

Bridge concepts for domain ontology alignment and data documentation

OntoCommons Ecosystem (OCES)

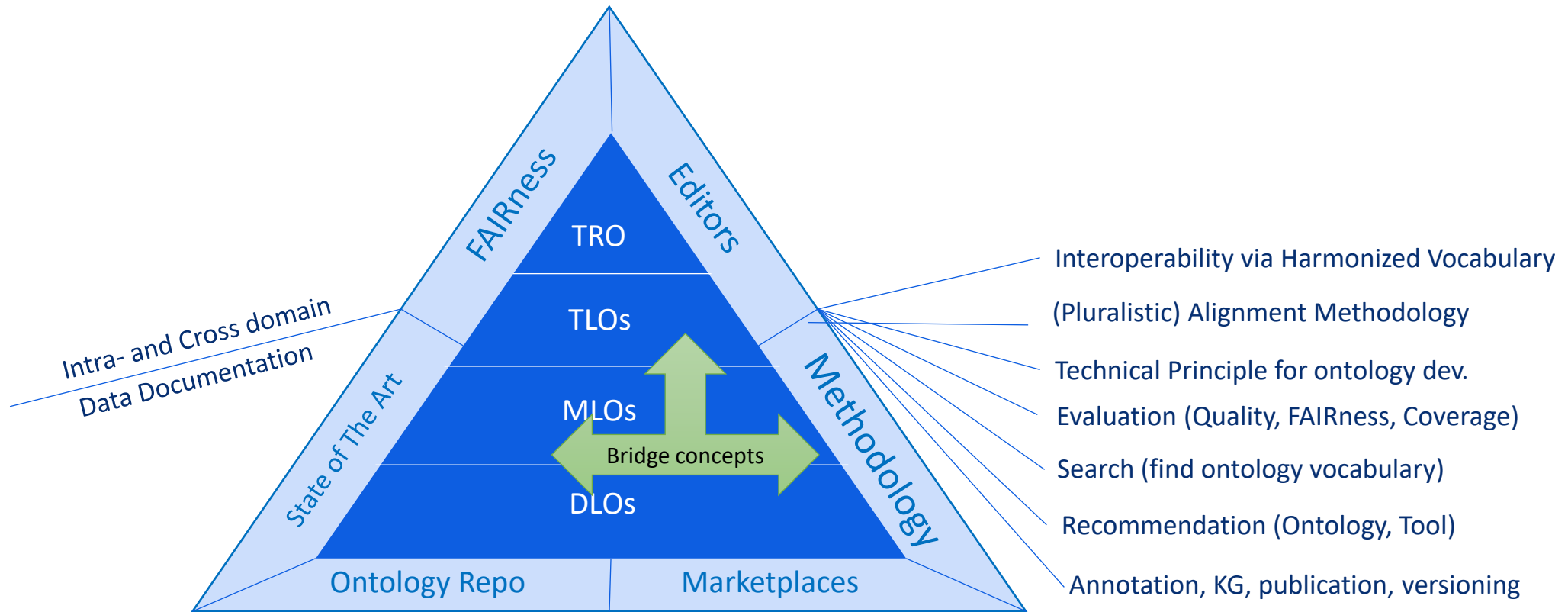
Arkopaul Sarkar (ENIT)

OntoCommons Member and WP3 Lead

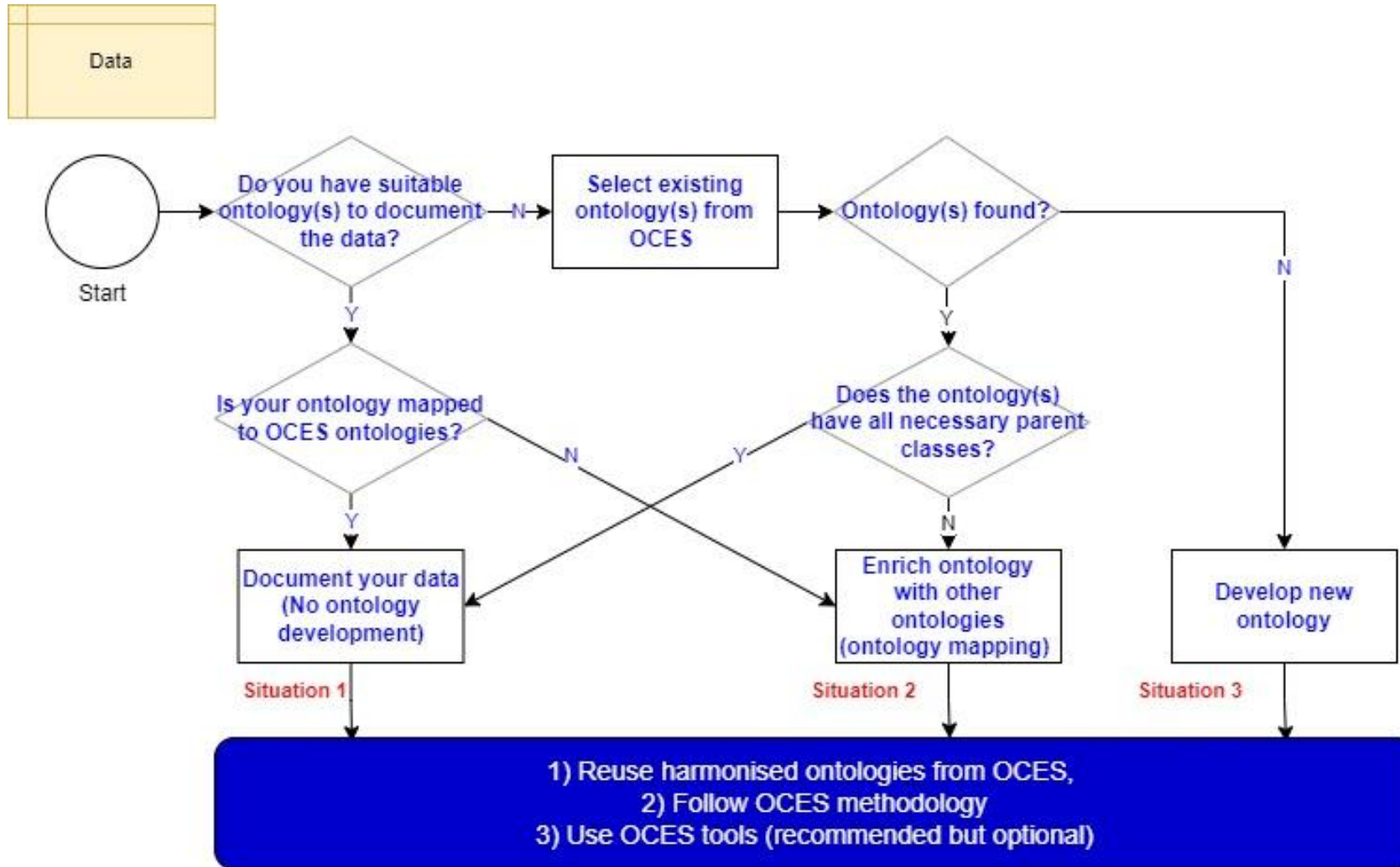


The most tangible outcome – OntoCommons Ecosystem

- OCES is a combination of fully harmonized ontology artifacts (from top to domain) and associated tools and methodologies for building upon existing and creating future ontologies. The complementary components of **OCES therefore provide a complete solution for data documentation in the NMBP domains.**

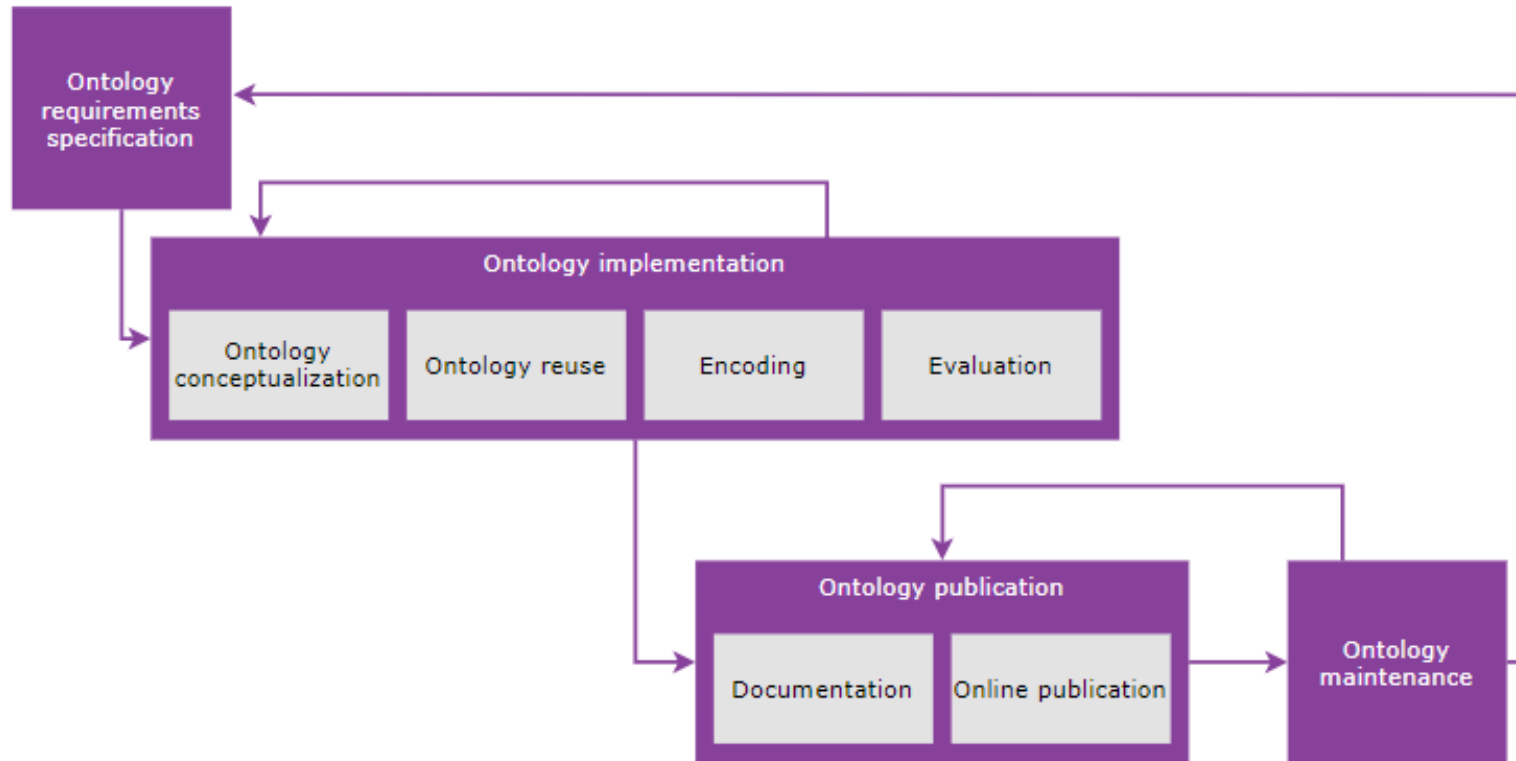


Different needs for data documentation

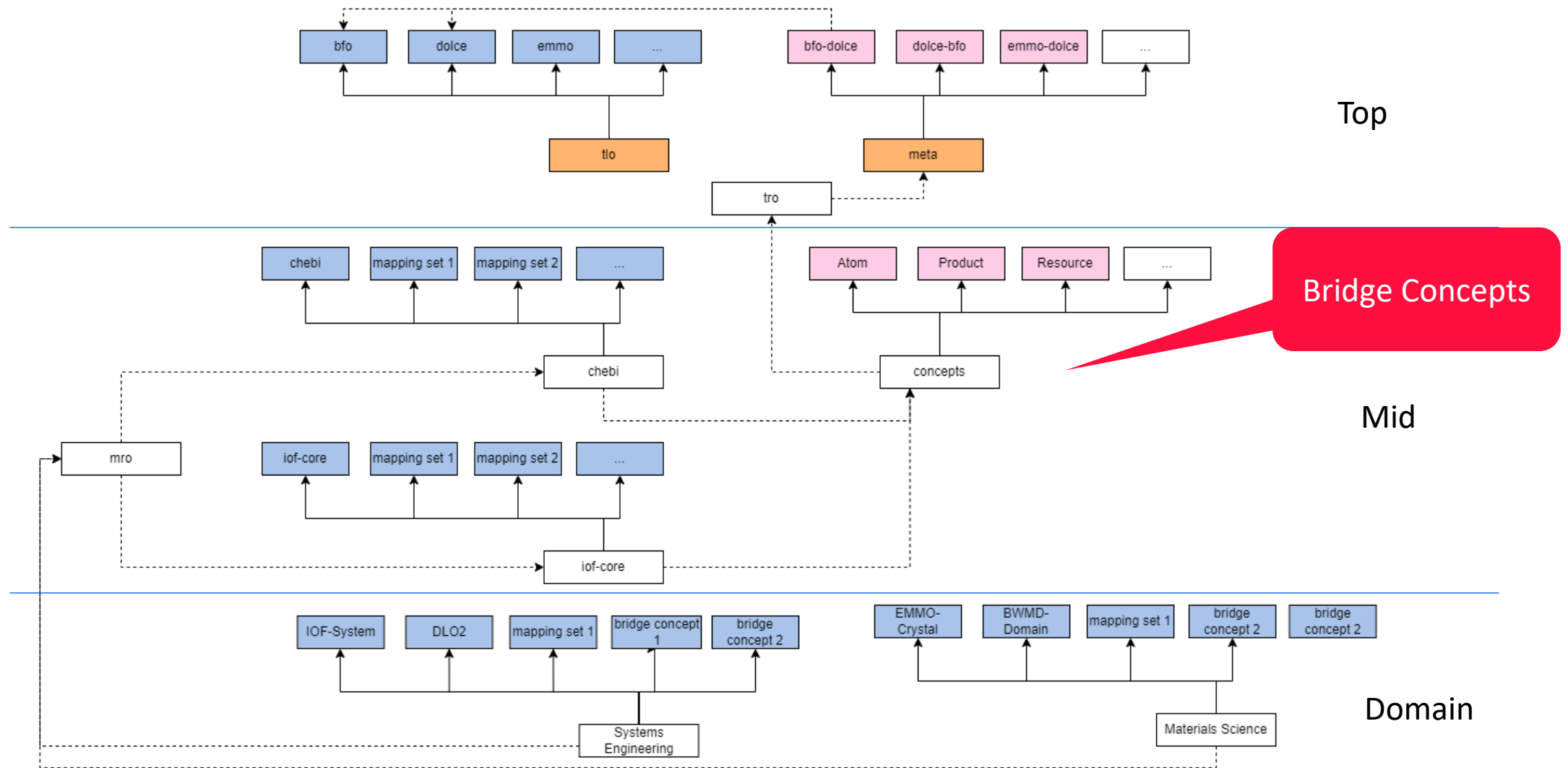


Develop new ontology

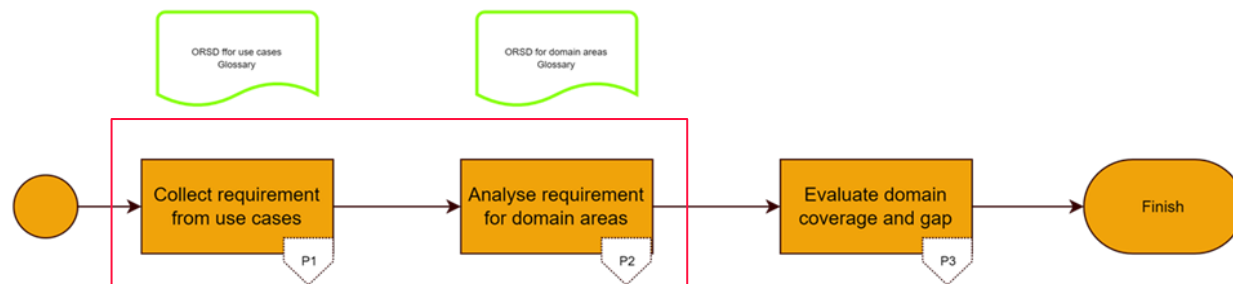
- Follow LOT methodology and Ontology Technical Principle



Reusing Ontology (Import ontology stack)



Ontology Requirement Specification



CQ

Identifier (domain+id)	Sprint	Competency Question / Natural language sentence (fact)	Answer	Status (Proposed, Accepted, Rejected, Pending, Deprecated)
UC1-1	UC interview	What are the types of resource?	Human resource, intangible resource, material resource	Accepted
UC1-2	UC interview	What are the types of manufacturing resource?	Equipment, facilities	Accepted
UC1-3	UC interview	What are the types of equipment?	Drilling adapter, drilling template, measuring equipment, robot, fastener, wedge	Accepted
UC1-4	UC interview	What are the types of materials?	Manufacturing material, raw material, assembly	Accepted
UC1-5	UC interview	What are the components of an assembly?	None.	Accepted
UC1-6	UC interview	What are the types of assembly?	Front fuselage, rear fuselage	Accepted
UC1-7	UC interview	What are the types of part?	Buttstrap, fastener, frame, stabiliser, stringer	Accepted
UC1-8	UC interview	What are the functions for different resources?		Accepted
UC1-9	UC interview	What are the qualities of different resources?		Accepted
UC1-10	UC interview	What are the qualities of different materials?		Accepted
UC1-11	UC interview	What are the qualities of different processes?		Accepted

Terms list

1	Term	Wordnet synonym	UC	CQ	Hyponym (type of)	Meronym (part of)
16	System		1	16,17,18,22,24,30,32		
27						
28	Process	same.	2	1,2,4		
104	InanimatePhysicalObject		3	34		
105						
106	Device	none	6	1,16	logistic terminals, sensors, control system, and traffic routing	
107	Service	none.	6	2,12,13,14,19	site configuration for yard management and logistics on warehouse	
108	Process	same.	6	3,12,13,14,16,19	truck identification, weighting process	
109	Action	activity.	6	4,16,18	open a terminal barrier, display a message in a terminal, inform	
110	Vehicle	none.	6	5,15,21		
111	Material	same.	6	6,7,12,15,21		
112	Agent	none.	6	7,9,10	vehicle driver, access manager, vehicle	
113	Transportation	transit, transfer, fare	6	7,12		
114	Yard	ground	6	8,20		

ORSD

Ontology Requirements Specification Document	
1	Purpose (mandatory) The use case aims to demonstrate: - decreased development time via automatized decision making and improved re-usability, - improved reliability via traceability, - improved communication between product, assembly and industrial system experts via data integration and increased domain knowledge interoperability.
2	Scope (mandatory) Increase the interoperability and improve the communication between aircraft design, assembly design and the industrial system design
3	Implementation Language (optional)
4	Intended End-Users (optional) 1) Knowledge scientist 2) System engineering expert 3) Assembly process engineer 4) Simulation engineer
5	Intended Uses The system is expected to support decision-making during aircraft industrial system design. Some expected benefits include: 1) Predict behavior, explore architectural alternatives early in the development process, and perform trade studies to assess which design choices make the most sense for manufacturing performance. 2) Develop a cognitive twin based on captured domain knowledge, models and simulations. 3) Perform a Business transformation that includes new organizations and new roles to develop the models and to perform manufacturing engineering activities.
6	Ontology Requirements 1. Non-Functional Requirements This use case will be based on the output of a relevant project (QUALITY) pilot. Another objective is to improve the interoperability by aligning the application ontology to the top level ontology or top reference ontology which are expected output of OntoCommons. 1. Functional Requirements: Lists or tables of requirements written as Competency Questions and sentences
7	Pre-Glossary of Terms (optional) 1. Terms from Competency Questions 1. Terms from Answers 1. Objects

Domain coverage analysis

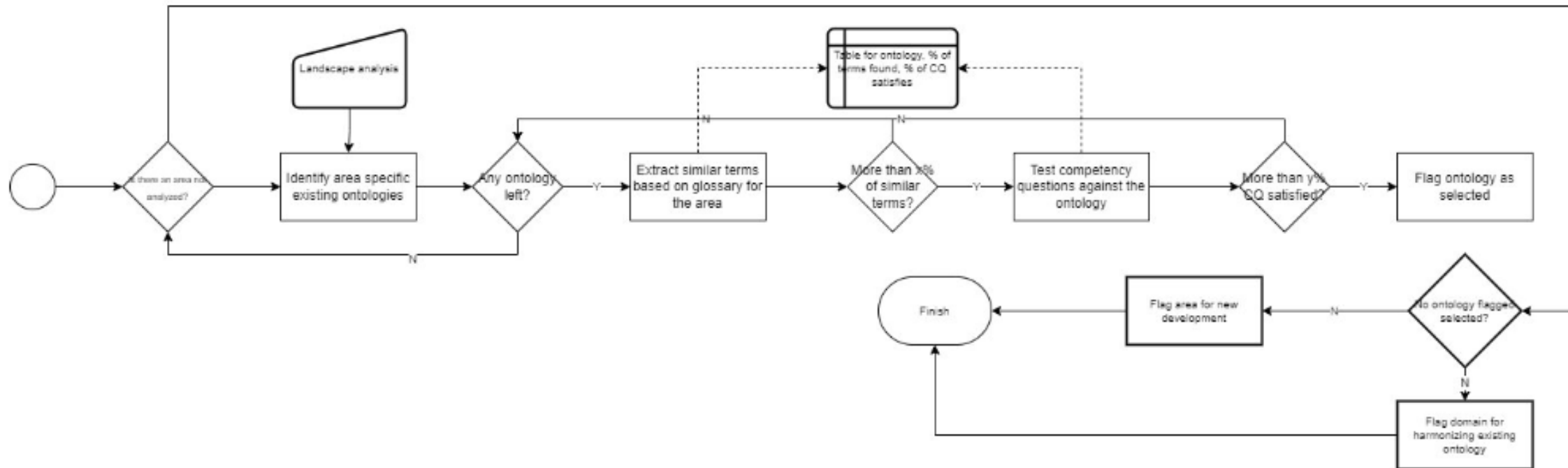


Figure 1 - General workflow of domain coverage analysis

Domain ontology harmonization

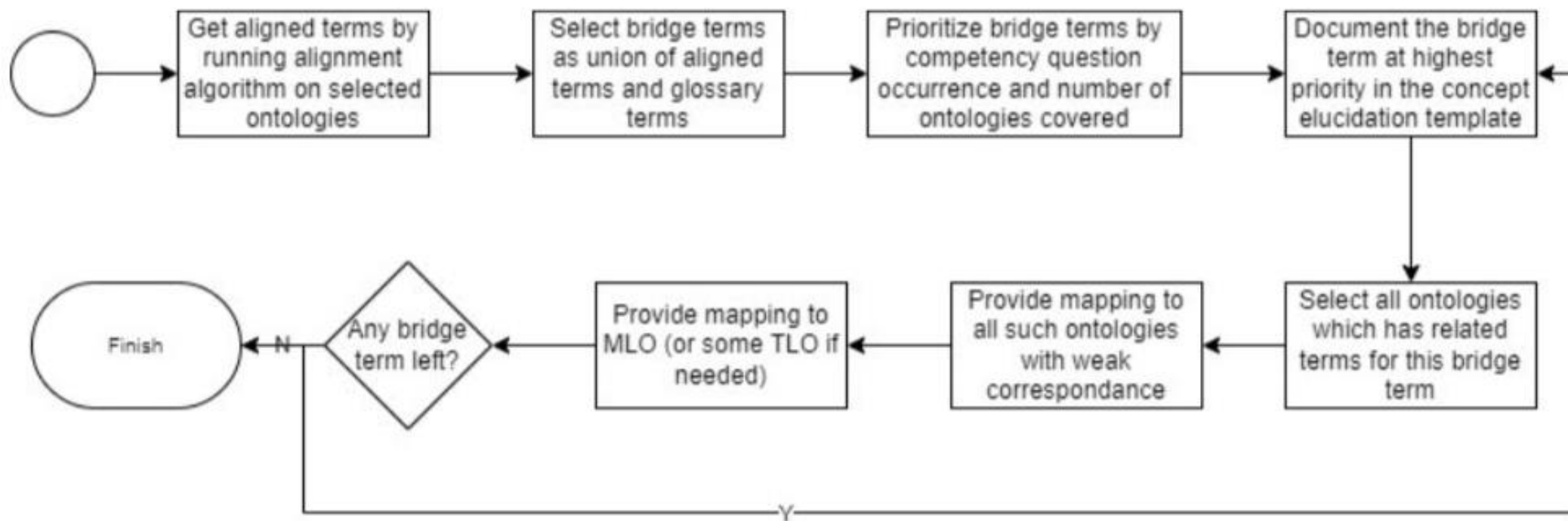


Figure 2 - General workflow of harmonization of domain ontologies

Hands on demonstration

- Assumes basic knowledge of ontology and reasoning.
- Familiarity with Protégé framework.
- The use case used is requires only application-level ontology with some domain reference or mid-level concepts.
- For top-level reference only BFO is used. Considers only IOF-Core and SAREF as reference ontology (they are at mid-level as per OCES stack).
- Multiple top-level scenario is not covered.
- Many other formalities (e.g., annotation, metadata, encoding format) are not covered.

Use case

Use case: Two temperature and one turbidity sensor monitors the water quality of a fish tank. Any turbidity reading more than 200 is considered unsafe.

1	Sensor	TimeStamp	Temperature (C)	Turbidity (NTU)
2	temp-sensor-1 at 30 cm depth	09:22:08	20.03	
3	temp-sensor-1 at 30 cm depth	09:25:38	21.00	
4	temp-sensor-1 at 30 cm depth	09:29:08	20.92	
5	temp-sensor-1 at 30 cm depth	09:32:38	20.40	
6	temp-sensor-1 at 30 cm depth	09:36:08	20.31	
7	temp-sensor-1 at 30 cm depth	09:39:38	21.97	
8	turb-sensor-2 at 30 cm depth	17:31:51		191.52
9	turb-sensor-2 at 30 cm depth	17:35:21		192.24
10	turb-sensor-2 at 30 cm depth	17:38:51		191.45
11	turb-sensor-2 at 30 cm depth	17:42:21		191.19
12	turb-sensor-2 at 30 cm depth	17:45:51		210.13
13	turb-sensor-2 at 30 cm depth	17:49:21		192.78
14	turb-sensor-3 at 60 cm depth	17:31:51		192.43
15	turb-sensor-3 at 60 cm depth	17:35:21		190.46
16	turb-sensor-3 at 60 cm depth	17:38:51		191.86
17	turb-sensor-3 at 60 cm depth	17:42:21		194.70
18	turb-sensor-3 at 60 cm depth	17:45:51		192.68
19	turb-sensor-3 at 60 cm depth	17:49:21		192.56

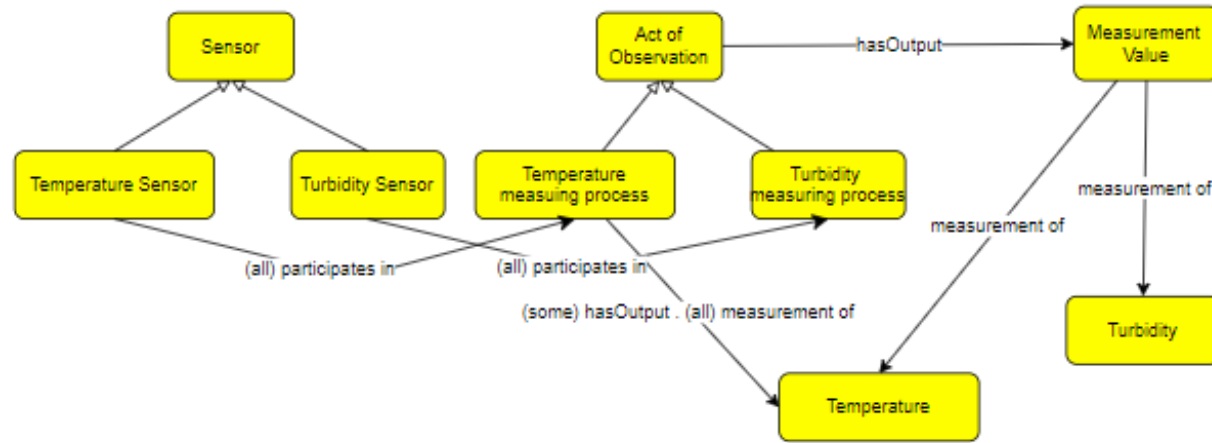
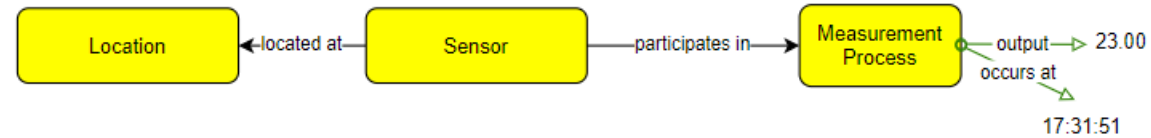
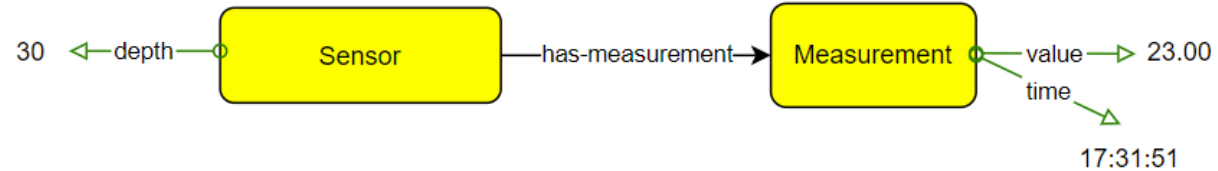
ID	Competency Questions	Answers
1	What are the properties of water being measured?	Temperature, Turbidity
2	How temperature of the water is measured?	By temp-sensor-1
3	Where are the sensors located?	at 30 m and 60 m depth
4	When did the water become unsafe?	at 17:45:51

Terms

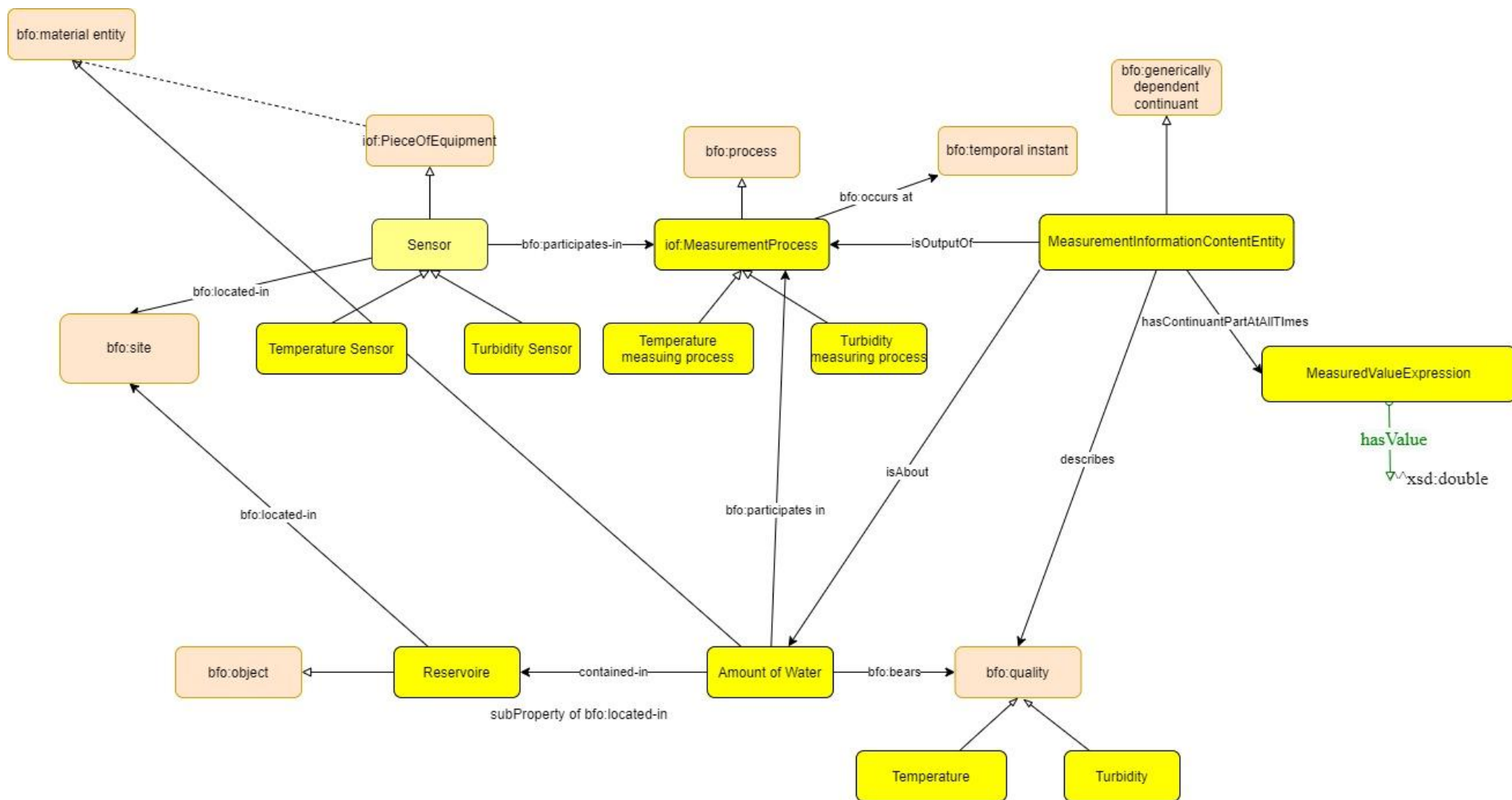
Sensors, Temperature Sensor, Depth, Turbidity, Measurement, Time....

Ontology Conceptualization

- Iterate to improve.
- Ontological thinking!
 - “What is” regression
 - Common sense
 - Foundational patterns from Top level.
- Replace specific relations with generic.
- Apply constraints to relations to derive definition
- Fix ontological commitment!
- Tool: Chowk
(<https://chowk.linkeddata.es/>)



Ontology Conceptualization (cont.)



Browse

Browse the library of ontologies

Showing 28 of 28 Sort: Popular

[Submit New Ontology](#)

Entry Type

☒ Ontology (28)

☐ Ontology View (0)

Uploaded in the Last

Category

☐ Computer Scienc... (3)

☐ Material Science ... (1)

☐ Mechanical and I... (17)

☐ Other (6)

☐ Physics and Che... (0)

☐ Thermal and Pro... (1)

Semantically Integrated Planning Model (SIMPM)

Semantically Integrated Manufacturing Planning Model(SIMPM), an upper-level ontology is a collection of OWL (Ontology Web Language) axioms, which may provide upper level semantics for capturing the knowledge of manufacturing process planning

Uploaded: 12/11/21

classes: 47 FAIR score: 232.75 instances: 3

Industry 4.0 Knowledge Graph (I40KG)

The Industry 4.0 Knowledge Graph, I40KG or previously Standards Ontology (STO), represents standards, standardization organizations and standardization frameworks for the Industry 4.0 area.

Uploaded: 12/1/21

classes: 89 FAIR score: 196 instances: 1,382

Industrial MAintenance Management Ontology (IMAMO)

IMAMO Powerloom and UML class diagram version were developed By Hedi Karray et al in the scope of the European project SMAC at femto-st Institute, University of Franche-Comté.

Uploaded: 12/8/21

classes: 108 FAIR score: 234 instances: 3

SAREF-extension for the industry and manufacturing domain

Last updated: November 29, 2021

[Summary](#)
[Classes](#)
[Properties](#)
[Instances](#)
[Notes](#)
[Mappings](#)
[Widgets](#)

Details

Acronym: SAREF4INMA

Visibility: Public

Description: SAREF4INMA is an extension of SAREF for the industry and manufacturing domain. SAREF4INMA focuses on extending SAREF for the industry and manufacturing domain to solve the lack of interoperability between various types of production equipment that produce items in a factory and, once outside the factory, between different organizations in the value chain to uniquely track back the produced items to the corresponding production equipment, batches, material and precise time in which they were manufactured. SAREF4INMA is specified and published by ETSI in the TS 103 410-5 associated to this ontology file. SAREF4INMA was created to be aligned with related initiatives in the smart industry and manufacturing domain in terms of modelling and standardization, such as the Reference Architecture Model for Industry 4.0 (RAMI), which combines several standards used by the various national initiatives in Europe that support digitalization in manufacturing. The full list of use cases, standards and requirements that guided the creation of SAREF4INMA are described in the associated ETSI TR 103 507.

Status: Production

Format: OWL

Contact: Alba Fernandez-Izquierdo, albafernandez@fi.upm.es

Categories: Mechanical and Industrial Engineering

Additional Metadata

Deprecated: false

Endorsed By: ETSI (<https://www.etsi.org/>)

Example Identifier: <https://saref.etsi.org/saref4inma/ActualMeasurement>

Funded By: ETSI (<https://www.etsi.org/>)

Contributors: Laura Daniele (TNO) Alba Fernandez Izquierdo (Universidad Politécnica de Madrid) Raúl García-Castro (Universidad Politécnica de Madrid) Mike de Rooze (TNO)

Creators: Maria Bouaida-Villalon (Universidad Politécnica de Madrid) Matthias Buntar (TNO)

Links

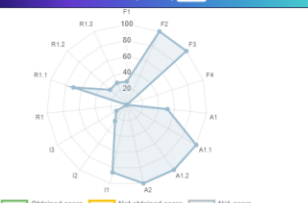
[Go to the REST API JSON entry](#)

Get my metadata back

[N-Tuple](#) [JSON-LD](#) [RDF/XML](#)

FAIR Scores

Total score: 251.13 (52.0%)



[Summary](#)
[Classes](#)
[Properties](#)
[Instances](#)
[Notes](#)
[Mappings](#)
[Widgets](#)

Jump to:

[Capability](#)

[DescriptiveInformationContentEntity](#)

[DirectiveInformationContentEntity](#)

[InformationContentEntity](#)

[ManufacturingMachine](#)

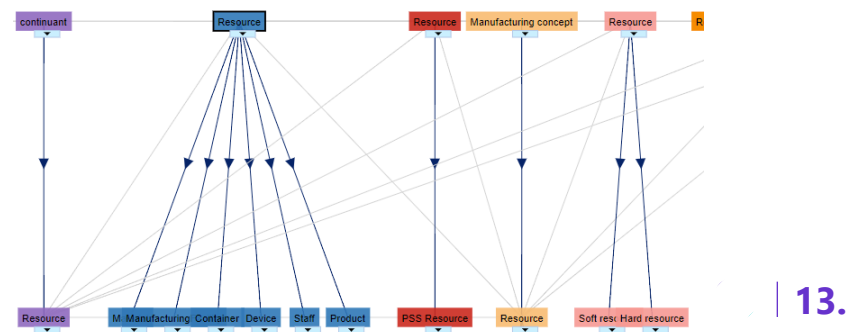
[ManufacturingProcess](#)

[ManufacturingTool](#)

Internal mappings

MAPPING TO	ONTOLOGY
capability	Manufacturing Service Description Language
Capability	ManuService
Capability	Reference Generalized Ontological model

[Create New Mapping](#) [Create New External Mapping](#)



Ontology Recommender

Get recommendations for the most relevant ontologies based on an excerpt from a biomedical text or a list of keywords

What is the **function** or **capability** of **equipment**?

Recommended ontologies

POS.	ONTOLOGY	FINAL SCORE	COVERAGE SCORE	ACCEPTANCE SCORE	DETAIL SCORE	SPECIALIZATION SCORE
1	MSDL	73.3	100.0	0.0	33.3	88.9
2	IOF-CORE	58.0	66.7	0.0	57.5	84.9
3	SIMPM	40.4	33.3	0.0	47.1	100.0
4	GRACE	34.0	33.3	0.0	41.2	63.2

Download Ontology with Mappings (Under Development)

IOF Core
Last uploaded: Jan 1, 2022

Summary | Classes | Properties | Instances | Notes | Mappings | Widgets

Details

Id: iof-core
Visibility: Public

Metadata Vocabulary Used: local:local

Natural Language: 

Release Date: 2022-05-06T00:00:00+00:00

Use Imports: local:local

Used Ontology Engineering Tool: <http://protege.stanford.edu>

Version: Version 1 Beta - 2022-05-06

Submissions  

Version	Released 	Modified 	Uploaded 	Downloads
Version 1 Beta - 2022-05-06 <small>(Period, Instance, Instance, Annotation)</small>	05/06/2022		06/01/2022	OWL CSV RDF/XML

local:local

Projects using IOF-CORE 

No projects using IOF-CORE

[Edit Ontology](#)

☐ With Mappings 

Mapping Settings

Context name 

includes intermediates 

Specific to OCES context

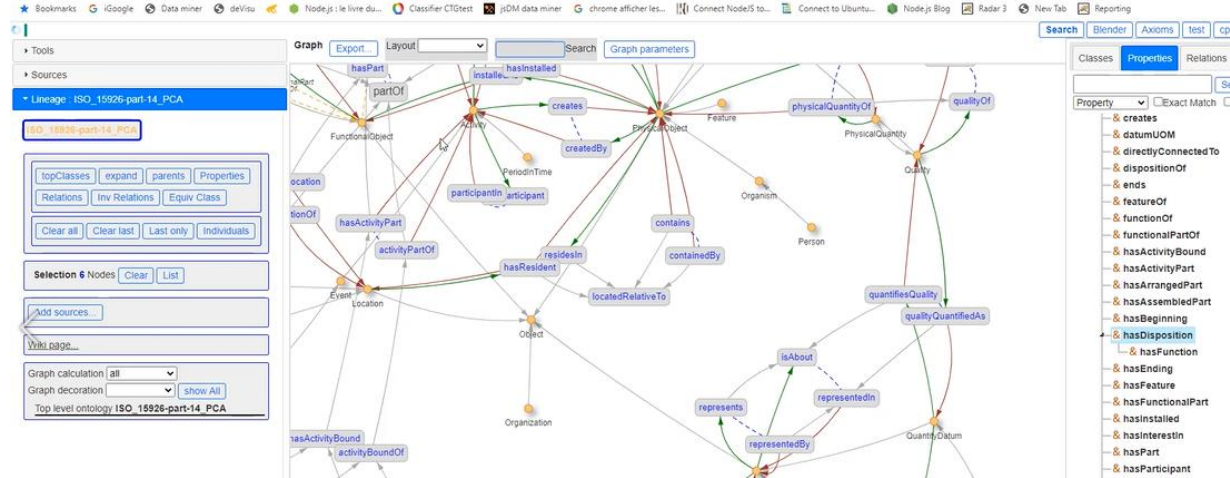
☐ BFO

☐ DOLCE

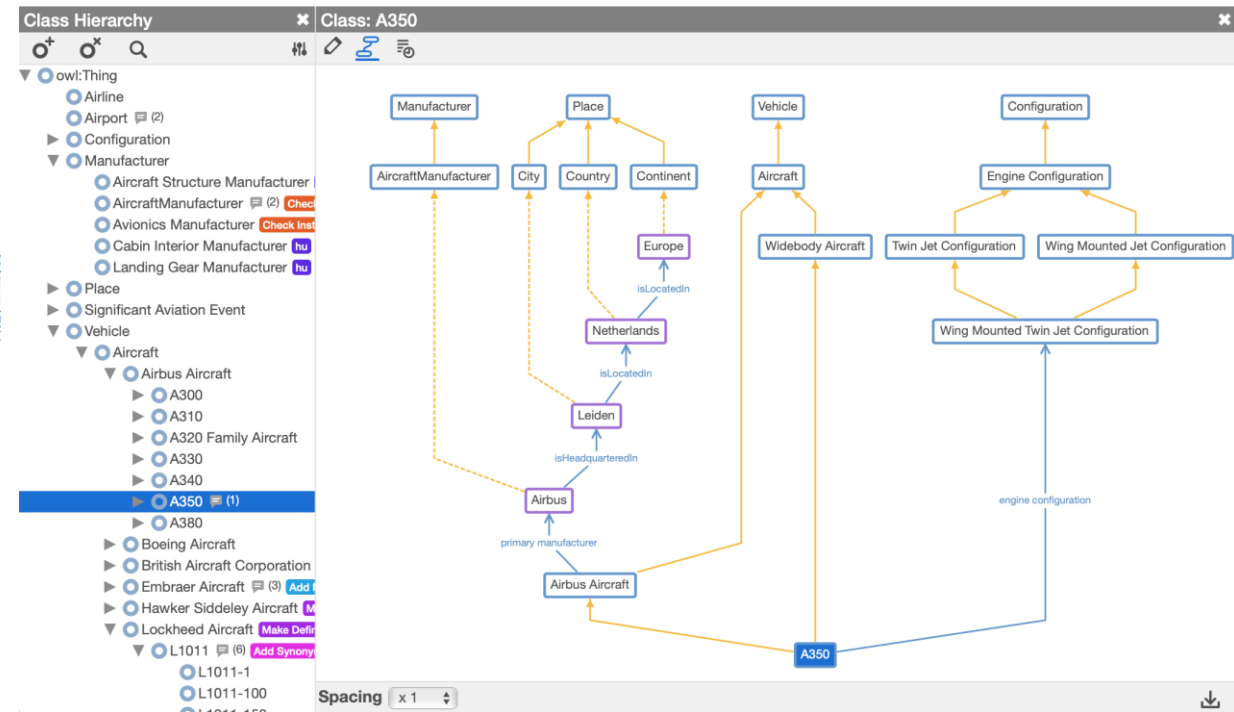
☐ EMMO

Ontology Encoding

- Two primary editors (completely free, natively hosted) are recommended.
- Currently being integrated to the ecosystem platform (IndustryPortal)



SousLeSens



OCEAN (Web-Protégé) collaborative development

Ontology Encoding (OCES Technical Principle)

- IRI Convention
 - OCIRI Grammar (based on RFC3987) –separate for TLO, MLO, DLO
 - Permanent host resolver (purl, w3id, doi, ARK)
 - Opaque identifier Scheme

A class 'Plastic' in a domain ontology called 'plastonto'

<http://purl.ontocommons.eu/ontology/dlo/srao-0000211/plastonto#oxcy4f>

- Metadata Convention
 - Common set of annotation properties for
 - Ontology metadata, Term metadata, Mapping metadata (SSSOM)
 - Based on MOD, OMV, DC, IOF-av, EMMO-av, FIBO-av

Ontology Encoding (OCES Technical Principle) cont...

- Language and expressivity
- Reasoner and prover
- Serialisation format
- Versioning scheme
- Development management and issue tracking

Annotating terms

SummaryClassesPropertiesInstancesNotesMappingsWidgets

Jump to:

entity

continuant

generically dependent continuant

independent continuant

immaterial entity

material entity

specifically dependent continuant

occurrent

event

process

history

planned process

business process

computing process

manufacturing process

material location change process

measurement process

state

process boundary

process characteristic

spatiotemporal region

temporal region

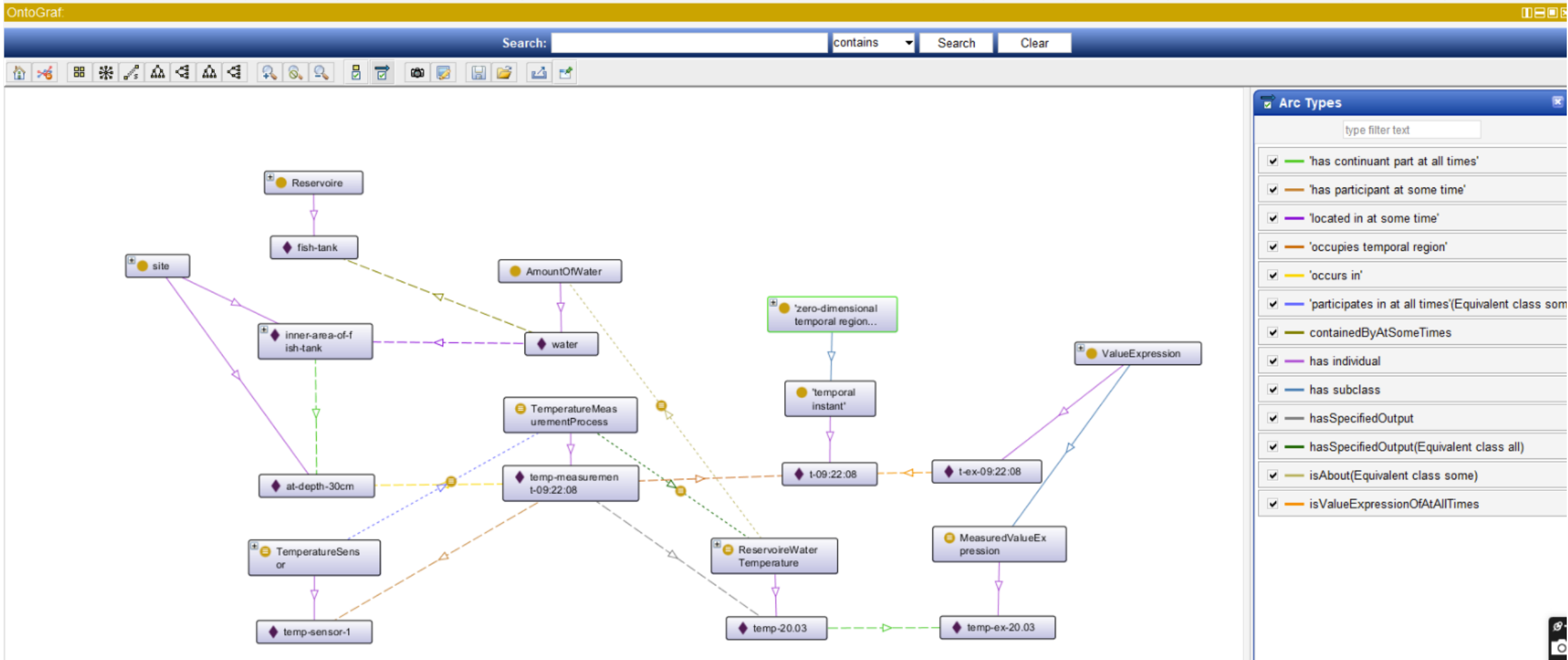
DetailsInstances (0)VisualizationNotes (0)Class Mappings (3)Access Class JSON

Preferred Name	manufacturing process
Definitions	<p>planned process that consists of a structured set of operations through which input material is transformed or modified into another material entity Manufacturing Process x implies x is a Planned Process that 'has input' some 'material entity' m and 'has specified output' y which is a Material Artifact or a 'material entity' that is 'prescribes by' some Design Specification d and x 'has participant at some time' some Machine or Person z that is the 'carrier of' some Plan Specification p that prescribes x $\text{ManufacturingProcess}(x) \rightarrow \text{PlannedProcess}(x) \wedge \exists m, \exists y, \exists p, \exists z (\text{MaterialEntity}(m) \wedge (\text{MaterialArtifact}(y) \vee \exists d (\text{MaterialEntity}(y) \wedge \text{DesignSpecification}(d) \wedge \text{prescribes}(d, y)) \wedge \text{PlanSpecification}(p) \wedge \text{prescribes}(p, x) \wedge (\text{Person}(z) \vee \text{Machine}(z)) \wedge \text{isCarrierOf}(z, p) \wedge \text{participatesInAtSomeTime}(z, x) \wedge \text{isInputOf}(m, x) \wedge \text{hasSpecifiedOutput}(x, y))$ 1. Structured set of activities or operations performed upon material to convert it from the raw material or a semfinished state to a state of further completion. [ISO 15531-1, ISO 15531-43:2006(en)] 2. Series of operations performed on material to convert it from a raw material or a semfinished state to a state of further completion. Manufacturing processes can be arranged in a process layout, product layout, cellular layout, or fixed-position layout. Manufacturing processes can be planned to support make-to-stock, make-to-order, assemble-to-order, and so forth, based on the strategic use and placement of inventories [APICS & ISO 15531-43]. 1. This definition presupposes that the outputs of a manufacturing process are in every case material artifacts or man-made substances. 2. Processes that have as their primary output, something immaterial or informational in nature (digital outputs), such as found in the production of software, will be considered separately at a later stage. 3.. There are other processes that while they may come into direct contact with a manufactured component or substance and are often considered part of the overall set of activities planned and executed to manufacture something, they are not "transformative" in nature relative to that which is manufactured, and are specifically excluded the definition. Examples include setup, tear down, transporting components or materials between locations, inspection, and so forth. This is addressed by output in the axiom. Setup => does not have output. Tear down like disassembly should still be considered transformative. 4. This definition places no additional restrictions on the output of a manufacturing process in terms of being in a state of completion (completed component or finished good).</p>
ID	https://purl.industrialontologies.org/ontology/core/Core/ManufacturingProcess
comment	<p>1. This definition presupposes that the outputs of a manufacturing process are in every case material artifacts or man-made substances. 2. Processes that have as their primary output, something immaterial or informational in nature (digital outputs), such as found in the production of software, will be considered separately at a later stage. 3.. There are other processes that while they may come into direct contact with a manufactured component or substance and are often considered part of the overall set of activities planned and executed to manufacture something, they are not "transformative" in nature relative to that which is manufactured, and are specifically excluded the definition. Examples include setup, tear down, transporting components or materials between locations, inspection, and so forth. This is addressed by output in the axiom. Setup => does not have output. Tear down like disassembly should still be considered transformative. 4. This definition places no additional restrictions on the output of a manufacturing process in terms of being in a state of completion (completed component or finished good).</p>
counter example	statistical process control and preventative maintenance management processes that maximize machine availability and the product quality of manufactured products.
example	Drilling a hole on an engine block; manufacturing operation for making a shaft consisting of milling, turning, and drilling manufacturing processes; assembly process, and quality control process; a manufacturing process that uses 3D printing to create the output material entity.
first order logic definition	$\text{ManufacturingProcess}(x) \rightarrow \text{PlannedProcess}(x) \wedge \exists m, \exists y, \exists p, \exists z (\text{MaterialEntity}(m) \wedge (\text{MaterialArtifact}(y) \vee \exists d (\text{MaterialEntity}(y) \wedge \text{DesignSpecification}(d) \wedge \text{prescribes}(d, y)) \wedge \text{PlanSpecification}(p) \wedge \text{prescribes}(p, x) \wedge (\text{Person}(z) \vee \text{Machine}(z)) \wedge \text{isCarrierOf}(z, p) \wedge \text{participatesInAtSomeTime}(z, x) \wedge \text{isInputOf}(m, x) \wedge \text{hasSpecifiedOutput}(x, y))$
label	manufacturing process
natural language definition	planned process that consists of a structured set of operations through which input material is transformed or modified into another material entity
prefixIRI	iof-core:ManufacturingProcess
prefLabel	manufacturing process
semi-formal natural language definition	Manufacturing Process x implies x is a Planned Process that 'has input' some 'material entity' m and 'has specified output' y which is a Material Artifact or a 'material entity' that is 'prescribes by' some Design Specification d and x 'has participant at some time' some Machine or Person z that is the 'carrier of' some Plan Specification p that prescribes x
subject matter expert explanation	<p>1. Structured set of activities or operations performed upon material to convert it from the raw material or a semfinished state to a state of further completion. [ISO 15531-1, ISO 15531-43:2006(en)] 2. Series of operations performed on material to convert it from a raw material or a semfinished state to a state of further completion. Manufacturing processes can be arranged in a process layout, product layout, cellular layout, or fixed-position layout. Manufacturing processes can be planned to support make-to-stock, make-to-order, assemble-to-order, and so forth, based on the strategic use and placement of inventories [APICS & ISO 15531-43].</p>
URL of	https://purl.industrialontologies.org/ontology/core/Core/PlannedProcess

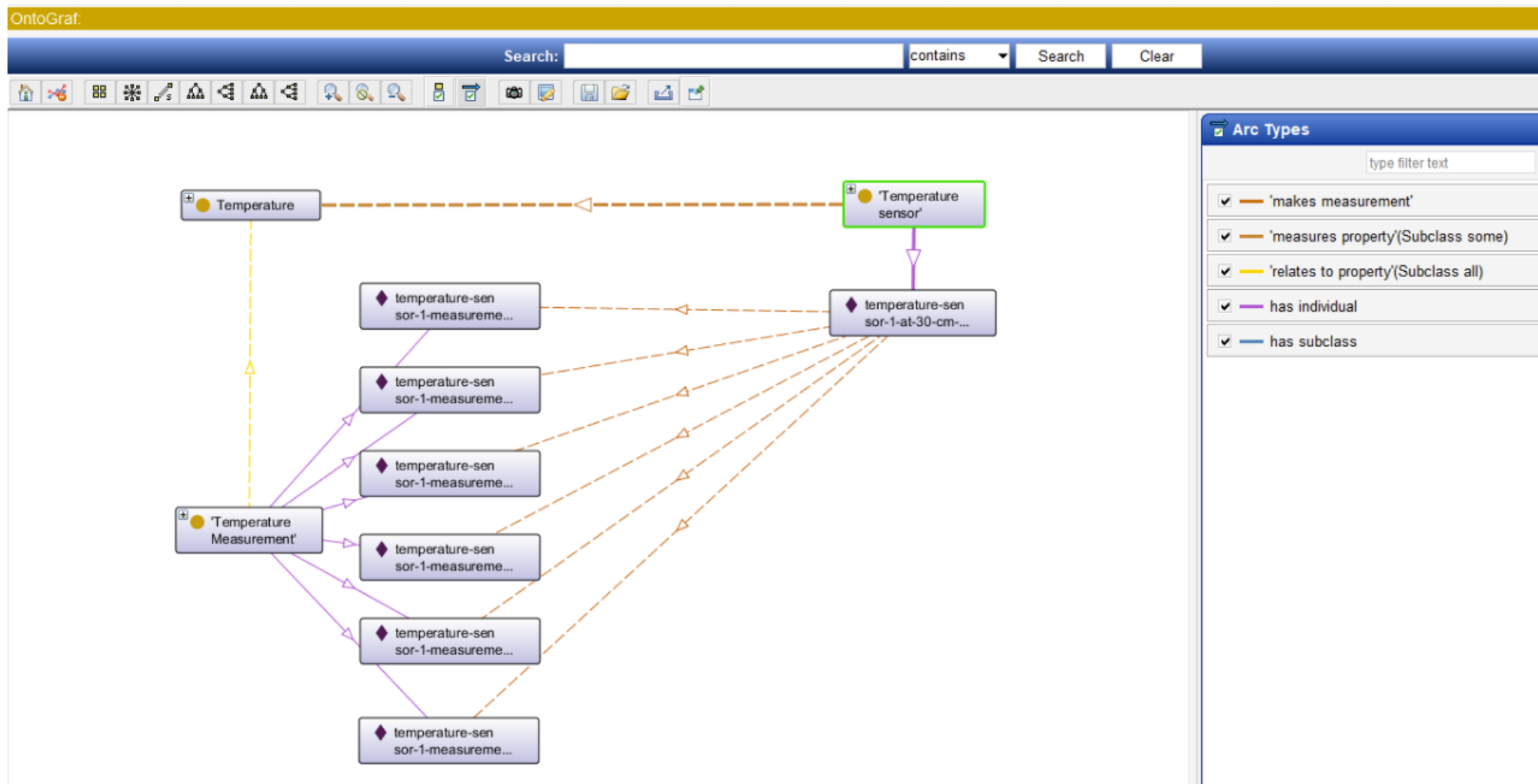
Documenting data with ontology

- — From CSV, Excel, or other flat files
 - — OntoRefine
- — From database (RDBMS)
 - — KGCreator, R2RML, RML, YARRRML
- — From complex structure (JSON, XML)
 - — XSPARQL
- — Generic, customizable
 - — SPARQL, along with Jena, RDFLib, OWLReady, OntoPy

Sensor data modeled in IOF-Core



Sensor data modeled in SAREF

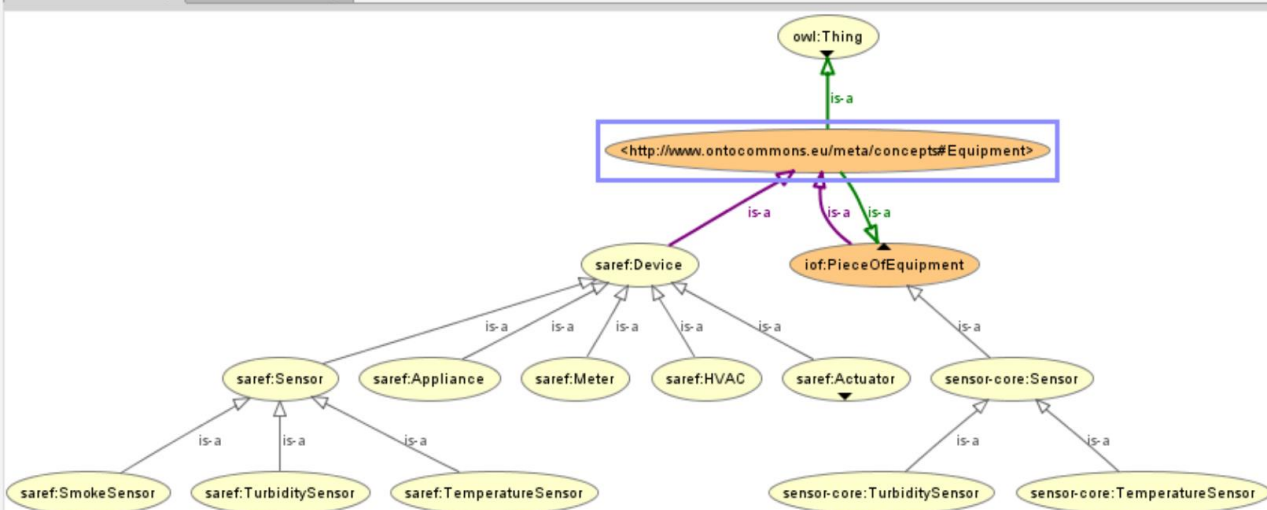


Alignment using bridge concepts

OWLviz: <http://www.ontocommons.eu/meta/concepts#Equipment>



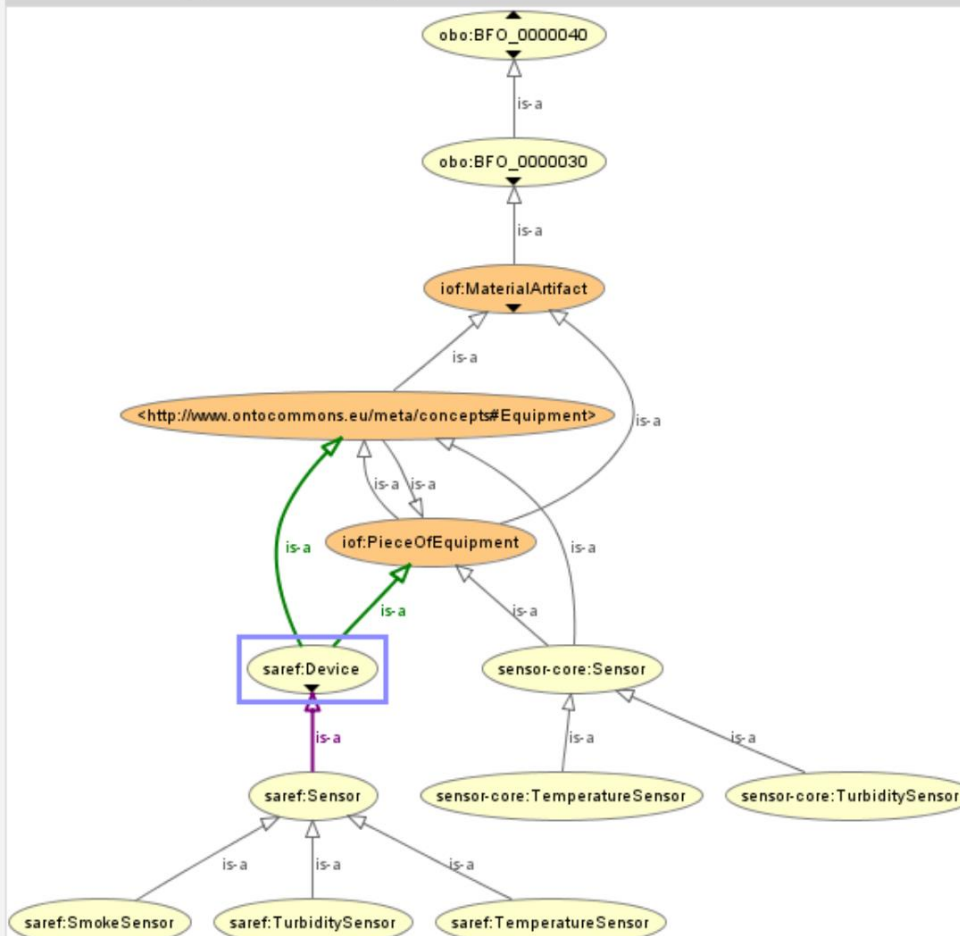
Asserted hierarchy Inferred hierarchy



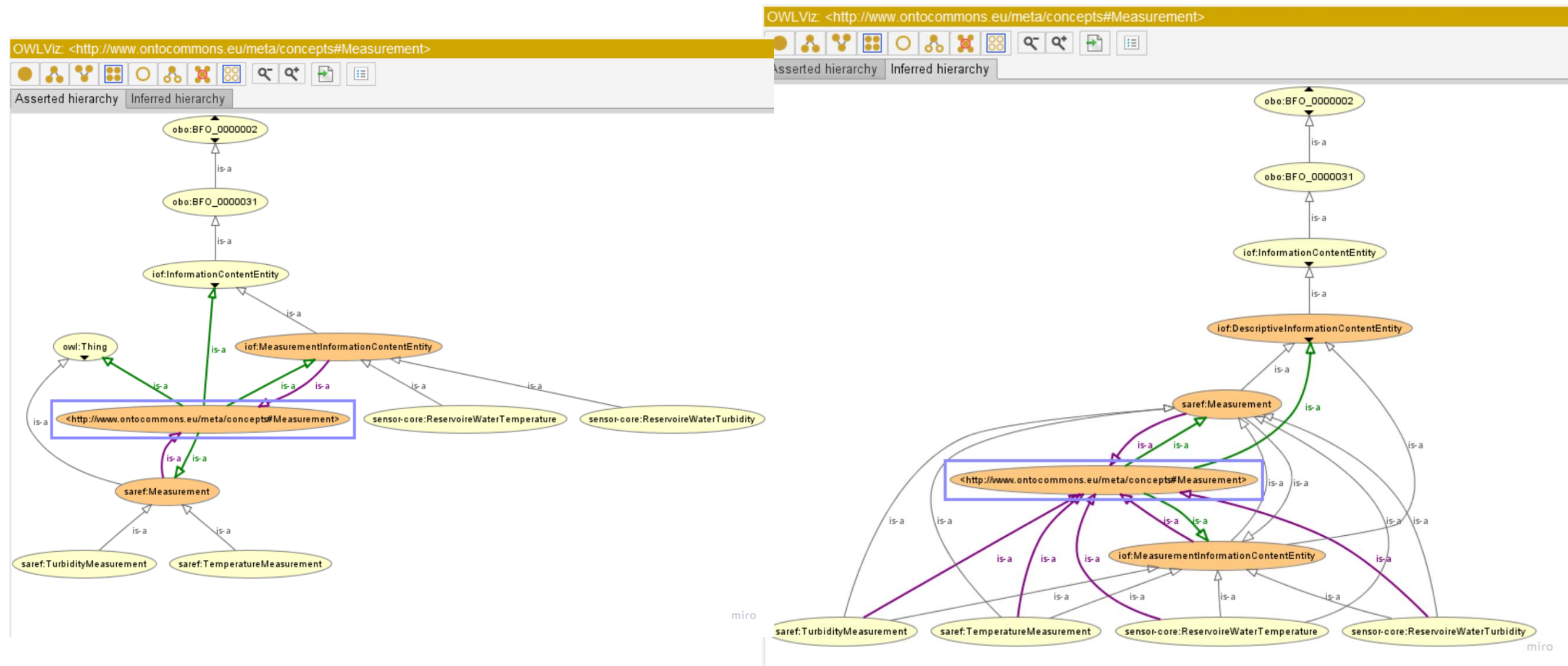
OWLviz: saref:Device



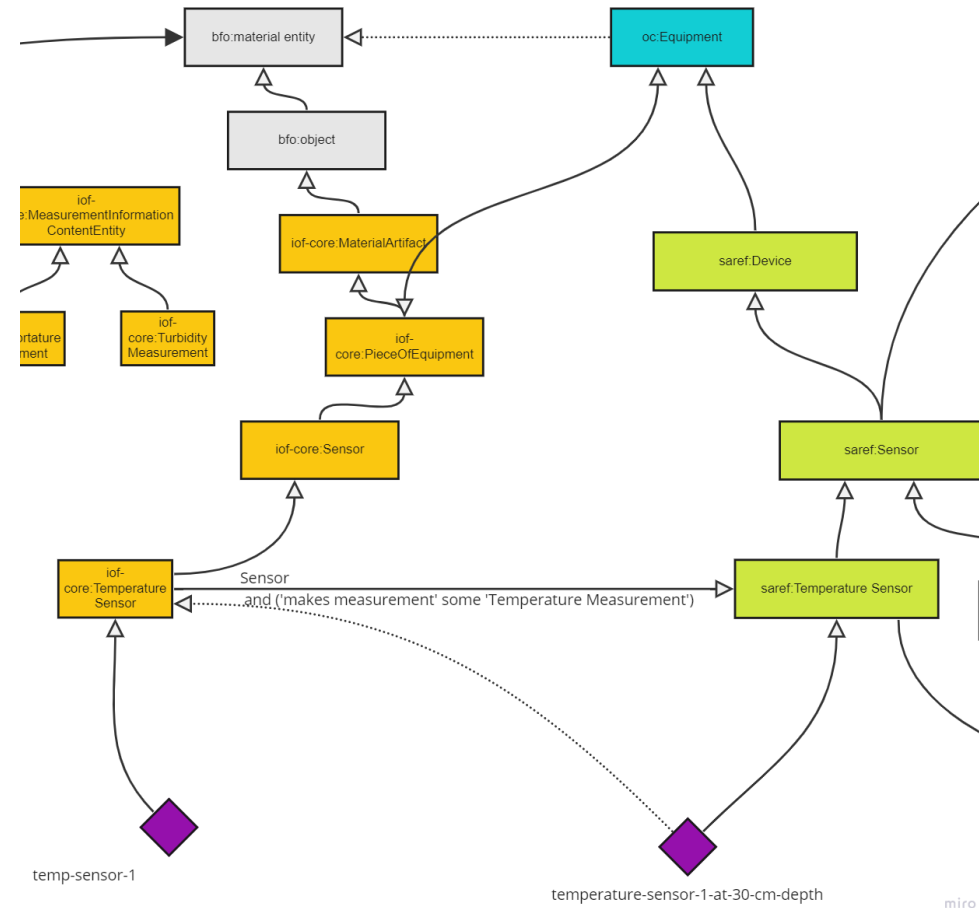
Asserted hierarchy Inferred hierarchy



Alignment using bridge concepts



Data interoperability through ontology alignment



How bridge concept prevents misalignment

Class hierarchy: :TemperatureMeasurement

Annotations: :TemperatureMeasurement

Annotations +

rdfs:label [language: en]
Temperature Measurement

Description: :TemperatureMeasurement

Equivalent To +

iof:MeasurementProcess
and (obo:BFO_0000057 some sensor-core:TemperatureSensor)

SubClass Of +

:Measurement

Help for inconsistent ontologies

Your ontology is inconsistent which means that the OWL reasoner will no longer be able to provide any useful information about the ontology.

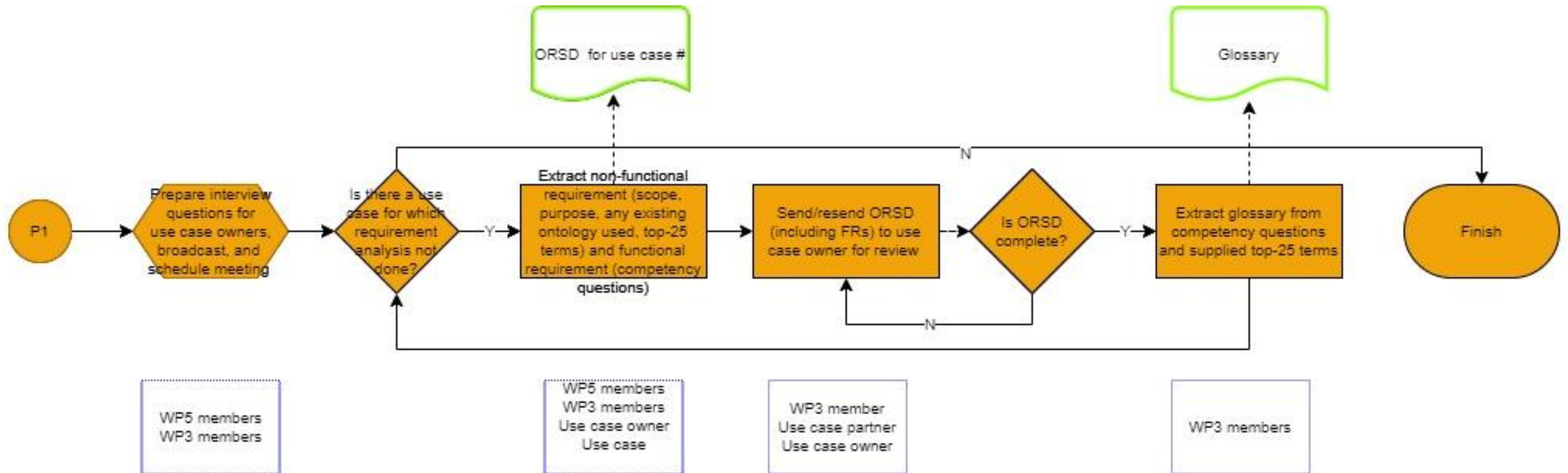
Explanation 1 ☐ Display laconic explanation

Explanation for: owl:Thing SubClassOf owl:Nothing

- 1) continuant DisjointWith occurrent
- 2) process SubClassOf occurrent
- 3) 'Temperature Measurement' EquivalentTo MeasurementProcess and ('has participant at some time' some TemperatureSensor)
- 4) temperature-sensor-1-measurement-2 Type 'Temperature Measurement'
- 5) 'participates in at some time' InverseOf 'has participant at some time'
- 6) Measurement EquivalentTo MeasurementInformationContentEntity
- 7) 'generically dependent continuant' SubClassOf continuant
- 8) InformationContentEntity SubClassOf 'generically dependent continuant'
- 9) Measurement EquivalentTo Measurement
- 10) 'participates in at some time' Range process
- 11) MeasurementInformationContentEntity SubClassOf InformationContentEntity
- 12) 'Temperature Measurement' SubClassOf Measurement

Requirement Engineering for OntoCommons Industrial Partners

Requirement gathering from partners



ORSD template

	A	B
1		Ontology Requirements Specification Document
2	1	Purpose (mandatory)
3		The primary goal of the use case is to reduce the number and size of, and time required for experiments, for identifying the behaviour of a material or combination of them (e.g., metal, coating, lubricant) with respect to specific operating conditions. The goal is planned to be achieved via better representation of material experiments, enriching existing data with additional background knowledge, easing data retrieval and navigation through related resources.
4	2	Scope (mandatory)
5		The use case will provide ontology-based access to a materials' tribological-related information to abstract from underlying data structures.
6	3	Implementation Language and existing standards and ontologies
7		TribAln ontology (TribAln 2.0), EMMO / EMMC, VAR Ontology
8	4	Intended End-Users
9		Tribological expert, Ontology engineer/Semantic technologies expert, Software developer
10	5	Intended Uses
11		We should be able to have an API to query the information of experiments. The information would be represented with adequate ontology terms, but the API would abstract the end-user from the necessary underlying SPARQL queries.
12	6	Non-Functional Requirements
13		The goal is planned to be achieved via a common representation of material tribological experiments.
14		Enriching existing data with additional background knowledge
15		1. Functional Requirements: Lists or tables of requirements written as Competency Questions and sentences
16		
17	7	Pre-Glossary of Terms (optional)
18		1. Terms from Competency Questions

Sample data/ Testing/ Benchmarking

- How to collect sample data?
 - Confidentiality, Security
 - Ontocommons procedure and policies
- How to publish FAIR data with semantic annotation
- Evaluation and benchmarking



Thanks

Questions?

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