ESWC26

Same Data; Different Models (SDDM - 2026)

Antrea Christou[1], Cogan Shimizu[1], Davide Di Pierro[2], María Poveda-Villalón[3], Andrea Giovanni Nuzzolese[4], John Beverley, Anna Sofia Lippolis[5], Danaï Symeonidou[6], Lylia Abrouk[7]

[1]Wright State University, USA
[2]Université de Montpellier, France
[3]Universidad Politecnica de Madrid, Spain
[4]CNR, Italy
[5]Università di Bologna, Italy
[6]Inrae, France
[7]Université Bourgogne Europe, France

Schedule

1. Overview & Methodological Context
2. Session 1 - Linked Open Terms (LOT) + Chowlk
3. Session 2 - Basic Formal Terms (BFO)
4. Questions/ Discussion
5. Coffee Break (30 m)
6. Session 3 - exTreme Design (XD)
7. Ontology Engineering and KGEs

Speakers

- **María Poveda-Villalón**, Universidad Politecnica de Madrid, Spain.
- **Anna Sofia Lippolis**, Università di Bologna, Italy & CNR, Italy
- **John Beverley**, University of Buffalo

Ontology Engineering

Ontology engineering is the discipline that investigates the principles, methods, and tools for creating and maintaining ontologies (Iqbal et al., 2013).

Today's pipeline of popular methodologies:

1. Requirements Elicitation

2. Ontology Conceptualization

3. Ontology Evaluation

Why do we need it?

Many examples of failures are known, mostly based on the following aspects:

lack of consensus

lack of interoperability

lack of formality

technological limits

Comparative Experiment

A *one-fits-all* methodology does not exist due to different requirements, data, and resources (e.g., available people). In this tutorial, you will have an overview of the following ones:

- Linked Open Terms (Poveda-Villalón et al., 2020) - 304 citations,
- eXtreme Design (Presutti et al., 2009) - 197 citation,
- Basic Formal Ontology (Otte et al., 2020) - 202 citations,
- Ontology Engineering with LLMs (Lippolis et al., 2025) - 46 citations.

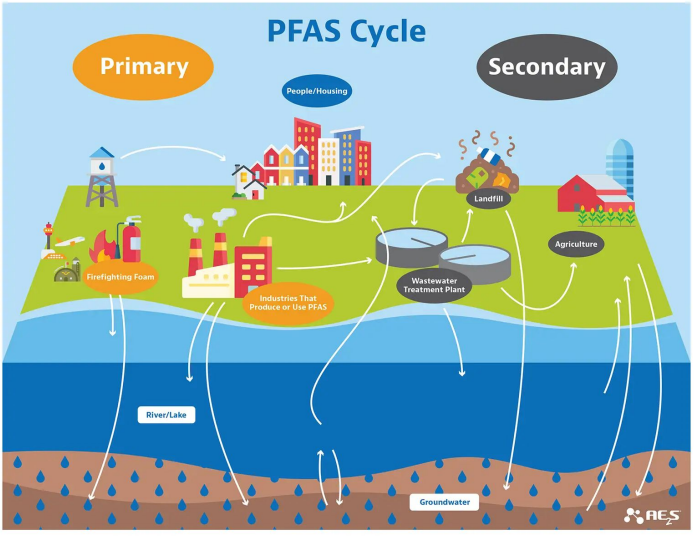
Use Case - PFAS

Per-and polyfluoroalkyl substances - PFAS

- Persistent artificial molecules
- Exposing significant risks to human health

Illustration credit: capecod.gov

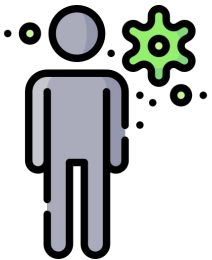
PFAS Lifecycle



PFAS Sub-areas

Chemistry

Exposure



Measurements

What is PDH (**P**FAS **D**ATA **H**UB)?

PFAS DATA HUB **French platform dedicated to environmental data**

Centralizes heterogeneous pollution resources

- **Scientific papers**
- **Technical reports**
- **Government documents**
- **Environmental observations**

· https://pdh.cnrs.fr/en/

Why is PDH useful for PFAS?

Scattered Knowledge

PFAS knowledge is currently scattered across many different sources.

Multiple Formats

Data exists in various forms: PDFs, technical reports, and measurements.

Complex Analysis

Manual analysis of these diverse sources is difficult and time-consuming.

PDH Solution

PDH effectively aggregates and centralizes all relevant information.

What information can we extract?

Entities

- PFAS compounds
- Locations
- Measurements

Health & Regs

- Health effects
- Regulations

Relations

- “Contaminates”
- “Detected_in”
- “Causes”

PDH Entities

Chemical entities:

PFAS compounds (PFOA, PFOS, GenX) , Other pollutants

Environmental entities:

Rivers, lakes, groundwater, Industrial sites

Measurement entities:

Concentration values, Sampling dates

Health entities:

Toxicity effects, Bioaccumulation

Examples from PDH

“PFOA detected in groundwater near industrial area”

Entity: PFOA

Location: groundwater

Relation: “detected_in”

“PFOS concentration exceeded regulatory threshold”

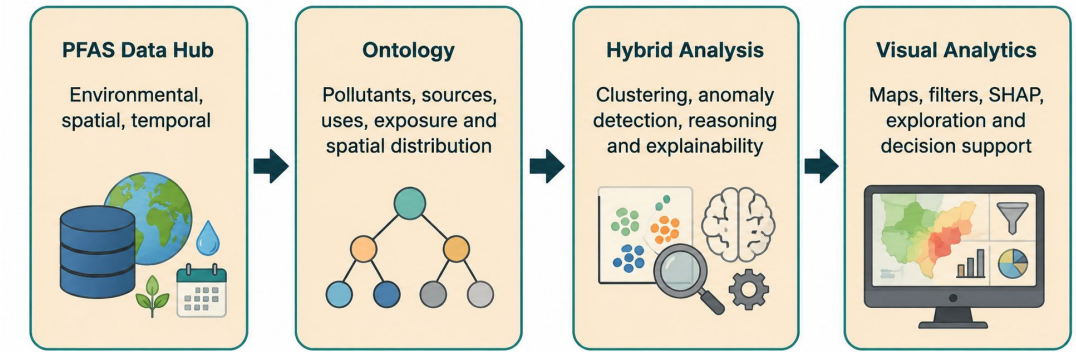
Entity: PFOS

Measurement: concentration value

Relation: “exceeds_threshold”

EAD project based on PDH

Environmental **A**nomaly **D**etection and Health Impacts: Addressing PFAS Risks



https://labrouk.github.io/site/EAD.html

EAD project based on PDH

Session 1C: Ontology Engineering (I) May 12th

"OntoPFAS: an Ontology for the Forever Chemicals"

*Davide Di Pierro, **Lylia Abrouk**, Alexis Guyot, **Danai Symeonidou**, Pierre Labadie and Benjamin Lysaniuk*

Project Networking session

"EAD: Environmental Anomaly Detection and Health Impacts for PFAS Risk Analysis"

Lylia Abrouk**, Davide Di Pierro and **Danai Symeonidou

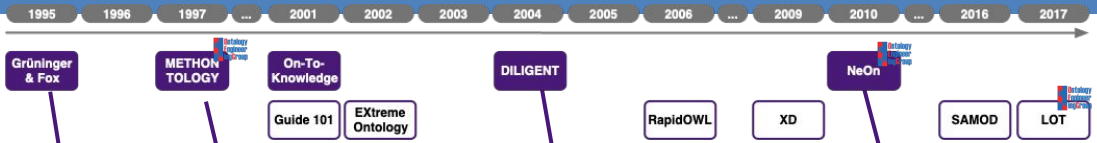
LOT Ontology development methodology

Same Data Different Model tutorial ESWC2026

María Poveda Villalón, Ontology Engineering Group
Universidad Politécnica de Madrid, Spain
[mpoveda@fi.upm.es].

10th June 2026

This work was supported by the grant “SOEL: Supporting Ontology Engineering with Large Language Models” PID2023-152703NA-I00 funded by MCIN/AEI/10.13039/501100011033 and by ``ERDF/UE''.



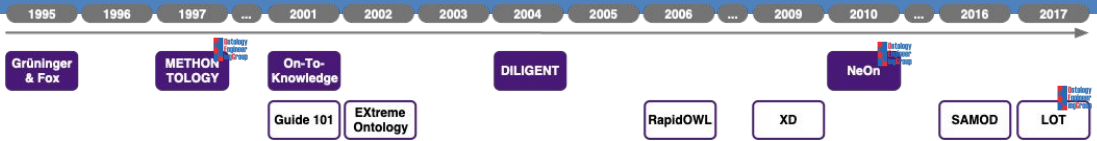
- Competency Questions technique

- Intermediate representations
- Activities identification and definition
- Activities organization

- Best practices
- Lightweight
- Common problems addressed
- Frames oriented… but still applicable

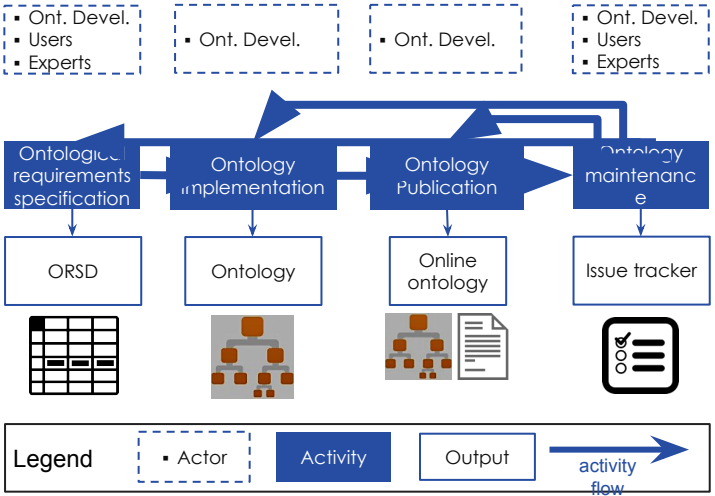
- Collaborative process
- Local adaptations

- 9 Scenarios
- Activity templates
- Guidelines for: specification, ontology reuse, NOR reuse, ODP reuse, scheduling, etc.

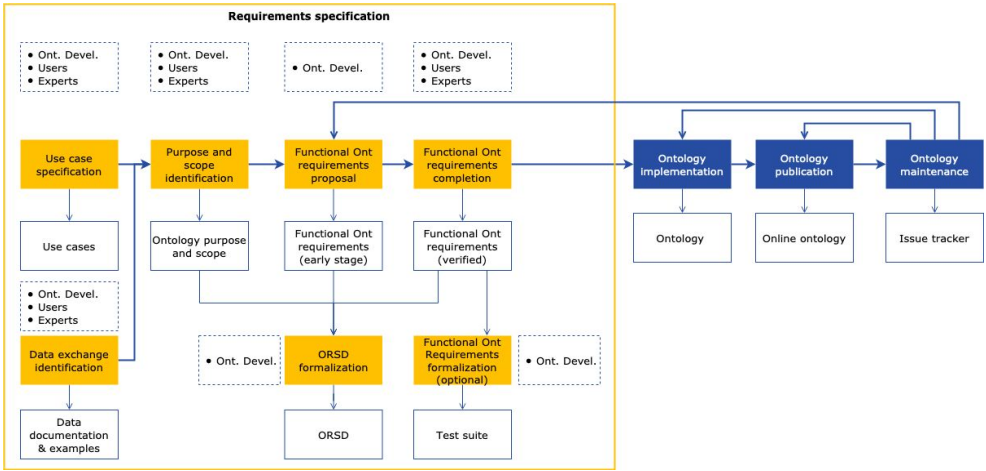


- Towards lightweight and agile processes
- Inspiration from software development practices
- Coupling Software and ontology development

Slide taken from “Trendy Practices and Tools in Ontological Engineering” by Dr. María Poveda Villalón



http://lot.linkeddata.es/


Requirements specification
• Ont. Devel.
• Users
• Experts
• Ont. Devel.
• Users
• Experts
• Ont. Devel.
• Ont. Devel.
• Users
• Experts
Use case specification
Purpose and scope identification
Functional Ont requirements proposal
Functional Ont requirements completion
Ontology implementation
Ontology publication
Ontology maintenance
Use cases
Ontology purpose and scope
Functional Ont requirements (early stage)
Functional Ont requirements (verified)
Ontology
Online ontology
Issue tracker
• Ont. Devel.
• Users
• Experts
Data exchange identification
• Ont. Devel.
ORSD formalization
Functional Ont Requirements formalization (optional)
• Ont. Devel.
Data documentation & examples
ORSD
Test suite

Sample Type Key:

SAMPLE TYPE	DESCRIPTION	SAMPLE TYPE	DESCRIPTION
AS	ASH (BOTTOM & FLY)	NRV	NON-ROOT VEGETABLES
BC	BEDROCK CHIPS	O	OFFAL
BD	BLOOD	POL	POLYMER
BM	BUILDING MATERIAL	PO	PORE WATER
CO	COMPOST	PW	PROCESS WATER
DW	DRINKING WATER	RV	ROOT VEGETABLES
E	EGG	SA	SAWDUST
FE	FEED	SD	SEDIMENT
FA	FLY ASH	SF	SKINLESS FILET
FR	FRUIT	SL	SOIL
GR	GRAINS (GROWN BY FARM)	SOF	SKIN-ON FILET
GW	GROUNDWATER	SPG	SEPTAGE
L	LEACHATE	SR	STORM WATER RUNOFF
LG	LEAFY GREENS	SU	SLUDGE
LV	LIVER	SW	SURFACE WATER
MA	MANURE	U	UNKNOWN
MEA	MEAT	V	VEGETATION
MLK	MILK	WH	WHOLE
MU	MUSCLE	WS	WHOLE WITHOUT SKIN
N	NEAT SAMPLE	WW	WASTE WATER

Requirements specification

- Ont. Devel.
- Users
- Experts

- Ont. Devel.
- Users
- Experts

- Ont. Devel.

- Ont. Devel.
- Users
- Experts

MAINE PFAS DATA (2007-2022)

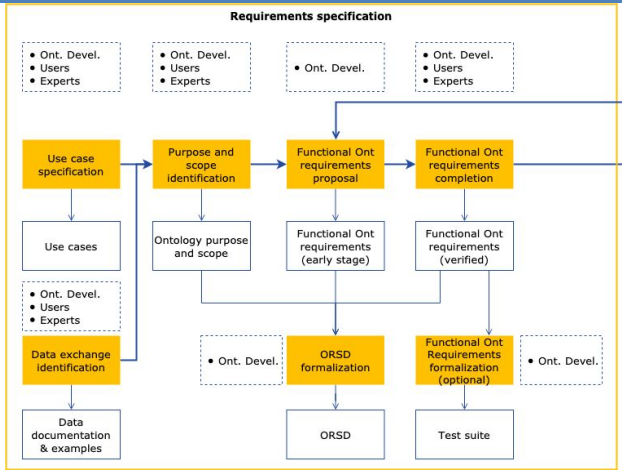
CURRENT SITE NAME	Town	SAMPLE POINT SEQ	SAMPLE DATE	SAMPLE TYPE	PARAMETER	CONCENTRATION	UNITS	LAB QUALIFIER
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFBS_A	17,2	ng/L	
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFHPA_A	310	ng/L	
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFHPS_A	35,4	ng/L	
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFNA_A	42,2	ng/L	
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFTEA_A		ng/L	U
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	8:2 FTS_A	14,4	ng/L	J
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFHXDA_A		ng/L	U
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFNS_A		ng/L	U
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFTRIA_A		ng/L	U
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFOSA	23,1	ng/L	
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	4:2 FTS_A	0,745	ng/L	J
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	ADONA_A		ng/L	U
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFOS_A	1410	ng/L	
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFOA_A	1150	ng/L	
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFOA + PFOS	2560	ng/L	
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	SUM OF 6 PFAS	3050	ng/L	
TAHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	HFPO-DA_A		ng/L	U
TAHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	PFODA_A		ng/L	U
TAHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	PFOS_A	2,07	ng/L	
TAHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	PFUNDA_A		ng/L	U
TAHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	N-MeFOSAA		ng/L	U
TAHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	PFPEA_A	6,05	ng/L	
TAHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	PFPES_A		ng/L	U
TAHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	6:2 FTS_A	3,47	ng/L	J
TAHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	N-EtFOSAA		ng/L	U
TAHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	PFHXA_A	3,29	ng/L	
TAHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	PFDOA_A		ng/L	U
TAHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	PFOA_A	24,2	ng/L	
TAHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	PFDA_A		ng/L	U
TAHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	PFDS_A		ng/L	U

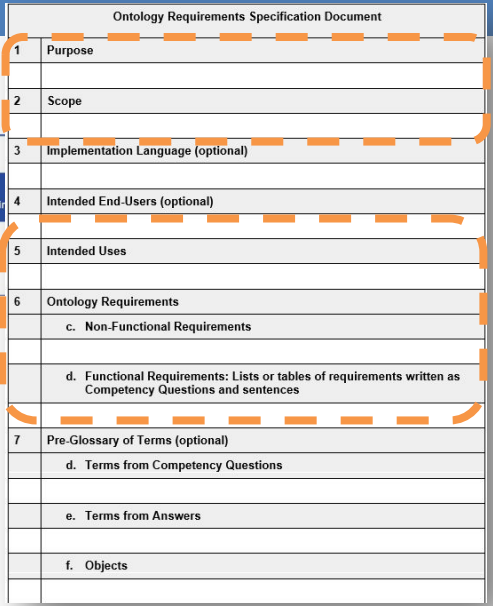
h Qualifier Key:

B	COMPOUND IS FOUND IN THE ASSOCIATED METHOD BLANK (ORGANIC) OR THE REPORTED VALUE WAS LESS T THE REPORTING LIMIT BUT GREATER THAN OR EQUAL TO THE INSTRUMENT DETECTION LIMIT (INORGANIC).
B*	COMPOUND IS FOUND IN THE ASSOCIATED METHOD BLANK (ORGANIC) OR THE REPORTED VALUE WAS LESS T THE REPORTING LIMIT BUT GREATER THAN OR EQUAL TO THE INSTRUMENT DETECTION LIMIT (INORGANIC) AN QC RESULTS ARE NOT WITHIN CONTROL LIMITS.
D	SAMPLE RESULT THAT REQUIRED DILUTION.
E	REPORTED VALUE IS ESTIMATED DUE TO PRESENCE OF INTERFERENCE (INORGANIC) OR COMPOUND EXCEEDE UPPER LEVEL OF CALIBRATION RANGE (ORGANIC).
EMPC	PEAK DETECTED, BUT DID NOT MEET QUANTIFICATION CRITERIA, RESULT REPORTED REPRESENTS THE ESTIMA MAXIMUM POSSIBLE CONCENTRATION.
J	ASSOCIATED VALUE IS ESTIMATED - MAY BE DUE TO FACTORS SUCH AS HOLDING TIME VIOLATIONS, BLANK CONTAMINATION, ETC.
J*	ASSOCIATED VALUE IS ESTIMATED AND QC RESULTS NOT WITHIN CONTROL LIMITS.
JB	ASSOCIATED VALUE IS AN ESTIMATE, COMPOUND IS FOUND IN THE ASSOCIATED METHOD BLANK.
LQV	LAB QUALIFIED, UNDEFINED. DATA SUBSEQUENTLY VALIDATED.
T	ANALYTE RECALCULATED AGAINST ALTERNATE LABELED COMPOUND(S) OR INTERNAL STANDARD.
U	NOT DETECTED ABOVE THE ASSOCIATED QUANTITATION LIMIT.
UJ	NOT DETECTED ABOVE THE ASSOCIATED QUANTITATION LIMIT AND ESTIMATED DUE TO VARIOUS QC DEVIATIO INCLUDING ELEVATED OR ESTIMATED QUANTITATION LIMIT.
UT	NOT DETECTED ABOVE THE ASSOCIATED QUANTITATION LIMIT; AND ANALYTE RECALCULATED AGAINST ALTER LABELED COMPOUND(S) OR INTERNAL STANDARD.
*	QC RESULTS NOT WITHIN CONTROL LIMITS.

Following Competency Questions/Natural language statements techniques

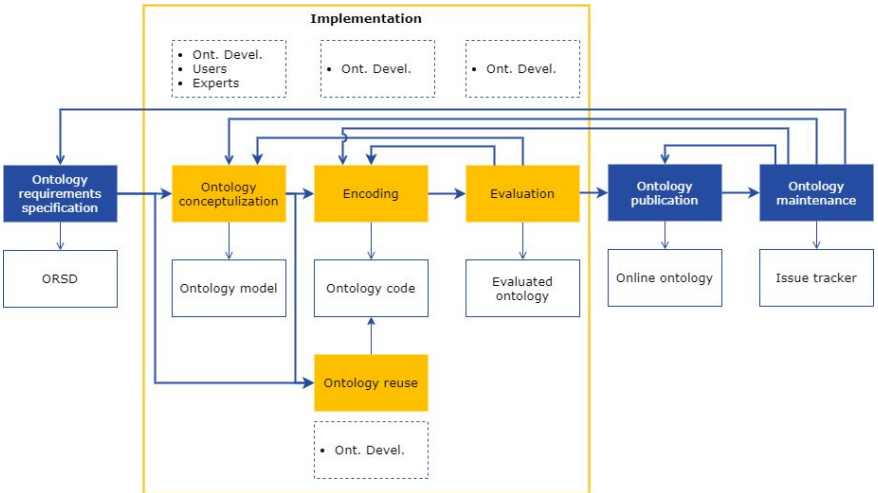
- A **sample record** shall be associated with a current **site name**
- A **site** shall have a textual **identifier** or **name**
- A **site** can be **located** within a **town**
- A town is a **geographic administrative entity**
- Multiple **sample records** can belong to the same **site**
- A **sample** shall be associated with a sample **point sequence identifier**
- A sample **point sequence identifier** shall include one **measurement** per **parameter**
- The possible **parameters** are: HFPO-DA_A, PFODA_A, PFOS_A, PFUNDA_A, N-MeFOSAA, PFPEA_A, PFPES_A, 6:2 FTS_A, N-EtFOSAA, PFHXA_A, PFDOA_A, PFOA_A, PFDA_A, PFDS_A, PFHXS_A, PFBA_A, PFBS_A, PFHPA_A, PFHPS_A, PFNA_A, PFTEA_A, 8:2 FTS_A, PFHXDA_A, PFNS_A, PFTRIA_A, PFOSA, 4:2 FTS_A, ADONA_A, PFOA + PFOS and SUM OF 6 PFAS
- A sample shall have a sample **date** that represents the time at which the sample was collected
- A sample shall have a **sample type**
- The possible **sample types** are: AS, BC, BD, BM, CO, DW, E, FE, FA, FR, GR, GW, L, LG, LV, MA, MEA, MLK, MU and N
- An analytical result shall have a **concentration value**
- Concentration values can be associated with **measurement units**
- An analytical result can optionally have a **laboratory qualifier**
- The possible **laboratory qualifiers** are: B, B*, D, E, EMPC, J, J*, JB, LQV, T, U, UJ, UT and *

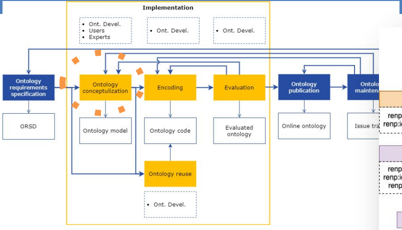


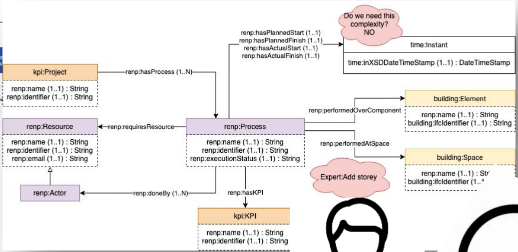


CORAL corpus provides examples and requirements patterns

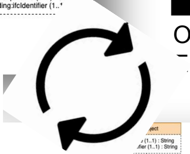
http://coralcorpus.linkeddata.es/


Implementation
• Ont. Devel.
• Users
• Experts
• Ont. Devel.
• Ont. Devel.
Ontology requirements specification
Ontology conceptulization
Encoding
Evaluation
Ontology publication
Ontology maintenance
ORSD
Ontology model
Ontology code
Evaluated ontology
Online ontology
Issue tracker
Ontology reuse
• Ont. Devel.

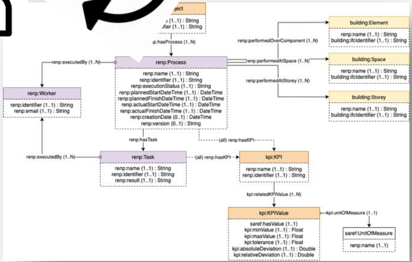




Ontology Engineer



Domain Expert

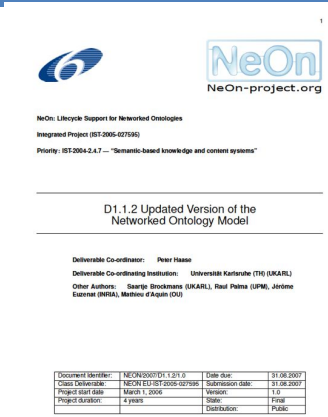


- **Goal**: build an ontology model from the ontological requirements identified.
  - Could be graphical or described in a formal system
- You can use
  - Blackboard
  - Pen & pencil
  - Draw.io (diagrams.net, visio, yEd.

Chowlk

https://chowlk.linkeddata.es/

- Based on UML_Ont profile [Haase, et al., 2009]
- Building blocks for OWL 1 and some OWL 2
  - Metadata
  - Prefixes
  - OWL elements
- Notation **alternatives**
  - **Compact** vs extended versions
  - Abbreviations



1

NeOn-project.org

NeOn: Lifecycle Support for Networked Ontologies

Integrated Project (IST-2005-027595)

Priority: IST-2004-2.4.7 — "Semantic-based knowledge and content systems"

D1.1.2 Updated Version of the Networked Ontology Model

Deliverable Co-ordinator: Peter Haase

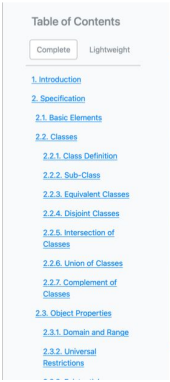
Deliverable Co-ordinating Institution: Universität Karlsruhe (TH) (UKARL)

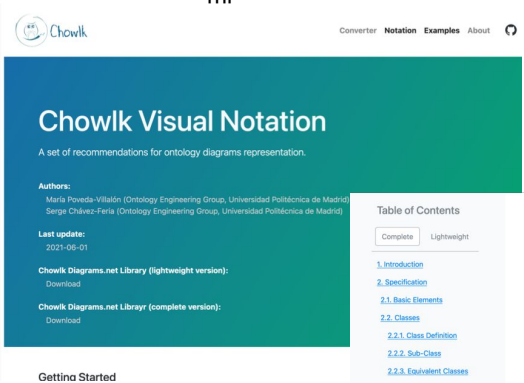
Other Authors: Saartje Brockmans (UKARL), Raul Palma (UPM), Jérôme Euzenat (INRIA), Mathieu d'Aquin (OU)

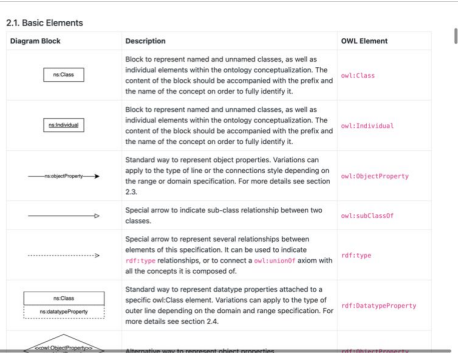
Document Identifier:	NEON/2007/D1.1.2/1.0	Date due:	31.08.2007
Class Deliverable:	NEON EU-IST-2005-027595	Submission date:	31.08.2007
Project start date	March 1, 2006	Version:	1.0
Project duration:	4 years	State:	Final
		Distribution:	Public

UML_Ont (Haase, et al. "D1. 1.2 updated version of the networked ontology model." NeOn Project Deliverable. (2009).

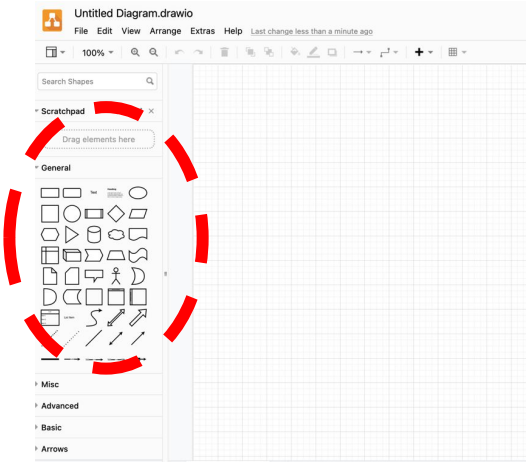
https://chowlk.linkeddata.es/notation.html

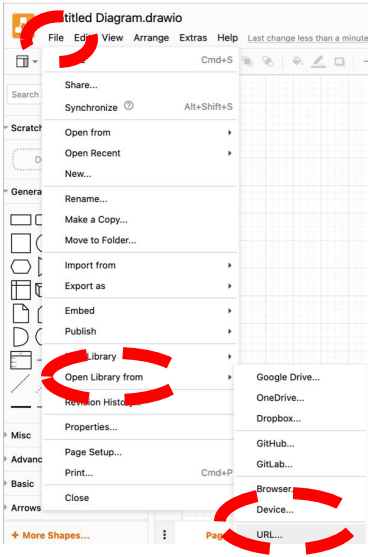


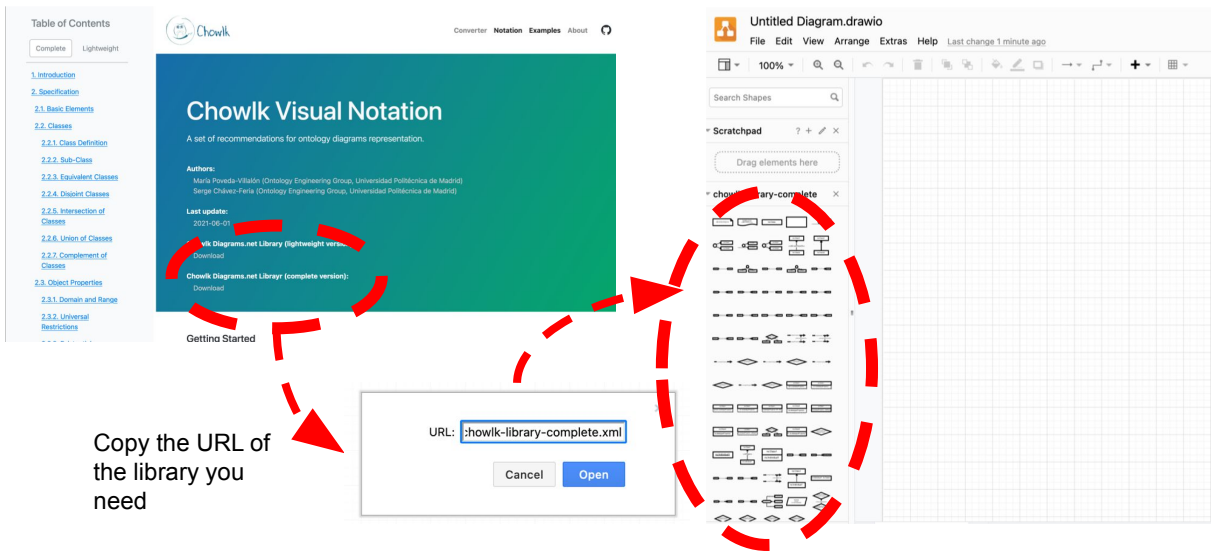





Chowlk
Visual notation
Templates

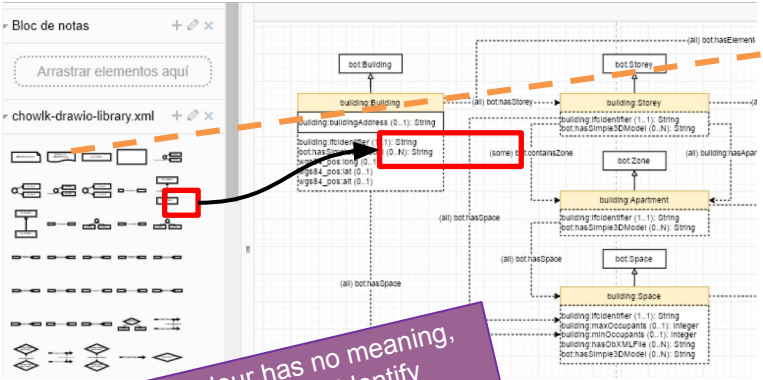

Untitled Diagram.drawio
File Edit View Arrange Extras Help Last change less than a minute ago
100%
Search Shapes
Scratchpad
Drag elements here
General
Misc
Advanced
Basic
Arrows

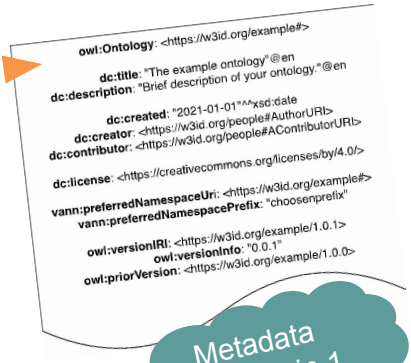

Untitled Diagram.drawio
File Edit View Arrange Extras Help Last change less than a minute
Cmd+S
Share...
Synchronize
Alt+Shift+S
Open from
Open Recent
New...
Rename...
Make a Copy...
Move to Folder...
Import from
Export as
Embed
Publish
Library
Open Library from
Properties...
Page Setup...
Print...
Cmd+P
Close
Google Drive...
OneDrive...
Dropbox...
GitHub...
GitLab...
Device...
URL...
Misc
Basic
Arrows
+ More Shapes...



Copy the URL of the library you need

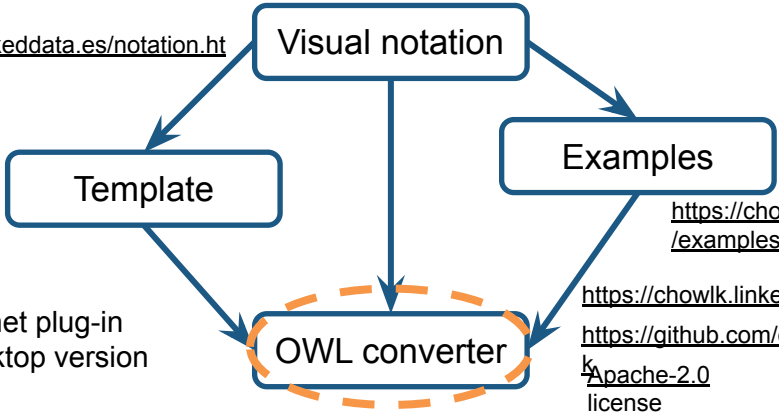
- You can now look for the subset of shapes and just click to use them





Tip: colour has no meaning, you can use it to identify namespaces in classes

https://chowlk.linkeddata.es/notation.html



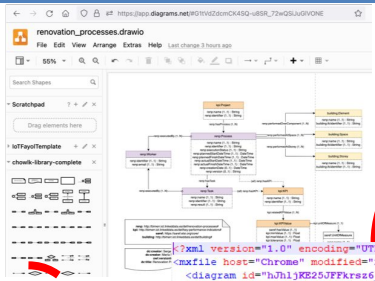
https://chowlk.linkeddata.es/examples.html

+ diagrams.net plug-in
Only for desktop version

https://chowlk.linkeddata.es

https://github.com/oeg-upm/Chowlk

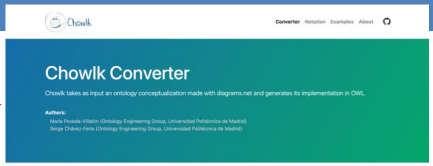
Apache-2.0 license

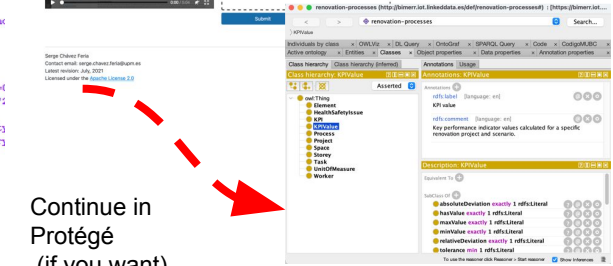


Export XML from diagrams.net

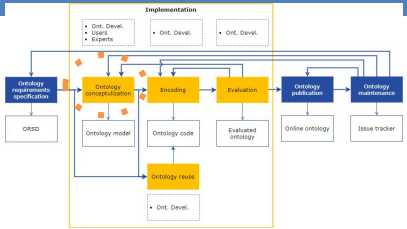
Convert into OWL with Chowlk

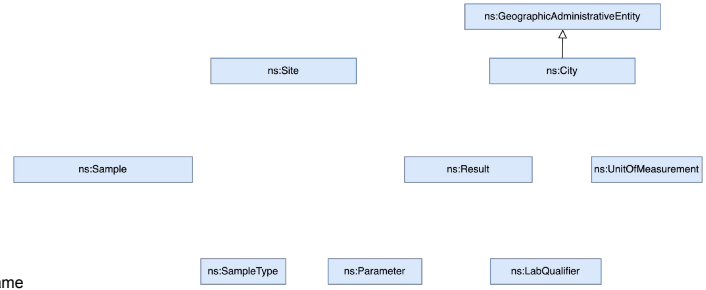
```
<?xml version="1.0" encoding="UTF-8"?>
<mxfile host="Chrome" modified="2020-11-16T14:41:32.661Z" agent="
  <diagram id="hJhljKE25JFKrsz6_xK">
    <mxGraphModel dx="20674" dy="19061" grid="1" gridSize="10" gu
      <root>
        <mxCell id="0" />
        <mxCell id="1" parent="0" />
        <mxCell id="2" style="edgeStyle=orthogonalEdgeStyle;round
          <mxGeometry relative="1" as="geometry">
            <mxPoint x="-17271" y="-17490" as="targetPoint" />
          </mxGeometry>
        </mxCell>
        <mxCell id="3" value="building:Building" style="rounded=(
          <mxGeometry x="-17547" y="-17470.999999999998" width="
        </mxCell>
        <mxCell id="4" value="(all) bot:hasStorey" style="edgeSty
          <mxGeometry x="-0.1468" y="-2" relative="1" as="geometry
            <Array as="points">
              <mxPoint x="-17470" y="-17457" />
              <mxPoint x="-17470" y="-17403" />
            </Array>
            <mxPoint as="offset" />
          </mxGeometry>
        </mxCell>
```



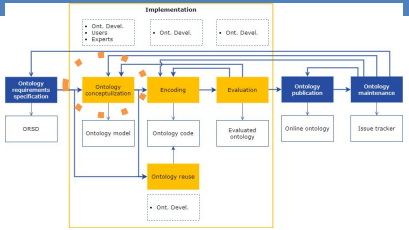


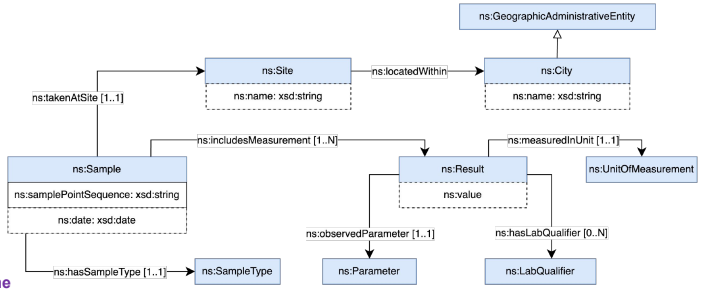
Continue in Protégé (if you want)



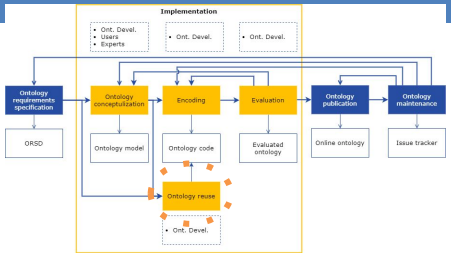


- A **sample record** shall be associated with a current **site** name
- A site shall have a textual identifier or name
- A site can be located within a **town**
- A town is a **geographic administrative entity**
- Multiple sample records can belong to the same site
- A sample shall be associated with a sample point sequence identifier
- A sample point sequence identifier shall include one **measurement** per **parameter**
- The possible **parameters** are: …
- A sample shall have a sample date that represents the time at which the sample was collected
- A sample shall have a sample type
- The possible **sample types** are: ..-
- An analytical **result** shall have a concentration value
- Concentration values can be associated with **measurement units**
- An analytical result can optionally have a **laboratory qualifier**
- The possible laboratory **qualifiers** are: …



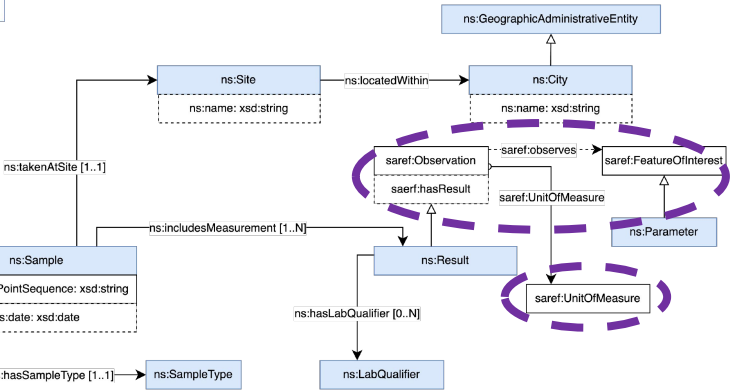


- A sample record shall be associated with a current site **name**
- A site shall have a textual **identifier** or name
- A site can be **located within** a town
- A town is a geographic administrative entity
- Multiple sample records can belong to the same site
- A sample **shall be associated with** a sample point sequence identifier
- A sample point sequence identifier shall include one measurement per parameter
- The possible parameters are: …
- A sample shall have a sample **date** that represents the time at which the sample was collected
- A sample shall **have** a sample **type**
- The possible sample types are: ..-
- An analytical result shall **have** a concentration **value**
- Concentration values **can be associated with** measurement units
- An analytical result can **optionally have** a laboratory **qualifier**
- The possible laboratory qualifiers are: …

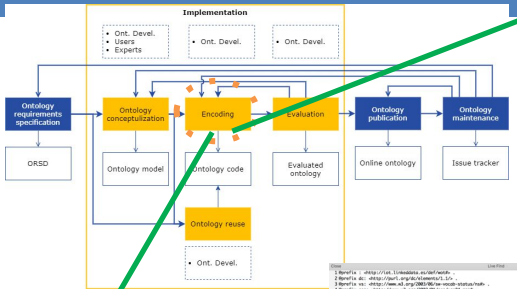


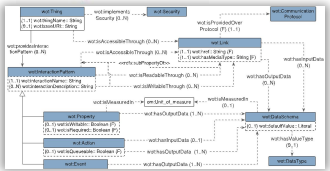
Look for existing ontologies:
https://lov.linkeddata.es
https://bioportal.bioontology.org/search

Or other resources:
https://www.disgenet.org/
https://www.kegg.jp/
http://patho.phenomebrowser.net/#/
https://www.uniprot.org/
Etc.



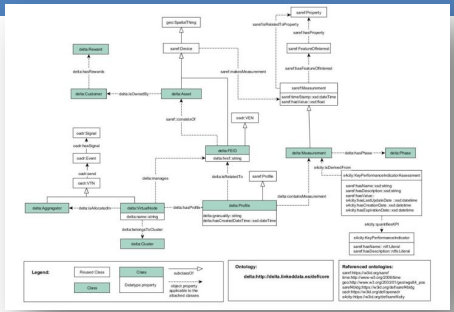
Openly managed in GitHub

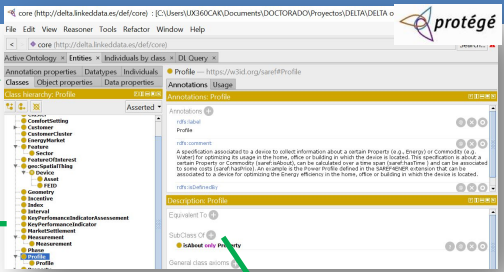


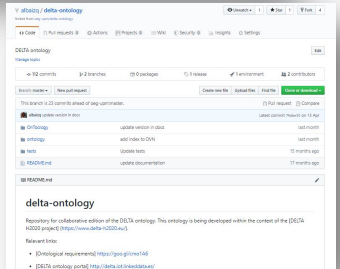


GitHub repository

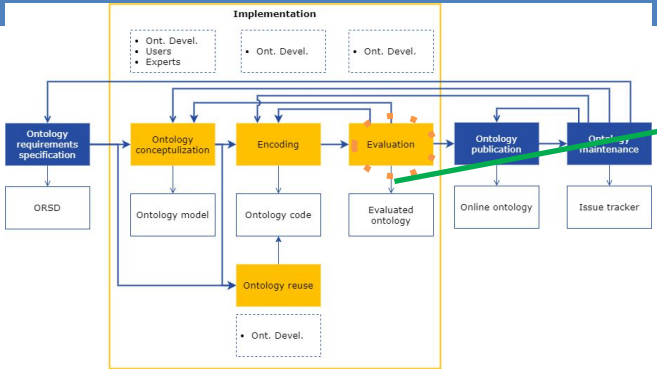
https://github.com/mariapoveda/vicinity-ontology-wot

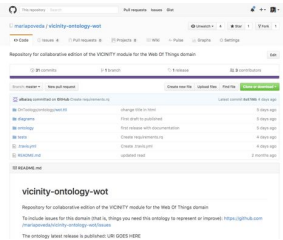

Legend:
Ontology:
Referenced ontologies:


protégé
File Edit View Reasoner Tools Refactor Window Help
Annotations
Description: Profile


delta-ontology
Repository for collaborative edition of the DELTA ontology. This ontology is being developed within the context of the [DELTA H2020 project] (https://www.delta-h2020.eu/).
Relevant links:


GitHub





Online and **notifications** in **GitHub** repository

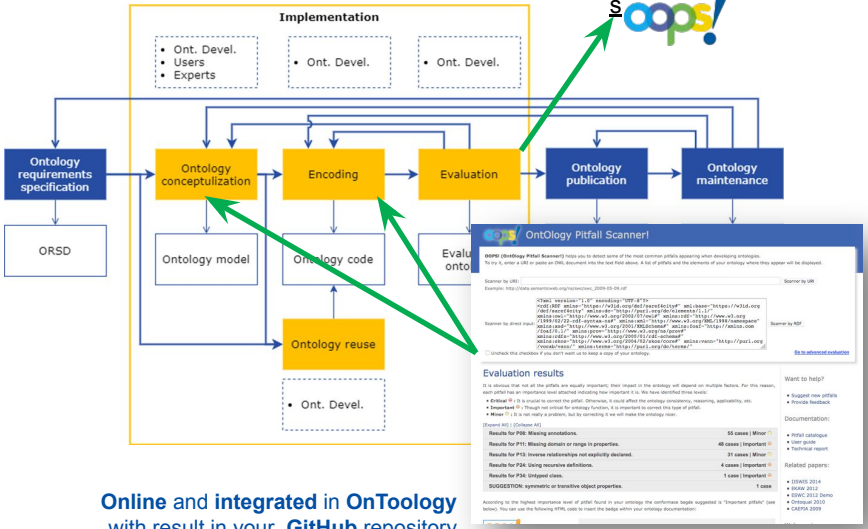
https://github.com/mariapoveda/vicinity-ontology-wot

- It refers to the activity of checking the technical quality of an ontology against a frame of reference. [NeOn]
  - Logical consistency checking
  - Domain coverage
  - Check common errors
  - Check functional requirements

OOPS! (http://oops.linkeddata.es/)

Themis (http://themis.linkeddata.es)

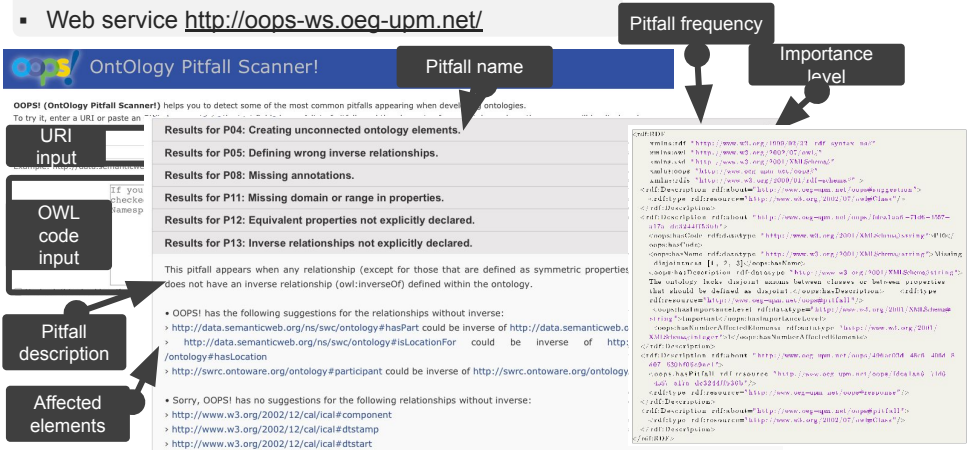
http://oops.linkeddata.es



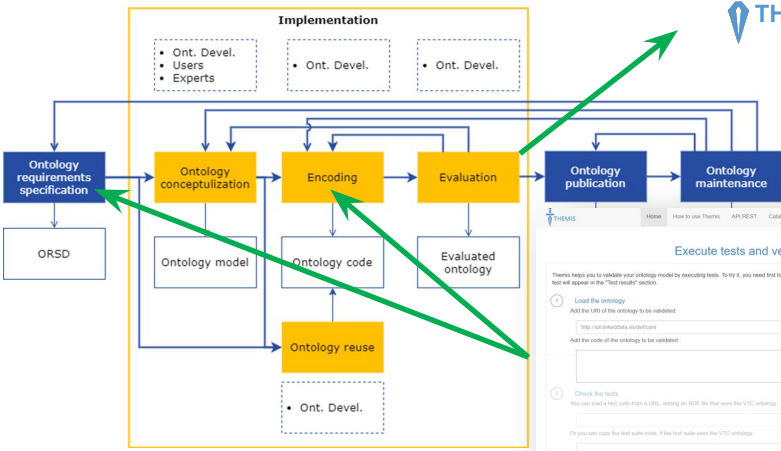
Online and **integrated** in **OnToology** with result in your **GitHub** repository

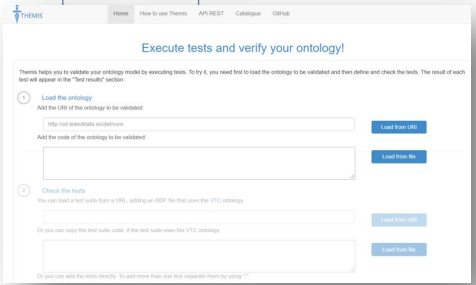
Slide taken from "Trendy Practices and Tools in Ontological Engineering" by Dr. María Poveda Villalón

- Implements the **48** detection methods for **33 pitfalls**
  - Pitfalls selection
  - Selection by dimensions and aspects
- Web user interface http://oops.linkeddata.es/
- Web service http://oops-ws.oeg-upm.net/



Slide taken from “Trendy Practices and Tools in Ontological Engineering” by Dr. María Poveda Villalón



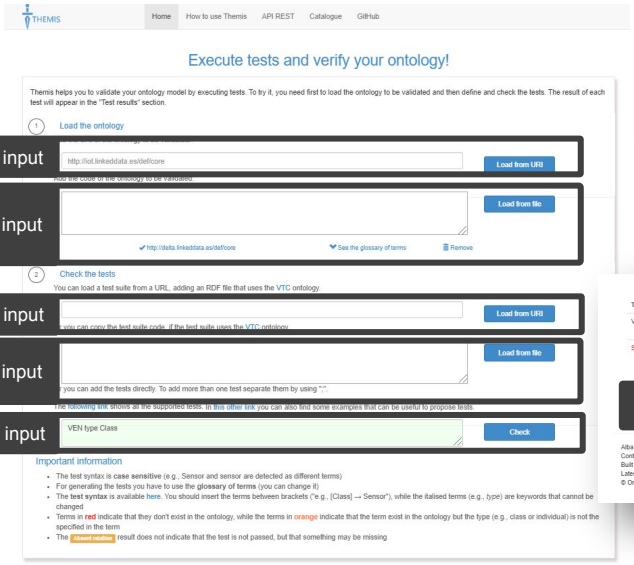


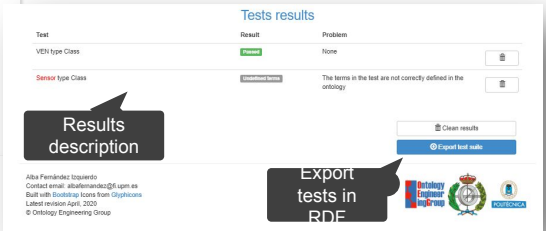
Available as an **online** web application and a **REST API**. Also **integrated** in **OnToology**

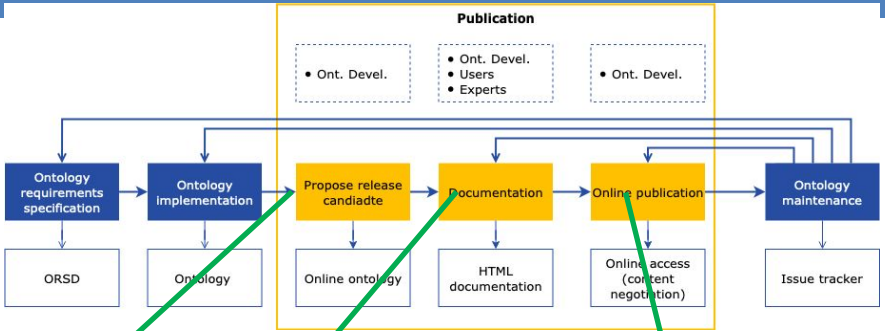
http://themis.linkeddata.es

Evaluation - Themis

- Tool to execute tests to verify an ontology
- Based on a controlled testing language
- Allows to load test files
- Web user interface http://themis.linkeddata.es/







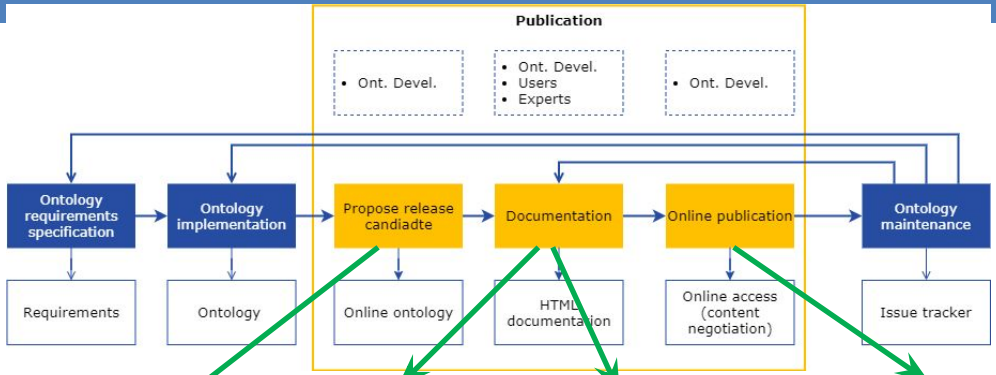
WIDOCO

- HTML generation from OWL code
- Multilingual
- Separated sections

+ Diagrams
+ Descriptions
+ Examples

Chowlk

- Own URI
- purl, w3id, etc.
- Content negotiation
- Registry

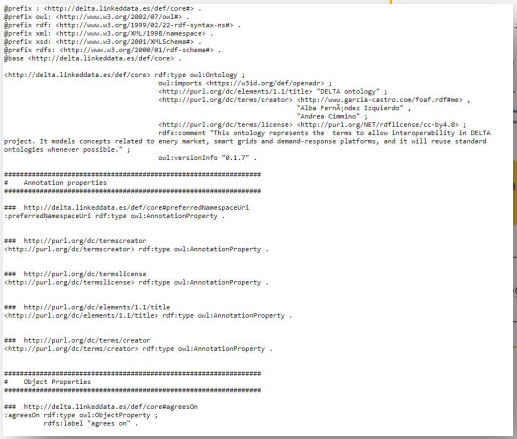


WIDOCO

- HTML generation from OWL code
- Multilingual
- Separated sections

+ Diagrams and examples (Some ideas: https://arxiv.org/abs/2003.13084)
  + Same/tools:
  + Draw.io
  + yEd graph editor
  + Microsoft Visio

- Own URI
- purl, w3id, etc.
- Content negotiation
- Registry



```
@prefix : <http://delta.linkeddata.es/def/core#> .
@prefix owl: <http://www.w3.org/2002/07/owl#> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix xml: <http://www.w3.org/XML/1998/namespace> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@base <http://delta.linkeddata.es/def/core> .

<http://delta.linkeddata.es/def/core> rdf:type owl:Ontology ;
                                      owl:imports <https://w3id.org/def/openadr> ;
                                      <http://purl.org/dc/elements/1.1/title> "DELTA ontology" ;
                                      <http://purl.org/dc/terms/creator> <http://www.garcia-castro.com/foaf.rdf#me> ,
                                                                         "Alba fernÁndez Izquierdo" ,
                                                                         "Andrea Cimmino" ;
                                      <http://purl.org/dc/terms/license> <http://purl.org/NET/rdflicense/cc-by4.0> ;
                                      rdfs:comment "This ontology represents the  terms to allow interoperability in DELTA
project. It models concepts related to energy market, smart grids and demand-response platforms, and it will reuse standard
ontologies whenever possible." ;
                                      owl:versionInfo "0.1.7" .

#################################################################
#    Annotation properties
#################################################################

###  http://delta.linkeddata.es/def/core#preferredNamespaceUri
:preferredNamespaceUri rdf:type owl:AnnotationProperty .


###  http://purl.org/dc/terms/creator
<http://purl.org/dc/terms/creator> rdf:type owl:AnnotationProperty .


###  http://purl.org/dc/terms/license
<http://purl.org/dc/terms/license> rdf:type owl:AnnotationProperty .


###  http://purl.org/dc/elements/1.1/title
<http://purl.org/dc/elements/1.1/title> rdf:type owl:AnnotationProperty .


###  http://purl.org/dc/terms/creator
<http://purl.org/dc/terms/creator> rdf:type owl:AnnotationProperty .


#################################################################
#    Object Properties
#################################################################

###  http://delta.linkeddata.es/def/core#agreesOn
:agreesOn rdf:type owl:ObjectProperty ;
          rdfs:label "agrees on" .
```

DELTA ontology

Revision:
0.1.7

Authors:
Alba Fernández Izquierdo
Raul Garcia Castro
Andrea Cimmino

Download serialization:
Format_JSON_LD | Format_RDF/XML | Format_N-Triples | Format_TTL

License:
License http://purl.org/NET/rdflicense/cc-by4.0

Provenance of this page

2. DELTA ontology: Overview

back to ToC

This ontology has the following classes and properties.

Classes

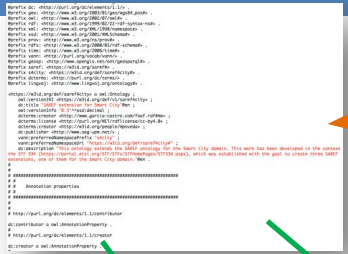
Aggregator Asset Cluster Comfort setting Consumer Customer Customer cluster Device Energy Energy Market Feature Feature Of Interest FEID Frequency Geometry Incentive Index instant Key Performance Indicator Key performance indicator assessment measurement Measurement Payment Phase Power price Profile Profile Property Prosumer Reward Sector Smart contract System constraint Temporal entity Time interval Transaction unit of measure Virtual node Voltage

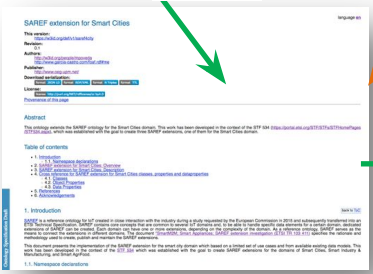
Object Properties

agrees on allocates consists of consumes has aggregated property has comfort settings has currency has delivery time has duration has feature of interest has incentive has index has payment has phase has profile has reward has smart contract has system constraint has transaction hasGeometry is allocated in is derived from is located at is measured in is owned by is related to measurement is related to property is valid during period isAbout makes measurement manages measures property owns quantifies k p i

Data Properties

cluster description cluster name description granularity has points has value href name sector name status timestamp type

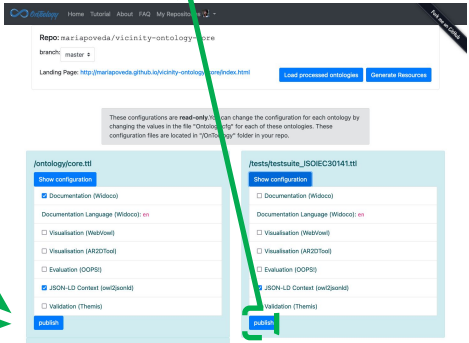




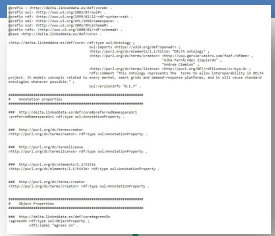
WIDOCO

Content Negotiation

Publish at: https://w3id.org/def/saref4city



GitHub



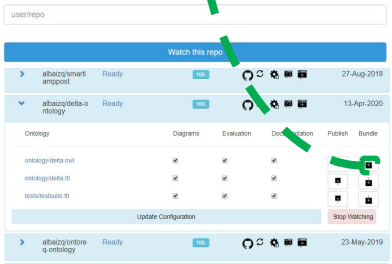
Content Negotiation

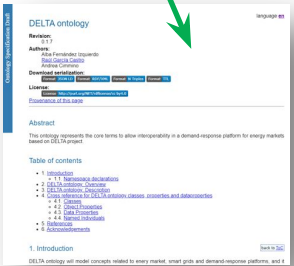
Server

upload bundle

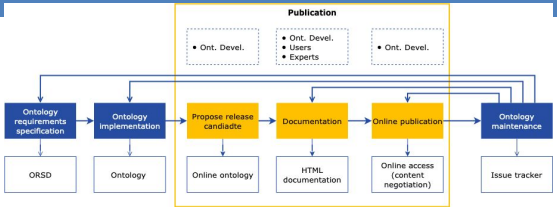
Download bundle

http://delta.linkeddata.es/def/core#





GitHub



- **Mission: promote and facilitate the reuse of well documented vocabularies in the Linked Data ecosystem**

Vocabularies registry and index

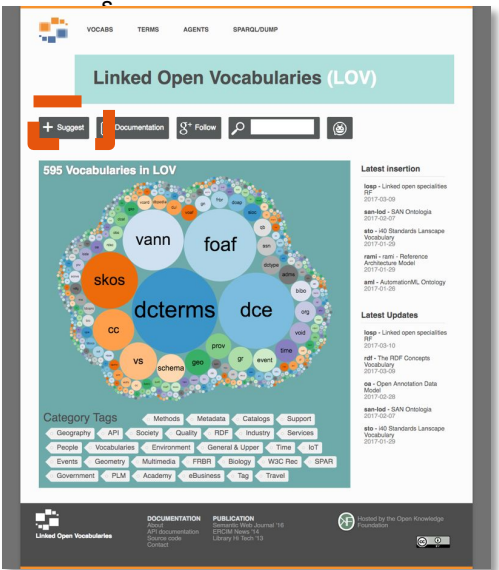
Datalift

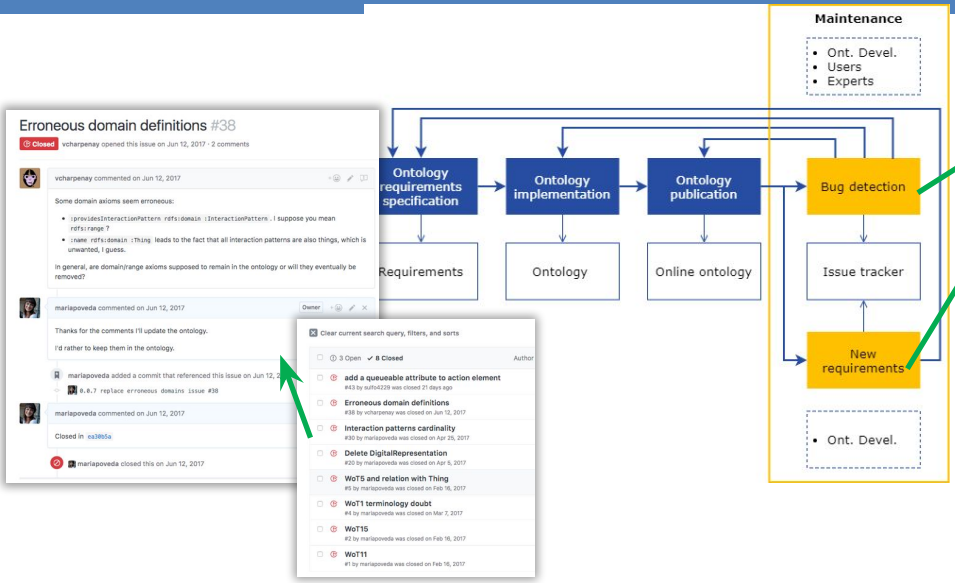
http://datalift.org/

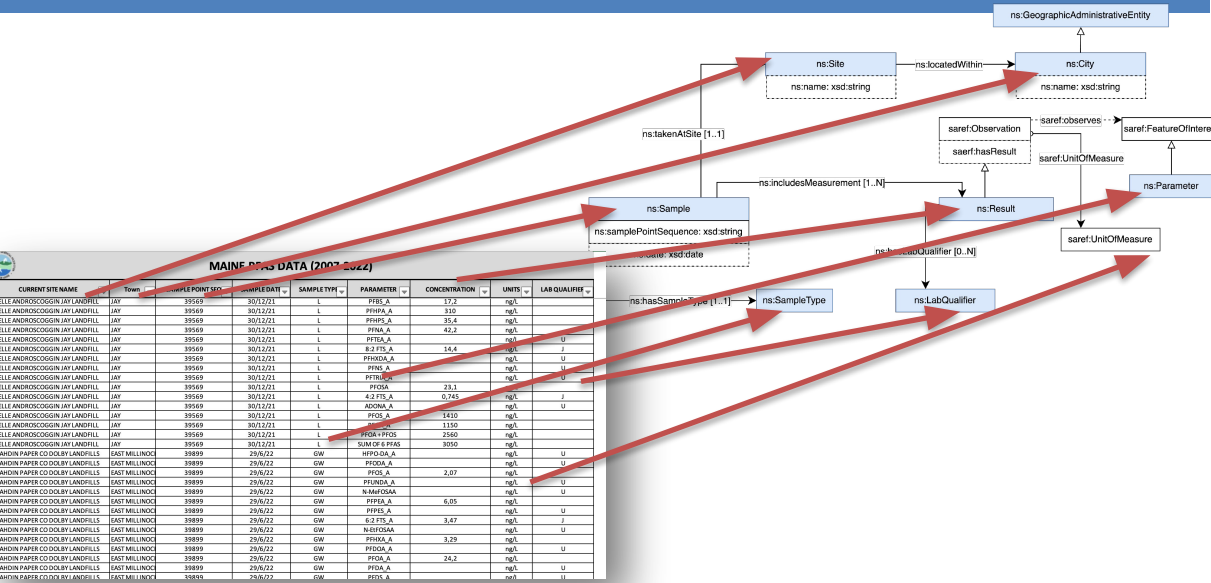
Started at 2011

Hosted by OEG

https://lov.linkeddata.e
s




Maintenance
Ont. Devel.
Users
Experts
Openly reported in GitHub issue tracker: new needs, bugs, etc.
Ontology requirements specification
Ontology implementation
Ontology publication
Bug detection
Requirements
Ontology
Online ontology
Issue tracker
New requirements
Ont. Devel.
Erroneous domain definitions #38
Closed
vcharpenay opened this issue on Jun 12, 2017 · 2 comments
vcharpenay commented on Jun 12, 2017
Some domain axioms seem erroneous:
:providesInteractionPattern rdfs:domain :InteractionPattern . I suppose you mean rdfs:range ?
:name rdfs:domain :Thing leads to the fact that all interaction patterns are also things, which is unwanted, I guess.
In general, are domain/range axioms supposed to remain in the ontology or will they eventually be removed?
mariapoveda commented on Jun 12, 2017
Owner
Thanks for the comments I'll update the ontology.
I'd rather to keep them in the ontology.
mariapoveda added a commit that referenced this issue on Jun 12, 2
0.0.7 replace erroneous domains issue #38
mariapoveda commented on Jun 12, 2017
Closed in ea3855a
mariapoveda closed this on Jun 12, 2017
Clear current search query, filters, and sorts
3 Open
8 Closed
Author
add a queueable attribute to action element
#43 by sufo4229 was closed 21 days ago
Erroneous domain definitions
#38 by vcharpenay was closed on Jun 12, 2017
Interaction patterns cardinality
#30 by mariapoveda was closed on Apr 25, 2017
Delete DigitalRepresentation
#20 by mariapoveda was closed on Apr 5, 2017
WoT5 and relation with Thing
#5 by mariapoveda was closed on Feb 16, 2017
WoT1 terminology doubt
#4 by mariapoveda was closed on Mar 7, 2017
WoT15
#2 by mariapoveda was closed on Feb 16, 2017
WoT11
#1 by mariapoveda was closed on Feb 16, 2017



MAINE PFAS DATA (2007-2022)

CURRENT SITE NAME	Town	SAMPLE POINT SEQ	SAMPLE DATE	SAMPLE TYPE	PARAMETER	CONCENTRATION	UNITS	LAB QUALIFIER
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFBS_A	17,2	ng/L	
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFHPA_A	310	ng/L	
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFHPS_A	35,4	ng/L	
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFNA_A	42,2	ng/L	
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFTEA_A		ng/L	U
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	8-2 FTS_A	14,4	ng/L	J
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFHXDA_A		ng/L	U
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFNS_A		ng/L	U
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFTRIA_A		ng/L	U
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFOSA	23,1	ng/L	
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	4-2 FTS_A	0,745	ng/L	J
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	ADONA_A		ng/L	U
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFOS_A	1410	ng/L	
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFOA_A	1150	ng/L	
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	PFOA + PFOS	2560	ng/L	
ELLE ANDROSCOGGIN JAY LANDFILL	JAY	39569	30/12/21	L	SUM OF 6 PFAS	3050	ng/L	
AHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	HFPO-DA_A		ng/L	U
AHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	PFDOA_A		ng/L	U
AHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	PFOS_A	2,07	ng/L	
AHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	PFUNDA_A		ng/L	U
AHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	N-MeFOSAA		ng/L	U
AHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	PFPEA_A	6,05	ng/L	
AHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	PFBS_A		ng/L	U
AHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	6:2 FTS_A	3,47	ng/L	J
AHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	N-EtFOSAA		ng/L	U
AHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	PFHXA_A	3,29	ng/L	
AHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	PFDOA_A		ng/L	U
AHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	PFOA_A	24,2	ng/L	
AHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	PFOA_A		ng/L	U
AHDIN PAPER CO DOLBY LANDFILLS	EAST MILLINOCI	39899	29/6/22	GW	PFDS_A		ng/L	U

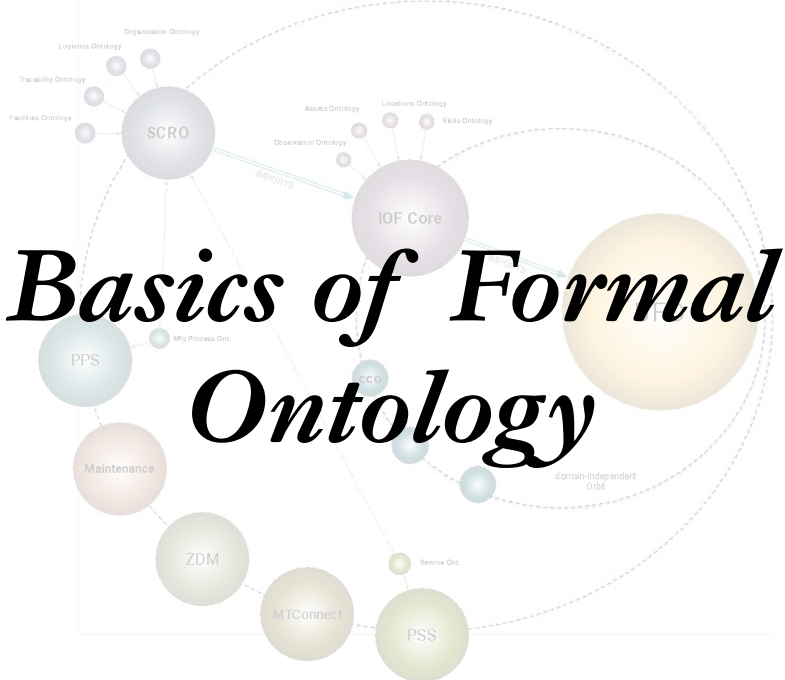
LOT Ontology development methodology

Same Data Different Model tutorial ESWC2026

María Poveda Villalón, Ontology Engineering Group
Universidad Politécnica de Madrid, Spain
[mpoveda@fi.upm.es].

10th June 2026

This work was supported by the grant “SOEL: Supporting Ontology Engineering with Large Language Models” PID2023-152703NA-I00 funded by MCIN/AEI/10.13039/501100011033 and by ``ERDF/UE''.



Basics of Formal Ontology

INSTRUCTOR

John Beverley, PhD

President, *National Center for Ontological Research*
Assistant Professor, *University at Buffalo*
Associate Director, *Institute of AI and Data Science*
CEO, *Acacia Knowledge Systems Inc.*

Outline

- Motivation for Ontology Engineering
- Motivation for Basic Formal Ontology
- Theory of BFO
- Building Ontologies with BFO

Outline

- Motivation for Ontology Engineering
- Motivation for Basic Formal Ontology
- Theory of BFO
- Building Ontologies with BFO

Information Silos

An *information silo* is an information repository, e.g. management system, database, the content of which cannot be integrated with that of other information repositories using standard computing strategies

Interoperability Strategies

- For the sake of argument, let us call "interoperability strategies" those strategies that mitigate or eliminate information silos

- Interoperability strategies may be divided along at least three axes

Machine-Machine
Human-Human
Human-Machine

Machine-Machine Interoperability

- Involves addressing the more familiar information silos

- Associated interoperability strategies often emphasize common metadata standards, business logic, APIs, etc.

Any two heterogeneous information systems share some underlying formal structure

Human-Human Interoperability

- Involves addressing what we might call social silos, which undermine consistent communication among agents

- Human-Human Interoperability strategies often emphasize consensus-building exercises, dictionaries, evaluation of natural language, etc.

Any two speakers of a given natural language share some underlying formal structure

Human-Machine Interoperability

- Involves encoding human-human interoperable solutions in a machine-readable manner

- Associated interoperability strategies often emphasize data schemas, ontologies, knowledge graphs, etc.

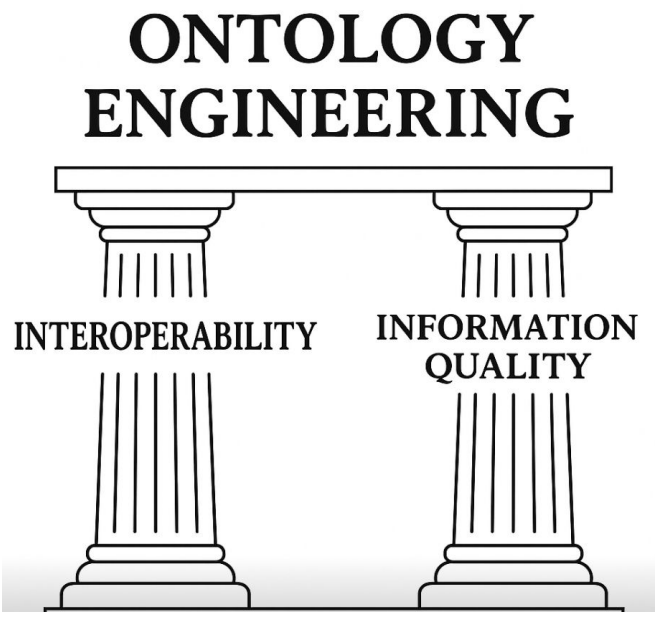
Any two heterogeneous information systems share some underlying formal structure

Promise of Ontology Engineering

- Ontologies are formally well-defined machine-interpretable controlled vocabularies designed to represent entities and logical relationships among them

- Ontologies make **explicit** the **implicit** meanings buried in datasets, by using basic principles of formal logic

- Ontologies provide a **semantic layer** to connect information silos


ONTOLOGY
ENGINEERING
INTEROPERABILITY
INFORMATION
QUALITY

ONTOLOGY ENGINEERING IS A DISCIPLINE FOCUSED ON STRATEGIES THAT SIMULTANEOUSLY ADDRESS INFORMATION SILOS AND IMPROVE INFORMATION QUALITY

Connection between Pillars

- Too much **emphasis on interoperability** leads to ontology artifacts that lack the the rich axiomatization needed to leverage tools to support information quality improvement

- Too much **emphasis on the information quality** results in information silos, unable to leverage common semantics in computing systems to promote interoperability

Best Practices

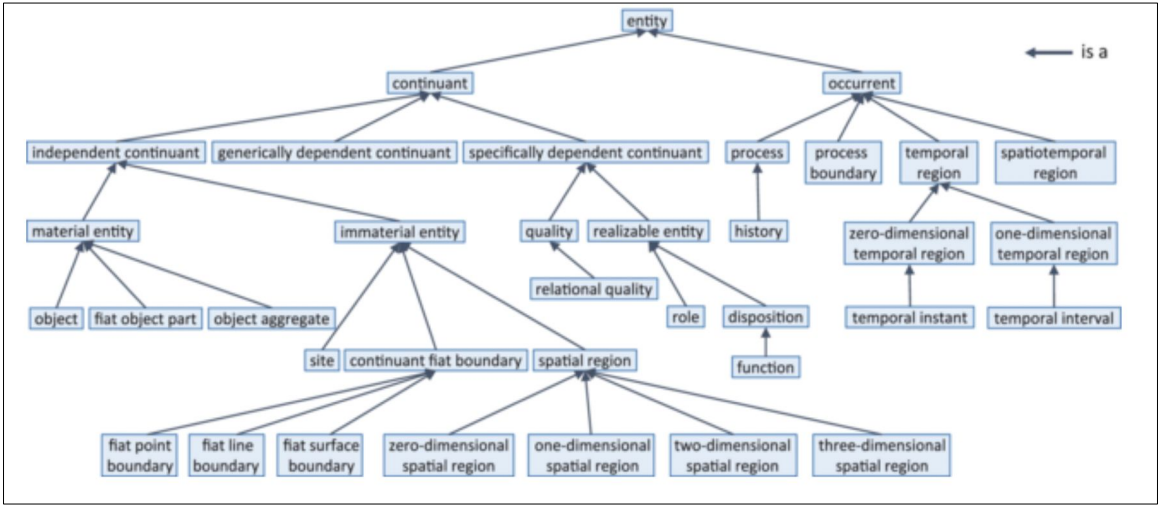
- Pursuing **interoperability** and **information quality** simultaneously can be pursued by adopting common best practices in our community

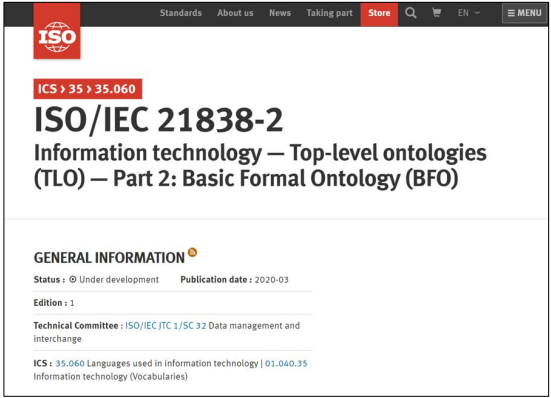
- Many of which are shared with the software development community, such as having a **top-level ontology**, adopting **modularization**, and so on

Outline

- Motivation for Ontology Engineering
- Motivation for Basic Formal Ontology
- Theory of BFO
- Building Ontologies with BFO

CERTAIN INTEROPERABILITY STRATEGIES SUPPORT IMPROVED DATA QUALITY BETTER THAN OTHERS


entity
is a
continuant
occurrent
independent continuant
generically dependent continuant
specifically dependent continuant
process
process boundary
temporal region
spatiotemporal region
material entity
immaterial entity
quality
realizable entity
history
zero-dimensional temporal region
one-dimensional temporal region
relational quality
object
fiat object part
object aggregate
role
disposition
temporal instant
temporal interval
site
continuant fiat boundary
spatial region
function
fiat point boundary
fiat line boundary
fiat surface boundary
zero-dimensional spatial region
one-dimensional spatial region
two-dimensional spatial region
three-dimensional spatial region



MEMORANDUM FOR CHIEF DIGITAL AND ARTIFICIAL INTELLIGENCE OFFICER COUNCIL MEMBERS
INTELLIGENCE COMMUNITY CHIEF DATA OFFICER COUNCIL MEMBERS

SUBJECT: Baseline Standards for Formal Ontology within the Department of Defense and the Intelligence Community

In April 2023, the Chief Digital and Artificial Intelligence Officer Council and the Intelligence Community Chief Data Officer Council chartered the joint Department of Defense (DoD) and Intelligence Community (IC) Ontology Working Group (DIOWG). It was tasked with developing coordinated ontologies to set the agreed definitions and standard necessary to make data machine understandable. Based on the DIOWG's recommendations, both Councils direct the use of three baselines: Top-Level Ontology, Basic Formal Ontology, and Common Core Ontology. These will set the baseline standards for formal DoD and IC ontology.

By aligning the DoD and IC ontologies to a common set of top and mid-level standards, the combined enterprise will realize significant gains in data interoperability, federated search and discovery, decreased analytic timelines, and better cost efficiency. This common approach to data ontology is key to deriving value from shared data assets at speed and scale. The DIOWG has provided additional background information on these international ontological standards in Attachment A.

The nation's warfighters and intelligence professionals will need to have a decisional advantage in the immediate future and that can only be unlocked through the sharing of interoperable data. The next steps for the DIOWG are to codify recommended principles and governance processes to manage the DoD-IC Ontology Foundry. The DIOWG collaboration site can be accessed by visiting https://www.trmc.osd.mil/wiki/display/DIOWG/.

WADE LORI C VYTRP0 — Digitally signed by WADE LORI C VYTRP0 Date: 2024.01.25 14:33:16 -05'00'

MARTELL.CRAIG H.ARRY.1269768988 — Digitally signed by MARTELL.CRAIG.HARRY.126 9768988 Date: 2024.01.04 15:11:45 -08'00'

Lori Wade
Intelligence Community Chief Data Officer
Office of the Director of National Intelligence

Dr. Craig H. Martell
Chief Digital and Artificial Intelligence Officer
Department of Defense

DoD-IC Enterprise Standards Baseline

Standards Citations for ISO 21838: Parts 1 and 2

Joint Enterprise Standards Committee (JESC) Plenary was held 23 Oct 2024 . DoD IT Standards Registry (DISR) 24-2.0 (i.e., the DoD-IC joint enterprise standards baseline) was published 07 Nov 2024 . The baseline includes the two Change Requests (CRs) for TLO and BFO. Congratulations all and thank you!

DISR 24-2 Baseline (published on 7 Nov 2024) Includes Entries for ISO/IEC 21838 Parts 1 and 2. Their citations are below:

Standard Reference Number	303330	303321
Standard Identifier	ISO/IEC 21838-1:2021	ISO/IEC 21838-2:2021
Standard Title	Information Technology – Top Level Ontologies (TLO) – Part 1: Requirements	Information Technology – Top Level Ontologies (TLO
Standard Class	Standard	Standard
DoD Status	Mandated	Mandated
DoD Sunset Date		
DoD Sunset Event		
Date Introduced to Registry	07-Nov-2024	07-Nov-2024
Date DoD Emerging		
Date DoD Mandated	07-Nov-2024	07-Nov-2024

Joint Enterprise Standards Committee (JESC) Applications Technical Working Group

About JESC

The JESC serves as the governance body for DoD information technology (IT) standards, and for Intelligence Community (IC) enterprise standards. These include data standards critical to the ADL Initiative's development of a Total Learning Architecture (TLA) for DoD education and training.

The JESC, which includes subordinate committees, working groups, and ad-hoc enterprise standards activities, recommends common enterprise standards, profiles, and specifications for DoD and IC information environments. Standards approved by this committee are mandated by DoD's Chief Information Officer for Department-wide use and acquisitions.

BFO Ecosystem

700+ Projects

BFO Basic Formal Ontology

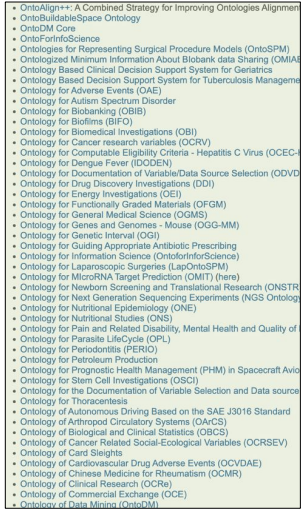
Home GitHub Guidebook Publications FOL Users Tutorials

Users

Below you will find an alphabetical list of ontologies and institutions/groups usin

Ontologies

- ACGT Master Ontology (ACGT MO)
- Actionable Intelligence Retrieval System (AIRS)
- Addiction Ontology (Addict-O)
- Additive Manufacturing Ontology (AMO)
- Adolescent Depression Ontology (ADO)
- Adverse Event Reporting Ontology (AERO)
- AFO Foundational Ontology
- African Wildlife Ontology (AWO)
- Agronomic Linked Data (AgroLD)
- Agronomy Ontology (AGRO)
- Aircraft System Ontology
- Algorithm-Implementation-Execution Ontology Design Pattern
- Alzheimer Disease Ontology (ADO)
- Alzheimer's Disease Diagnosis Ontology (ADDO)
- Anatomy of the Insect Skeleto-Muscular system ontology (AISM)
- Animals in Context Ontology (ACO)
- Anthropological Notation Ontology (ANNO)
- Antimicrobial-Microorganism Ontology
- Apollo Structured Vocabulary (Apollo-SV)
- Argument Ontology (ARGO)
- ARIES (Arkansas Imaging Enterprise System) Knowledge Graph
- Asset Management Ontology (AMODO)
- Autism-DSM-ADI-R Ontology (ADAR)
- Bacterial Clinical Infectious Diseases Ontology (BCIDO)
- Baden Württemberg Materials Digital Domain Ontology (BWMD)
- Bank Ontology
- Battle Management Ontology (BMO)
- Behavior Change Intervention Ontology (BCIO)
- Behaviour Change Technique Ontology
- Behavior Perspective Model (BPM)
- Beta Cell Genomics Application Ontology (BCGO)
- Bio-Knowledge Network Ontology (BioKNO)
- BioAssay Ontology
- Bioinformatics Web Service Ontology (OBIWS)
- Biological Collections Ontology (BCO)
- Biomedical Ethics Ontology
- Biomedical Grid Terminology (BiomedGT, retired)
- Biomedical Study - Lifecycle Management (BMS-LM) core ontology
- Biomimetic Ontology
- BioTop: a biomedical top-domain ontology



- OntoAlign++: A Combined Strategy for Improving Ontologies Alignment
- OntoBuildableSpace Ontology
- OntoDM Core
- OntoForInfoScience
- Ontologies for Representing Surgical Procedure Models (OntoSPM)
- Ontologized Minimum Information About Biobank data Sharing (OMIAB
- Ontology Based Clinical Decision Support System for Geriatrics
- Ontology Based Decision Support System for Tuberculosis Manageme
- Ontology for Adverse Events (OAE)
- Ontology for Autism Spectrum Disorder
- Ontology for Biobanking (OBIB)
- Ontology for Biofilms (BIFO)
- Ontology for Biomedical Investigations (OBI)
- Ontology for Cancer research variables (OCRV)
- Ontology for Computable Eligibility Criteria - Hepatitis C Virus (OCEC-
- Ontology for Dengue Fever (IDODEN)
- Ontology for Documentation of Variable/Data Source Selection (ODVD
- Ontology for Drug Discovery Investigations (DDI)
- Ontology for Energy Investigations (OEI)
- Ontology for Functionally Graded Materials (OFGM)
- Ontology for General Medical Science (OGMS)
- Ontology for Genes and Genomes - Mouse (OGG-MM)
- Ontology for Genetic Interval (OGI)
- Ontology for Guiding Appropriate Antibiotic Prescribing
- Ontology for Information Science (OntoforInforScience)
- Ontology for Laparoscopic Surgeries (LapOntoSPM)
- Ontology for MIcroRNA Target Prediction (OMIT) (here)
- Ontology for Newborn Screening and Translational Research (ONSTR
- Ontology for Next Generation Sequencing Experiments (NGS Ontolog
- Ontology for Nutritional Epidemiology (ONE)
- Ontology for Nutritional Studies (ONS)
- Ontology for Pain and Related Disability, Mental Health and Quality of
- Ontology for Parasite LifeCycle (OPL)
- Ontology for Periodontitis (PERIO)
- Ontology for Petroleum Production
- Ontology for Prognostic Health Management (PHM) in Spacecraft Avio
- Ontology for Stem Cell Investigations (OSCI)
- Ontology for the Documentation of Variable Selection and Data source
- Ontology for Thoracentesis
- Ontology of Autonomous Driving Based on the SAE J3016 Standard
- Ontology of Arthropod Circulatory Systems (OArCS)
- Ontology of Biological and Clinical Statistics (OBCS)
- Ontology of Cancer Related Social-Ecological Variables (OCRSEV)
- Ontology of Card Sleights
- Ontology of Cardiovascular Drug Adverse Events (OCVDAE)
- Ontology of Chinese Medicine for Rheumatism (OCMR)
- Ontology of Clinical Research (OCRe)
- Ontology of Commercial Exchange (OCE)
- Ontology of Data Mining (OntoDM)

- Shop-Floor Digital Twin (DT) ontology
- Situated and Interactive Multimodal Conversations
- Situation Awareness Ontology (SAO)
- Sketch Map Ontology
- Skin Physiology Ontology (SPO)
- Sleep Domain Ontology (SDO)
- SMART Protocols: SeMAntic RepresenTation for Experimental Protocols
- Smart Ultrasound in Obstetrics and Gynecology (SUOG) Ontology
- SNOMED CT (SCT) Standard Ontology
- Social Determinants of Health Ontology (SDoHO)
- Social Psychology Ontology (SPO)
- Socialog Ontology for Social Simulation
- Software Ontology (SWO)
- Software, Disabilities and Competences Ontology (SODIC)
- Soil Food Web Ontology
- Space Domain Ontologies (SDO)
- Space Object Ontology (SOO)
- Spatial Graph Adapter (SGA) Ontology Design Pattern
- Spatial Relation Ontology
- Spatiotemporal Ontology for the Administrative Units of Switzerland (SONADUS
- Special Nuclear Materials Detection Ontology (SNM-DO)
- Statistics Ontology (STATO)
- STATO-LMM Linear Mixed Model Ontology
- Style of Delivery Ontology
- Subcellular Anatomy Ontology (SAO)
- Suggested Ontology for Pharmacogenomics (SO-Pharm)
- Supply Chain Traceability Ontology
- Surface Water Ontology (SWO)
- Survey Ontology
- Sustainable Development and Climate (SDC) Ontology
- Symptomatic Treatment of Multiple Sclerosis Ontology (STMSO)
- Taxonomy for Rehabilitation of Knee Conditions (TRAK)
- The Common Rule Ontology (CRO)
- The Trope Ontology
- Time Event Ontology (TEO)
- Toxic Process Ontology (TXPO)
- Trade-Space Analysis Tool for Constellations (TAT-C) ontology
- Traditional Chinese Drugs Ontology (TCDO)
- Translational Medicine Ontology (TMO)

Methodological Convictions

- **Realism** – BFO is designed to represent the world, rather than simply concepts about the world
- **Hub & Spoke** – BFO is a hub from which spoke ontologies extend
- **Fallibilism** – BFO is committed to tracking scientific research over time, which might change
- **Adequatism** – BFO is non-reductive, classes and relations motivated by research communities are not 'paraphrased away' for example

Methodological Convictions

- **Realism** – BFO is designed to represent the world, rather than simply concepts about the world
- **Hub & Spoke** – BFO is a hub from which spoke ontologies extend
- **Fallibilism** – BFO is committed to tracking scientific research over time, which might change
- **Adequatism** – BFO is non-reductive, classes and relations motivated by research communities are not 'paraphrased away' for example

Realism

If we attempt to go from the words we use to the world, it is unlikely that we will end up in the same place

If we attempt to go from the world to the words we use, it is more likely we will remain coordinated

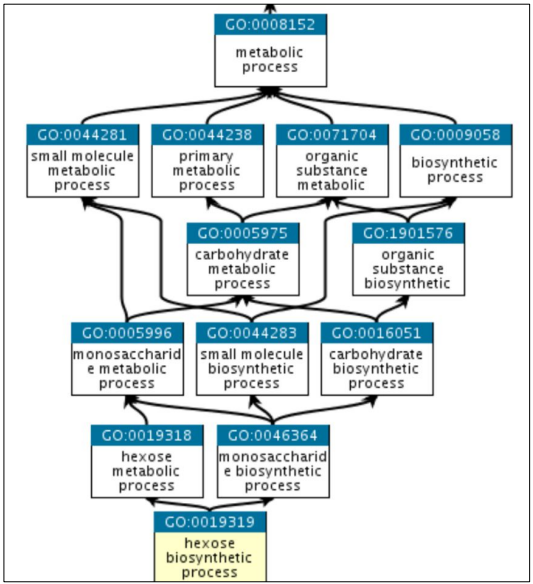
Methodological Convictions

- **Realism** – BFO is designed to represent the world, rather than simply concepts about the world
- **Hub & Spoke** – BFO is a hub from which spoke ontologies extend
- **Fallibilism** – BFO is committed to tracking scientific research over time, which might change
- **Adequatism** – BFO is non-reductive, classes and relations motivated by research communities are not 'paraphrased away' for example

Gene Ontology - 1998

GENEONTOLOGY
Unifying Biology

The mission of the GO Consortium is to develop a comprehensive, **computational model of biological systems**, ranging from the molecular to the organism level, across the multiplicity of species in the tree of life.



Proliferation of Ontologies

- When developed correctly, ontologies provide **common vocabularies** with **common semantics** across **multiple domains**
- The success of the Gene Ontology led to a proliferation of ontologies developed by subject-matter experts, computer scientists, and logicians
- Almost **none** of which were developed in coordination
- The result was **massive incompatibility** of terms and relations, confusion, in-fighting, name-calling, etc.

Open Biological and Biomedical Ontologies

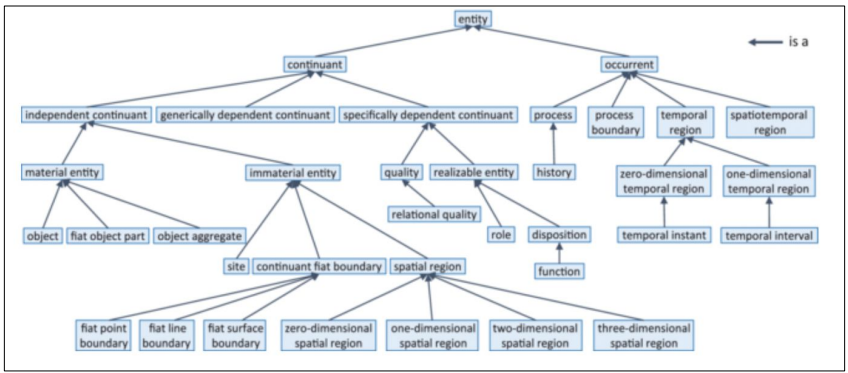
- In 2005, a consortium of biologists decided to create standards for ontology development

- Such as requiring ontologies be open-source, have documentation, include definitions for vocabulary terms **and...**

- **Align to a top-level ontology which provides a starting point for all ontology development...**

Basic Formal Ontology

BFO is such a standard, used by over 700 open-source groups, the first ISO/IEC top-level ontology standard, and a "baseline standard" for DOD-IC ontology development



python™ *Analogy*

- BFO is analogous to the **Python programming language**; extensions of BFO are analogous to **Python libraries**
- You **could** create code that allows you to interact with, say, dataframes or you could **instead** start with Python and import a library like Pandas
- You **could** create ontology elements that allow you to model artifacts and processes or you **could** instead start with BFO and import an extension

‘Foundry’ Efforts

Open Biological and

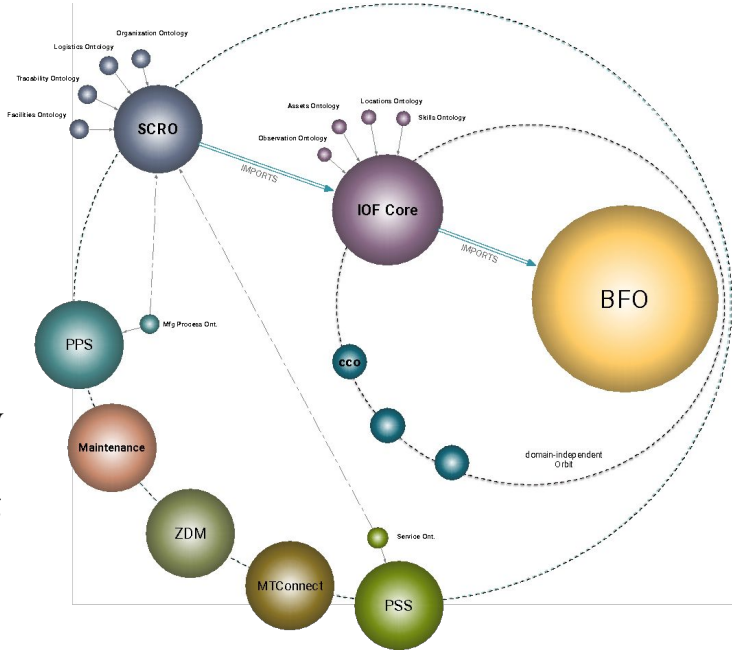
Industrial Ontologies Foundry

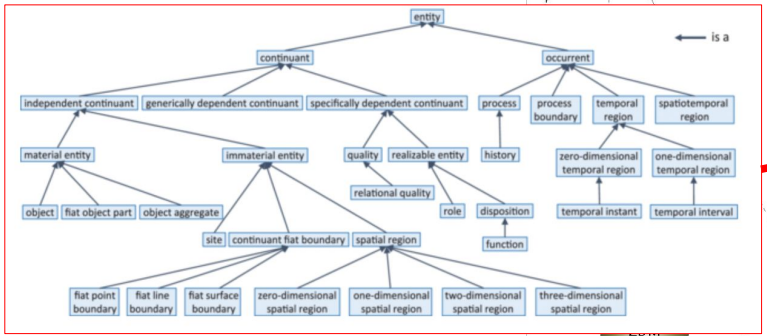
DOD-IC Foundry

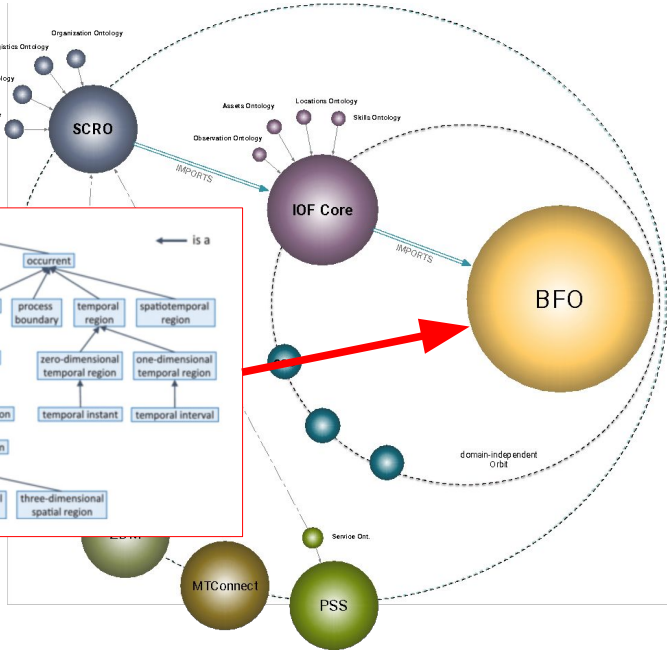
Hub & Spoke

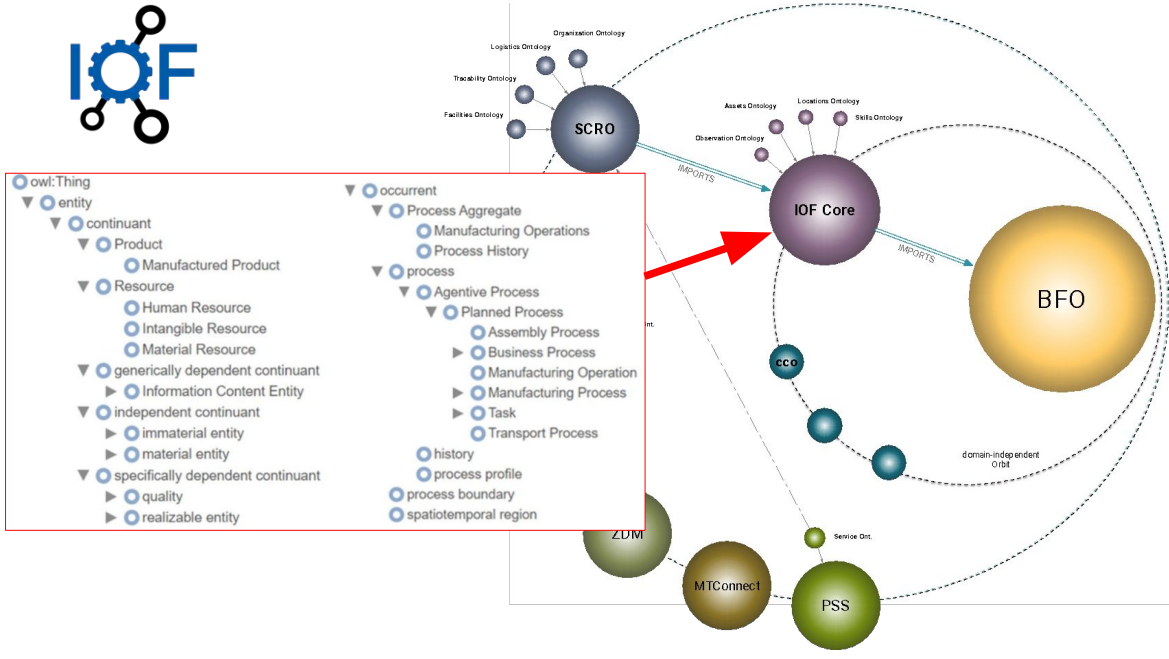
Ontologies extending from BFO are modules in a larger hub & spoke structure

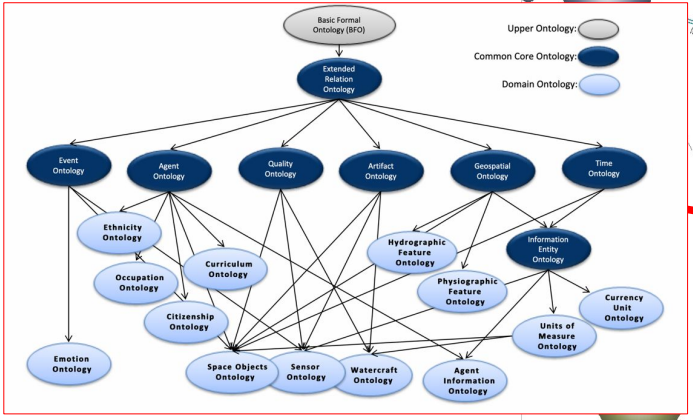
Ontologies are extended by **downward population**, new classes have parent classes in a hierarchy ultimately leading to a BFO class

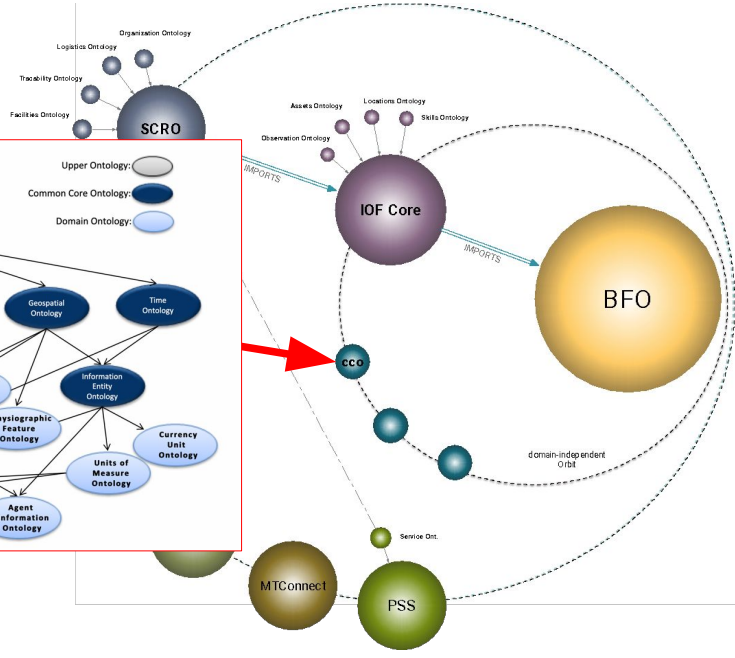



entity
is a
continuant
occurrent
independent continuant
generically dependent continuant
specifically dependent continuant
process
process boundary
temporal region
spatiotemporal region
material entity
immaterial entity
quality
realizable entity
history
zero-dimensional temporal region
one-dimensional temporal region
relational quality
object
fiat object part
object aggregate
role
disposition
temporal instant
temporal interval
site
continuant fiat boundary
spatial region
function
fiat point boundary
fiat line boundary
fiat surface boundary
zero-dimensional spatial region
one-dimensional spatial region
two-dimensional spatial region
three-dimensional spatial region

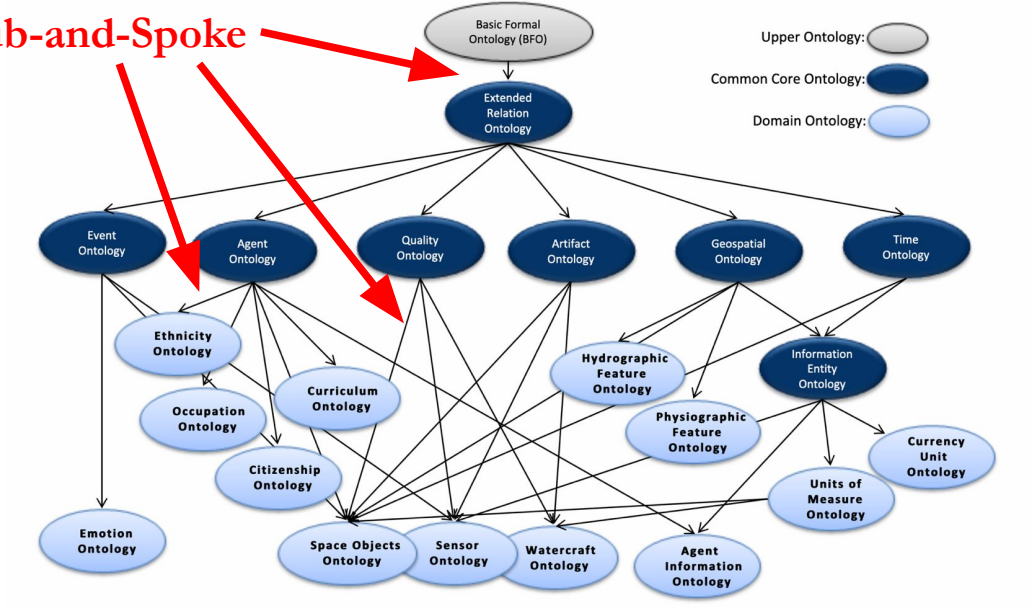

Organization Ontology
Logistics Ontology
Traceability Ontology
Facilities Ontology
SCRO
IMPORTS
Assets Ontology
Locations Ontology
Skills Ontology
Observation Ontology
IOF Core
IMPORTS
BFO
domain-independent Orbit
Service Ont.
MTConnect
PSS


owl:Thing
entity
continuant
Product
Manufactured Product
Resource
Human Resource
Intangible Resource
Material Resource
generically dependent continuant
Information Content Entity
independent continuant
immaterial entity
material entity
specifically dependent continuant
quality
realizable entity
occurrent
Process Aggregate
Manufacturing Operations
Process History
process
Agentive Process
Planned Process
Assembly Process
Business Process
Manufacturing Operation
Manufacturing Process
Task
Transport Process
history
process profile
process boundary
spatiotemporal region
Organization Ontology
Logistics Ontology
Tracability Ontology
Facilities Ontology
SCRO
Assets Ontology
Locations Ontology
Skills Ontology
Observation Ontology
IMPORTS
IOF Core
IMPORTS
BFO
CCO
domain-independent
Orbit
ZDM
Service Ont.
MTConnect
PSS


Basic Formal Ontology (BFO)
Extended Relation Ontology
Upper Ontology:
Common Core Ontology:
Domain Ontology:
Event Ontology
Agent Ontology
Quality Ontology
Artifact Ontology
Geospatial Ontology
Time Ontology
Ethnicity Ontology
Occupation Ontology
Curriculum Ontology
Citizenship Ontology
Hydrographic Feature Ontology
Physiographic Feature Ontology
Information Entity Ontology
Currency Unit Ontology
Units of Measure Ontology
Emotion Ontology
Space Objects Ontology
Sensor Ontology
Watercraft Ontology
Agent Information Ontology


Organization Ontology
Logistics Ontology
Traceability Ontology
Facilities Ontology
SCRO
Assets Ontology
Locations Ontology
Skills Ontology
Observation Ontology
IMPORTS
IOF Core
IMPORTS
BFO
CCO
domain-independent Orbit
Service Ont.
MTConnect
PSS

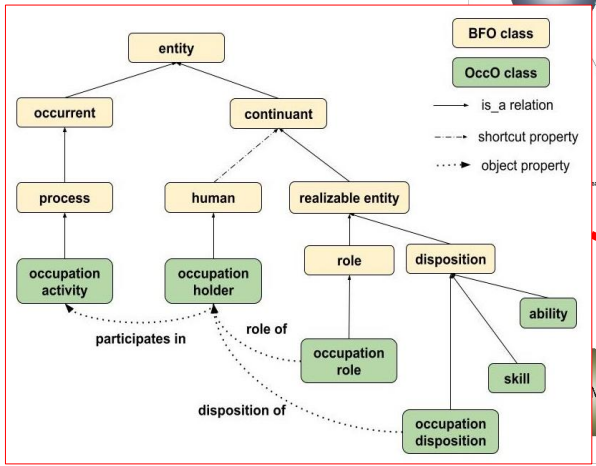
Hub-and-Spoke

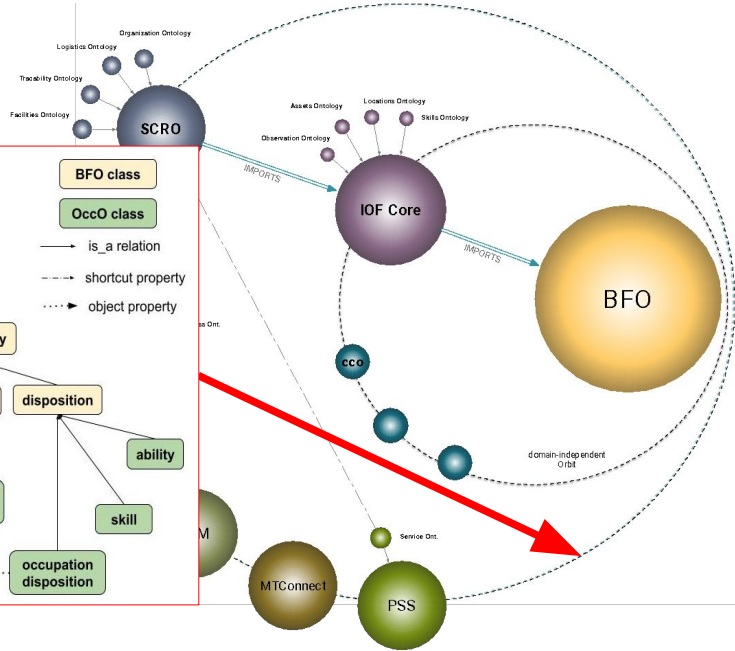


Methodological Convictions

- **Realism** – BFO is designed to represent the world, rather than simply concepts about the world
- **Hub & Spoke** – BFO is a hub from which spoke ontologies extend
- **Fallibilism** – BFO is committed to tracking scientific research over time, which might change
- **Adequatism** – BFO is non-reductive, classes and relations motivated by research communities are not 'paraphrased away' for example

The Occupation Ontology





51 jobs that don't exist anymore

Some of these jobs have transformed into new roles with new titles due to technological advances, while others are now common colloquial terms despite disappearing as actual jobs. Here are 51 jobs that are no longer around:

1. Leech collector

A leech collector was responsible for retrieving the blood-sucking worms from their natural habitat for doctors to use. Individuals with this job used the legs of animals or their own legs to lure leeches from creeks and rivers.

2. Knocker upper

Knocker uppers, or knocker-ups, were responsible for waking people up by making loud noises before electronic alarm clocks existed. People in the 1800s would hire these individuals to shoot peas at their windows or tap on the glass using a long pole to wake them up.

51 jobs that don't exist anymore

10 Disappearing Jobs That Won't Exist in 10 Years: Professions That Won't Guarantee Career Opportunities in 2024

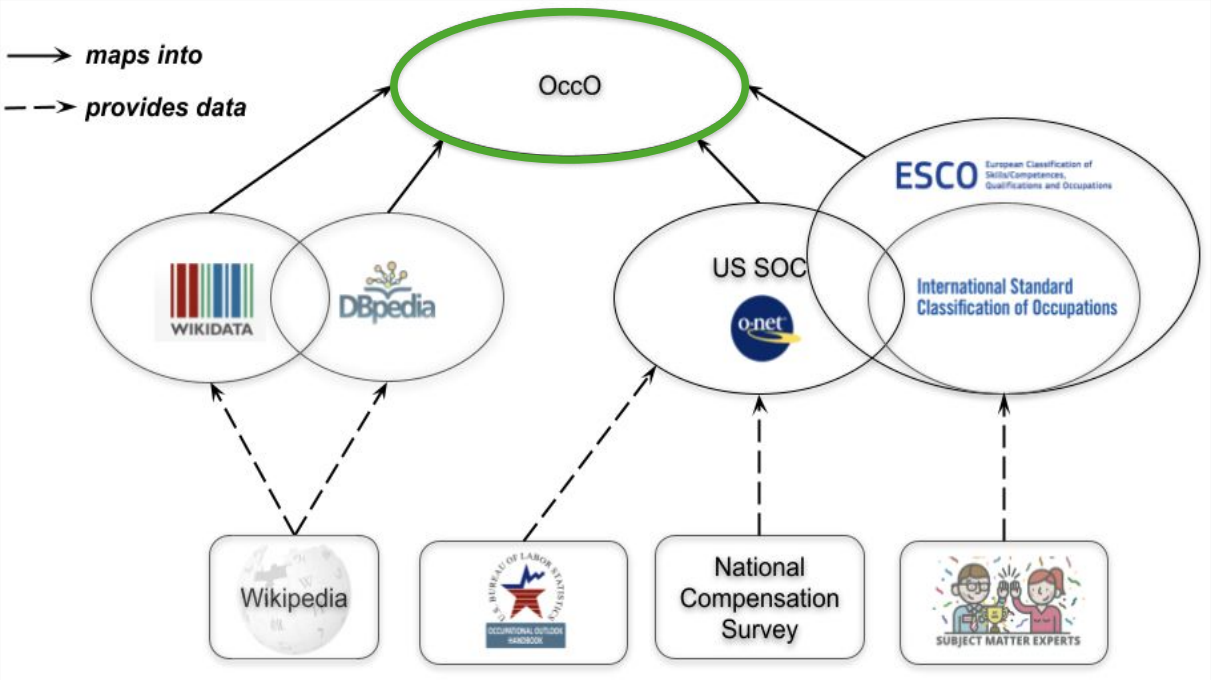
from their natural habitat for doctors to use. Individuals with this job used the

7 Jobs That Don't Exist Today but Will in the Next 5 Years Because of AI How AI will change the future of work.

using a long pole to wake them up.

Methodological Convictions

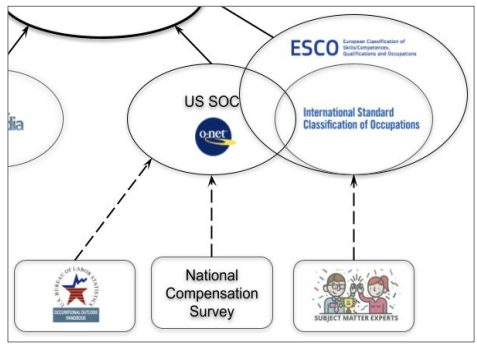
- **Realism** – BFO is designed to represent the world, rather than simply concepts about the world
- **Hub & Spoke** – BFO is a hub from which spoke ontologies extend
- **Fallibilism** – BFO is committed to tracking scientific research over time, which might change
- **Adequatism** – BFO is non-reductive, classes and relations motivated by research communities are not 'paraphrased away' for example


maps into
provides data
OccO
ESCO
European Classification of Skills/Competences, Qualifications and Occupations
WIKIDATA
DBpedia
US SOC
o-net
International Standard Classification of Occupations
Wikipedia
U.S. BUREAU OF LABOR STATISTICS
OCCUPATIONAL OUTLOOK HANDBOOK
National Compensation Survey
SUBJECT MATTER EXPERTS

Adequatism

- Does US SOC cover everything within its intended scope? Likely not.

- A common **semantic layer** connecting standards reflecting occupation-related information allows for **cross-validation**, identification of **gaps in coverage**, **overlooked synonymous** labels and descriptions, etc.



ESCO

Description

Code

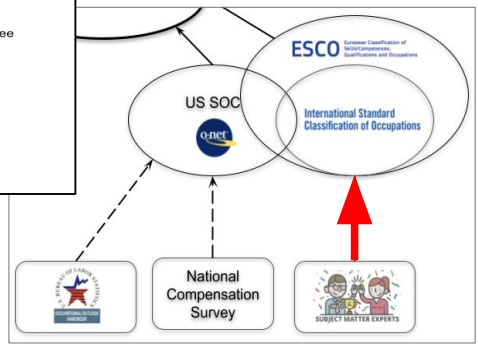
5132.1.1

Description

Barista's prepare specialised types of coffee using professional equipment in a hospitality/coffee shop/bar unit.

Alternative Labels

barista | coffee bartender | coffee maker | specialised bartender | specialised coffee bartender



Subject-matter experts - among other sources – inform the development of ISCO and ESCO standards

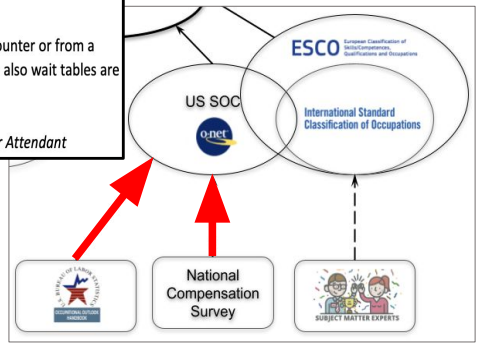
US SOC

35-3020 Fast Food and Counter Workers
This broad occupation is the same as the detailed occupation:
35-3023 Fast Food and Counter Workers

35-3023 Fast Food and Counter Workers
Perform duties such as taking orders and serving food and beverages. Serve customers at counter or from a steam table. May take payment. May prepare food and beverages. Counter attendants who also wait tables are included in "Waiters and Waitresses" (35-3031),

Illustrative examples: Barista, Cafeteria Server, Ice Cream Server, Mess Attendant, Snack Bar Attendant

The National Compensation Survey and Occupation Outlook Handbook inform the development of US SOC/O*NET



Semantic Enrichment

- Ontologies designed using a top-level ontology and follow well-defined strategies for preserving semantics through extensions

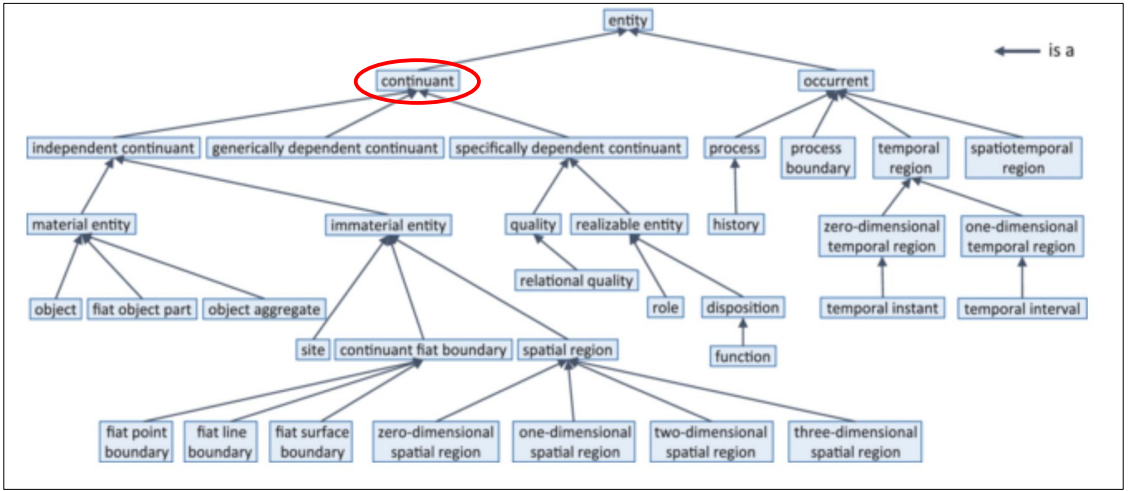
- **Exploration**, **discovery**, **prediction**, and **analysis** of enriched data can be conducted using the semantic stack and emerging semantic tooling

- All owing to rich shared semantics

Outline

- Motivation for Ontology Engineering
- Motivation for Basic Formal Ontology
- Theory of BFO
- Building Ontologies with BFO

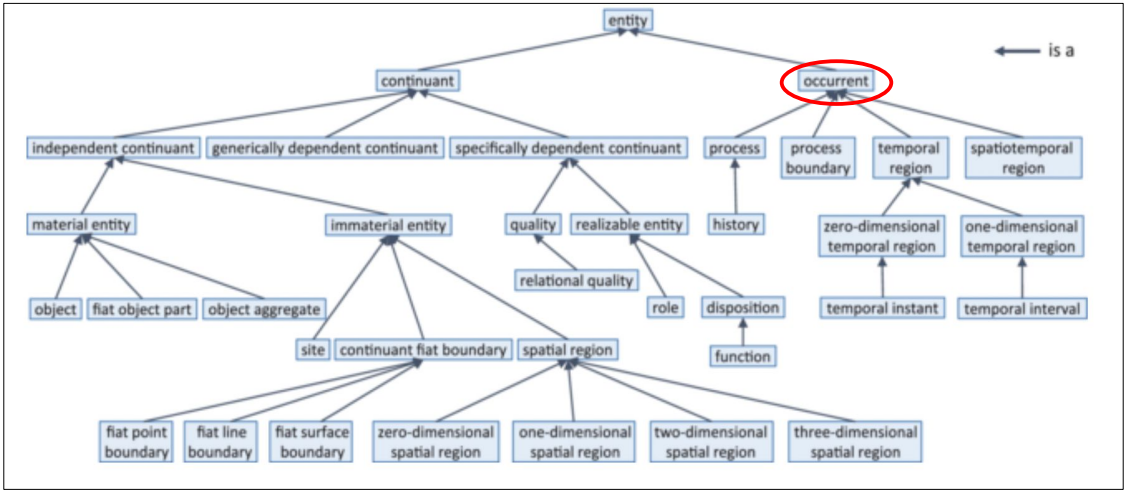
Continuant


entity
is a
continuant
occurrent
independent continuant
generically dependent continuant
specifically dependent continuant
process
process boundary
temporal region
spatiotemporal region
material entity
immaterial entity
quality
realizable entity
history
zero-dimensional temporal region
one-dimensional temporal region
relational quality
object
fiat object part
object aggregate
role
disposition
temporal instant
temporal interval
site
continuant fiat boundary
spatial region
function
fiat point boundary
fiat line boundary
fiat surface boundary
zero-dimensional spatial region
one-dimensional spatial region
two-dimensional spatial region
three-dimensional spatial region

Continuant

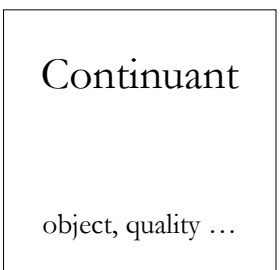
- Continuants exist in time, wholly present whenever they exist at all; they are entities that lack temporal parts

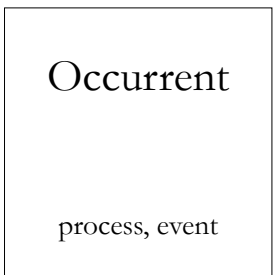
Occurrent


entity
is a
continuant
occurrent
independent continuant
generically dependent continuant
specifically dependent continuant
process
process boundary
temporal region
spatiotemporal region
material entity
immaterial entity
quality
realizable entity
history
zero-dimensional temporal region
one-dimensional temporal region
relational quality
object
fiat object part
object aggregate
role
disposition
temporal instant
temporal interval
site
continuant fiat boundary
spatial region
function
fiat point boundary
fiat line boundary
fiat surface boundary
zero-dimensional spatial region
one-dimensional spatial region
two-dimensional spatial region
three-dimensional spatial region

Occurrent

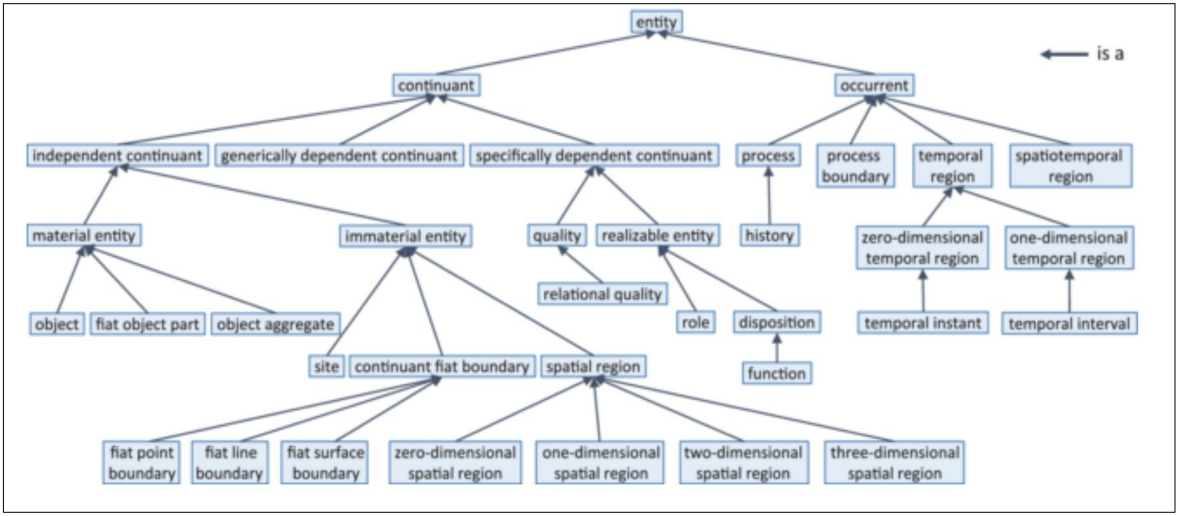
- Occurrents exist over time, in that they have temporal parts



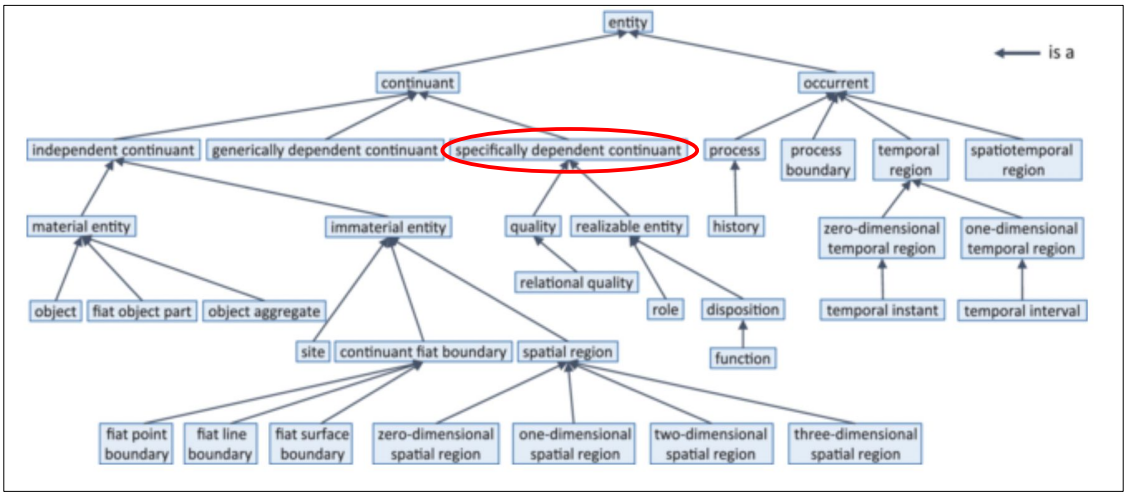


Classes represent collections of instances
For example: the class of *tables* falls under the class of *objects* and your dinner table would be an instance of the former

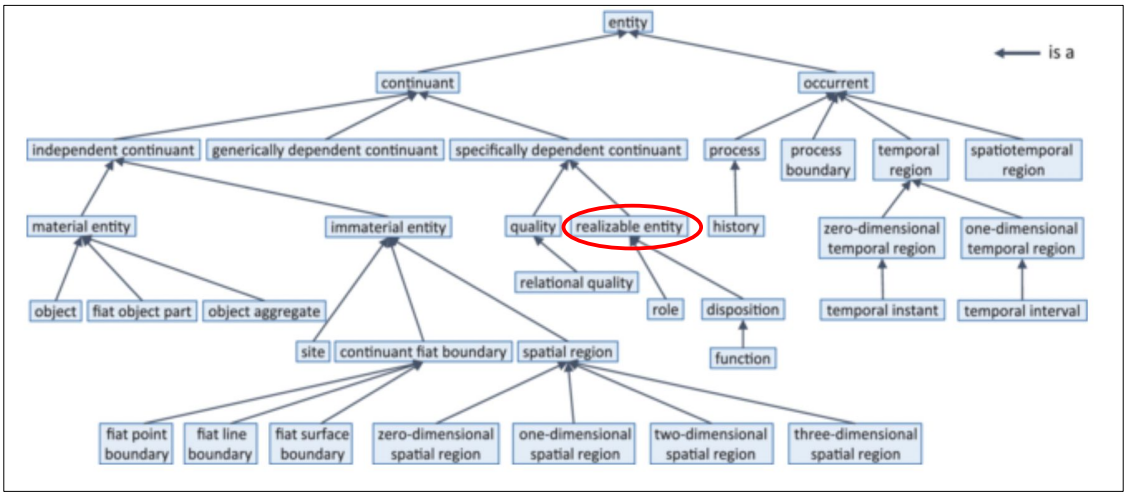
Class A *is_a* Class B means any instance of Class A is an instance of Class B



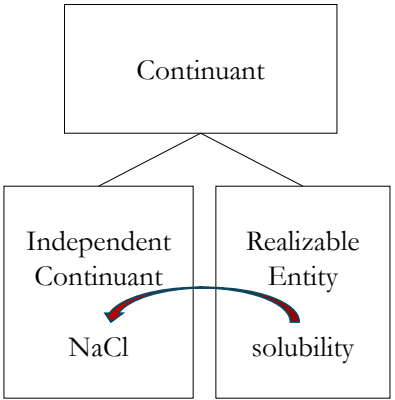
Specifically Dependent Continuant



Realizable Entity



Realizable Entity



Not all dependent entities fully manifest when they exist

Realizable Entity

- Attributes of some material bearer that only become manifest under certain conditions

- Put another way, realizable entities underwrite what bearers can do

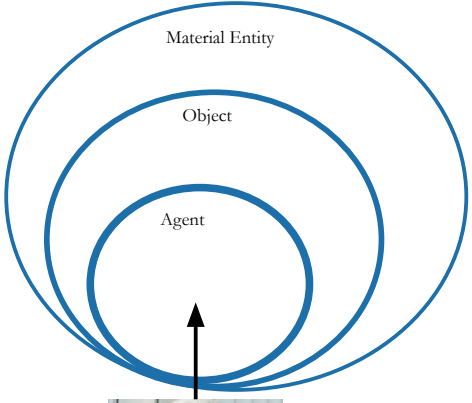
Rule of Thumb

There is a portion of sodium chloride before you

- Suppose I ask "Does this portion exhibit a lattice structure?"
- You need only look at the salt to find an answer
- Suppose I ask "Is this portion soluble in unsaturated H_2O?"
- You cannot simply look at the salt to find an answer

Barry Smith instance_of Agent

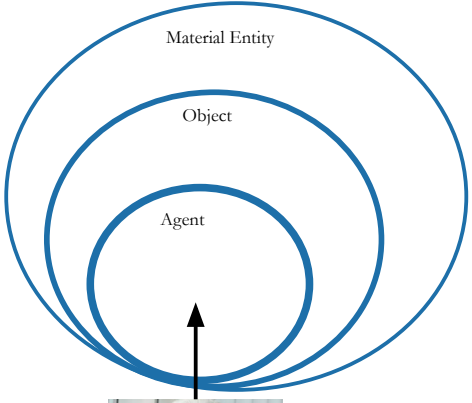
CLASSES

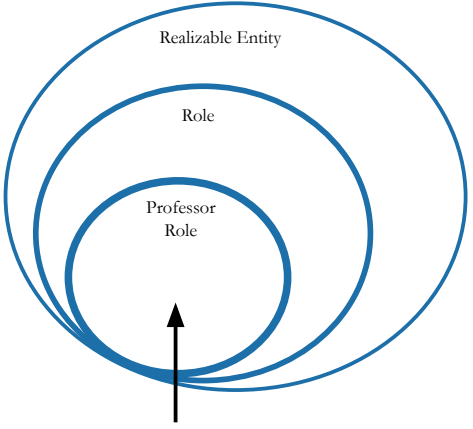


INSTANCES

SUNY Professor instance_of Professor Role

CLASSES





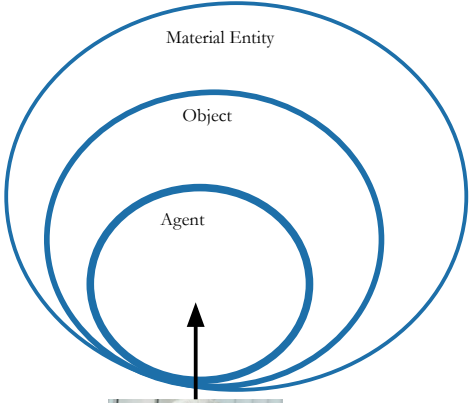
INSTANCES

SUNY Distinguished Professor of Philosophy

Julian Park Chair

Barry Smith bearer_of SUNY Professor

CLASSES

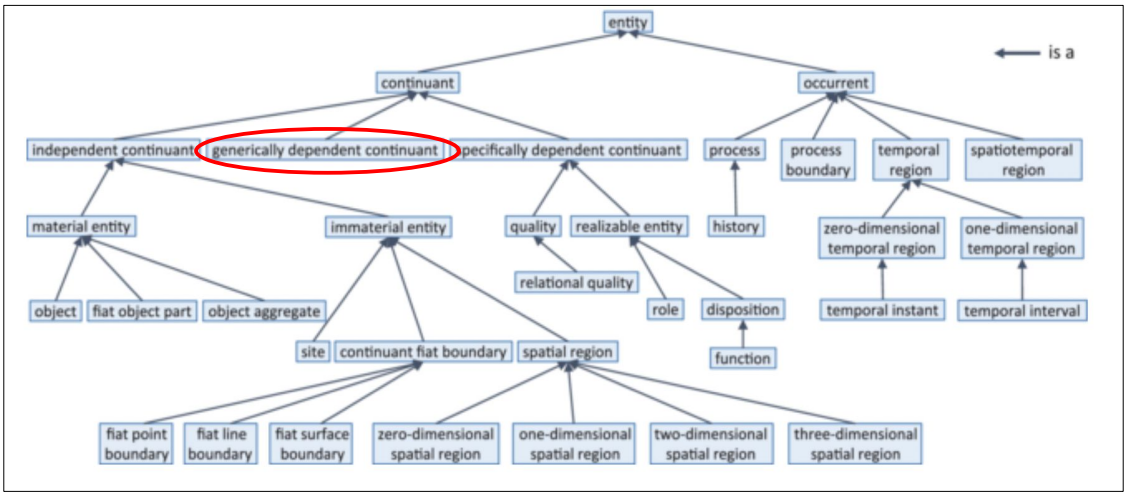


INSTANCES

SUNY Distinguished Professor of Philosophy

Julian Park Chair

Generically Dependent Continuant



Patterns

- A need arose to represent dependent entities that could migrate across bearers

- This need led to **generically dependent continuants**, continuants that are in some sense copyable, i.e. patterns

- For example, “Snow is white” and “Schnee ist weiß” may be used to express numerically identical content, i.e. the same pattern

Real Patterns

- Some patterns are necessarily **about** something; some patterns are not
- "Snow is white" expresses content that is **about** snow
- "cm" or "." are not necessarily **about** anything; they are nevertheless patterns
- Most **generically dependent entities** represented in BFO extensions are patterns that are **about** something

Aboutness

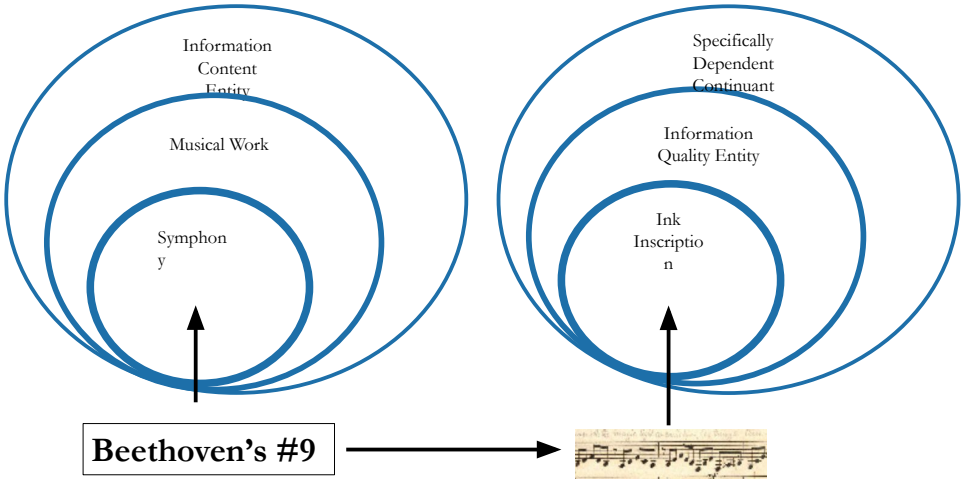
- **Information** is a pattern that is **about** something

- In BFO extensions - such as the Information Artifact Ontology and the Information Entity Ontology - information is represented by the class **Information Content Entity**

- Where the "is about" relation is understood to be primitive:

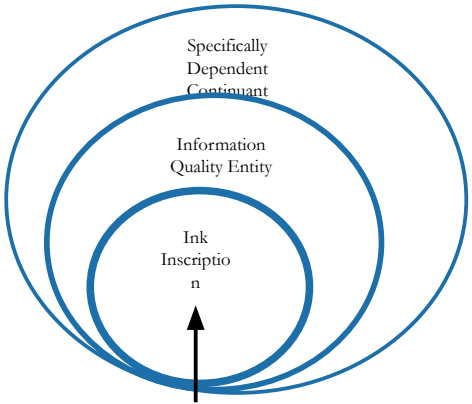
definition [language: en]
A primitive relationship between an Information Content Entity and some Entity.

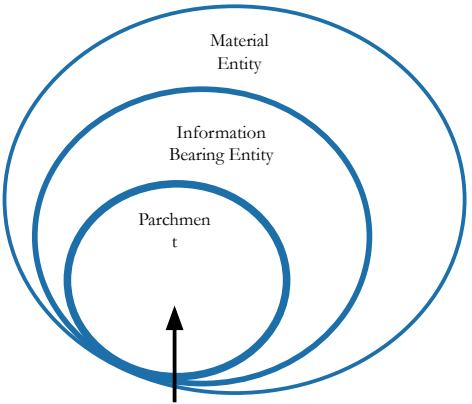
#9 Concretized in Ink Inscription



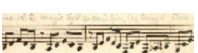
Ink Inscription inheres in Parchment

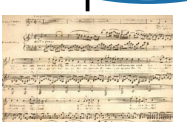
CLASSES





INSTANCES

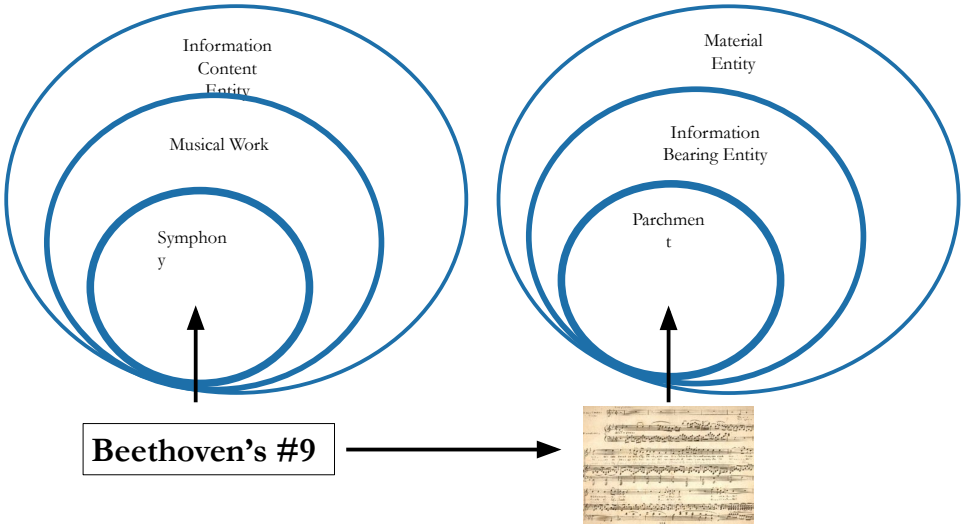




#9 Generically Dependent On Parchment

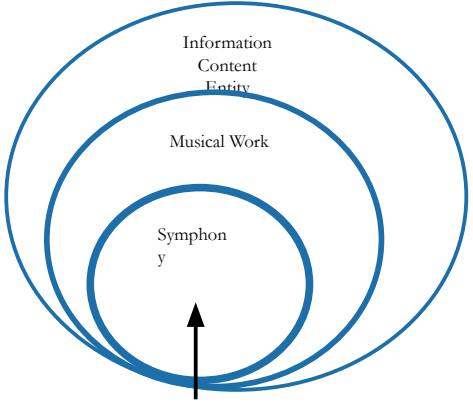
CLASSES

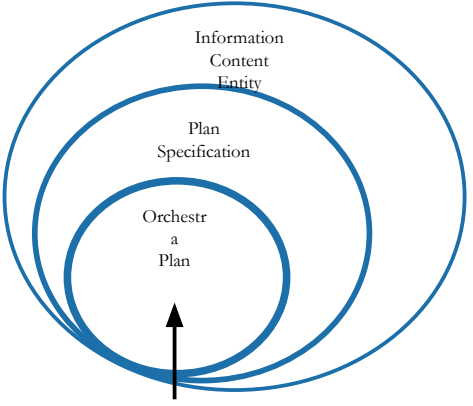
INSTANCES



#9 is about Orchestra Plan

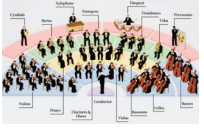
CLASSES





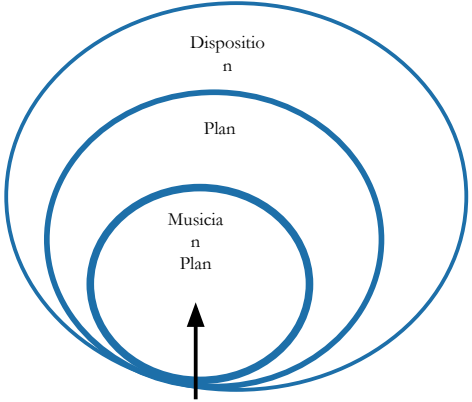
INSTANCES

Beethoven's #9

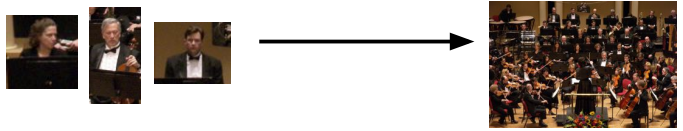


Musician Plan realized in #9 Performance

CLASSES



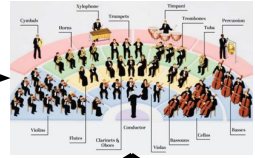
INSTANCES



Beethoven's #9th Symphony

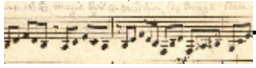
Beethoven's #9

is about

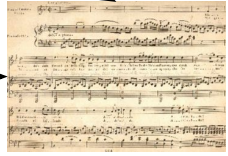


generically depends on

concretized in



inheres in



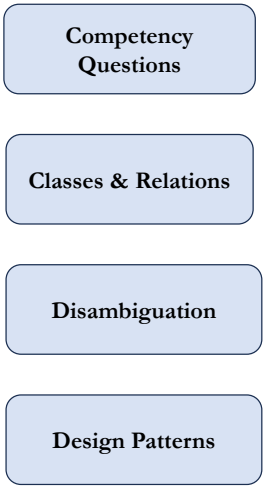
concretized in

has realization

Outline

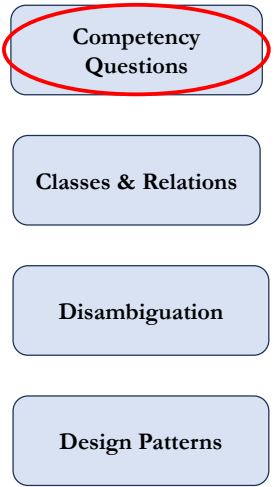
- Motivation for Ontology Engineering
- Motivation for Basic Formal Ontology
- Theory of BFO
- Building Ontologies with BFO

Guidance


Competency Questions
Classes & Relations
Disambiguation
Design Patterns

Guidance

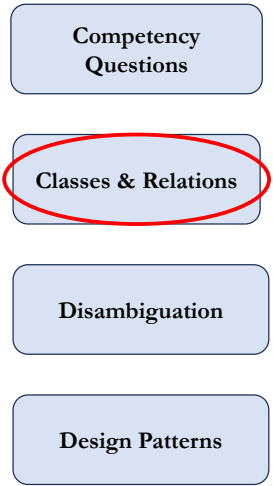
- Competency questions are **used to guide ontology development** and **generate unit tests** to ensure ontologies are sufficiently well-developed
- Identify a preliminary list of competency questions **first**
- They will help you scope your project

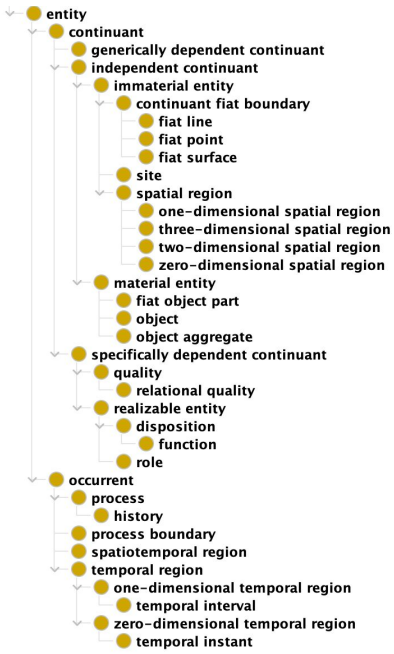


At what speed does a patrol boat move in knots over an hour?

Classes & Relations

- Using competency questions as guidance, list the classes and relations you will need to represent to answer the questions
- Create this list through the lens of, say, Basic Formal Ontology (BFO) and/or Common Core Ontologies classes and relations
- I illustrate using BFO




entity
continuant
generically dependent continuant
independent continuant
immaterial entity
continuant fiat boundary
fiat line
fiat point
fiat surface
site
spatial region
one-dimensional spatial region
three-dimensional spatial region
two-dimensional spatial region
zero-dimensional spatial region
material entity
fiat object part
object
object aggregate
specifically dependent continuant
quality
relational quality
realizable entity
disposition
function
role
occurrent
process
history
process boundary
spatiotemporal region
temporal region
one-dimensional temporal region
temporal interval
zero-dimensional temporal region
temporal instant


concretizes
continuant part of
member part of
environs
exists at
first instant of
generically depends on
has continuant part
has member part
has first instant
has history
has last instant
has material basis
has occurrent part
has temporal part
has participant
has realization
history of
is carrier of
is concretized by
last instant of
located in
location of
material basis of
occupies spatial region
occupies spatiotemporal region
occupies temporal region
occurrent part of
temporal part of
occurs in
participates in
preceded by
precedes
realizes
spatially projects onto
specifically depended on by
bearer of
specifically depends on
inheres in
temporally projects onto

Rules of Thumb

- When identifying classes, describe:

1. Material entities within scope, i.e. **Material Entity**
2. Qualities these material entities have, i.e. **Quality**
3. What these material entities could do, i.e. **Realizable Entity**
4. What these material entities actually do, i.e. **Process**
5. Where these material entities and boundaries are located, i.e. **Immaterial Entity**
6. When these entities exist, i.e. **Temporal Region**
7. Information we use to talk about 1-6, i.e. **Generically Depedent Continuant**

https://github.com/BFO-ontology/BFO-2020

Classes

- Material Entities –
- Qualities –
- Processes –
- Realizables –
- Sites & Boundaries –
- Temporal Region –
- Information –

At what speed does a patrol boat move in knots over an hour?

Classes

- Material Entities – **Patrol boat**
- Qualities –
- Processes –
- Realizables –
- Sites & Boundaries –
- Temporal Region –
- Information –

At what speed does a patrol boat move in knots over an hour?

Classes

- Material Entities – Patrol boat
- Qualities –
- Processes – **Act of motion**
- Realizables –
- Sites & Boundaries –
- Temporal Region –
- Information –

At what speed does a patrol boat move in knots over an hour?

Classes

- Material Entities – Patrol boat
- Qualities –
- Processes – Act of motion, **speed?**
- Realizables –
- Sites & Boundaries –
- Temporal Region –
- Information – **speed?**

At what speed does a patrol boat move in knots over an hour?

Classes

- Material Entities – Patrol boat
- Qualities –
- Processes – Act of motion, speed*
- Realizables –
- Sites & Boundaries –
- Temporal Region –
- Information – speed*

use * to note ambiguity then move on; we will revisit

At what speed does a patrol boat move in knots over an hour?

Classes

- Material Entities – Patrol boat
- Qualities –
- Processes – Act of motion, speed*
- Realizables –
- Sites & Boundaries –
- Temporal Region –
- Information – speed*, **knots measurement**

At what speed does a patrol boat move in knots over an hour?

Classes

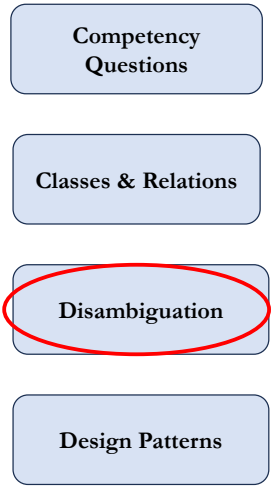
- Material Entities – Patrol boat
- Qualities –
- Processes – Act of motion, speed*
- Realizables –
- Sites & Boundaries –
- Temporal Region – **hours***
- Information – speed*, knots measurement, **hours***

use * to note ambiguity then move on; we will revisit

At what speed does a patrol boat move in knots over an hour?

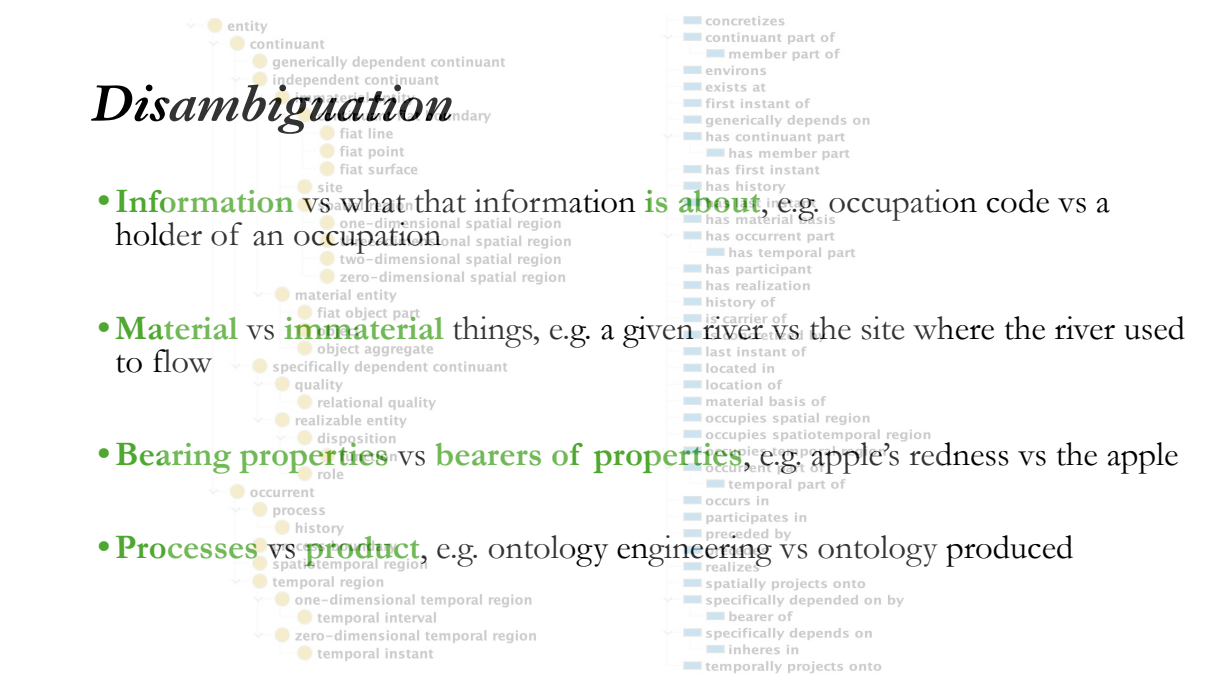
Disambiguate

- Logic is **demanding**, in part because it is **complete**
- We make explicit the implicit semantics within data, which requires disambiguating
- It is easier to stitch meaning together having cut it from whole cloth, than it is from disparate meanings



Disambiguation

- **Information** vs what that information **is about**, e.g. occupation code vs a holder of an occupation
- **Material** vs **immaterial** things, e.g. a given river vs the site where the river used to flow
- **Bearing properties** vs **bearers of properties**, e.g. apple's redness vs the apple
- **Processes** vs **product**, e.g. ontology engineering vs ontology produced



Disambiguation

- **Information** vs what that information **is about**, e.g. occupation code vs a holder of an occupation
- **Material** vs **immaterial** things, e.g. a given river vs the site where the river used to flow
- **Bearing properties** vs **bearers of properties**, e.g. apple's redness vs the apple
- **Processes** vs **product**, e.g. ontology engineering vs ontology produced

Revisiting Ambiguity

- "speed" as a process vs information about a process

Revisiting Ambiguity

- "speed" as a process vs information about a process

- Speed is the magnitude of a change in position over time

INFORMATION

Revisiting Ambiguity

- "speed" as a process vs information about a process

- Speed is the changing of position over time

PROCESS

Revisiting Ambiguity

- "speed" as a process vs information about a process

At what speed does a patrol boat move in knots over an hour?

WHICH DO WE CARE ABOUT FOR THIS COMPETENCY QUESTION?

Simplify

- Material Entities – Patrol boat
- Qualities –
- Processes – Act of motion, speed*
- Realizables –
- Sites & Boundaries –
- Temporal Region – hours*
- Information – speed*, knots measurement, hours*

At what speed does a patrol boat move in knots over an hour?

Simplify

- Material Entities – Patrol boat
- ~~Qualities –~~
- Processes – Act of motion, speed*
- ~~Realizables –~~
- ~~Sites & Boundaries –~~
- Temporal Region – hours*
- Information – ~~speed*,~~ knots measurement, ~~hours*~~

simplify the list

At what speed does a patrol boat move in knots over an hour?

Relations

- Material Entities – Patrol boat
- Processes – Act of motion, speed
- Temporal Region – hours
- Information – knots measurement

and reflect on relationships among the listed entities

At what speed does a patrol boat move in knots over an hour?

Rules of Thumb

- When identifying relations, describe:

1. Qualities to material entities, i.e. **inheres in**
2. Realizables to material entities, i.e. **inheres in**, **has material basis**
3. Processes to material entities, i.e **participates in**
4. Realizables to processes, i.e. **has realization**
5. Immaterial location of material entity, i.e. **located in**
6. When any such entities exist, i.e. **exists at**, **datatype property**
7. When any such entities carry information, e.g. **generically depends on**

https://github.com/BFO-ontology/BFO-2020

Relations

- Material Entities – **Patrol boat**
- Processes – **Act of motion**, speed
- Temporal Region – hours
- Information – knots measurement

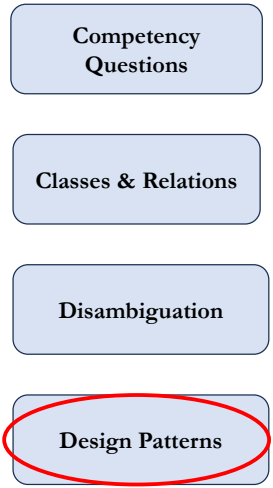
patrol boats participate in processes

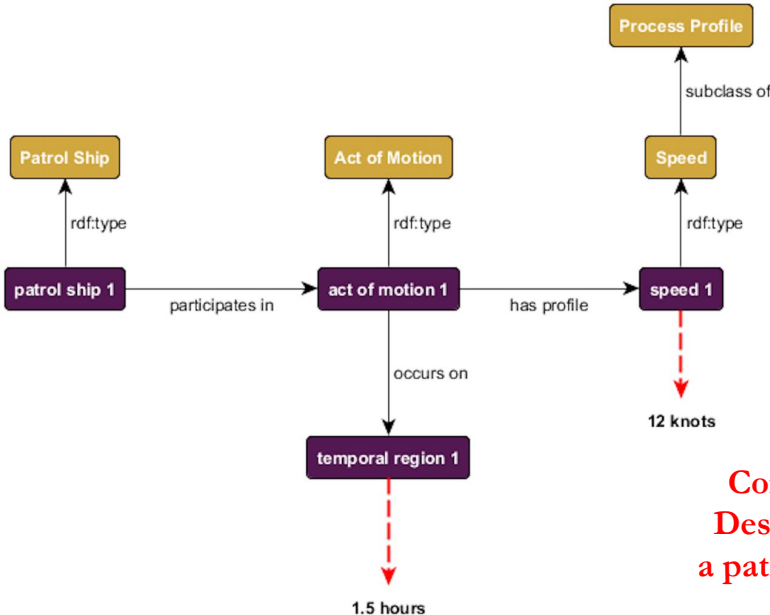
https://github.com/BFO-ontology/BFO-2020

Design Patterns

- Classes and relations identified, turn next to constructing visual representations reflecting the competency questions

- If you have completed the preceding steps, this should be relatively straightforward





Common Core Ontologies Design Pattern representing a patrol ship traveling 12 knots over 1.5 hours

CI/CD Semantic Pipeline

- Extract, normalize, and transform data into a structured format
- Using RDFlib, construct RDF graphs that conform to a design pattern
- Leverage ROBOT DevOps to verify ontology/data integrity, e.g. OWL reasoners, SPARQL, SHACL
- Leverage targeted reasoning with SPARQL to identify novel relationships
- Update design pattern with new relationships, then repeat

CI/CD Semantic Pipeline

- Extract, normalize, and transform data into a structured format
- Using RDFlib, construct RDF graphs that conform to a design pattern
- Leverage ROBOT DevOps to verify ontology/data integrity, e.g. OWL reasoners, SPARQL, SHACL
- Leverage targeted reasoning with SPARQL to identify novel relationships
- Update design pattern with new relationships, then repeat

ETL Guide: Normalizing Sensor Measurements with Pandas

Goal: Combine raw sources, such as `src/data/sensor_A.csv` and `src/data/sensor_B.json`, into a single clean CSV: `src/data/readings_normalized.csv`.

"Clean"

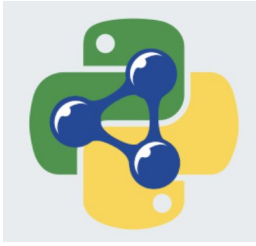
- **Consistent columns**: `artifact_id, sdc_kind, unit_label, value, timestamp`
- **Consistent datatypes**: `artifact_id|sdc_kind|unit_label` = strings; `value` = numeric; `timestamp` = ISO 8601 string (UTC preferred)
- **Consistent units**: normalize unit labels to a single spelling/abbreviation (e.g., `C` not `celsius`, `kg` not `Kilogram`)

You will write a **small Python script** (e.g., `src/scripts/normalize_readings.py`) that uses **Pandas** to load inputs, standardize, and output the normalized CSV. Use the following canonical scheme as a guide:

column	type	examples
artifact_id	str	`A-001`, `pump-42`
sdc_kind	str	`temperature`, `mass`, `length`
unit_label	str	`C`, `kg`, `m`
value	float	`23.5`, `72.0`
timestamp	str	`2025-10-16T12:00:00Z`

CI/CD Semantic Pipeline

- Extract, normalize, and transform data into a structured format
- Using RDFlib, construct RDF graphs that conform to a design pattern
- Leverage ROBOT DevOps to verify ontology/data integrity, e.g. OWL reasoners, SPARQL, SHACL
- Leverage targeted reasoning with SPARQL to identify novel relationships
- Update design pattern with new relationships, then repeat

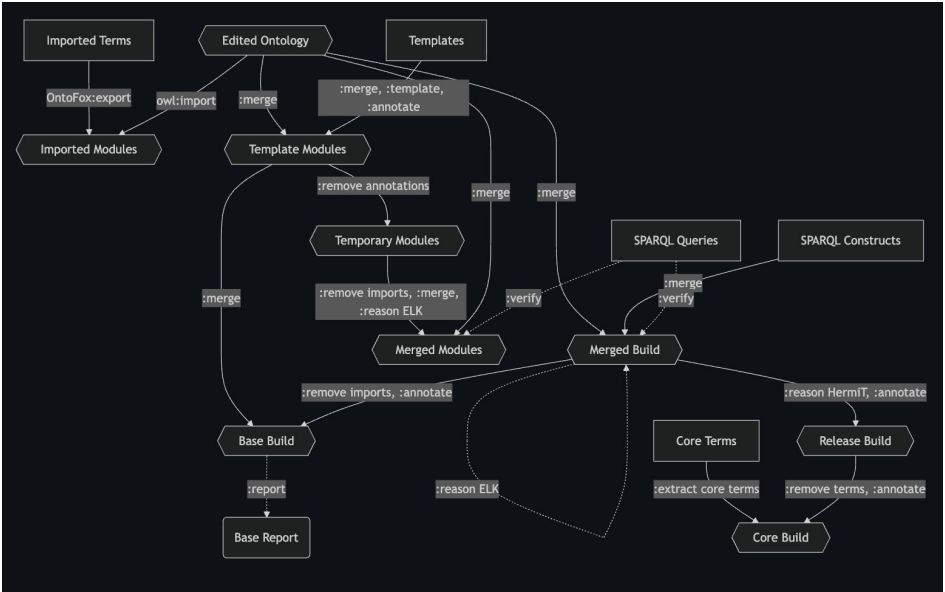


```python
# ———————— Build graph ————————
def main():
    if not IN_CSV.exists():
        raise FileNotFoundError(f"Missing input CSV: {IN_CSV}")

    g = Graph()
    g.bind("cco", CCO)
    g.bind("bfo", BFO)
    g.bind("rdfs", RDFS)
    g.bind("xsd", XSD)
    g.bind("ex", EX)

    # Caches so we only mint each node once
    artifact_nodes = {}
    sdc_nodes = {}
    unit_nodes = {}

    with IN_CSV.open(newline="", encoding="utf-8") as fh:
        reader = csv.DictReader(fh)
        rows = list(reader)

    for i, row in enumerate(rows, start=1):
        artifact_id = (row.get("artifact_id") or "").strip()
        sdc_kind    = (row.get("sdc_kind") or "").strip()
        unit_label  = (row.get("unit_label") or "").strip()
        value_str   = (row.get("value") or "").strip()
        timestamp   = (row.get("timestamp") or "").strip()

        if not (artifact_id and sdc_kind and unit_label and value_str and timestamp):
            # Skip incomplete rows (shouldn't happen if ETL enforced)
            continue
```

CI/CD Semantic Pipeline

- Extract, normalize, and transform data into a structured format
- Using RDFlib, construct RDF graphs that conform to a design pattern
- Leverage ROBOT DevOps to verify ontology/data integrity, e.g. OWL reasoners, SPARQL, SHACL
- Leverage targeted reasoning with SPARQL to identify novel relationships
- Update design pattern with new relationships, then repeat

ROBOT ROBOT is an OBO Tool



CI/CD Semantic Pipeline

- Extract, normalize, and transform data into a structured format
- Using RDFlib, construct RDF graphs that conform to a design pattern
- Leverage ROBOT DevOps to verify ontology/data integrity, e.g. OWL reasoners, SPARQL, SHACL
- Leverage targeted reasoning with SPARQL to identify novel relationships
- Update design pattern with new relationships, then repeat

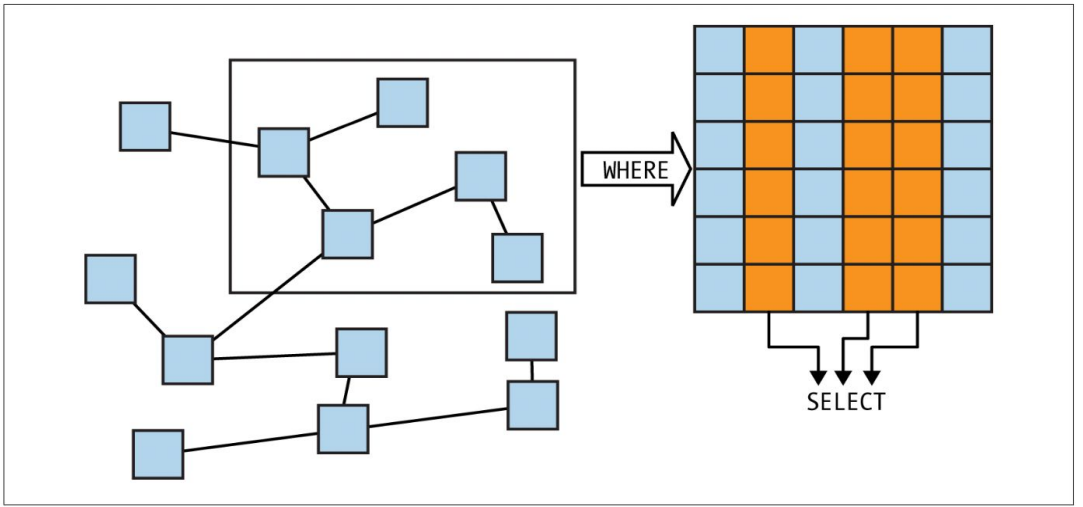


Figure 1-1. WHERE specifies data to pull out; SELECT picks which data to display

CI/CD Semantic Pipeline

- Extract, normalize, and transform data into a structured format
- Using RDFlib, construct RDF graphs that conform to a design pattern
- Leverage ROBOT DevOps to verify ontology/data integrity, e.g. OWL reasoners, SPARQL, SHACL
- Leverage targeted reasoning with SPARQL to identify novel relationships
- Update design pattern with new relationships, then repeat

Whenever you **add one new dataset** (like `sensor_C.csv`) to the `src/data/` folder and push to GitHub, the provided workflow will automatically:

1. Run your **ETL script** to update `src/data/readings_normalized.csv`.
2. Run your **RDFlib script** to rebuild `src/measure_cco.ttl`.
3. Run **SPARQL QC** checks to verify annotation and logical consistency.
4. Run **SHACL** validation to confirm data integrity.

If everything is correct, your workflow run will show a ✅ next to each step in GitHub Actions.

```yaml
name: Ontology Workflow

on:
  push:
    paths:
      - "projects/project-4/assignment/src/data/**"

jobs:
  build-and-validate:
    runs-on: ubuntu-latest
    timeout-minutes: 15
```

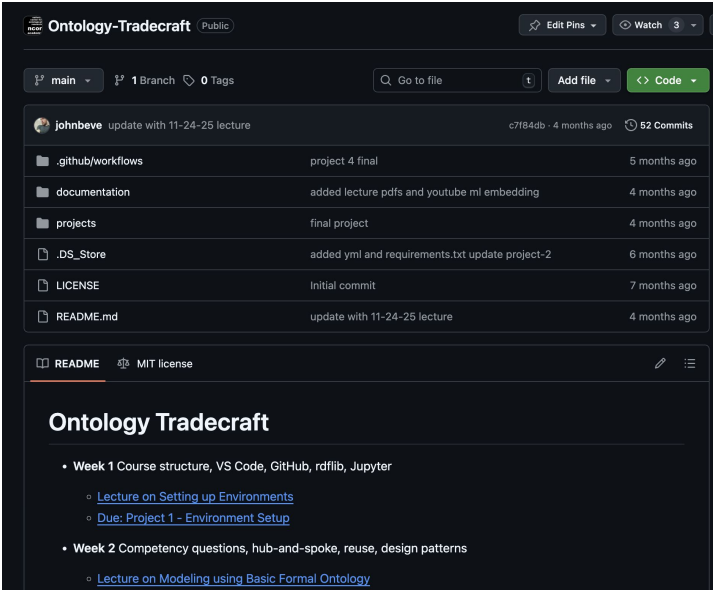
```
4/assignment
```

```
OJECT_ROOT }}
```

```
r diff below
```

```
ADDED file under src/data/**
```

```yaml
          id: detect
          shell: bash
          run: |
            BEFORE_SHA="${{ github.event.before }}"
            AFTER_SHA="${{ github.sha }}"

            # Handle first-push edge case
            if [[ "$BEFORE_SHA" == "0000000000000000000000000000000000000000" || -z "$BEFORE_SHA" ]]; then
              if git rev-parse HEAD^ >/dev/null 2>&1; then
                BEFORE_SHA="$(git rev-parse HEAD^)"
              else
                BEFORE_SHA="$AFTER_SHA"
```



https://github.com/Applied-Ontology-Education/Ontology-Tradecraft

WE MAKE EXPLICIT THE IMPLICIT SEMANTICS IN DATASETS, IN THE INTEREST OF ADDRESSING INTEROPERABILITY CHALLENGES AND IMPROVING DATA QUALITY VIA GENERAL AND TARGETED REASONING

Assignment

For each case, construct a BFO-conformant design pattern with justification

https://github.com/Applied-Ontology-Education/2025-C-FORS-BFO-Session

Design Pattern Guidance

- Include a legend or key
- Visually distinguish **classes** from **instances** from **strings**
- Distingish **direct relations** from **shortcuts**
- Read arrows as reflecting "any instance of class X arrow some instance of class Y"
- Carefully determine how specific/broad to make your design patterns

Submission Guidance

- Create a GitHub account and fork the **C-FORS** BFO Summer repo (see **here for GitHub** guidance)
- Save a diagram reflecting your design pattern to your forked repository in the "Submit" directory
- Save a written justification of your design pattern choices
- Open a Pull Request to the **C-FORS** repository

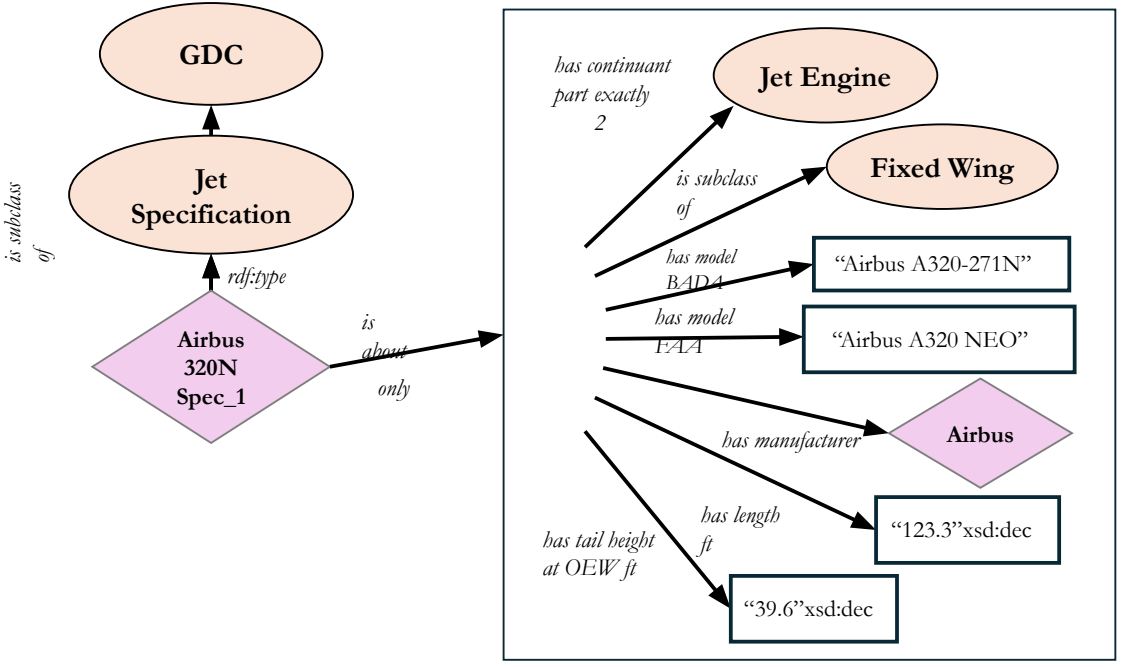
Case 1

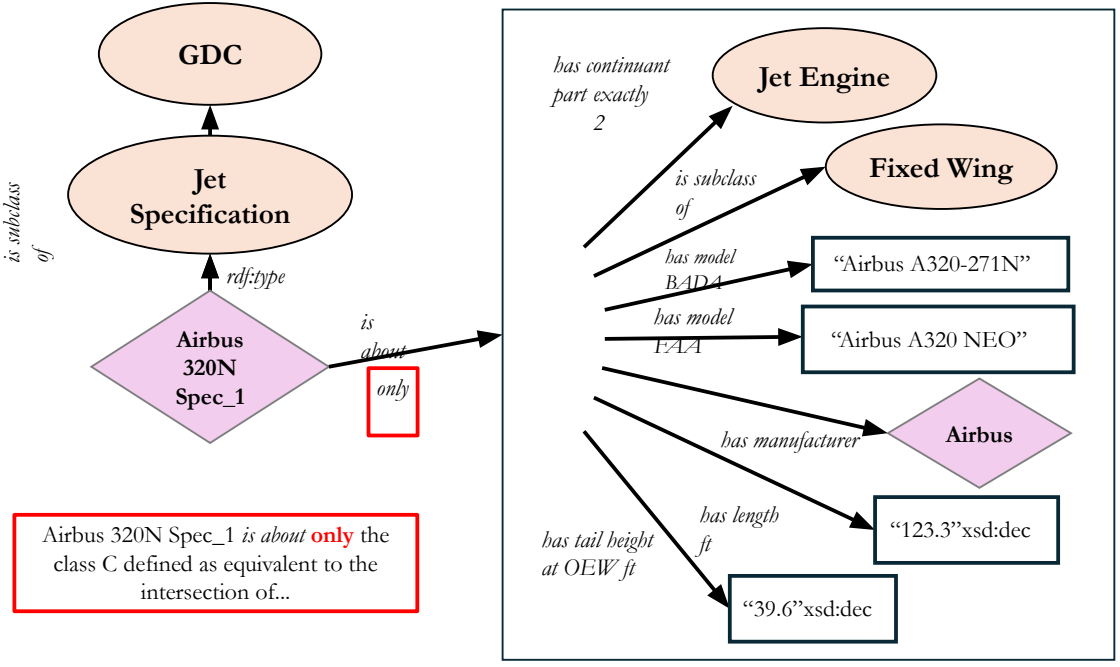
In aircraft_data.xlsx you will find a row for the Airbus A320 Neo.

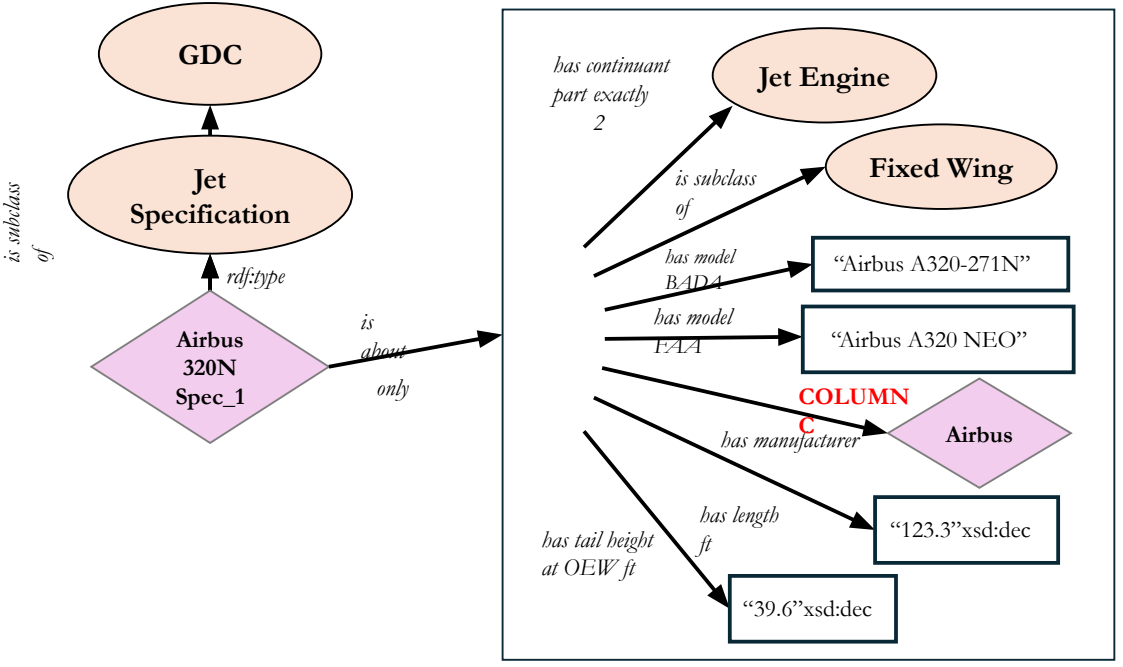
Construct a BFO-conformant design pattern reflecting the content of every column associated with that row.

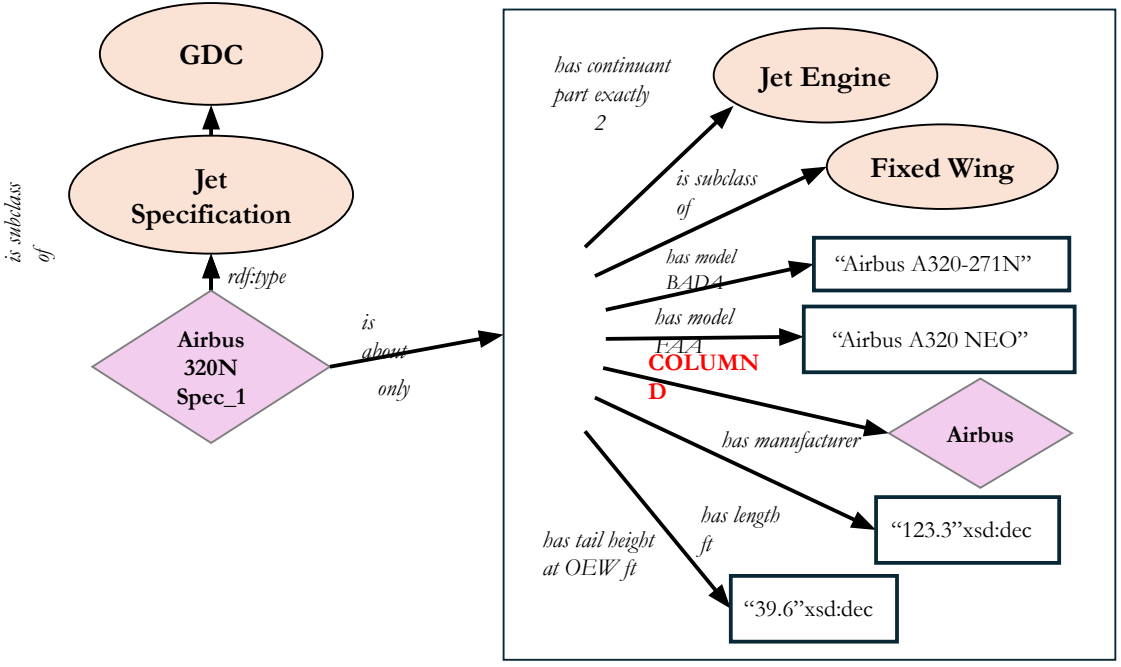
	A	B	C	D	E	F	G	H	I	J	K	L
1	ICAO_Code	FAA_Designator	Manufacturer	Model_FAA	Model_BADA	Physical_Class_Engine	Num_Engines	AAC	AAC_minimum	AAC_maximum	ADG	TDG
7	A306	A306	AIRBUS	Airbus A300 B4-600	Airbus A300B4-622	Jet	2	C			IV	5
8	A30B	A30B	AIRBUS	Airbus A300-B2	Airbus A300B4-203	Jet	2	C			IV	5
9	A310	A310	AIRBUS	Airbus A310	Airbus A310-204	Jet	2	C			IV	5
10	A318	A318	AIRBUS	Airbus A318	Airbus A318-112	Jet	2	C			III	3
11	A319	A319	AIRBUS	Airbus A319	Airbus A319-131	Jet	2	C			III	3
12	A320	A320	AIRBUS	Airbus A320	Airbus A320-231	Jet	2	C			III	3
13	A321	A321	AIRBUS	Airbus A321	Airbus A321-111	Jet	2	D	C	D	III	3
14	A332	A332	AIRBUS	Airbus A330-200	Airbus A330-243	Jet	2	C			V	5
15	A333	A333	AIRBUS	Airbus A330-300	Airbus A330-301	Jet	2	C			V	5

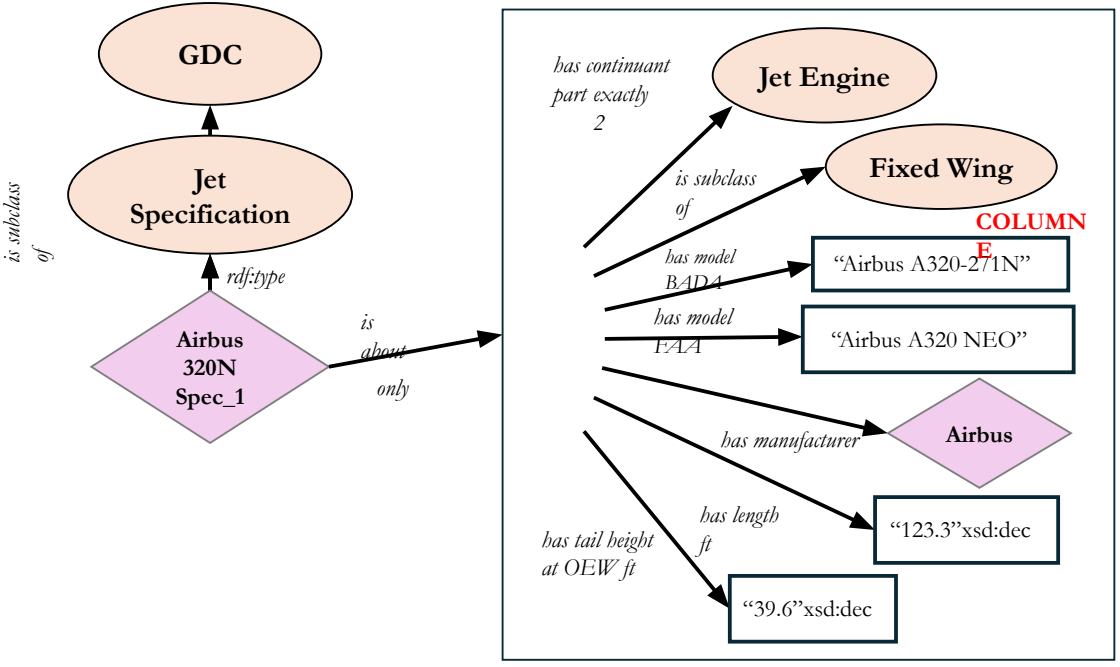
	A	B	C	D	E	F	G	H	I	J	K	L
1	ICAO_Code	FAA_Designator	Manufacturer	Model_FAA	Model_BADA	Physical_Class_Engine	Num_Engines	AAC	AAC_minimum	AAC_maximum	ADG	TDG
7	A306	A306	AIRBUS	Airbus A300 B4-600	Airbus A300B4-622	Jet	2	C			IV	5
8	A30B	A30B	AIRBUS	Airbus A300-B2	Airbus A300B4-203	Jet	2	C			IV	5
9	A310	A310	AIRBUS	Airbus A310	Airbus A310-204	Jet	2	C			IV	5
10	A318	A318	AIRBUS	Airbus A318	Airbus A318-112	Jet	2	C			III	3
11	A319	A319	AIRBUS	Airbus A319	Airbus A319-131	Jet	2	C			III	3
12	A320	A320	AIRBUS	Airbus A320	Airbus A320-231	Jet	2	C			III	3
13	A321	A321	AIRBUS	Airbus A321	Airbus A321-111	Jet	2	D	C	D	III	3
14	A332	A332	AIRBUS	Airbus A330-200	Airbus A330-243	Jet	2	C			V	5
15	A333	A333	AIRBUS	Airbus A330-300	Airbus A330-301	Jet	2	C			V	5

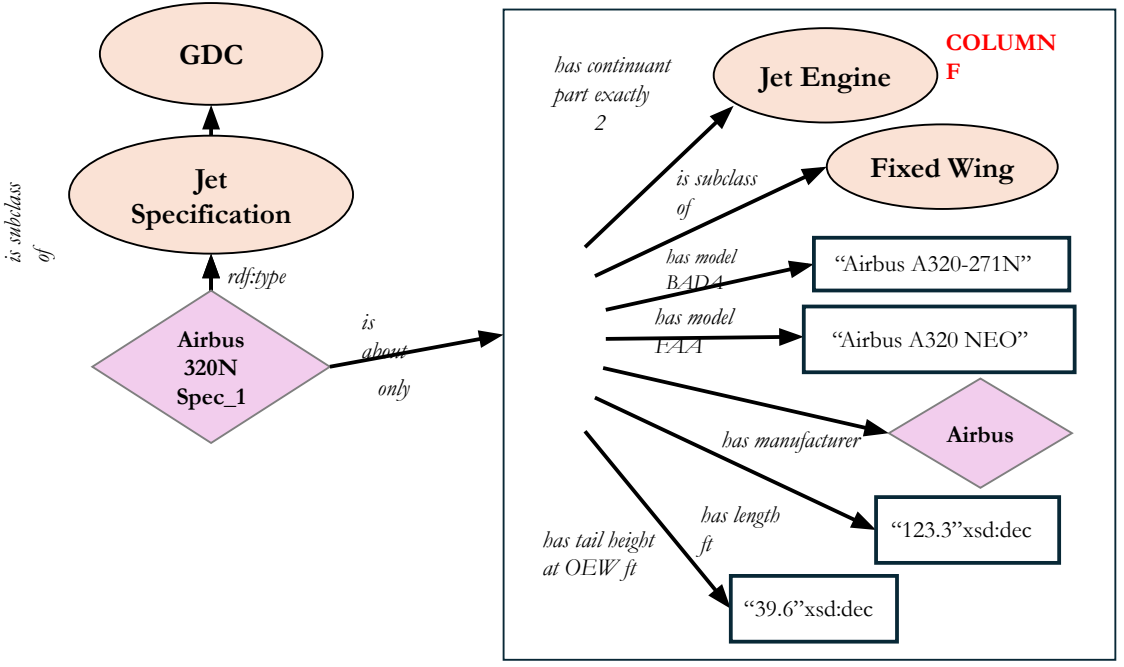

GDC
Jet Specification
is subclass of
rdf:type
Airbus 320N Spec_1
is about only
has continuant part exactly 2
Jet Engine
is subclass of
Fixed Wing
has model BADA
"Airbus A320-271N"
has model FAA
"Airbus A320 NEO"
has manufacturer
Airbus
has length ft
"123.3"xsd:dec
has tail height at OEW ft
"39.6"xsd:dec

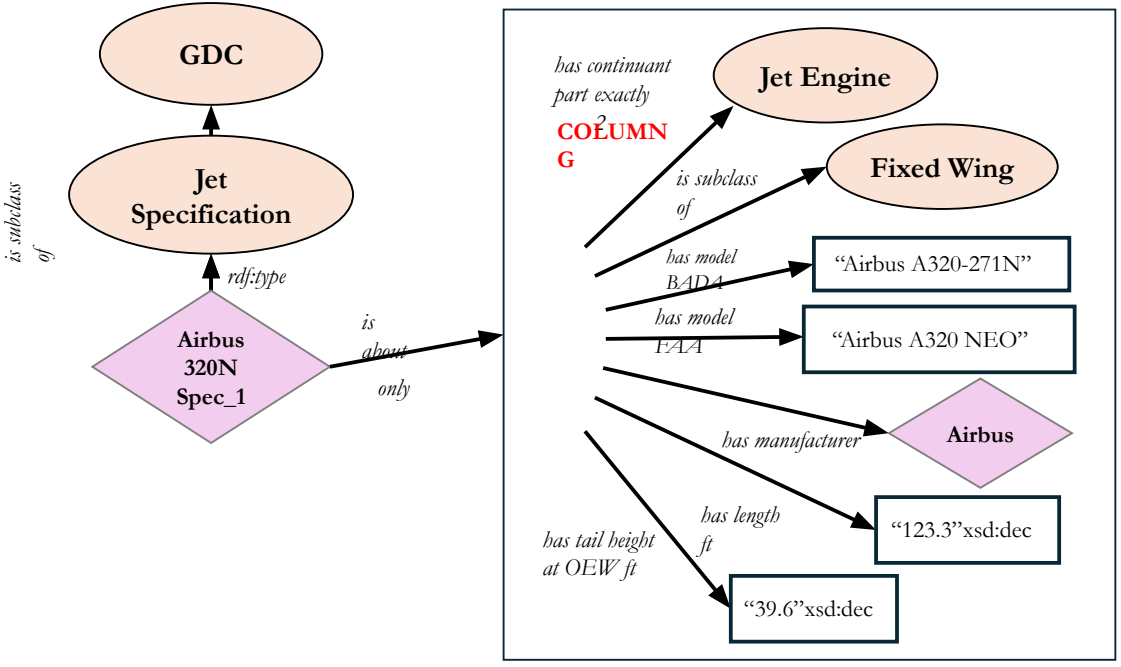

GDC
Jet Specification
is subclass of
rdf:type
Airbus 320N Spec_1
is about
only
Airbus 320N Spec_1 is about only the class C defined as equivalent to the intersection of...
has continuant part exactly 2
Jet Engine
is subclass of
Fixed Wing
has model BADA
"Airbus A320-271N"
has model FAA
"Airbus A320 NEO"
has manufacturer
Airbus
has length ft
"123.3"xsd:dec
has tail height at OEW ft
"39.6"xsd:dec

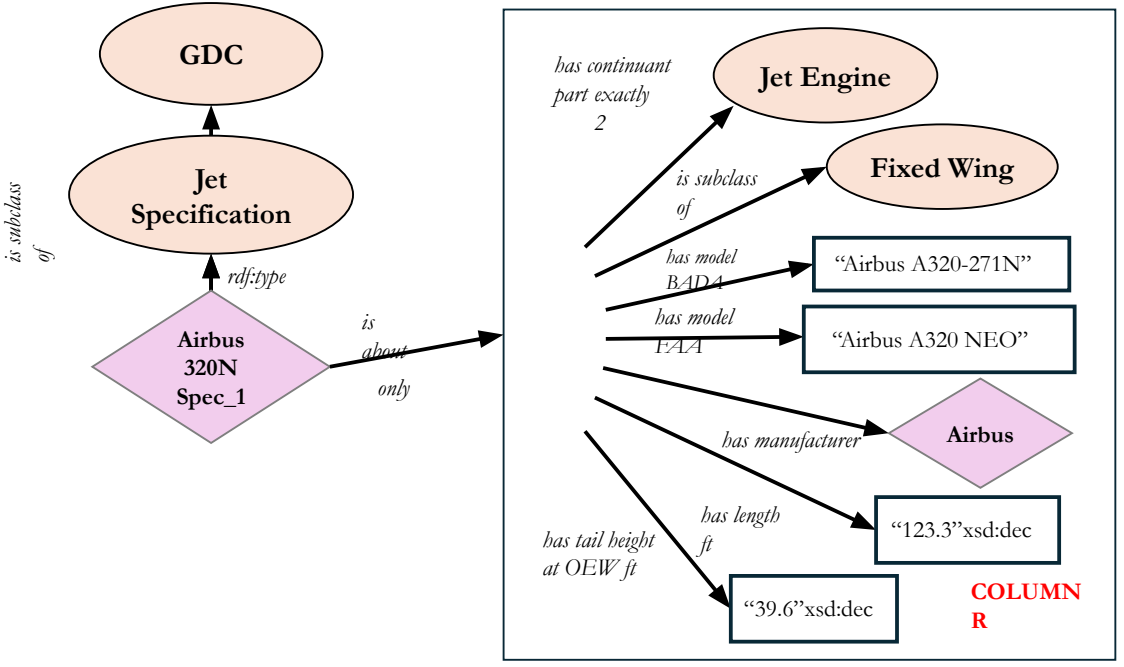

GDC
Jet Specification
is subclass of
rdf:type
Airbus 320N Spec_1
is about only
has continuant part exactly 2
Jet Engine
is subclass of
Fixed Wing
has model BADA
"Airbus A320-271N"
has model FAA
"Airbus A320 NEO"
COLUMN C
has manufacturer
Airbus
has length ft
"123.3"xsd:dec
has tail height at OEW ft
"39.6"xsd:dec

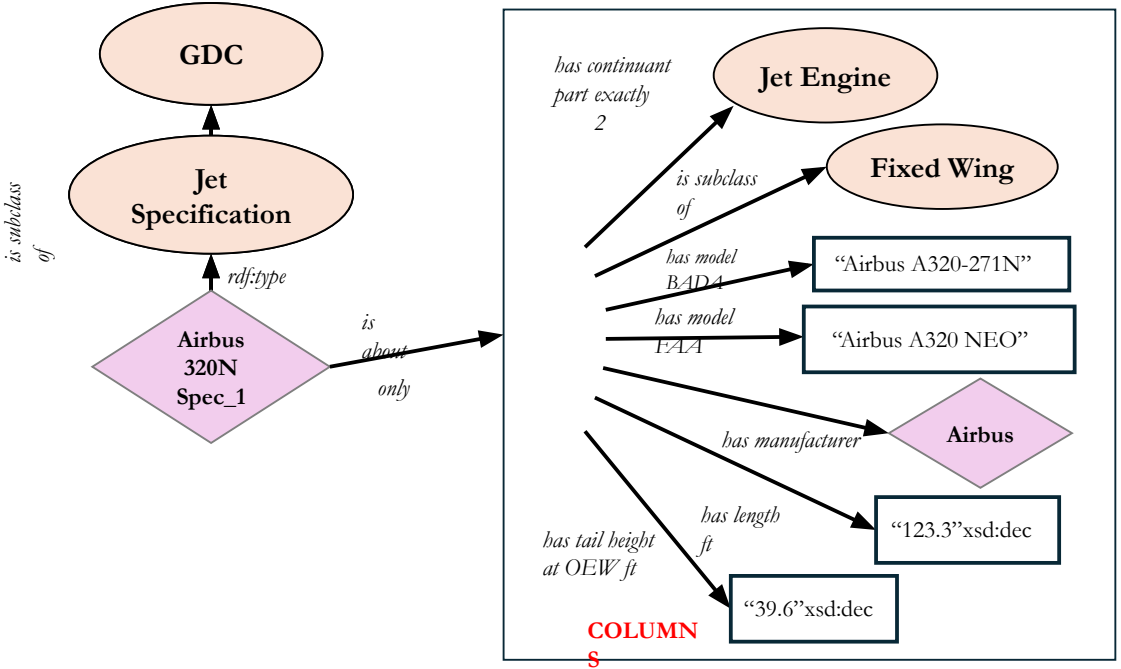

GDC
Jet Specification
is subclass of
rdf:type
Airbus 320N Spec_1
is about only
has continuant part exactly 2
Jet Engine
is subclass of
Fixed Wing
has model BADA
"Airbus A320-271N"
has model FAA
"Airbus A320 NEO"
COLUMN D
has manufacturer
Airbus
has length ft
"123.3"xsd:dec
has tail height at OEW ft
"39.6"xsd:dec

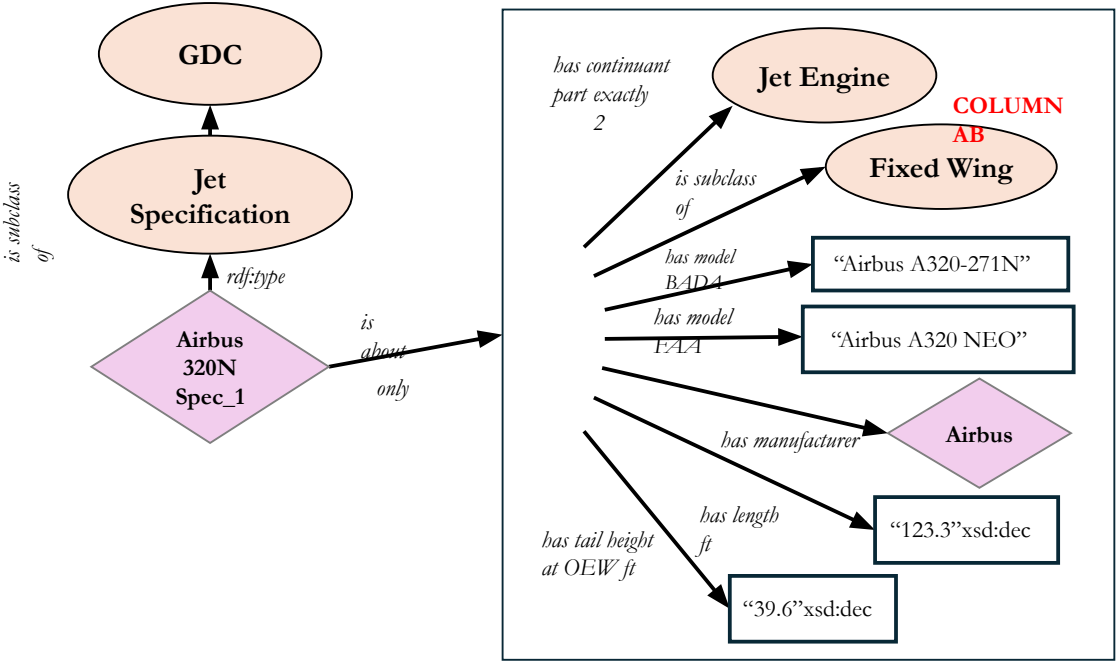

GDC
Jet Specification
is subclass of
rdf:type
Airbus 320N Spec_1
is about only
has continuant part exactly 2
Jet Engine
is subclass of
Fixed Wing
COLUMN E
has model BADA
"Airbus A320-271N"
has model FAA
"Airbus A320 NEO"
has manufacturer
Airbus
has length ft
"123.3"xsd:dec
has tail height at OEW ft
"39.6"xsd:dec

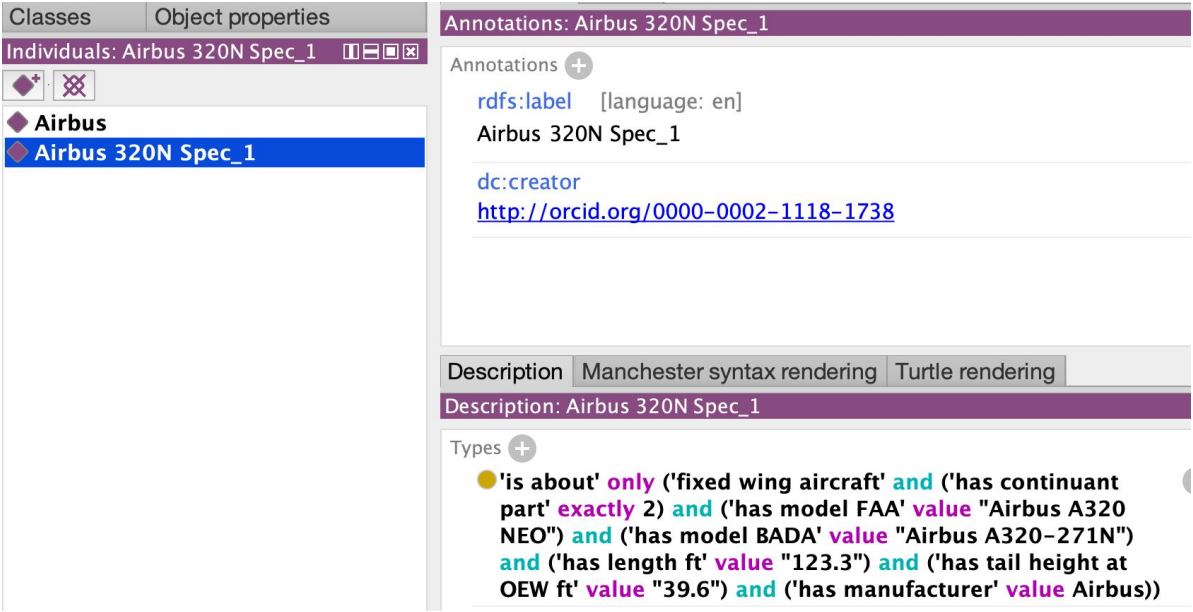

GDC
Jet Specification
is subclass of
rdf:type
Airbus 320N Spec_1
is about only
COLUMN F
has continuant part exactly 2
Jet Engine
is subclass of
Fixed Wing
has model BADA
"Airbus A320-271N"
has model FAA
"Airbus A320 NEO"
has manufacturer
Airbus
has length ft
"123.3"xsd:dec
has tail height at OEW ft
"39.6"xsd:dec


GDC
Jet Specification
is subclass of
rdf:type
Airbus 320N Spec_1
is about only
has continuant part exactly 2
COLUMN G
Jet Engine
is subclass of
Fixed Wing
has model BADA
"Airbus A320-271N"
has model FAA
"Airbus A320 NEO"
has manufacturer
Airbus
has length ft
"123.3"xsd:dec
has tail height at OEW ft
"39.6"xsd:dec


GDC
Jet Specification
is subclass of
rdf:type
Airbus 320N Spec_1
is about only
has continuant part exactly 2
Jet Engine
is subclass of
Fixed Wing
has model BADA
"Airbus A320-271N"
has model FAA
"Airbus A320 NEO"
has manufacturer
Airbus
has length ft
"123.3"xsd:dec
has tail height at OEW ft
"39.6"xsd:dec
COLUMN R


GDC
Jet Specification
is subclass of
rdf:type
Airbus 320N Spec_1
is about only
has continuant part exactly 2
Jet Engine
is subclass of
Fixed Wing
has model BADA
"Airbus A320-271N"
has model FAA
"Airbus A320 NEO"
has manufacturer
Airbus
has length ft
"123.3"xsd:dec
has tail height at OEW ft
"39.6"xsd:dec
COLUMNS


GDC
Jet Specification
is subclass of
rdf:type
Airbus 320N Spec_1
is about only
has continuant part exactly 2
Jet Engine
COLUMN AB
Fixed Wing
is subclass of
has model BADA
"Airbus A320-271N"
has model FAA
"Airbus A320 NEO"
has manufacturer
Airbus
has length ft
"123.3"xsd:dec
has tail height at OEW ft
"39.6"xsd:dec


Classes
Object properties
Individuals: Airbus 320N Spec_1
Airbus
Airbus 320N Spec_1
Annotations: Airbus 320N Spec_1
Annotations
rdfs:label [language: en]
Airbus 320N Spec_1
dc:creator
http://orcid.org/0000-0002-1118-1738
Description
Manchester syntax rendering
Turtle rendering
Description: Airbus 320N Spec_1
Types
'is about' only ('fixed wing aircraft' and ('has continuant part' exactly 2) and ('has model FAA' value "Airbus A320 NEO") and ('has model BADA' value "Airbus A320-271N") and ('has length ft' value "123.3") and ('has tail height at OEW ft' value "39.6") and ('has manufacturer' value Airbus))

Case 2

In aircraft_data.xlsx you will find a row for the Airbus A320-111, designed to have a maximum knot approach speed of 142. However, after 5 approaches, an instance has obtained an average maximum knot approach speed of 139.

Construct a BFO-conformant design pattern reflecting the preceding phenomena.

Case 3

In soc_structure_definitions.xlsx you will find three "SOC_TITLE" entries that mention "Aerospace Engineer".

Construct a BFO-conformant design pattern that reflects all three entries and their respective "SOC Definitions".

Case 4

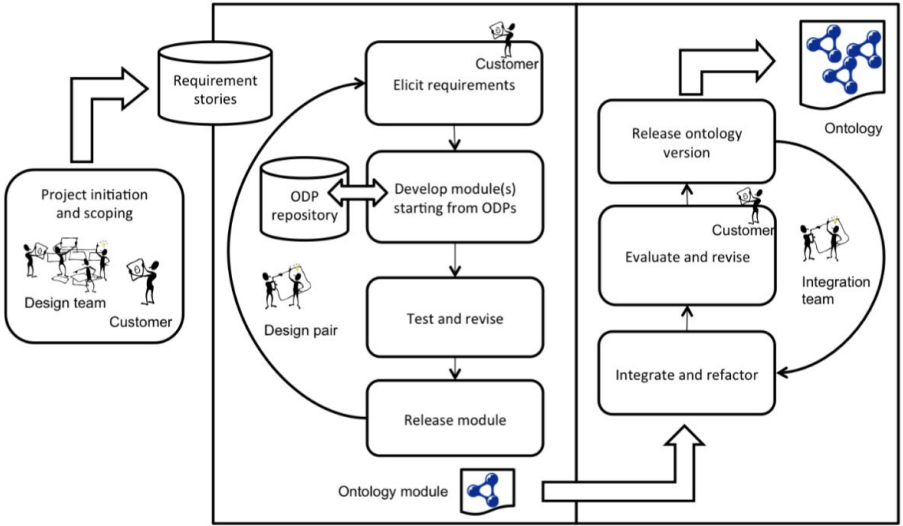
In employment_wage_May_2024.xlsx you will find three "OCC_TITLE" entries that mention "Aerospace Engineer".

Construct a BFO-conformant design pattern that reflects all three entries and their associated column information.

Solutions

https://www.youtube.com/watch?v=rXEsc0dDdsA

XD



STLAB
SEMANTIC TECHNOLOGY LABORATORY

Why XD (and ontology engineering) for this use case?

Data is heterogeneous, e.g. different countries use different substance names for the same chemical
Also: different matrices/units/coordinate systems

With an ontology, we can align and standardize all of these and query them efficiently!

With XD: we can reuse patterns, develop and refine quickly (iterative process), ground ourselves in requirements

STLAB
SEMANTIC TECHNOLOGY LABORATORY

Let’s see some data

Dataset, ID	Name	Category	WHY chosen
france_ades, 28	Measurement	Large authority dataset	canonical example
norway_2021_lake_Tyrifjorden, 83	Measurement	Small (109 rows)	surface waters, pfas
IT_MITENI_GW, 55	Measurement Groundwater near MITENI plant	(major Italian PFAS case)	high concentrations

The requirements (user stories)

XD starts with the customer. In XD terminology: the *customer team* is the PDH researchers, environmental scientists, and investigative journalists; the *design team* is us (the ontology engineers); and the *testing team* will later validate CQs against the ontology.

User stories:

"As a researcher, I want to know which PFAS substances were measured at a given water body and at what concentrations, so I can assess contamination severity over time."

"As a policy analyst, I want to identify which industrial sites are known or presumptive PFAS sources in a given country, so I can map regulatory exposure."

"As a journalist, I want to find all measurement points above a regulatory threshold (e.g., 100 ng/L) that are near airports or military bases, to investigate proximity between pollution sources and affected water bodies."

Good examples of user stories

Polifonia:
https://github.com/polifonia-project/stories

The requirements (Competency Questions)

CQ1: What PFAS substances were detected at a given location?

CQ2: What is the concentration of a given substance at a given sampling point, and in what unit?

CQ3: When was a given observation made?

CQ4: Which water body does a sampling point belong to?

Can you think of something else?

The requirements (Competency Questions)

CQ1: What **PFAS substances** were **detected** at a given **location**?

CQ2: What is the concentration of a given substance at a given sampling point, and in what unit?

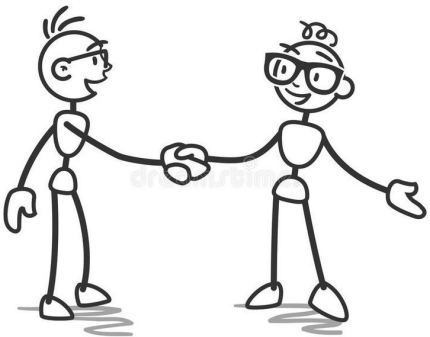
CQ3: When was a given observation made?

CQ4: Which water body does a sampling point belong to?

Can you think of something else?

Modeling for a specific domain?

Domain modeling = collaboration



Ontology Design Patterns (ODP) selection

Measurements and observations: SSN/SOSA
Quantity/parameter
Time: TimeInterval

Where? https://github.com/odpa/patterns-repository + WOP works, national works

Disadvantage: not all of them and low coverage :((*more on that later*)

ODP selection

Measurements and observations: SSN/SOSA
Quantity/parameter
Time: TimeInterval
Where?
https://github.com/odpa/patterns-repository +
WOP works

But also previous works!
See: https://github.com/whow-project

Hydrography, Water indicator, Water Monitoring
https://github.com/whow-project

STLAB
SEMANTIC TECHNOLOGY LABORATORY

Mapping cols to concepts

Dataset → dataset
Location → lat, lon
France → Country
date → date
unit → unit of measure
substance …
value …
less than …

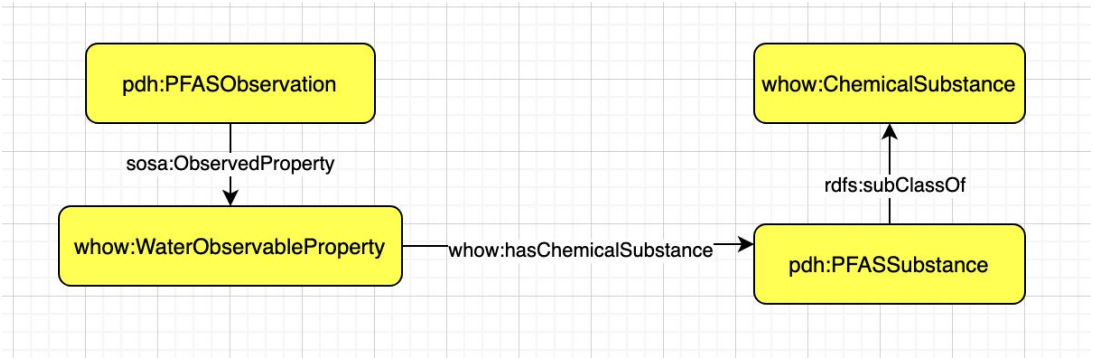
The diagram

draw.io: https://app.diagrams.net/
yEd: https://www.yworks.com/products/yed

Use the Graffoo notation

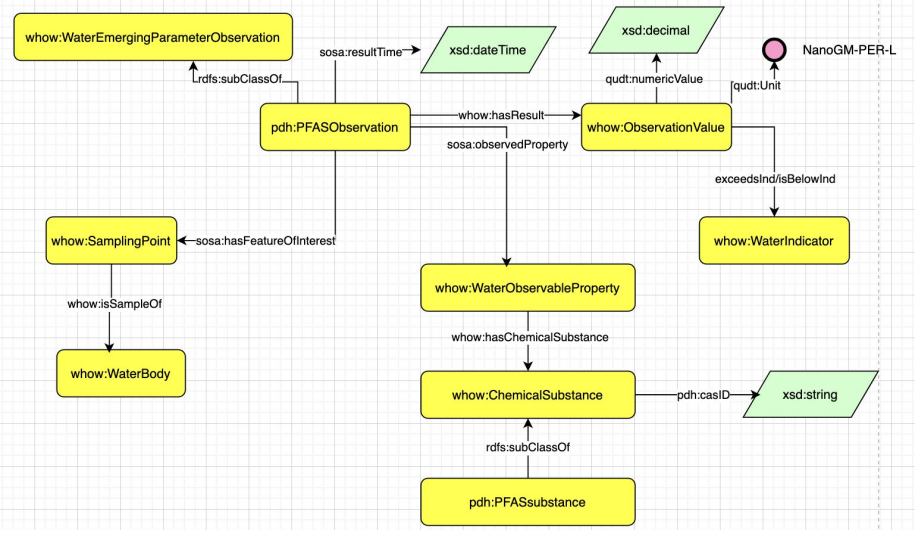
https://github.com/luigi-asprino/Graffoo4DrawIO

But also: example of modelling pattern



A `pdh:PFASObservation` observes the **concentration of a PFAS chemical substance in water** as a `whow-wm:WaterObservableProperty`, which is linked to the actual chemical, such as PFOA or PFOS, via `whow-wm:hasChemicalSubstance`.

The resulting module (Protégé)



STLAB
SEMANTIC TECHNOLOGY LABORATORY

Did it answer the CQs?

CQ1 ✅ — What PFAS substances were detected at a given location?

```
SELECT ?substance ?label WHERE {
  ?obs sosa:hasFeatureOfInterest site:tyrifjorden_S1 ;
       sosa:observedProperty ?prop .
  ?prop whow-wm:hasChemicalSubstance ?substance .
  ?substance rdfs:label ?label .
}
```

STLAB
SEMANTIC TECHNOLOGY LABORATORY

Did it answer the CQs?

CQ2 ✅ — What is the concentration of a given substance at a given sampling point, and in what unit?

```
SELECT ?value ?unit WHERE {
  ?obs sosa:hasFeatureOfInterest site:miteni_GW1 ;
       sosa:observedProperty ?prop ;
       whow-wm:hasResult ?result .
  ?prop whow-wm:hasChemicalSubstance substance:PFHxA .
  ?result qudt:numericValue ?value ;
          qudt:unit ?unit .
}
```

STLAB
SEMANTIC TECHNOLOGY LABORATORY

Did it answer the CQs?

CQ3 ✅ — When was a given observation made?

```
SELECT ?time WHERE {
  obs:france_ades_001 sosa:resultTime ?time .
}
```

Did it answer the CQs?

CQ4 ✅ — Which water body does a sampling point belong to?

```
SELECT ?wb ?label WHERE {
  site:tyrifjorden_S1 whow-wm:isSamplingPointOf ?wb .
  ?wb rdfs:label ?label .
}
```

STLAB
SEMANTIC TECHNOLOGY LABORATORY

Takeaway

CQs are used both for elicitation and for testing → their formulation is fundamental

We can reuse existing material and work in modules that we can combine for an ontology network → never reinvent the wheel if not necessary :)

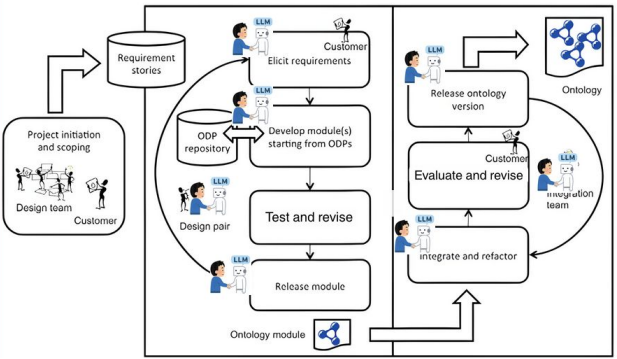
Collaboration is key (and we need consensus)

Tools are helpful!

STLAB
SEMANTIC TECHNOLOGY LABORATORY

Takeaway (ii) – challenges and open problems

- The ODP catalogue is limited and is still evolving
- Reuse requires expertise
- Still, resource consuming: What about LLMs?

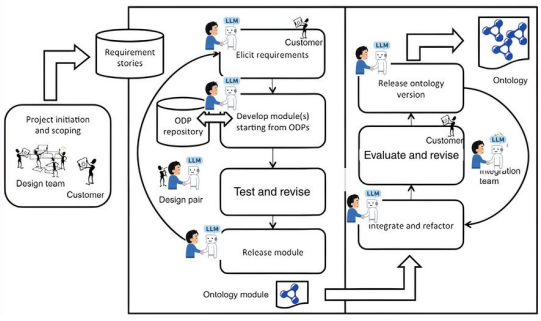


STLAB
SEMANTIC TECHNOLOGY LABORATORY

LLMs for KE

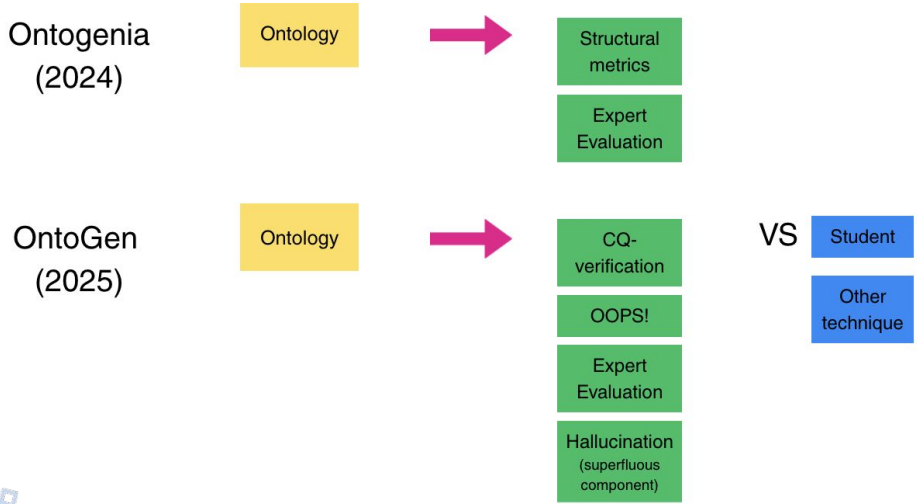
Many studies on ontology generation (&co)! From our side:

- Lippolis et al. 2024 → pilot generation with patterns
- Lippolis et al. 2025 → comparative generation on a wider dataset
- Lippolis et al. 2025b → domain-specific generation with reasoning models



The general idea is to automate the whole XD workflow. But it's challenging

LLMs for KE – evaluation



STLAB
SEMANTIC TECHNOLOGY LABORATORY

LLMs for KE (key points)

- Lack of dedicated datasets
- If data is available, data leakage risks
- Reproducibility? (see Saeedizade et al. 2025)
- Evaluation metrics? → as multidimensional as possible
- Conclusions: LLMs produce decent *drafts*, but this is not enough:
  - logical and structural issues
  - flawed when human-made requirements are flawed (propagation)
  - less comprehensive
  - less coverage (+ unnecessary, duplicate elements…)
  - no consensus (?)
  - Assistants? Automation? Human in the loop (who and how)?

Suggestions

- Reuse
- Document
- Careful with LLMs

WHOW project:
https://github.com/whow-project

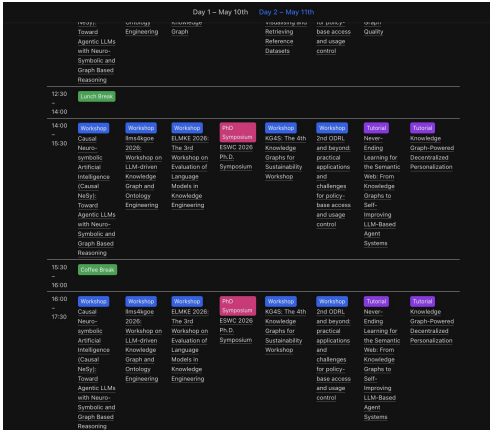
Contact us

annasofia.lippolis@istc.cnr.it
andreagiovanni.nuzzolese@istc.cnr.it

STLAB
SEMANTIC TECHNOLOGY LABORATORY

Self promo :)

If interested in evaluation, come check out our EMLKE workshop on the evaluation of Language Models and our paper in the main conference!



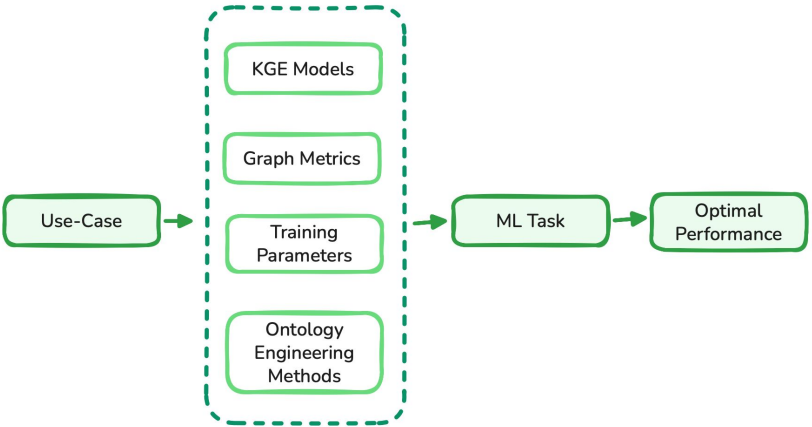
Session 4C: Ontology Engineering (II)

Resource

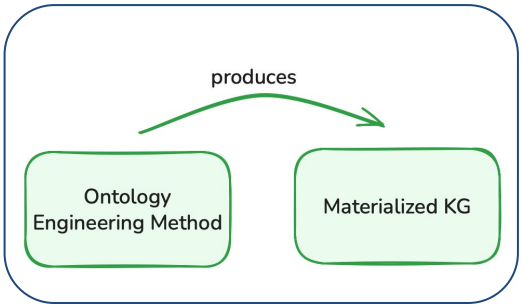
Bench4KE: Benchmarking Automated Competency Question Generation

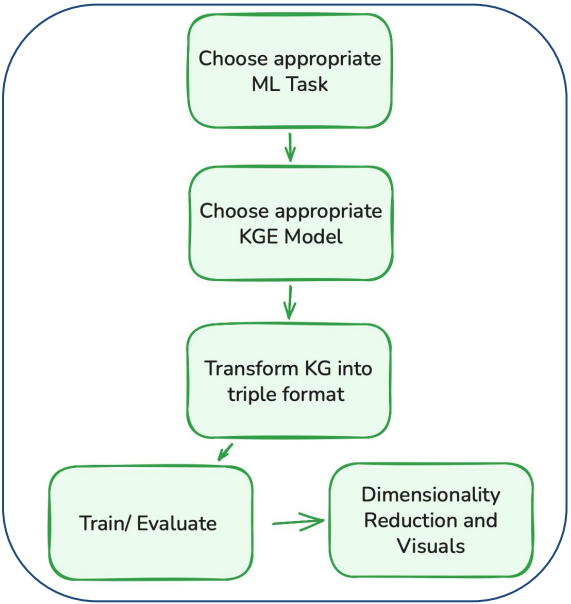
Anna Sofia Lippolis, Minh Davide Ragagni, Paolo Ciancarini, Andrea Giovanni Nuzzolese and Valentina Presutti

Ontology Engineering and KGEs



Ontology Engineering and KGEs





Ontology Engineering and KGEs

LOT

Resulting ttl

```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix owl: <http://www.w3.org/2002/07/owl#> .
@prefix ns: <https://w3id.org/def/sddm#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix foaf: <http://xmlns.com/foaf/0.1/> .

<http://sddm.org/resource/Sample/39173PIXELLEANDROSCOGGINJAYLANDFILL> a ns:Sample .
<http://sddm.org/resource/Site/PIXELLEANDROSCOGGINJAYLANDFILL> a ns:Site;
ns:name "PIXELLE ANDROSCOGGIN JAY LANDFILL" .
<http://sddm.org/resource/City/JAY> a ns:City;
ns:name "JAY" .
<http://sddm.org/resource/Site/PIXELLEANDROSCOGGINJAYLANDFILL> ns:locatedWithin <http://sddm.
org/resource/City/JAY> .
<http://sddm.org/resource/Sample/39173PIXELLEANDROSCOGGINJAYLANDFILL> ns:takenAtSite <http://
sddm.org/resource/Site/PIXELLEANDROSCOGGINJAYLANDFILL> .
<http://sddm.org/resource/Result/39173HFPO-DA_A> a ns:Result;
ns:hasLabQualifier <http://sddm.org/resource/LabQualifier/U>;
<https://saref.etsi.org/core/observes> <http://sddm.org/resource/Parameter/HFPO-DA_A>;
<https://saref.etsi.org/core/isMeasuredIn> <http://sddm.org/resource/UnitOfMeasure/ng/L> .
<http://sddm.org/resource/Sample/39173PIXELLEANDROSCOGGINJAYLANDFILL> ns:includesMeasurement
<http://sddm.org/resource/Result/39173HFPO-DA_A>;
ns:samplePointSequence "39173";
ns:date "2021-12-30T12:40+01:00"^^<http://www.w3.org/2001/XMLSchema#date>;
a ns:Sample .
```

Ontology Engineering and KGEs

LOT

Triple extraction example

Subject	Predicate	Object
Sample/39173PIXELLEANDROSCOGGINJAYLANDFILL	rdf:type	ns:Sample
Site/PIXELLEANDROSCOGGINJAYLANDFILL	ns:locatedWithin	city/Jay
Sample/39173PIXELLEANDROSCOGGINJAYLANDFILL	ns:takenAtSite	Site/PIXELLEANDROSCOGGINJAYLANDFILL

Ontology Engineering and KGEs

LOT

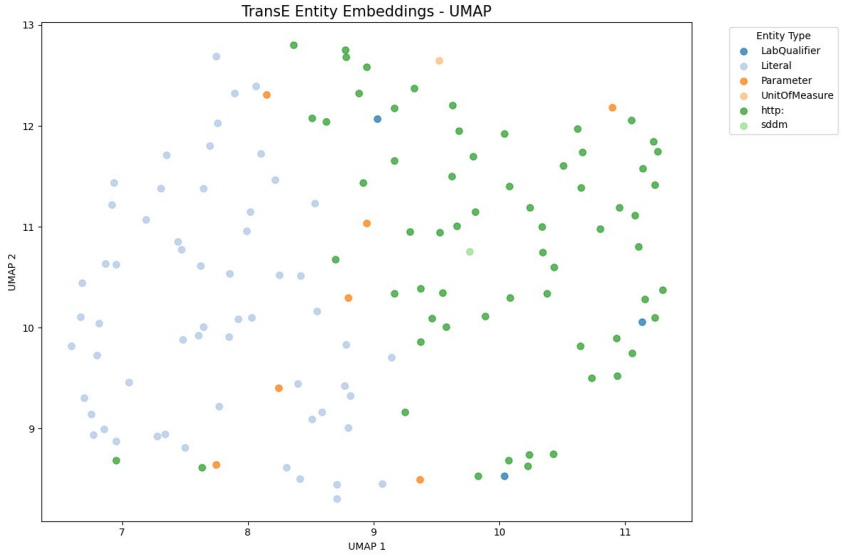
TransE results

Prediction Side	Hits@3	Hits@5	Hits@10
Both	0.536	0.589	0.696
Head	0.250	0.286	0.464
Tail	0.821	0.893	0.929

Ontology Engineering and KGEs

LOT

TransE Visual



ESWC26

THANK YOU FOR THE ATTENTION