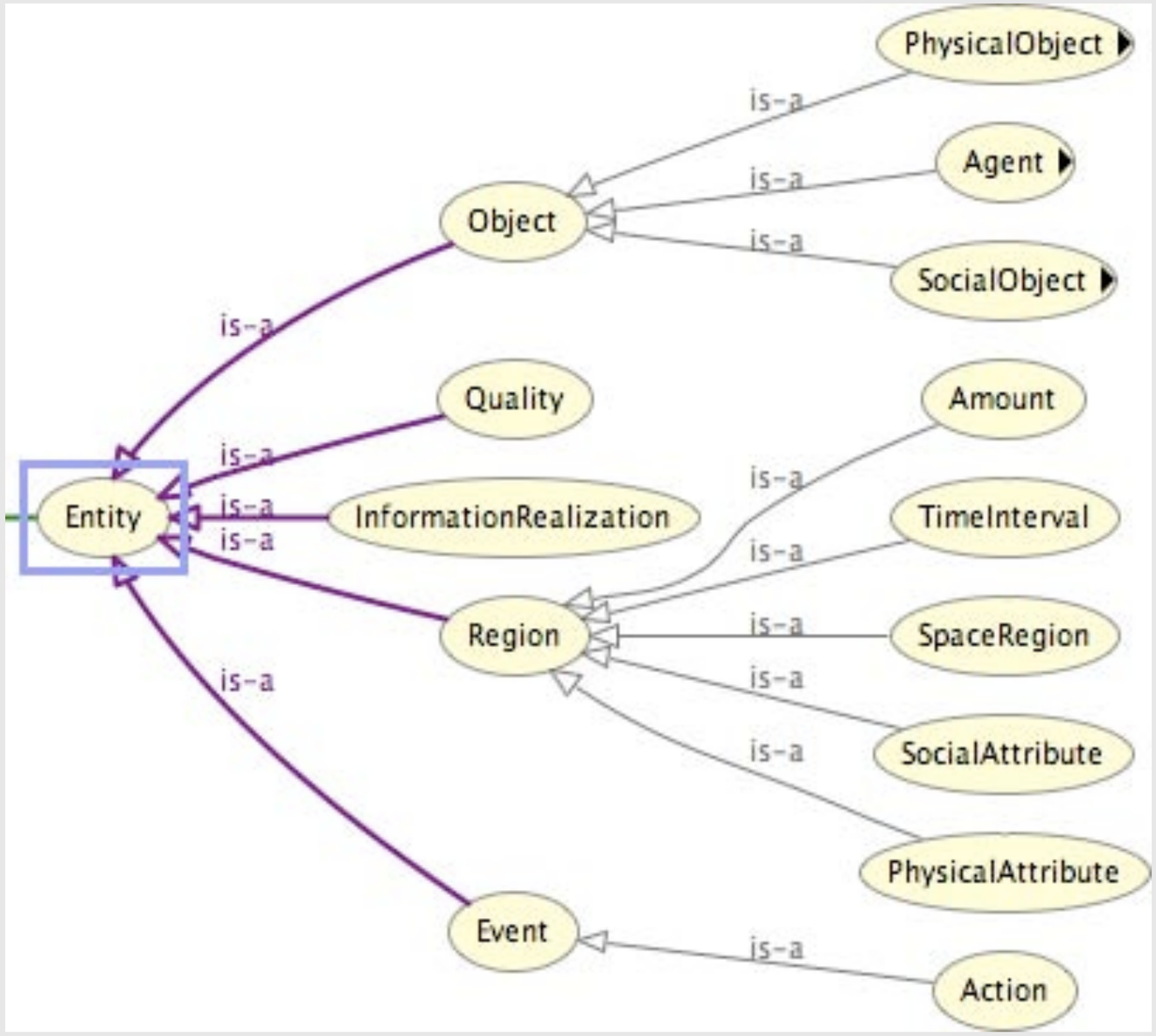


Examples of Internal APs

- 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.

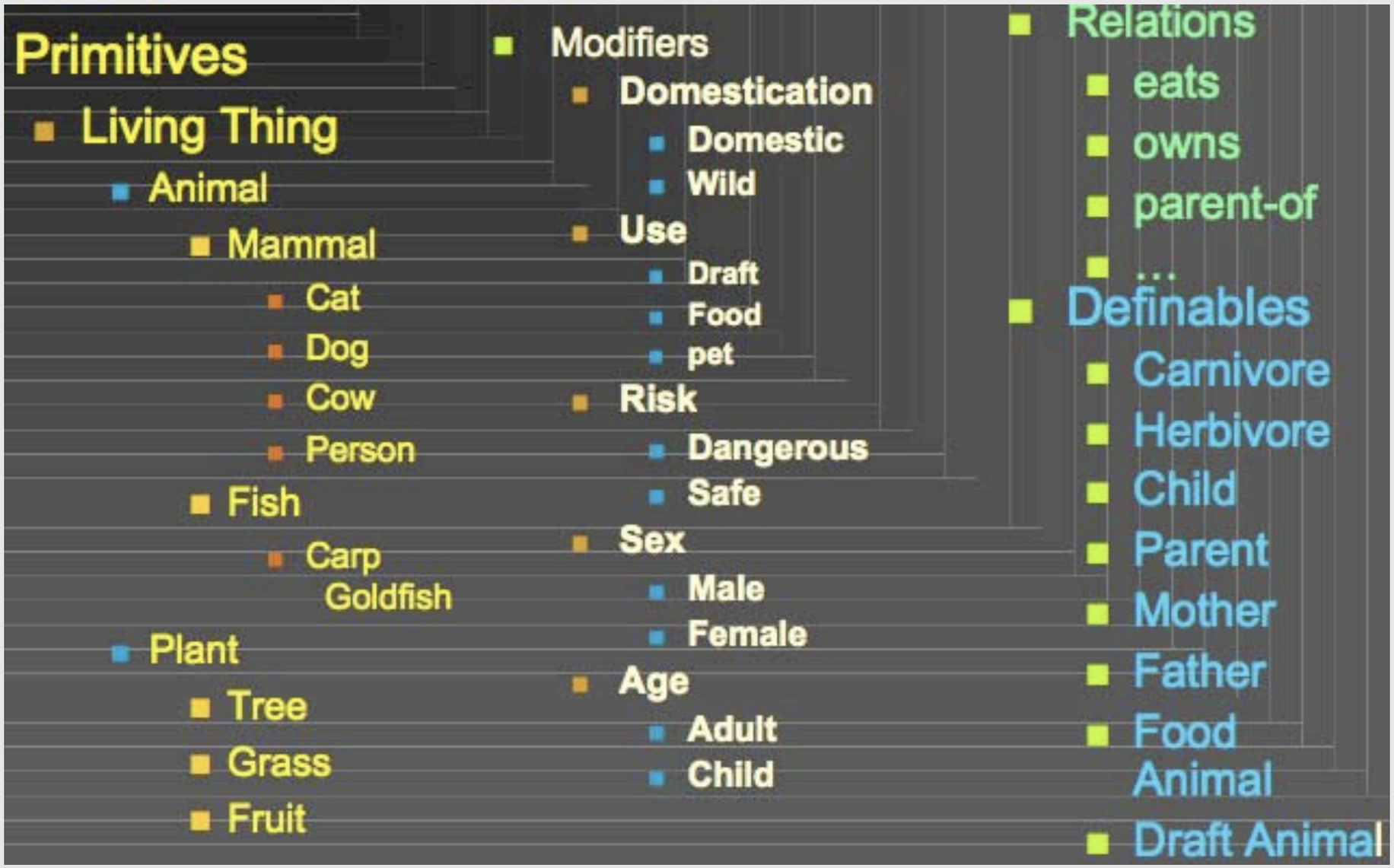
Taxonomy AP

- Intent
  - To create an ontology consisting only of a subsumption graph



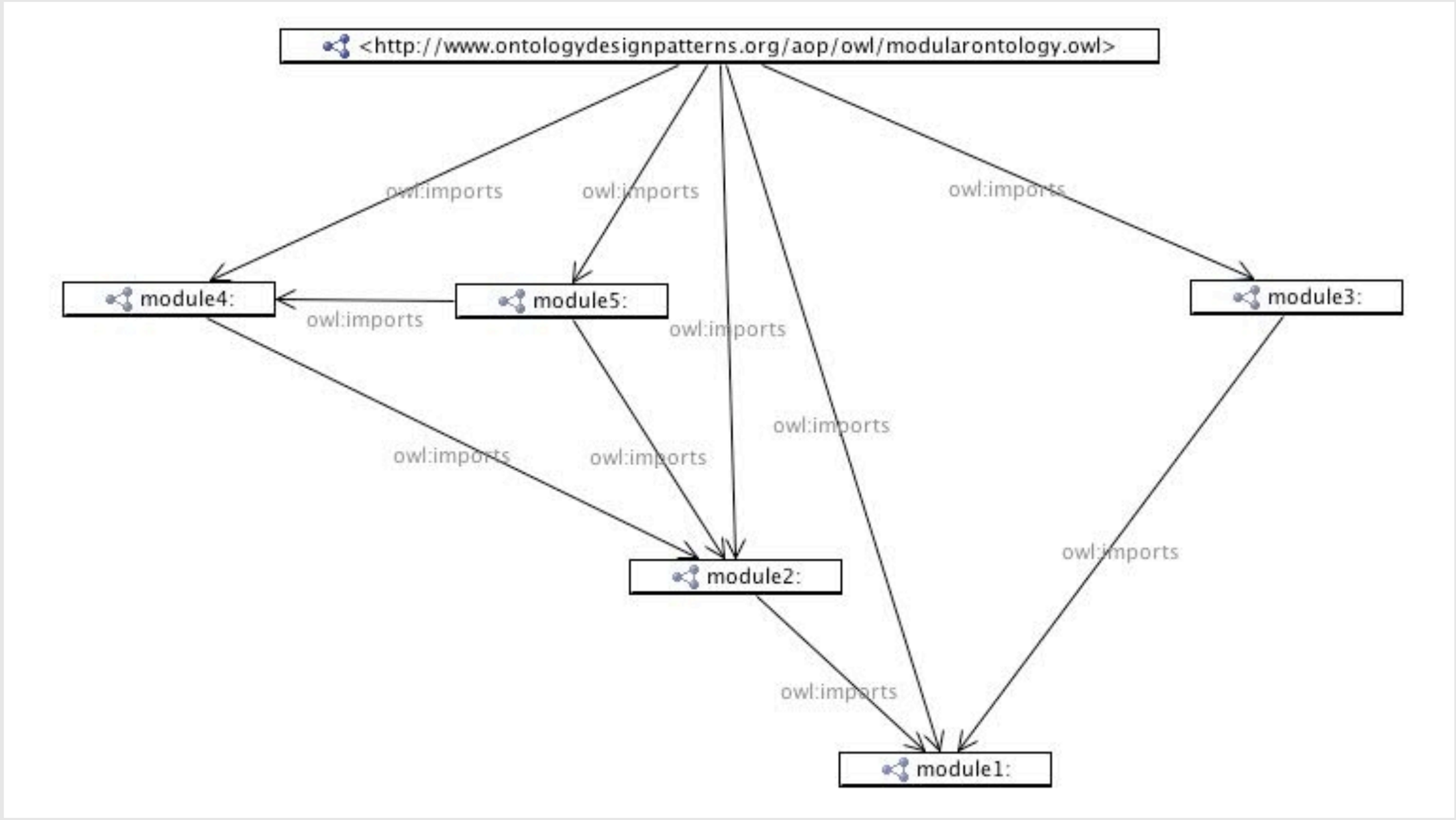
Primitives-Modifiers-Definables AP 1/2

- Intent: to create a compositional content architecture within an ontology
  - Choose some main axes
  - Add abstractions where needed; identify relations
  - Identify definable things, make names explicit



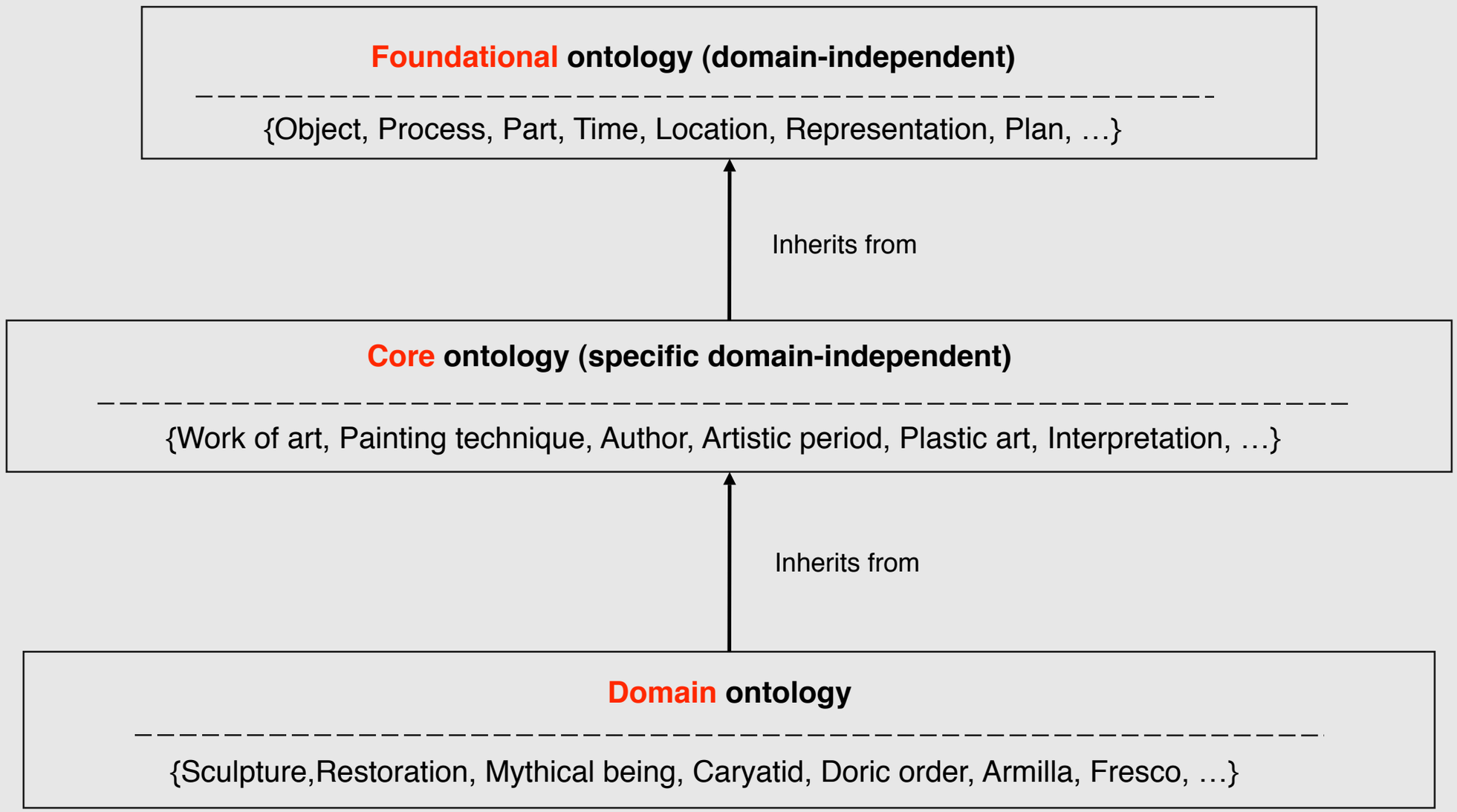
Modular AP

- Intent
  - To represent an ontology into self-consistent pieces, according to some criterion, and with an explicit ordering



Stratified AP (*external* AP)

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



Logical OPs

Definition

- A Logical OP is a formal expression, whose only parts are expressions from a logical vocabulary e.g., OWL DL, that solves a problem of expressivity

- Logical OPs are independent from a specific domain of interest
  - i.e. they are content-independent

- Logical OPs depend on the expressivity of the logical formalism that is used for representation
  - They help to solve design problems where the primitives of the representation language do not directly support certain logical constructs

- They can be of two types: *logical macros,* and *transformation patterns*

Logical macros

- Logical macros provide a shortcut to model a recurrent intuitive logical expression

Example:

the macro: ∇R.C [7]

colloquially means “every R must be a C”

formally: ∃R.⊤ ⊓ ∀R.C

in OWL:

the combination of an owl:allValuesFrom restriction with an owl:someValuesFrom restriction.

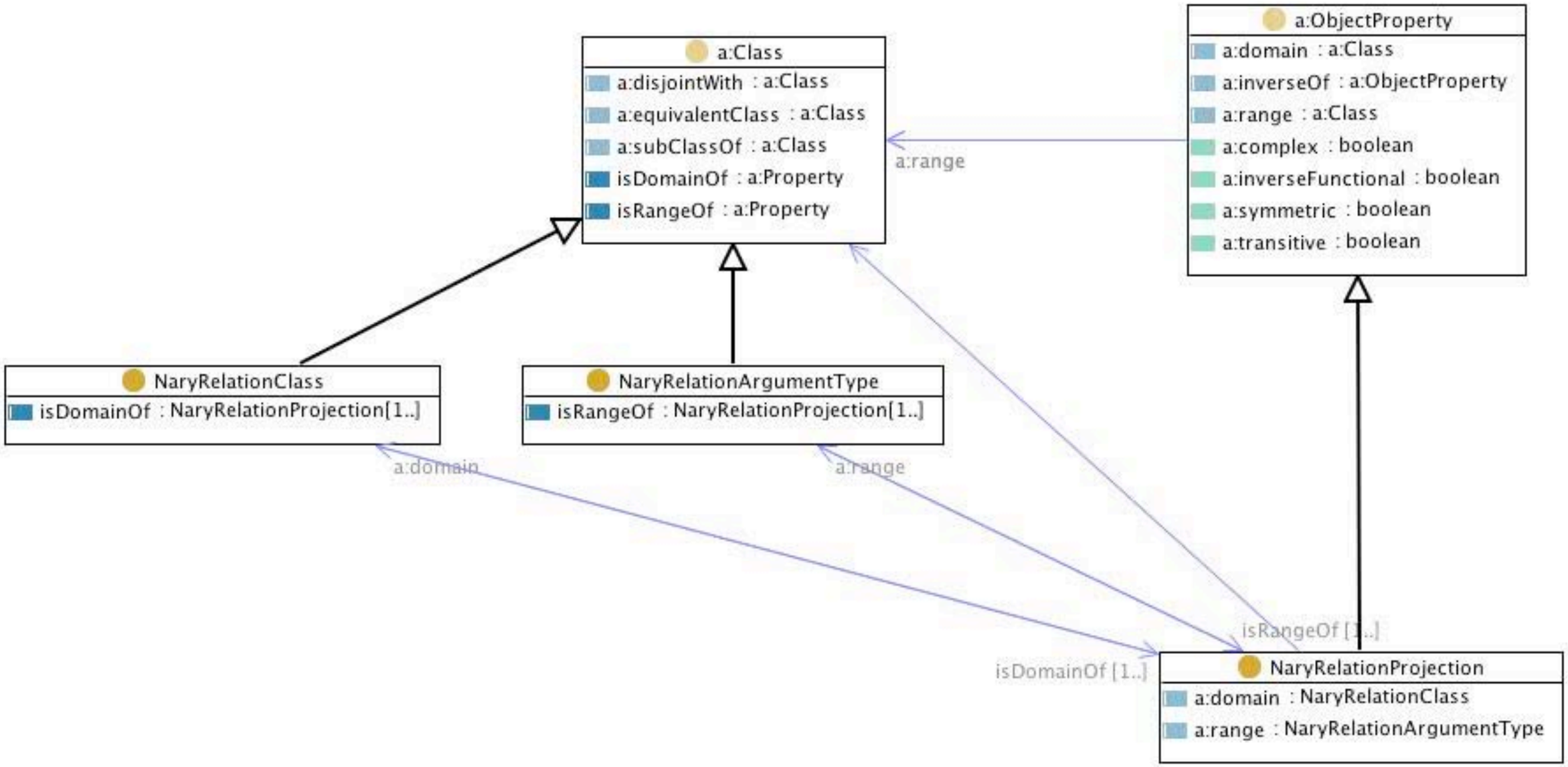
Transformation patterns

Definition

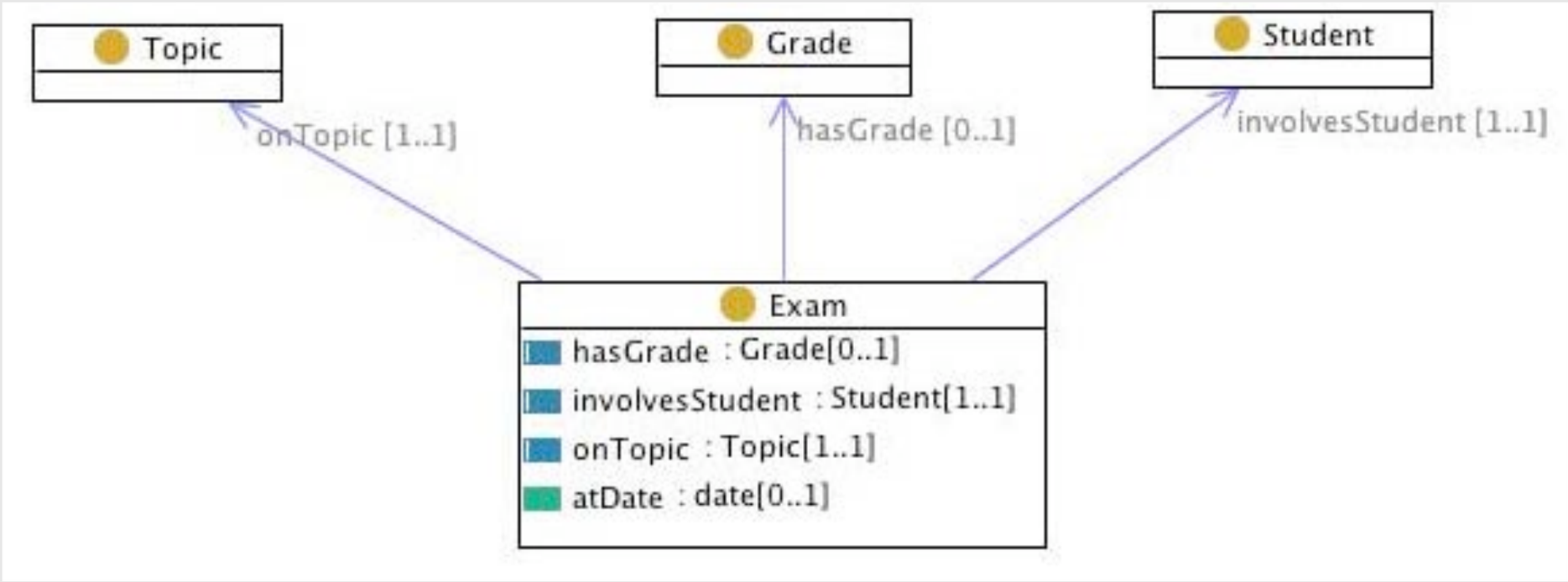
- Transformation patterns translate a logical expression from a logical language into another, which approximates the semantics of the first, in order to find a trade-off between requirements and expressivity

- We describe transformation patterns by two diagrams at different levels:
  - The first diagram shows the meta model elements needed for representing the pattern in OWL DL. Such elements are defined in http://www.loa-cnr.it/codeps/owl/owl10a.owl, an OWL ontology that encodes OWL DL constructs in a metamodel. The ontology is referred to by the prefix “a:”
  - The second diagram shows an example of usage for the Logical OP

Examples of Transformation patterns: N-ary relation (1/2)



Examples of Transformation pattern: N-ary relation (2/2)



But beware of identification constraints! [15]