UNIVERSITÉ DE GENÈVE

CENTRE UNIVERSITAIRE D'INFORMATIQUE

Semantic Data Exploitation in Urban Subsurface Planning

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The SUBSURFACE project

- Funded by Innosuisse, the Swiss Innovation Agency
- Research partners: HEPIA, Université de Genève
- Industrial partner: Topomat
- Application partners: Etat de Genève, SIG, Genève Aéroport

Schweizerische Eidgenossenschaft
Confédération suisse
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REPUBLIQUE
ET CANTON
DE GENEVE
POST TENEBRAS LUX

SIG

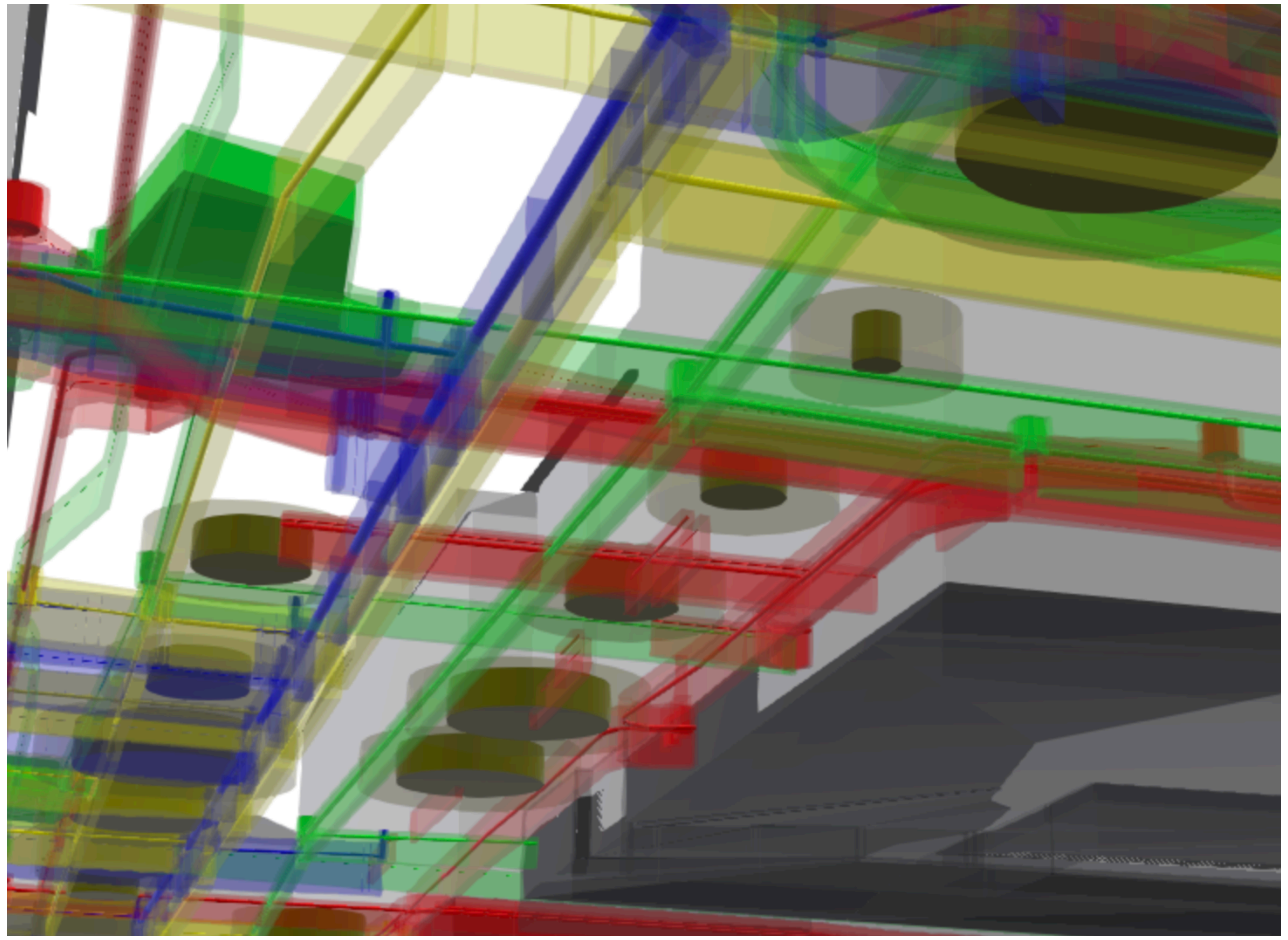
hepia
institut de recherche inPACT
paysage, architecture, construction
et territoire

topomat

Motivation

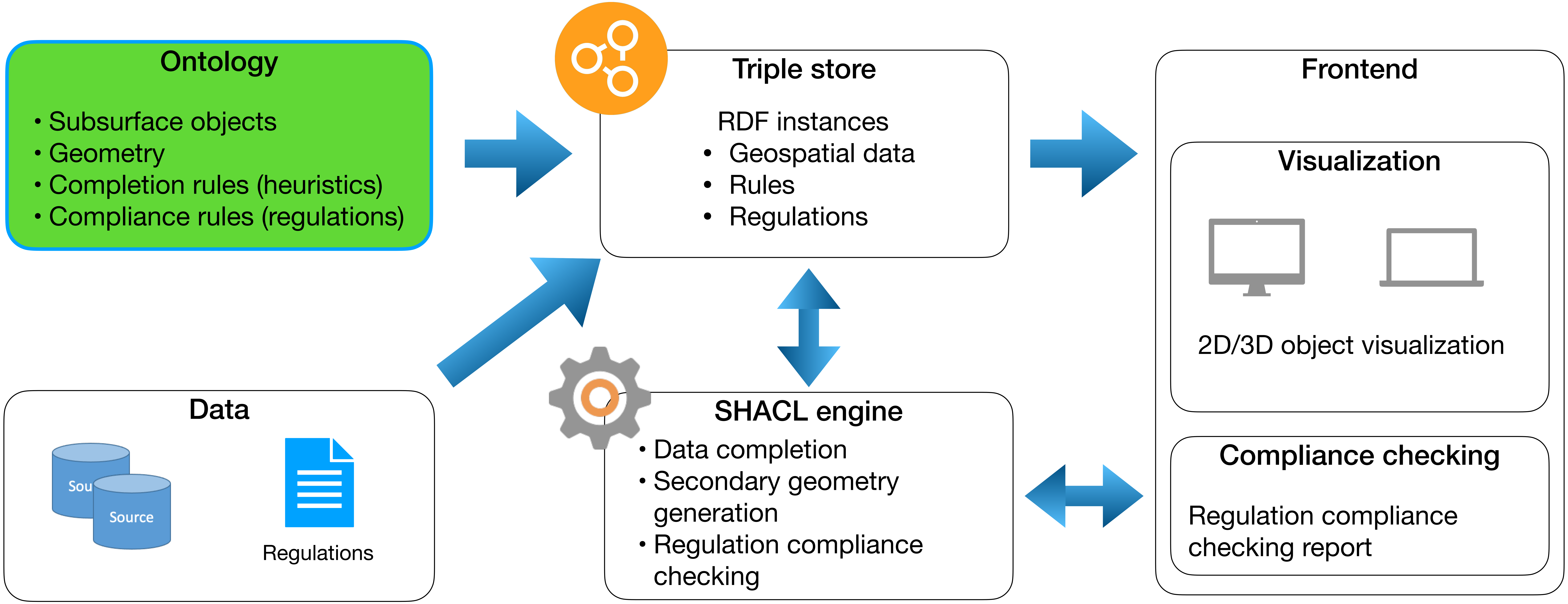
Urban planning: should the underground objects be taken into account?

- **Represent underground data**
- Data integration (BIM-GIS)
- Data completion
  - 3D-ify
  - infer missing information
- **Dealing with uncertainty**
- **Regulation compliance checking**



The SUBSURFACE project

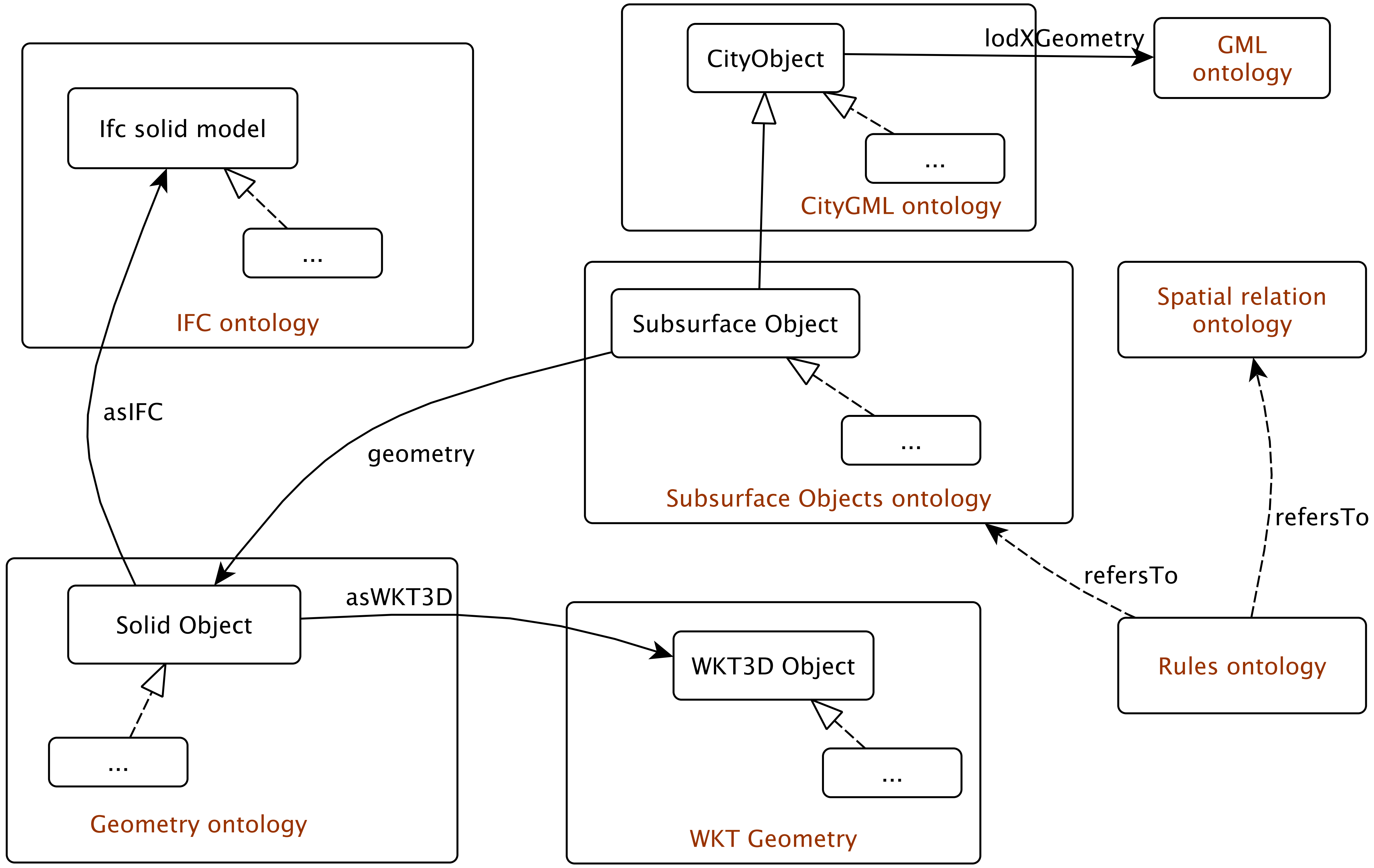
Overview



The SUBSURFACE ontology

We defined a set of interconnected ontologies to represent the **subsurface objects** as well as their **spatial relationships** and their **geometry**

- Subsurface Objects (sub)
- Geometry (geom)
- WKT Geometry (wkt)
- Rules ontology (rules)
- Spatial relation ontology (srel)
- CityGML Ontology (citygml)
- IFC Ontology (ifcOWL)



Métral, C., Daponte, V., Caselli, A., Di Marzo, G., and Falquet, G.: ONTOLOGY-BASED RULE COMPLIANCE CHECKING FOR SUBSURFACE OBJECTS, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLIV-4/W1-2020, 91–94, https://doi.org/10.5194/isprs-archives-XLIV-4-W1-2020-91-2020, 2020.

The SUBSURFACE project

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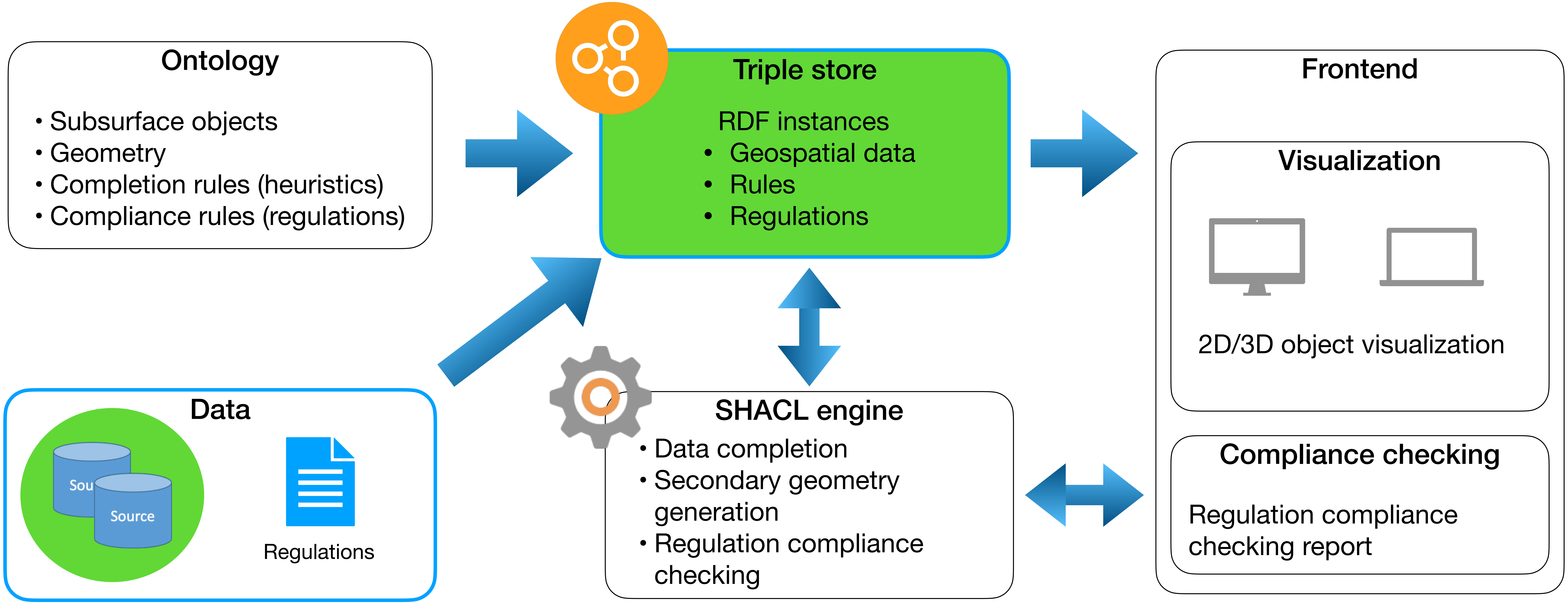
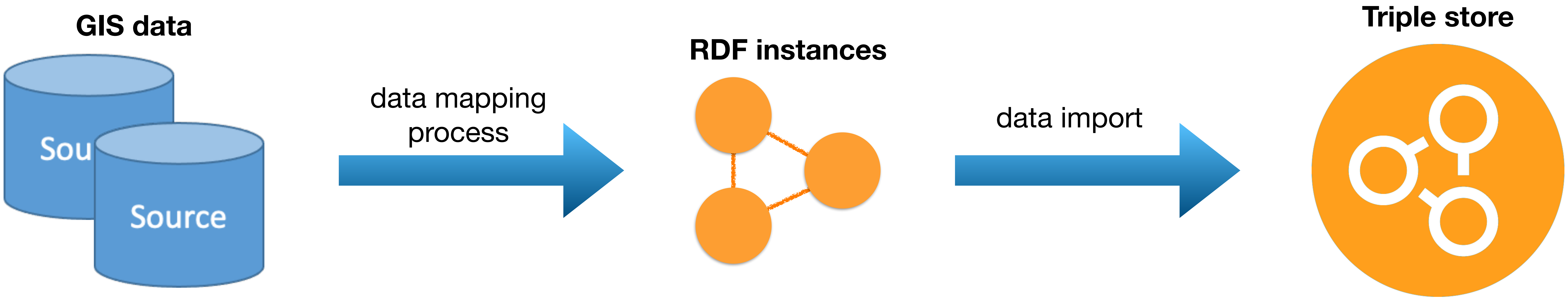
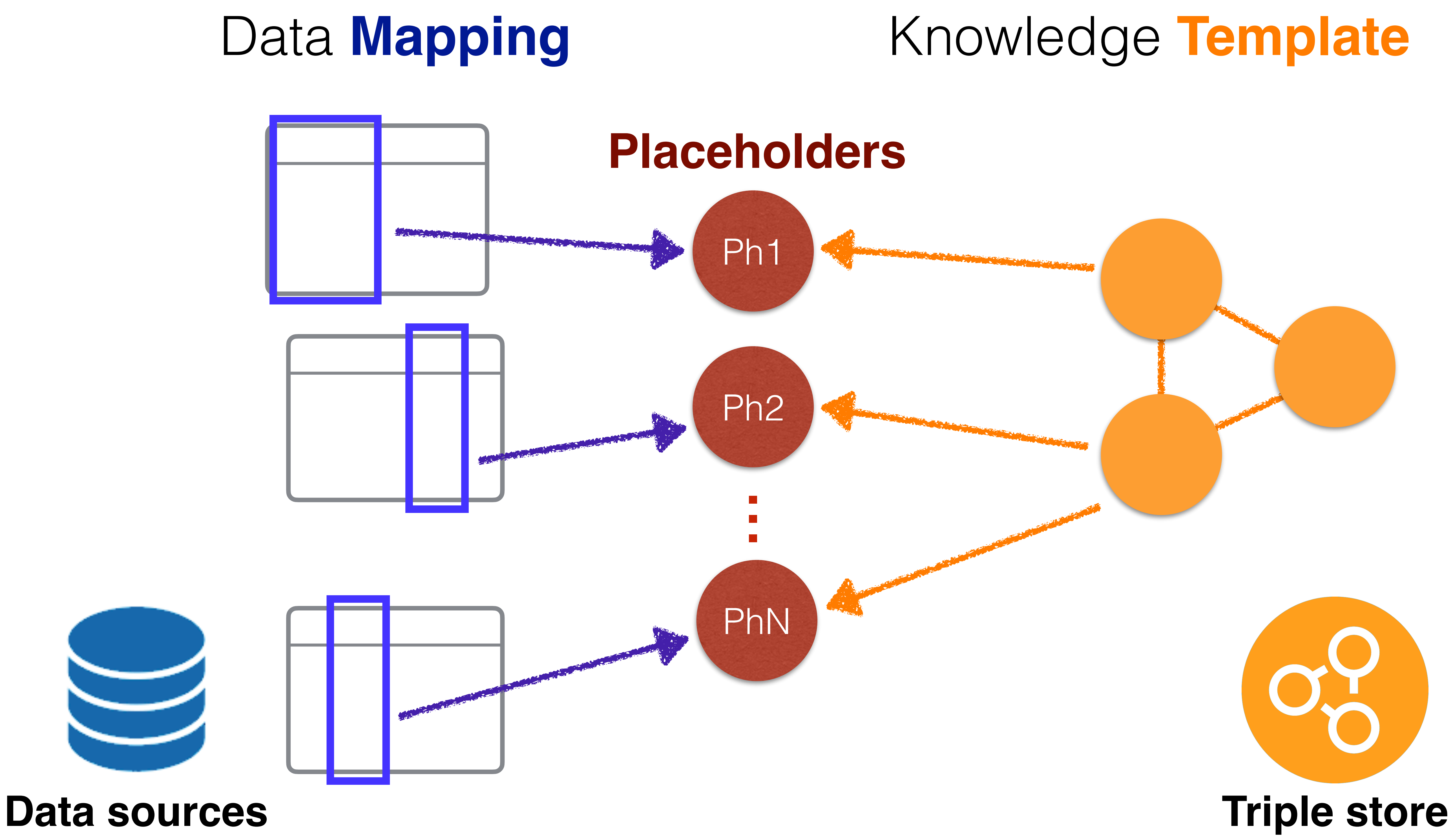


GIS data to RDF I



GIS data to RDF II



Data mapping: a JSON file that links each column with a placeholder

Knowledge Template: a graph that links each property with a placeholder

GIS data to RDF III

Data **Mapping**

L0

L1

L2

L3

```
{
  "domain": "GE_COR_SIPV_TR_",
  "mapping":
  {
      "L0":{
          "table":"cor_raw_sipv_ica_arbre_isole",
          "column": "id"
      },
      "L1":{
          "table":"cor_raw_sipv_ica_arbre_isole",
          "column": "geom"
      },
      "L2":{
          "table":"cor_raw_sipv_ica_arbre_isole",
          "column": "rayon_couronne"
      }
      "L3":{
          "table":"cor_raw_sipv_ica_arbre_isole",
          "column": "hauteur_totale"
      }
  }
}
```

Knowledge **Template**

- syntax: ***Turtle***
- PH_Subject is a Class

L0

```
:L0
  a ktmap:PH_Subject ;
  a sub:TreeRoot ;
  sub:height [
     a geom:Value ;
     geom:uom "m" ;
     geom:value :L3 ;
  ] ;
  geom:geometry [
     a sub:Cylinder ;
     geom:radius [
        a geom:Value ;
        geom:uom "m" ;
        geom:value :L2
     ] ;
     geom:center [
        a geom:Point ;
        geom:asWKT2D [
           a wkt:Point ;
           geom:WKT2Dvalue :L1 ;
        ] ;
     ] ;
  ] ;
```

L3

L2

L1

Dealing with geometry uncertainties

Common issue with underground objects

Actual geometry and positioning may differ from expected (measured/detected) one: **objects may move over the time**

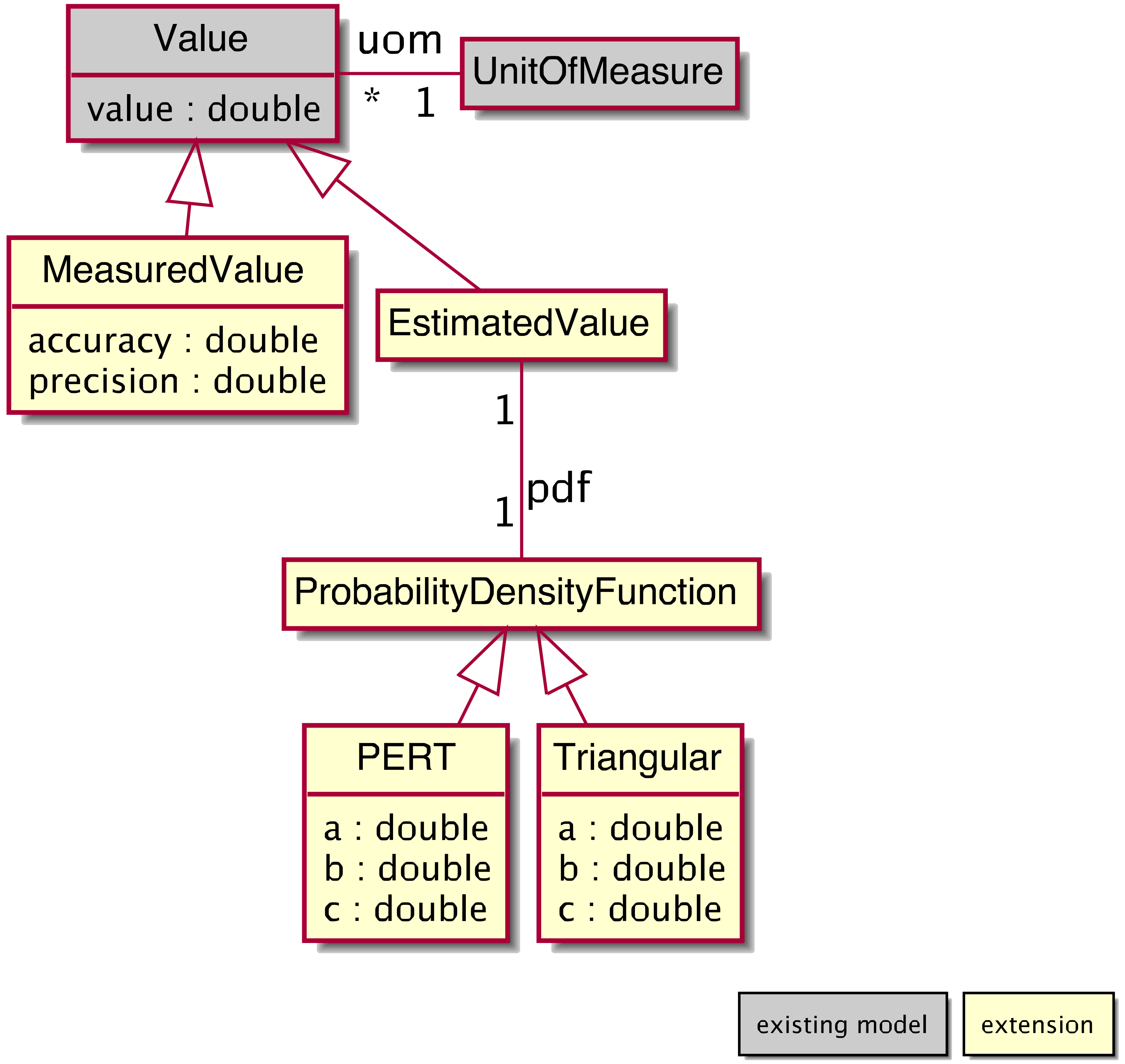
$\Downarrow$

Geometry and positioning have not always to be considered valid during the object lifetime

Dealing with geometry uncertainties

- We extended an existing model to represent both **known** (*Measured*) and **uncertain** (*Estimated*) values

- We also added properties for representing
    - Time-dependent geometries (*hasBeginning*, *hasEnd*)
    - Provenance/quality of the data (*provenance*)

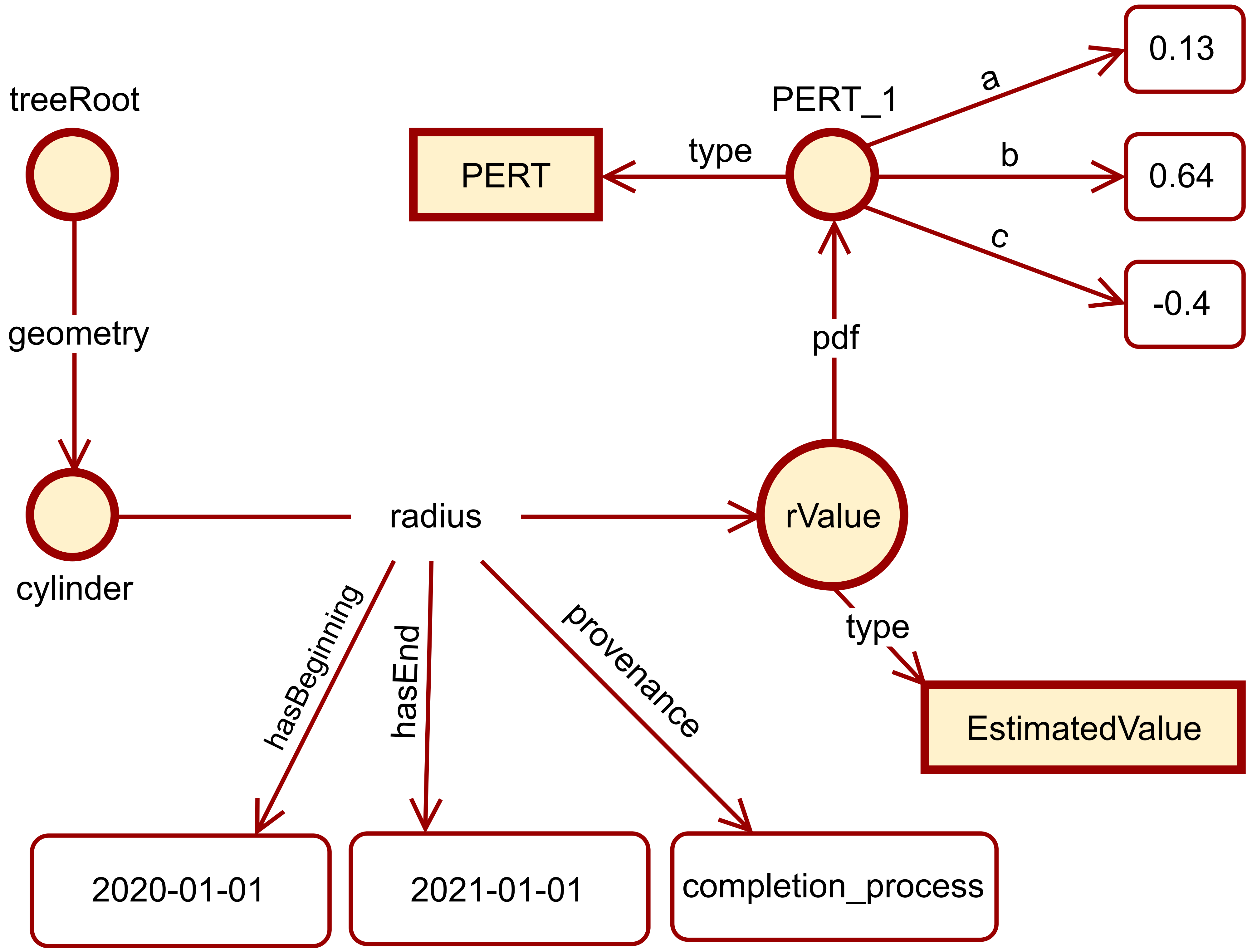


Caselli, A., Falquet, G., and Métral, C.: KNOWLEDGE GRAPH CONSTRUCTION FOR SUBSURFACE OBJECTS INCLUDING UNCERTAINTY AND TIME VARIATION, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLVI-4/W4-2021, 131–136.

Dealing with geometry uncertainties

Example

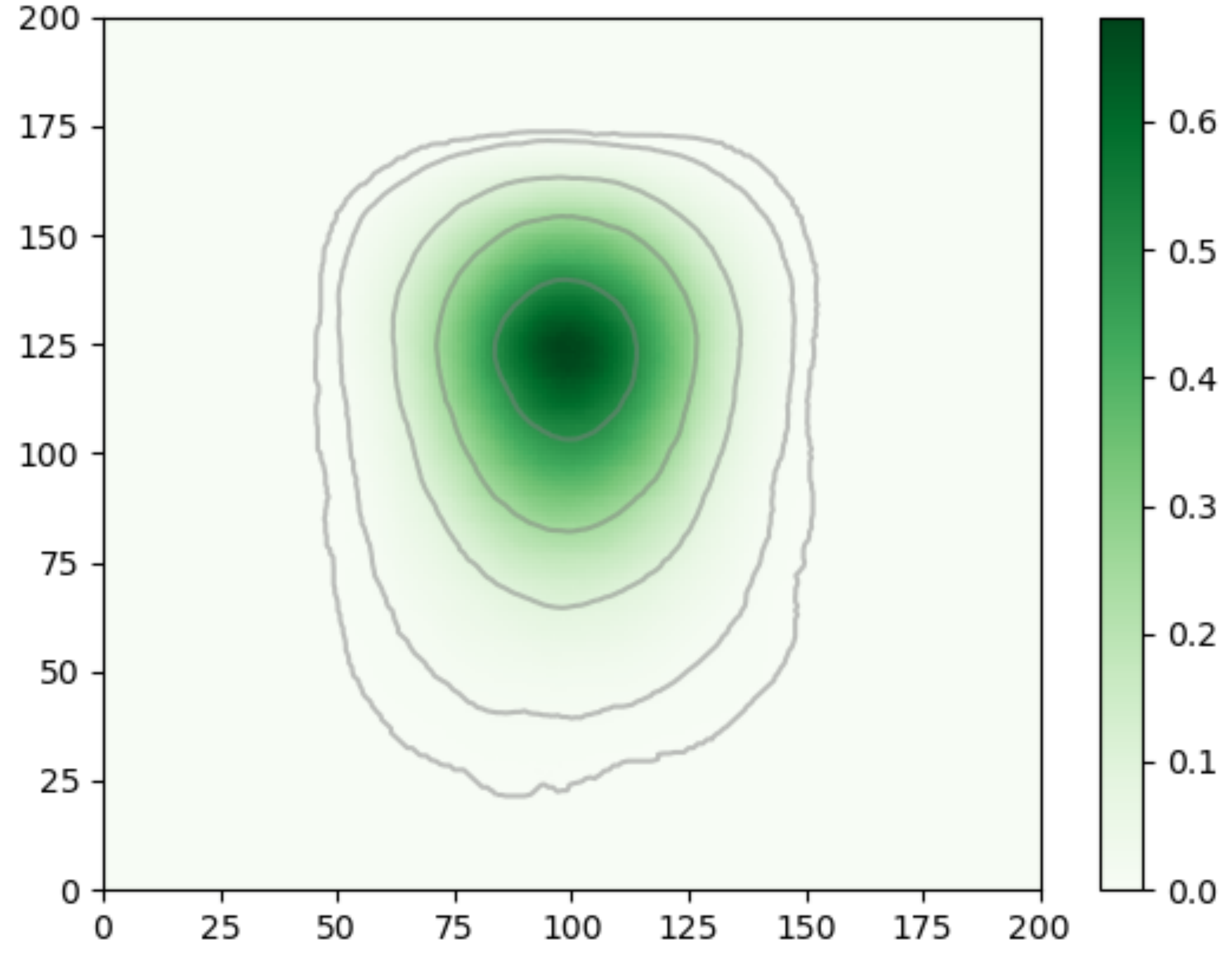
A TreeRoot object that has a cylindrical geometry with a radius value that is expressed through a probability density function and it is only valid within a certain time window.



Dealing with geometry uncertainties

Example of a possible usage: **Probabilistic collision detection**

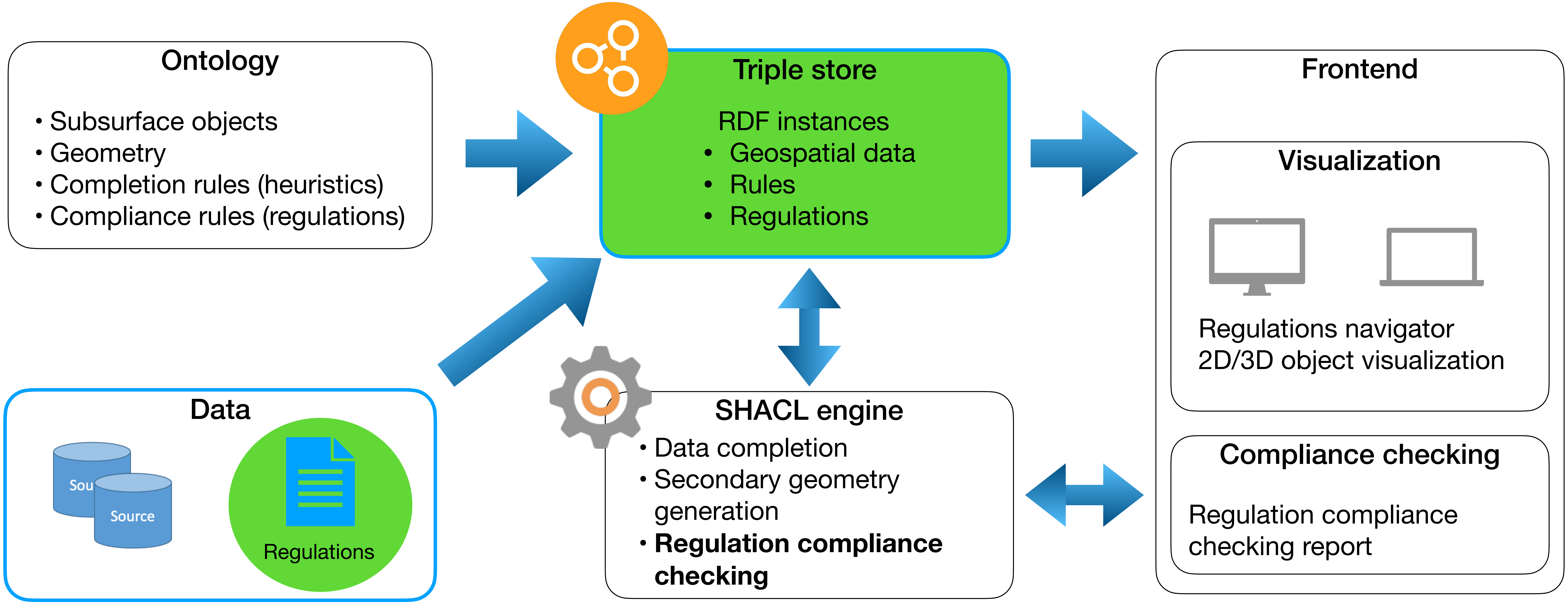
- Considering a single point and computing its collision probability with a subsurface object
- We obtain a value between 0 and 1 for each point of the 3D space
- These values can be taken to define the membership function of the fuzzy geometry (a fuzzy subset of R 3) of the subsurface object



Section of a fuzzy pipe. The contour lines correspond to membership levels 0.001, 0.01, 0.1, 0.25, 0.5.

The SUBSURFACE project

Overview



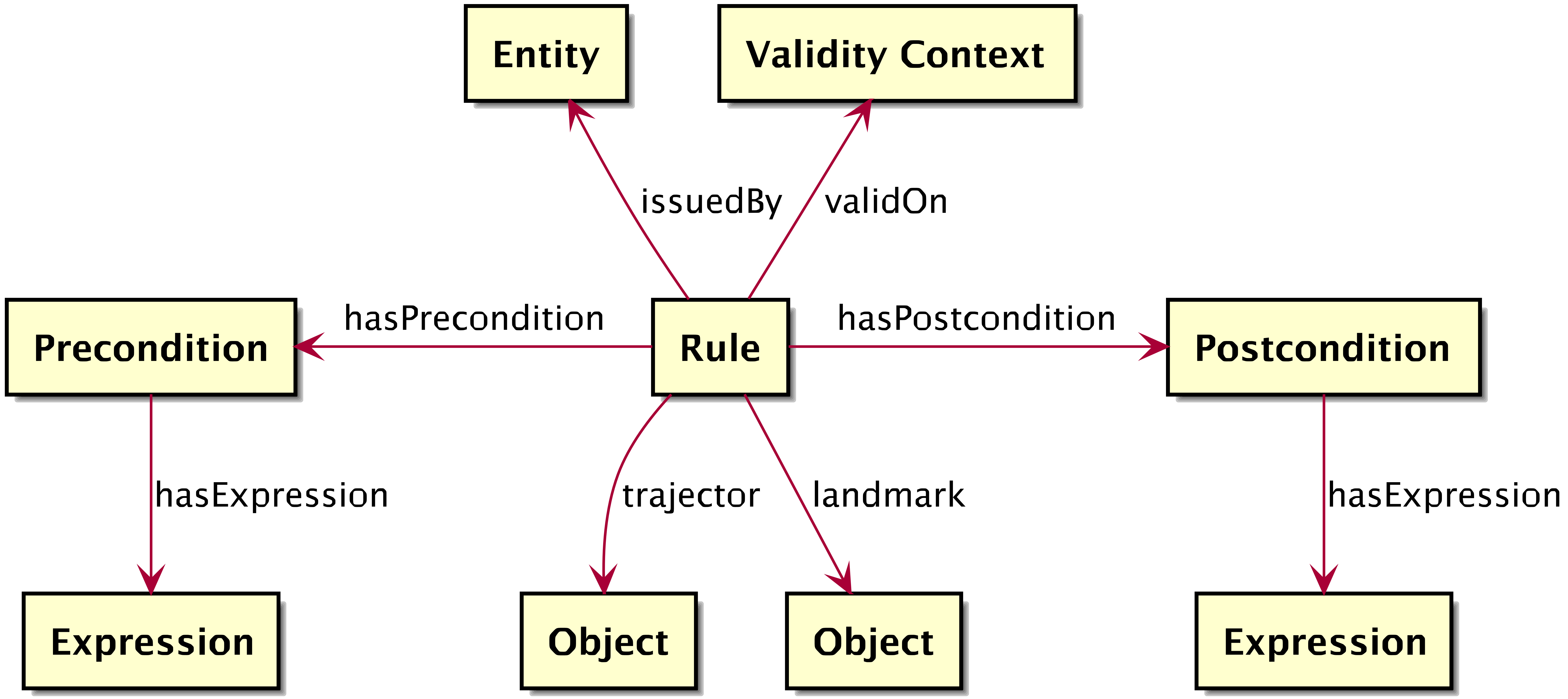
Formalize Regulations

Regulations are defined in natural language:

- no structure (made to be read by human)
- no formal language
- written by several entities (vocabulary issues)
- written in different languages
- …

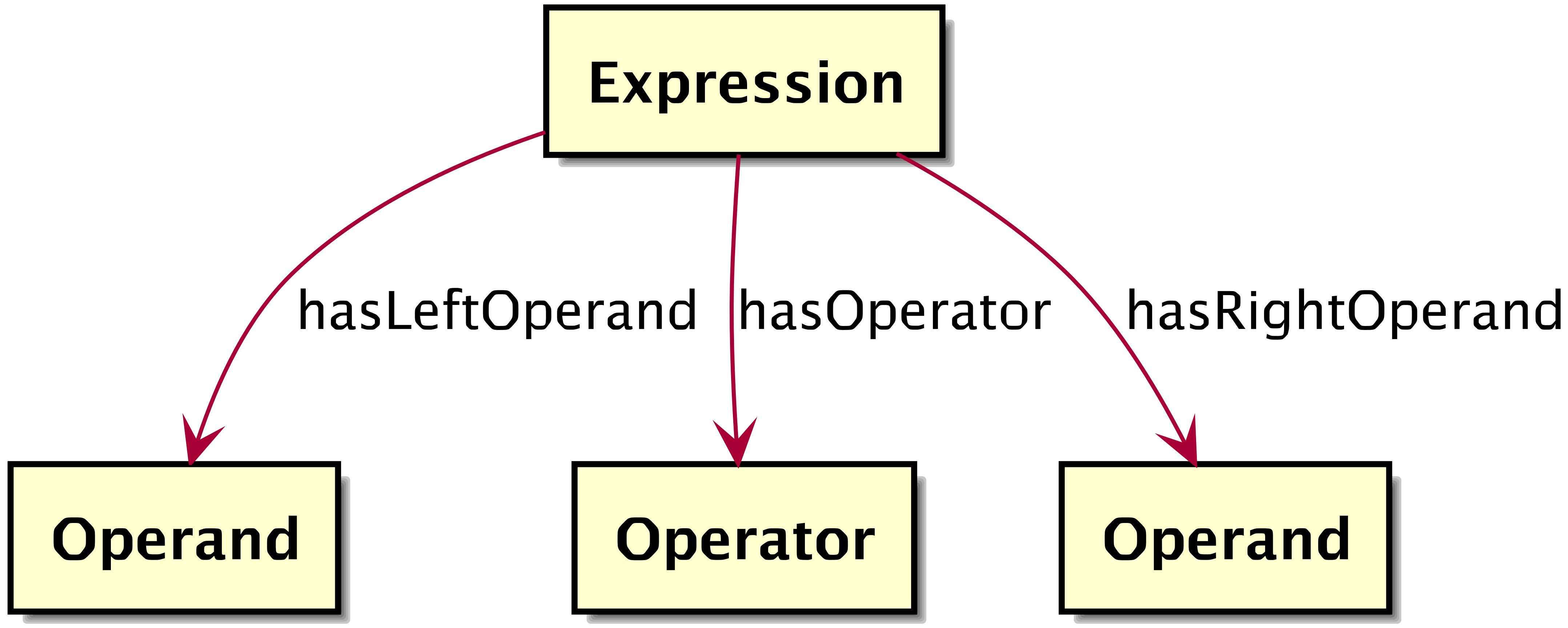
Ontology + Rule model + RDF

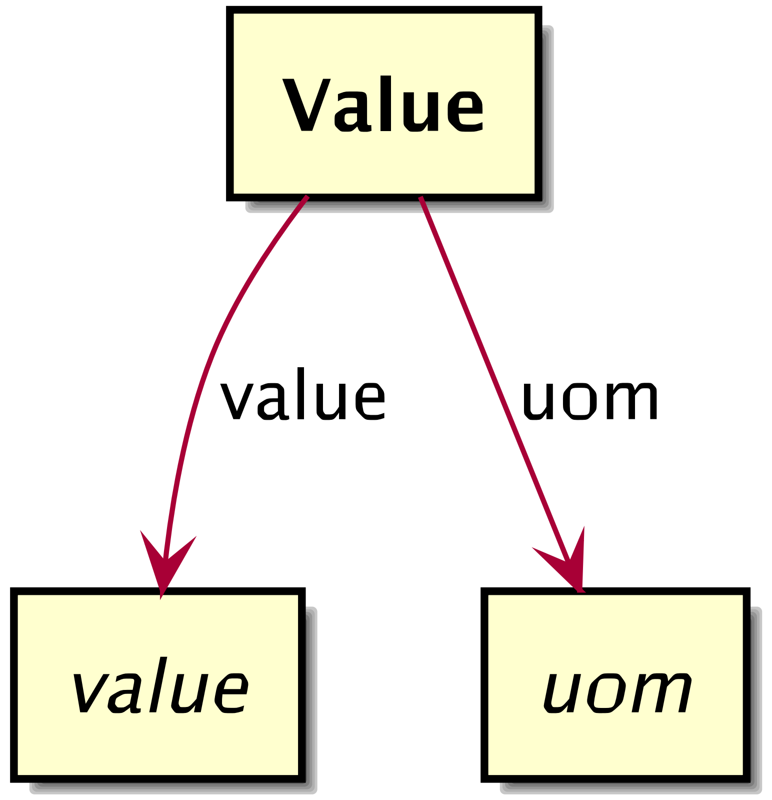
Generic Rule Representation Model I

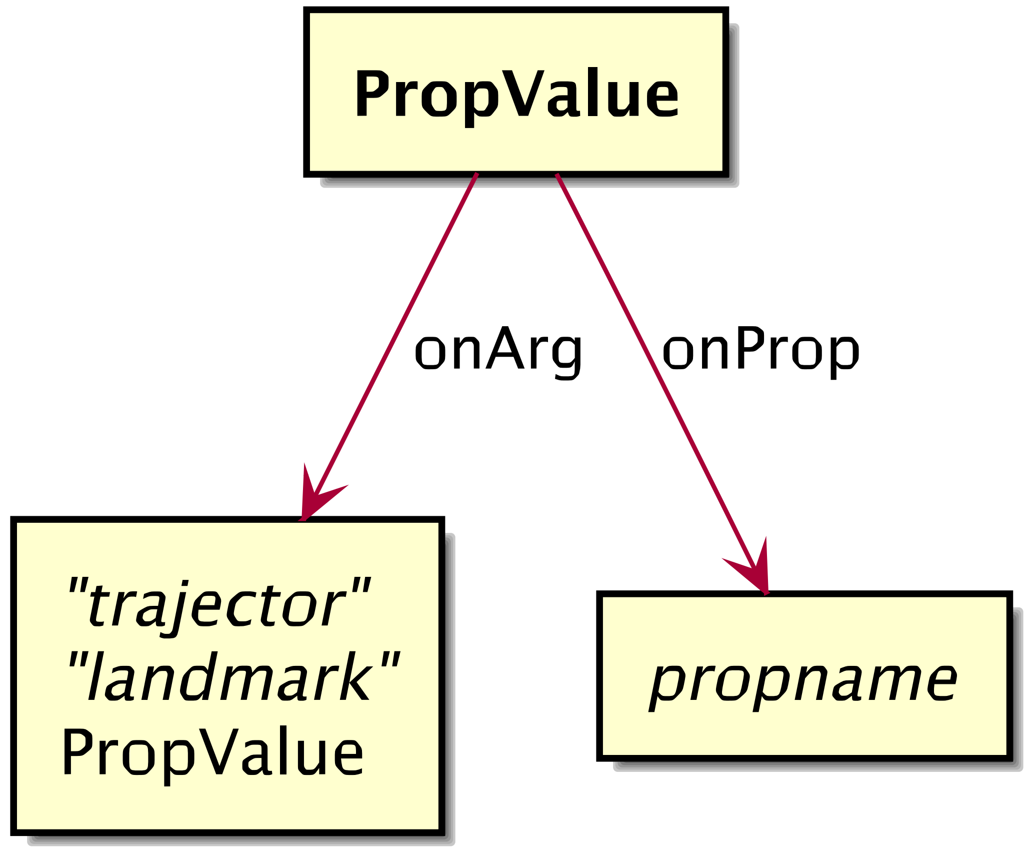


Caselli A, Daponte V, Falquet G, Métral C. A Rule Language Model for Subsurface Data Refinement. In: EG-ICE 2020 Workshop on Intelligent Computing in Engineering. Berlin: Universitätsverlag der TU Berlin; 2020:443-452. doi:http://dx.doi.org/10.14279/depositonce-9977

Generic Rule Representation Model II







Expression ::= Operand Operator Operand ;
Operand ::= “trajector” | “landmark” |
Value | PropValue | Expression ;
Operator ::= Mathematical | Logical | Spatial ;

Spatial operator / spatial relation = above, below, parallel, close, lateral distance, vertical distance, etc…

Formalizing regulations

3.3.3. Distances et croisements

L'implantation de tubes et conduites à proximité d'un bâtiment et ou d'un ouvrage enterré (fondation, fosse, etc.) est réglementé en fonction du réseau considéré. Des contrôles sont impératifs, pour permettre la mise en place de protections adaptées (explosion, rayonnement ORNI, etc.).

Sous réserve d'une modification des normes techniques applicables, les distances latérales entre des canalisations sont recommandées par type de tuyau (SIA 190) :

- D <= 350mm 0.25m
- D <= 700mm 0.35m
- D <= 1200mm 0.425m
- D > 1200mm 0.5m

… the ***lateral distance*** between the **pipes (trajector, landmark)** is recommended according to the pipe's type:

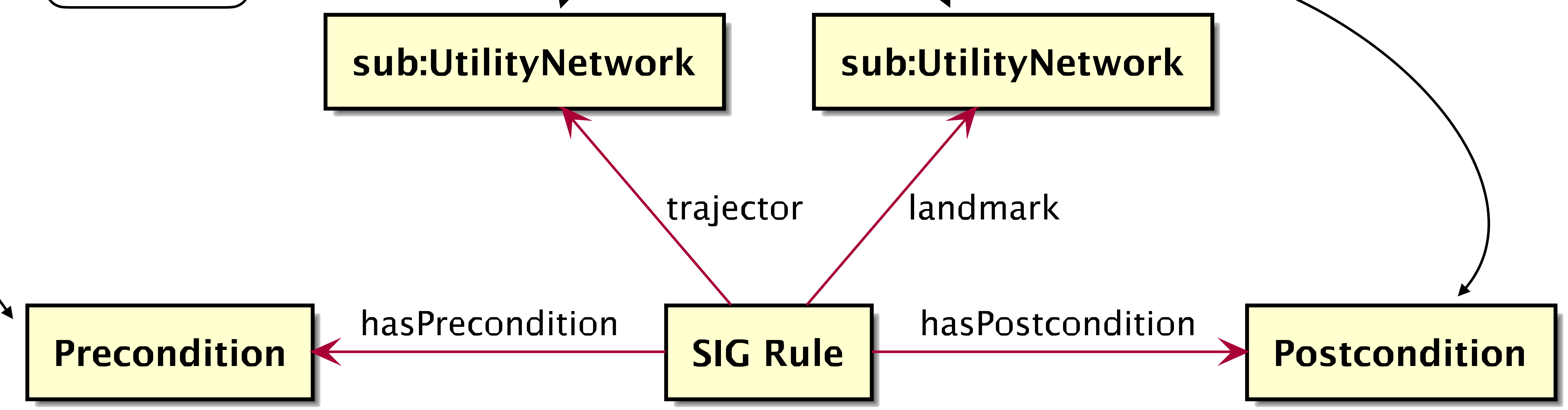
- ø <= 350mm 0.25m
- ø <= 700mm 0.35m
- ø <= 1200mm 0.425m
- ø > 1200mm 0.5m

Unofficial translation adapted from: Original text (FR): SIG — GUIDE DE CONCEPTION ET DE COORDINATION DES TRAVAUX EN SOUS-SOL, https://media.sig-ge.ch/

Formalizing regulations

… the ***lateral distance*** between the **pipes (trajector, landmark)** is recommended according to the pipe's type:

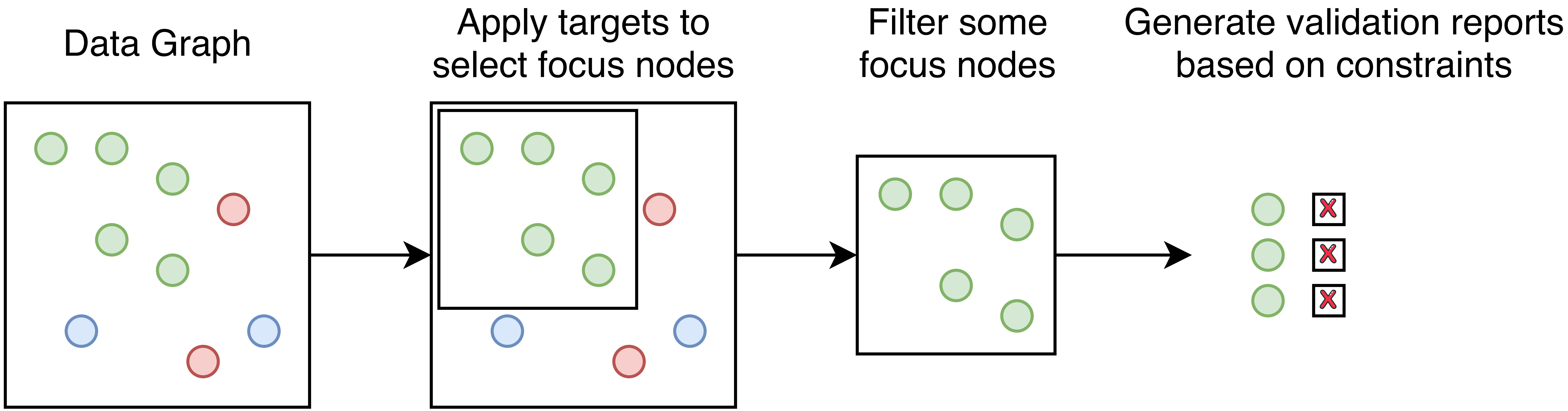
- ø <= 350mm 0.25m
- ø <= 700mm 0.35m
- ø <= 1200mm 0.425m
- ø > 1200mm 0.5m



Shapes Constraint Language (SHACL)

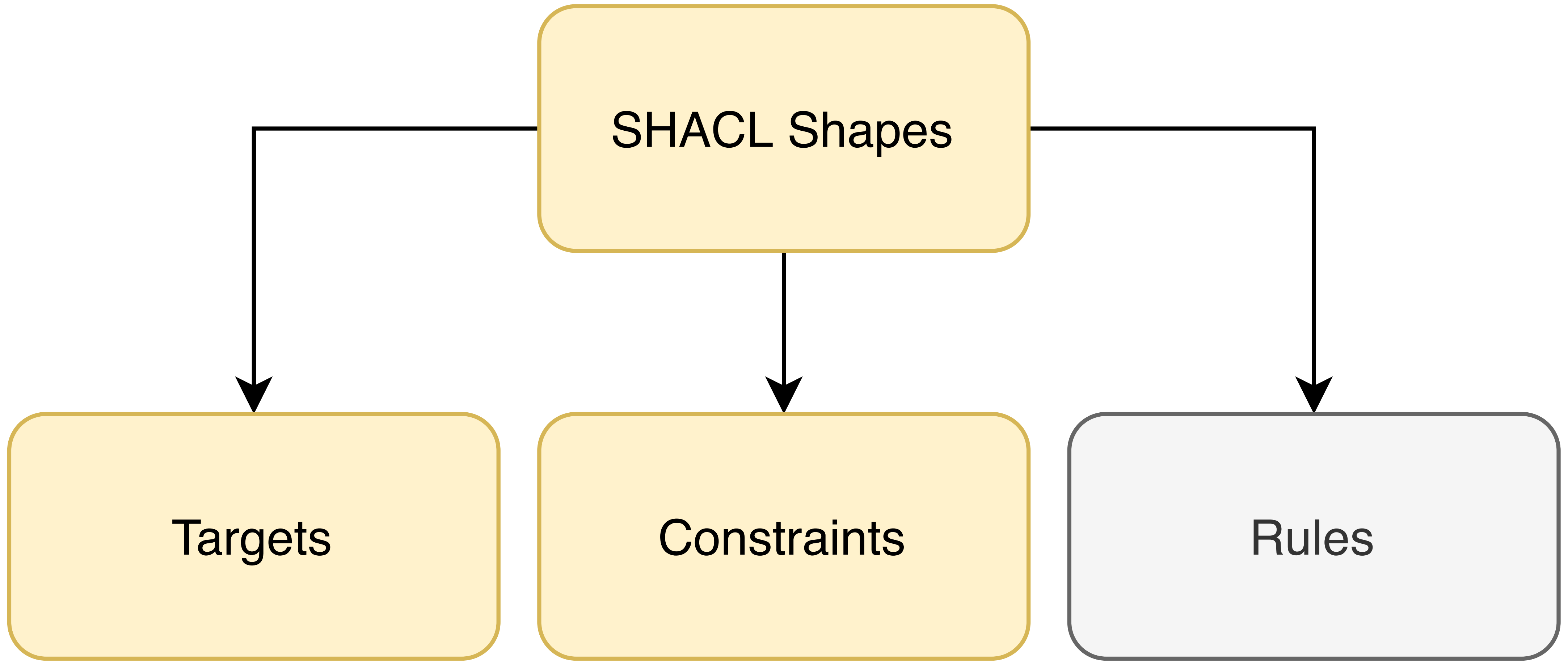
- W3C Recommendation (July 2017)
- Language for validating RDF graphs against conditions
- Shapes are defined in an RDF graph called “Shapes graph”
- The graph to be validated is called “Data graph”

SHACL Validation process



Regulations as SHACL validation constraints

Shapes Constraint Language (SHACL): validating RDF graphs against a set of conditions (shapes)



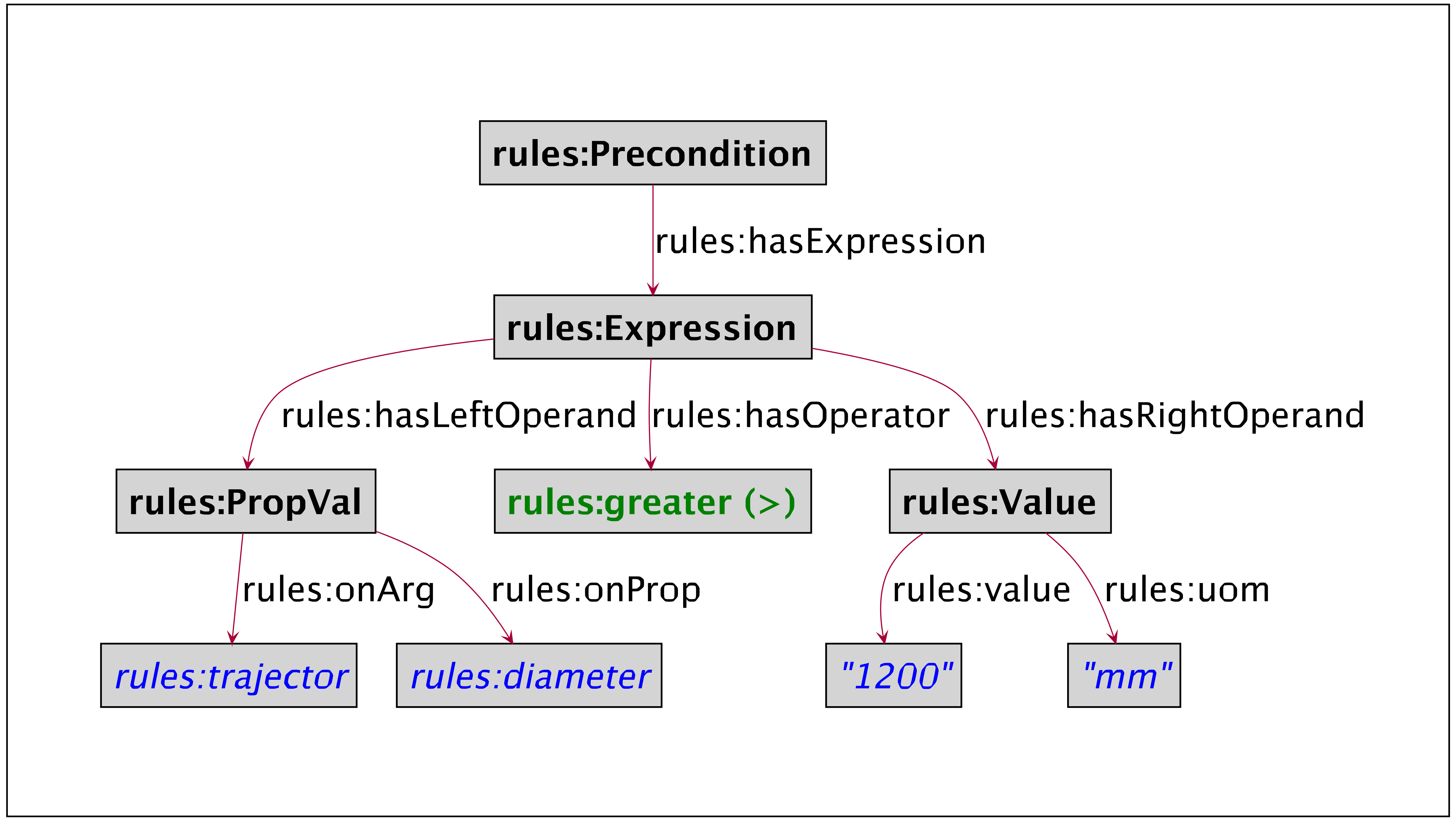
Rule **trajector** or **trajector + precondition**

Rule **postcondition**

Regulations as SHACL validation constraints

Precondition Example

ø > 1200mm

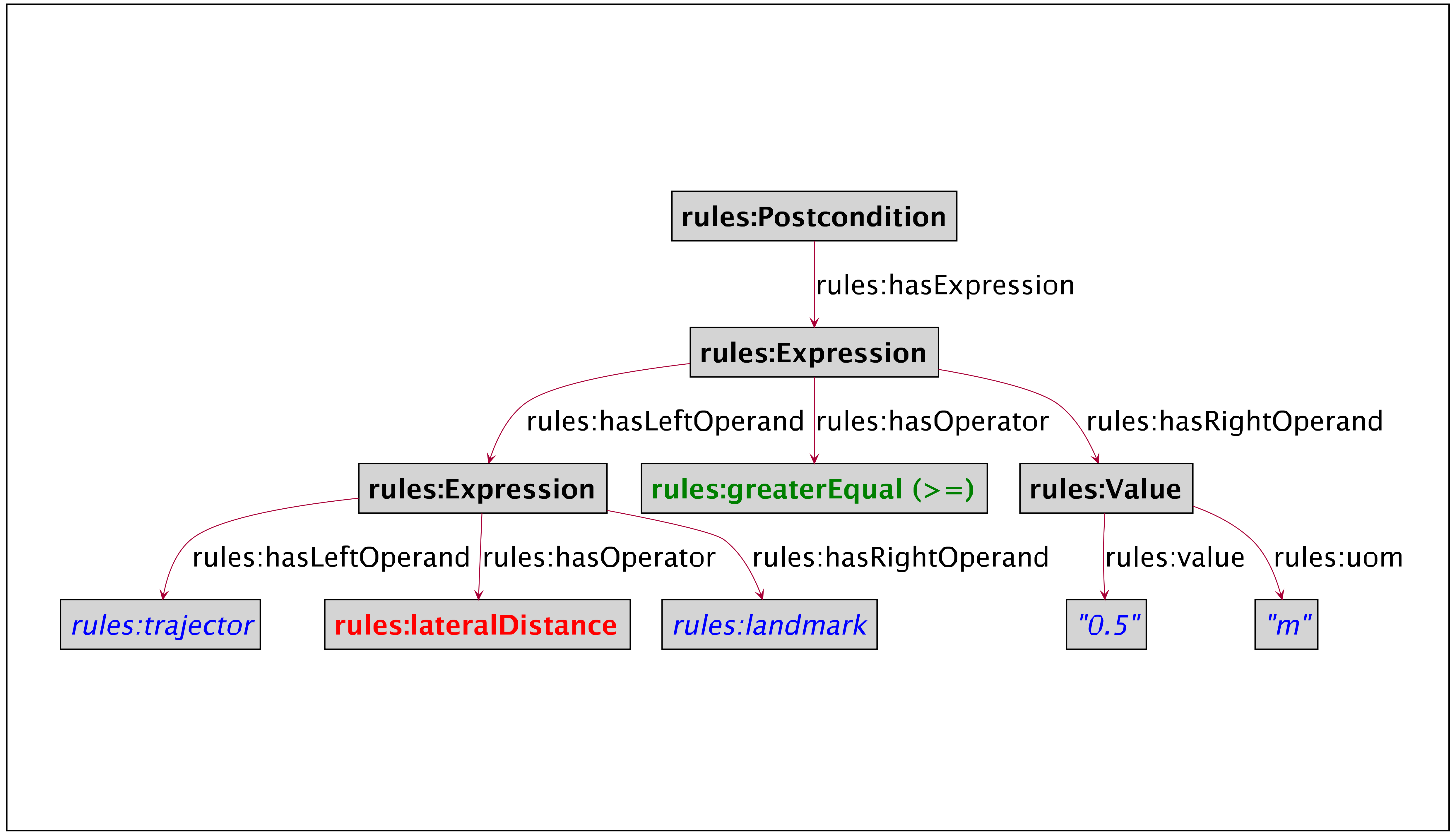



```
sh:target [
      rdf:type sh:SPARQLTarget ;
      sh:select """
         PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
         PREFIX sub: <http://cui.unige.ch/isi/onto/SubsurfaceObjects#>
         PREFIX rules: <http://cui.unige.ch/isi/onto/rules.ttl#>
         SELECT ?this
         WHERE {
            ?this a sub:UtilityNetwork .
            ?this rules:diameter ?diam .
            ?diam rules:val ?diamValue .
            FILTER(?diamValue > 1200) .
         }
         """ ;
    ] ;
```

Regulations as SHACL validation constraints

Postcondition Example

lateral distance => 0.5m

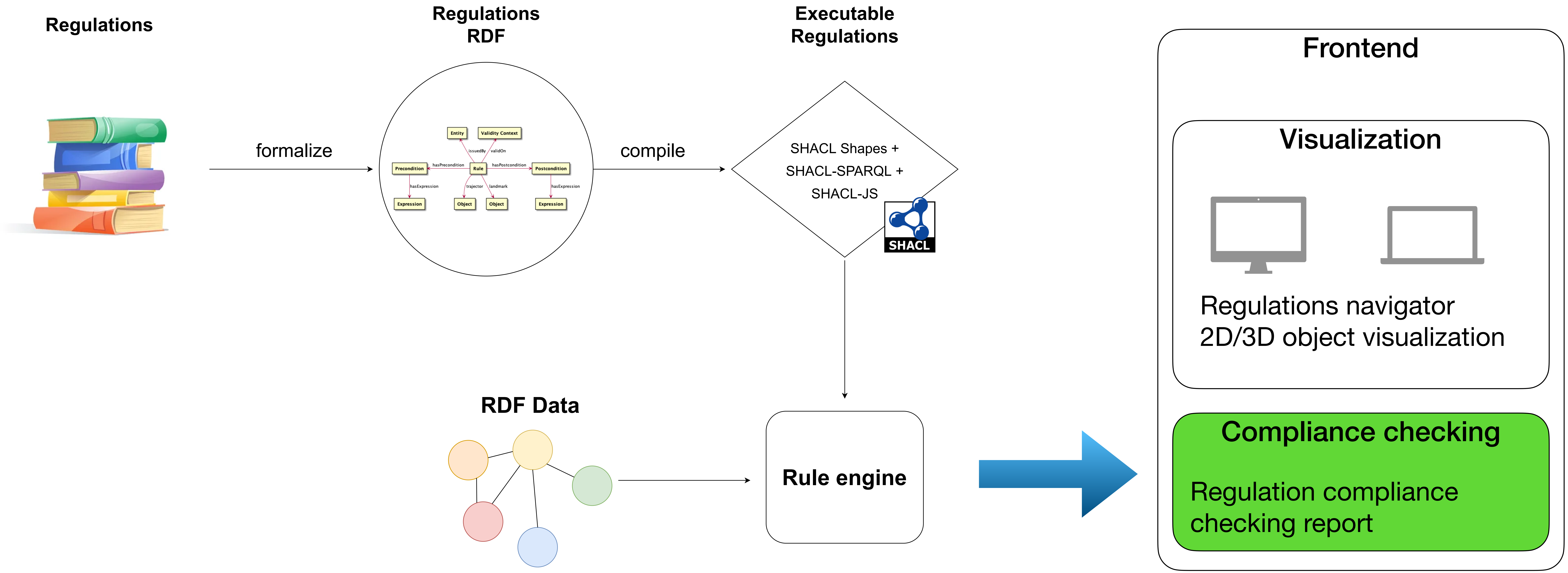



```
sh:sparql [
      rdf:type sh:SPARQLConstraint ;
      sh:message "Lateral distance between pipes. Diameter > 1200mm." ;
      sh:select """
          PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
          PREFIX sub: <http://cui.unige.ch/isi/onto/SubsurfaceObjects#>
          PREFIX rules: <http://cui.unige.ch/isi/onto/rules.ttl#>
          SELECT $this ?value
          WHERE {
              ?landmarkInst rdf:type sub:UtilityNetwork .
              FILTER(rules:lateral_distance($this, ?landmarkInst) < 0.5) .
          }
          """ ;
   ] ;
```

rules:lateral_distance is a sh:JSFunction
Outsourcing the **lateral distance** computation to some external service

Regulation compliance checking

Framework Architecture



Summary

- Ontologies to represent data of subsurface space
- Data mapping: geospatial data (GIS) to RDF
- Dealing with geometry uncertainties
- Rule model for formalizing regulations
- Executable version of the regulations using SHACL + SHACL extensions
- Automated regulation compliance checking

References

Métral, C., Daponte, V., Caselli, A., Di Marzo Serugendo, G., and Falquet, G. 2020. “Ontology-based Rule Compliance Checking for Subsurface Objects” In Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLIV-4/W1-2020, 91–94, https://doi.org/10.5194/isprs-archives-XLIV-4-W1-2020-91-2020.

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