WDAqua ITN
Answering Questions using Web Data

EUCLID
EdUcational Curriculum for the usage of LInked Data

Building and using ontologies

Elena Simperl, University of Southampton, UK
e.simperl@soton.ac.uk @esimperl

With contributions from "Linked Data: Survey of Adoption", tutorial at the 3rd Asian Semantic Web School ASWS 2011, Incheon, South Korea, July 2011 by Aidan Hogan, DERI, IE

Karlsruhe Institute of Technology · ontotext · The Open University · research · fluid Operations · semsphere

FUNDAMENTALS

Ontologies in Computer Science

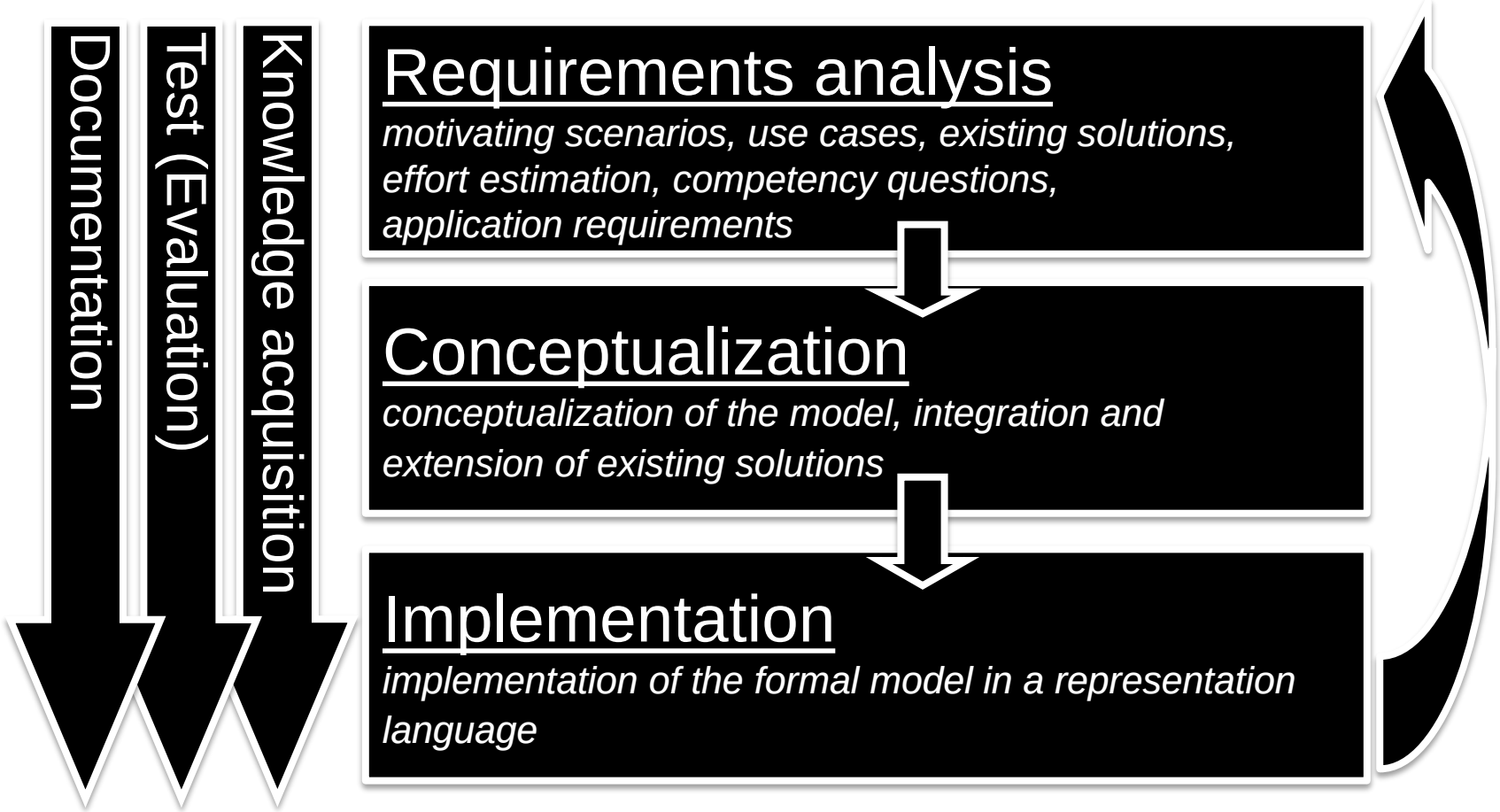
- An ontology defines a **domain of interest**
  - … in terms of the **things** you talk about in the domain, their **attributes,** as well as **relationships** between them
- Ontologies are used to
  - Share a **common understanding** about a domain among people and machines
  - Enable **reuse** of domain knowledge

ontology vocabulary
microformat conceptual graph
topic map thesaurus
schema
classification object model
semantic network
glossary taxonomy

class relationship entity type
slot particular object instance
universal attribute association
individual property role

Classical ontology engineering process

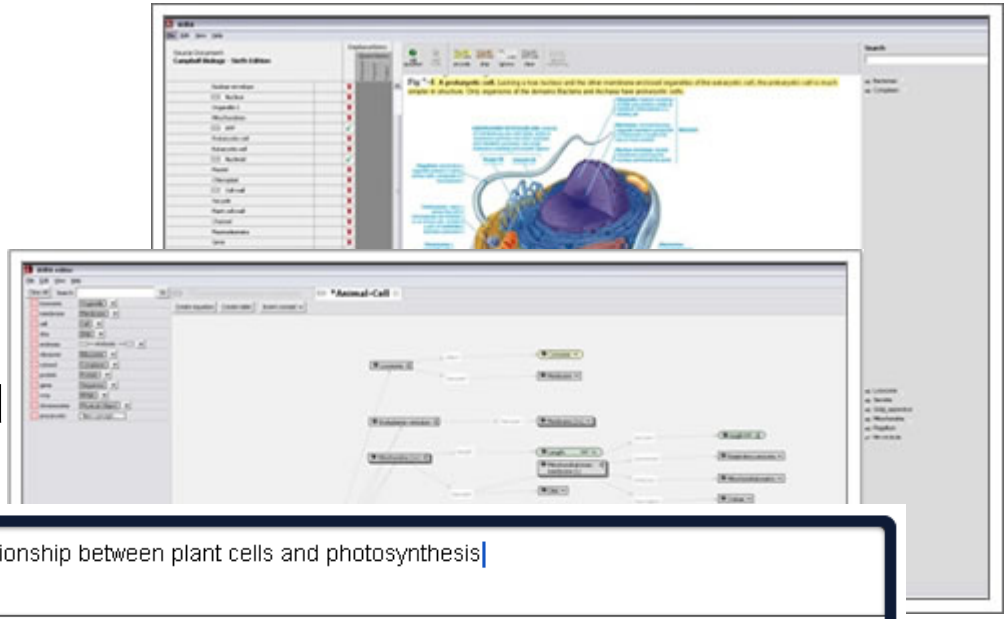
EUCLID
EdUcational Curriculum for the usage of LInked Data

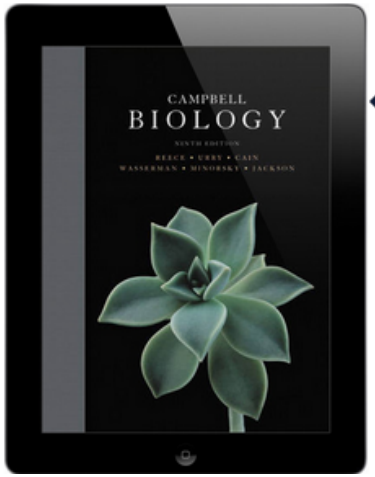


Example: Project Halo

EUCLID
EdUcational Curriculum for the usage of LInked Data

- Knowledge acquisition from text (books)
- Professional and crowdsourced annotation
- Question analysis and answering through a combination of NLP and reasoning techniques





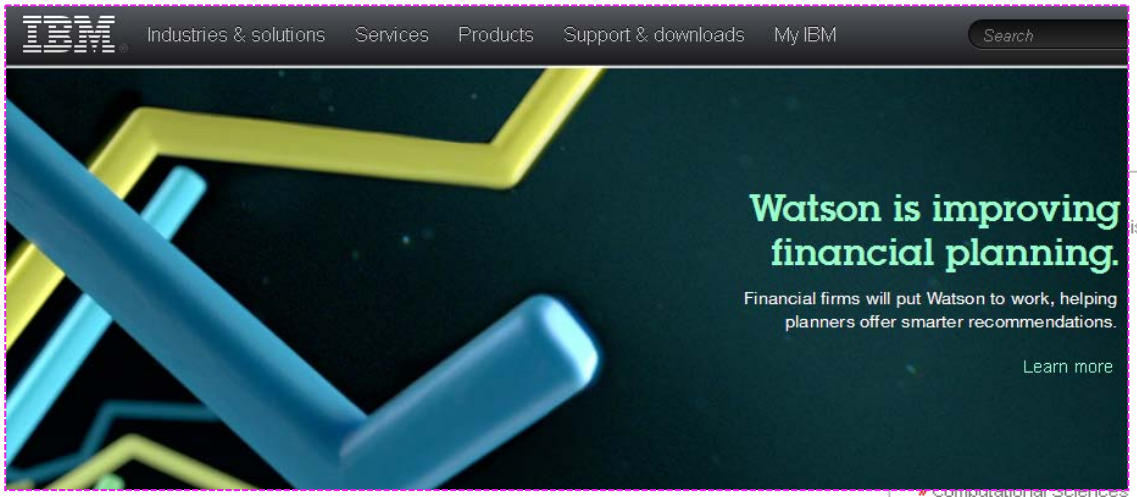
What is the relationship between plant cells and photosynthesis

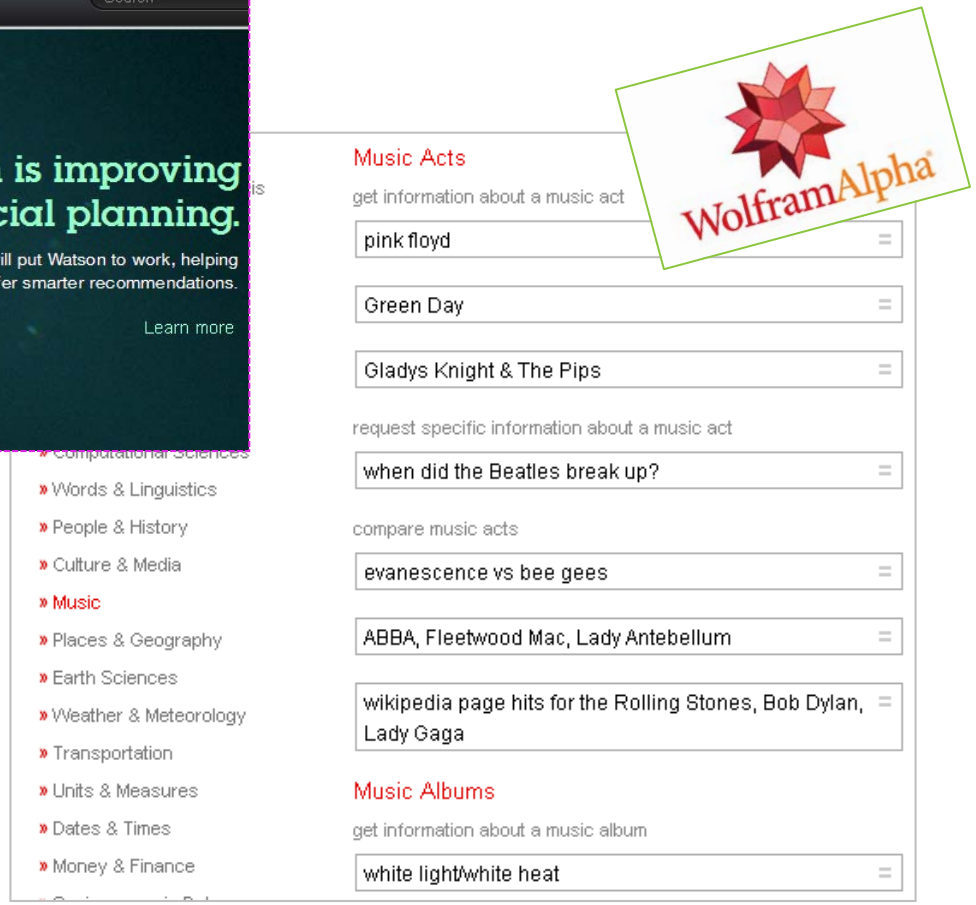
define	Define **cellular respiration**
structure	What is the structure of a **chloroplast**?
function	What is the function of a **plasma membrane** in a **eukaryotic cell**?
compare	What are the differences between **chloroplasts** and **mitochondria**?
relate	If the **chloroplasts** were removed from a **plant**, what events would be affected?
search	Search book for **photosynthesis**

Images from http://www.projecthalo.com and http://www.inquireproject.com/

More examples

EUCLID
EdUcational Curriculum for the usage of LInked Data





Images from http://www.ibm.com/watson, http://www.wolframalpha.com/examples/Music.html, http://www.apple.com

Semantic technologies are not **THE** solution to creating intelligent applications, but only one (essential) component

The Linked Data movement has promoted one approach to create and publish semantic data

- They created momentum for the Semantic Web, as well as several useful data sets

Rich knowledge representations can be extremely valuable, but are costly to achieve

System	Scope	Input	Result	Core Technology
Inquire intelligent textbook	single textbook	simple English queries	formatted data and relevant textbook content	symbolic AI
Wolfram Alpha computational knowledge engine	curated data from "primary sources"	word phrases with mathematical operators	formatted data	Mathematica
Siri virtual personal assistant	emails, calendar, weather, maps, movies, etc.	voice commands	performs tasks	service integration via speech dialog
Google Search index of world's information	open domain text on the web	keywords and search queries	web documents	statistical AI, PageRank

Table from http://www.inquireproject.com/

Our scenario: the Linked Data management life cycle

EUCLID
EdUcational Curriculum for the usage of LInked Data

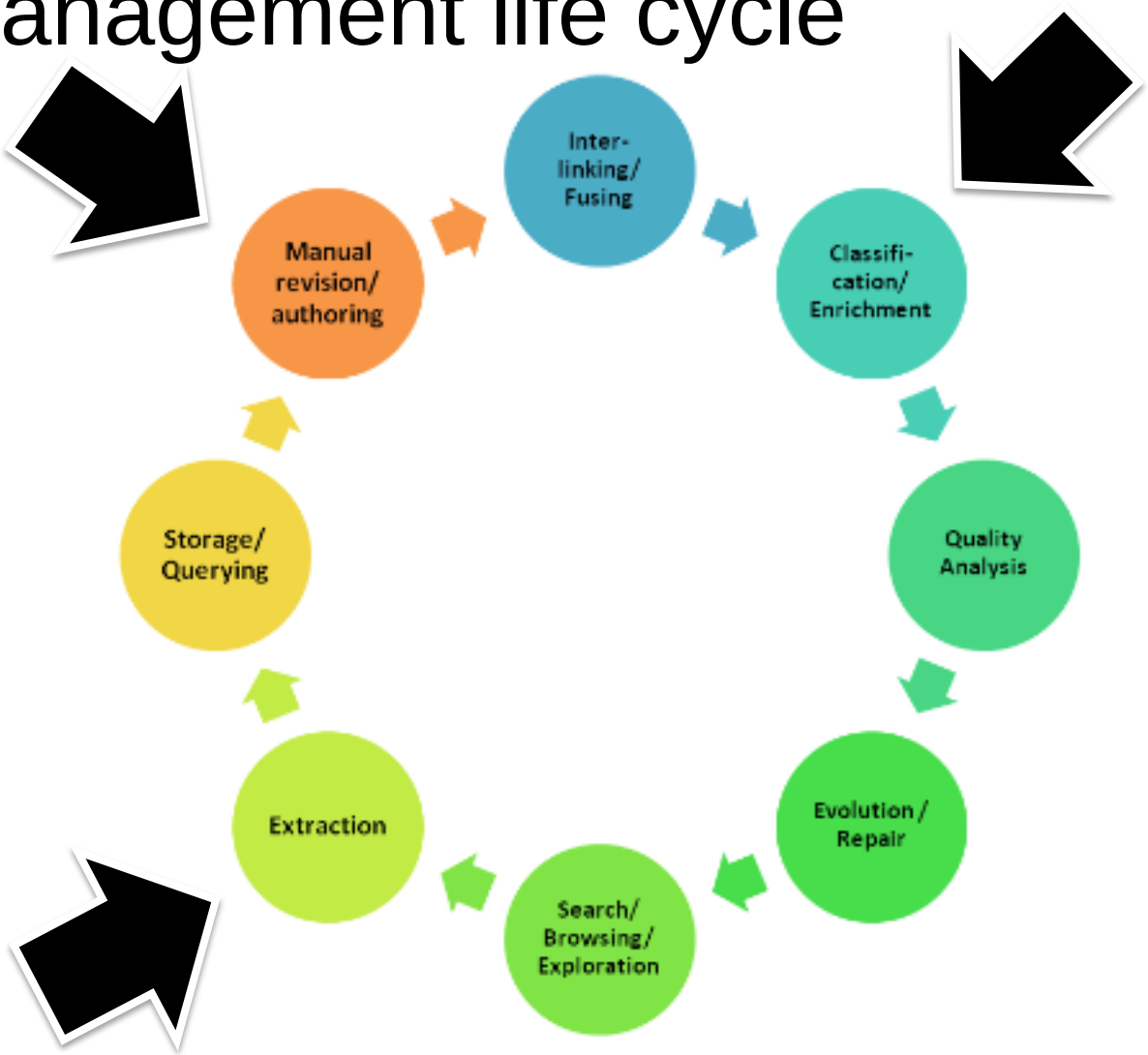
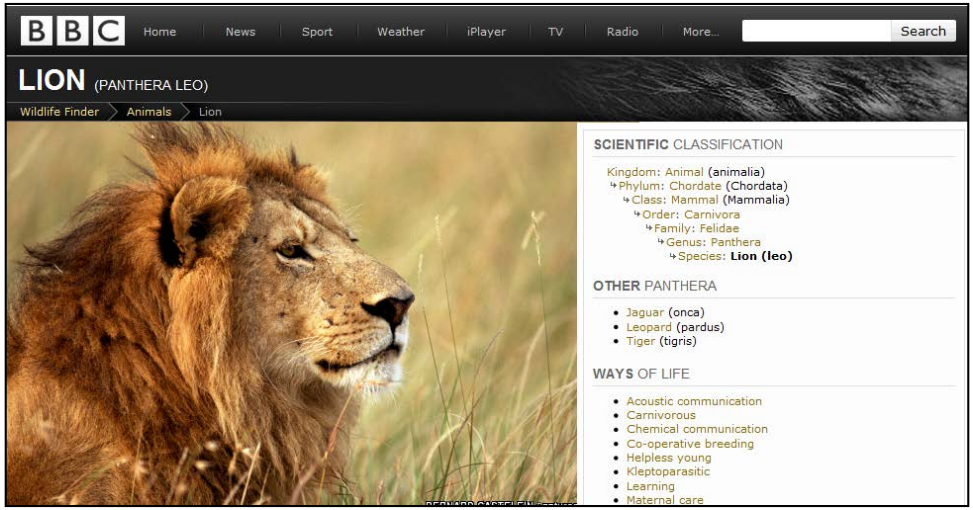


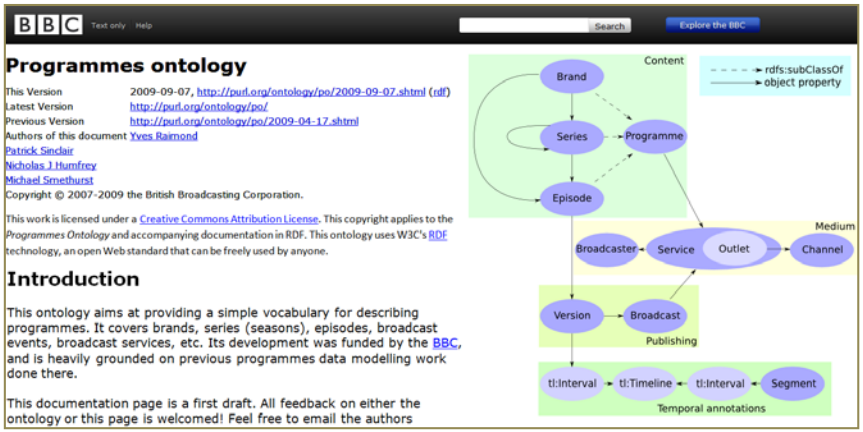
Image from http://wiki.lod2.eu/

Example: BBC

„Design for a world where Google is your homepage, Wikipedia is your CMS, and humans, software developers and machines are your users“

- Various micro-sites built and maintained manually
- No integration across sites in terms of content and metadata
- Use cases
  - Find and explore content on specific (and related) topics
  - Maintain and re-organize sites
  - Leverage external resources
- Ontology: One page per thing, reusing DBpedia and MusicBrainz IDs, different labels





http://www.slideshare.net/reduxd/beyond-the-polar-bear

Core ontology engineering activities in our scenario

- **Find ontologies**
- **Select ontologies**
- **Adjust/extend ontologies**

- Popular activities we do **not** consider here
  - Requirements analysis
  - Knowledge representation
  - Ontology learning
  - Ontology alignment
  - ...
- See previous summer schools http://videolectures.net/eswc2012_summer_school/

- This is **not** a tutorial about
  - Ontology engineering tools e.g., **Protégé** (see http://protege.stanford.edu/)
  - Ontology languages e.g., RDFS, OWL

FIND ONTOLOGIES

Finding existing ontologies

- Linked Open Vocabularies: over 400 vocabularies, used in the LOD cloud
  - http://lov.okfn.org
- Protégé Ontologies: several hundreds of ontologies, cross-domain
  - http://protegewiki.stanford.edu/index.php/Protege_Ontology_Library#OWL_ontologies
- Open Ontology Repository: life sciences and other domains
  - http://ontolog.cim3.net/cgi-bin/wiki.pl?OpenOntologyRepository
- Dumontier Lab: life sciences ontologies
  - http://dumontierlab.com/index.php?page=ontologies
- Tones: ontologies used mainly for testing purposes
  - http://rpc295.cs.man.ac.uk:8080/repository/
- OBO Foundation Ontologies: hundreds of life sciences ontologies, including mappings
  - http://www.obofoundry.org/
- NCBO Bioportal: hundreds of medical ontologies
  - http://bioportal.bioontology.org/
- VoCamps
  - http://vocamp.org/wiki/Main_Page

Linked Open Vocabularies

EUCLID
EdUcational Curriculum for the usage of LInked Data

music Search

Filter by Domain

- W3C Rec (0)
- City (6)
- Data & Systems (2)
- General (40)
- Library (117)
- Life (123)
- Market (2)
- Media (9)

Filter by Type

- rdfs:Class (142)
- rdf:Property (223)
- voaf:Vocabulary (8)
- Other (38)

Filter by Vocabulary (43)

- mo (106)
- music (69)
- rdarel (29)
- rdarole (27)
- rdag1 (21)
- schema (21)
- bf (13)

380 results in 43 vocabularies

music (voaf:Vocabulary) score:0.682
rdfs:label **Music** Vocabulary
dcterms:title **Music** Vocabulary @en
rdfs:comment A vocabulary, or **music** ontology, to descri...be classical **music** and performances. C.....es (categories) for **music**al works, events, in.....sure to distinguish **music**al works (e.g. Opera.....model to describe a **music**al work, its represe..... scores, etc) and a **music**al event to present ...
dcterms:description A vocabulary, or **music** ontology, to descri...be classical **music** and performances. C.....es (categories) for **music**al works, events, in.....sure to distinguish **music**al works (e.g. Opera.....model to describe a **music**al work, its represe..... scores, etc) and a **music**al event to present ... @en
vann:preferredNamespacePrefix **music**
vann:preferredNamespaceUri .../www.kanzaki.com/ns/**music**#

af:MusicSegment (owl:Class) score:0.568
rdfs:label **Music**
rdfs:comment ...dio segment holding **music**. This classifier ...

http://lov.okfn.org/dataset/lov/lov#MUSIC (voaf:VocabularySpace) score:0.568
dcterms:title **Music** and Sound @en
dcterms:description **Music**, Sound, Audio files @en
bibo:shortTitle **Music** @en

bbc:Music (bbc:Product) score:0.568
rdfs:label **Music** @en-gb
rdfs:comment ...bDocuments from BBC **Music**. @en-gb

mrel:mus (owl:ObjectProperty) score:0.511
rdfs:label **Music**ian @en
skos:prefLabel **Music**ian @en
mads:authoritativeLabel **Music**ian @en

schema:musicBy (rdf:Property) score:0.438
rdfs:label **music**By

mo (voaf:Vocabulary) score:0.405
dcterms:title **Music** Ontology @en

See http://lov.okfn.org

Linked Open Vocabularies (2)

EUCLID
EdUcational Curriculum for the usage of LInked Data

Information about mo

Metrics:

Overall score with current parameters	**0.405**
Best ratio search words in labels	0.357
Nb occurences in main labels	2
Nb occurences in secondary labels	2
Nb occurences in LOD datasets	144239
Nb occurences in LOV datasets	18
Nb of vocabularies which reference this element	5

Element information:

URI	**http://purl.org/ontology/mo/**
rdf:type	owl:Thing > owl:Ontology > voaf:Vocabulary
vocabulary	null
is dc:hasPart of	All > Life > Music
dcterms:title	Music Ontology @en
dce:title	The Music Ontology
dcterms:description	The Music Ontology Specification provides main concepts and properties fo describing music (i.e. artists, albums and tracks) on the Semantic Web @en
dce:description	The Music Ontology Specification provides main concepts and properties fo describing music (i.e. artists, albums and tracks) on the Semantic Web.

Close

Dublin Core

Properties in the */terms/* namespace	abstract, accessRights, accrualMethod, accrualPeriodicity, accrualPolicy, alternative, audience, available, bibliographicCitation, conformsTo, contributor, coverage, created, creator, date, dateAccepted, dateCopyrighted, dateSubmitted, description, educationLevel, extent, format, hasFormat, hasPart, hasVersion, identifier, instructionalMethod, isFormatOf, isPartOf, isReferencedBy, isReplacedBy, isRequiredBy, issued, isVersionOf, language, license, mediator, medium, modified, provenance, publisher, references, relation, replaces, requires, rights, rightsHolder, source, spatial, subject, tableOfContents, temporal, title, type, valid
Properties in the legacy */elements/1.1/* namespace	contributor, coverage, creator, date, description, format, identifier, language, publisher, relation, rights, source, subject, title, type
Vocabulary Encoding Schemes	DCMIType, DDC, IMT, LCC, LCSH, MESH, NLM, TGN, UDC
Syntax Encoding Schemes	Box, ISO3166, ISO639-2, ISO639-3, Period, Point, RFC1766, RFC3066, RFC4646, RFC5646, URI, W3CDTF
Classes	Agent, AgentClass, BibliographicResource, FileFormat, Frequency, Jurisdiction, LicenseDocument, LinguisticSystem, Location, LocationPeriodOrJurisdiction, MediaType, MediaTypeOrExtent, MethodOfAccrual, MethodOfInstruction, PeriodOfTime, PhysicalMedium, PhysicalResource, Policy, ProvenanceStatement, RightsStatement, SizeOrDuration, Standard

Table from http://dublincore.org/documents/dcmi-terms/

Friend Of A Friend

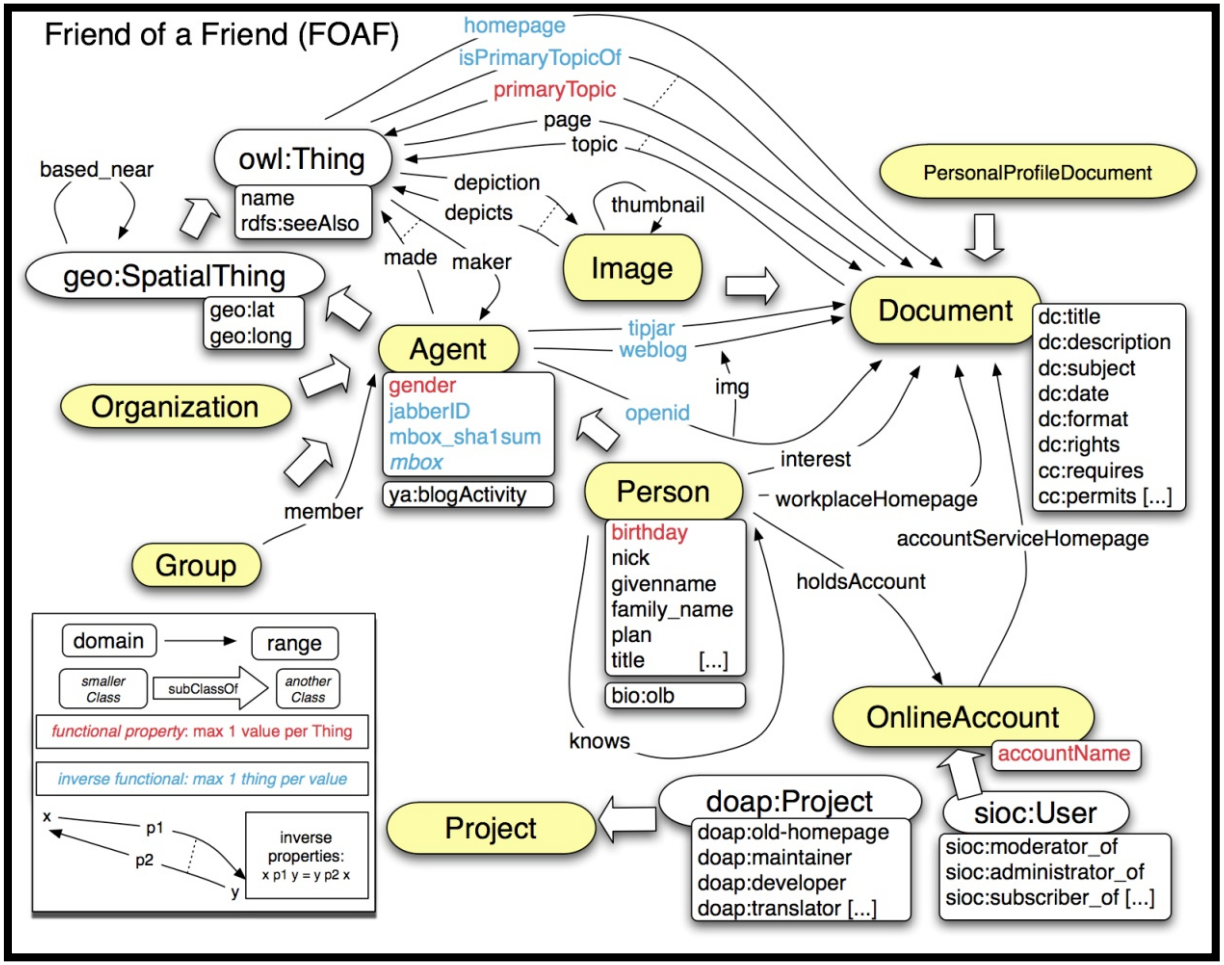


Image (originally found) at http://www.deri.ie/fileadmin/images/blog/: Breslin

PROV-O

EUCLID
EdUcational Curriculum for the usage of LInked Data

W3C Recommendation

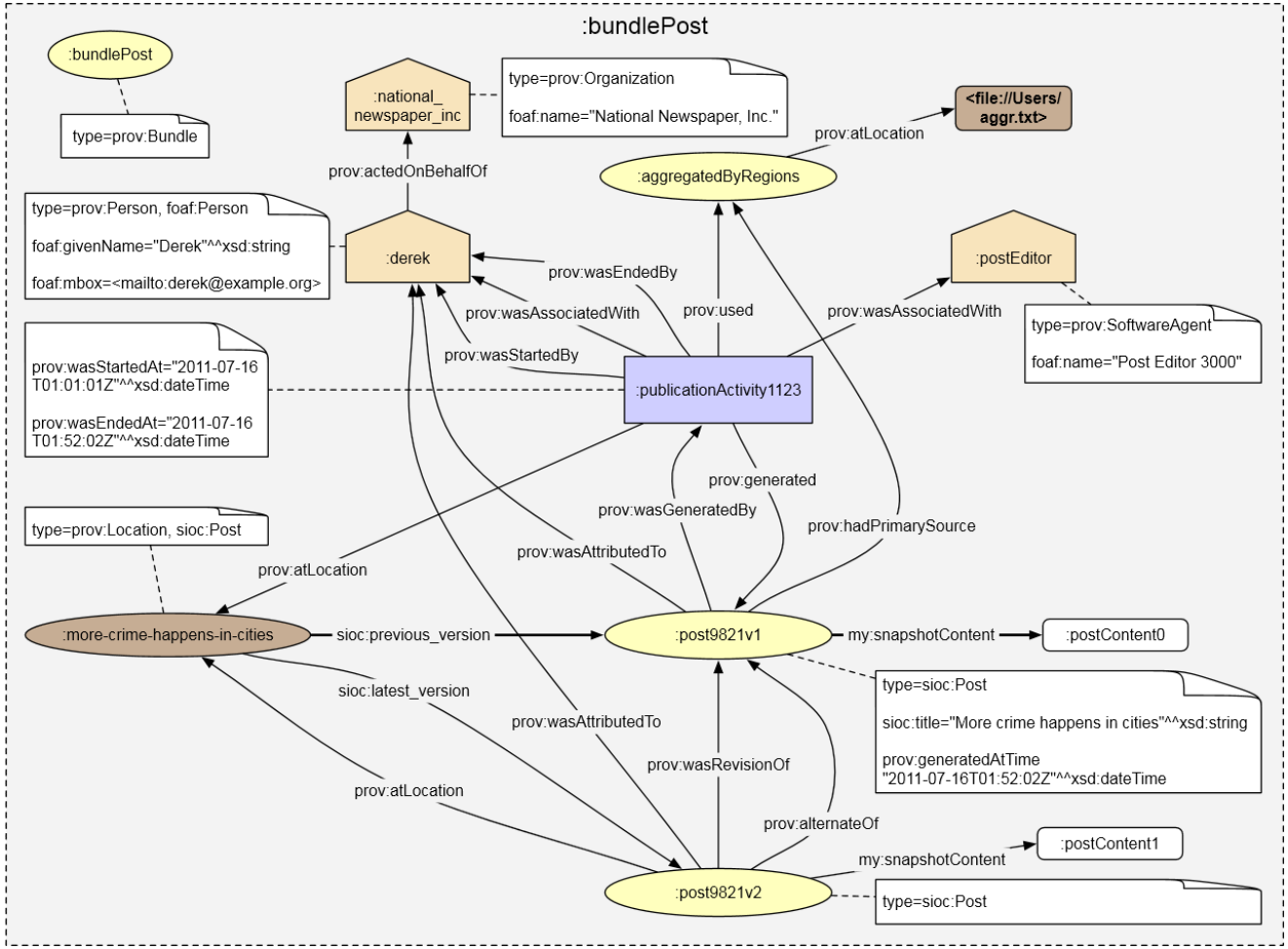


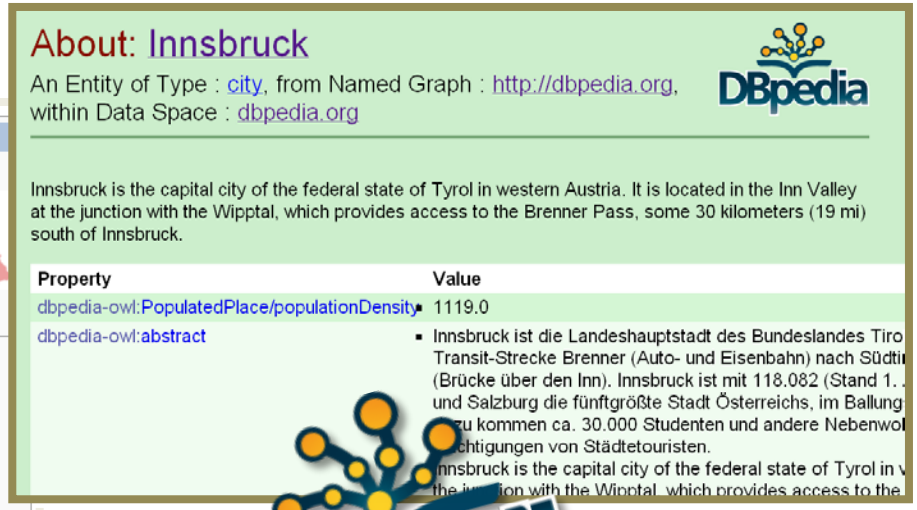
Image from http://www.w3.org/TR/2012/WD-prov-o-20120724/

DBpedia

- **Classes and properties for Wikipedia export (infoboxes), regularly updated**

```
{{Infobox Town AT |
  name = Innsbruck |
  image_coa =  InnsbruckWappen.png |
  image_map = Karte-tirol-I.png |
  state = [[Tyrol]] |
  regbzk = [[Statutory city]] |
  population = 117,342 |
  population_as_of = 2006 |
  pop_dens = 1,119 |
  area = 104.91 |
  elevation = 574 |
  lat_deg = 47 |
  lat_min = 16 |
  lat_hem = N |
  lon_deg = 11 |
  lon_min = 23 |
  lon_hem = E |
  postal_code = 6010-6080 |
  area_code = 0512 |
  licence = I |
  mayor = Hilde Zach |
  website = [http://innsbruck.at] |
}}
```

Innsbruck	
Country	Austria
State	Tyrol
Administrative region	Statutory city
Population	117,342 (2006)
Area	104.91 km²
Population density	1,119 /km²
Elevation	574 m
Coordinates	47°16' N 11°23' E
Postal code	6010-6080
Area code	0512
Licence plate code	I
Mayor	Hilde Zach
Website	www.innsbruck.at



About: Innsbruck

An Entity of Type : city, from Named Graph : http://dbpedia.org, within Data Space : dbpedia.org

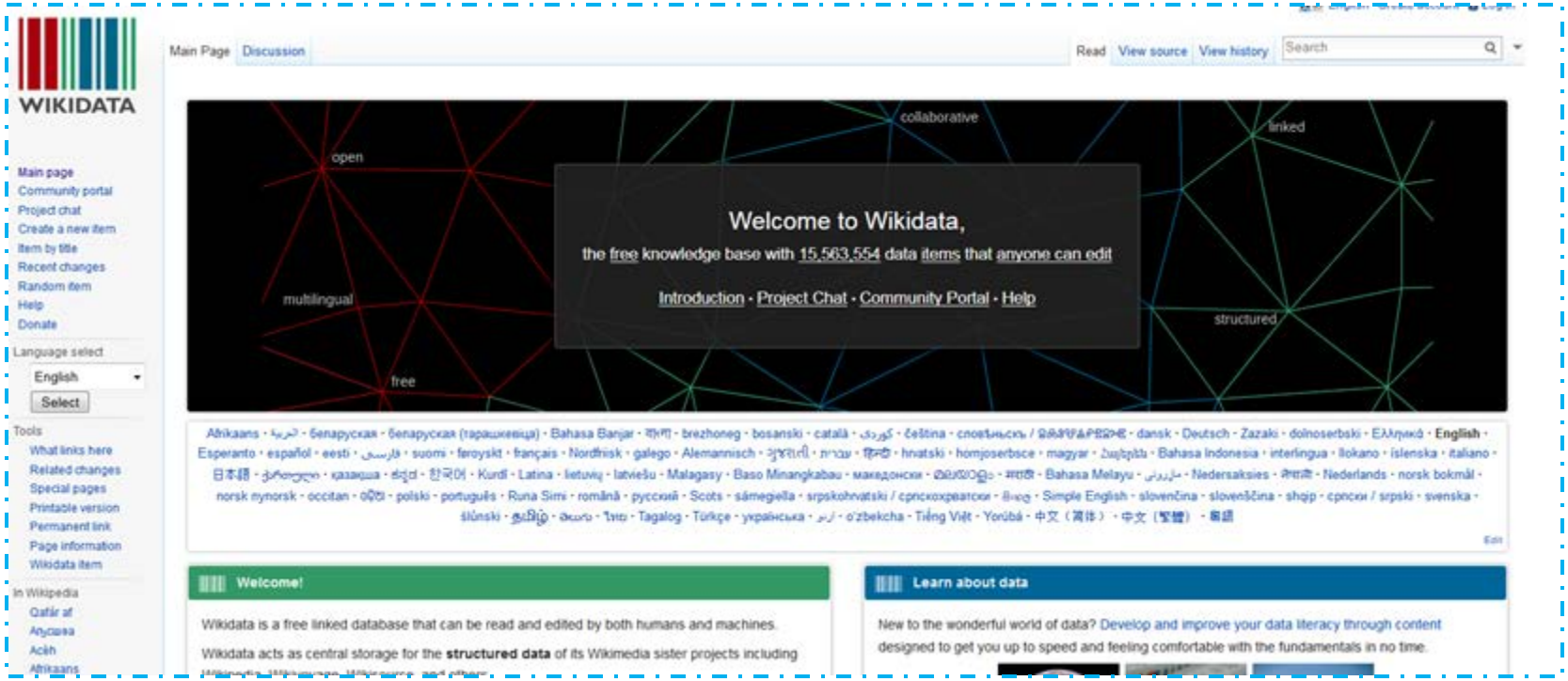
Innsbruck is the capital city of the federal state of Tyrol in western Austria. It is located in the Inn Valley at the junction with the Wipptal, which provides access to the Brenner Pass, some 30 kilometers (19 mi) south of Innsbruck.

Property	Value
dbpedia-owl:PopulatedPlace/populationDensity	1119.0
dbpedia-owl:abstract	Innsbruck ist die Landeshauptstadt des Bundeslandes Tiro Transit-Strecke Brenner (Auto- und Eisenbahn) nach Südti (Brücke über den Inn). Innsbruck ist mit 118.082 (Stand 1. und Salzburg die fünftgrößte Stadt Österreichs, im Ballung zu kommen ca. 30.000 Studenten und andere Nebenwol chtigungen von Städtetouristen.
	Innsbruck is the capital city of the federal state of Tyrol in the junction with the Wipptal, which provides access to the

See http://wiki.dbpedia.org/

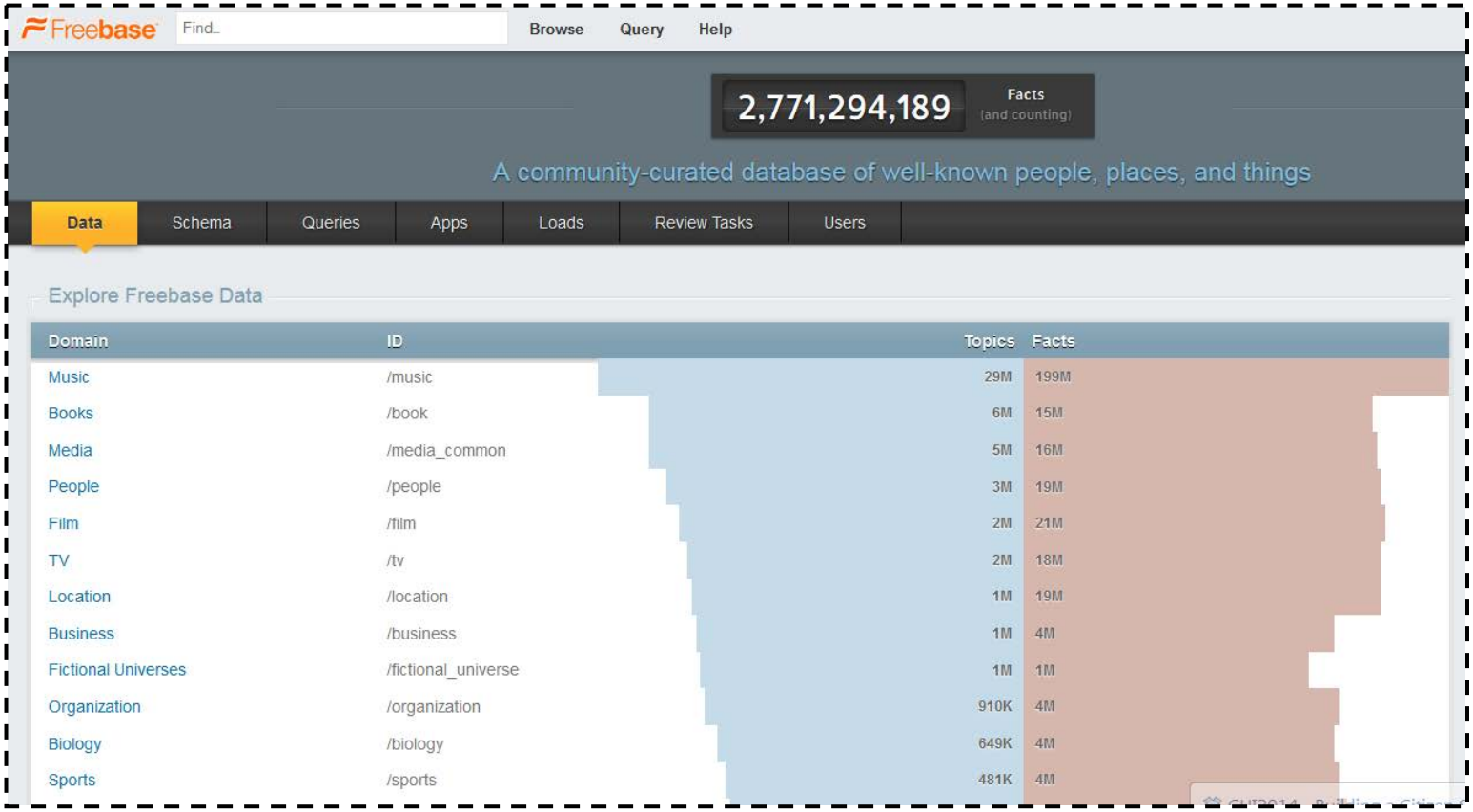
Wikidata

EUCLID
EdUcational Curriculum for the usage of LInked Data



See http://www.wikidata.org/

Freebase



http://www.freebase.com

Semantically Interlinked Online Communities

EUCLID
EdUcational Curriculum for the usage of LInked Data

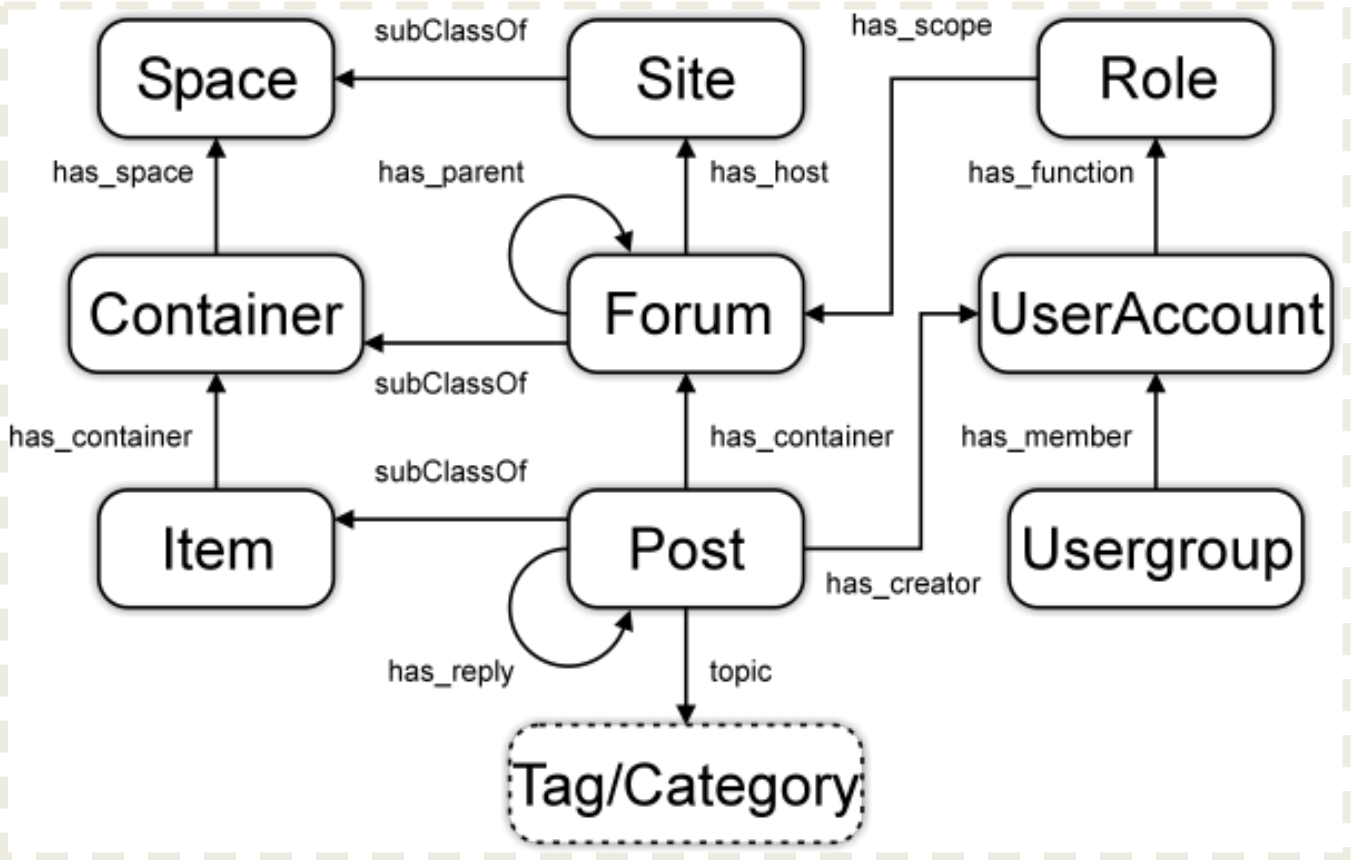


Image from http://rdfs.org/sioc/spec/: Bojārs, Breslin et al.

Simple Knowledge Organization System

EUCLID
EdUcational Curriculum for the usage of LInked Data

W3C Recommendation

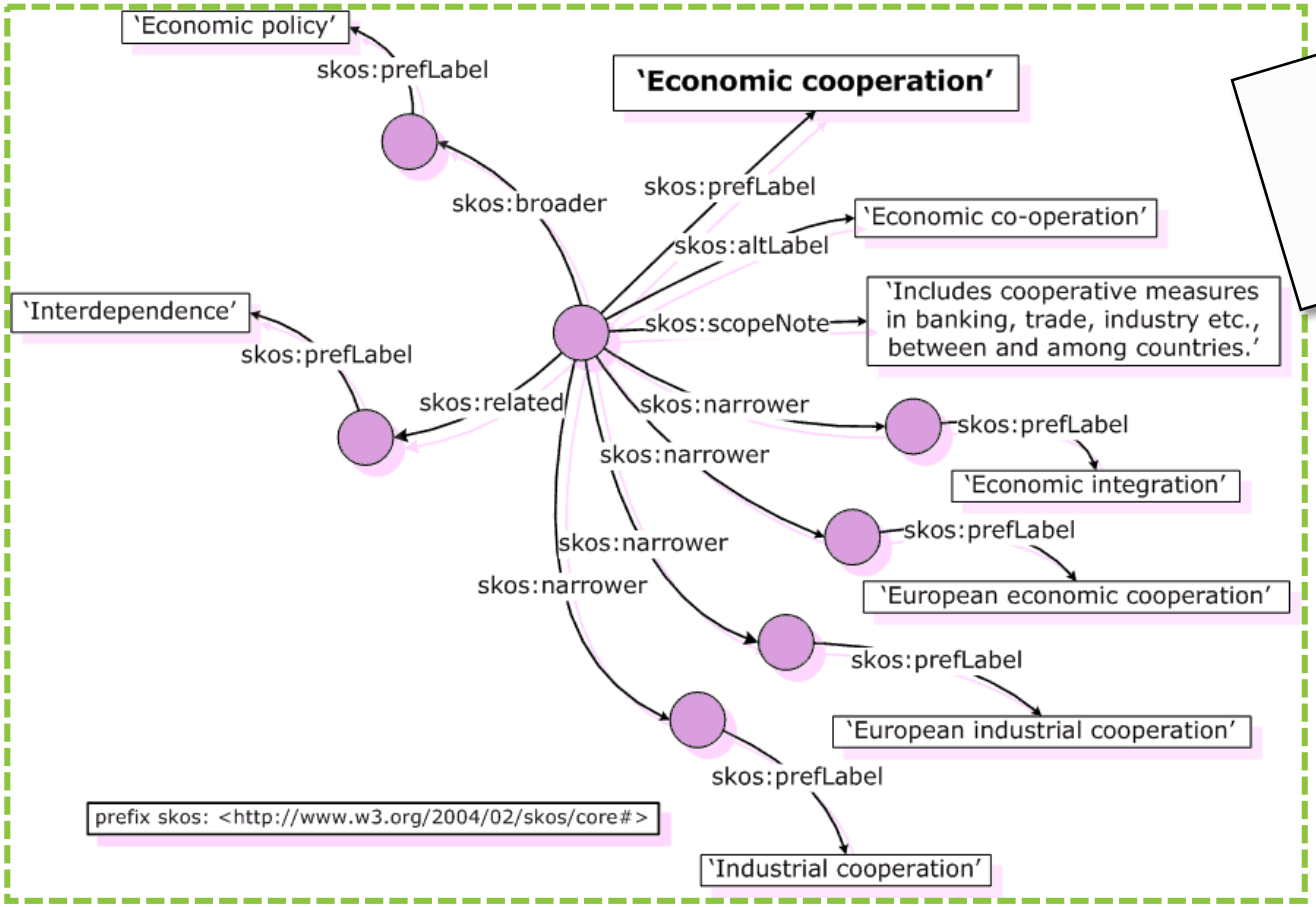


Image from http://www.w3.org/TR/swbp-skos-core-guide: Miles, Brickley

Description Of A Project

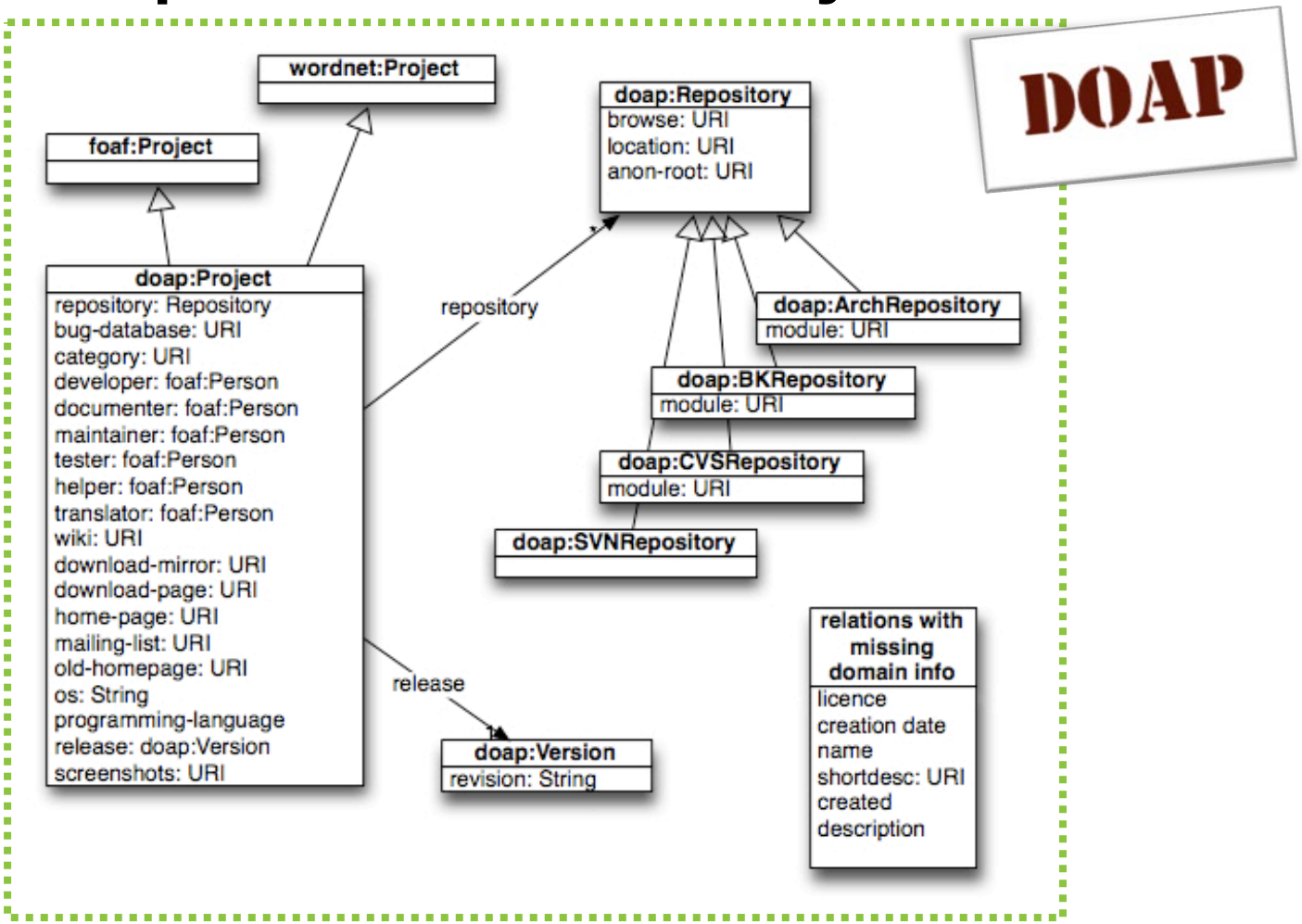


Image from http://code.google.com/p/baetle/wiki/DoapOntology: Breslin

Music Ontology

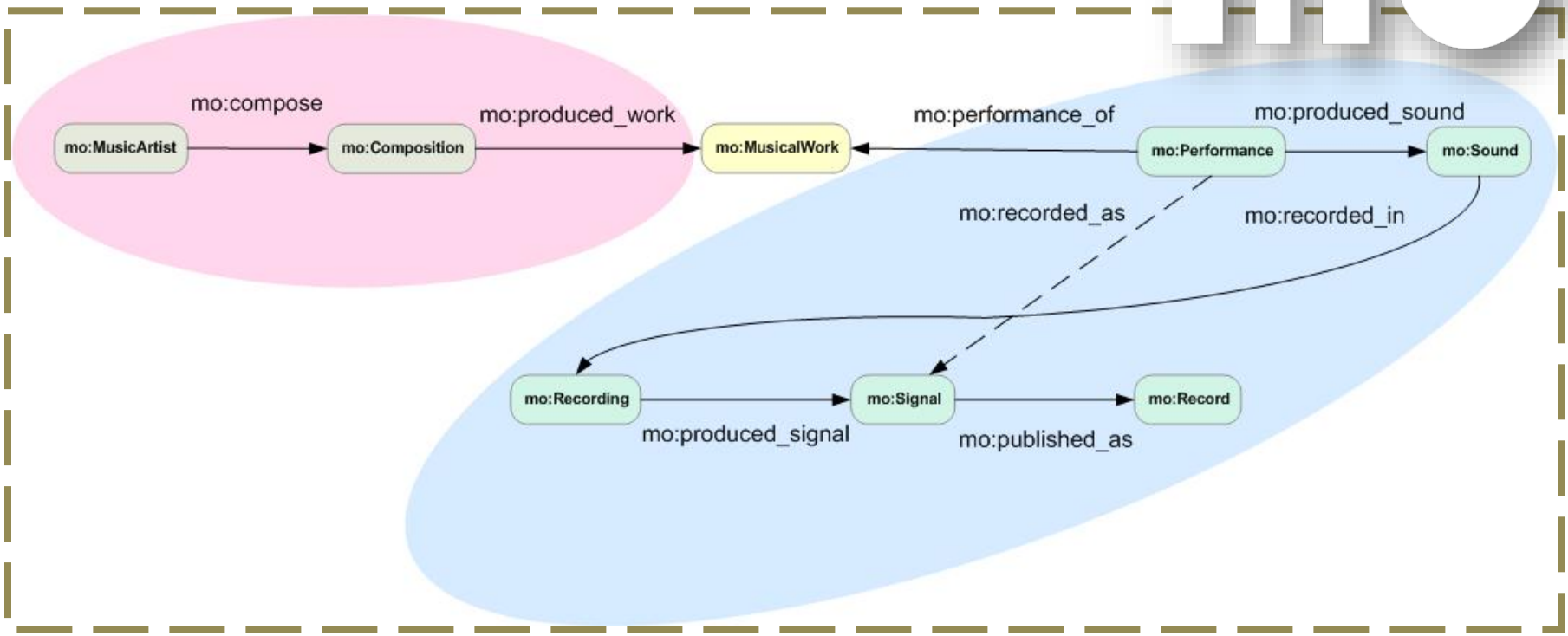


Image from http://musicontology.com/:Raimond, Giasson

http://www.w3.org/TR/wordnet-rdf/

WordNet

EUCLID
EdUcational Curriculum for the usage of LInked Data

WordNet

Apache Tomcat

WNWS
WordNet Web Service
for Apache Tomcat server

Bernard Bou
bbou@ac-toulouse.fr

This **Java** Web service produces XML output to word queries of the WordNet database. The release is in the form of a web archive (jar or zip format) which is ready to deploy but also contains both the sources and Intel native support needed for deployment (other platforms may refer to http://wnjn.sf.net). This application is under the GPL license agreement.

1. **excel**
quality; "made an excellent speech"; "the school has excellent teachers"; "a first-class mind")

```
(TOP (S (NP (JJ excellent) )
      (VP (VBZ is)
         (NP (NP (NN something) )
            (PP (IN of)
               (NP (DT the) (JJS highest) (NN quality) ) ) ) )
      (. .) ) )
```

excellent:JJ(x1) -> **of**:IN(x1, x2) **highest**:JJ(x1)
quality:NN(x1)

```
<wf pos="IN" >of</wf>
<wf pos="DT" >the</wf>
<wf pos="JJS" lemma="high" quality="silver" wnsn="1"
```

Welcome to the 2nd release of

eXtended WordNet

The goal of this project is to develop a tool that takes as input the current or future versions of WordNet and automatically generates an eXtended WordNet that provides
intended t
of Word

In the eX
glosses a
transform
words are

Université de Neuchâtel unine [home]

Search

5 facilities

UniNE > Information Management Institute > projects >

directory sitemap localisation

iii Information Management Institute

- presentation
- projects
  - Zenodotus
  - knOWLer
  - ICDBrowser
  - IKARO
  - SplitTrees
  - HTS Classifier
- publications
- teaching

knOWLer

knOWLer is an ontology-based information management system targeting semantic integration into large-scale information syst
is provided through an ontology language (OWL), showing that ontological reasoning can be scaled to sizes of standard IR syster

OWL Representation of the WordNet Ontology

WordNet.OWL is an OWL-ontology based on WordNet 1.7.1 lexical database.

WordNet171.OWL contains both the ontology schema and the instances.

This OWL representation of the WordNet ontology can be freely used provided that proper references [1] are mentioned. F
consider the WordNet licence in case of commercial use of this ontology.

Download: wordnet171.owl.gz (aprox. 8.5Mb).

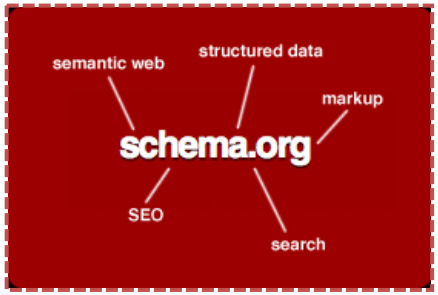
schema.org

EUCLID
EdUcational Curriculum for the usage of LInked Data

- Collection of schemas to mark-up structured content in HTML pages

Thing: additionalType, alternateName, description, image, name, sameAs, url
- Action: agent, endTime, instrument, location, object, participant, result, startTime
  - AchieveAction
    - LoseAction: winner
    - TieAction
    - WinAction: loser
  - AssessAction
    - ChooseAction: option
      - VoteAction: candidate
    - IgnoreAction
    - ReactAction
      - AgreeAction

Note: as of 2014-04-04 this tree is not entirely up to date. Additional types have been added: see EmailMessage, Reservation, Question and Answer, added in version 1.1. Version 1.2 added the Potential Actions vocabulary, see potentialAction, EntryPoint, target, actionStatus, ActionStatusType, ActiveActionStatus, CompletedActionStatus, PotentialActionStatus.



See also http://schema.org/docs/full.html

GoodRelations

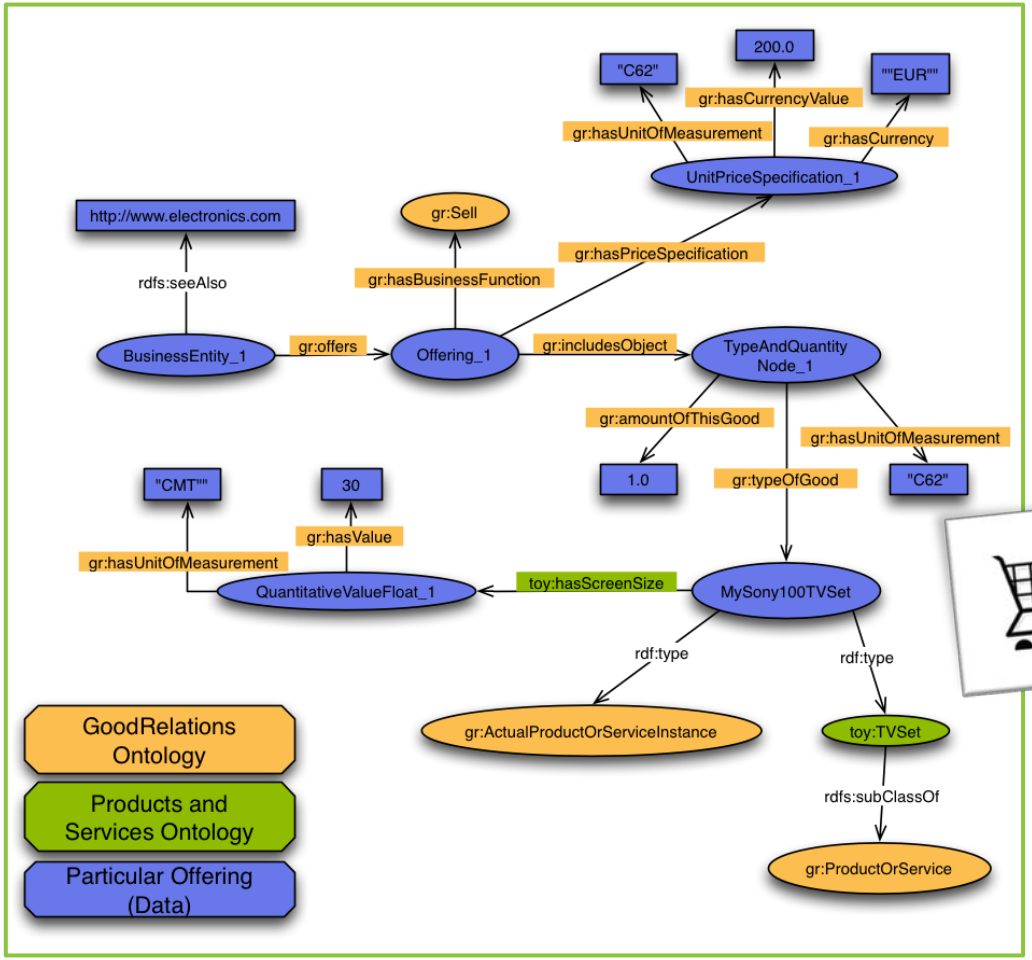


Image from http://www.heppnetz.de/projects/goodrelations/primer/: Hepp

Life sciences and healthcare

EUCLID
EdUcational Curriculum for the usage of LInked Data

The Open Biological and Biomedical Ontologies

Home | Contact

Ontologies Resources Participate About

The OBO Foundry is a collaborative experiment involving developers of science-based ontologies who are establishing a set of principles for ontology development with the goal of creating a suite of orthogonal interoperable reference ontologies in the biomedical domain. The groups developing ontologies who have expressed an interest in this goal are listed below, followed by other relevant efforts in this domain.

In addition to a listing of OBO ontologies, this site also provides a statement of the OBO Foundry principles, discussion fora, technical infrastructure, and other services to facilitate ontology development. We welcome feedback and encourage participation.

Click any column header to sort the table by that column. The 🐾s link to the term request trackers for the listed ontologies.

OBO Foundry ontologies

Title	Domain	Prefix	File	Last changed
Biological process	biological process	GO	go.obo	
Cellular component	anatomy	GO	go.obo	
Chemical entities of biological interest	biochemistry	CHEBI	chebi.obo	
Molecular function	biological function	GO	go.obo	
Ontology for biomedical investigations	experiments	OBI	obi.owl	
Phenotypic quality	phenotype	PATO	quality.obo	
Plant Ontology	anatomy and development	PO	plant_ontology.obo?view=co	
PRotein Ontology (PRO)	proteins	PR	pro.obo	
Xenopus anatomy and development	anatomy	XAO	xenopus_anatomy.obo	
Zebrafish anatomy and development	anatomy	ZFA	zfa.obo	

OBO Foundry candidate ontologies and other ontologies of interest

Quick Links

- Mappings between ontologies
- Download alternate formats
- About the OBO Foundry
- Current events
- How to join
- OBO Foundry paper in *Nature Biotechnology*, November 2007

Other Ontology Lists

- OntoBee
- Ontology Lookup Service (OLS) (OBO Foundry term lookup)

http://www.obofoundry.org/

Getty vocabularies

EUCLID
EdUcational Curriculum for the usage of LInked Data

Explore the Getty
Connect with Us | Shop
Search

Visit
Museum
Research Institute
Conservation Institute
Foundation
Publications
About the Getty

The Getty Research Institute

Events | Special Collections | Library | Search Tools & Databases | Scholars & Projects | Publications | About the GRI

Print Share

- Getty Research Portal
- Collection Inventories & Finding Aids
- Photo Archive
- Research Guides & Bibliographies
- Digital Collections
- Article & Research Databases
- Collecting & Provenance Research
- BHA & RILA
- Getty Vocabularies
  - Art & Architecture Thesaurus (AAT) ®
  - Cultural Objects Name Authority (CONA) ®
  - Getty Thesaurus of Geographic Names (TGN) ®
  - Union List of Artist Names (ULAN) ®
  - Contribute
  - Editorial Guidelines
  - **Getty Vocabularies as Linked Open Data**
  - Frequently Asked Questions
  - Obtain the Getty Vocabularies
  - Training Materials

Getty Vocabularies as Linked Open Data

The Getty vocabularies are constructed to allow their use in linked data. A project to publish AAT, TGN, ULAN, and CONA to the LOD (Linked Open Data) cloud is underway. The documents on this page contain news and presentations about releasing the Getty vocabularies as LOD. These materials are subject to frequent modification and addition.

Linked Open data
GETTY VOCABULARIES

- News and Status of the Project
- What Is LOD?
- Introduction to Getty Vocabularies as LOD (PDF, 3.8 MB, 46pp)
- Linked Open Data Flier (PDF, 1 MB, 1pp)
- List of External Advisors (PDF, 88KB, 7pp)

The AAT and TGN are now available as LOD. They are published under the ODC-By 1.0 license.

- **Developers and programmers, technical documentation to help you explore the AAT and TGN data is available at the SPARQL endpoint at vocab.getty.edu**

News and Status of the Project

Inside Perspective

- Unlocking hidden resources for scholars

Have a Question?

Contact the Vocabulary Program

http://www.getty.edu/research/tools/vocabularies/lod/index.html

SELECT ONTOLOGIES

Selecting relevant ontologies

- Key: domain and usage
  - There are many different points of view upon a domain
  - Use popular ontologies

- You might need to adjust/expand an existing ontology to
  - Lexicalization
  - Implementation language (e.g., RDFS, OWL, frames, SKOS)
  - Level of granularity
  - Level of expressivity
  - Instance data

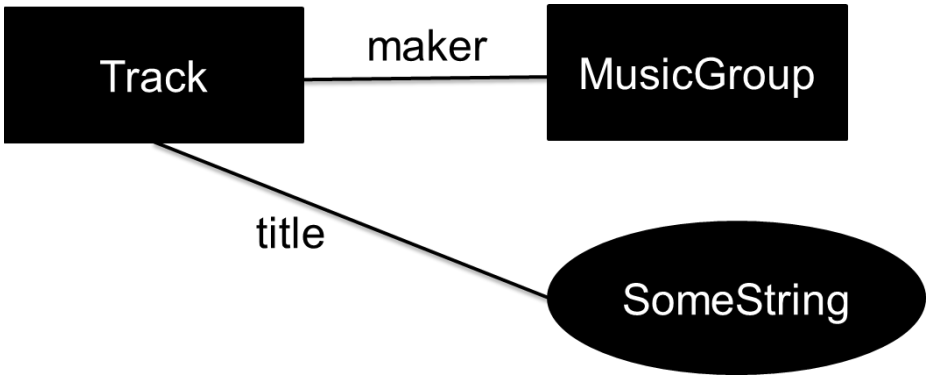
- Be aware of/that
  - Imports: transitive dependency between ontologies
  - Changes in imported ontologies can result in inconsistencies and changes of meanings and interpretations, as well as computational aspects

Brief introduction to ontology conceptualization

ADJUST/EXPAND

Basics

- Ontological primitives in this tutorial
- Classes
- Instances
- Attributes
- Relationships
- Literals



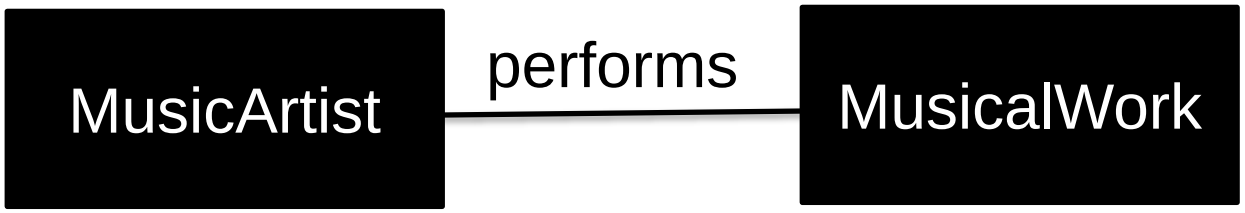
- In real applications
  - Ontology languages with different degrees of formality and support for
    - Different types of nodes
    - Different types of edges
    - Built-in features of nodes and edges
  - Nodes and edges may come from different ontologies
  - (Ideally) provenance metadata attached to nodes and edges

Example: OWL

- Classes
- Instances
  - Set of classes is not always disjunct from set of instances
- Datatype properties
- Object properties
- Constraints
  - Cardinality
  - Range constraints (all values, some values etc.)
- Others
  - Imports
  - Annotations
  - …

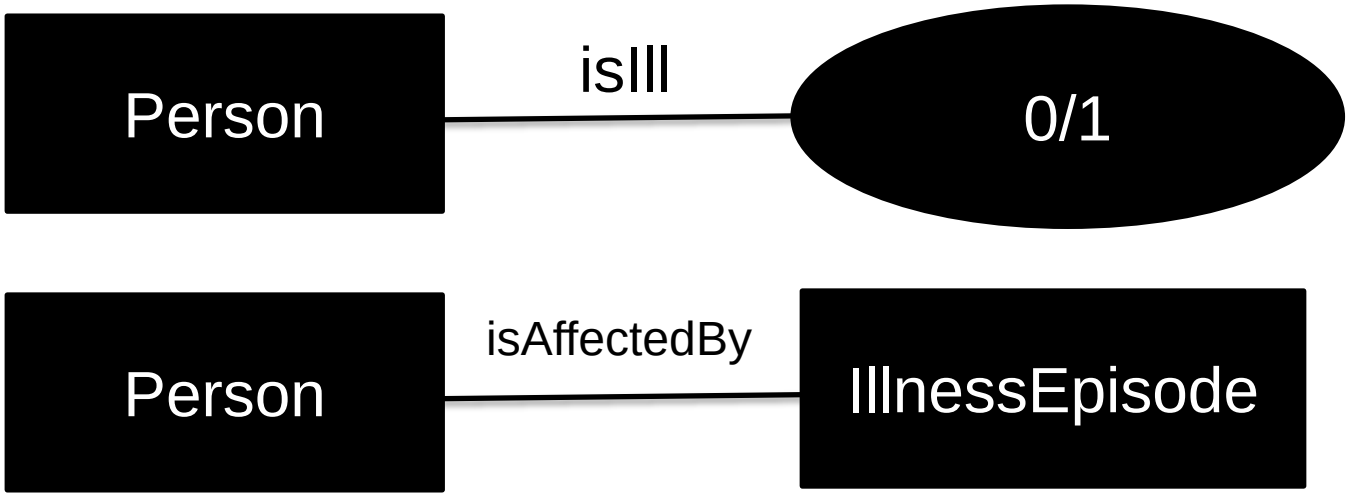
Classes

- A class represents a set of instances
- A class should be cohesive, meaninfully named, and relevant
- Classes represent domain concepts and not the words that denote these concepts
  - Synonyms for the same concept do not represent different classes



Classes (2)

- Typically nouns and nominal phrases, but not restricted to them
  - Verbs can be modeled as classes, if the emphasis is on the process as a whole rather than the actual execution
  - No pronouns



Cohesiveness

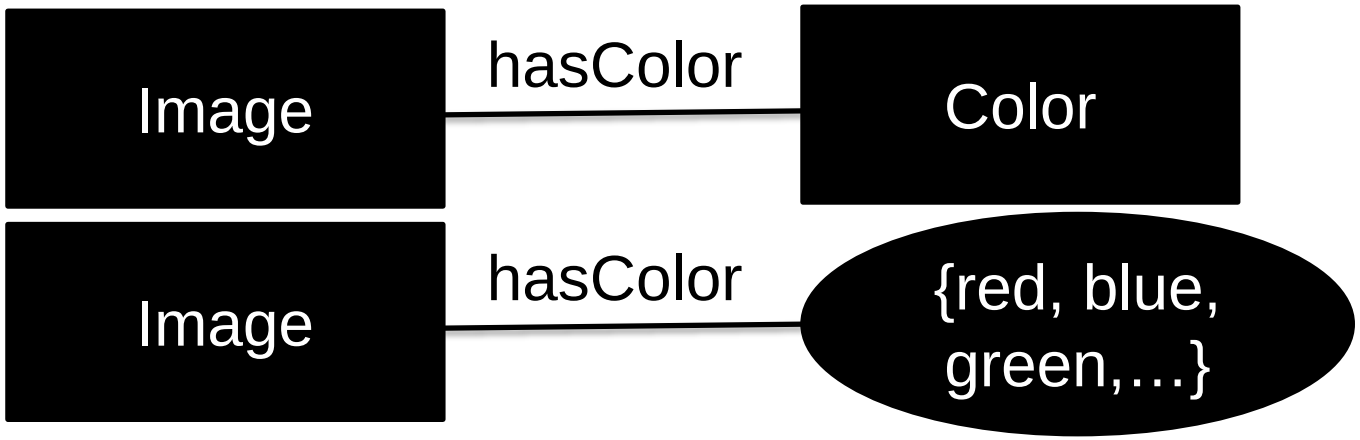
- A class should represent one thing, all of that thing and nothing but that thing
  - Why: Reusability, maintenance, see also OO design
- You can prove cohesion by giving the class a representative name, typically nouns
    - No plural form, e.g, Albums
    - No others, utilities etc.
- On a related note: avoid ambiguous terms
  - Manager, handler, processor, list, information, item, data etc.

Instances

- Entities of a certain type
  - Abstract entities (e.g., Jazz music) are allowed
- Issues
  - Distinction between classes and instances
    - Example: Stradivarius
  - Choice of the most appropriate class
    - Example: Violetta Valery
- Identity vs individuality: entities may change values, but remain members of the same class
  - Example: Age of child vs person

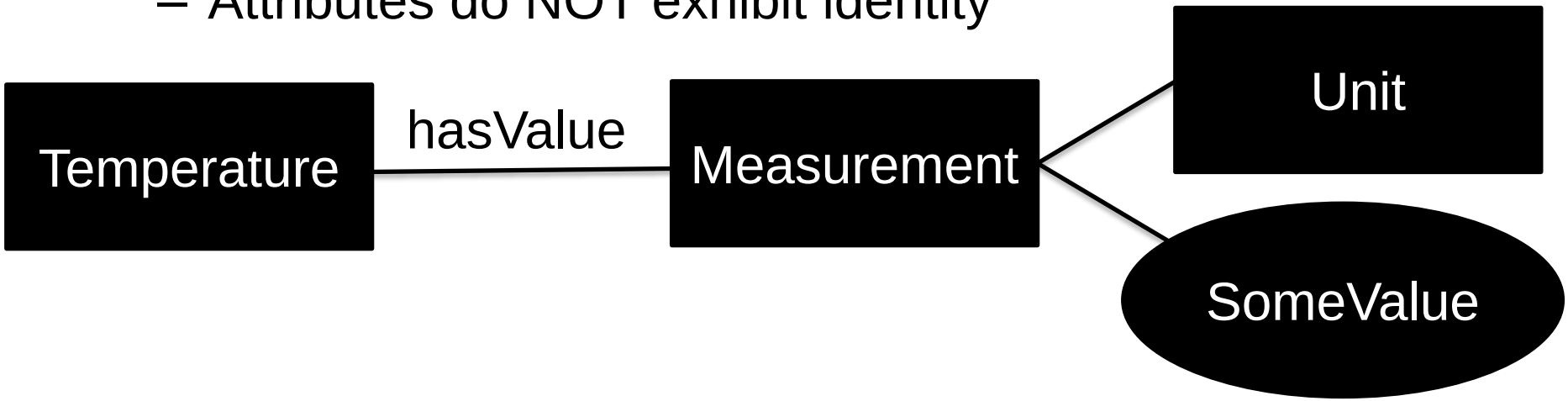
Characterizing classes

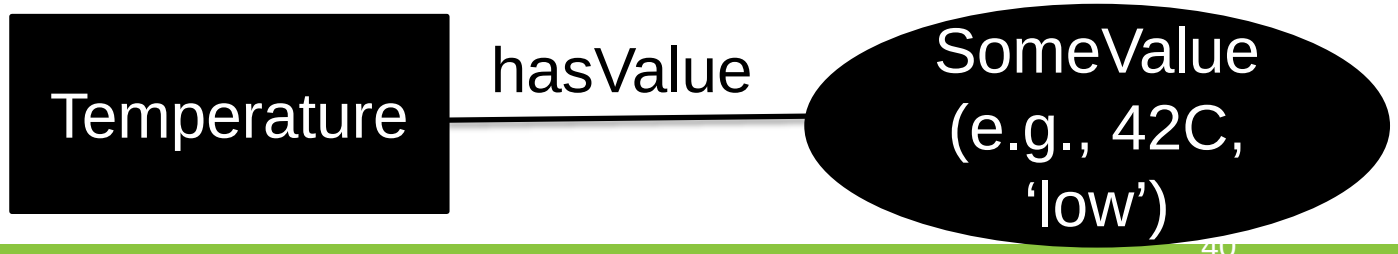
- Two types of principal characteristics
  - ‚Measurable' properties of a class: attributes
  - Inter-entity connections: relationships associations



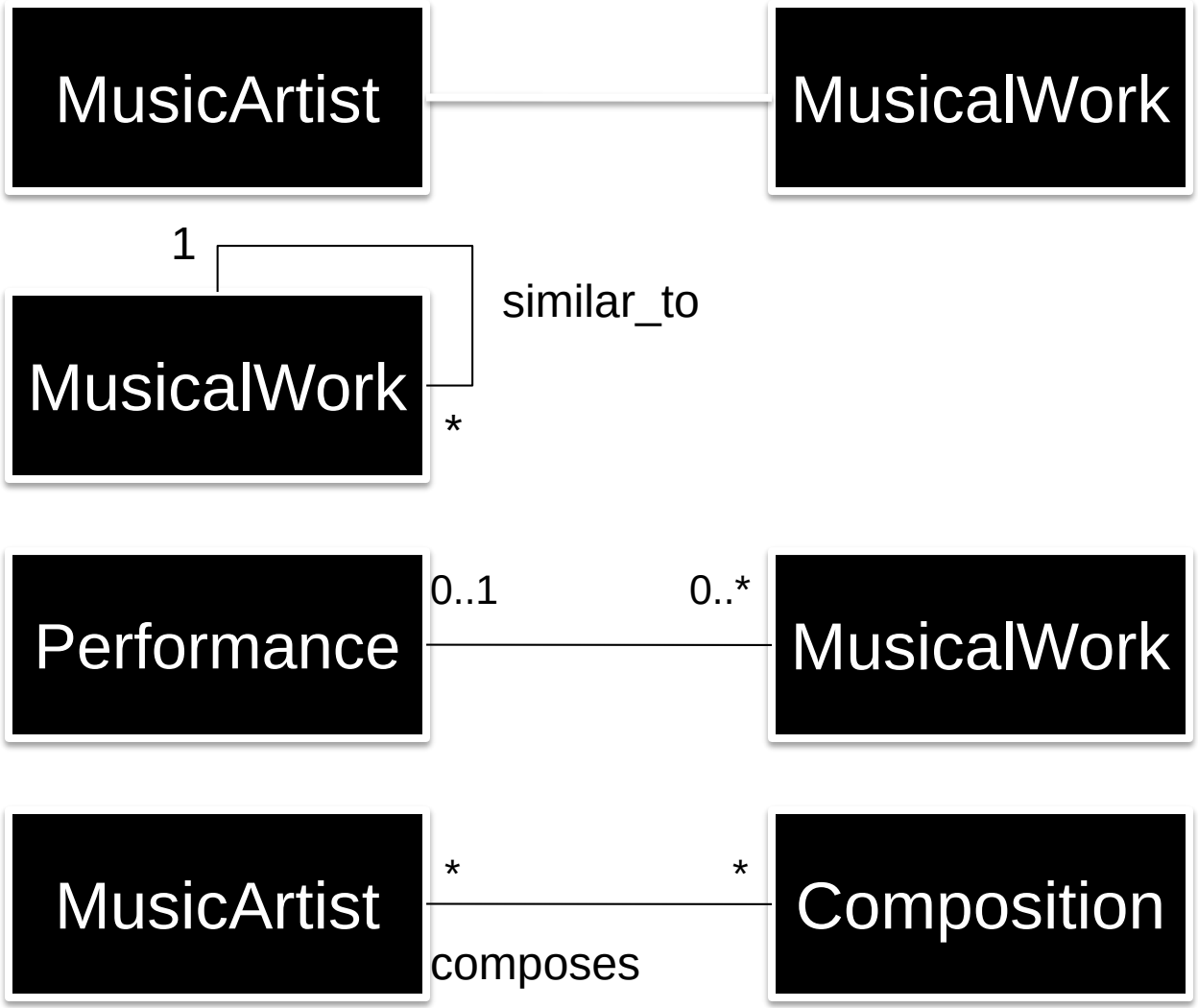
Attributes

- An attribute is a measurable property of a class
  - Scalar values: choice from a range of possibilities
  - Attributes do NOT exhibit identity





Relationships



Some instances of a class hold a relationship with some instances of another class

Class hierarchy

- A subclass of a class represents a concept that is a “kind of” the concept that the superclass represents

- A subclass has
  - Additional properties
  - Restrictions different from those of the superclass, or
  - Participates in different relationships than the superclasses

- Multiple inheritance may be possible

Class hierarchy (2)

- All the siblings in the hierarchy (except for the ones at the root) must be at the same level of generality
- If a class has only one direct subclass there may be a modeling problem or the ontology is not complete
- If there are more than a dozen subclasses for a given class then additional intermediate categories might be necessary
- Roles are not subclasses
- Application dependent or subjective
  - Example: Artist and person
  - Example: Rectangle and square

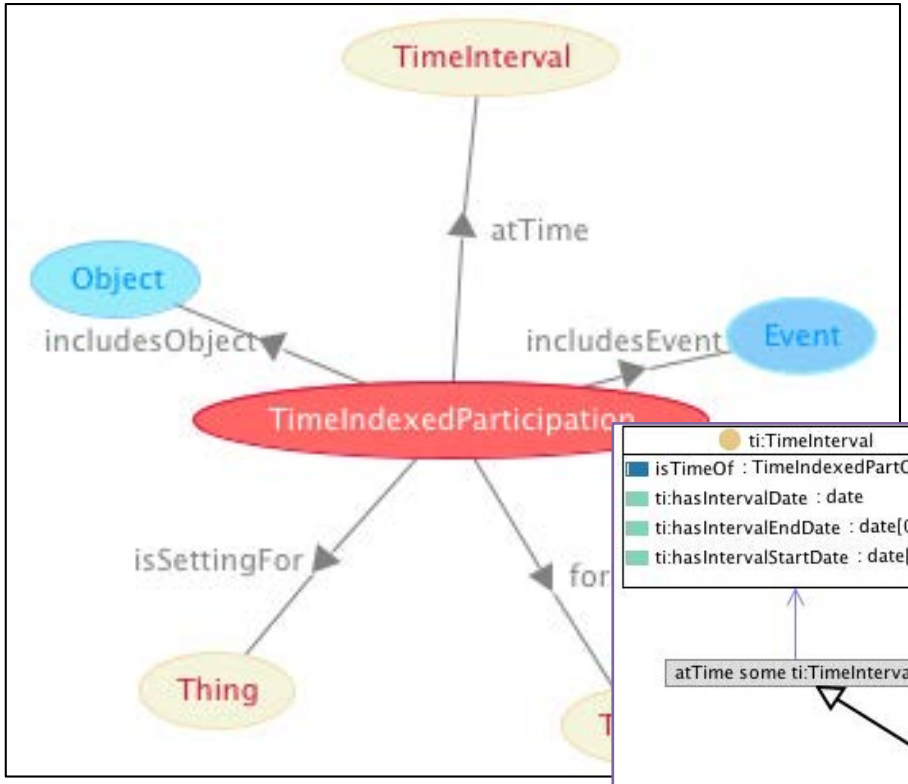
Formal properties of ontologies

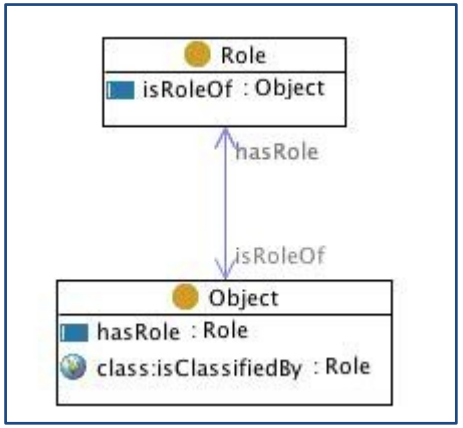
- Identity
  - Example: triangle as three edges of the same length vs edge length and angle
  - Example: the same clay vs the same statue
  - See also primary keys in ER modeling
- Types and roles
  - Roles hold because an instance happens to participate in some relationship with another instance (at some point in time), and not because they care essential to identify these instances
  - Example: Person vs student vs employee
- Dependence
  - Existence depends on other instance
  - Example: Student and university
- Concreteness
  - Has physical location (not necessarily real)
  - Example: Violetta Valery
- Unity
  - Is identified by the sum of its parts
  - Example: Piece of stone vs person vs pile of stones

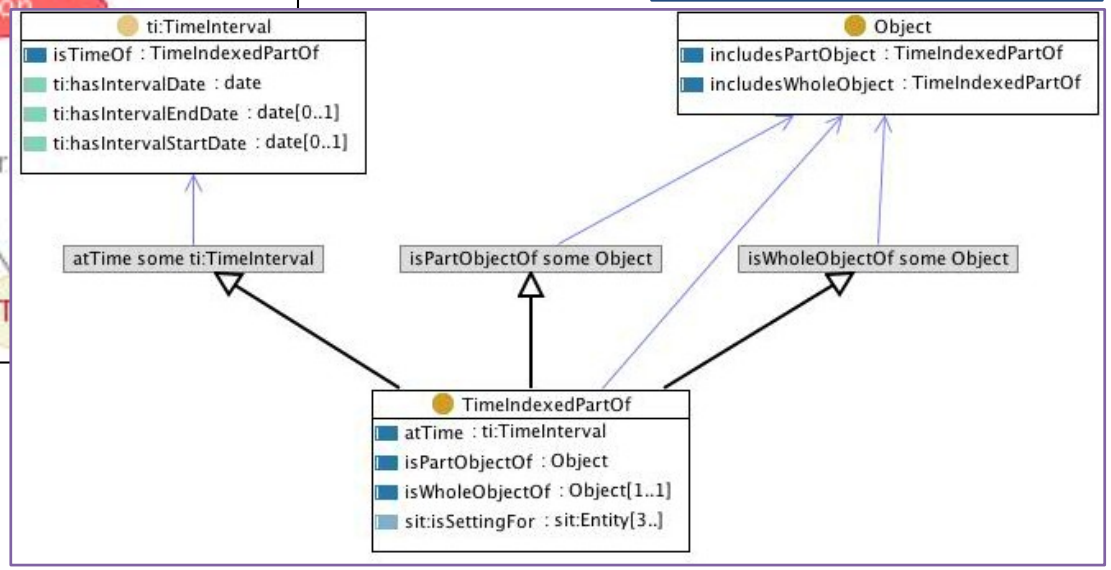
- These properties are inherited along by subclasses and instances
- Used to
  - Test ontological consistency
  - Avoid unintended inferences
  - Improve extendibility
  - Improve reusability

- See also
  - OntoClean (http://en.wikipedia.org/wiki/OntoClean)

Ontology design paterns







Content from http://ontologydesignpatterns.org/

http://www.euclid-project.eu

EUCLID
EdUcational Curriculum for the usage of LInked Data

WDAqua ITN
Answering Questions using Web Data

eBook

HTML

kindle amazonkindle

ePUB

iBooks

Course

HTML

iTunes U

Other channels

@euclid_project

euclidproject

euclidproject