Ontology Engineering

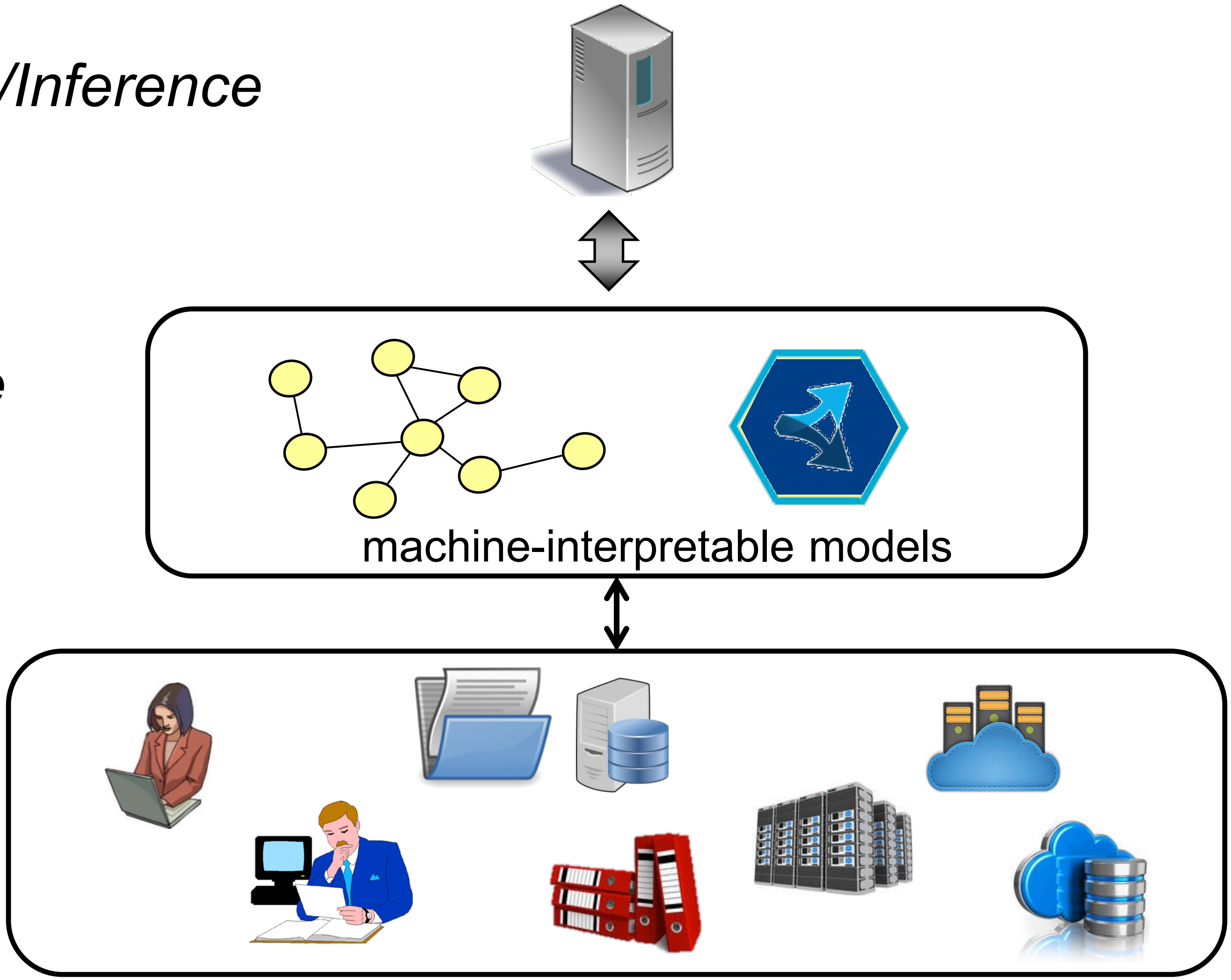
Knut Hinkelmann

Knowledge-Representation and Reasoning

Reasoning/Inference

Knowledge Base

Reality



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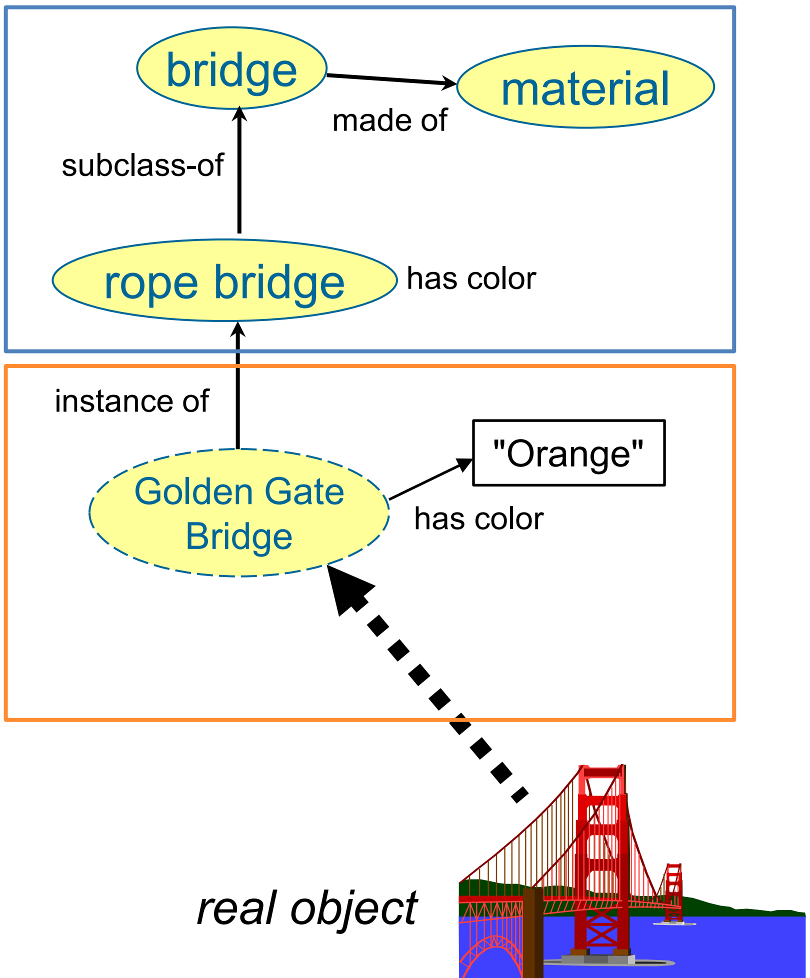
An Ontology – very informal

An ontology is a formal explicit description of concepts in a domain of discourse



- An ***ontology*** consists of
  - Concepts (Classes),
  - Relationships (Object Properties) between concepts
  - Attributes (Data Properties) of concepts
  - Constraints that hold between/for the concepts,
- An ontology together with a set of individual instances constitutes a ***knowledge base***

https://people.cs.uct.ac.za/~mkeet/OEbook/slides/L1IntroOE19.pptx ontology engineering

is

knowledge engineering

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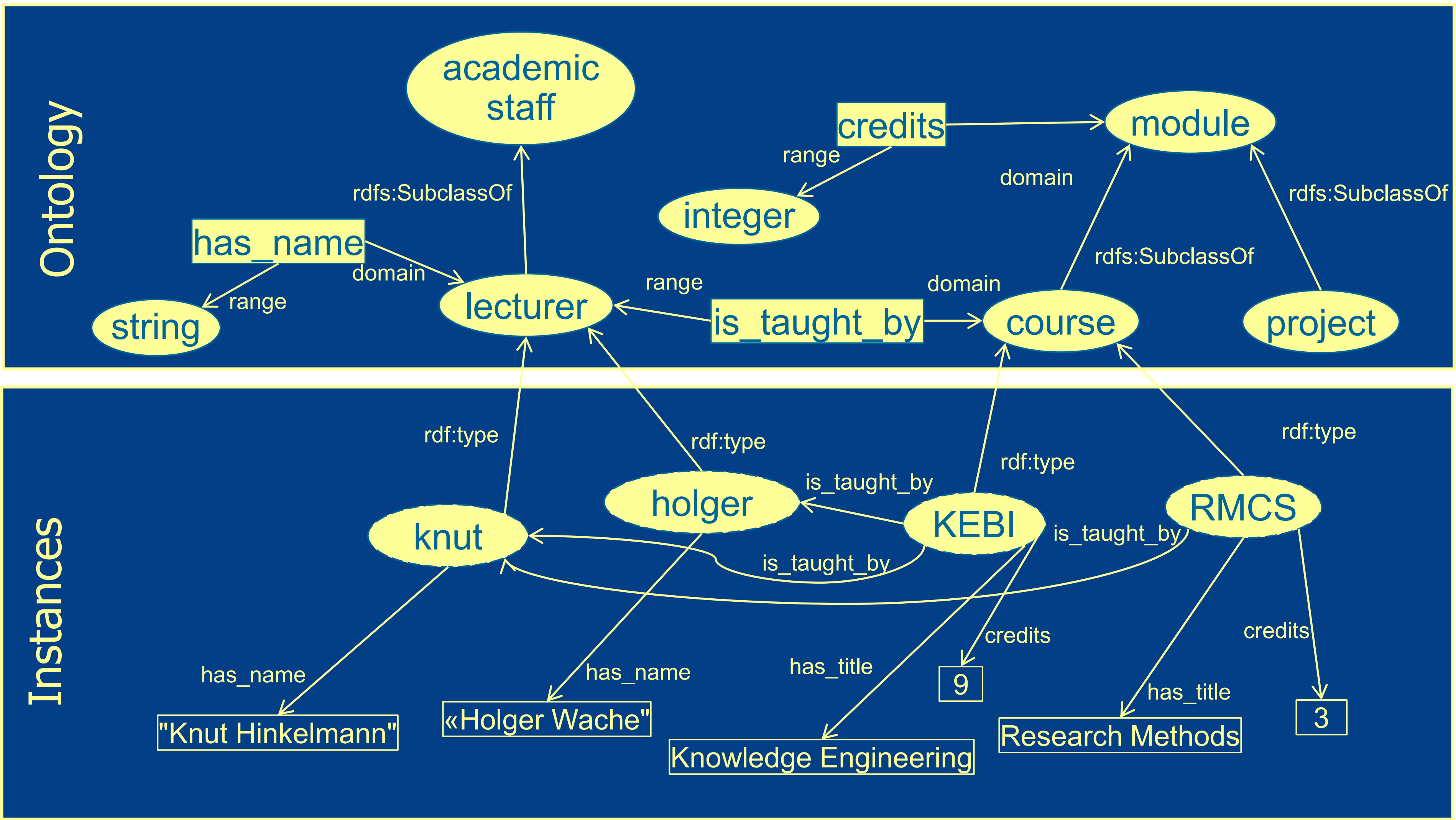
Example of an Ontology

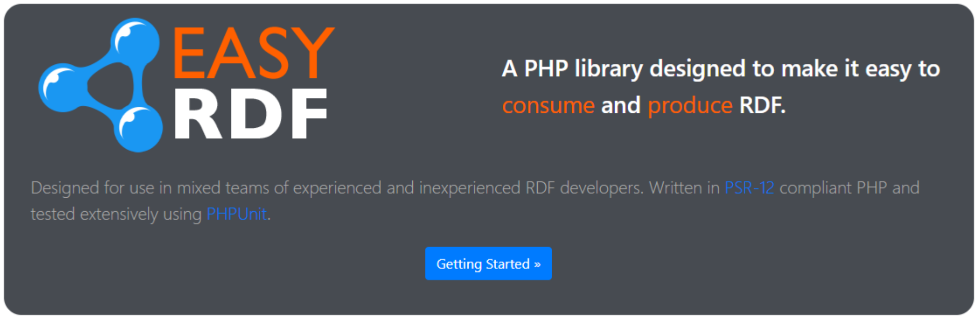


Ontology Representation Formalisms

- Representations of Ontologies
  - ***RDF(S)*** ← Our focus
  - OWL
  - Neo4J
  - …

Tools: Examples of Programming Libraries

EasyRDF for PHP: https://www.easyrdf.org/



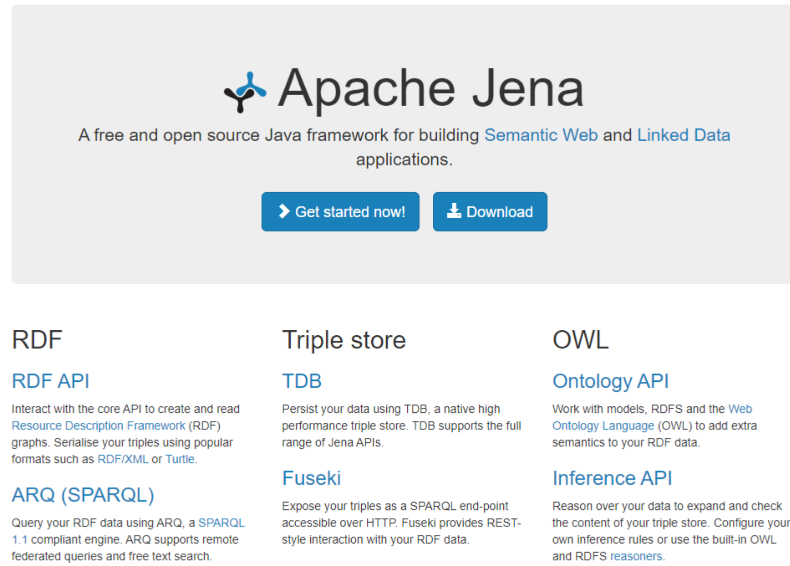
EASY RDF

A PHP library designed to make it easy to consume and produce RDF.

Designed for use in mixed teams of experienced and inexperienced RDF developers. Written in PSR-12 compliant PHP and tested extensively using PHPUnit.

Getting Started »

Apache Jena for Java: https://jena.apache.org/



Apache Jena

A free and open source Java framework for building Semantic Web and Linked Data applications.

Get started now! Download

RDF

RDF API

Interact with the core API to create and read Resource Description Framework (RDF) graphs. Serialise your triples using popular formats such as RDF/XML or Turtle.

ARQ (SPARQL)

Query your RDF data using ARQ, a SPARQL 1.1 compliant engine. ARQ supports remote federated queries and free text search.

Triple store

TDB

Persist your data using TDB, a native high performance triple store. TDB supports the full range of Jena APIs.

Fuseki

Expose your triples as a SPARQL end-point accessible over HTTP. Fuseki provides REST-style interaction with your RDF data.

OWL

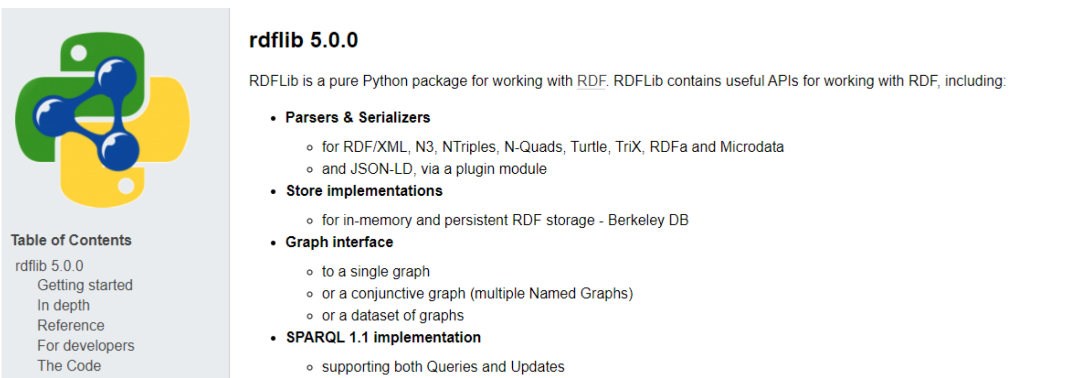
Ontology API

Work with models, RDFS and the Web Ontology Language (OWL) to add extra semantics to your RDF data.

Inference API

Reason over your data to expand and check the content of your triple store. Configure your own inference rules or use the built-in OWL and RDFS reasoners.

RDFLib for Python: https://rdflib.readthedocs.io/en/stable/



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rdflib 5.0.0

RDFLib is a pure Python package for working with RDF. RDFLib contains useful APIs for working with RDF, including:

- **Parsers & Serializers**
  - for RDF/XML, N3, NTriples, N-Quads, Turtle, TriX, RDFa and Microdata
  - and JSON-LD, via a plugin module
- **Store implementations**
  - for in-memory and persistent RDF storage - Berkeley DB
- **Graph interface**
  - to a single graph
  - or a conjunctive graph (multiple Named Graphs)
  - or a dataset of graphs
- **SPARQL 1.1 implementation**
  - supporting both Queries and Updates

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Tool: Ontology Engineering

https://protege.stanford.edu/

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Creating an Ontology

- Defining classes in the ontology
- Arranging the classes in a taxonomic (subclass-superclass) hierarchy
- Defining properties and describing allowed values for the properties
- Creating instances and filling the values for properties

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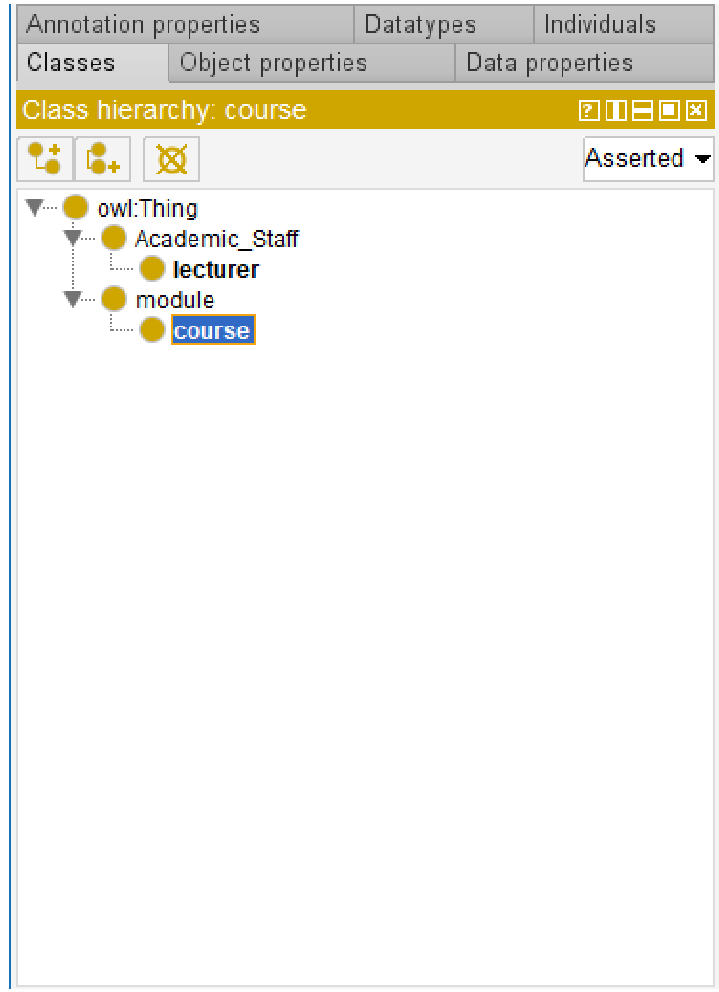
Define Classes and Class Hierarchy

- There are several approaches
  - Top-down: Start with the most general concept, and work your way down
  - Bottom-up: Start with the most specific, ad work your way up
  - Combination



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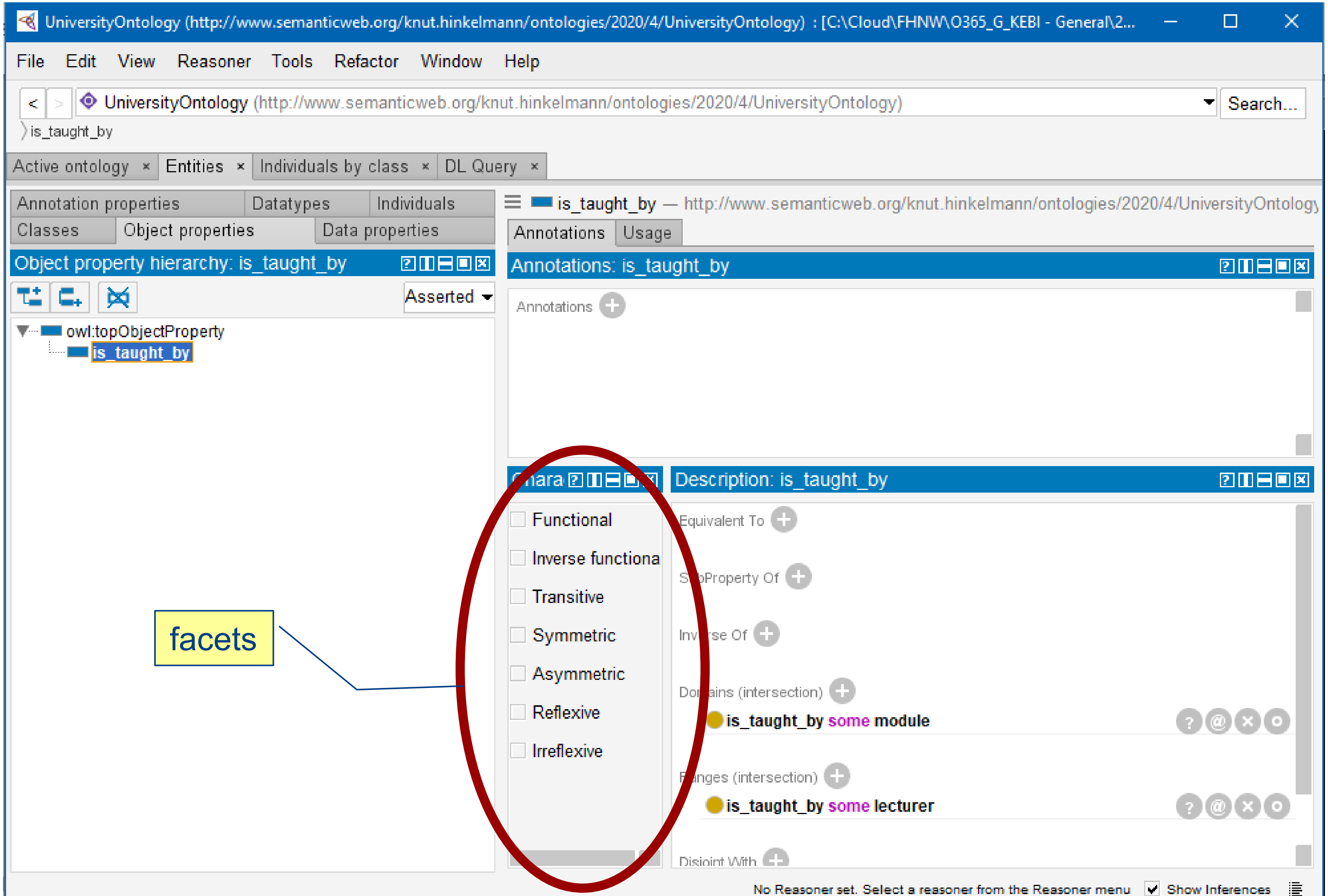
Define Properties of Classes

- Describe the internal structure of concepts
  - Data Properties: Attributes
    - Range are data types like String, Integer, …
  - Object Properties: Relations to other concepts
    - Range are Classes
- Desribe facets: Characteristics of Properties
- Inheritance to Subclasses

Object Property



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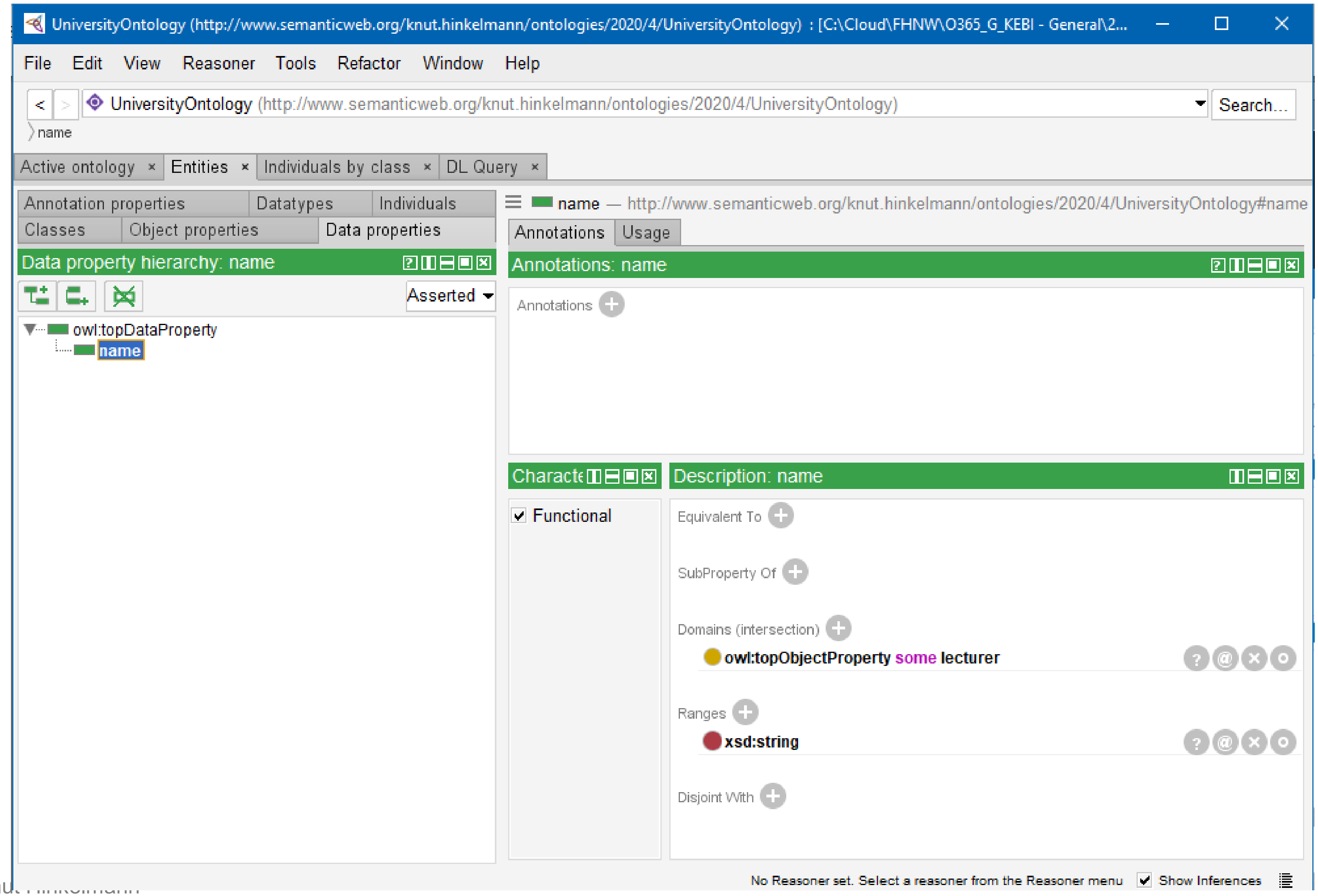
Data Property



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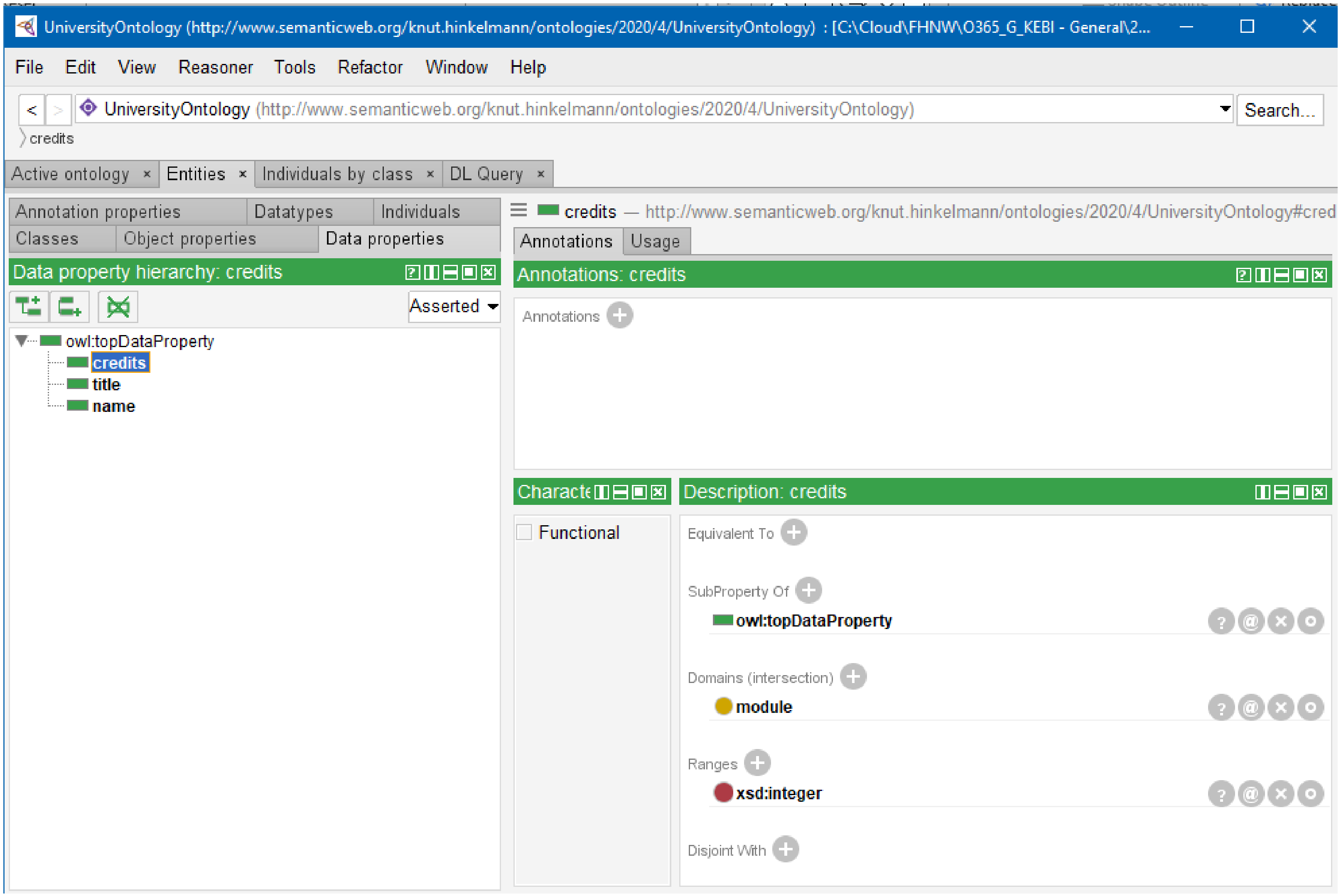
Data Property



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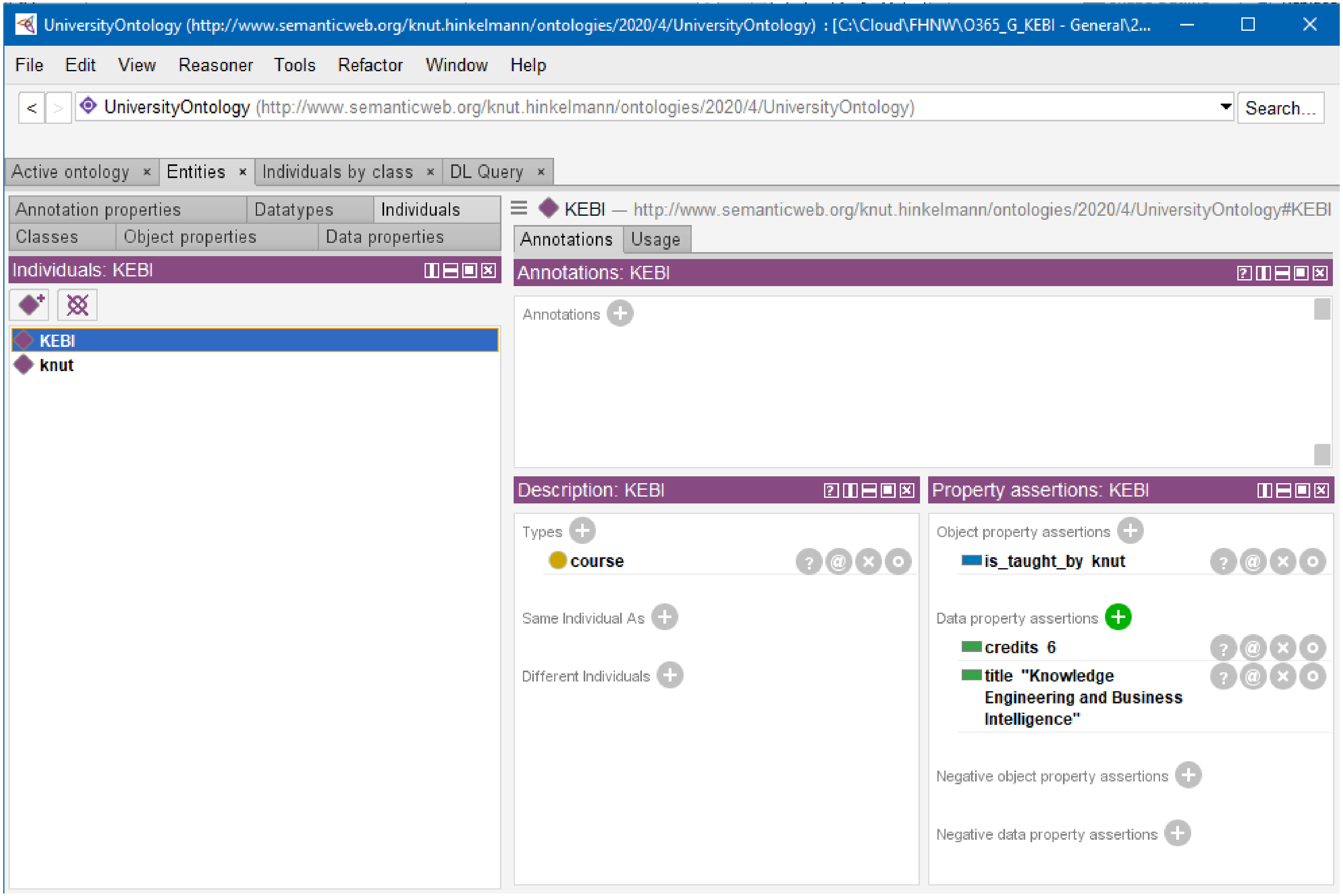
Instances



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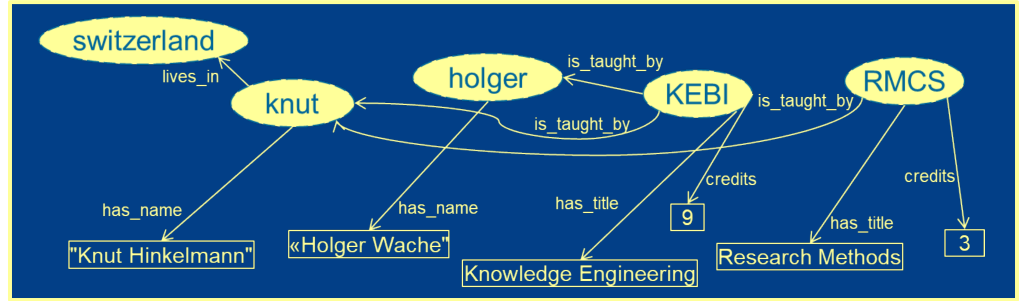
Exercise

- Add new class: country
- Add a property: A lecturer lives in a country
- Add new instance: Knut lives in Switzerland
- Add new classes and properties for the following knowledge
  - A project is a module
  - A Master Thesis is a project
  - Supervisor is a lecturer
  - A project has a supervisor
  - A project is performed by a student
- Add new instances
  - Giordano is a student who is performing a master thesis that is supervised by knut

Querying an Ontology



- Queries are mostly about navigating the graph in search of some patterns
- Sample types of queries
  - Navigating along a graph path, e.g who are the lecturers of KEBI

    SELECT ?x WHERE {:KEBI :is_taught_by ?x}
  - Navigating along a graph path with intermediate values, e.g. what are the names of the lecturers of KEBI

    SELECT ?x ?y WHERE {:KEBI :is_taught_by ?x.
    ?x :has_name ?y}
  - Navigating a path in reverse, e.g which modules is knut teaching

    SELECT ?x WHERE {?x :is_taught_by :knut}
  - Discover relationships, what is the relationship between KEBI and knut

    SELECT ?rel WHERE {:KEBI ?rel :knut}
  - Chain of relationships, what chain exists between KEBI and switzerland

    SELECT ?rel1 ?y ?rel2 WHERE {:KEBI ?rel1 ?y.
    ?y ?rel2 :switzerland}

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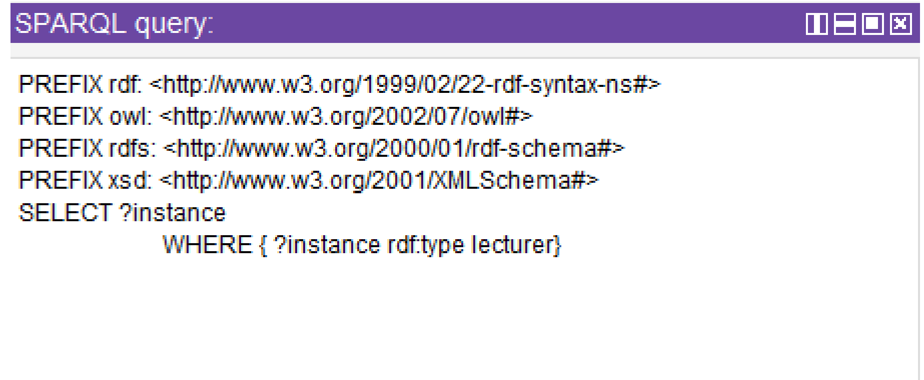
Querying



- Query Language: SPARQL
  - Variables: ?x
- Elements are denoted as URI
  - Prefixes for Abbrevations
    - Example: PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
- Sample query: Select all lecturers:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX uo: <http://www.semanticweb.org/knut.hinkelmann/ontologies/2020/4/UniversityOntology#>
SELECT ?subject
        WHERE { ?subject rdf:type uo:lecturer }
```

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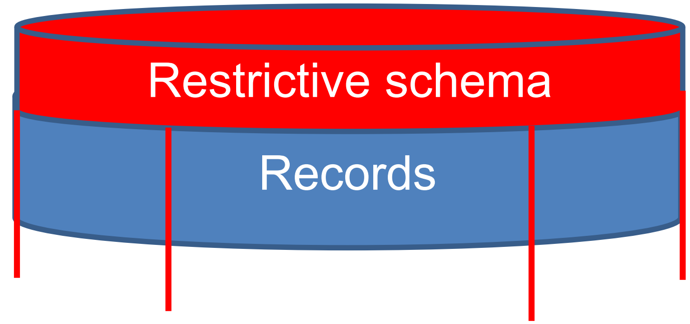
RDF Graphs vs Databases

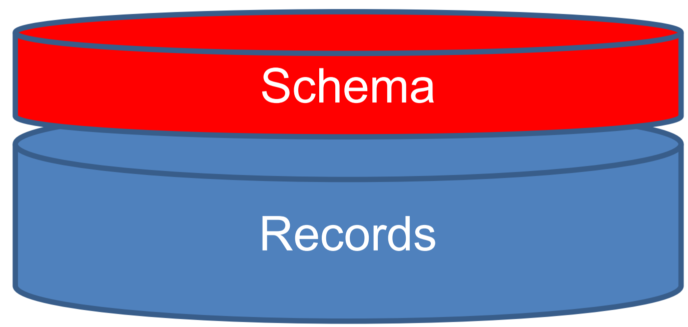
Schema is decoupled from data!

In SQL databases, you cannot do anything before having a schema (the "DB structure")



In RDF graphs, ***schema is decoupled from "records"***

- Schema can be created after data
- Schema is optional (data can be queried in the absence of a schema)



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Exercise: Modeling Process Knowledge in an Ontology

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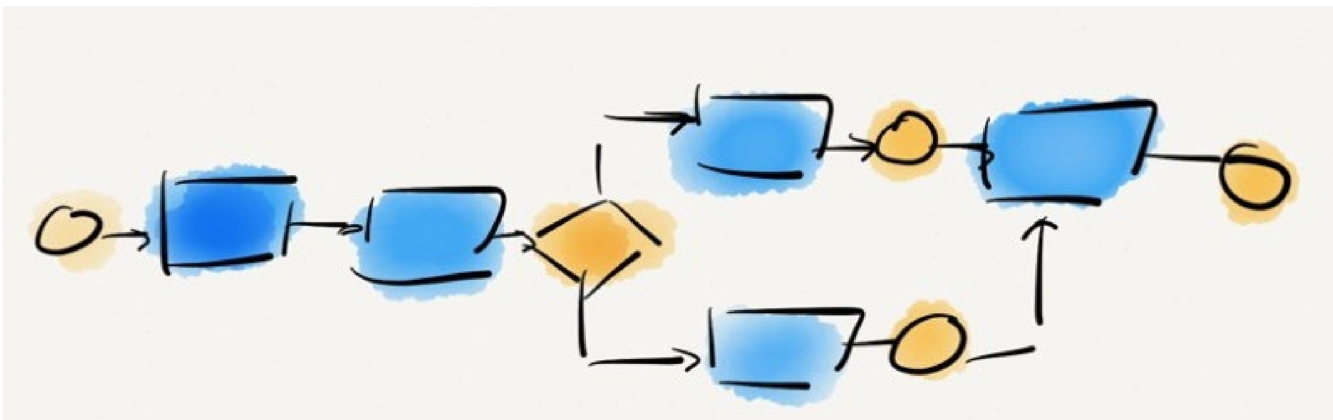
Exercise: Modeling Process Knowledge in an Ontology

- We create a knowledge base for process knowledge
  - ♦ Define the ontology
  - ♦ Represent knowledge of a process



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Ontology Development 101

1. Determine the domain and scope of the ontology
2. Consider reusing existing ontologies
3. Enumerate important terms
4. Define classes and class hierarchy
5. Define the data and object properties of classes
6. Define the facets of properties
7. Create instances

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Determine the domain and scope of the ontology

- What is the domain that the ontology will cover?
- For what we are going to use the ontology?
- For what types of questions the information in the ontology should provide answers? → Competency questions
- Who will use and maintain the ontology?

Competency Questions

- One of the ways to determine the scope of the ontology is to sketch a list of questions that a knowledge base based on the ontology should be able to answer (Gruninger and Fox 1995)
  - ♦ Does the ontology contain enough information to answer these types of questions?
  - ♦ Do the answers require a particular level of detail or representation of a particular area?

- Exercise: We want to represent knowledge about
  - the process flow
  - Responsibilies for tasks
- Competency Questions:
  - Who executes task X?
  - Which task is executed after task X?
  - When can task X start?
- Sample process:

The waiter serves the beverages. Then the waiter serves the food. When the guests are finished, the waiter presents the bill.

Consider reusing existing ontologies

- It is always worth considering what others have done, and check if their work can be refined and extended for our particular domain and task
- Mandatory if the system needs to interact with other applications that have already committed to particular ontologies or controlled vocabularies

Enumerate important terms in the ontology

- What are the terms we would like to talk about?
- What are their properties?
- What would we like to say about those terms?

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Define Classes and Class Hierarchy

- Several possible approaches in developing a class hierarchy:
  - Top-down: General to specific concepts
  - Bottom-up: Specific to general concepts
  - Combination: Salient to general and specific concepts
- Classes for
  - Modeling Objects
  - Relations

Define the properties of classes

- Describe the internal structure of concepts
  - Data Properties: Attributes
    - Range are data typles like String, Integer, …
  - Object Properties: Relations to other concepts
    - Range are Classes
- Inheritance to Subclasses

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Create Instances

- Model a business process in an ontology

The waiter serves the beverages. Then the waiter serves the food. When the guests are finished, the waiter presents the bill.

Modeling Business Processes as graphical models is more adequate