Ontology Engineering
- The basics of OWL

Eva Blomqvist

eva.blomqvist@liu.se

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Outline

- Recap from the ontology intro
- Ontology languages and logic
- Main focus: OWL
  - What does the OWL language contain?
  - Common misconceptions

Reminders from ontology intro

Components

- concepts
  - represent a set or class of entities in a domain

    immune response
  - organized in taxonomies (hierarchies based on e.g. *is-a* or *is-part-of*)

    immune response is-a *defense response*

- instances
  - often not represented in an ontology (instantiated ontology)

Components

- relations

  R: C1 x C2 x … x Cn

Protein hasName ProteinName

Chromosone hasSubcellularLocation Nucleus

Components

- axioms

  ‘facts that are always true’

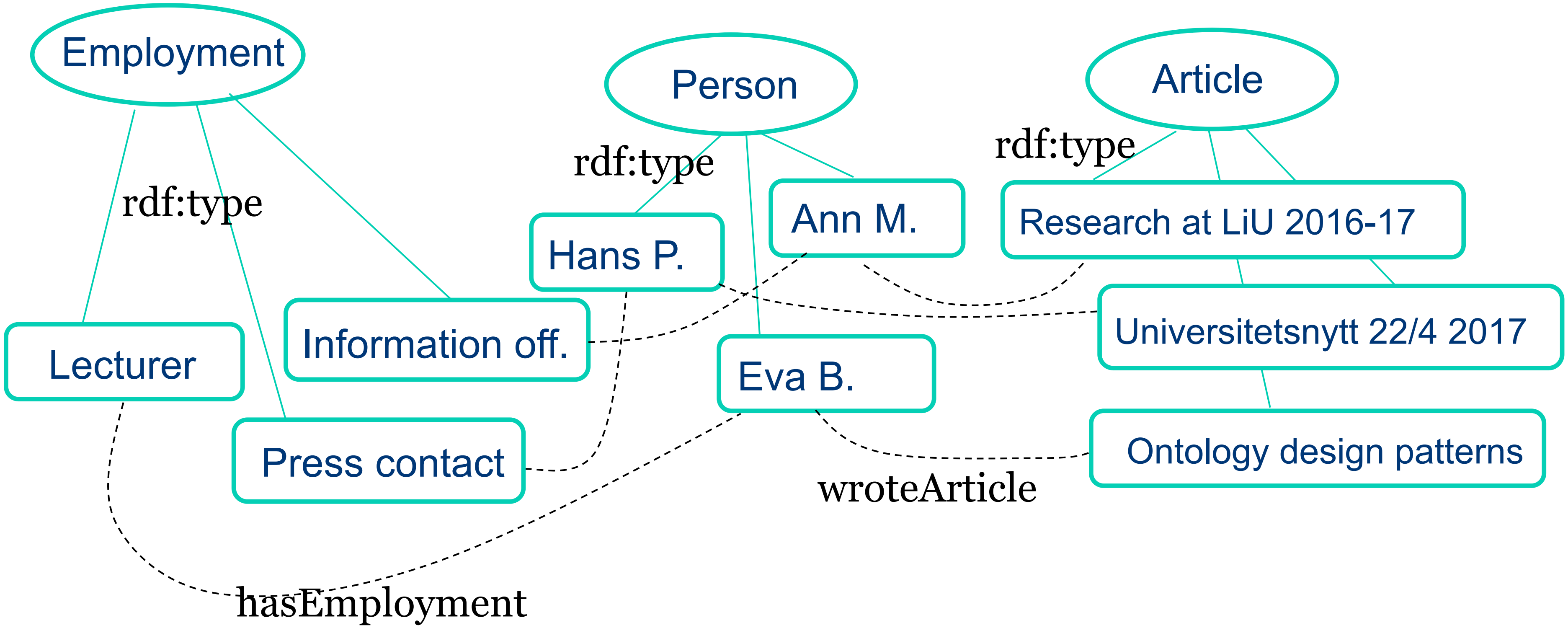
The origin of a protein is always of the type ‘gene coding origin type’

Each protein has at least one source.

A helix can never be a sheet and vice versa.

Example

We have a lot of data and want to be able to ask for all research articles



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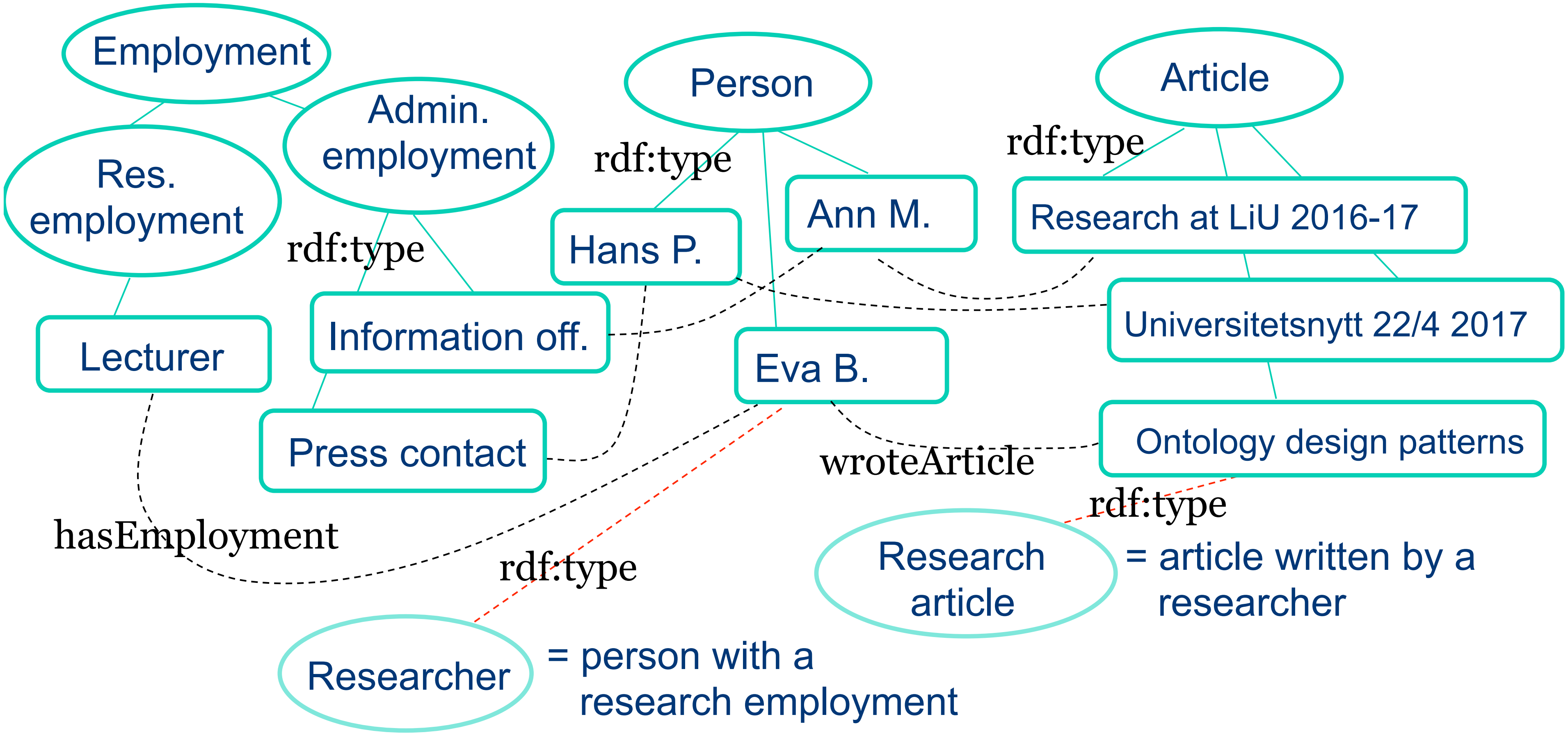

Ontologies as vocabularies for RDF data

- Concepts (classes) that represent the types of instances in the data
- Properties that can be used as predicates in our RDF triples

Then we can add more… IF we need to

In this course we focus on task-oriented ontologies, i.e. ontologies that serves a specific purpose, fulfils a certain set of requirements

Ontology languages for the Semantic Web

RDF(S): RDF Schema

- RDF gives a data representation format and ways to serialize, but it does not give any special meaning to vocabulary such as “subClassOf” or “range”
- Triple interpretation is an arbitrary binary relation
- RDF Schema extends RDF with a schema vocabulary
  - Classes as types for individuals: rdfs:Class, rdfs:Literal, rdfs:Datatype, rdf:type and rdfs:subClassOf, etc.
  - Property relations: rdf:Property, rdfs:subPropertyOf, rdfs:range, rdfs:domain, etc.
  - Annotations: rdfs:label, rdfs:comment, etc.

RDF/RDF(S) “Liberality”

- No distinction between classes and instances (individuals)
- Properties can themselves have properties
- No distinction between language constructors and ontology vocabulary, so constructors can be applied to themselves/each other

What does RDF(S) give us?

- Ability to use simple schema/vocabularies when describing our resources

- Consistent vocabulary use and sharing

- Simple inference, e.g. inheritance in a taxonomy

- But…
  - In some cases too weak to describe resources in sufficient detail
  - Not formally based on any logic

What are Description Logics?

- A family of logic based Knowledge Representation formalisms
  - Descendants of Semantic Networks, Minsky's frames, and KL-ONE
  - Describe domain in terms of concepts (classes), roles (relationships) and individuals

- Distinguished by
  - Formal semantics (model theoretic)
    - Decidable fragments of FOL
    - Closely related to Propositional Modal & Dynamic Logics
  - Provision of inference services
    - Sound and complete decision procedures for key problems
    - Implemented systems (highly optimized)

DL Semantics

- Model theoretic semantics. An interpretation consists of
  - A domain of discourse (a collection of objects)
  - Functions mapping
    - classes to set of objects
    - properties to sets of pairs of objects
  - Rules describe how to interpret the constructors and tell us when an interpretation is a model.
- In DL, a class description is thus a characterization of the individuals that are members of that class.

OWL

- DL-based language
- OWL2 is the latest version of the standard (https://www.w3.org/TR/owl2-primer/)
- Different language profiles
  - OWL EL
    - Intended for large ontologies with many classes, mainly used for classification tasks
    - Example use: biomedical ontologies
    - Not allowed: negation, disjunction, inverse properties, universal quantification on properties
  - OWL QL
    - Covers most features of UML and ER-models, so is suitable for use with relational data
    - Example use: ontologies used to access relational data
  - OWL RL
    - Reasoning can be implemented as rules
    - Does not allow expressions that assume an anonymous individual

OWL syntaxes

- Abstract syntax
  - Used in the definition of the language
- Manchester syntax
- OWL in RDF
  - RDF/XML presentation
  - Turtle
- …

OWL Class Constructors

Constructor	Example, Turtle syntax	Example, Manchester syntax
<Classes>	:Human rdf:type owl:Class	Class: Human
intersectionOf	owl:intersectionOf (:Human :Male)	Human and Male
unionOf	owl:unionOf (:Male :Female)	Female or Male
complementOf	owl:complementOf (:Male)	not Male
oneOf	owl:oneOf (:John :Mary)	{John, Mary}

OWL Individual Axioms

Axiom	Example, Turtle syntax	Example, Manchester syntax
<Individual>	:Mary rdf:type :Human	Individual: Mary Types: Human
<Fact>	:Mary :worksWith :John	Individual: John Facts: worksWith Mary
differentFrom	:Mary owl:differentFrom :John	Individual: Mary DifferentFrom: John
sameAs	:Mary owl:sameAs :May	Individual: Mary SameAs: May

OWL Class Axioms

Axiom	Example, Turtle syntax	Example, Manchester syntax
subClassOf	:Woman rdfs:subClassOf :Human	Class: Woman SubClassOf: Human
equivalentClass	:Person owl:equivalentClass :Human	Class: Person EquivalentTo: Human
disjointClass	[] rdf:type owl:AllDisjointClasses ; owl:members (:Woman :Man) .	DisjointClasses: Woman, Man

OWL Class Constructors (cont.)

Constructor	Example, Turtle syntax	Example, Manchester syntax
someValuesFrom	owl:onProperty :hasChild ; owl:someValuesFrom :Male	hasChild some Male
allValuesFrom	owl:onProperty :hasChild ; owl:allValuesFrom :Female	hasChild only Female
minCardinality	owl:minQualifiedCardinality "2"^^xsd:nonNegativeInteger ; owl:onProperty :hasChild	hasChild min 2
maxCardinality	owl:maxQualifiedCardinality "2"^^xsd:nonNegativeInteger ; owl:onProperty :hasChild	hasChild max 2

OWL Property Axioms

Axiom	Example, Turtle syntax	Example, Manchester syntax
subPropertyOf	:hasSon rdfs:subPropertyOf :hasChild	ObjectProperty: hasSon SubPropertyOf: hasChild
domain	:hasChild rdfs:domain :Parent	ObjectProperty: hasChild Domain: Parent
range	:hasSon rdfs:range :Man	ObjectProperty: hasSon Range: Man
symmetric	:worksWith rdf:type owl:SymmetricProperty	ObjectProperty: worksWith Characteristics: Symmetric
transitive	:hasAncestor rdf:type owl:TransitiveProperty	ObjectProperty: hasAncestor Characteristics: Transitive
inverseOf	:hasParent owl:inverseOf :hasChild	ObjectProperty: hasParent InverseOf: hasChild

Other useful OWL constructs

- XML namespaces and prefixes
  - Turtle: @prefix : <http://example.com/owl/families/> .
    @prefix owl: <http://www.w3.org/2002/07/owl#> .
  - Manchester: Prefix: : <http://example.com/owl/families/>
    Prefix: owl: <http://www.w3.org/2002/07/owl#>
- Datatype properties and XML schema datatypes
  - Turtle: :John :hasAge 33
  - Manchester: Individual: John
    Facts: hasAge "33"^^xsd:integer
- Property chains and keys
- owl:imports
- owl:Ontology
- Annotation properties
  - rdfs:label, rdfs:comment, …

Common misconceptions

- Disjointness of primitives
- Properties do not "belong" to classes
- 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 an unsatisfiable class
- Similarly with individuals – the so-called Unique Name Assumption does not hold, and individuals are not considered to be distinct unless explicitly asserted to be so.

Properties

- Unlike frame-based languages, UML and many other common modelling languages in OWL properties do not "belong" to any specific class
- To "connect" a property to a class we can
  - Add domain and range axioms of the property
  - Add restrictions on the class
- But neither is necessary for it to be a valid OWL ontology!

Domain and Range

- Note domain and range are NOT interpreted as a constraint as you might expect
- Domain and range assertions allow us to make inferences about individuals
- Example

```
:hasChild rdfs:domain :Parent
:Mary :hasChild :Bob
```

  - If we haven't said anything else about Mary or Bob, this is not an error. But we can now infer that Mary is a Parent

And/Or and quantification

- The logical connectives *and* and *or* often cause confusion
  - Milk and sugar? Tea or coffee? – think carefully of the meaning when modeling
- Quantification can be contrary to our intuition.
  - Universal quantification over an empty set is true
  - `:John` may belong to the class `:OnlyDaughterParent` if he has no child at all and we describe that class as:

```
:OnlyDaughterParent  rdf:type    owl:Class ;
    owl:equivalentClass  [
        rdf:type             owl:Restriction ;
        owl:onProperty       :hasChild ;
        owl:allValuesFrom    :Female
    ] .
```

- Existential quantification may imply the existence of an individual that we don't know the name of

Closed 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 only through 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 don't know that x is of type C, then we assume that x is NOT of type C

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