Ontology Design Patterns

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Outline

- Motivation for ontology design patterns
- Logical ODPs
- Content ODPs
- Other ODPs and best practices
- Exercise

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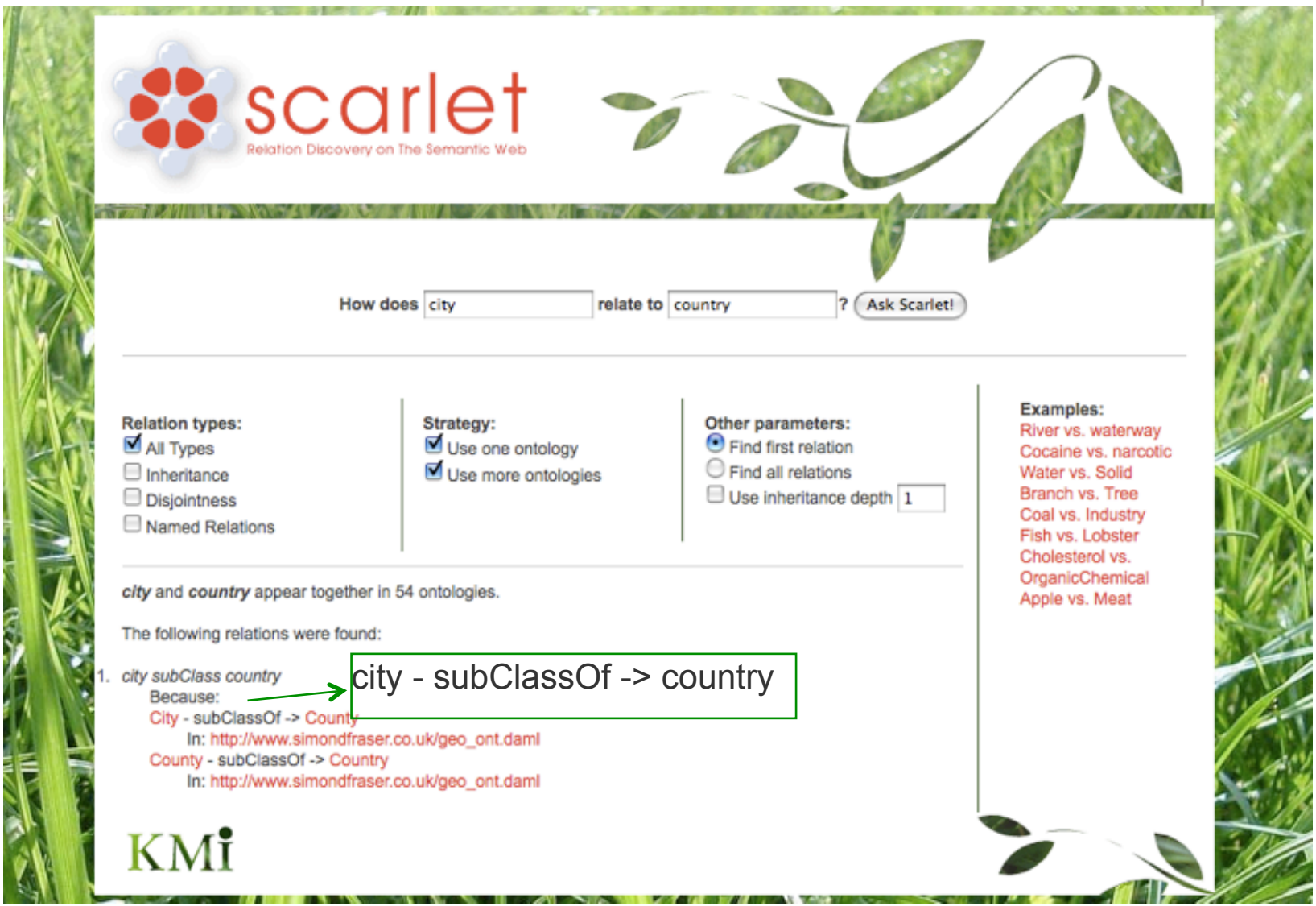
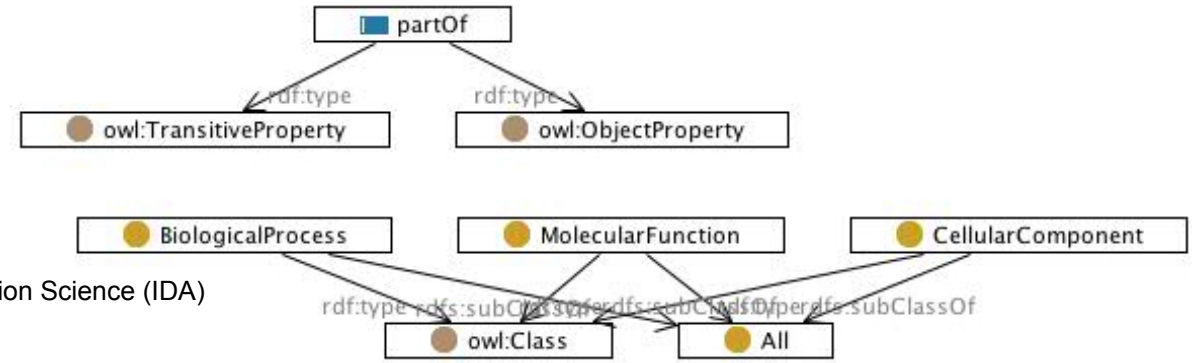

scarlet
Relation Discovery on The Semantic Web
How does city relate to country ? Ask Scarlet!
Relation types:
All Types
Inheritance
Disjointness
Named Relations
Strategy:
Use one ontology
Use more ontologies
Other parameters:
Find first relation
Find all relations
Use inheritance depth 1
Examples:
River vs. waterway
Cocaine vs. narcotic
Water vs. Solid
Branch vs. Tree
Coal vs. Industry
Fish vs. Lobster
Cholesterol vs. OrganicChemical
Apple vs. Meat
city and country appear together in 54 ontologies.
The following relations were found:
1. city subClass country
Because:
City - subClassOf -> County
In: http://www.simondfraser.co.uk/geo_ont.daml
County - subClassOf -> Country
In: http://www.simondfraser.co.uk/geo_ont.daml
city - subClassOf -> country
KMi

What we can do with OWL

- ... (maybe) we can check the consistency, classify, and query our knowledge base
- ... but, remember the Scarlet example
  - City subClassOf Country
- Logical consistency is not the main problem
  - e.g. owl:sameAs can be wrongly used and still we have consistency
- Why is OWL not enough?
  - OWL gives us logical language constructs, but does not give us any guidelines on how to use them in order to solve our tasks.
  - E.g. modeling something as an individual, a class, or an object property can be quite arbitrary

Solutions?

- OWL is not enough for building a good ontology, and we cannot ask all web users neither to learn logic, or to study ontology design
- Reusable solutions are here through Ontology Design Patterns, which help reducing arbitrariness without asking for sophisticated skills ...
- ... provided that tools are built for any user ☺



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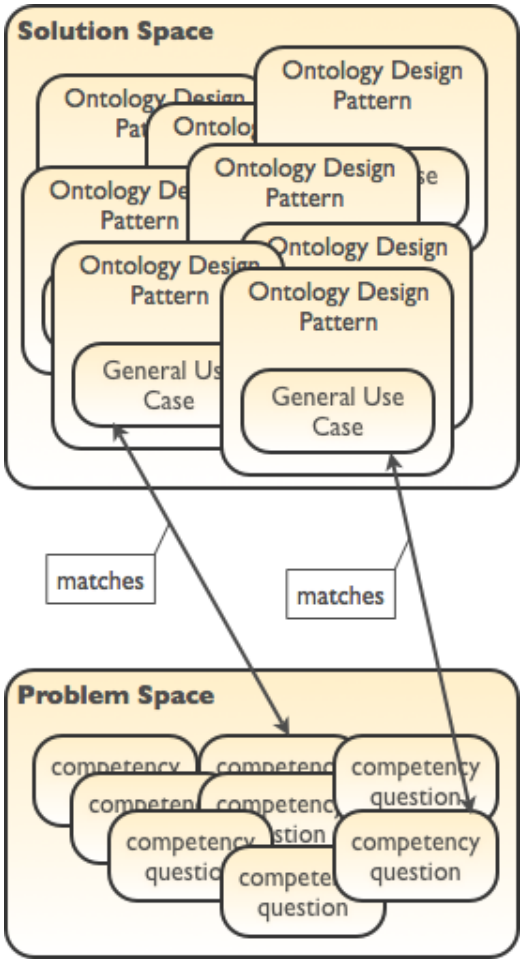
Ontology Design Patterns

An ontology design pattern is a reusable successful solution to a recurrent modeling problem



Logical Ontology Design Patterns

LiU expanding reality

Logical ODPs

- *Definition*
  - A Logical ODP is a formal expression, whose only parts are expressions from a logical vocabulary e.g., OWL, that solves a problem of expressivity
- Logical ODPs are independent from a specific domain of interest
  - i.e. they are content-independent

Logical ODPs

- A Logical ODP describes a formal expression that can be *exemplified, morphed, and instantiated* in order to solve a domain modeling issue
- **owl:Class:_:x rdfs:subClassOf owl:Restriction:_:y**
- *Inflammation rdfs:subClassOf (localizedIn some BodyPart)*
- *Colitis rdfs:subClassOf (localizedIn some Colon)*
- *John's_colitis localizedIn John's_colon*

Logical macros and Transformation ODPs

- Logical macros provide a shortcut to model a recurrent intuitive logical expression
  - Example:
    - Formally: R some Thing and R only C
    - Things that R, R at least one thing that is only C
    - Carnivore animals eat only animals + Carnivore animals eat some (at least one) animals
- Transformation ODPs
  - Example: Transforming a more expressive construct into something that can be expressed in OWL

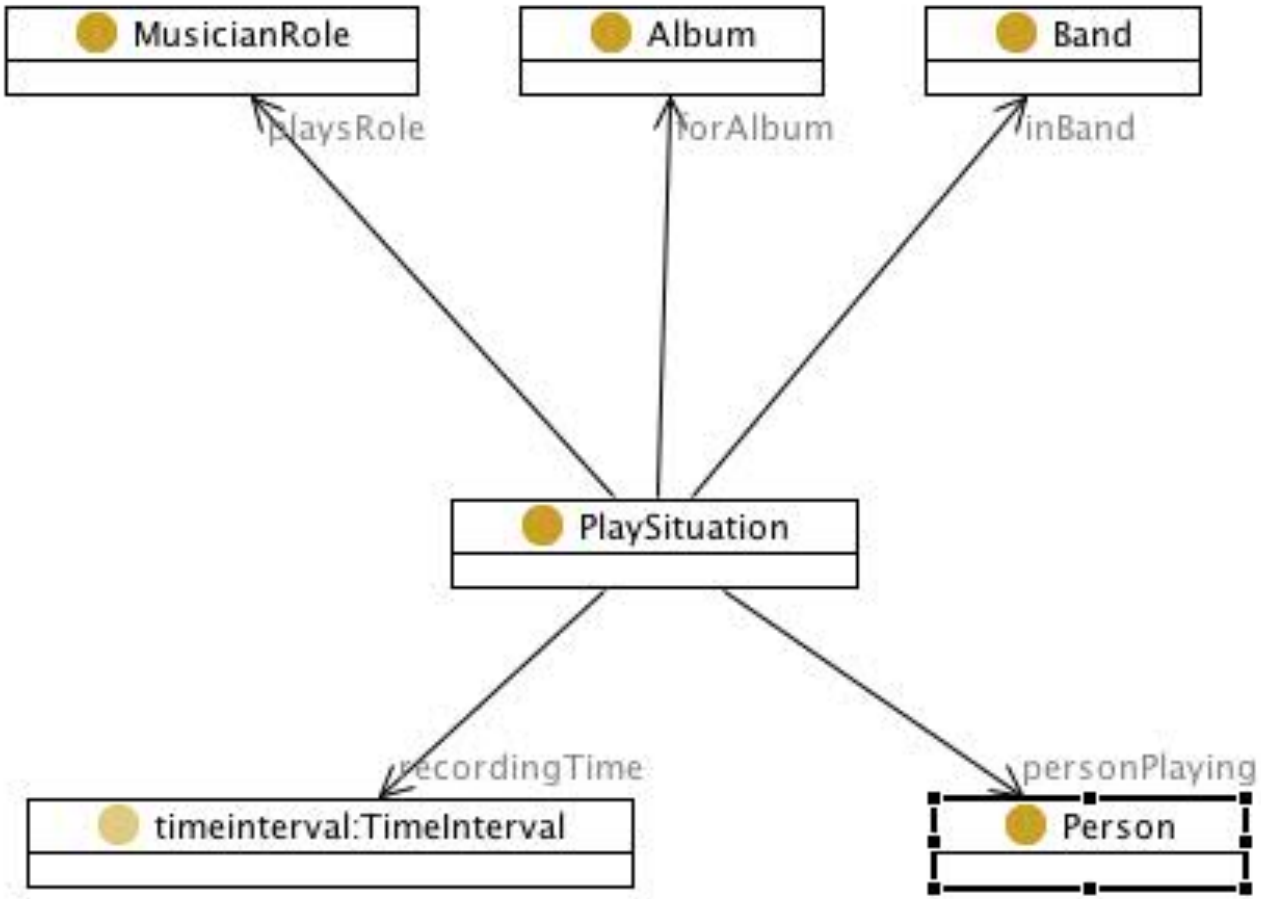
Transformation ODPs
Example: N-ary relation

- Chad Smith was the drum player of Red Hot Chili Peppers when they recorded their album Stadium Arcadium from September 2004 to December 2005.
- A person plays a certain role in a band during an album recording, taking place during a certain time interval

- N-ary relation:
  - PlaySituation(Person, MusicianRole, Band, Album, TimeInterval)

  - How can we express this in OWL with only binary relations?

Transformation ODPs
Example: N-ary relation



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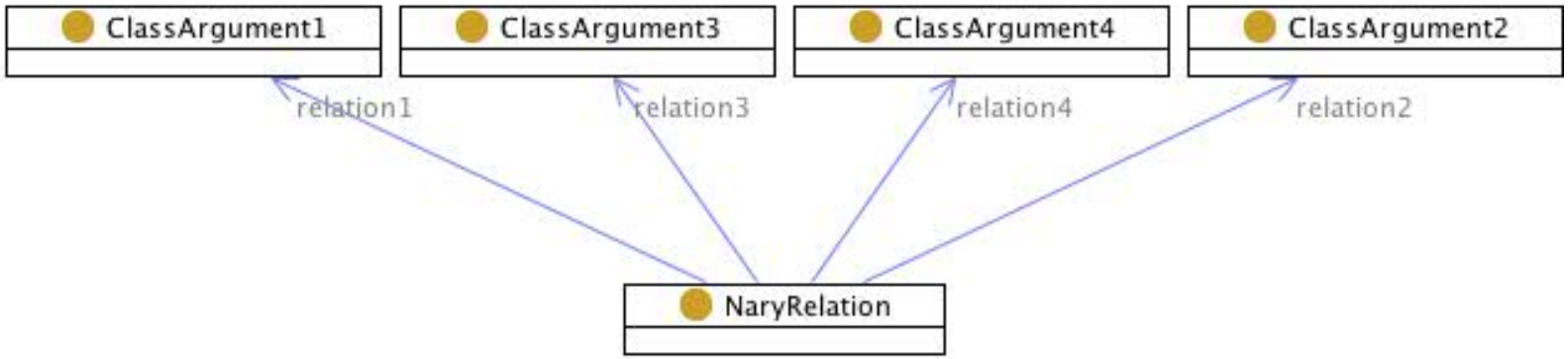
Transformation ODPs
Example: N-ary relation



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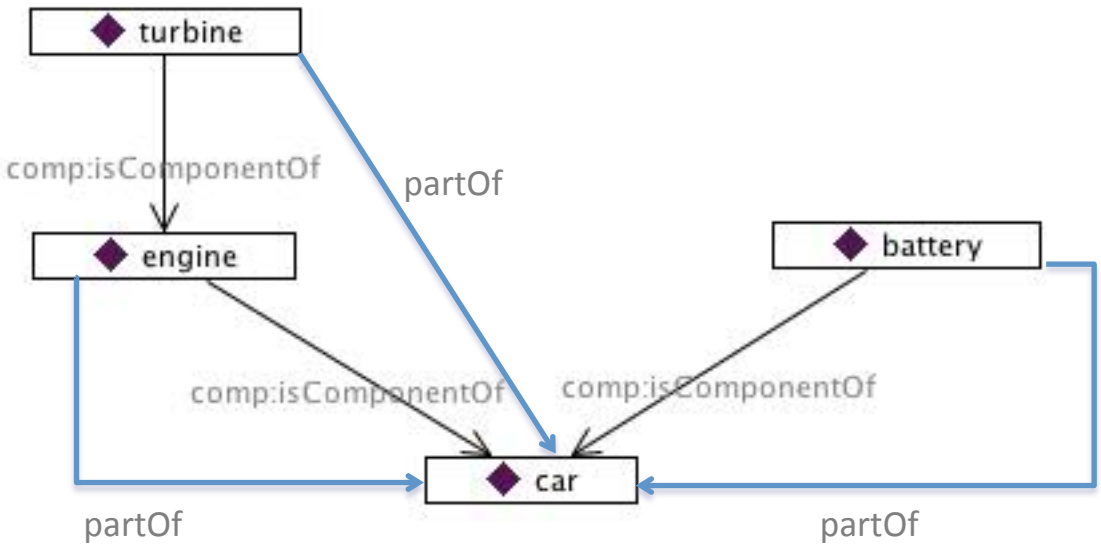
Transformation ODPs
Example: Transitive Reduction

- I want to represent that a car is composed of several parts
  - part of – transitive property
- I also want to represent that each part can have “direct” components
  - e.g. the turbine is a component of the engine
- The turbine is a component of the engine, hence it is part of the car, but not its “direct” component

Transformation ODPs
Example: Direct components in a car



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Transformation ODPs
Example: Transitive reduction

aProperty rdf:type owl:TransitiveProperty

anotherProperty rdfs:subPropertyOf aProperty

anotherProperty does not inherit transitivity, but:

entity1 anotherProperty entity2

implies

entity1 aProperty entity2

Content ODPs

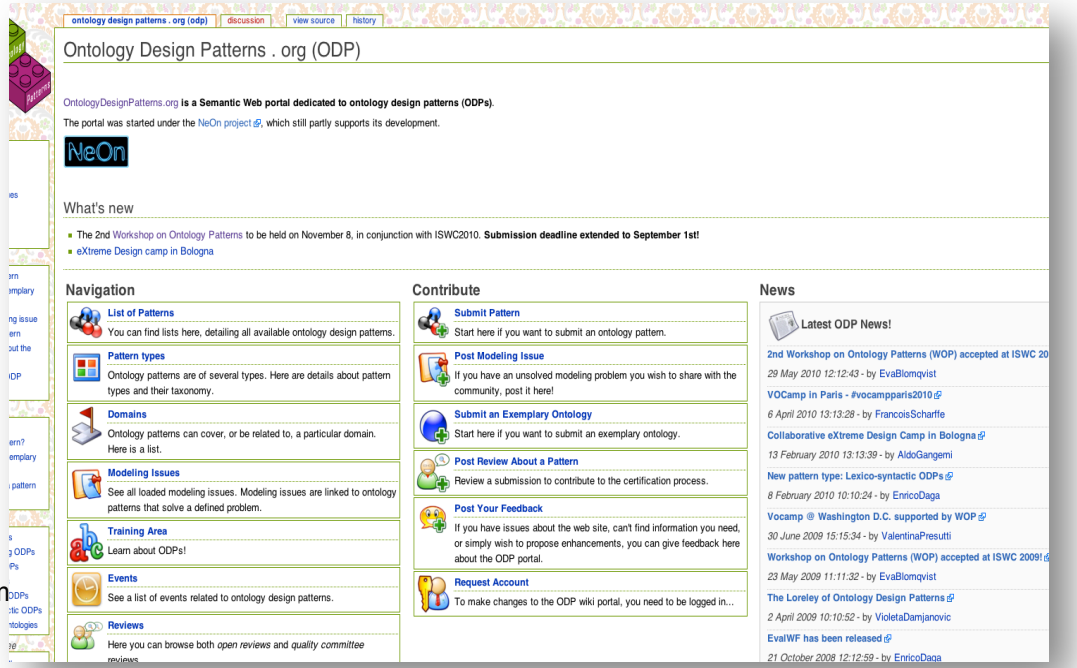
LiU expanding reality

Content ODPs (CPs)

- CPs encode conceptual, rather than logical design patterns.
  - Logical ODPs solve design problems independently of a particular conceptualization
  - CPs are patterns for solving design problems for the domain classes and properties that populate an ontology, therefore they address content problems
- CPs are instantiations of Logical ODPs (or of compositions of Logical ODPs), featuring a non-empty signature
  - Hence, they have an explicit non-logical vocabulary for a specific domain of interest, i.e. they are content-dependent

Catalogues of CPs

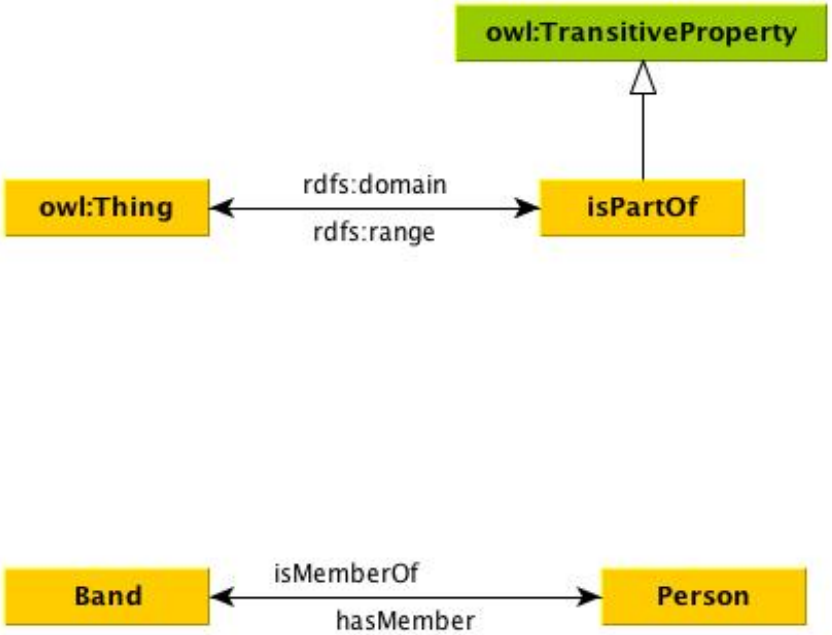
- Content ODPs are collected and described in catalogues and comply to a common presentation template
- The ontologydesignpatterns.org initiative maintains a repository of CPs and a semantic wiki for their description, discussion, evaluation, certification, etc.

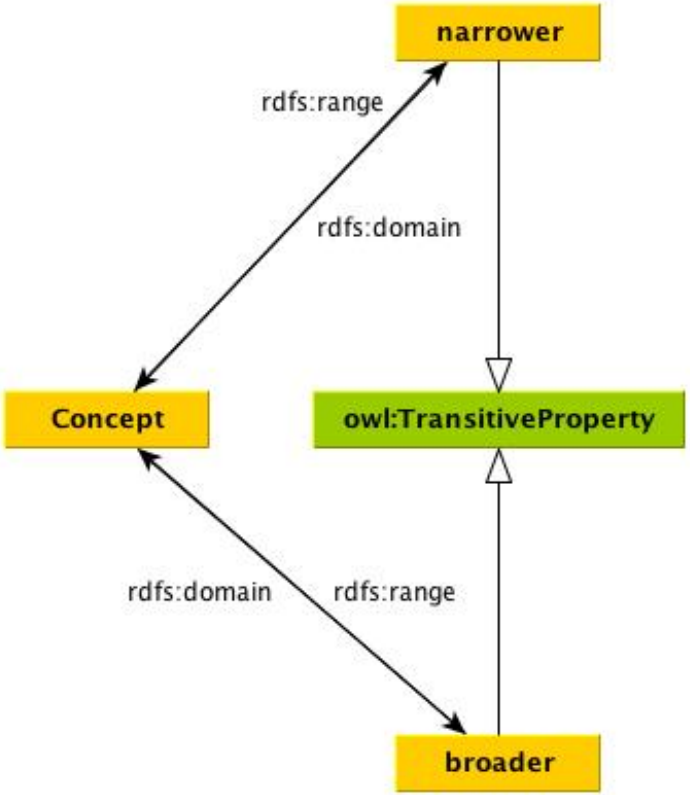


Pragmatic characteristics of CPs

- Domain-dependent
  - Expressed with a domain-specific (non-logical) vocabulary
- Requirement-covering
  - Solve domain modeling problems (expressible as use-cases, tasks or “competency questions”), at a typical maximum size (cf. blink)
- Reasoning-relevant components
  - Allow some form of inference (minimal axiomatization, e.g. not an isolated class)
- Cognitively-relevant components
  - Catch relevant core notions of a domain and the related expertise -- blink knowledge
- Linguistically-relevant components
  - Are lexically grounded, e.g. they match linguistic frames, or at least a domain terminology
- Examples:
  - PartOf, Participation, Plan, Legal Norm, Legal Fact, Sales Order, Research Topic, Legal Contract, Inflammation, Medical Guideline, Gene Ontology Top, Situation, TimeInterval, etc.

Examples of CPs





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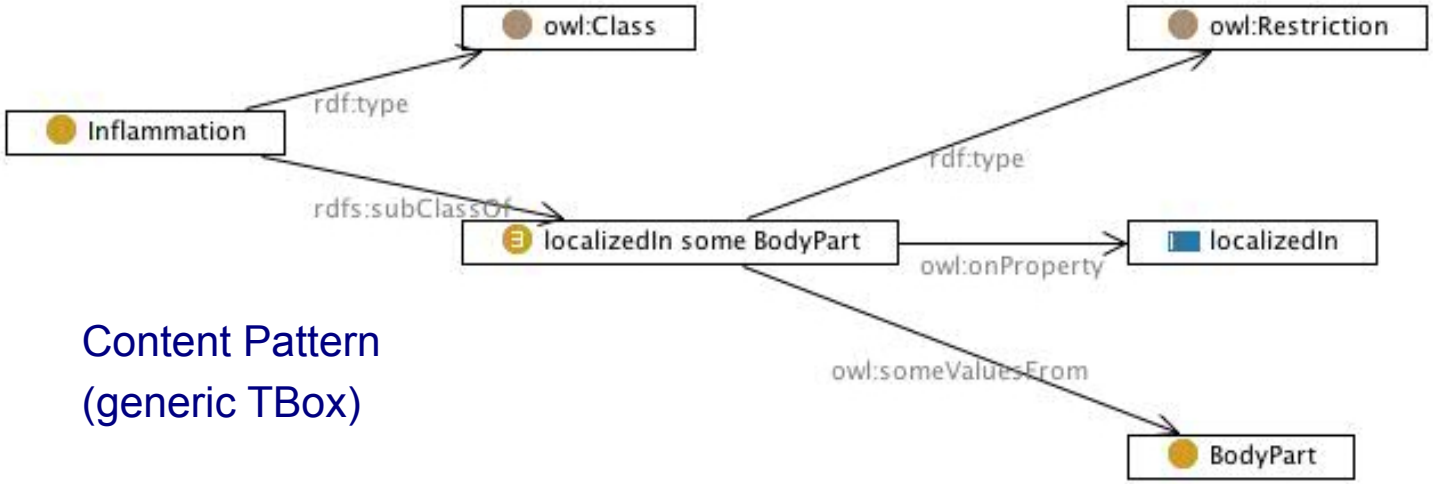
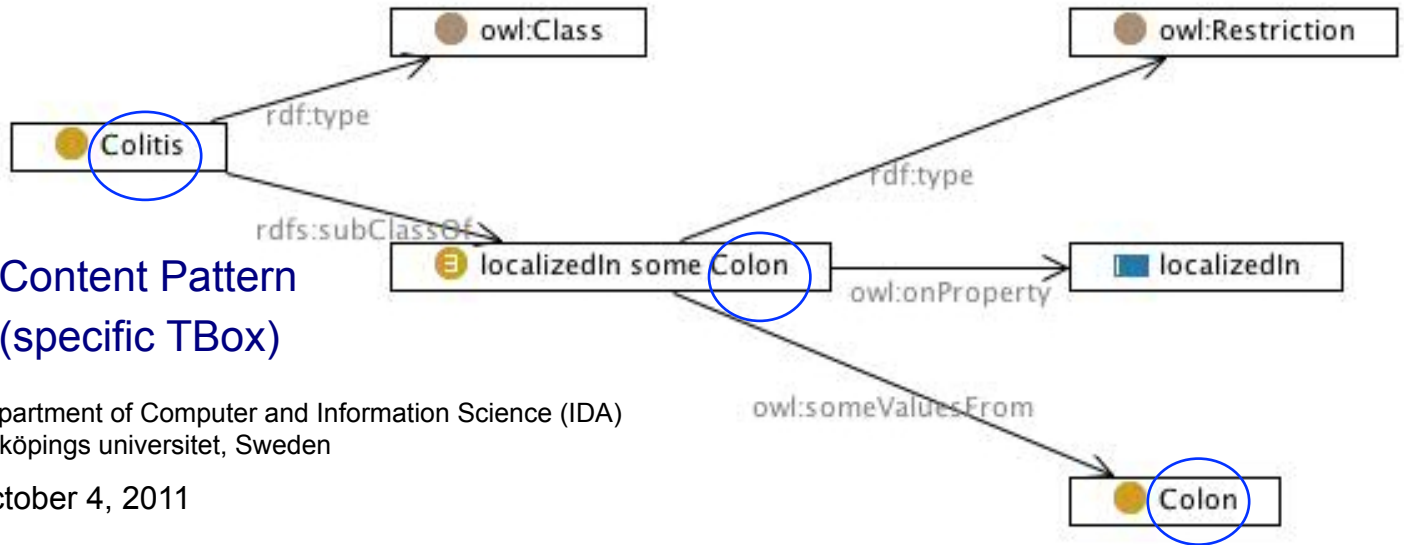
Examples of CPs



Content Pattern
(generic TBox)



Content Pattern
(specific TBox)

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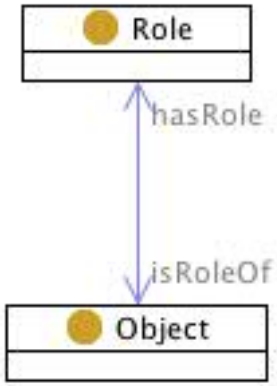
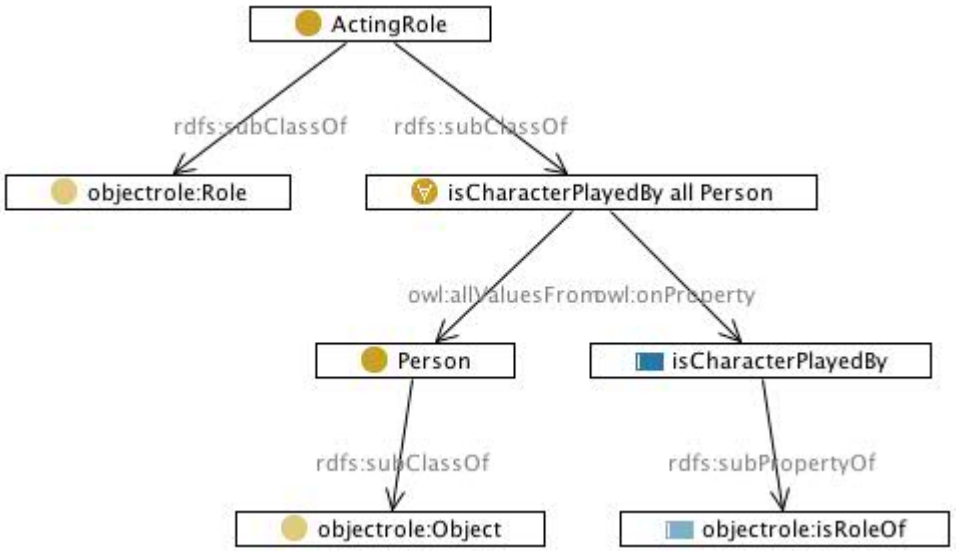
Sample Specialization





- A content pattern CP_2 specializes CP_1 if at least one ontology element of CP_2 is subsumed by an ontology element of CP_1
  - i.e., either by *rdfs:subClassOf* or *rdfs:subPropertyOf*

Composition

- The composition operation relates two CPs and results into a new ontology
- The resulting ontology is composed of the union of the ontology elements and axioms from the two CPs, plus the axioms (e.g. disjointness, equivalence, etc.) that are added in order to link the CPs
- The composition of CP_1 and CP_2 consists of creating a semantic association between CP_1 and CP_2 by adding at least one new axiom, which involves ontology elements from both CP_1 and CP_2
- Typically, also new elements ("expansion") are added when composing

General Content ODPs

- Roles of objects
- Classification
- Part-whole relationships
- Membership
- Information and its realization
- Sequences
- Topics
- Time
- Places
- Moving
- Plans
- Events
- Descriptions and Situations

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Example: Roles of objects

- Objects can play different roles in different situations
- Depending on the constraints given by the requirements, modeling of objects and their roles can be addressed differently
- Do we want to represent properties of roles?
- Do we want to classify objects based on their roles?
- Do we want to assert facts about roles?

Roles of objects

- A beer mug used as vase
- Books used as table's legs
- A sax player (person)
- A song writer (person)

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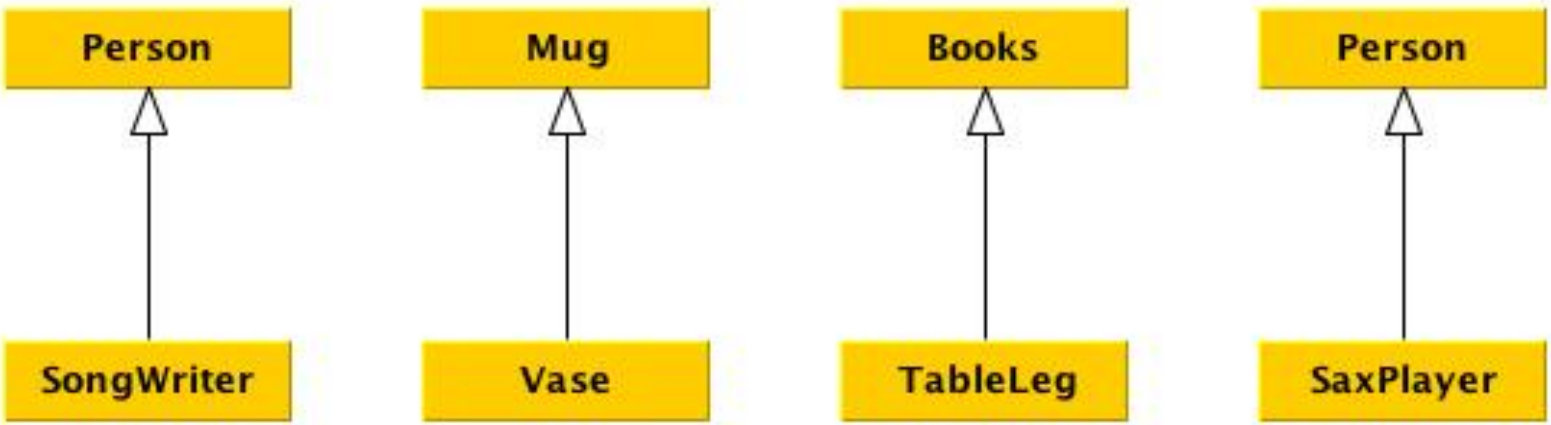
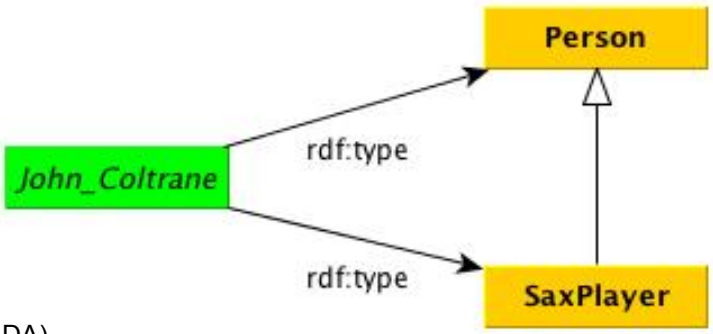
1st ODP: Roles as classes

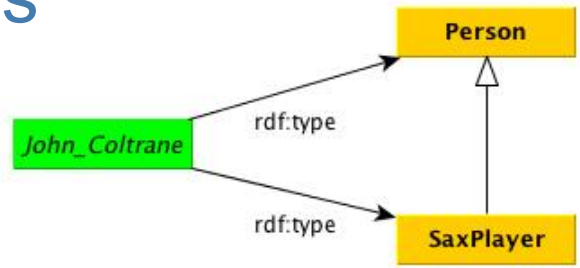


1st ODP: Roles as classes

- An object and its roles are related through the rdf:type property
- rdf:type relations can be either asserted or inferred through classification
- In order to automatically classify individuals in a certain class the ontology has to define appropriate axioms

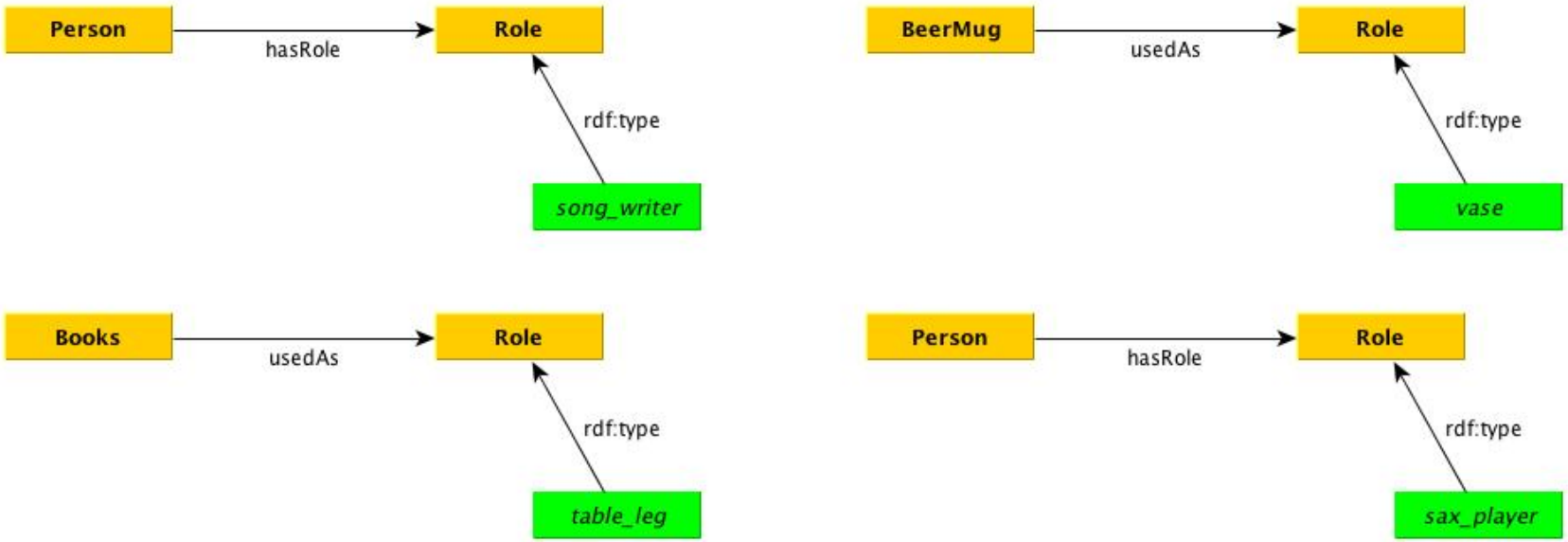


1st ODP: Roles as classes



- Consequences
  - Low expressivity
  - Roles are described at TBox level
  - Class taxonomy is bigger - a class for each role
  - Class taxonomy is entangled - multi-typing
  - ABox is smaller – same individual, several (role) types
  - Automatic classification of individuals through rdfs:subClassOf inheritance – with proper axioms
  - Roles cannot be indexed in terms of space and time
  - Facts about roles cannot be expressed e.g. “Roles in UniBo can be student, professor, researcher”, “Valentina is teacher for KMDM course”
  - Queries: `?x a SongWriter`
- General CQs
  - What things have a certain (role) type?

2nd ODP: Roles as individuals



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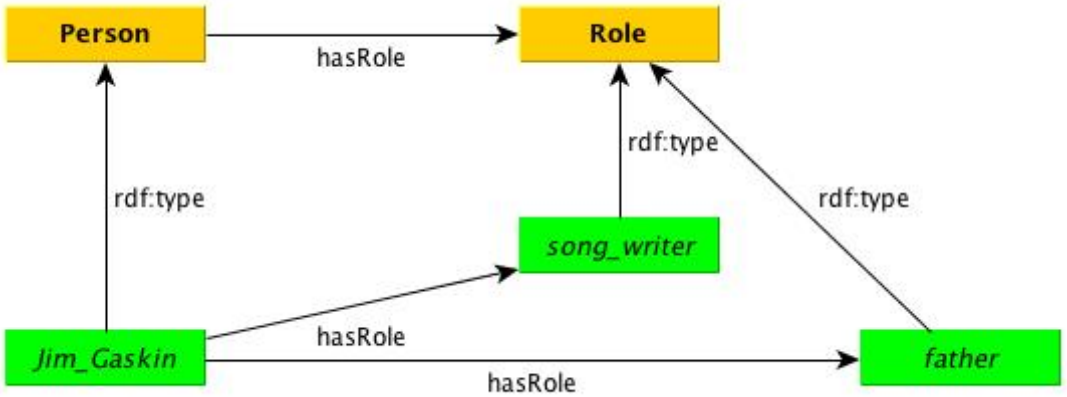
2nd ODP: Roles as individuals

- An object and its roles are related through domain-specific relations
- Relations between an object and its roles have to be asserted
- Automatic inference of relations between an object and its roles can be obtained through property subsumption



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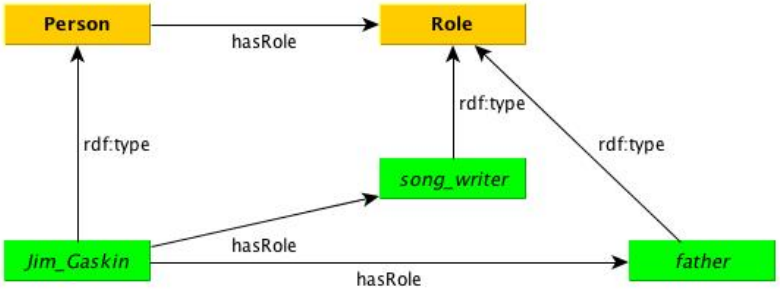
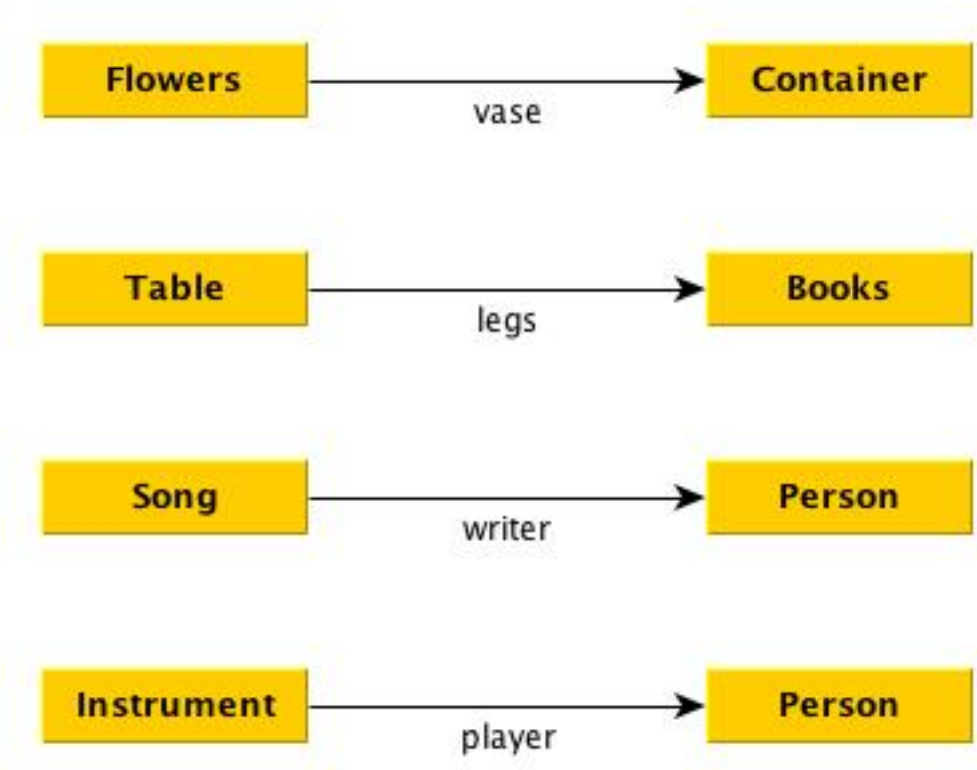
2nd ODP: Roles as individuals



- Consequences
  - More expressive
  - Roles are described at ABox level
  - Class taxonomy is smaller – roles are individuals
  - Abox is bigger
  - Facts on roles can be asserted
  - Roles can be indexed in terms of time and space - through n-ary relations
  - N-ary relations are needed for relating an object to its role with respect to some other object e.g. Valentina is teacher for KMDM course
    - kmdm_teacher involvesPerson Valentina
    - kmdm_teacher involvesRole teacher
    - kmdm_teacher involvesCourse KMDM
    - Valentina hasRole teacher
  - Roles do not type objects, no automatic classification of objects
  - Queries: `?x hasRole ?y ; ?x a Role`
- General CQs
  - What roles does an object have? What things have a certain role?

3rd ODP: Roles as properties



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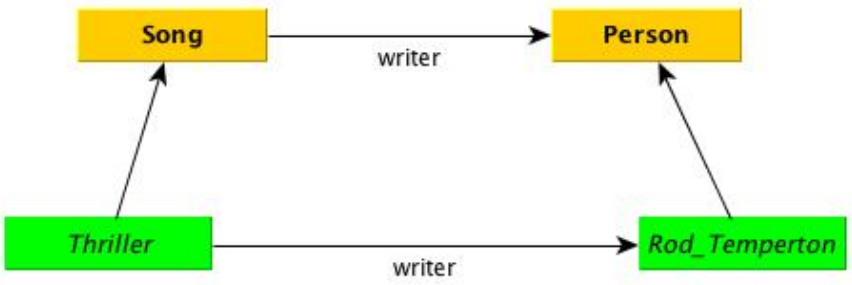
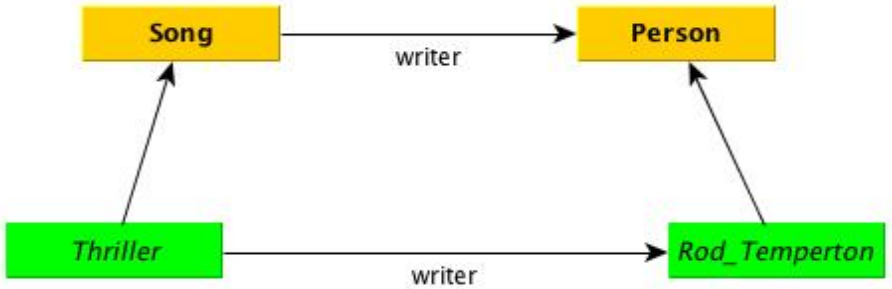
3rd ODP: Roles as properties

- The semantics of “having a role” is embedded in the name of a property
- Objects are not explicitly related to their roles, they are related to other things through a property expressing an action they perform, a role they play
- Most common pattern in the web of data for modeling roles



3rd ODP: Roles as properties

- Consequences
  - Smaller taxonomy of classes
  - Bigger taxonomy of properties – a property for each role
  - Simpler graph of data – one triple for “Valentina is teacher for KMDM course”
    - `Valentina teaches KMDM`
  - Roles cannot be indexed in terms of space and time
  - Semantics of roles is implicit (embedded in a property name)
  - Facts about roles cannot be expressed
  - Queries: ?x teaches ?y
- General CQs
  - Who did something?

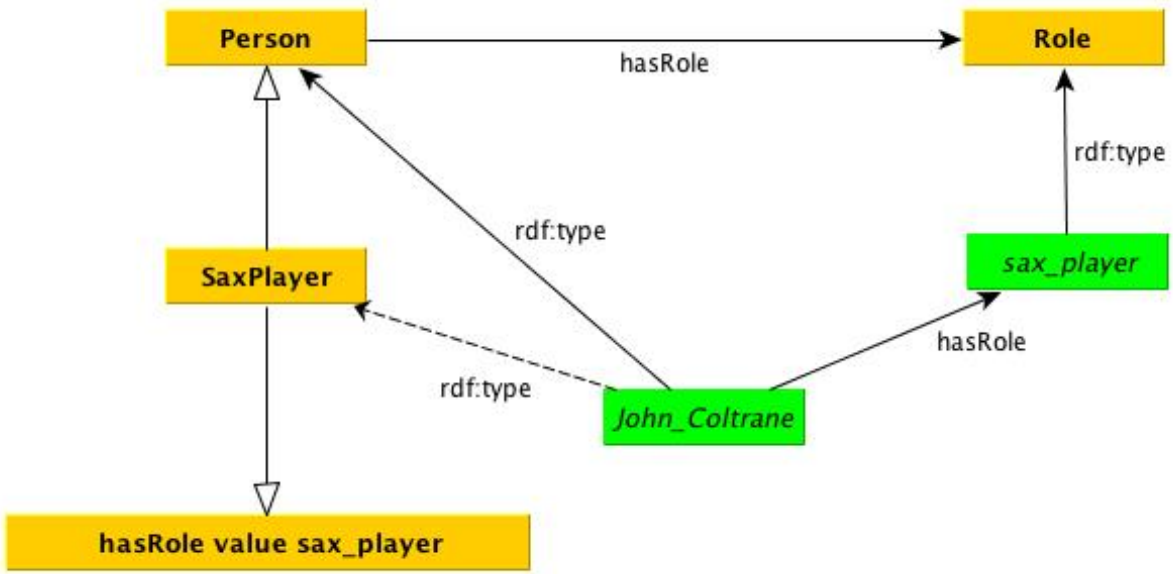


ODPs for Roles of objects - Summary

- The three solutions differ in expressivity, simplicity, and CQs
  - Simplest is roles as properties
  - Most expressive is roles as individuals
  - Least expressive is roles as classes
- Each of them has pros and cons
- The choice depends on requirements
- What about combining them?

Combining roles as instances with roles as classes

- A class Role
- A class for each Role e.g. SaxPlayer
- A property restriction on classes representing roles, for automatic classification



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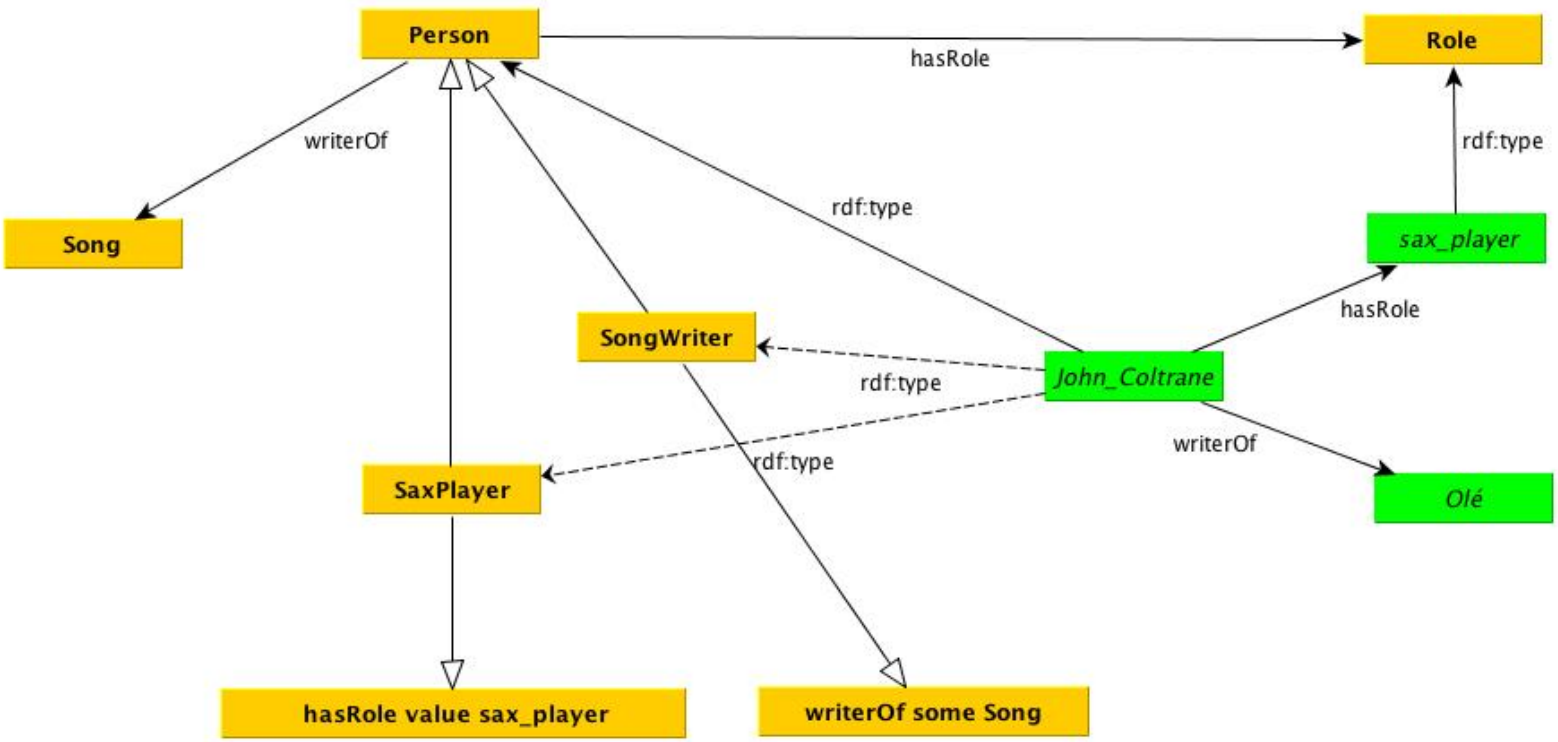
…and add roles as properties

- Note the restriction on property writerOf



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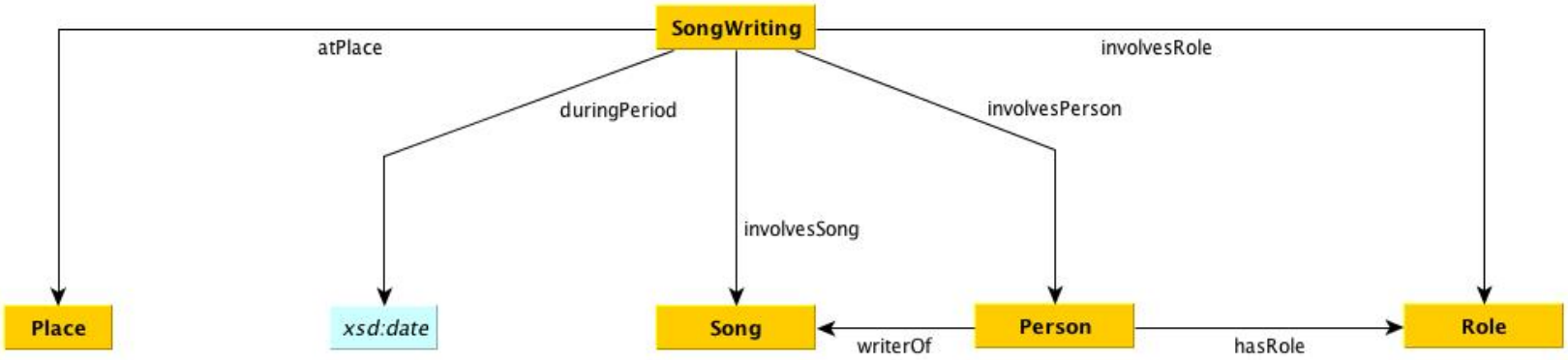
Indexing roles in terms of time and space



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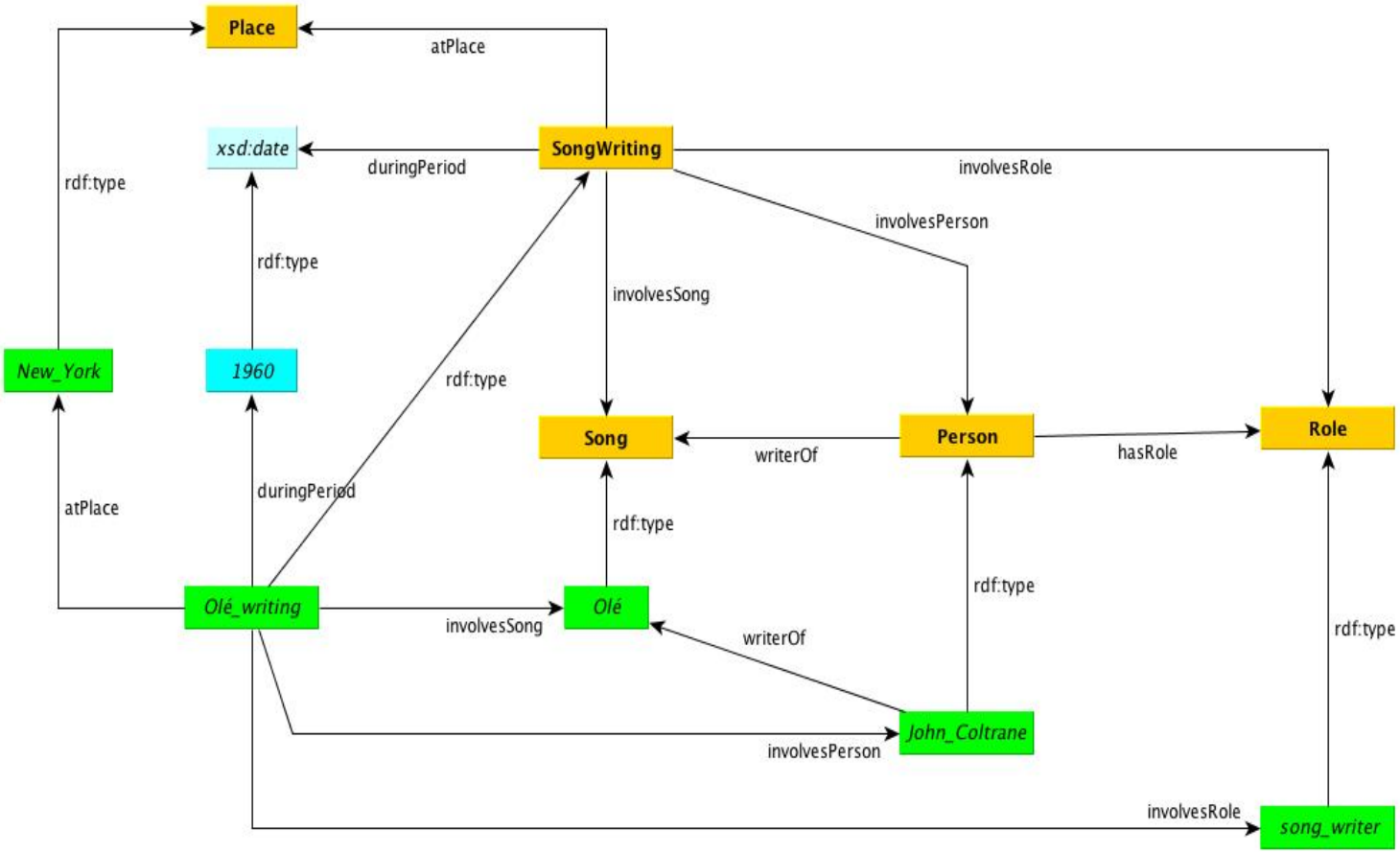
Indexing roles in terms of time and space



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Content ODPs for roles of objects

- The general pattern is called “classification”
- Object-Role and Agent-Role
  - OWL pattern representing roles as individuals
  - http://ontologydesignpatterns.org/wiki/Submissions:Objectrole
  - http://ontologydesignpatterns.org/wiki/Submissions:AgentRole
- Time-indexed person role-pattern
  - http://ontologydesignpatterns.org/wiki/Submissions:Time_indexed_person_role
- Time-place-indexed object-role
  - N-ary relation representing an objects, the roles it plays at a certain date in a certain place
  - http://www.ontologydesignpatterns.org/cp/owl/dul/timeplaceindexedobjectrole.owl

Other ODPs?

- Lexico-syntactic ODPs
  - What patterns in text correspond to logical constructs, e.g. in OWL?
- Presentation ODPs
  - Templates for annotation and documentation
  - Naming conventions
    - Singular for class names
    - Readable property names
    - URI conventions
- Correspondence ODPs
  - Reengineering ODPs for transforming DBs, XML etc into OWL
  - Alignment patterns, i.e. correspondence between alternative modeling choices

ODPs vs. “best practices”?

- ODPs ideally represent “best practices”
- Some things that are called “best practices” in other areas are collected under the ODP umbrella
  - C.f. naming conventions
- What about automatically generated ODPs? Top-down vs. bottom-up pattern engineering…
  - EKPs
  - Linguistic Frames

Exercise – Exploring the ODP portal

- ODP selection
- Given a set of requirements find Content ODPs that could be used as components in a solution

- http://ontologydesignpatterns.org/wiki/Training:Advanced_Ontology_Engineering_at_FOI_-_2011/Ontology_Design_Patterns