Using BIM for Energy-Efficient Renovation

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Outline

1. BIM and Renovation
   - What are the challenges
   - BIM4Ren structure
   - Experiment as much web semantic technologies as possible.
2. The BIM4Ren data model
   - Need to model uncertainty – OPM
   - Need to model building status
   - Data access – SPARQL/GraphQL-LD/RAMOSE
3. The conversion process
   - Based on SWRL rules
4. Additional features
   - SHACL checkers
   - A product of catalogue

BIM4Ren overview

BIM in Renovation

- BIM is mainly used on new projects
  - Need to digitize existing buildings (not just scanning)
  - Need a suitable model (IFC extension)…
  - … Usable in the construction & exploitation phases
- BIM and Renovation: a complementarity
  - Can be combined with Energy Audit interventions
- Different depths of renovation projects
  - Different Information for different projects

BIM in Renovation

BIM4Ren

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BIM4Ren Concept

BIM4Ren

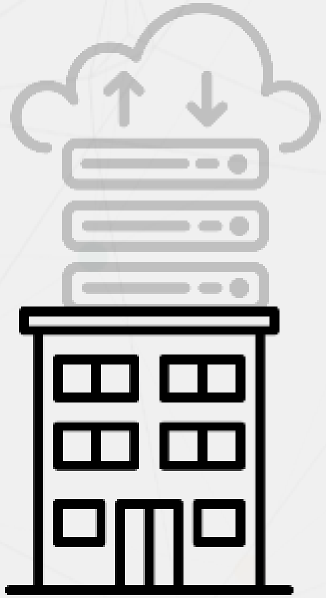
Data Management

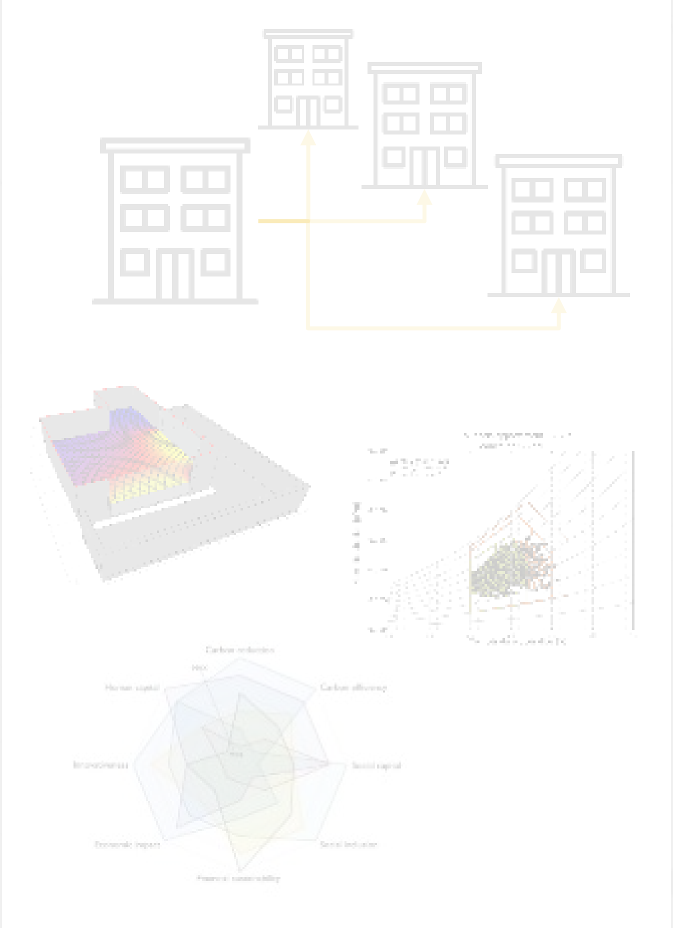
Data collection

Data- driven design

WHAT IS THE EXISTING DATA ?

- Year?
- Local regulation?
- Cost € ?
- Energy performance?
- Geometry?
- Stakeholders expectations?
- Type of occupants ?
- Renovation potential ?
- State of the existing infrastructure ?





Stakeholders involved in the renovation

BIM4Ren Concept

Digital inputs

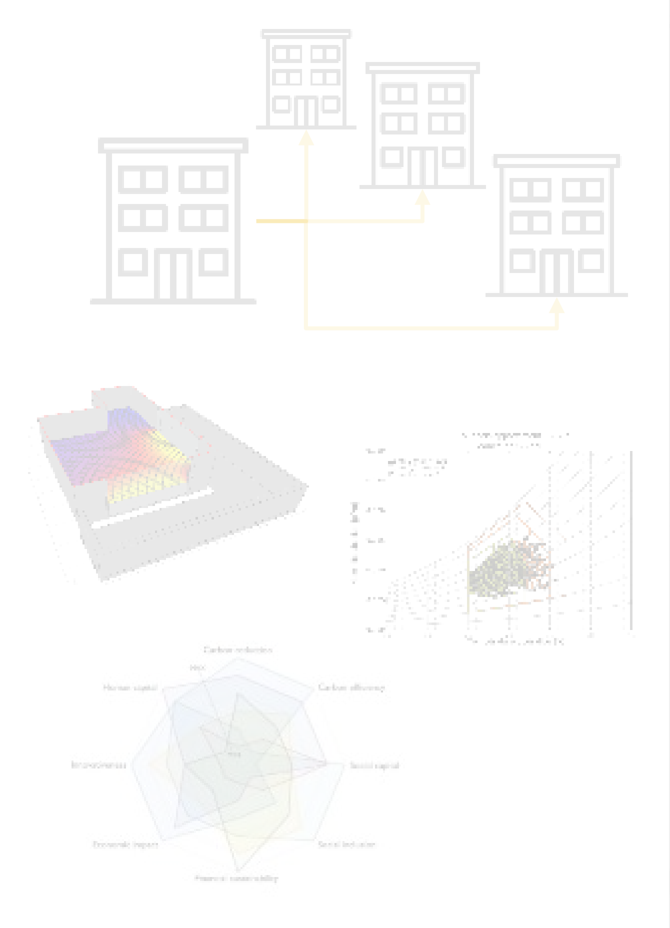
Data Management

Data collection

Data- driven design

WHAT IS THE EXISTING DATA ?

1. To create the BIM model
2. To organize, consolidate, secure
3. To validate the BIM model



Stakeholders involved in the renovation

BIM4Ren Concept

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Data Management

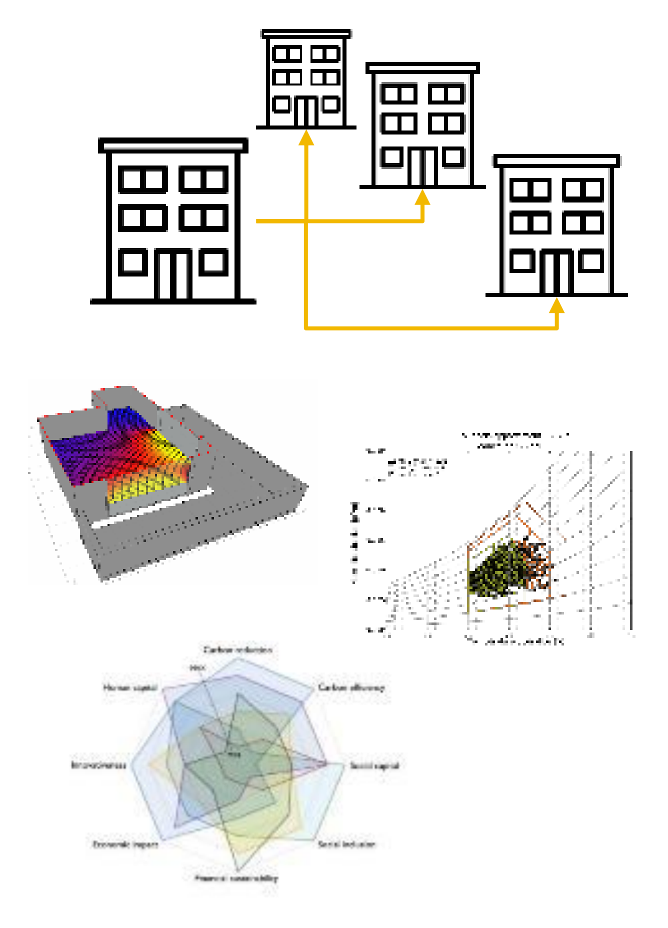
Exploit BIM

Data collection

Data- driven design

WHAT IS THE EXISTING DATA ?

1. To create the BIM model
2. To organize, consolidate, secure
3. To exploit the BIM model



Stakeholders involved in the renovation

BIM4Ren Concept

Digital inputs

Data Management

Data

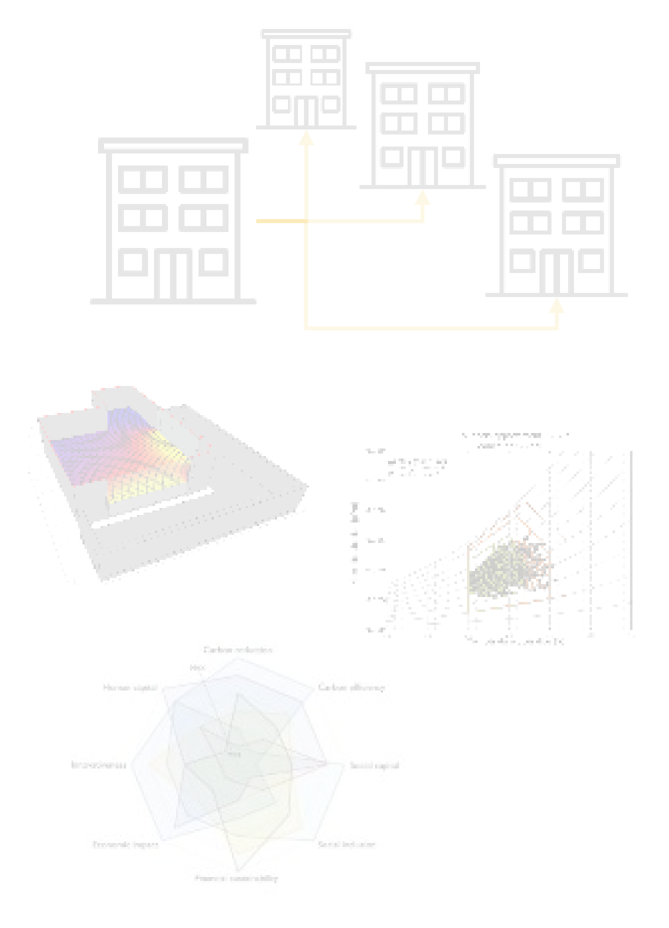
WHAT IS T
EXISTING D

Web semantic tools sandbox

- triple store
- BIM model for renovation
- checkers
- converters
- data access

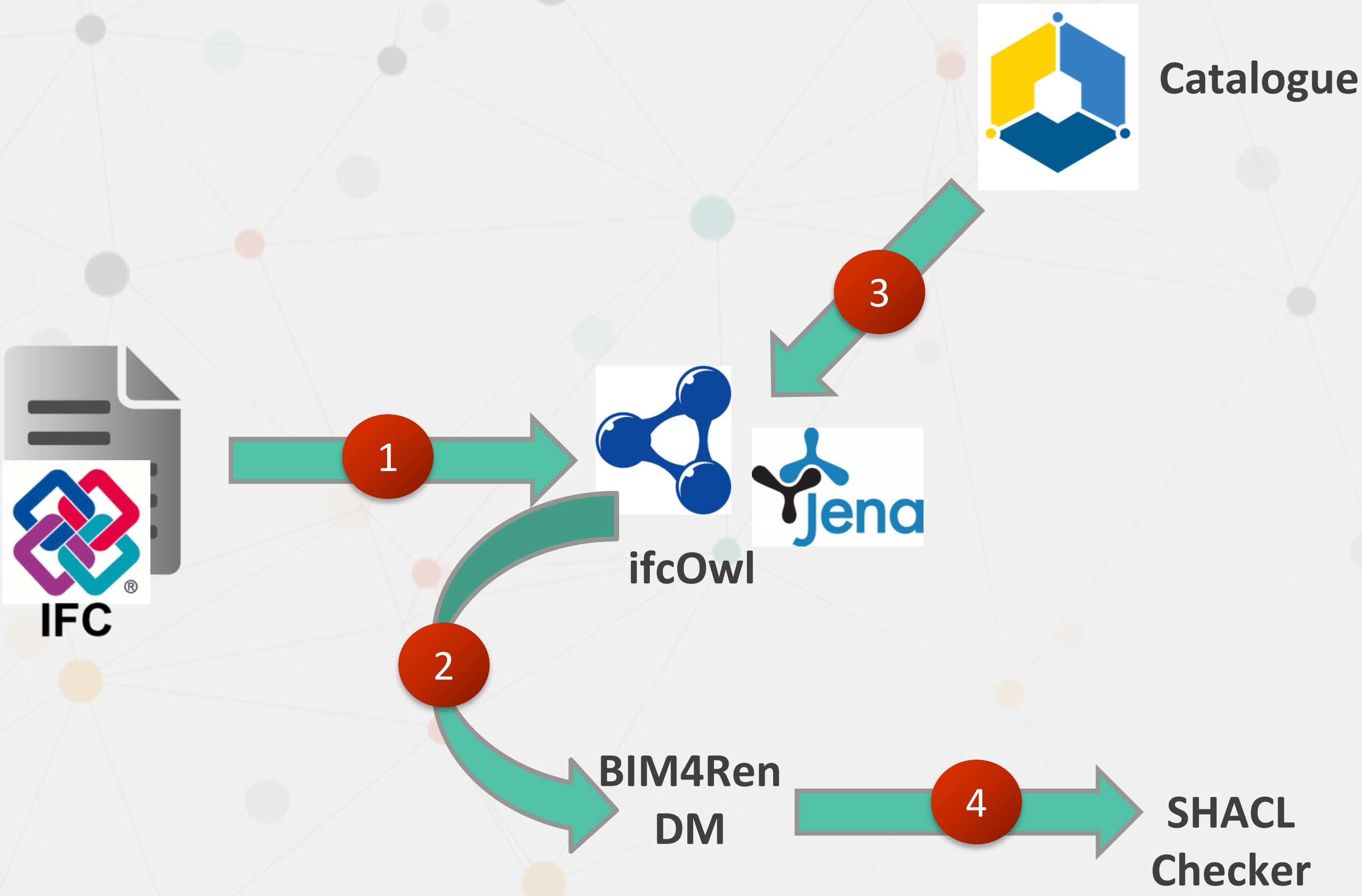
To create the BIM model
To organize, consolidate, secure
To validate the BIM model

Data- driven design



Stakeholders involved in the renovation

Deeper view



1 Conversion SPF to ifcOwl – loading to a triple store

2 Alignment with BIM4Ren data model

3 Enrichment from a LD catalogue

4 Checking information on models

The BIM4Ren data model

Goals

1 Need to model **uncertainty**

- ‘the composition of the external wall is **certainly brick + Xcm of glass wool**’
- The scan process has an **accuracy of X**

2 Need for **modularity**

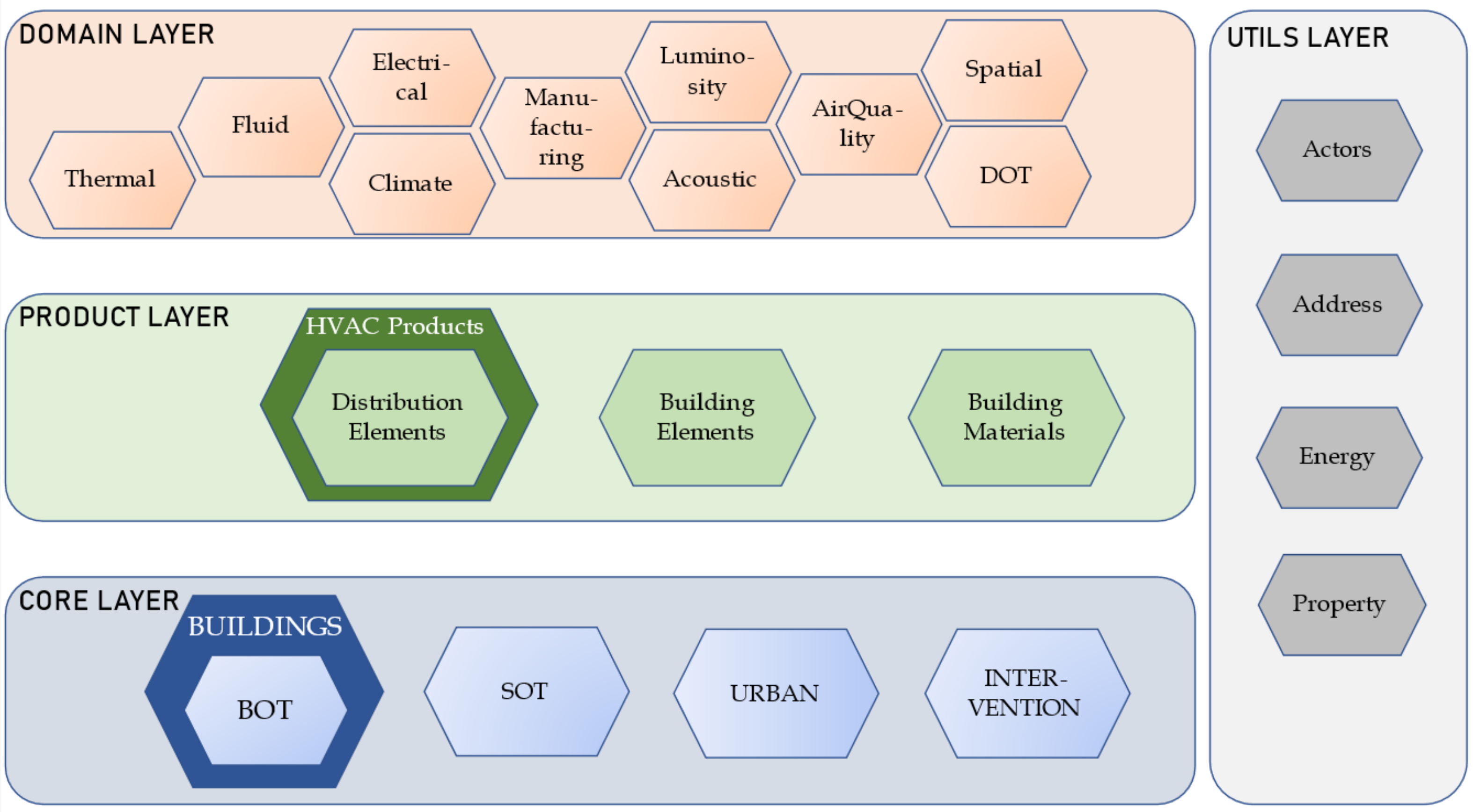
- Different type of renovation, different depth of renovation
- Models as simple as possible

Overview of the data model

https://models.bim4ren.eu

Modularity

- Independent ontologies
- 3 layers (quite similar to IFC layers)
- Design pattern through multiple inheritance



The Core layer

To describe specific aspects of a building, and to attach elements in it according to some specific properties

- **BOT**: Structure of the building
- **SOT**: Systems/network topology (MEP…)

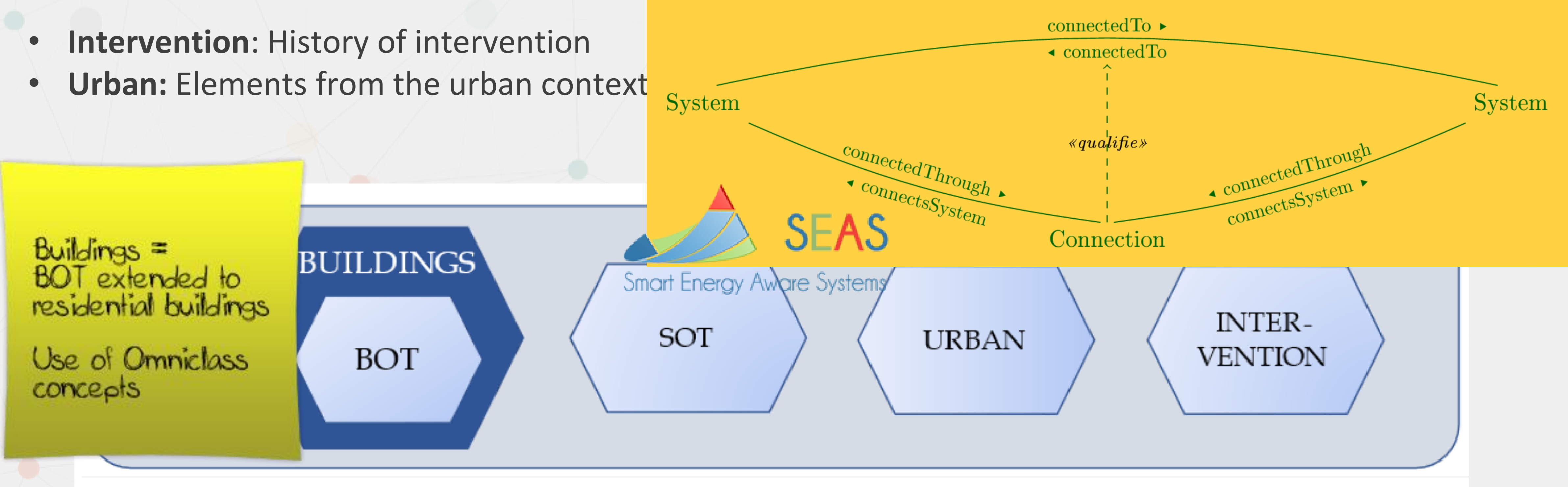
- **Intervention**: History of intervention
- **Urban:** Elements from the urban context

<u>Goal</u>: localize elements ('spatially')

<u>Goal</u>: what is the role of an element within the network? To which elements is it directly connected?

..)

..


Buildings = BOT extended to residential buildings

Use of Omniclass concepts

The Product layer

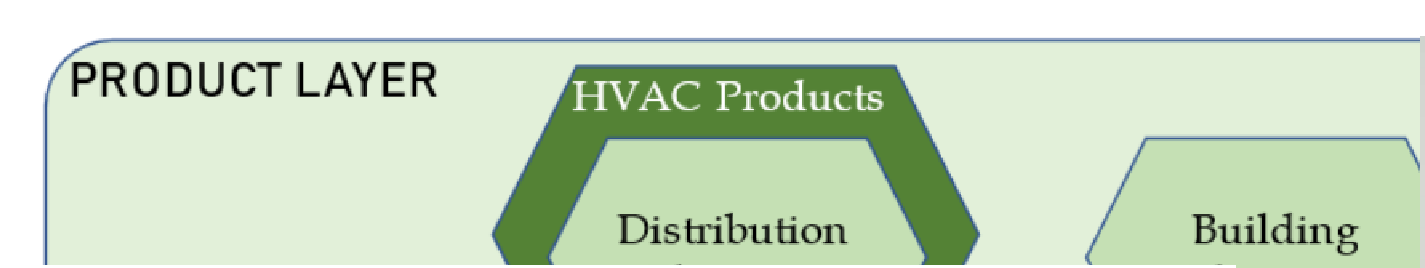
To categorize building products

- DistributionElements
- BuildingElements:
- BuildingMaterials

Goal: categories of products (distribution elements)

Goal: categories of products (building elements)

Goal: categories of materials (for LCA, BEM…)



Ontologies

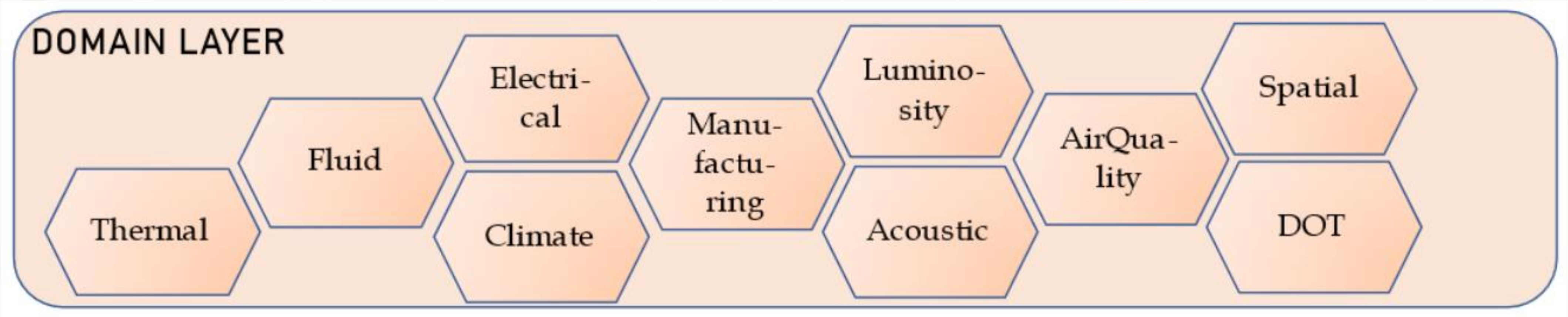
Product ontologies

Building Element: https://pi.pauwel.be/voc/buildingelement

Distribution Element: https://pi.pauwel.be/voc/distributionelement

Civil Element: https://pi.pauwel.be/voc/civilelement

The Domain layer

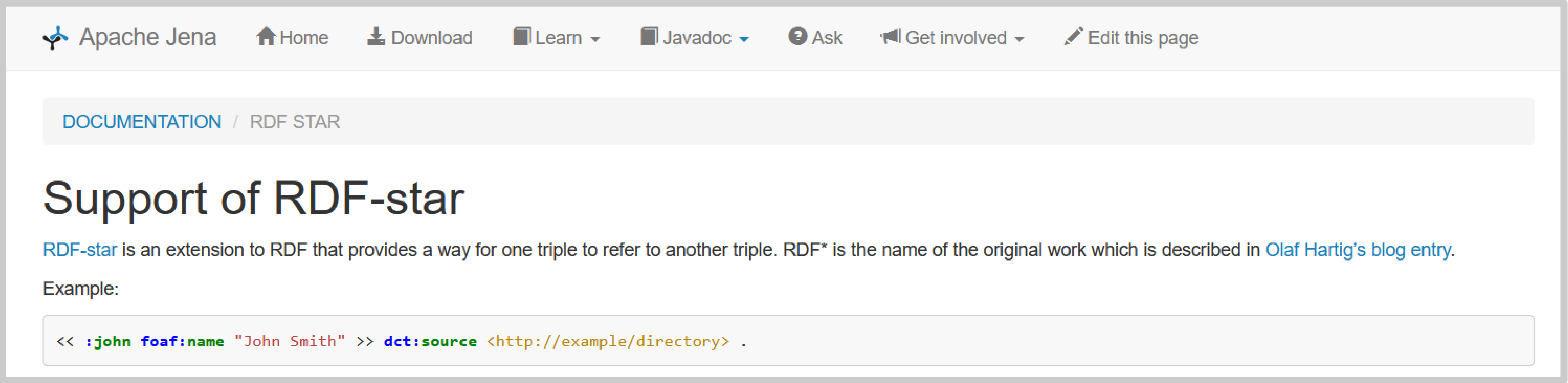


To associate specific domain properties to elements

- **Thermal**: thermal resistance, solar factor, coefficient of performance…
- **Fluid**: capacity, pressure…
- **Electrical**: nominal power, power in/out…
- **Manufacturing:** brand, product

…

The Property layer



DOCUMENTATION / RDF STAR

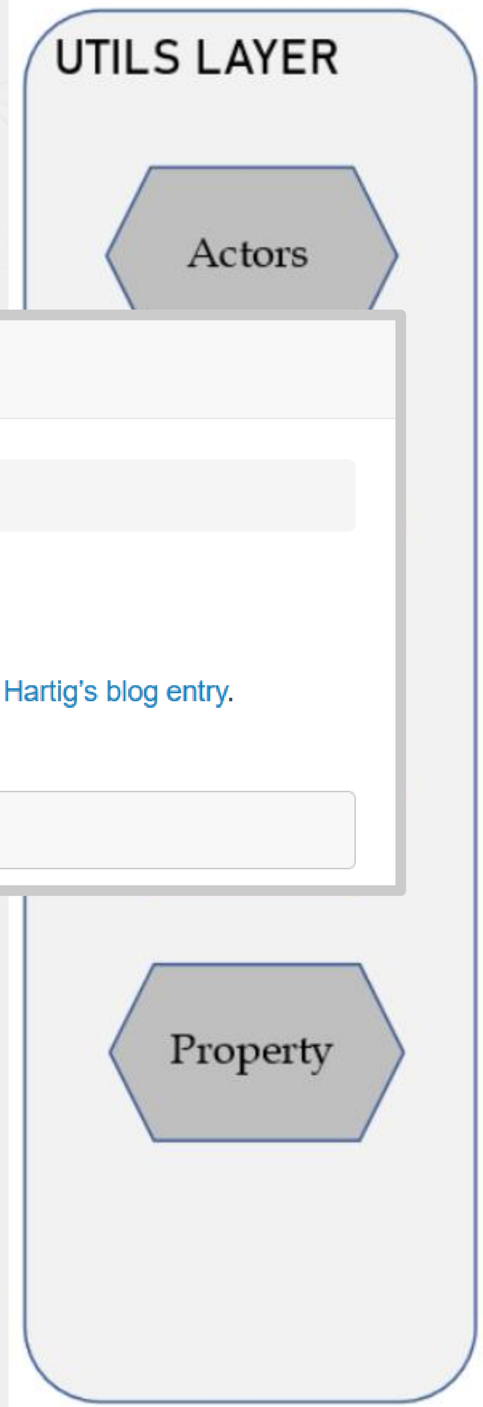
Support of RDF-star

RDF-star is an extension to RDF that provides a way for one triple to refer to another triple. RDF* is the name of the original work which is described in Olaf Hartig's blog entry.

Example:

```
<< :john foaf:name "John Smith" >> dct:source <http://example/directory> .
```

- Next candidate: RDF* !!!



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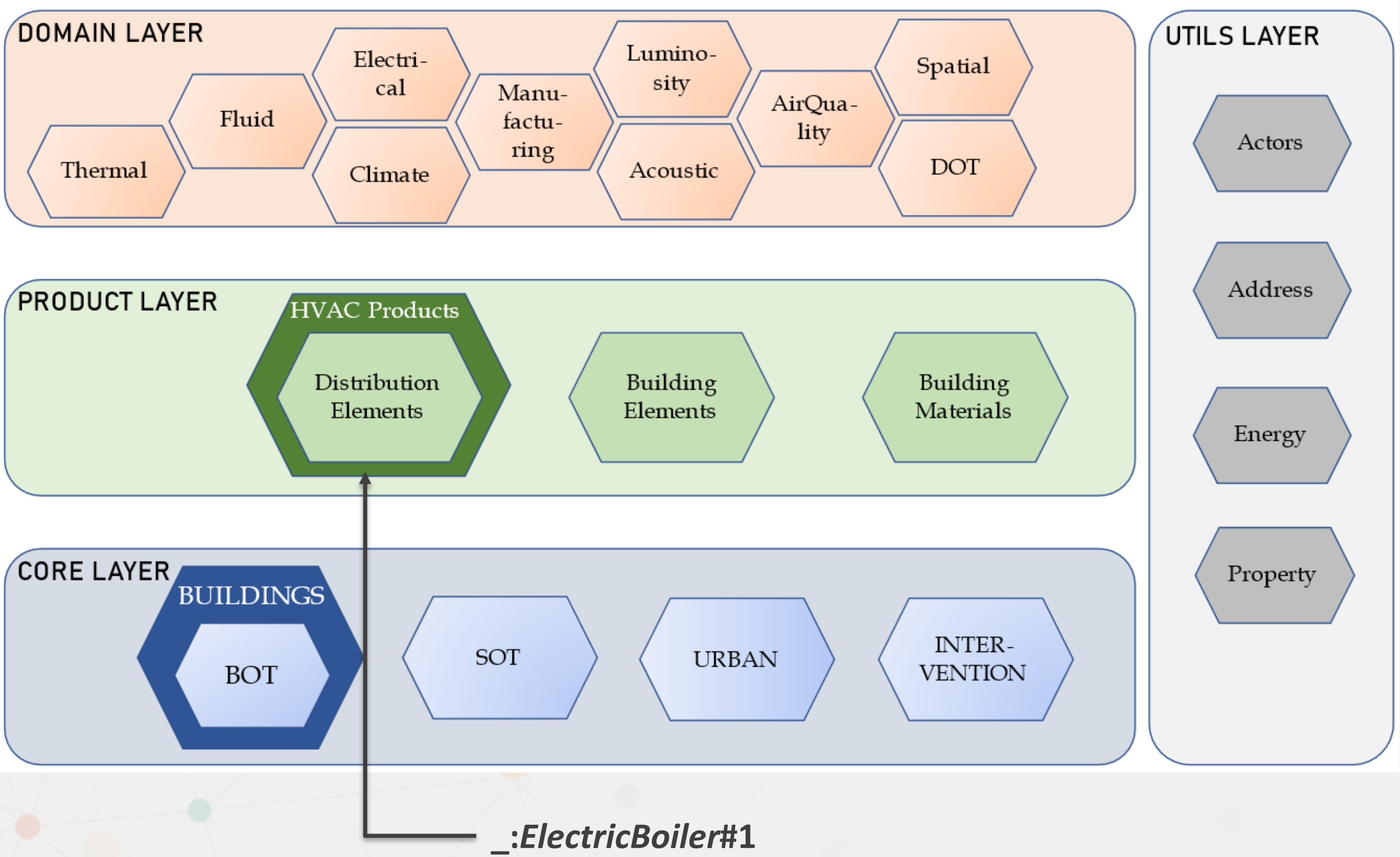
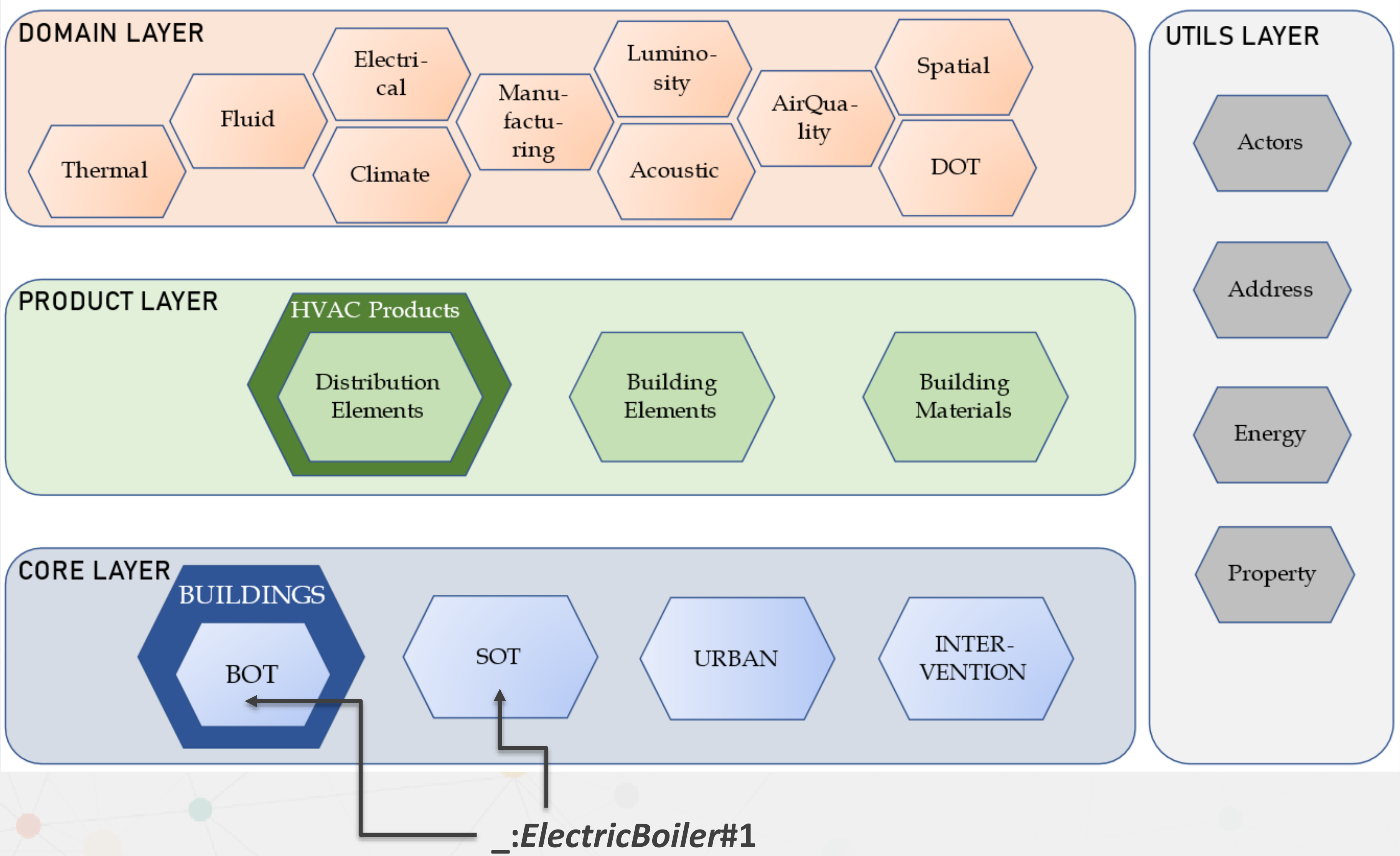
Full Modularity



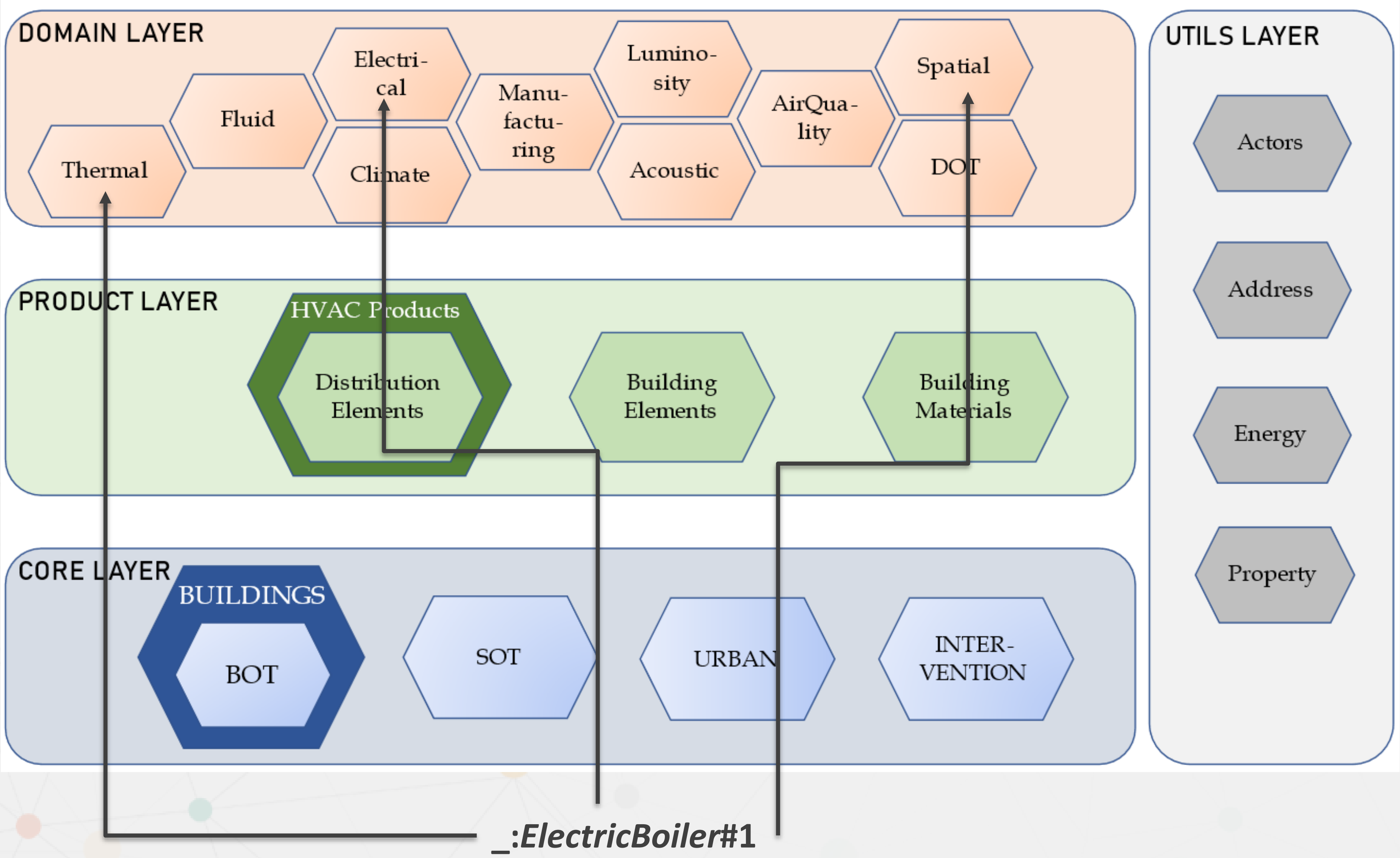
1. What type of product is this?

Full Modularity



1. What type of product is this?
2. Where is it located?
   - In the building
   - In my heating network.

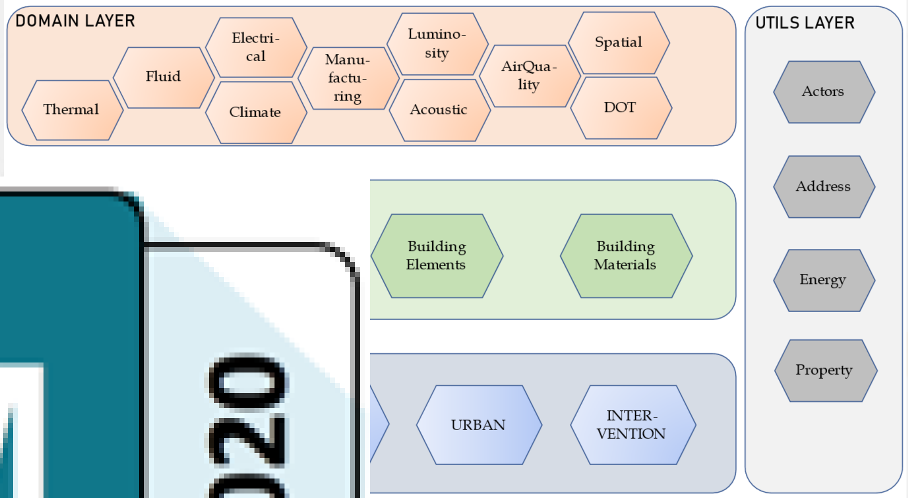
Full Modularity



1. What type of product is this?
2. Where is it located?
   - In the building
   - In my heating network.
3. What properties does it have?
   - For a thermal study
   - For an electrical study/dimensioning
   - Geometrical

Overview of the data model

- Modularity is being discussed in bSI
- Can a simple and modelling language-wide mechanism solv
- The model is **pr**
  - Product layer t
  - Core layer to as
  - Domain layer t Sets…)
- But fr
- Need under

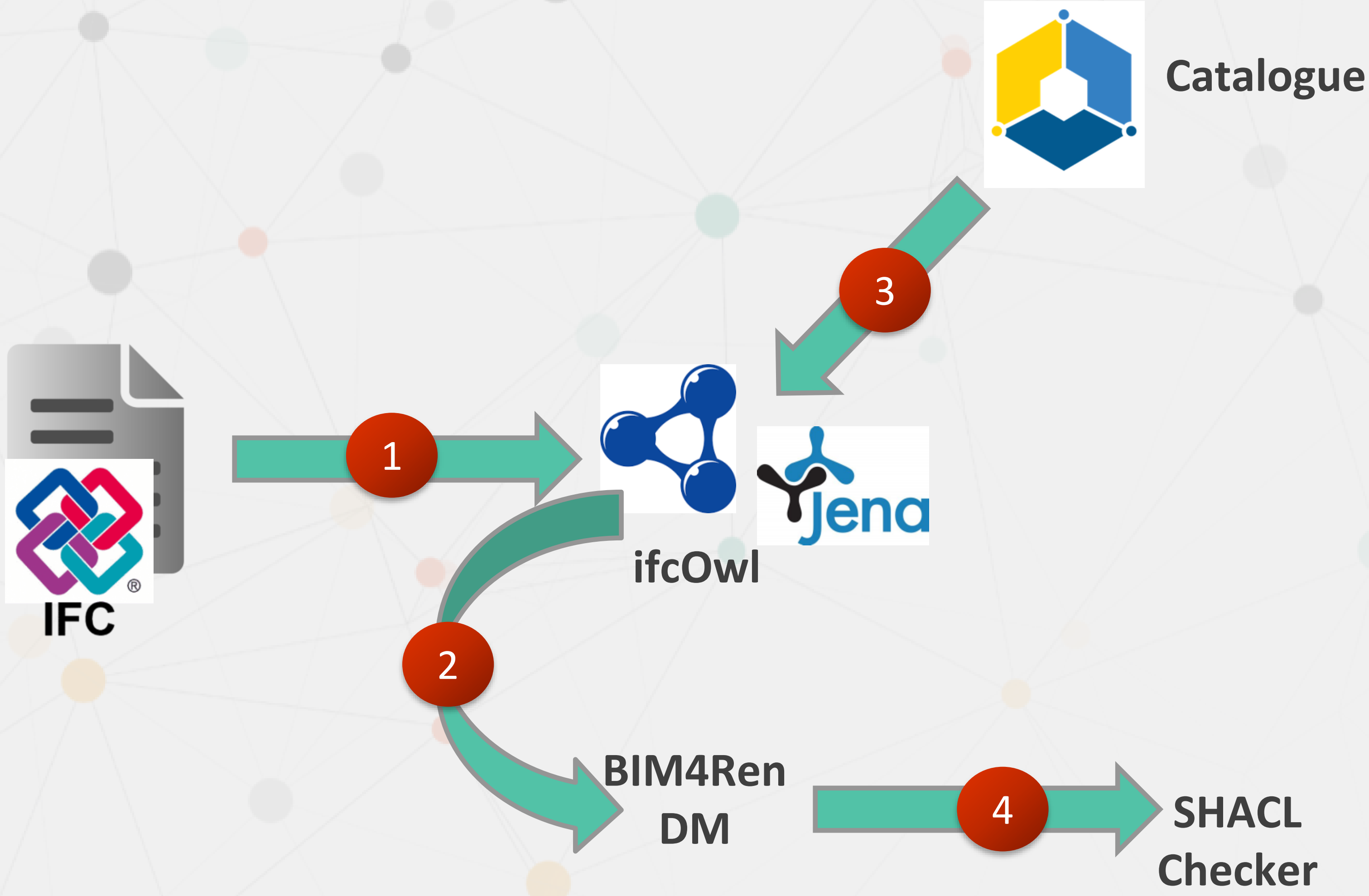


Multiple inheritance for a modular BIM

Pierre Bourreau[1], Nathalie Charbel[1], Jeroen Werbrouck[2], Madhumitha Senthilvel[3], Pieter Pauwels[4] and Jakob Beetz[3]

The conversion process

Why do we need conversion?



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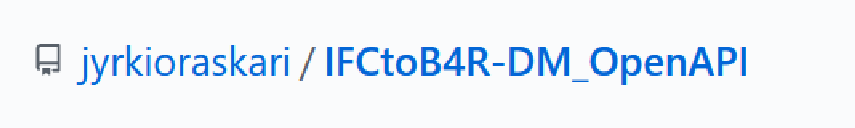
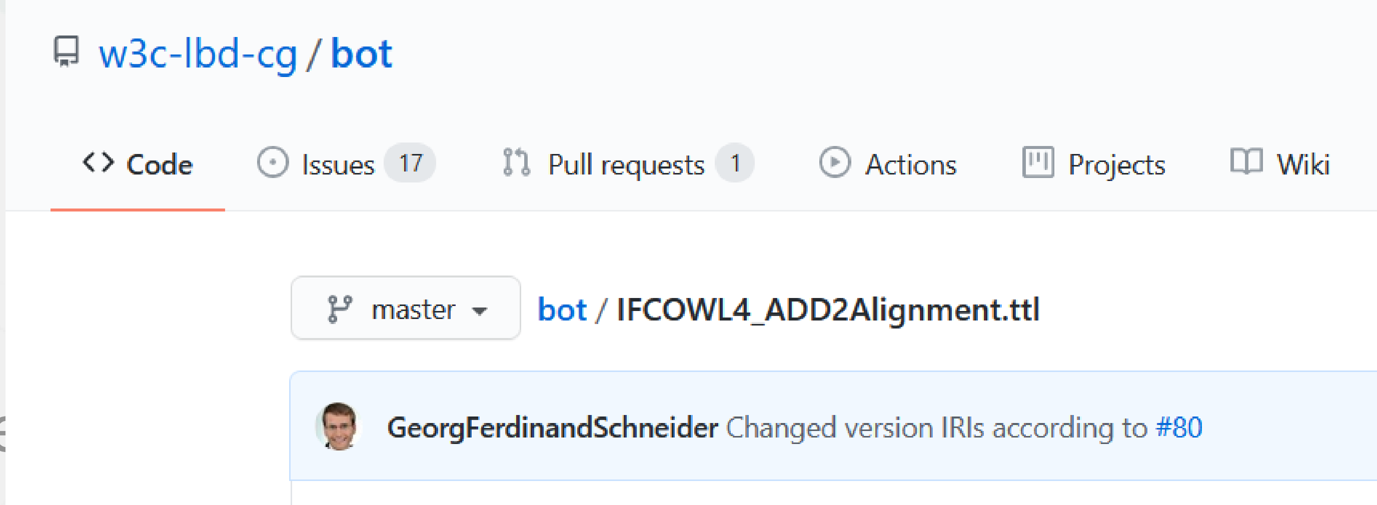
Conversion

1. IFC is the most common and open standard
   - We get IFCs from WiseBIM, ARtoBuild (geometry)
2. But IFC is quite complex => BIM4Ren model
   - Relations are objectified
   - Not all properties we want…
3. Enrich a geometric model with semantic information
   - CSTB develops POBIM based on ISO23386 - Ontology
   - BIM4Ren uses SML (CEN to-be standard)
4. CSTB: POBIM catalogue + ifcOwl
   - **Need to propagate changes on the BIM4Ren DM**
   - **ifcOwl to B4R (BOT+)** and **POBIM to SML**

Different options

- Static/programmatic conversion
  - ++Can cover all types of elements (geometry, relations...)
  - --Need save/convert/import procedure on changes
- Alignment
  - ++Dynamic in the triple store
  - --1-1 mapping
  - --Mostly covers classes, not relations


jyrkioraskari / IFCtoB4R-DM_OpenAPI

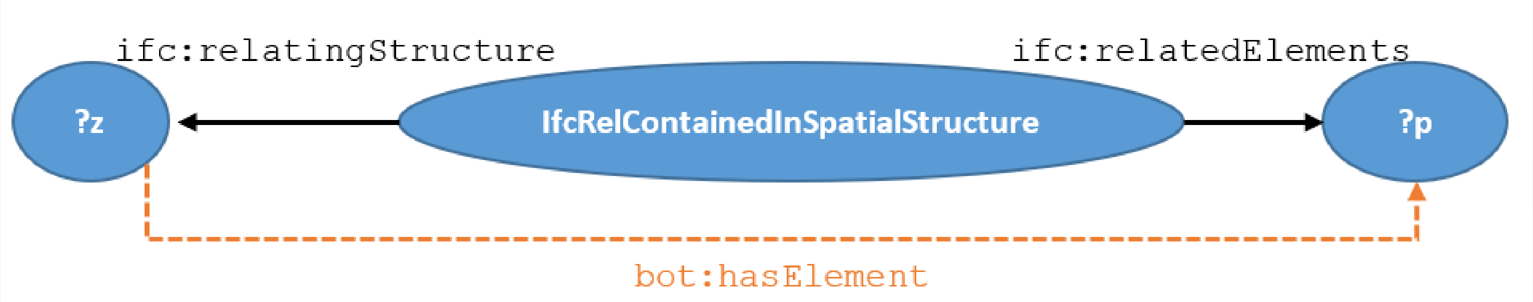

w3c-lbd-cg / bot

bot / IFCOWL4_ADD2Alignment.ttl

GeorgFerdinandSchneider Changed version IRIs according to #80

Relation mappings as Inference

- IFC relations are objectified
- The mapping can be expressed in logic



If ?z is a bot:Zone
And ?z and ?c are connected by an
ifc:relatedElements_IfcRelContainedInSpatialStructure relation
=> Then <?z; bot:hasElement; ?p>

Relation mappings as Inference

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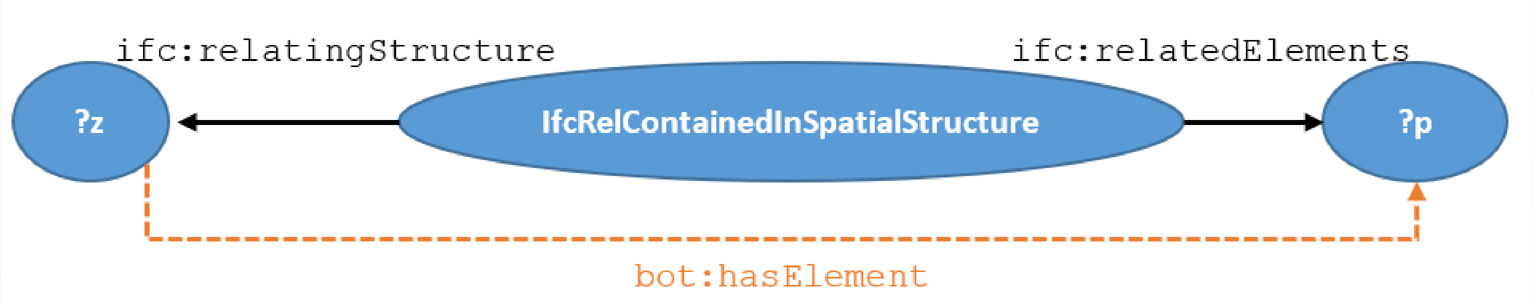
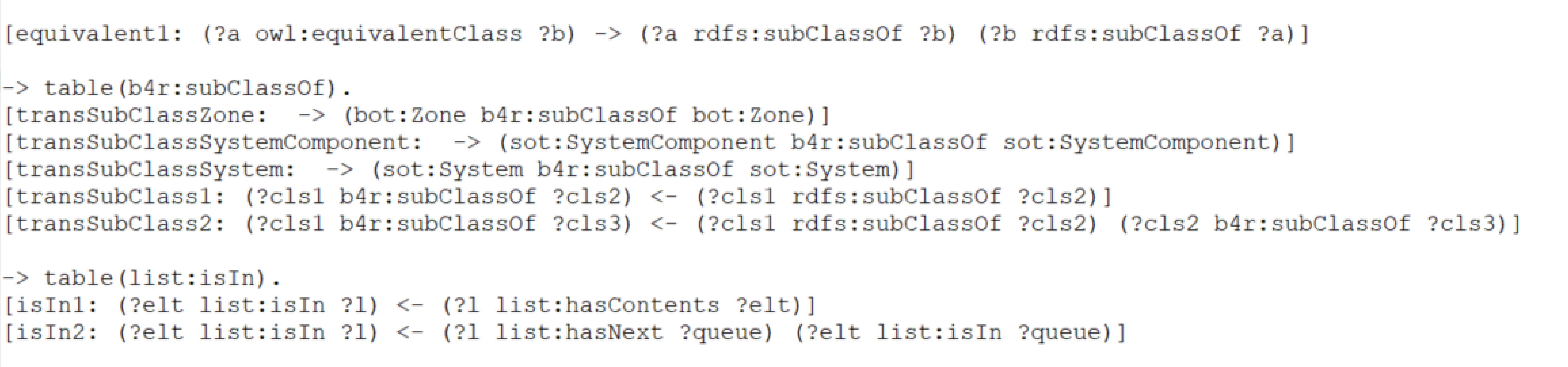
- The mapping can be expressed in logic



```
(?z rdf:type ?cl) (?cl rdfs:subClassOf* bot:Zone)
(?c ifc:relatingStructure_IfcRelContainedInSpatialStructure ?z)
(?c ifc:relatedElements_IfcRelContainedInSpatialStructure ?p)
=> (?z bot:hasElement ?p)
```

Utility rules

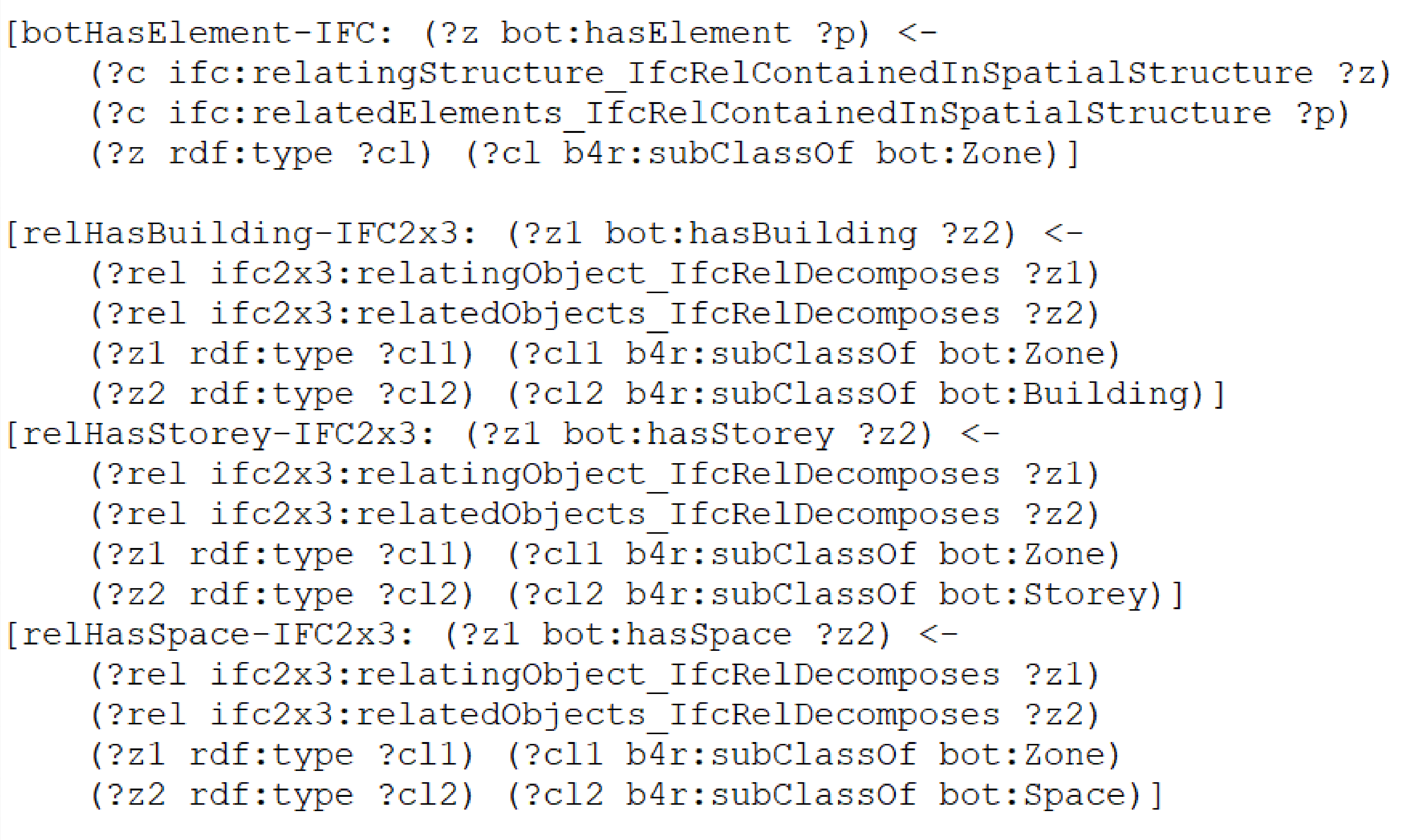


```
[equivalent1: (?a owl:equivalentClass ?b) -> (?a rdfs:subClassOf ?b) (?b rdfs:subClassOf ?a)]

-> table(b4r:subClassOf).
[transSubClassZone:  -> (bot:Zone b4r:subClassOf bot:Zone)]
[transSubClassSystemComponent:  -> (sot:SystemComponent b4r:subClassOf sot:SystemComponent)]
[transSubClassSystem:  -> (sot:System b4r:subClassOf sot:System)]
[transSubClass1: (?cls1 b4r:subClassOf ?cls2) <- (?cls1 rdfs:subClassOf ?cls2)]
[transSubClass2: (?cls1 b4r:subClassOf ?cls3) <- (?cls1 rdfs:subClassOf ?cls2) (?cls2 b4r:subClassOf ?cls3)]

-> table(list:isIn).
[isIn1: (?elt list:isIn ?l) <- (?l list:hasContents ?elt)]
[isIn2: (?elt list:isIn ?l) <- (?l list:hasNext ?queue) (?elt list:isIn ?queue)]
```

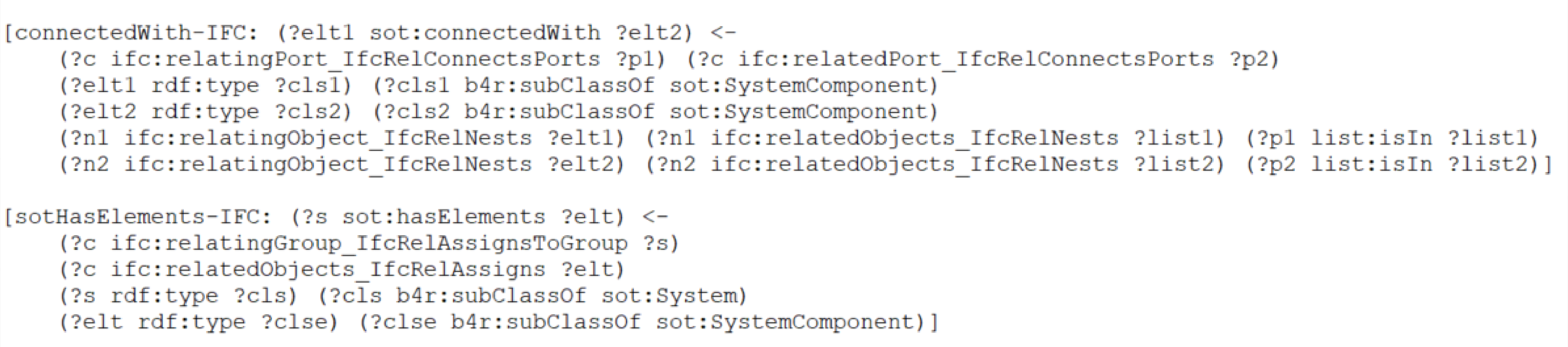
BOT rules



```
[botHasElement-IFC: (?z bot:hasElement ?p) <-
    (?c ifc:relatingStructure_IfcRelContainedInSpatialStructure ?z)
    (?c ifc:relatedElements_IfcRelContainedInSpatialStructure ?p)
    (?z rdf:type ?cl) (?cl b4r:subClassOf bot:Zone)]

[relHasBuilding-IFC2x3: (?z1 bot:hasBuilding ?z2) <-
    (?rel ifc2x3:relatingObject_IfcRelDecomposes ?z1)
    (?rel ifc2x3:relatedObjects_IfcRelDecomposes ?z2)
    (?z1 rdf:type ?cl1) (?cl1 b4r:subClassOf bot:Zone)
    (?z2 rdf:type ?cl2) (?cl2 b4r:subClassOf bot:Building)]
[relHasStorey-IFC2x3: (?z1 bot:hasStorey ?z2) <-
    (?rel ifc2x3:relatingObject_IfcRelDecomposes ?z1)
    (?rel ifc2x3:relatedObjects_IfcRelDecomposes ?z2)
    (?z1 rdf:type ?cl1) (?cl1 b4r:subClassOf bot:Zone)
    (?z2 rdf:type ?cl2) (?cl2 b4r:subClassOf bot:Storey)]
[relHasSpace-IFC2x3: (?z1 bot:hasSpace ?z2) <-
    (?rel ifc2x3:relatingObject_IfcRelDecomposes ?z1)
    (?rel ifc2x3:relatedObjects_IfcRelDecomposes ?z2)
    (?z1 rdf:type ?cl1) (?cl1 b4r:subClassOf bot:Zone)
    (?z2 rdf:type ?cl2) (?cl2 b4r:subClassOf bot:Space)]
```

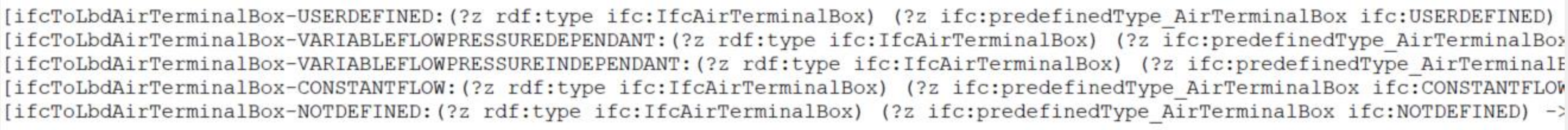
SOT rules



```
[connectedWith-IFC: (?elt1 sot:connectedWith ?elt2) <-
    (?c ifc:relatingPort_IfcRelConnectsPorts ?p1) (?c ifc:relatedPort_IfcRelConnectsPorts ?p2)
    (?elt1 rdf:type ?cls1) (?cls1 b4r:subClassOf sot:SystemComponent)
    (?elt2 rdf:type ?cls2) (?cls2 b4r:subClassOf sot:SystemComponent)
    (?n1 ifc:relatingObject_IfcRelNests ?elt1) (?n1 ifc:relatedObjects_IfcRelNests ?list1) (?p1 list:isIn ?list1)
    (?n2 ifc:relatingObject_IfcRelNests ?elt2) (?n2 ifc:relatedObjects_IfcRelNests ?list2) (?p2 list:isIn ?list2)]

[sotHasElements-IFC: (?s sot:hasElements ?elt) <-
    (?c ifc:relatingGroup_IfcRelAssignsToGroup ?s)
    (?c ifc:relatedObjects_IfcRelAssigns ?elt)
    (?s rdf:type ?cls) (?cls b4r:subClassOf sot:System)
    (?elt rdf:type ?clse) (?clse b4r:subClassOf sot:SystemComponent)]
```

Product layer rules



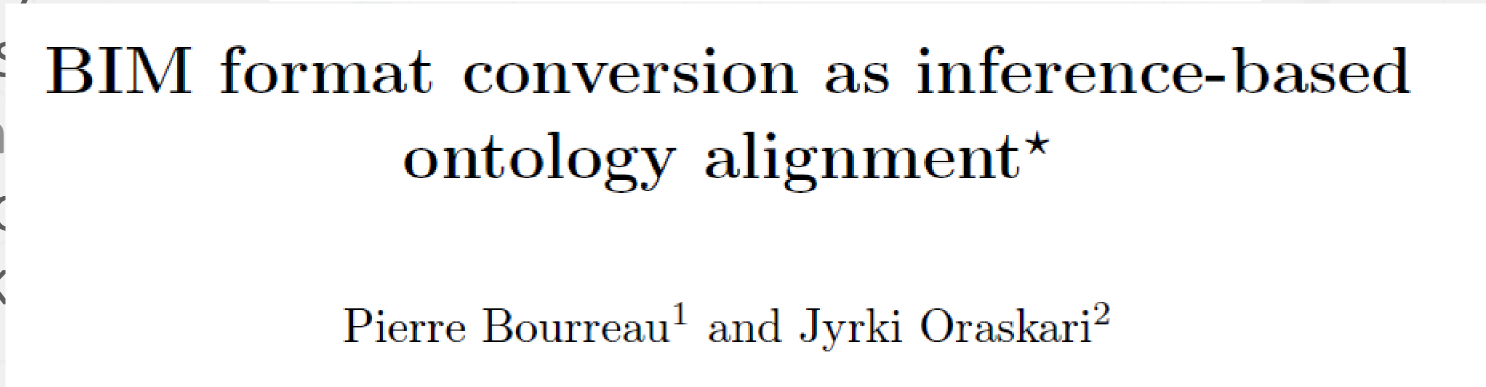
```
[ifcToLbdAirTerminalBox-USERDEFINED:(?z rdf:type ifc:IfcAirTerminalBox) (?z ifc:predefinedType_AirTerminalBox ifc:USERDEFINED)
[ifcToLbdAirTerminalBox-VARIABLEFLOWPRESSUREDEPENDANT:(?z rdf:type ifc:IfcAirTerminalBox) (?z ifc:predefinedType_AirTerminalBox
[ifcToLbdAirTerminalBox-VARIABLEFLOWPRESSUREINDEPENDANT:(?z rdf:type ifc:IfcAirTerminalBox) (?z ifc:predefinedType_AirTerminalB
[ifcToLbdAirTerminalBox-CONSTANTFLOW:(?z rdf:type ifc:IfcAirTerminalBox) (?z ifc:predefinedType_AirTerminalBox ifc:CONSTANTFLOW
[ifcToLbdAirTerminalBox-NOTDEFINED:(?z rdf:type ifc:IfcAirTerminalBox) (?z ifc:predefinedType_AirTerminalBox ifc:NOTDEFINED) ->
```

… + ~750 rules generated with a Python script

Properties

Some thoughts

- Multiplicity of on m
- Already a lot of t ntics (reasoning is one of them)
- Convers
  - Chan model
- Allows c nodel
- Remark t


BIM format conversion as inference-based ontology alignment*

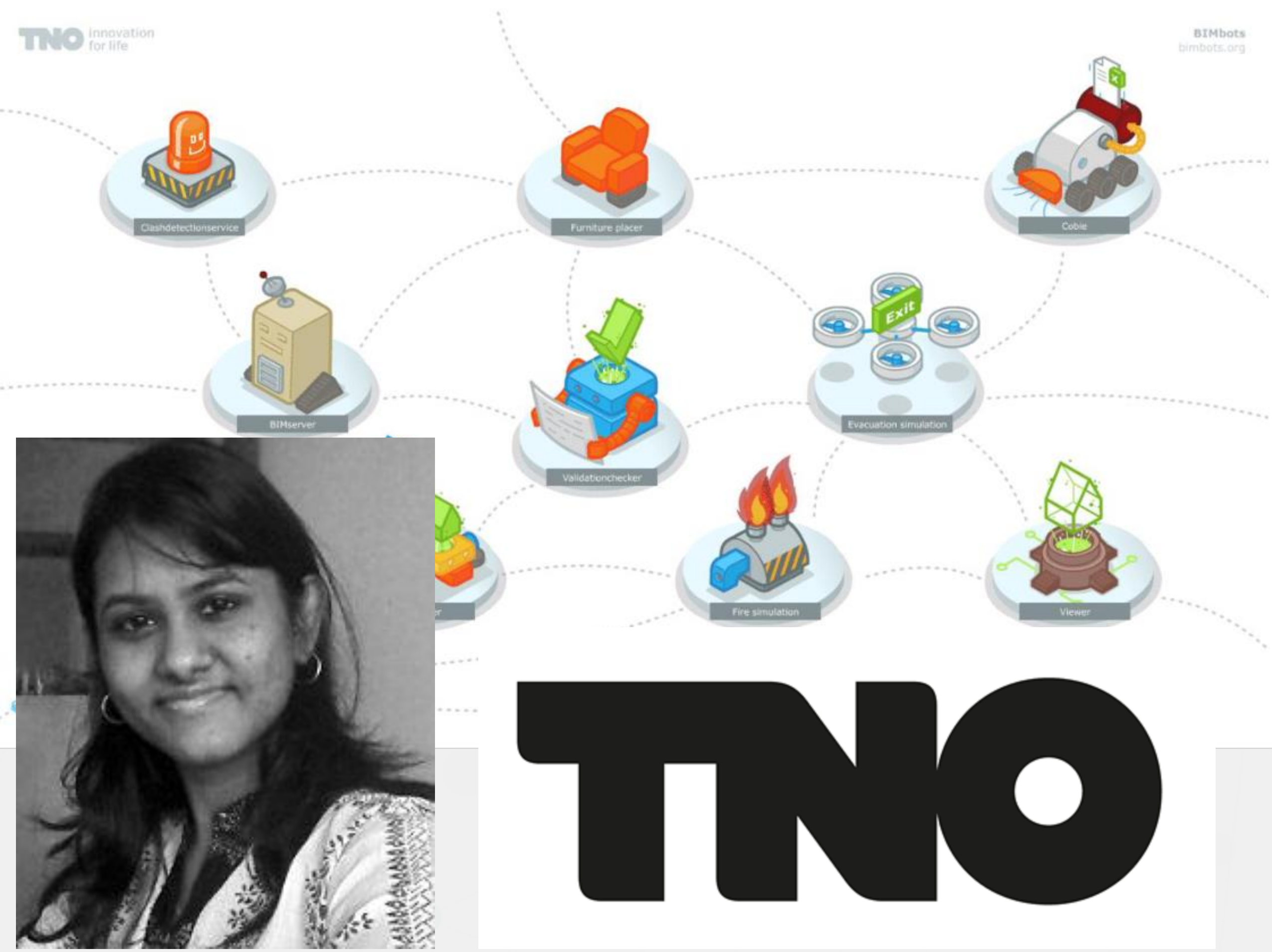
Pierre Bourreau[1] and Jyrki Oraskari[2]

- But no conversion on geometry
- BIM4Ren to ifcOwl: more complex (rules are not safe)
  - Use of `makeTemp()`

Some more things

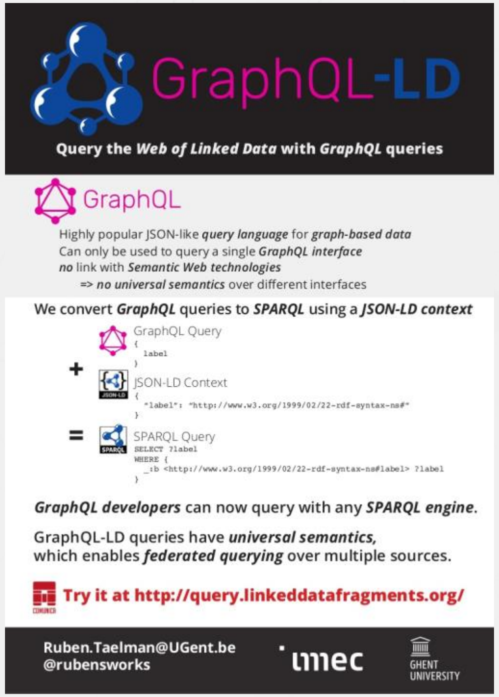
BIM Models checkers

- Checkers as (micro) web services
  - Micro service ≤ Web service
  - BIM Bots
- In BIM4Ren we use SHACL checkers
  - Semantic web micro services
  - Semantic BIM Bots
- Maestro Bot
  - Orchestration service



Data access

- SPARQL for free
  - Expert language
  - 0.X% of web service developers know it
- REST APIs
  - Easy to use
  - Kind of contract between server and client
  - Need to implement SPARQL Queries… tedious work (no ORM)
- GraphQL-LD
  - JS at either client of server
  - Restricted to queries (no edition) – still?
  - Kind of another expert language
- RAMOSE
  - Ease the deployment of REST APIs on top of SPARQL
  - Also restricted to Get
  - Need more work and contributions



GraphQL-LD

Query the *Web of Linked Data* with *GraphQL* queries

GraphQL

Highly popular JSON-like ***query language*** for ***graph-based data***
Can only be used to query a single ***GraphQL interface***
no link with ***Semantic Web technologies***
=> ***no universal semantics*** over different interfaces

We convert ***GraphQL*** queries to ***SPARQL*** using a ***JSON-LD context***

GraphQL Query
```
{
  label
}
```
+ JSON-LD Context
```
{
  "label": "http://www.w3.org/1999/02/22-rdf-syntax-ns#"
}
```
= SPARQL Query
```
SELECT ?label
WHERE {
  _:b <http://www.w3.org/1999/02/22-rdf-syntax-ns#label> ?label
}
```

GraphQL developers can now query with any ***SPARQL engine***.

GraphQL-LD queries have ***universal semantics,***
which enables ***federated querying*** over multiple sources.

Try it at http://query.linkeddatafragments.org/

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