Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

Ontologies and Knowledge Modelling

An Introduction with Examples.

Giacomo Lanza, Maximilian Gruber

Motivation

digitalization of industry

digital metro-
logical services

reuse (scientific) data
in new contexts

machine actionable data

rich metadata

clear meaning of
used concepts

explicit capturing of
expert knowledge

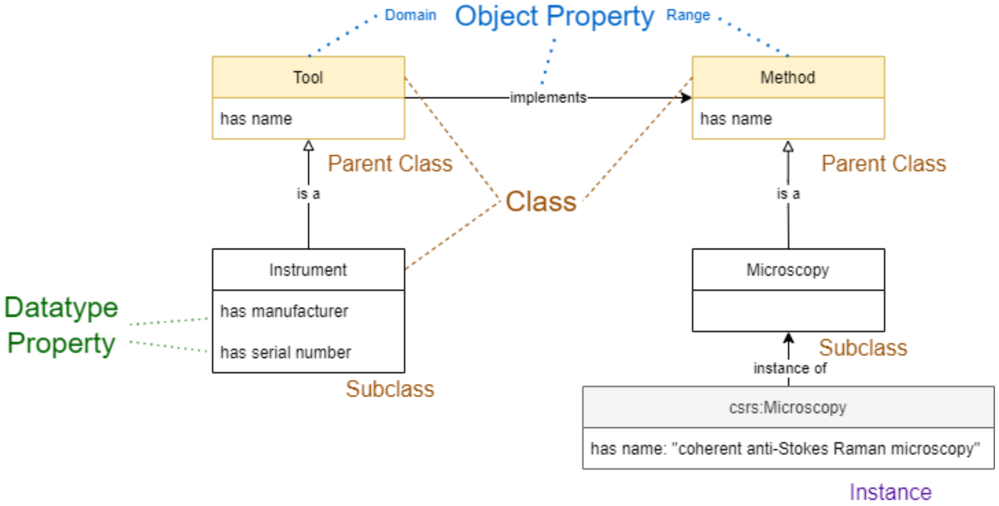
→ Ontologies play an important part in achieving this!

What is an Ontology?

Philosophy

→ Onto▪logy = study of being
What types of entities exist?
How do they relate to one another?

https://plato.stanford.edu/entries/logic-ontology/#DiffConcOnto



Semantic Web

W3C RDF

W3C OWL

Triples:
subject+predicate+object

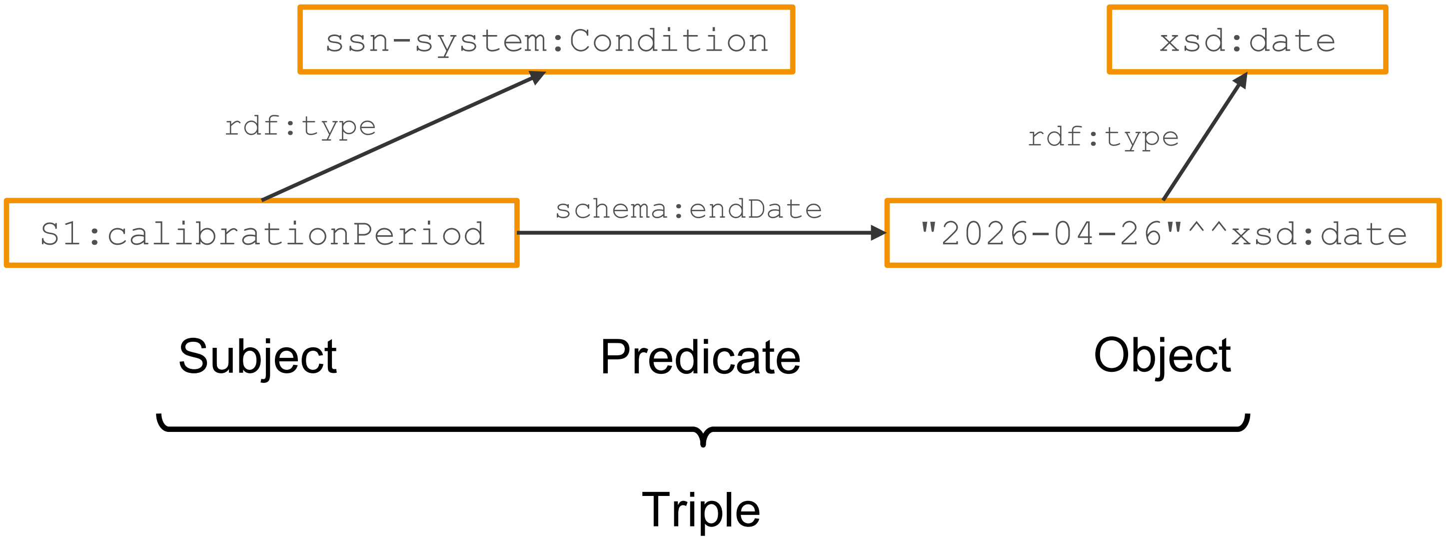
technical realization

Information Science

→ knowledge representation
represent concepts and relations
capture it in a formal way

Example 1: Knowledge as Triples

The calibration period ends on 12th April 2026.



Building Blocks of the Semantic Web

addition of formal logic to the web

- express data and rules
- reason about content
- describe and express complex properties
- remain decidable

integration with existing standards

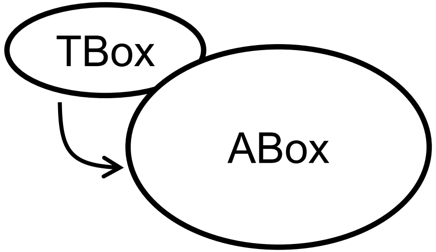
- build on accepted tools
- use (hidden) annotations in *XML*
- describe meaning and relations with *RDF*
- identify concepts globally using a *URI*

available collections of information

- capture domain specific knowledge
- ontologies define concepts and relations
- interrelate concepts between ontologies

(Advanced) Ontology Aspects

Terminology vs. Assertions

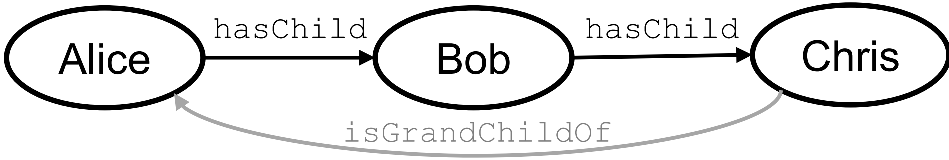


Serialization

.ttl

JSON-LD

Reasoning



Direct Semantics / Set Expressions

e.g., rdfs:subClassOf property means:
SubClassOf(CE_1 CE_2) <==> $(CE_1)^C \subseteq (CE_2)^C$

https://www.w3.org/TR/owl-direct-semantics/

OWL Profiles

reduced set of reasoning capabilities (supported relationship properties) at benefit of reduced computation complexity

Knowledge Graph Querying

```
SELECT ?parent ?child
WHERE
{
  ?parent hasChild ?child
}
```

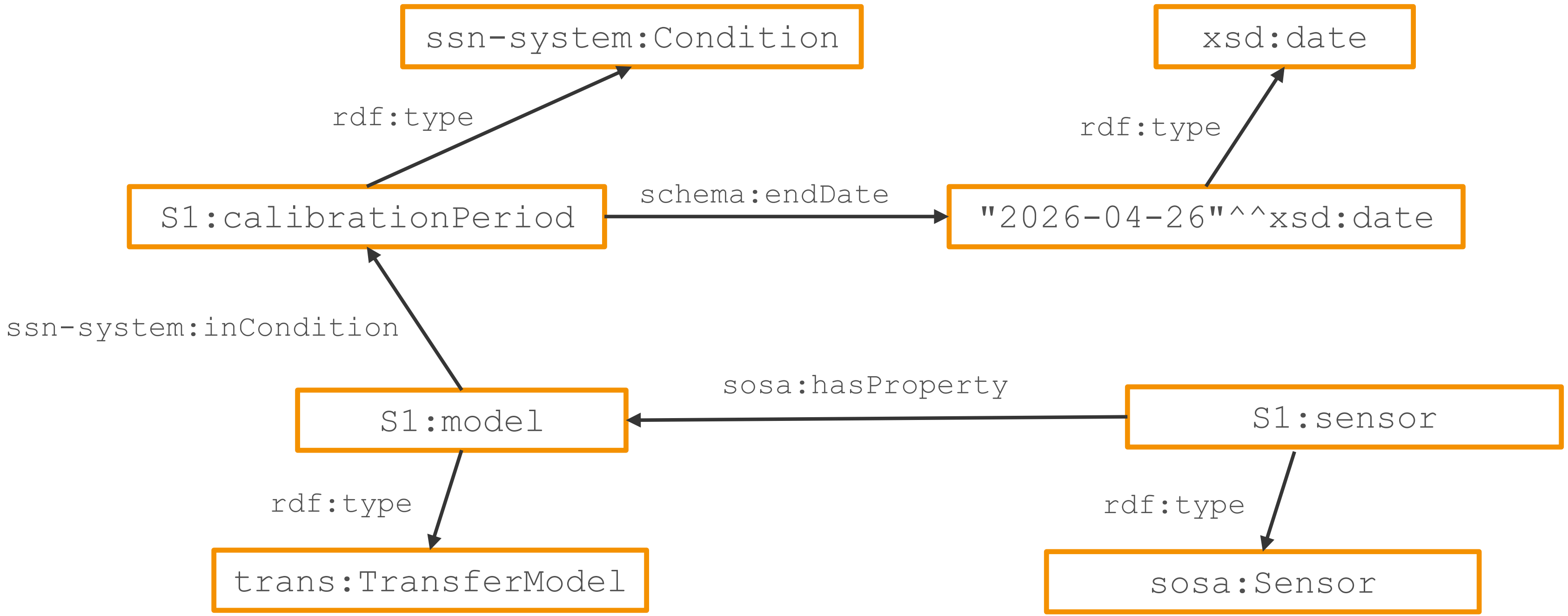
Graph Validation: `SHACL`

Ontology Alignment: `SSSOM`

Example 1: (continued)

~~The calibration period ends on 12th April 2026.~~

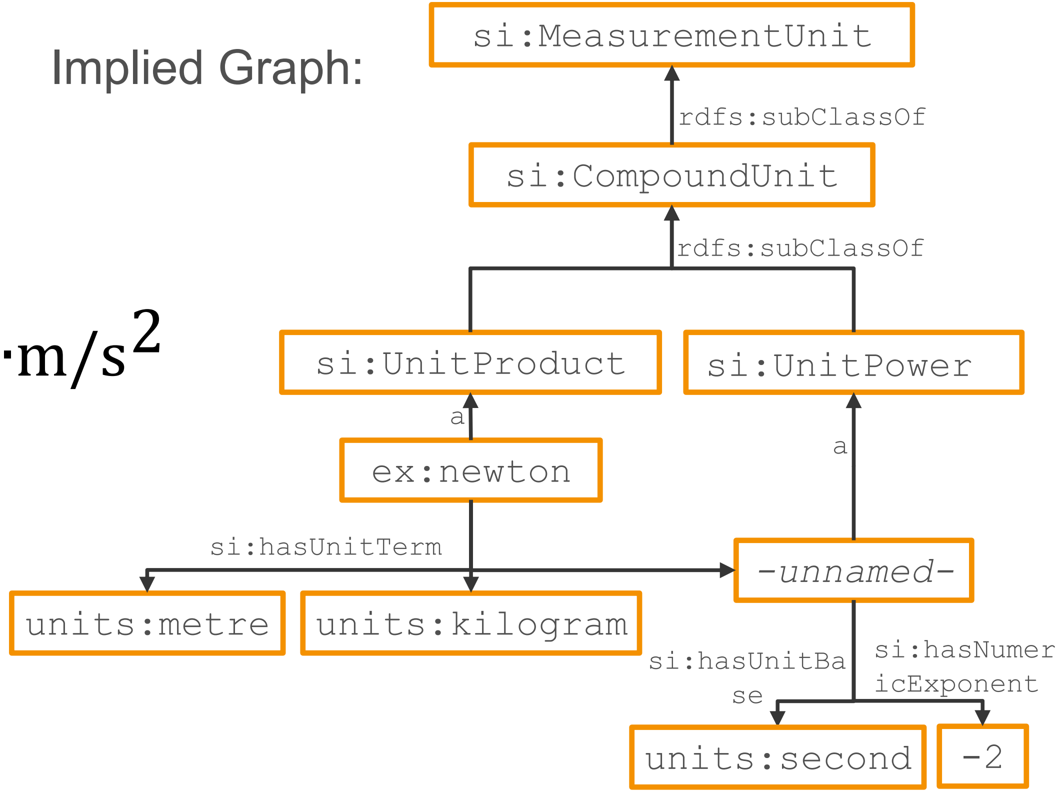
Sensor S1 is calibrated until 12th of April 2026.



Example 2: SI Reference Point (beta)

https://si-digital-framework.org/
https://github.com/TheBIPM/SI_Digital_Framework

Implied Graph:



Unit Equation:

$$1\ \mathrm{N} = 1\ \mathrm{kg{\cdot}m/s^2}$$

Turtle Syntax:

```
ex:newton a si:UnitProduct ;
    si:hasUnitTerm units:metre ;
    si:hasUnitTerm units:kilogram ;
    si:hasUnitTerm [
        a si:UnitPower ;
        si:hasUnitBase units:second ;
        si:hasNumericExponent -2
    ] .
```

Example 3: Encode Measurement Data

plain text

```
1.2 3.0 2.3 2.1
0.06
µg
```

JSON

```
{
 "data" : [1.2 3.0 2.3 2.1],
 "uncertainty" : 0.06,
 "unit" : "µg"
}
```

JSON-LD

```
{
 "@context": "..."
 "data" : [1.2 3.0 2.3 2.1],
 "uncertainty" : 0.06,
 "unit" : "unit:microgram"
}
```

plain text → JSON:

+ standardized parsing
+ named entries

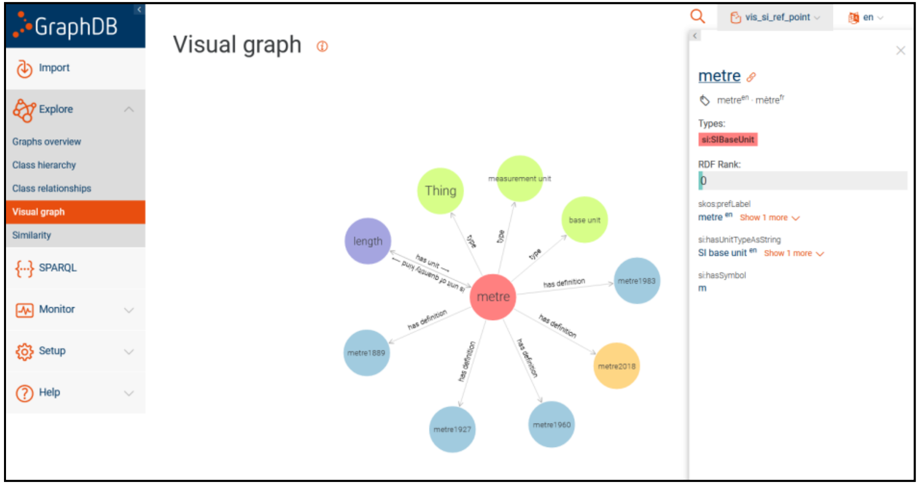
JSON → JSON-LD:

+ semantic context
→ knowledge graph

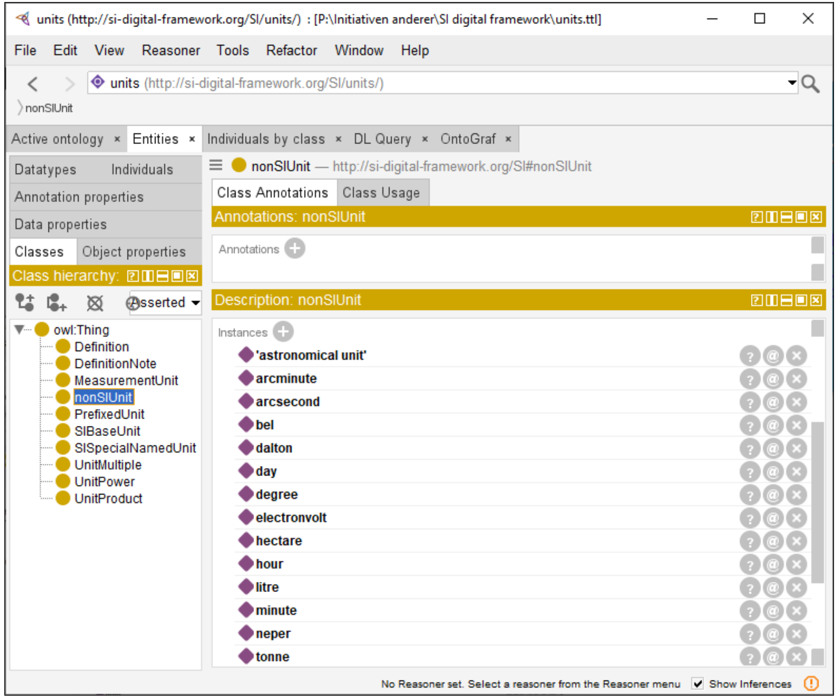
→ Using Ontologies to FAIR-up data communcitation (e.g. API responses)

Tools and Methods

GraphDB



Protégé



Code packages, e.g., Python:

- rdflib
- owlready2
- pyshacl

Questions and Discussion :-)