Linked Data and Semantic Web

Link to slides: http://tiny.cc/7y4ukz

2011

BSc Architectural Engineering

DTU

2011	BSc Architectural Engineering	DTU
2013	MSc Architectural Engineering	DTU

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2013-2016	HVAC Engineer Axel Towers | Bispebjerg Hospital lab&log

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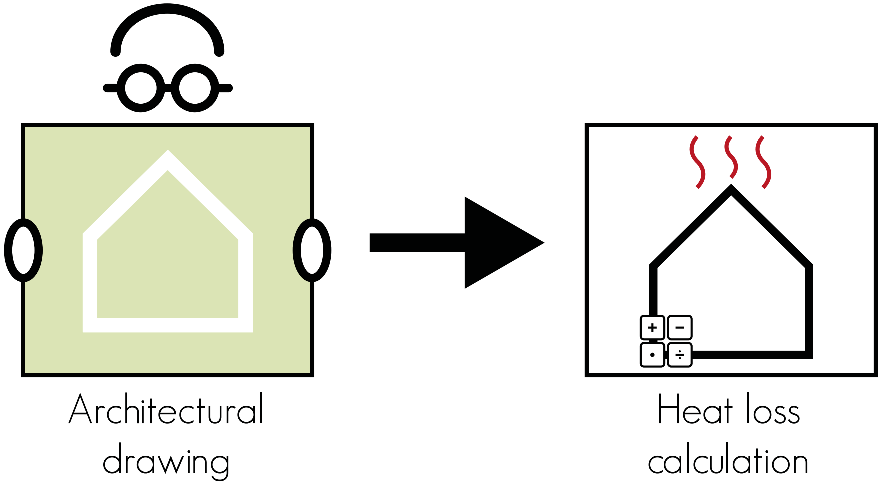
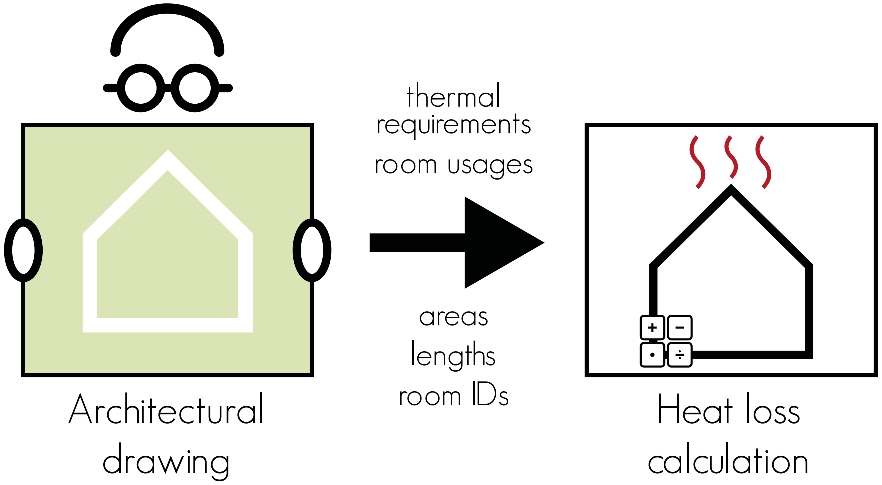
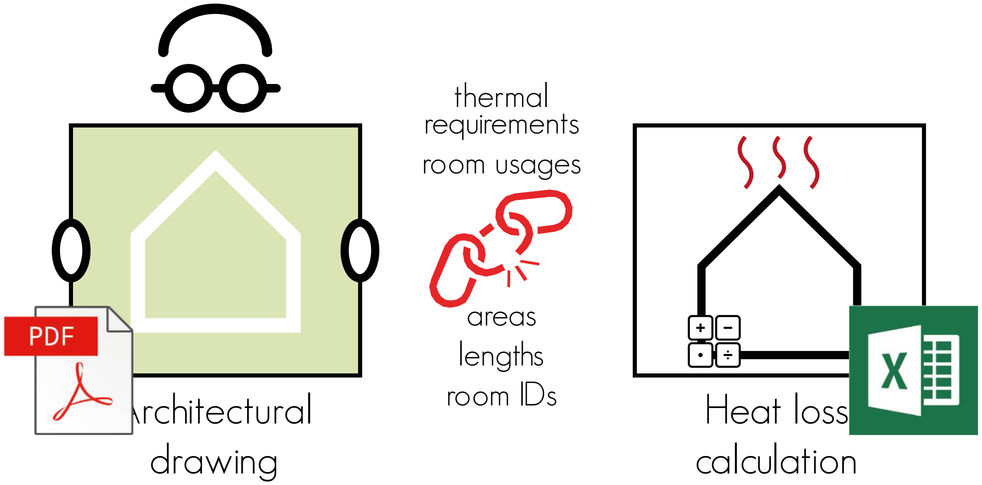
2019-	Niras web-BIM

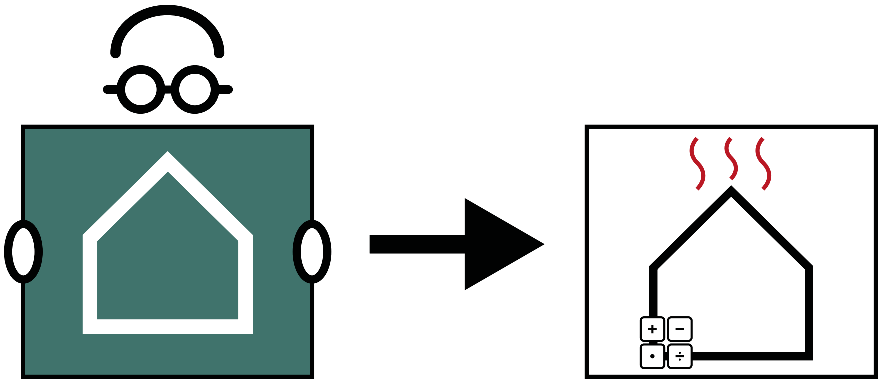
Some personal statements

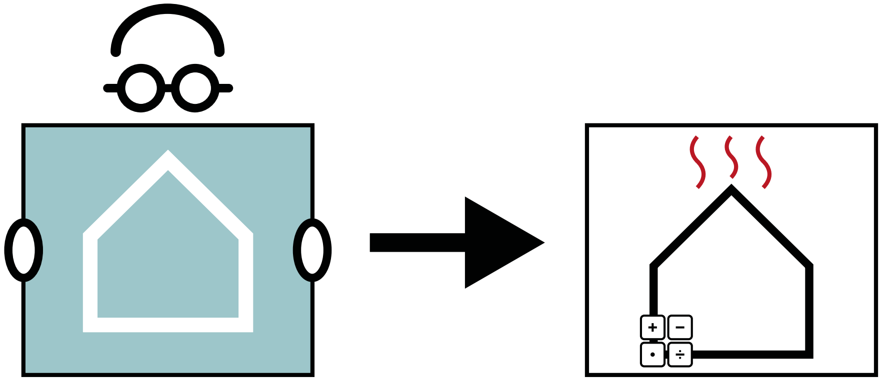
"Our industry works in a document-centric manner rather than a data-centric one"

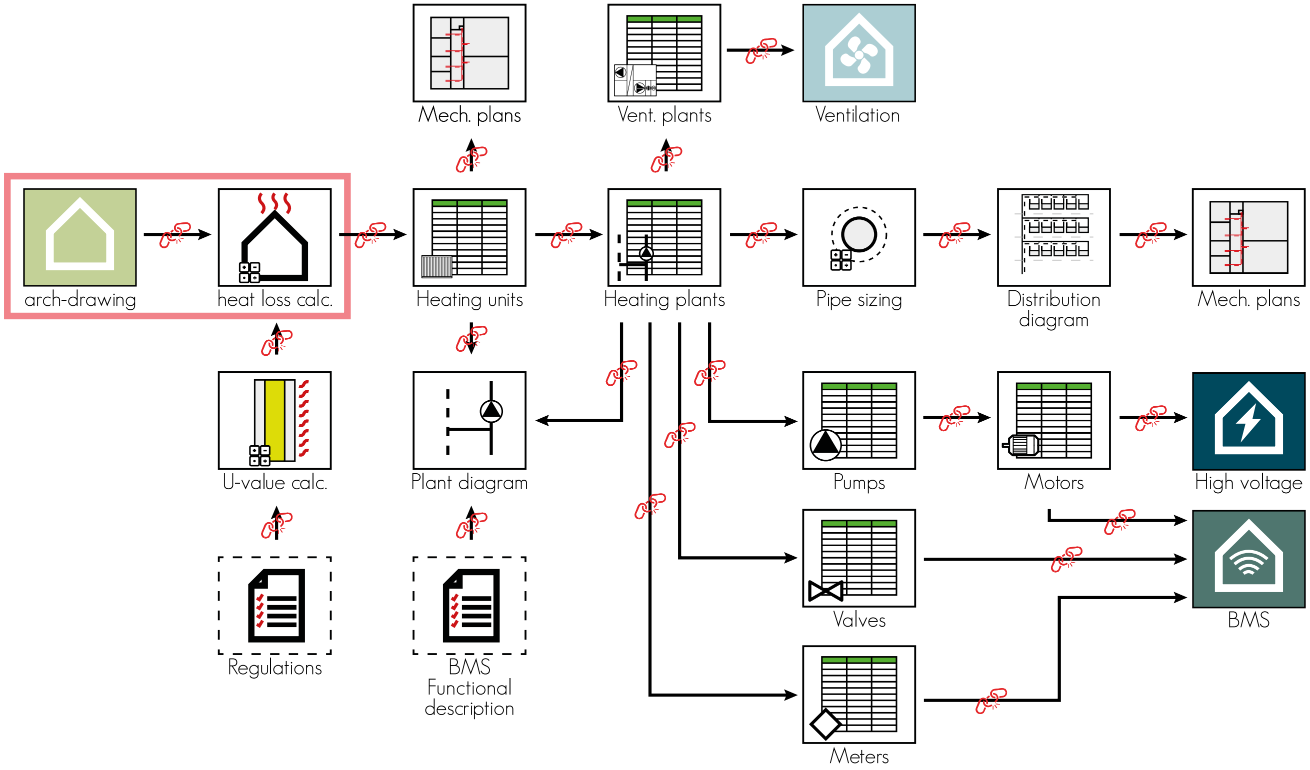

Architectural drawing
Heat loss calculation


thermal
requirements
room usages
areas
lengths
room IDs
Architectural
drawing
Heat loss
calculation

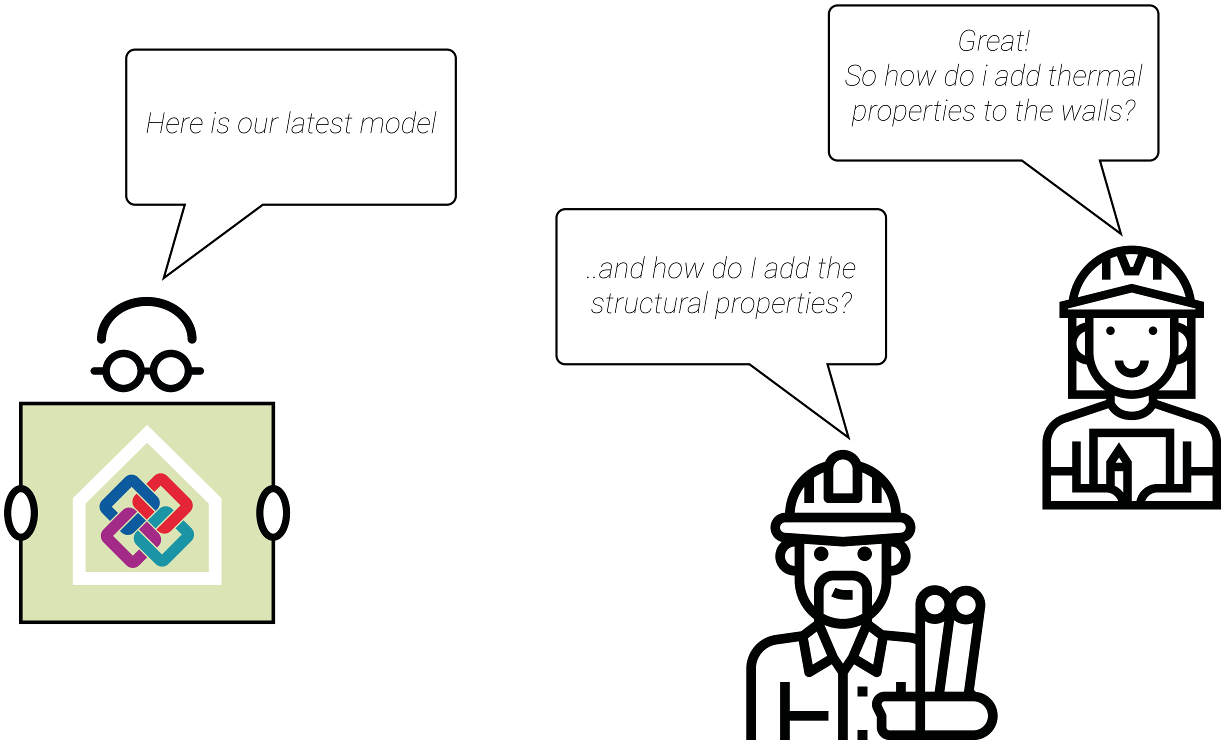

PDF
Architectural
drawing
thermal
requirements
room usages
areas
lengths
room IDs
Heat loss
calculation

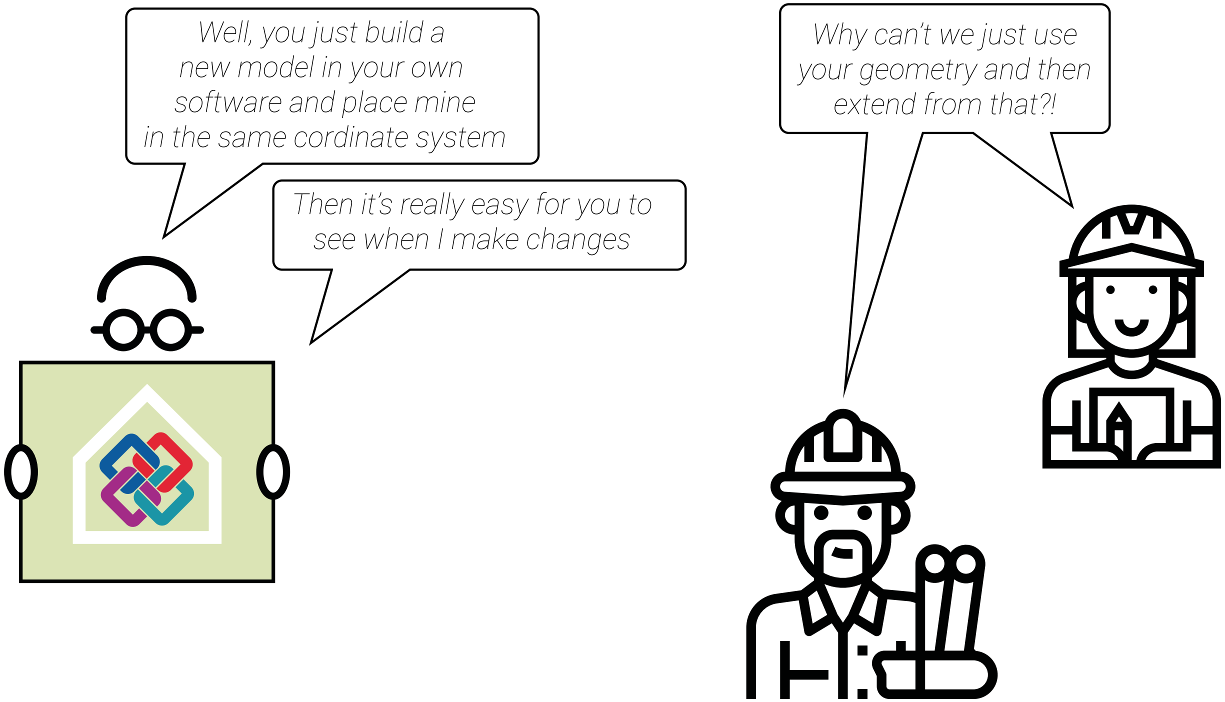




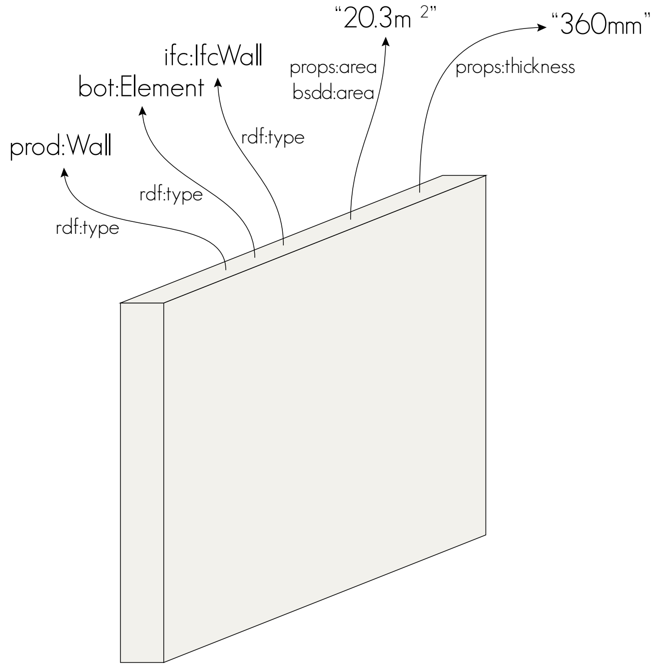

Mech. plans
Vent. plants
Ventilation
arch-drawing
heat loss calc.
Heating units
Heating plants
Pipe sizing
Distribution diagram
Mech. plans
U-value calc.
Plant diagram
Pumps
Motors
High voltage
Valves
BMS
Regulations
BMS Functional description
Meters

"Exchange of BIM-data as files makes data integration impossible"

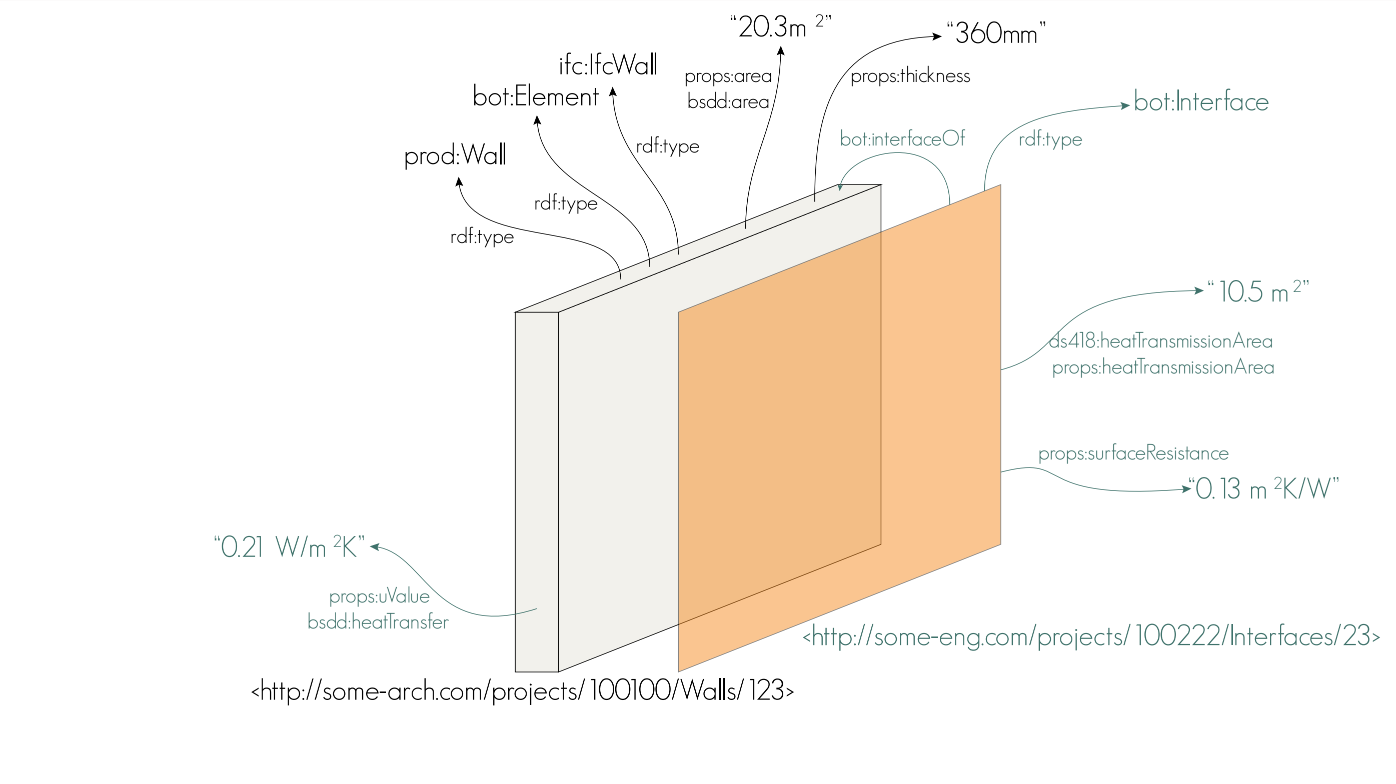

Here is our latest model
Great!
So how do i add thermal properties to the walls?
..and how do I add the structural properties?


Well, you just build a new model in your own software and place mine in the same cordinate system
Then it's really easy for you to see when I make changes
Why can't we just use your geometry and then extend from that?!

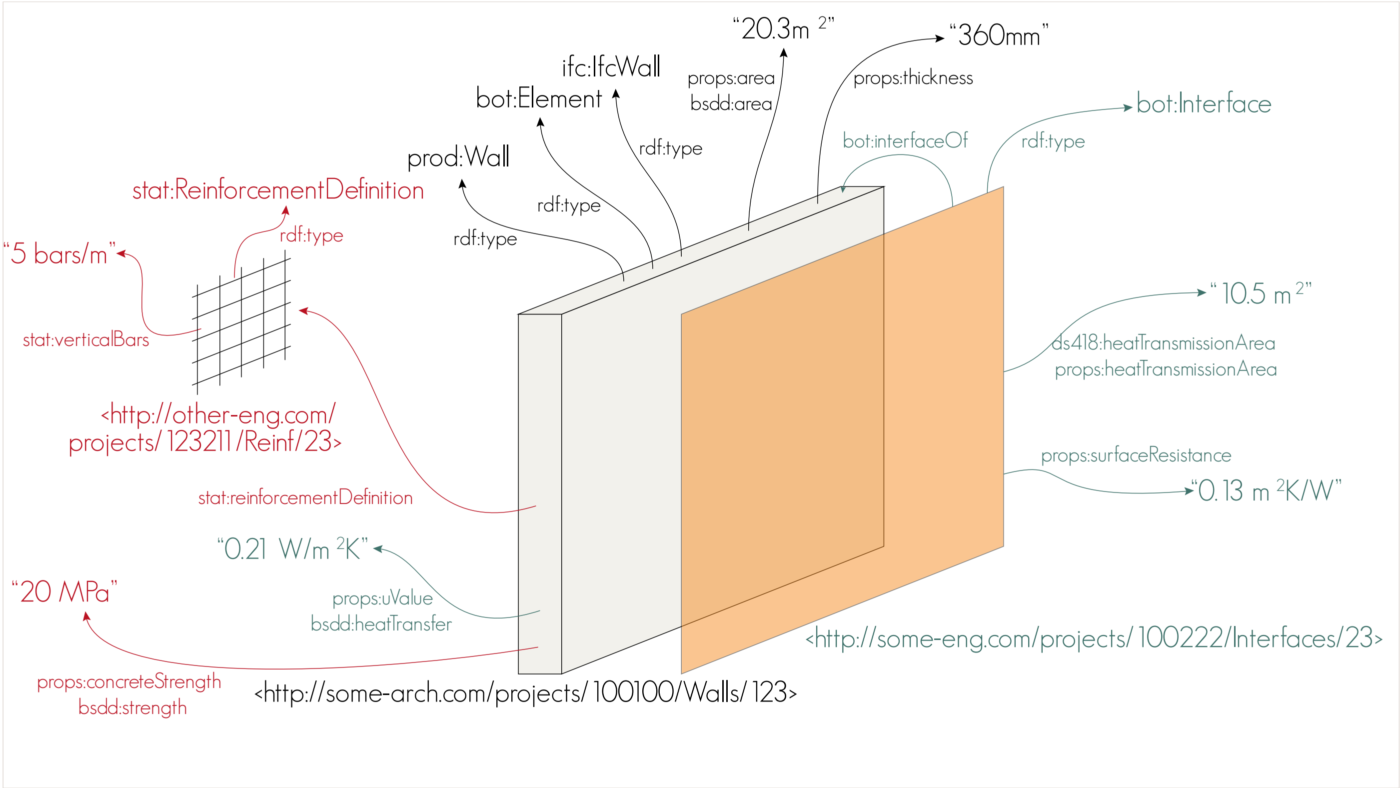
"We need to move from Today's monolitic nature of BIM to a network based one"



prod:Wall
rdf:type
bot:Element
rdf:type
ifc:IfcWall
rdf:type
"20.3m 2"
props:area
bsdd:area
"360mm"
props:thickness



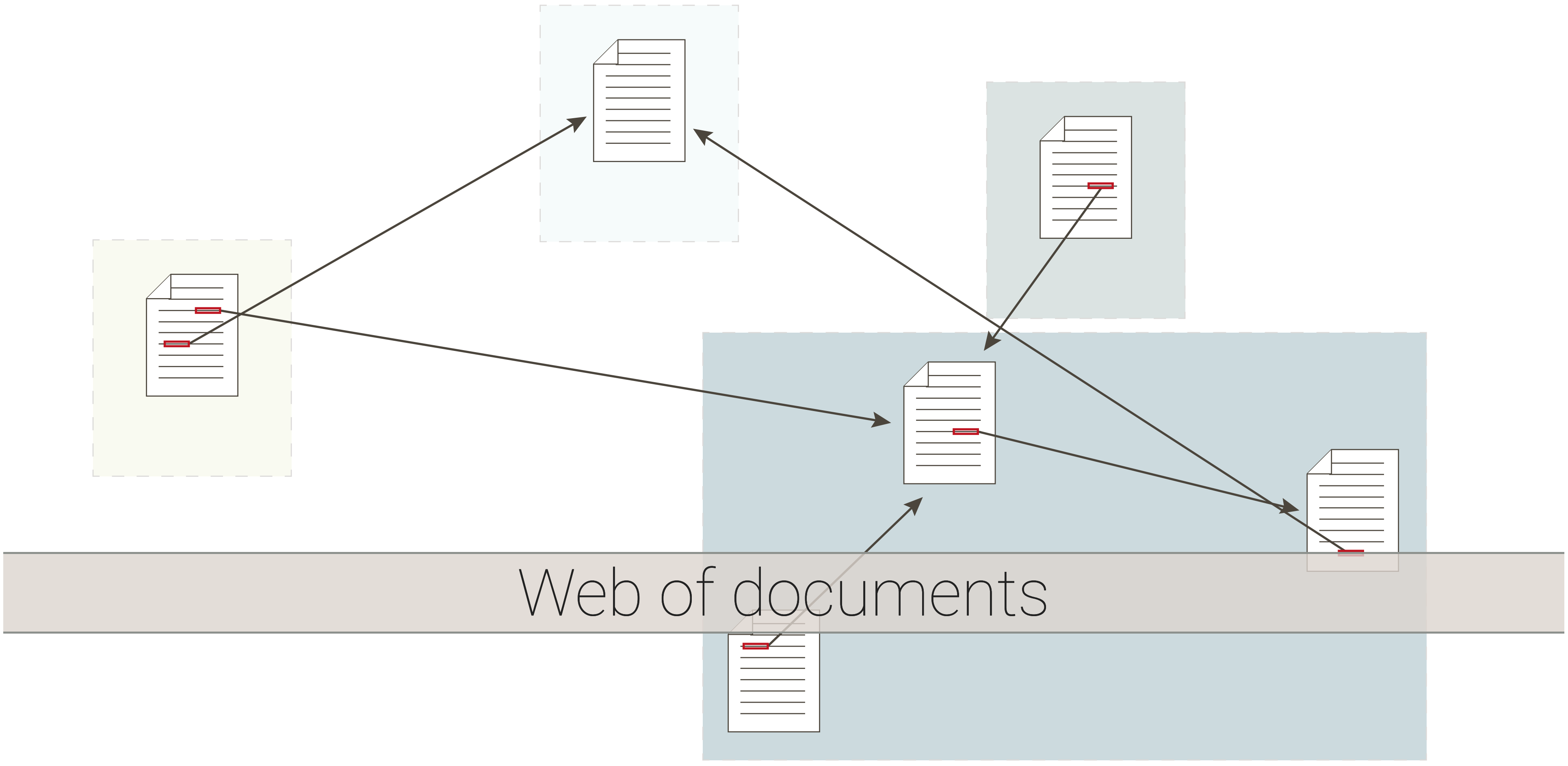
"20.3m 2"
"360mm"
ifc:IfcWall
props:area
bsdd:area
props:thickness
bot:Element
bot:Interface
bot:interfaceOf
rdf:type
prod:Wall
rdf:type
rdf:type
rdf:type
"10.5 m 2"
ds418:heatTransmissionArea
props:heatTransmissionArea
props:surfaceResistance
"0.13 m 2K/W"
"0.21 W/m 2K"
props:uValue
bsdd:heatTransfer
<http://some-eng.com/projects/100222/Interfaces/23>
<http://some-arch.com/projects/100100/Walls/123>

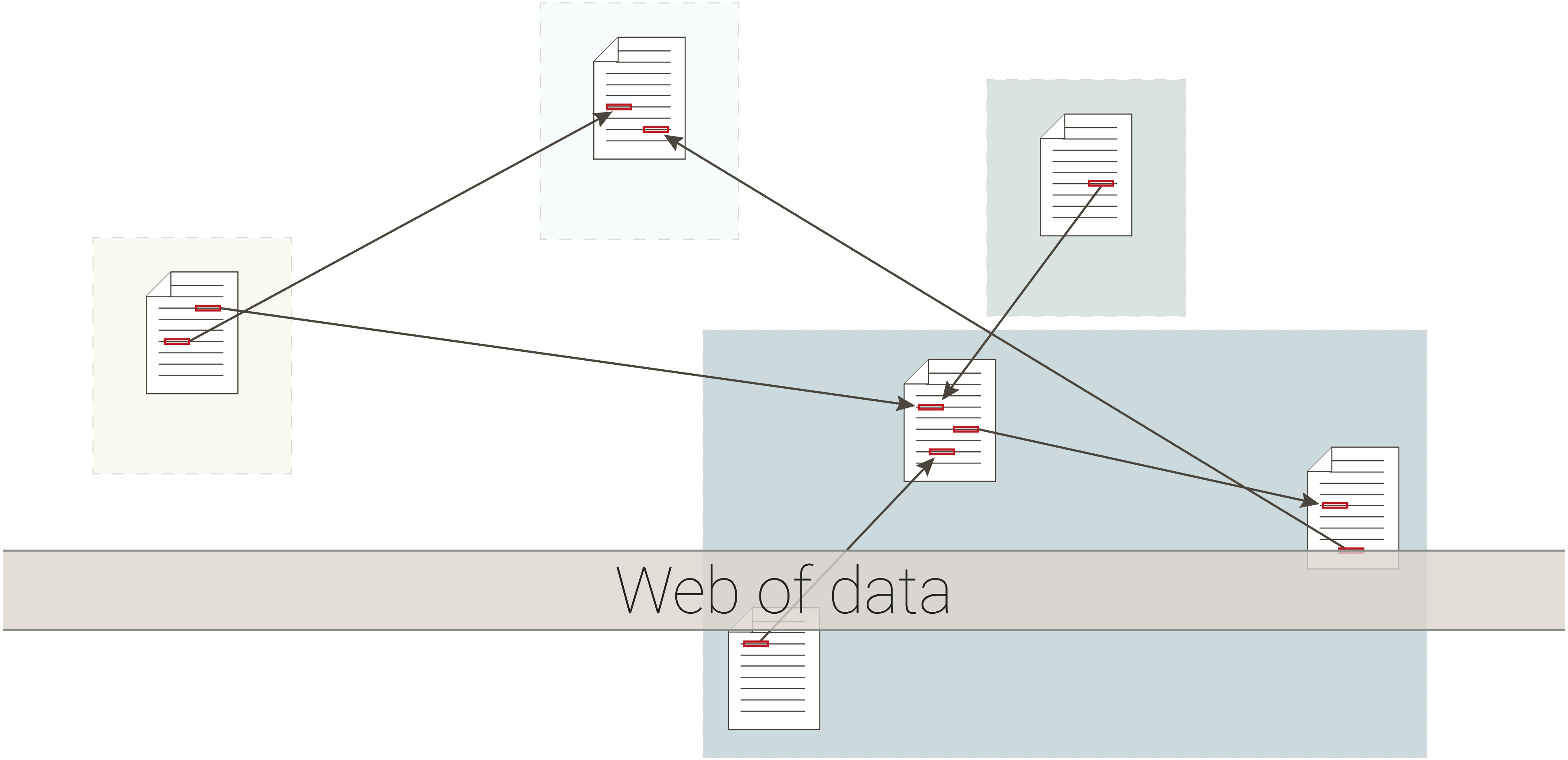


"20.3m 2"
"360mm"
ifc:IfcWall
props:area
bsdd:area
props:thickness
bot:Element
bot:Interface
bot:interfaceOf
rdf:type
rdf:type
prod:Wall
stat:ReinforcementDefinition
rdf:type
rdf:type
rdf:type
"5 bars/m"
stat:verticalBars
"10.5 m 2"
ds418:heatTransmissionArea
props:heatTransmissionArea
<http://other-eng.com/
projects/123211/Reinf/23>
props:surfaceResistance
"0.13 m 2K/W"
stat:reinforcementDefinition
"0.21 W/m 2K"
"20 MPa"
props:uValue
bsdd:heatTransfer
<http://some-eng.com/projects/100222/Interfaces/23>
props:concreteStrength
bsdd:strength
<http://some-arch.com/projects/100100/Walls/123>

So how do we do this?

The idea is to use the existing infrastructure of the World Wide Web to mediate a distributed, network-based BIM


Web of documents


Web of data

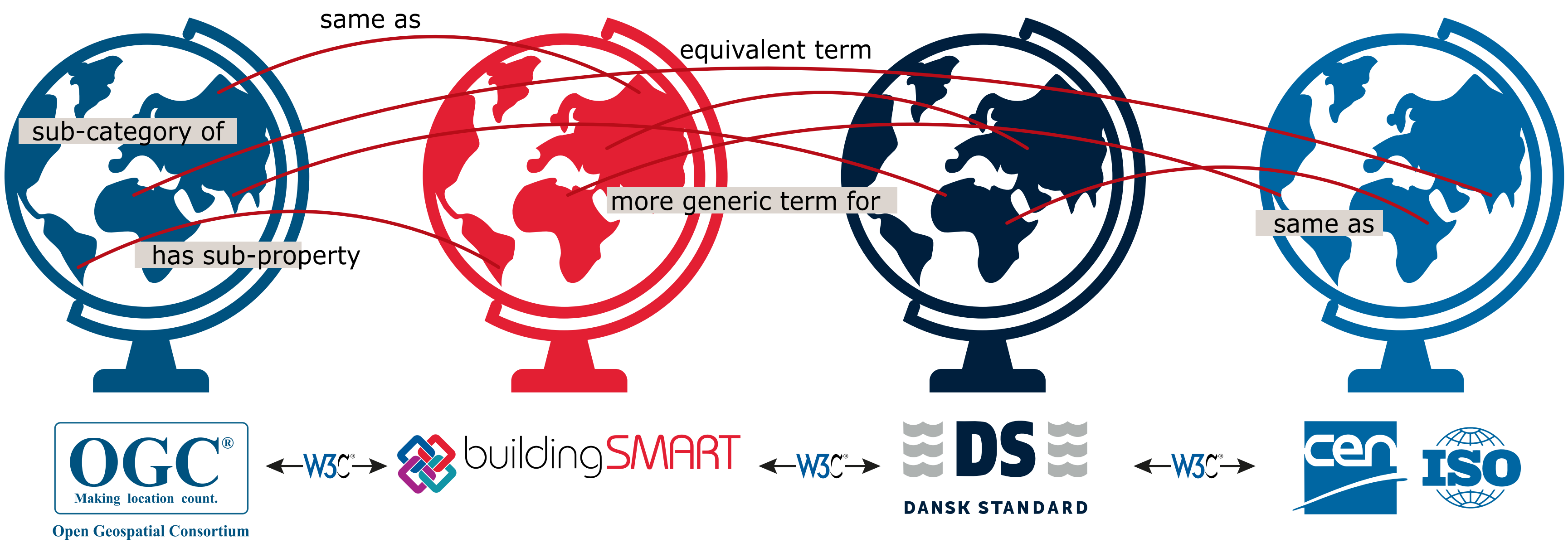
Data is stored and hosted by the stakeholder who generated it and is responsible for it

Data can be shared with authenticated people or be made publicly available

The model data can be extended with Linked Open Data (products, material properties, IoT, GIS)

Even the schemas are distributed, and can therefore extend one another

Current situation: Open standards in isolated closed worlds



Linked data benefit: Standards use, extend and refer to one another

The technical details

Linked Data principles

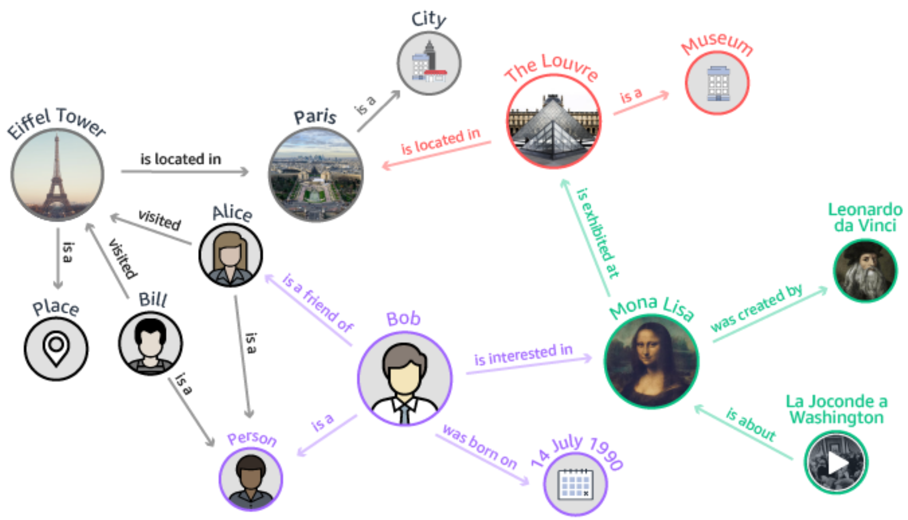
1. Use URIs as names for things
2. Use HTTP URIs so that people can look up those names
3. When someone looks up a URI, provide useful information, using the standards (RDF, SPARQL)
4. Include links to other URIs. so that they can discover more things

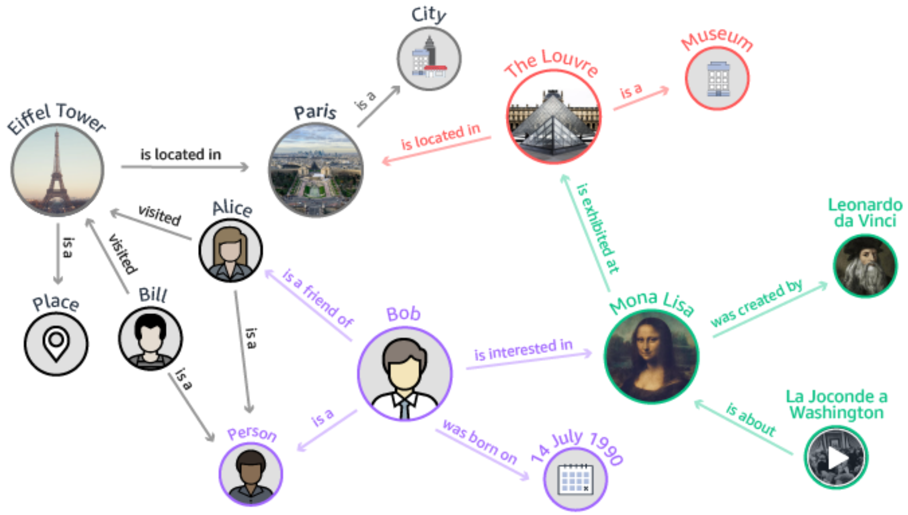
(The semantic web but not necessarily with reasoning and description logics)

RDF: Resource Description Framework


predicate
Subject
Object


has_window
Wall_002
Window_022


City
is a
Paris
The Louvre
is a
Museum
Eiffel Tower
is located in
is located in
visited
Alice
is exhibited at
Leonardo da Vinci
is a
visited
Place
Bill
is a
is a friend of
Bob
Mona Lisa
was created by
is interested in
is a
is a
La Joconde a Washington
is about
Person
was born on
14 July 1990



City
The Louvre
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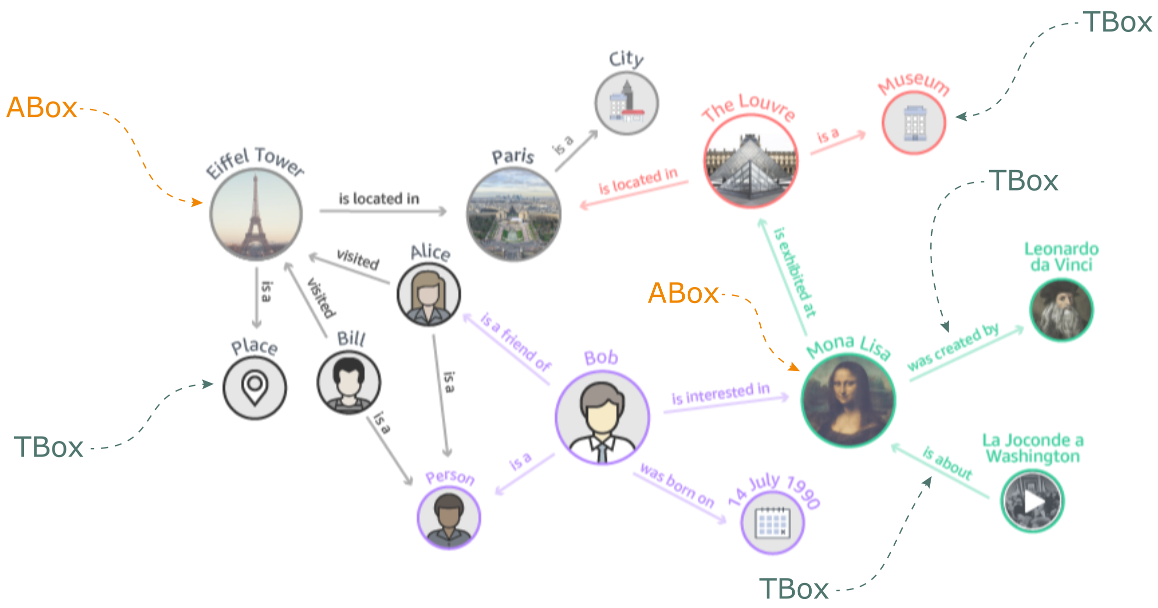

ABox
Eiffel Tower
is located in
Paris
is a
City
The Louvre
is located in
is a
Museum
TBox
TBox
visited
Alice
visited
Bill
is a
Place
is a
is a
is a friend of
Bob
is exhibited at
ABox
Mona Lisa
was created by
Leonardo da Vinci
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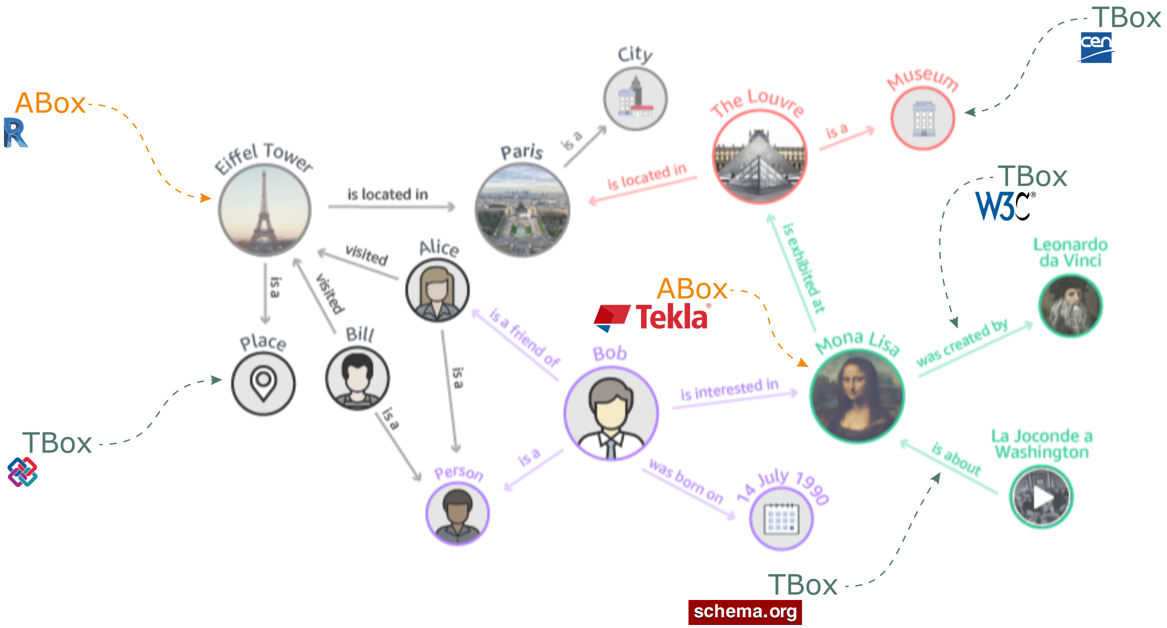
TBox
TBox



ABox
TBox
City
Museum
The Louvre
is a
Eiffel Tower
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is a
is located in
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TBox
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visited
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is a
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Place
Bill
is a friend of
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is a
is interested in
TBox
is a
La Joconde a Washington
Person
is a
was born on
14 July 1990
is about
TBox
schema.org

```
# CLASSIFICATION
<Eiffel_Tower> <is_a> <Place> .
<Paris> <is_a> <City> .
<Bill> <is_a> <Person> .
<Alice> <is_a> <Person> .
<Bob> <is_a> <Person> .
<The_Louvre> <is_a> <Museum> .
```

These are not HTTP URIs

```
# CLASSIFICATION
<Eiffel_Tower> <is_a> <Place> .
<Paris> <is_a> <City> .
<Bill> <is_a> <Person> .
<Alice> <is_a> <Person> .
<Bob> <is_a> <Person> .
<The_Louvre> <is_a> <Museum> .
```

```
<https://my-awesome-knowledge-graph.org/resources/Eiffel_Tower>
  <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://schema.or
<https://my-awesome-knowledge-graph.org/resources/Paris>
  <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://schema.or
<https://my-awesome-knowledge-graph.org/resources/Bill>
  <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://schema.or
<https://my-awesome-knowledge-graph.org/resources/Alice>
  <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://schema.or
<https://my-awesome-knowledge-graph.org/resources/Bob>
  <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://schema.or
<https://my-awesome-knowledge-graph.org/resources/The_Louvre>
  <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://schema.or
```

```
<https://my-awesome-knowledge-graph.org/resources/Eiffel_Tower>
  <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://schema.or
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  <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://schema.or
<https://my-awesome-knowledge-graph.org/resources/Bill>
  <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://schema.or
<https://my-awesome-knowledge-graph.org/resources/Alice>
  <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://schema.or
<https://my-awesome-knowledge-graph.org/resources/Bob>
  <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://schema.or
<https://my-awesome-knowledge-graph.org/resources/The_Louvre>
  <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://schema.or
```

```
@prefix inst:   <https://my-awesome-knowledge-graph.org/resources/> .
@prefix rdf:    <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix schema: <http://schema.org/> .

inst:Eiffel_Tower   rdf:type    schema:Place .
inst:Paris          rdf:type    schema:City .
inst:Bill           rdf:type    schema:Person .
inst:Alice          rdf:type    schema:Person .
inst:Bob            rdf:type    schema:Person .
inst:The_Louvre     rdf:type    schema:Museum .
```

Relationships also need to have URIs

```
@prefix inst:   <https://my-awesome-knowledge-graph.org/resources/> .
@prefix xx:     <https://my-awesome-knowledge-graph.org/ontology/xx#>

# RELATIONSHIPS
inst:Eiffel_Tower               xx:is_located_in          inst:Paris .
inst:Alice                      xx:visited                inst:Eiffel_T
inst:Bill                       xx:visited                inst:Eiffel_T
inst:Bob                        xx:is_a_friend_of         inst:Alice .
inst:Bob                        xx:is_interested_in       inst:Person .
inst:Bob                        xx:was_born_on            "14 July 1990
inst:Mona_Lisa                  xx:is_exhibited_at        ints:The_Louv
ints:Mona_Lisa                  xx:was_created_by         ints:Leonardo
ints:La_Joconde_a_Washington    xx:is_about               ints:Mona_Lis
```

SPARQL: SPARQL Protocol and RDF Query Language

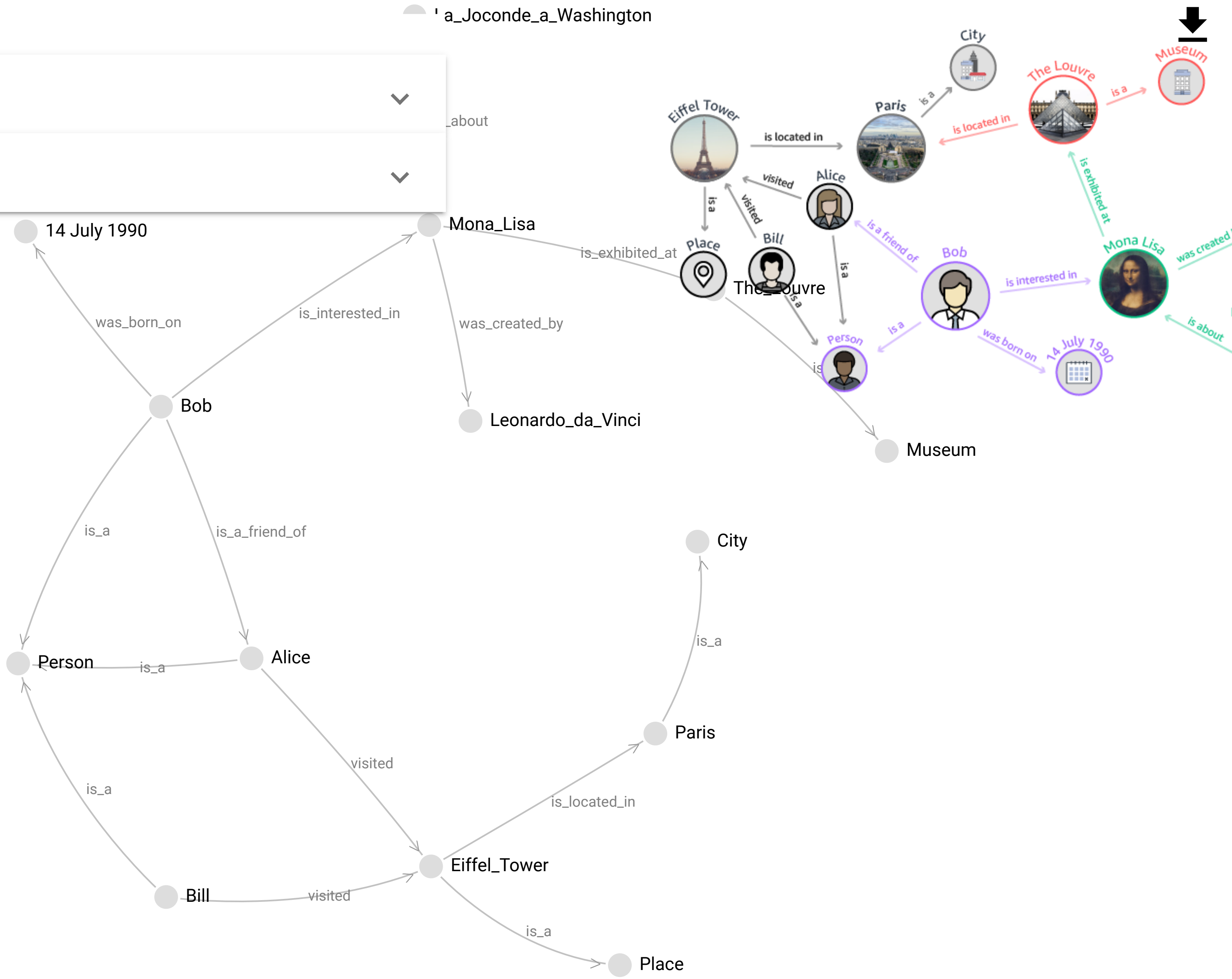
(Yes, the acronym is transitive - pretty annoying!)

SPARQL-visualizer | Intro-viz

By Mads Holten Rasmussen

Triples

Query



SPARQL-visualizer | Intro-viz

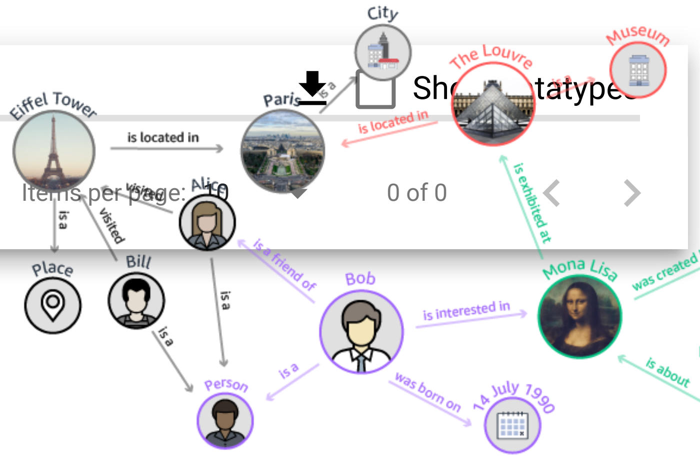
By Mads Holten Rasmussen

Triples

Query

Items per page: 10

0 of 0



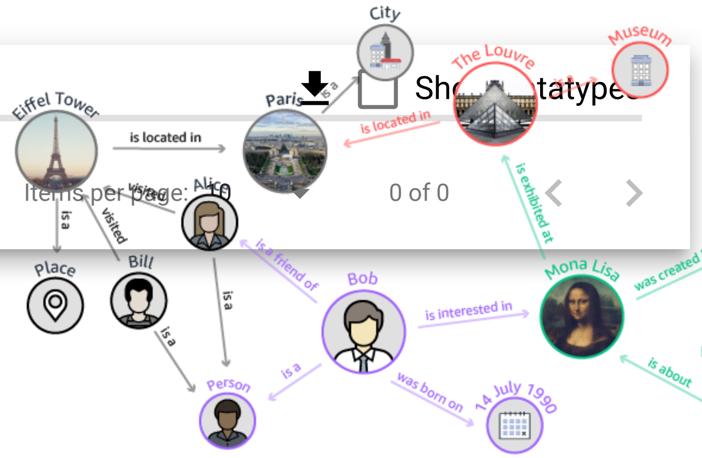
Return all triples in the graph

SPARQL-visualizer | Intro-viz

By Mads Holten Rasmussen

Triples

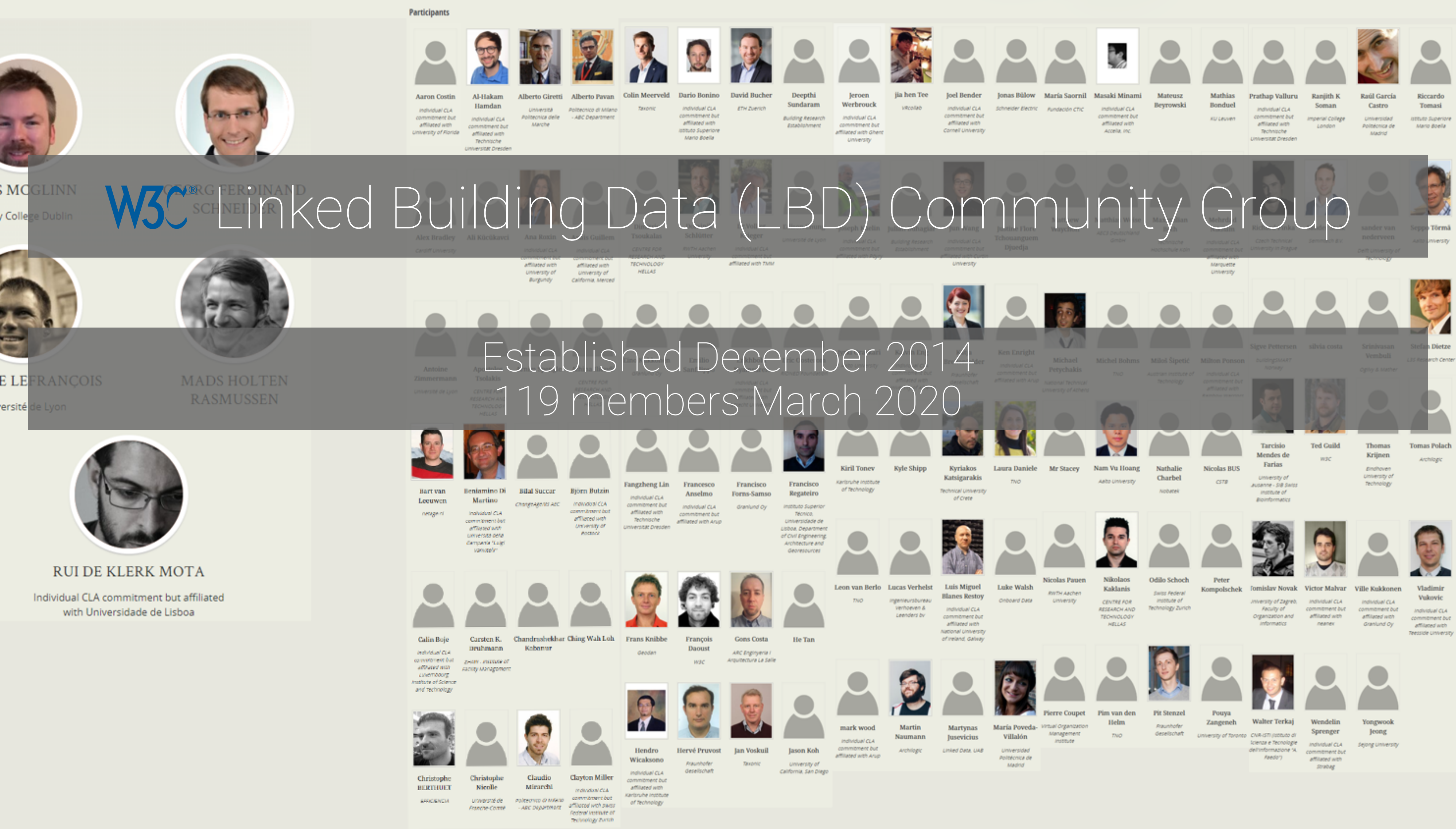
Query



Return people who visited the Eiffel Tower

My contributions to the community

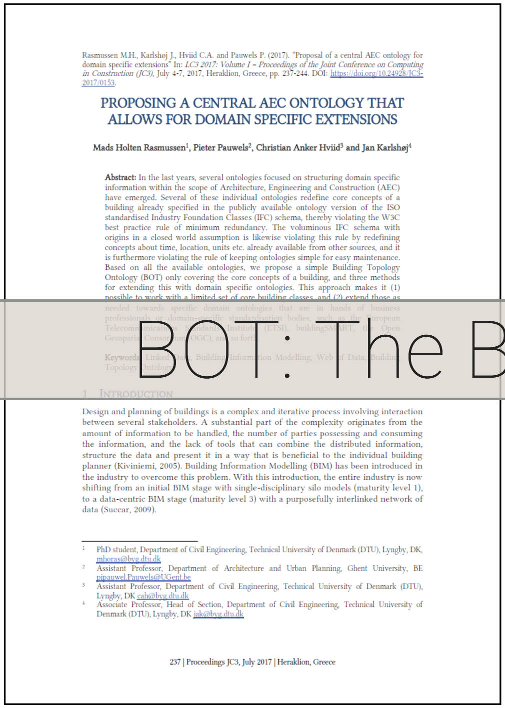
COMMUNITY & BUSINESS GROUPS

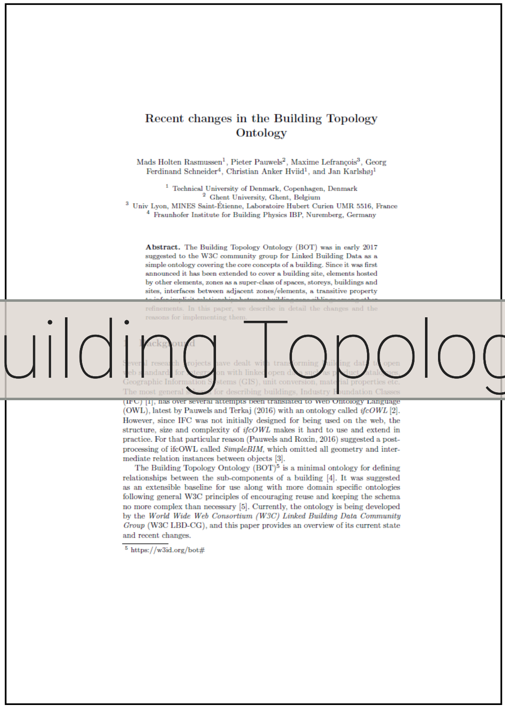


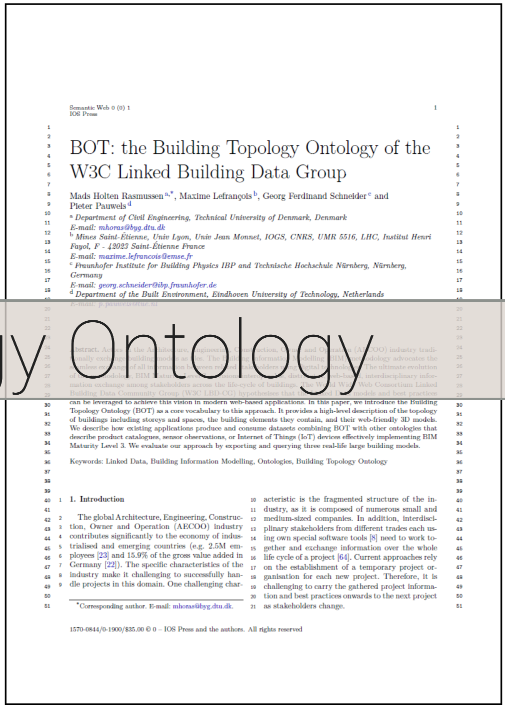
W3C® Linked Building Data (LBD) Community Group

Established December 2014
119 members March 2020

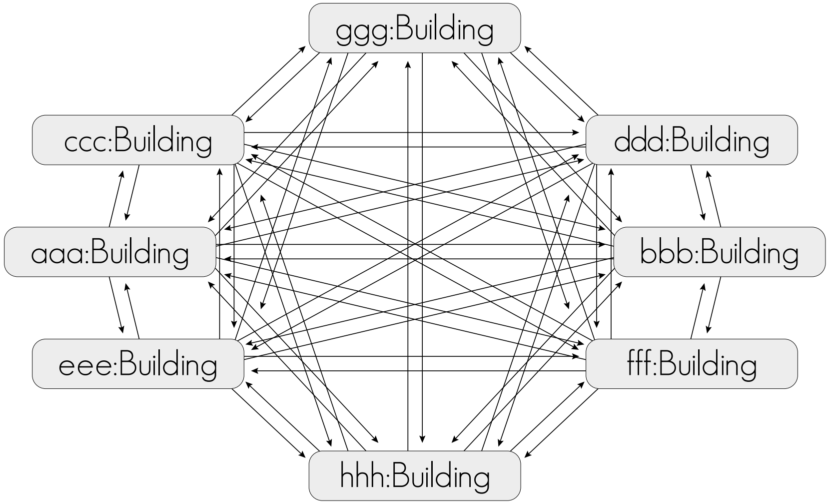
BOT: The Building Topology Ontology

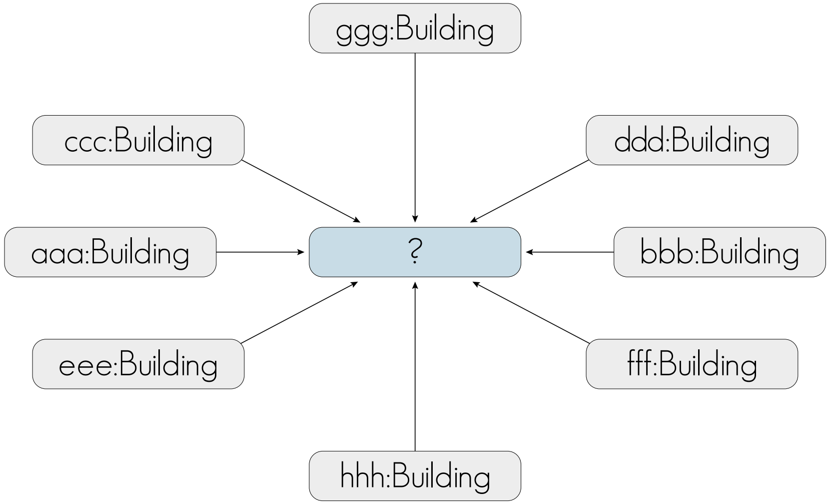




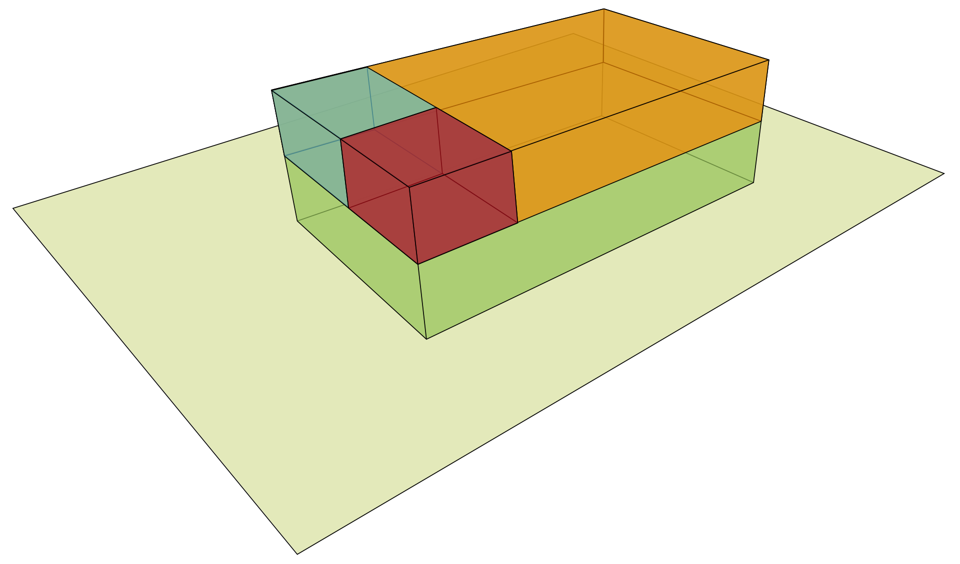


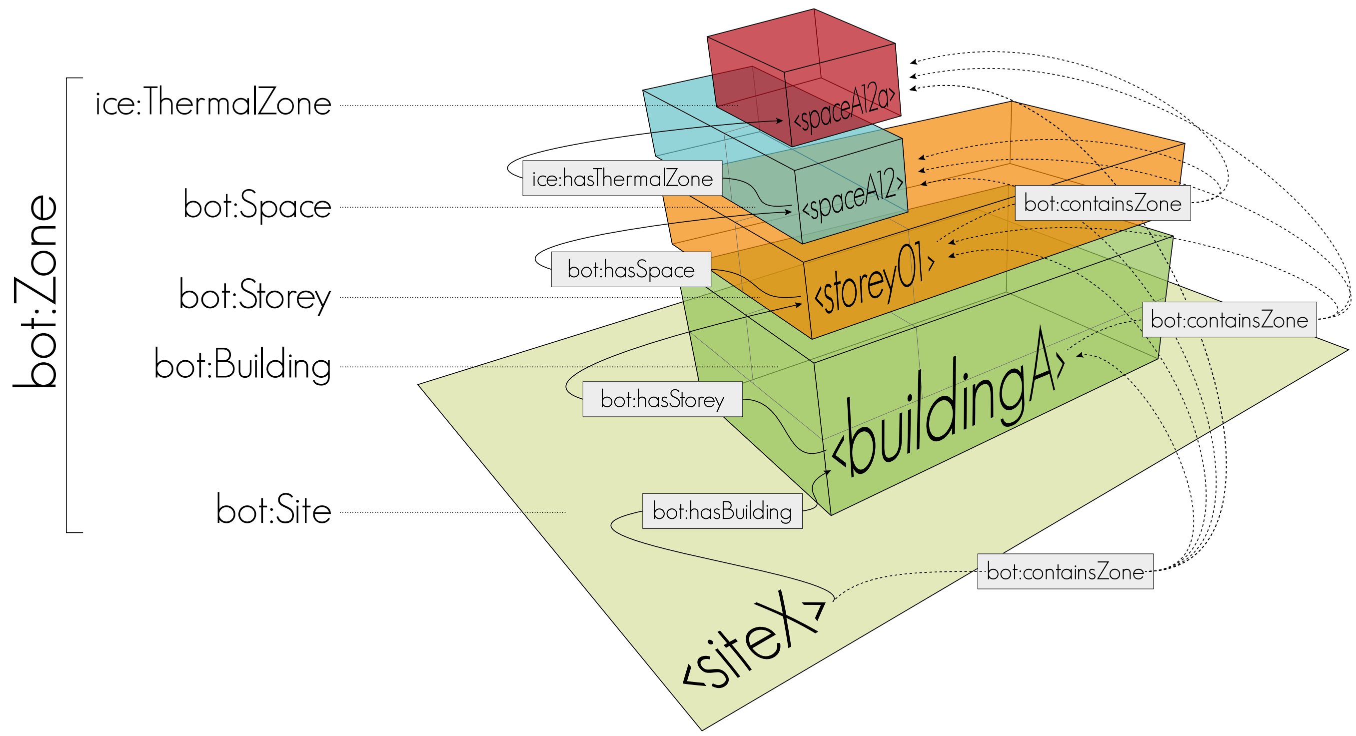

aaa:Building
bbb:Building
owl:equivalentClass


ggg:Building
ccc:Building
ddd:Building
aaa:Building
bbb:Building
eee:Building
fff:Building
hhh:Building

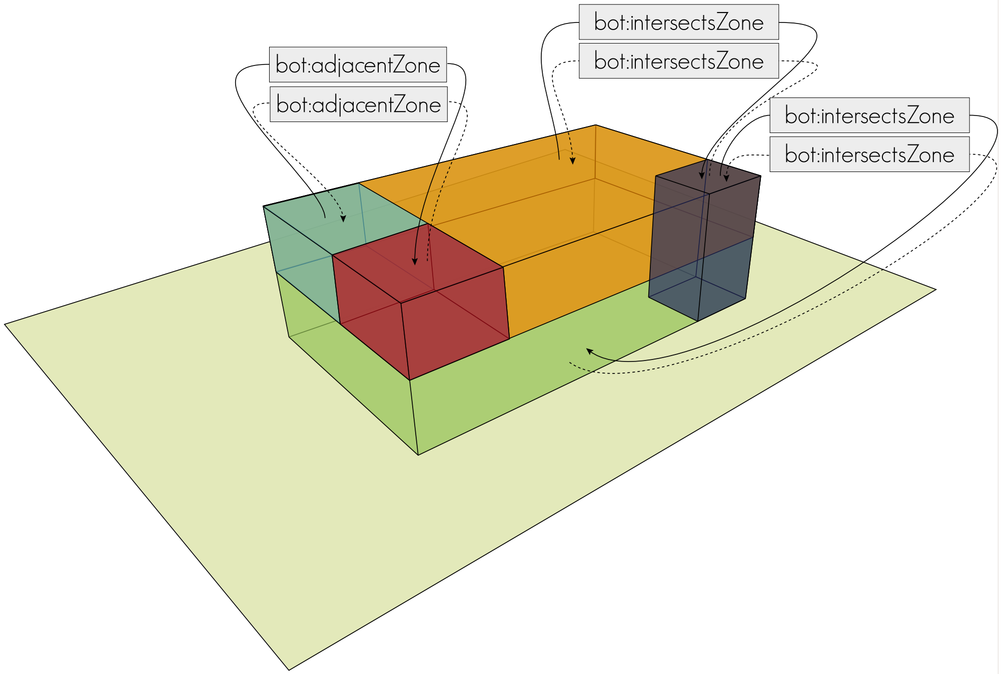

ggg:Building
ccc:Building
ddd:Building
aaa:Building
?
bbb:Building
eee:Building
fff:Building
hhh:Building

bot:Zone



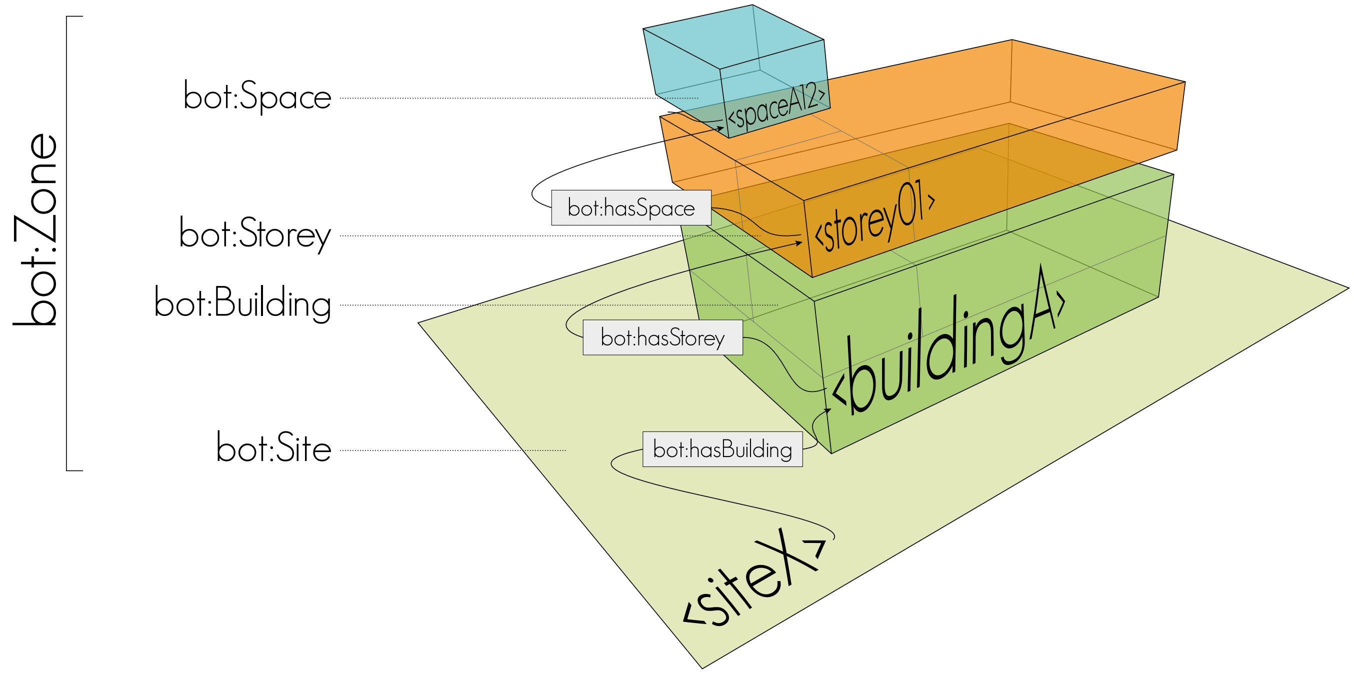


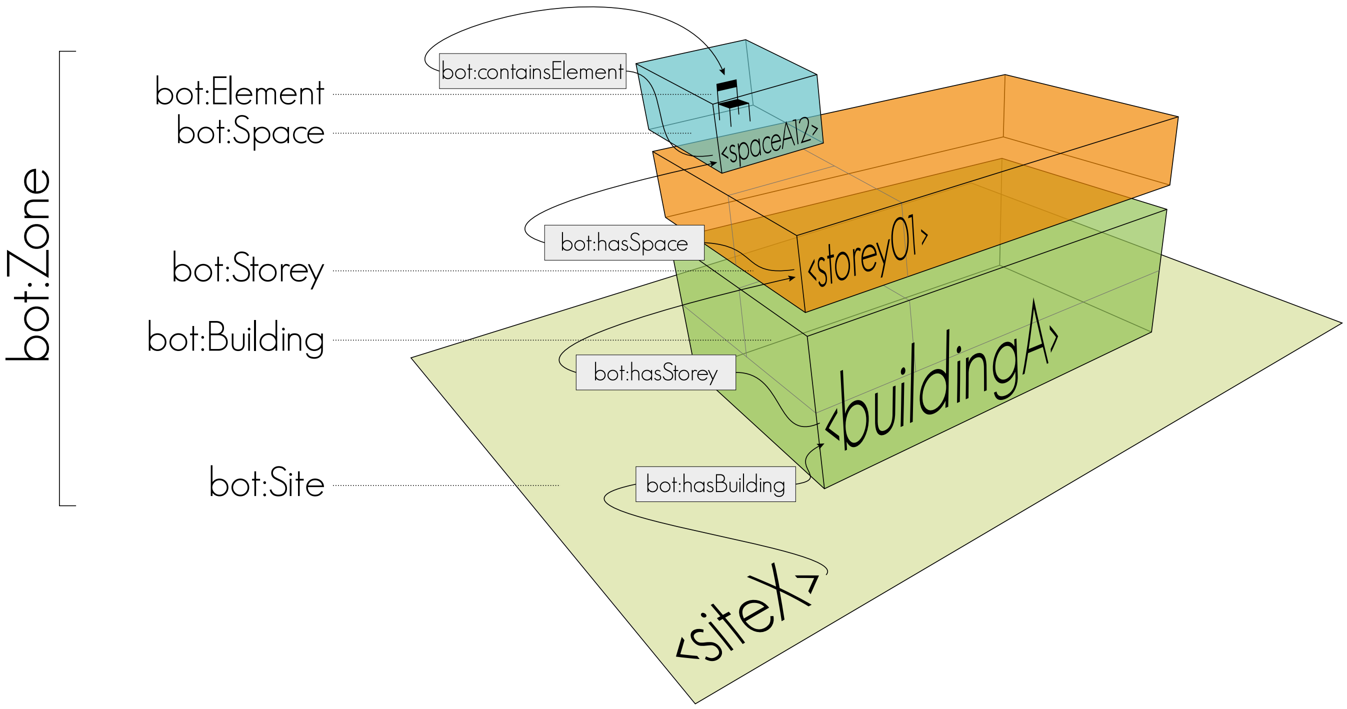
Dashed arrows = implicit knowledge inferred by reasoning



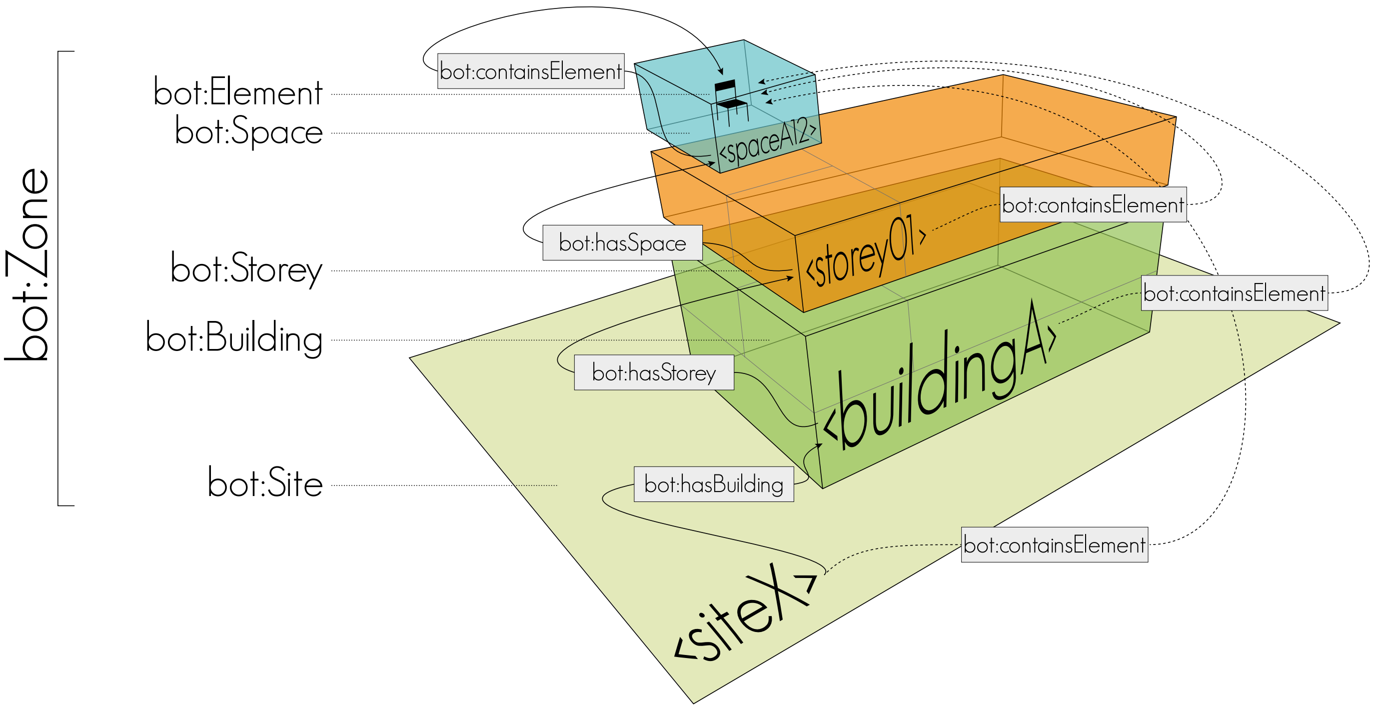
Dashed arrows = implicit knowledge inferred by reasoning

bot:Element


bot:Zone
bot:Space
bot:Storey
bot:Building
bot:Site
<spaceA12>
<storey01>
<buildingA>
<siteX>
bot:hasSpace
bot:hasStorey
bot:hasBuilding

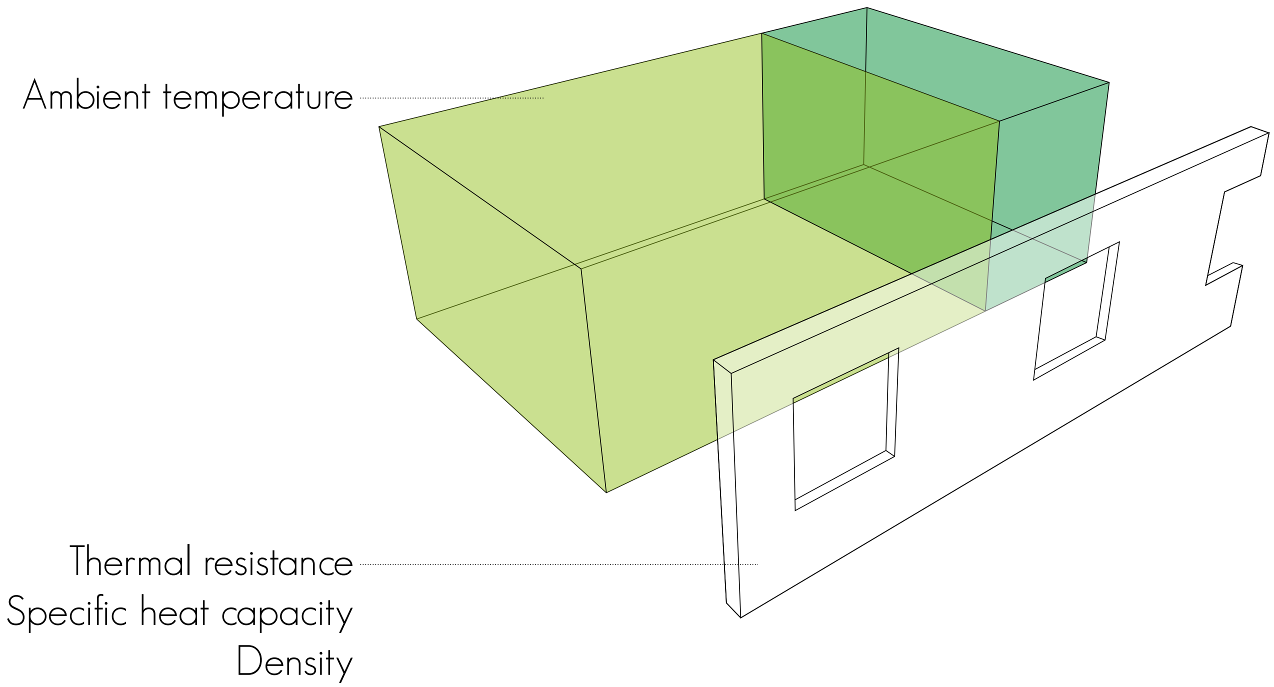


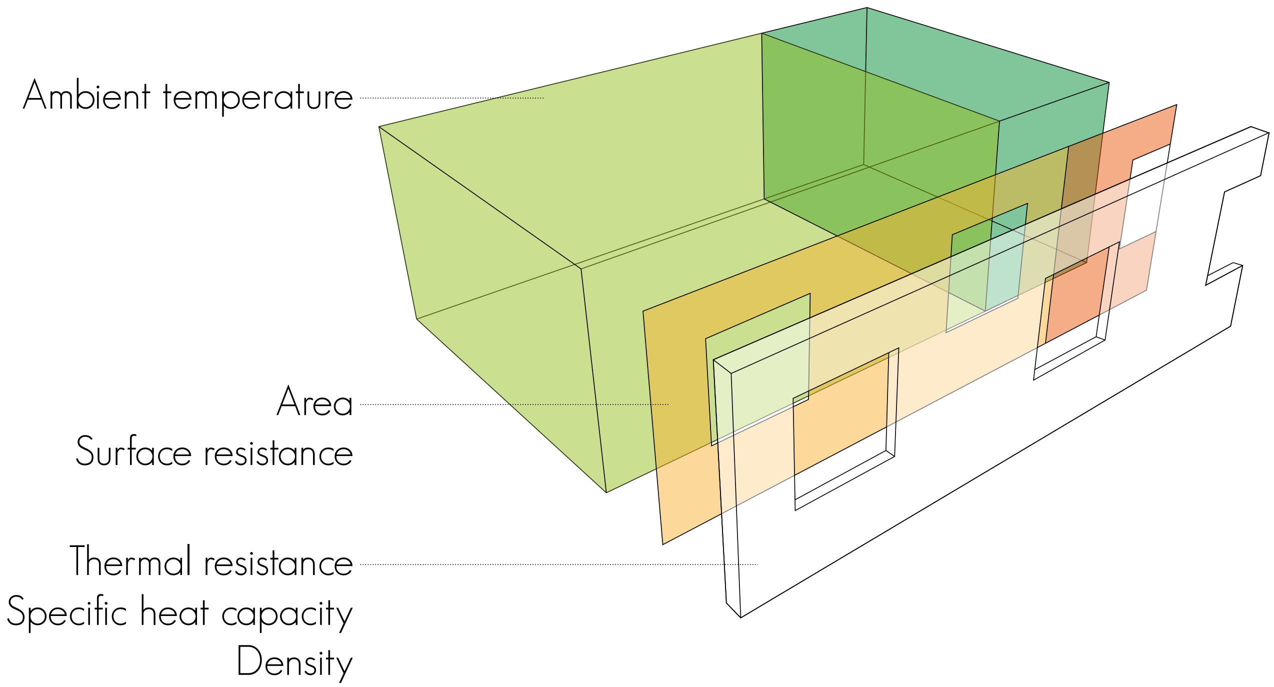
bot:Zone
bot:Element
bot:Space
bot:Storey
bot:Building
bot:Site
bot:containsElement
<spaceA12>
bot:hasSpace
<storey01>
bot:hasStorey
<buildingA>
bot:hasBuilding
<siteX>

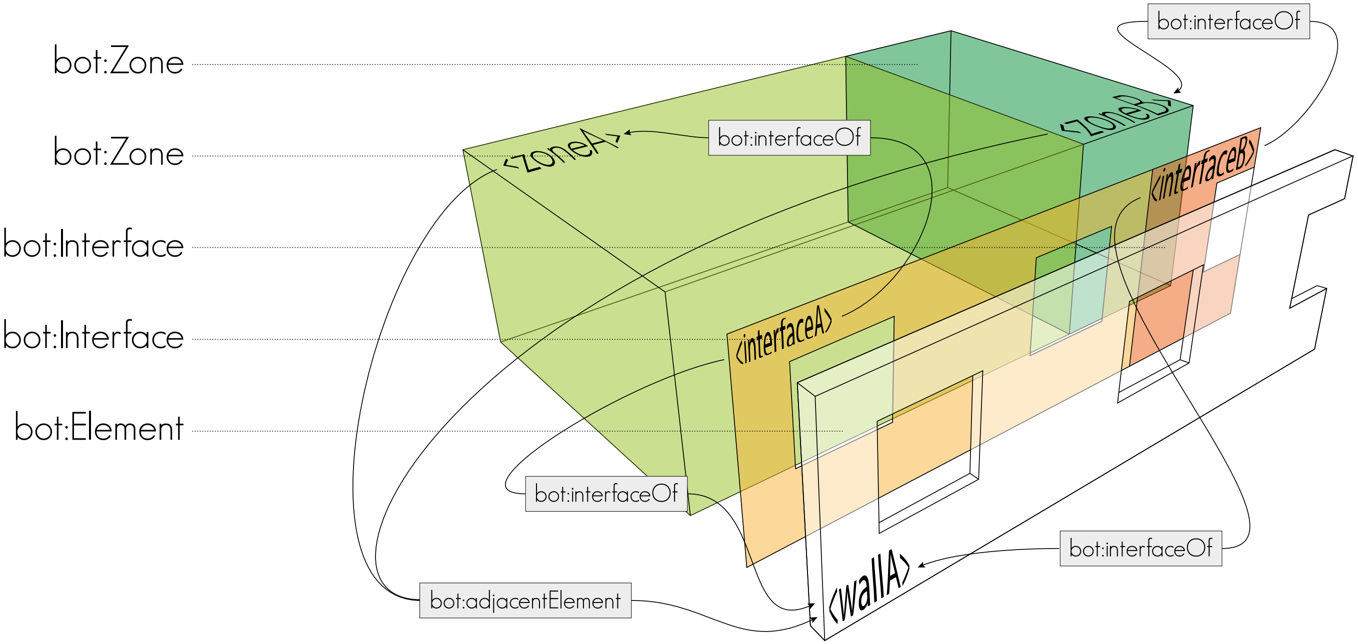


Dashed arrows = implicit knowledge inferred by reasoning

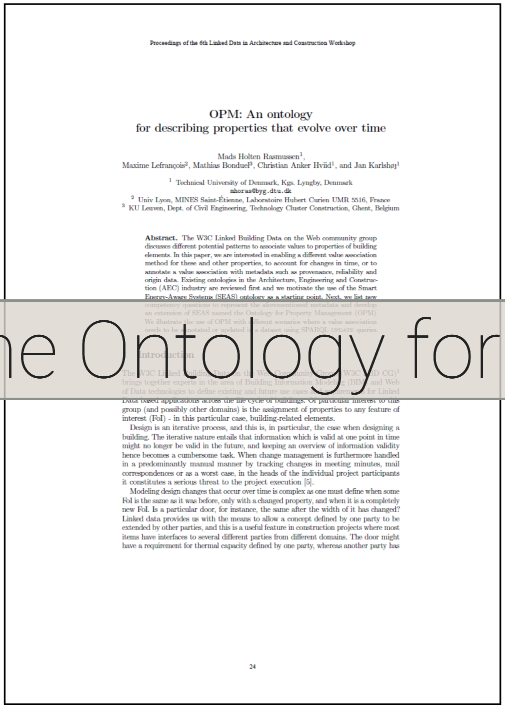
bot:Interface


Ambient temperature
Thermal resistance
Specific heat capacity
Density


Ambient temperature
Area
Surface resistance
Thermal resistance
Specific heat capacity
Density


bot:Zone
bot:Zone
bot:Interface
bot:Interface
bot:Element
<zoneA>
<zoneB>
<interfaceA>
<interfaceB>
<wallA>
bot:interfaceOf
bot:interfaceOf
bot:interfaceOf
bot:interfaceOf
bot:adjacentElement

OPM: The Ontology for Property Management


Proceedings of the 6th Linked Data in Architecture and Construction Workshop

OPM: An ontology for describing properties that evolve over time

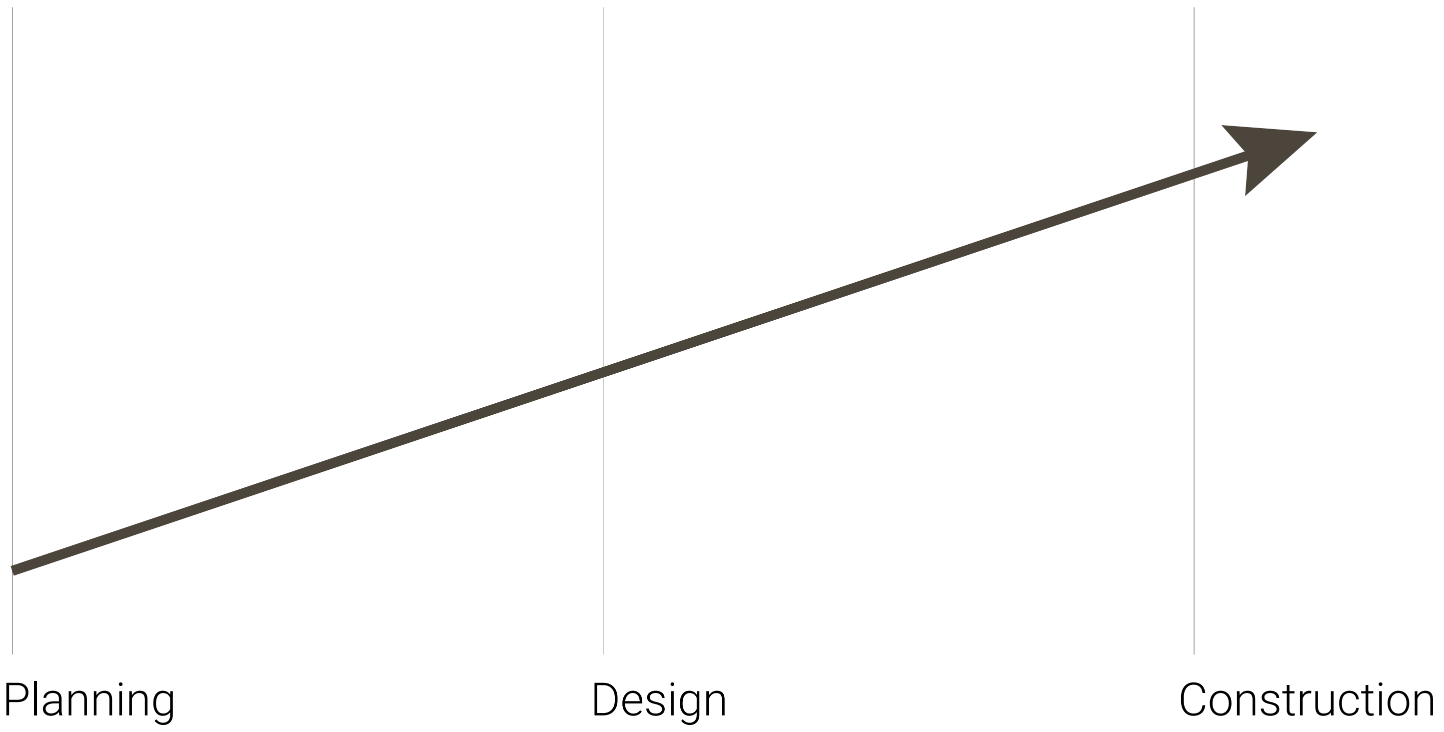
Mads Holten Rasmussen[1], Maxime Lefrançois[2], Mathias Bonduel[3], Christian Anker Hviid[1], and Jan Karlshøj[1]

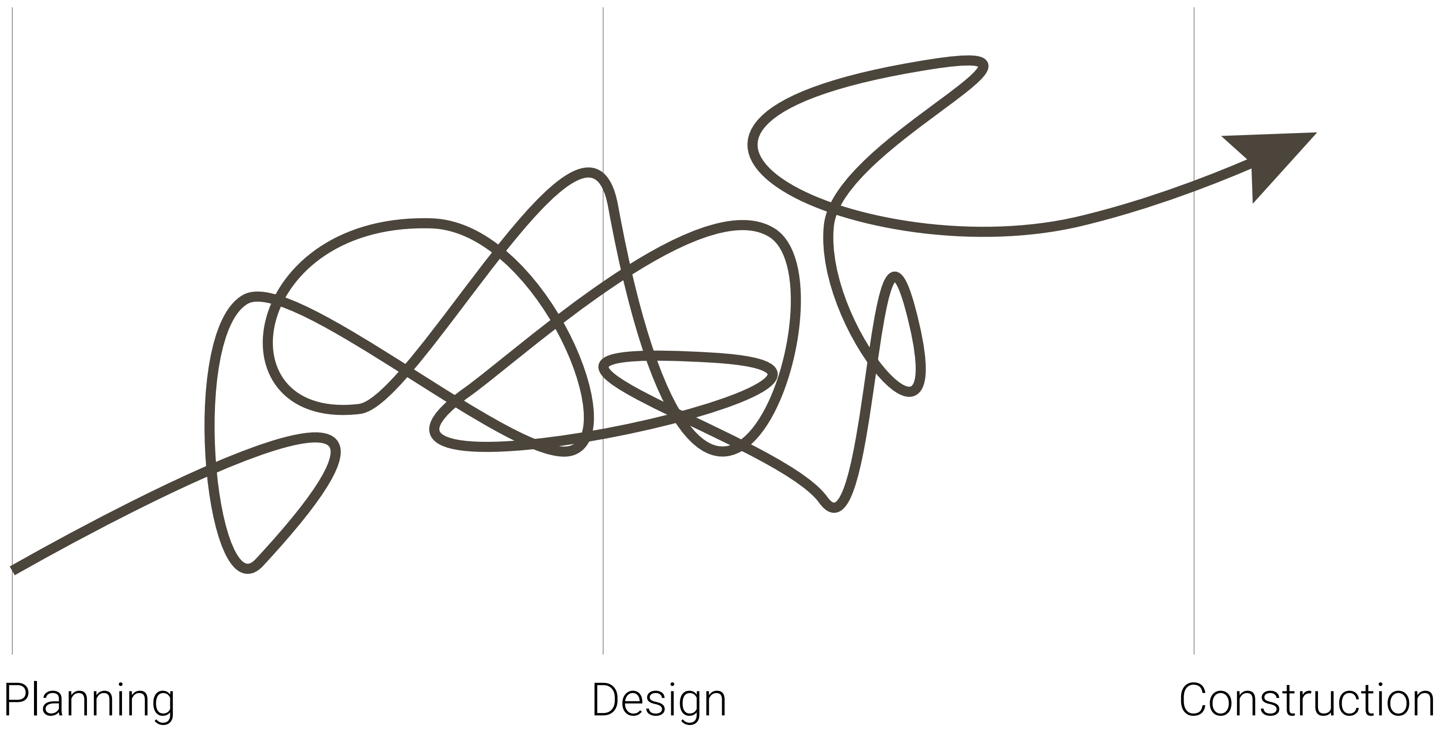

Automation in Construction 108 (2019) 102956

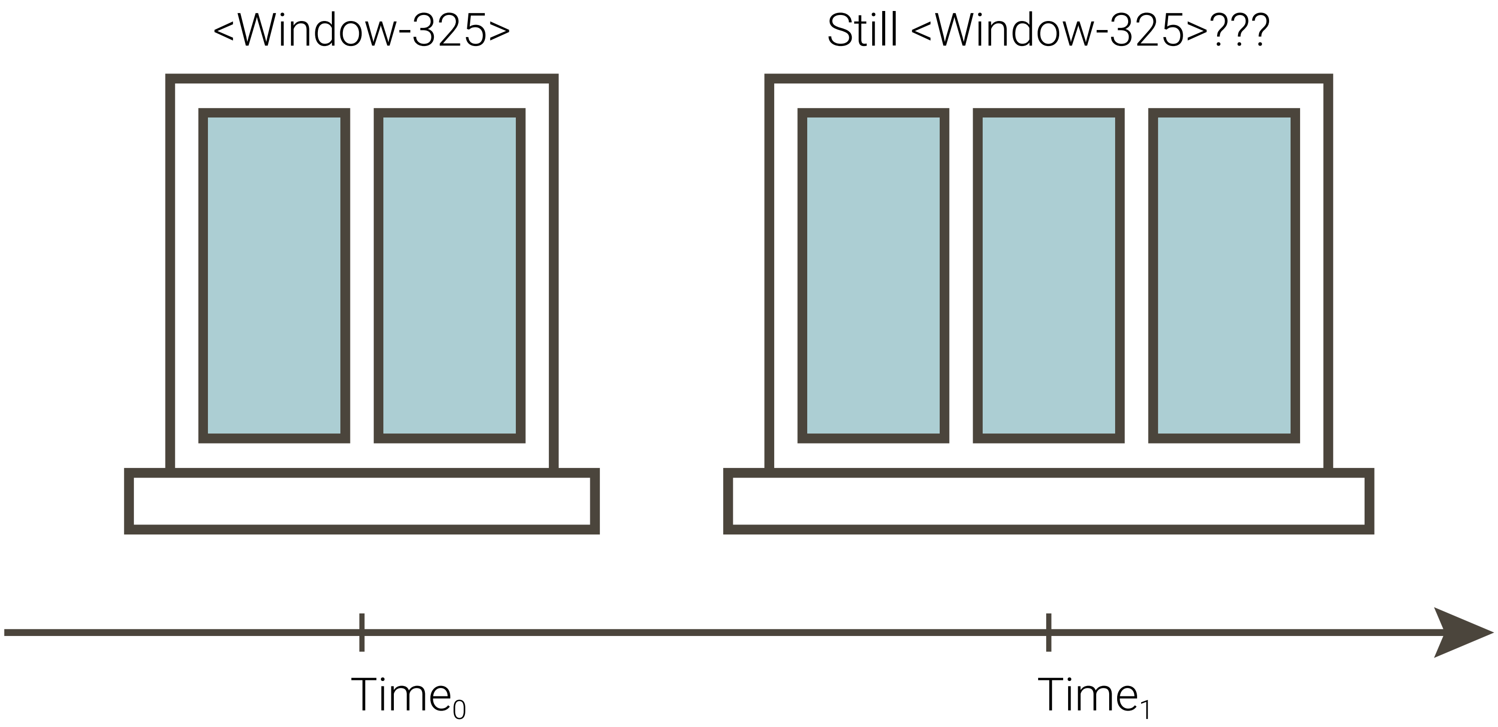
Automation in Construction

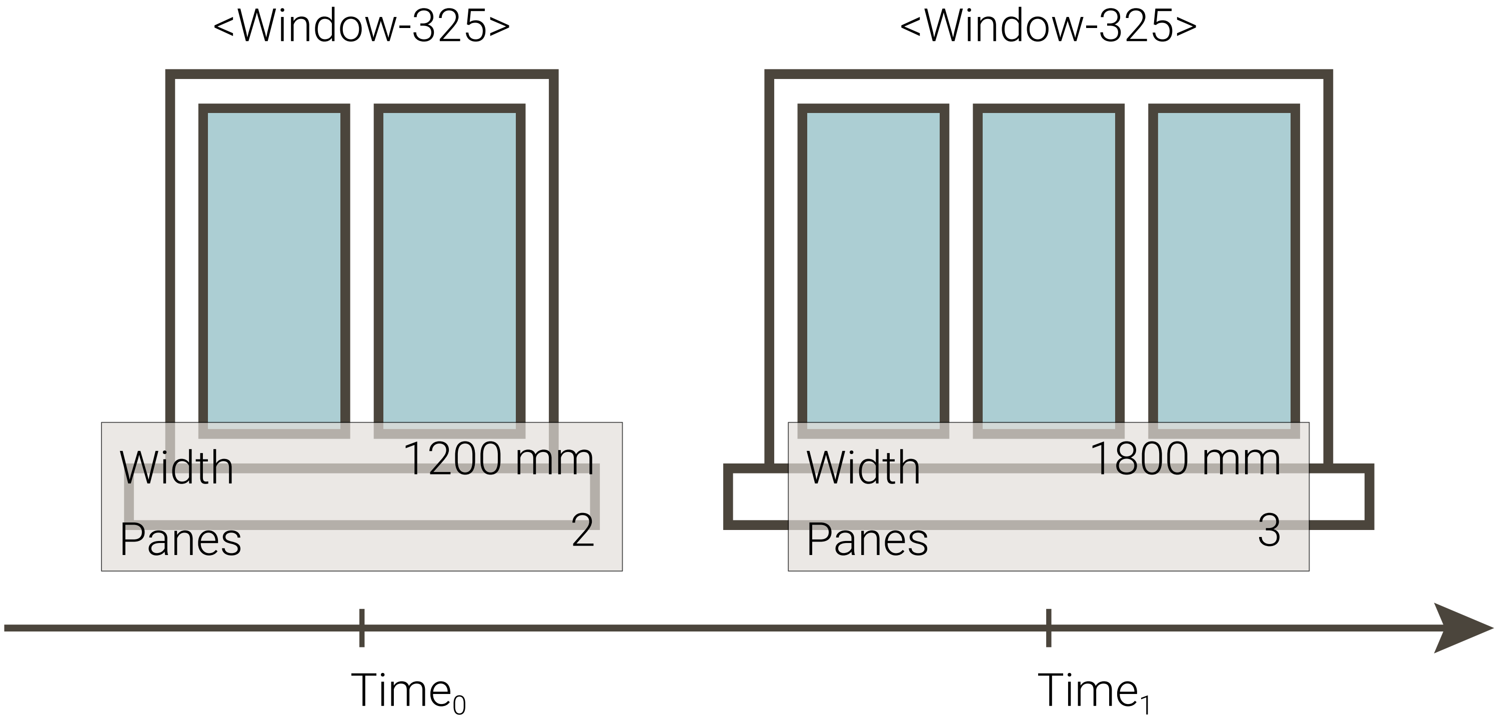
Managing interrelated project information in AEC Knowledge Graphs

Mads Holten Rasmussen[a,*], Maxime Lefrançois[b], Pieter Pauwels[c], Christian Anker Hviid[a], Jan Karlshøj[a]


Planning
Design
Construction


Planning
Design
Construction


<Window-325>
Still <Window-325>???
Time0
Time1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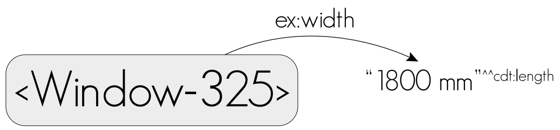
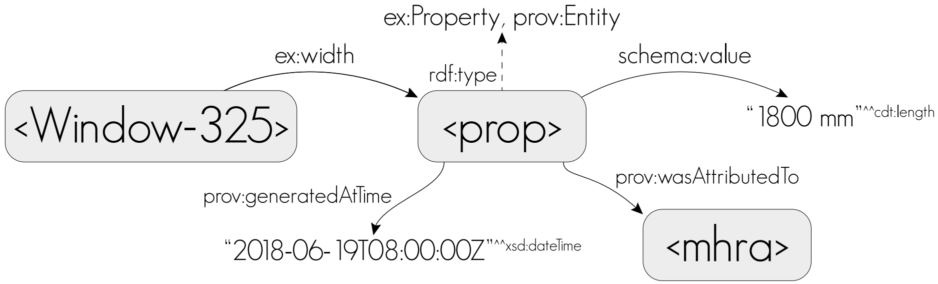
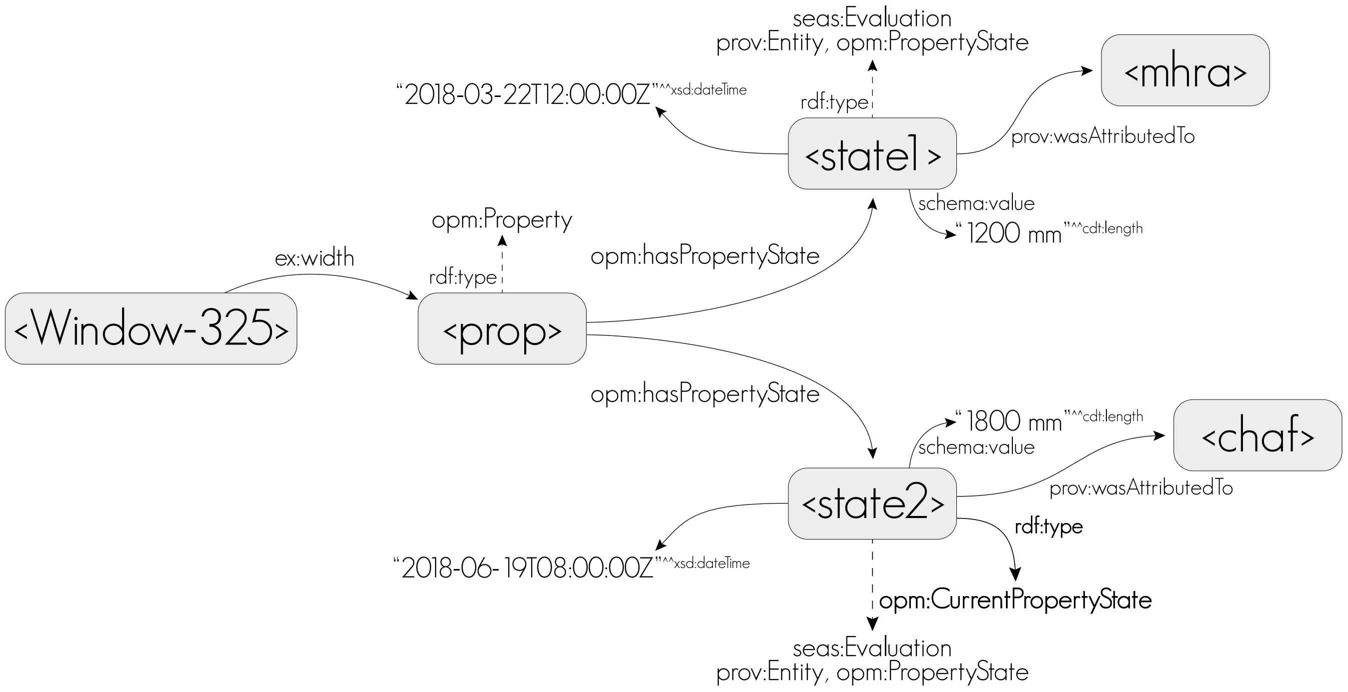
Width 1200 mm
Panes 2
<Window-325>
Width 1800 mm
Panes 3
$Time_0$
$Time_1$


ex:width
<Window-325>
" 1800 mm"^^cdt:length



ex:Property, prov:Entity
ex:width
rdf:type
schema:value
<Window-325>
<prop>
"1800 mm"^^cdt:length
prov:wasAttributedTo
prov:generatedAtTime
"2018-06-19T08:00:00Z"^^xsd:dateTime
<mhra>

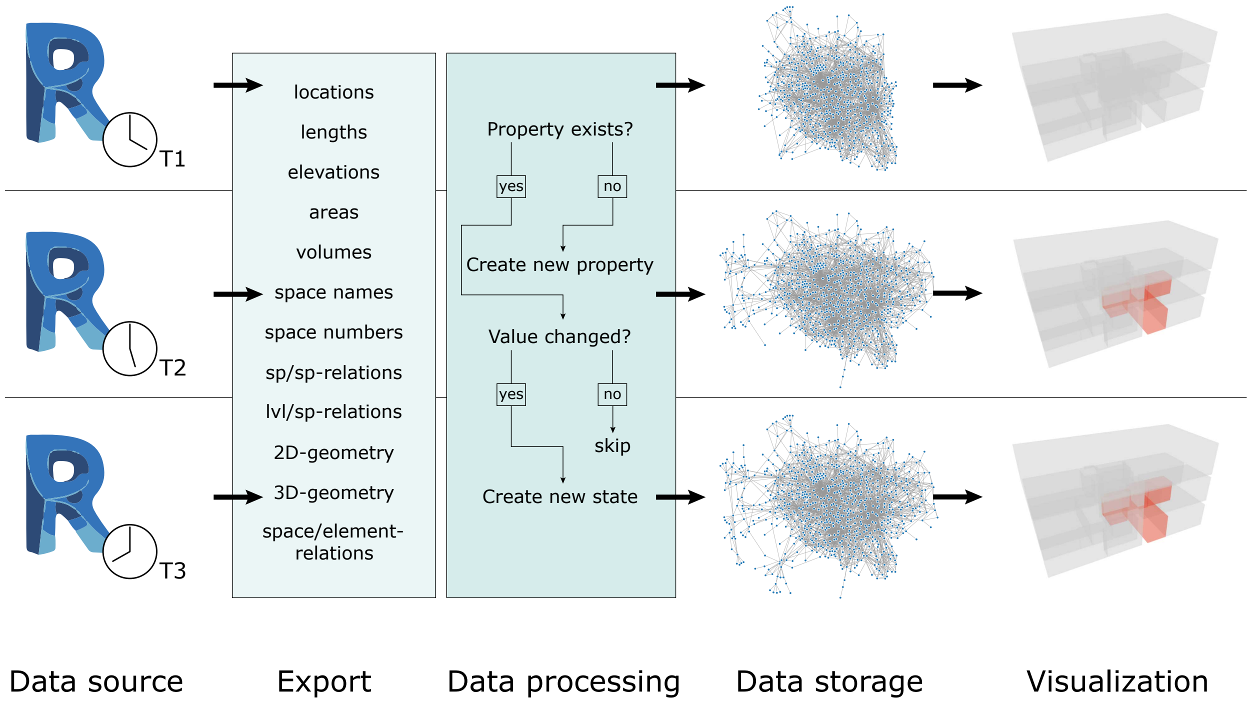


seas:Evaluation
prov:Entity, opm:PropertyState
"2018-03-22T12:00:00Z"^^xsd:dateTime
rdf:type
<mhra>
<state1>
prov:wasAttributedTo
schema:value
"1200 mm"^^cdt:length
opm:Property
ex:width
rdf:type
opm:hasPropertyState
<Window-325>
<prop>
opm:hasPropertyState
"1800 mm"^^cdt:length
schema:value
<chaf>
<state2>
prov:wasAttributedTo
rdf:type
"2018-06-19T08:00:00Z"^^xsd:dateTime
opm:CurrentPropertyState
seas:Evaluation
prov:Entity, opm:PropertyState

States also be classified for reliability. Is it an **assumption** or a **confirmed value**?

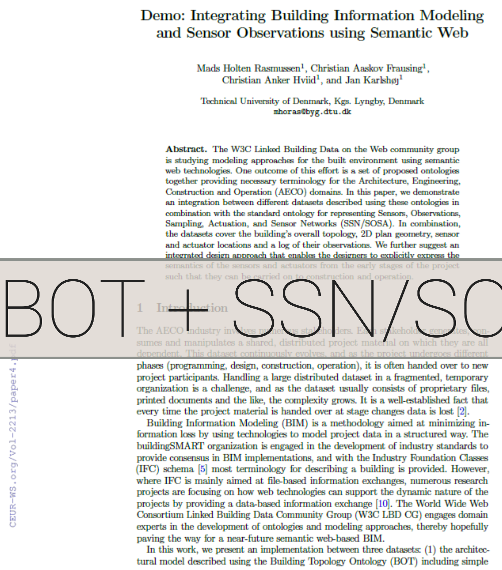
A **derived property state** can be related to the particular state of another property from which it was derived

If a **derived property state** refers to a state that is no longer the **current property state**, the derived property state becomes **outdated**


T1
T2
T3
locations
lengths
elevations
areas
volumes
space names
space numbers
sp/sp-relations
lvl/sp-relations
2D-geometry
3D-geometry
space/element-relations
Property exists?
yes
no
Create new property
Value changed?
yes
no
skip
Create new state
Data source
Export
Data processing
Data storage
Visualization

A case study

BOT + SSN/SOSA



Demo: Integrating Building Information Modeling and Sensor Observations using Semantic Web

Mads Holten Rasmussen[1], Christian Aaskov Frausing[1], Christian Anker Hviid[1], and Jan Karlshøj[1]

Technical University of Denmark, Kgs. Lyngby, Denmark
mhoras@byg.dtu.dk

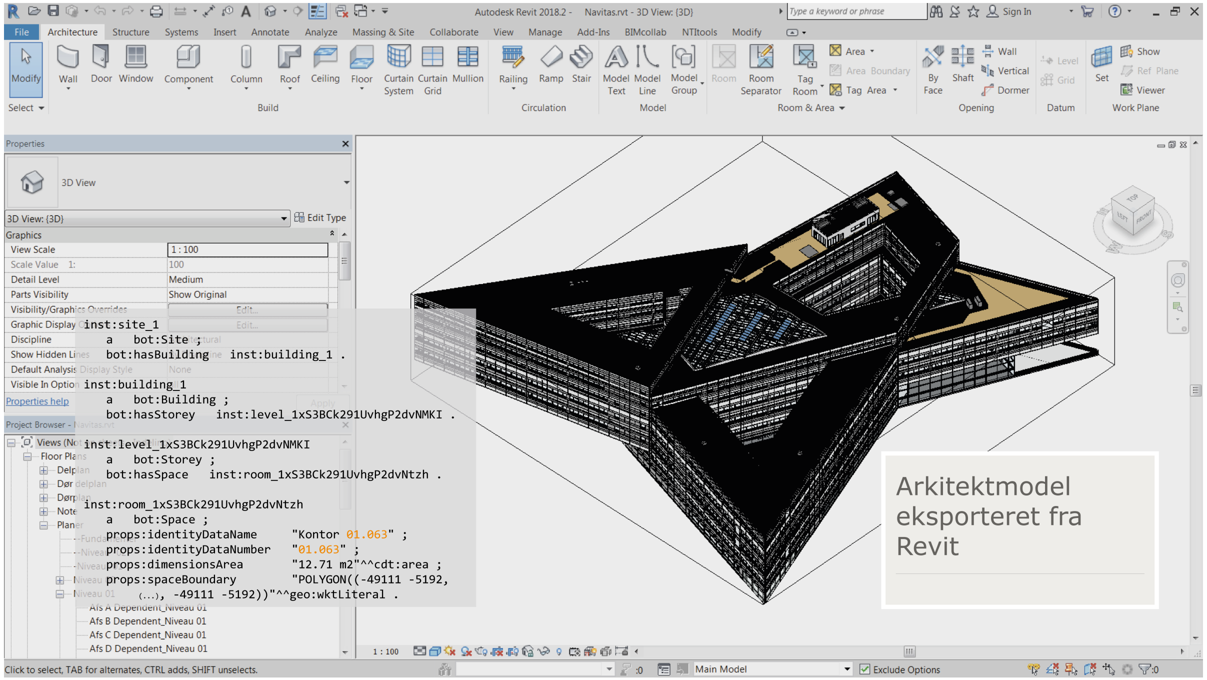
Abstract. The W3C Linked Building Data on the Web community group is studying modeling approaches for the built environment using semantic web technologies. One outcome of this effort is a set of proposed ontologies together providing necessary terminology for the Architecture, Engineering, Construction and Operation (AECO) domains. In this paper, we demonstrate an integration between different datasets described using these ontologies in combination with the standard ontology for representing Sensors, Observations, Sampling, Actuation, and Sensor Networks (SSN/SOSA). In combination, the datasets cover the building's overall topology, 2D plan geometry, sensor and actuator locations and a log of their observations. We further suggest an integrated design approach that enables the designers to explicitly express the semantics of the sensors and actuators from the early stages of the project such that they can be carried on to construction and operation.

1 Introduction

The AECO industry involves numerous stakeholders. Each stakeholder generates, consumes and manipulates a shared, distributed project material on which they are all dependent. This dataset continuously evolves, and as the project undergoes different phases (programming, design, construction, operation), it is often handed over to new project participants. Handling a large distributed dataset in a fragmented, temporary organization is a challenge, and as the dataset usually consists of proprietary files, printed documents and the like, the complexity grows. It is a well-established fact that every time the project material is handed over at stage changes data is lost [2].

Building Information Modeling (BIM) is a methodology aimed at minimizing information loss by using technologies to model project data in a structured way. The buildingSMART organization is engaged in the development of industry standards to provide consensus in BIM implementations, and with the Industry Foundation Classes (IFC) schema [5] most terminology for describing a building is provided. However, where IFC is mainly aimed at file-based information exchanges, numerous research projects are focusing on how web technologies can support the dynamic nature of the projects by providing a data-based information exchange [10]. The World Wide Web Consortium Linked Building Data Community Group (W3C LBD CG) engages domain experts in the development of ontologies and modeling approaches, thereby hopefully paving the way for a near-future semantic web-based BIM.

In this work, we present an implementation between three datasets: (1) the architectural model described using the Building Topology Ontology (BOT) including simple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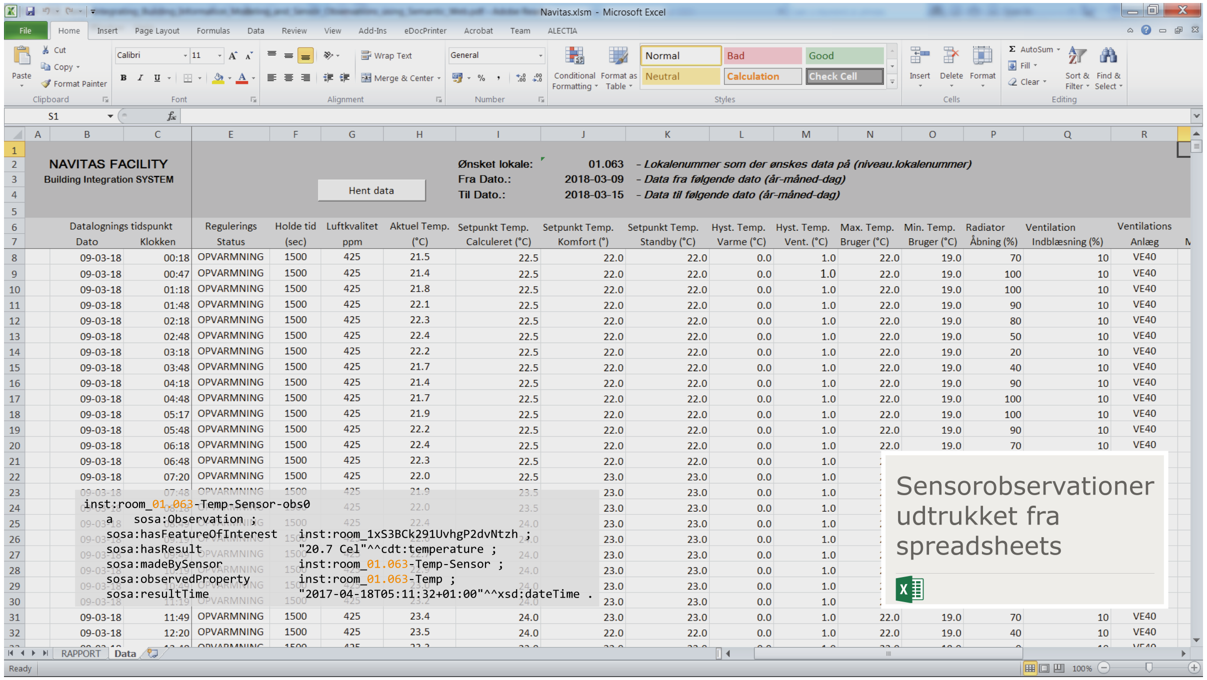
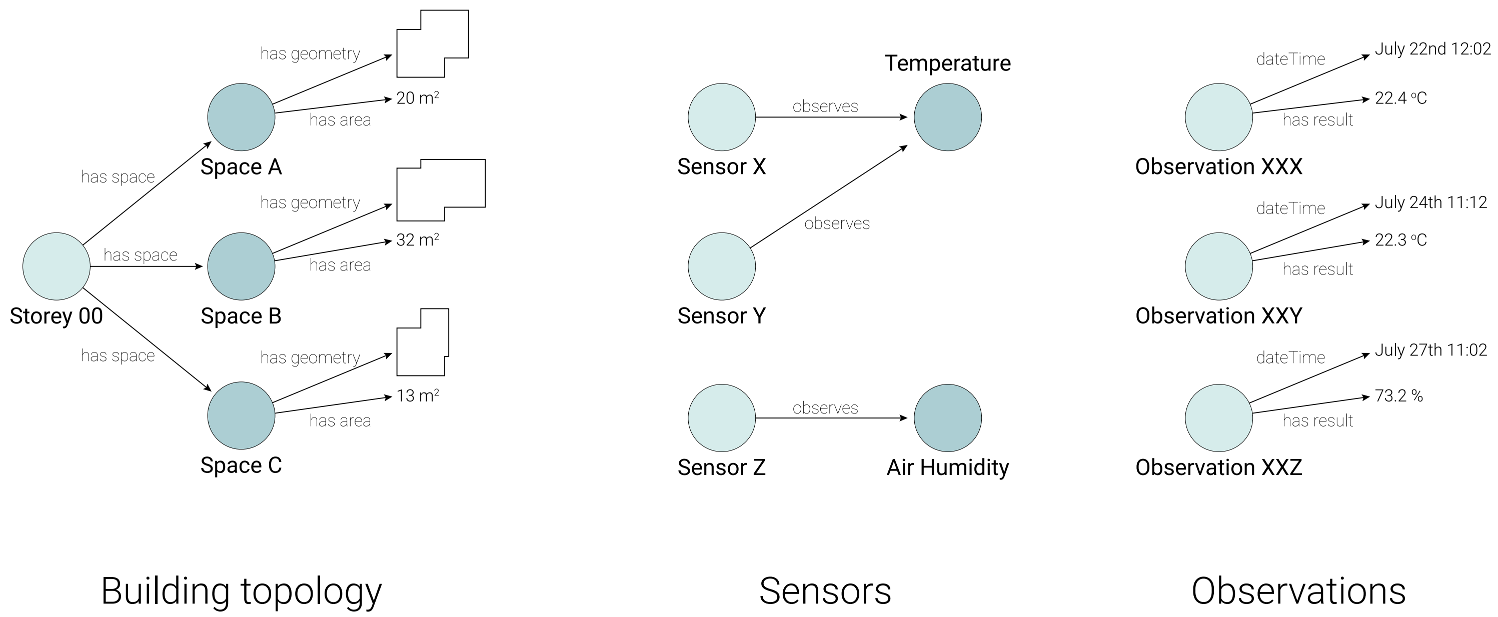
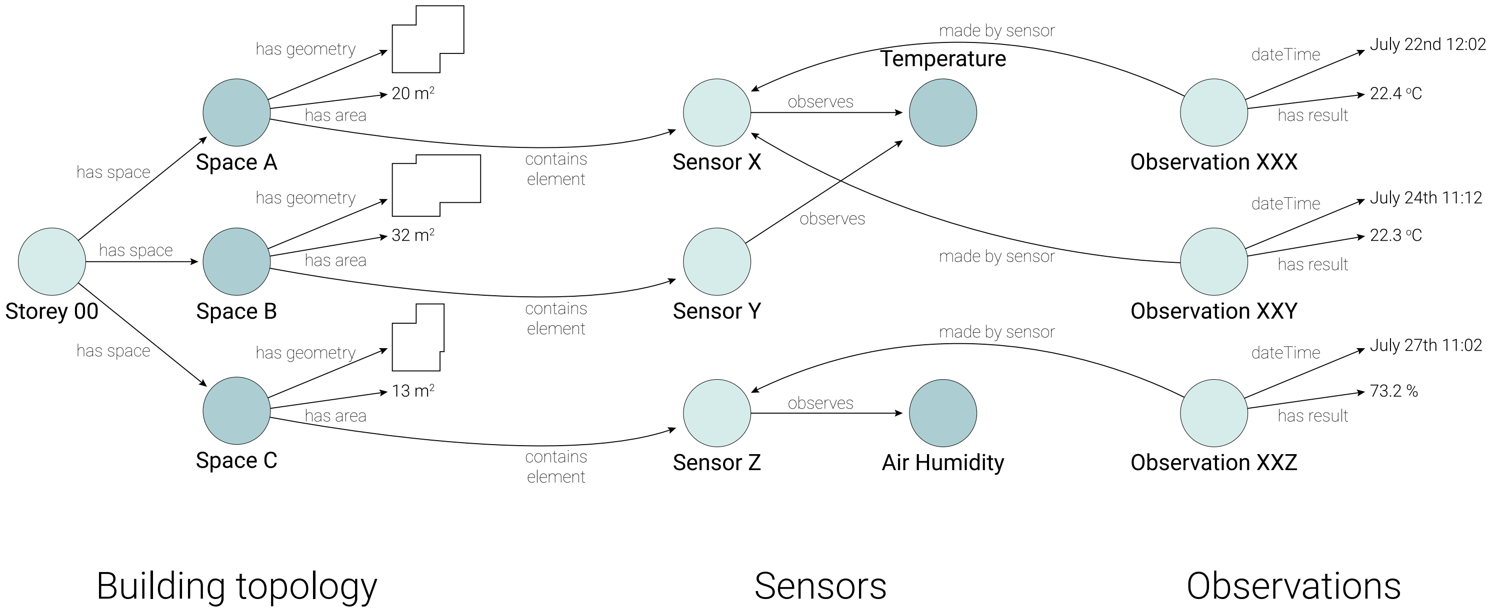
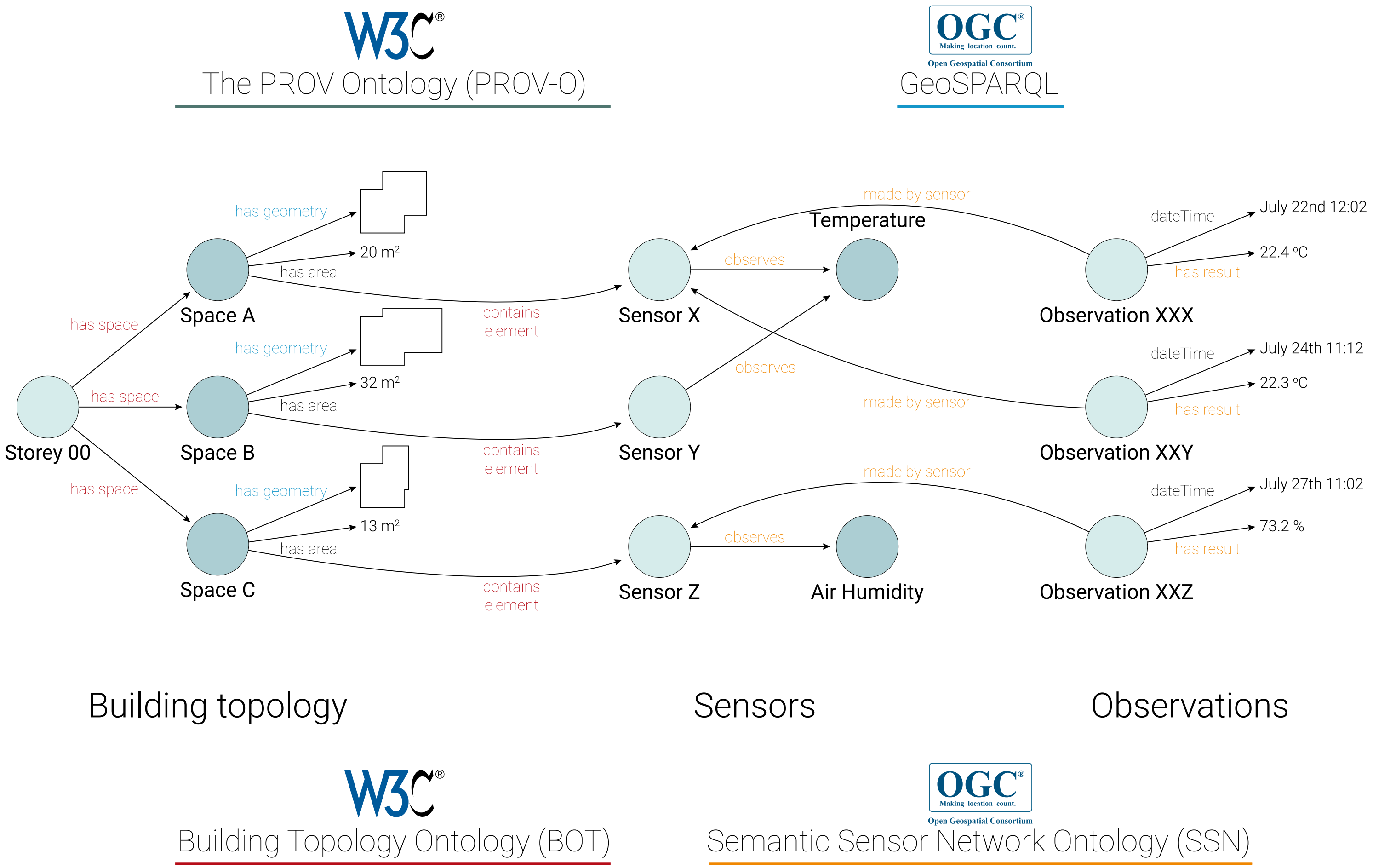
a bot:Site ;
bot:hasBuilding inst:building_1 .
inst:building_1
a bot:Building ;
bot:hasStorey inst:level_1xS3BCk291UvhgP2dvNMKI .
inst:level_1xS3BCk291UvhgP2dvNMKI
a bot:Storey ;
bot:hasSpace inst:room_1xS3BCk291UvhgP2dvNtzh .
inst:room_1xS3BCk291UvhgP2dvNtzh
a bot:Space ;
props:identityDataName "Kontor 01.063" ;
props:identityDataNumber "01.063" ;
props:dimensionsArea "12.71 m2"^^cdt:area ;
props:spaceBoundary "POLYGON((-49111 -5192,
(...), -49111 -5192))"^^geo:wktLiteral .
Arkitektmodel eksporteret fra Revit


Navitas.xlsm - Microsoft Excel
NAVITAS FACILITY
Building Integration SYSTEM
Hent data
Ønsket lokale: 01.063 - Lokalenummer som der ønskes data på (niveau.lokalenummer)
Fra Dato.: 2018-03-09 - Data fra følgende dato (år-måned-dag)
Til Dato.: 2018-03-15 - Data til følgende dato (år-måned-dag)
inst:room_01.063-Temp-Sensor-obs0
a sosa:Observation ;
sosa:hasFeatureOfInterest inst:room_1xS3BCk291UvhgP2dvNtzh ;
sosa:hasResult "20.7 Cel"^^cdt:temperature ;
sosa:madeBySensor inst:room_01.063-Temp-Sensor ;
sosa:observedProperty inst:room_01.063-Temp ;
sosa:resultTime "2017-04-18T05:11:32+01:00"^^xsd:dateTime .
Sensorobservationer udtrukket fra spreadsheets
RAPPORT
Data



has geometry
20 m²
has area
has space
Space A
has geometry
32 m²
has area
has space
Storey 00
Space B
has space
has geometry
13 m²
has area
Space C
Temperature
observes
Sensor X
observes
Sensor Y
observes
Sensor Z
Air Humidity
dateTime
July 22nd 12:02
22.4 °C
has result
Observation XXX
dateTime
July 24th 11:12
22.3 °C
has result
Observation XXY
dateTime
July 27th 11:02
73.2 %
has result
Observation XXZ
Building topology
Sensors
Observations


made by sensor
Temperature
has geometry
20 m²
has area
Space A
contains element
Sensor X
observes
dateTime
July 22nd 12:02
22.4 ºC
has result
Observation XXX
has space
has geometry
32 m²
has area
has space
Storey 00
Space B
contains element
Sensor Y
observes
made by sensor
dateTime
July 24th 11:12
22.3 ºC
has result
Observation XXY
has space
has geometry
13 m²
has area
Space C
contains element
Sensor Z
observes
Air Humidity
made by sensor
dateTime
July 27th 11:02
73.2 %
has result
Observation XXZ
Building topology
Sensors
Observations

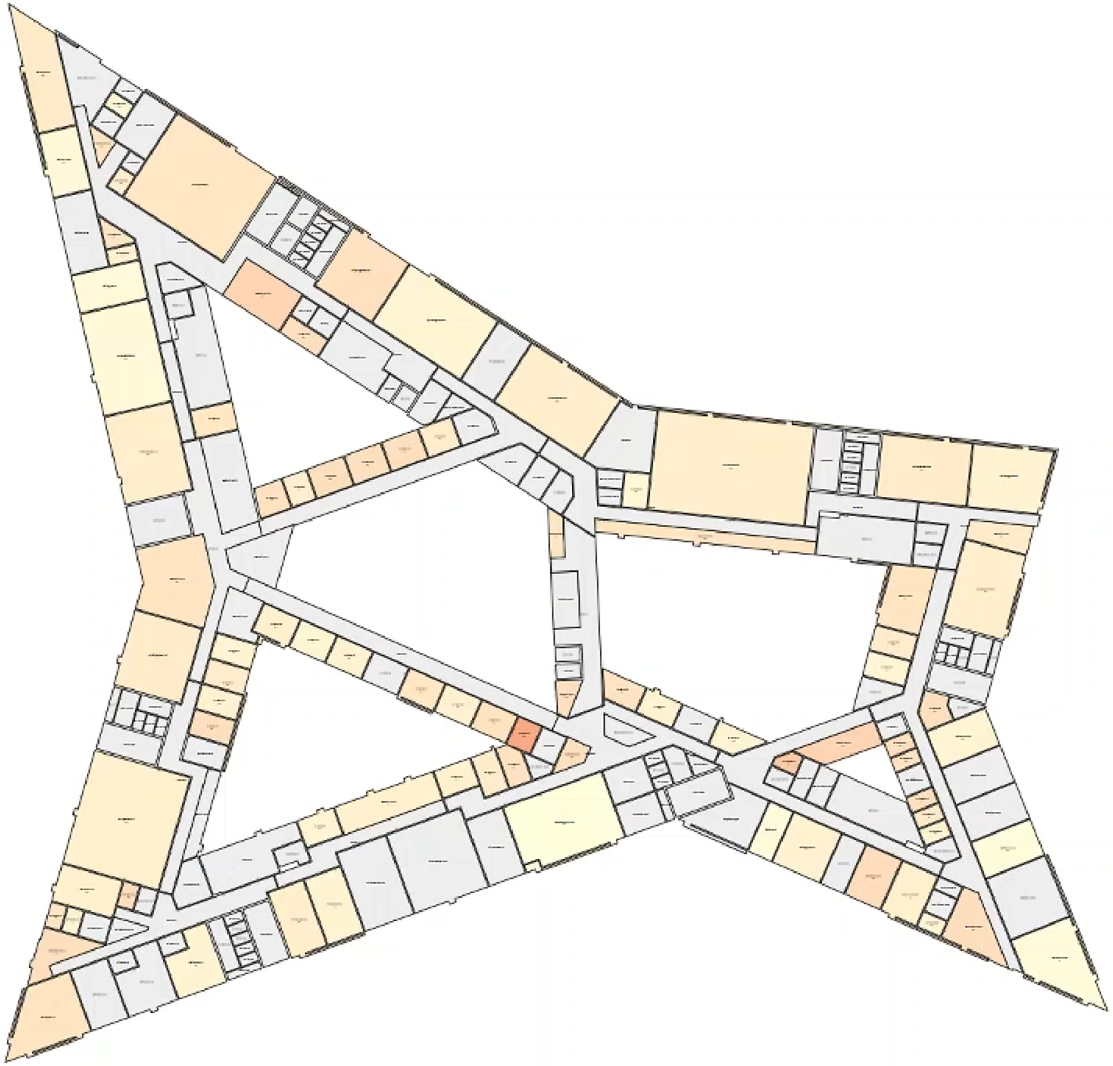

The PROV Ontology (PROV-O)
GeoSPARQL
has geometry
20 m²
has area
Space A
has space
has space
has space
Storey 00
has geometry
32 m²
has area
Space B
has geometry
13 m²
has area
Space C
contains element
contains element
contains element
Sensor X
Sensor Y
Sensor Z
observes
observes
observes
Temperature
Air Humidity
made by sensor
made by sensor
made by sensor
dateTime
July 22nd 12:02
22.4 °C
has result
Observation XXX
dateTime
July 24th 11:12
22.3 °C
has result
Observation XXY
dateTime
July 27th 11:02
73.2 %
has result
Observation XXZ
Building topology
Sensors
Observations
Building Topology Ontology (BOT)
Semantic Sensor Network Ontology (SSN)

Select level
Niveau 04

Color by
Max temperature

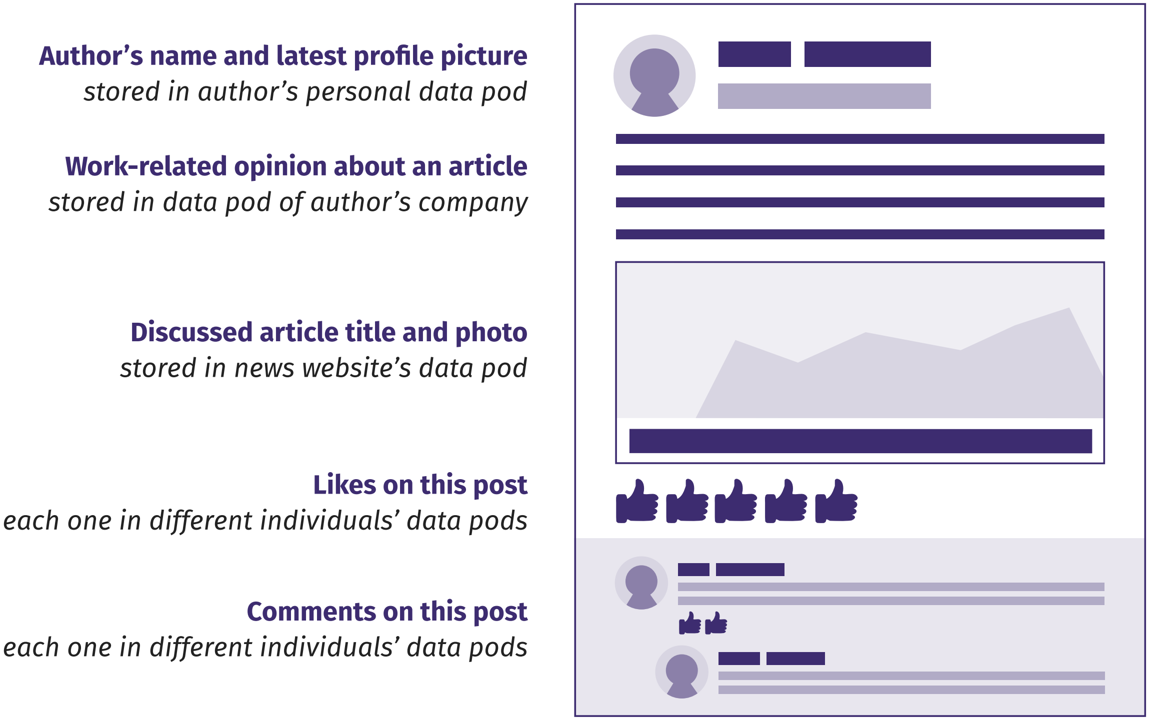
2D 3D

Show info

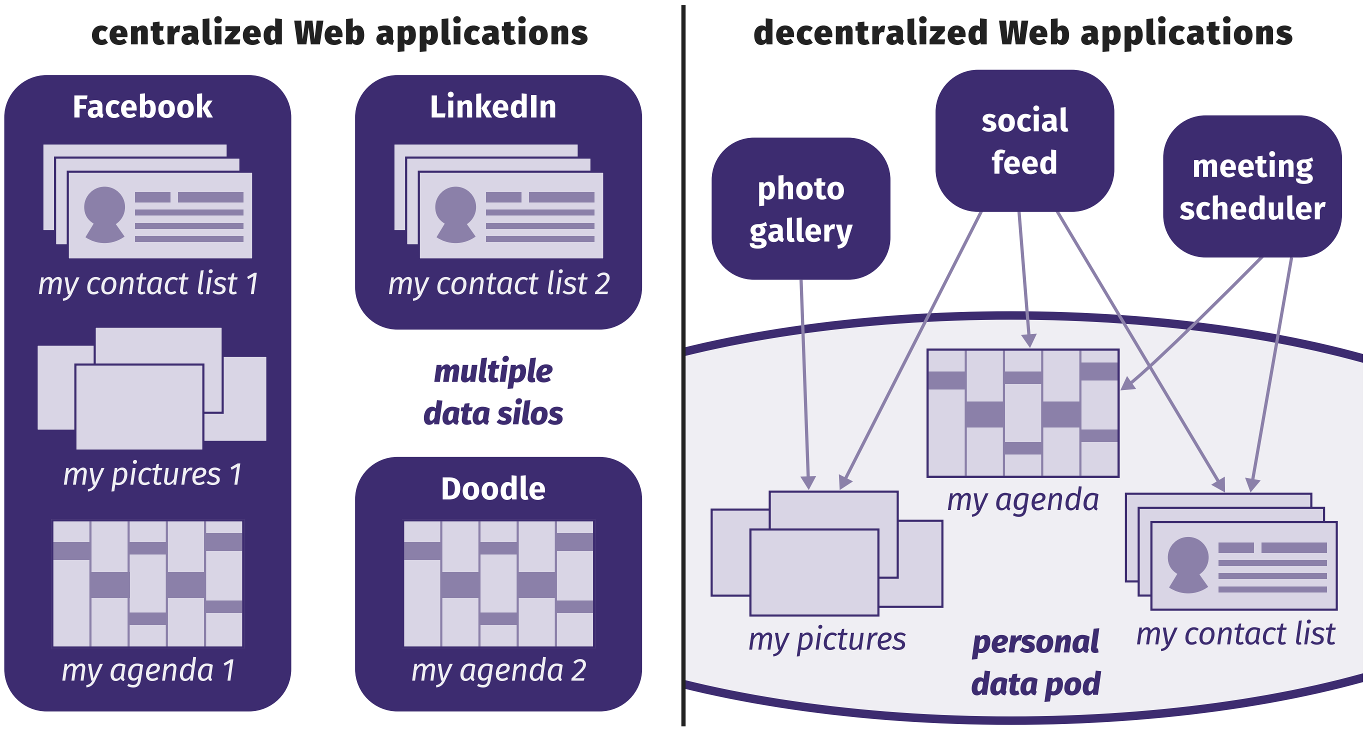


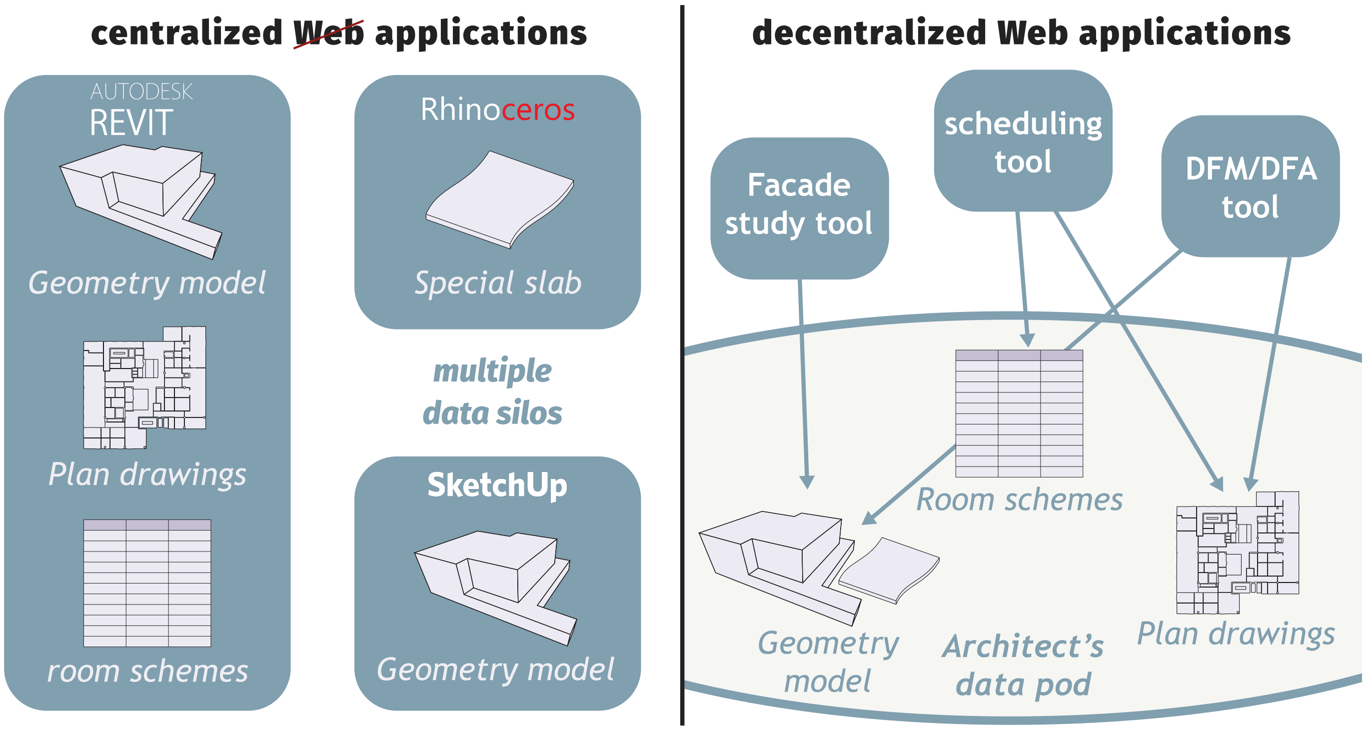
Press and hold "Alt" to pan

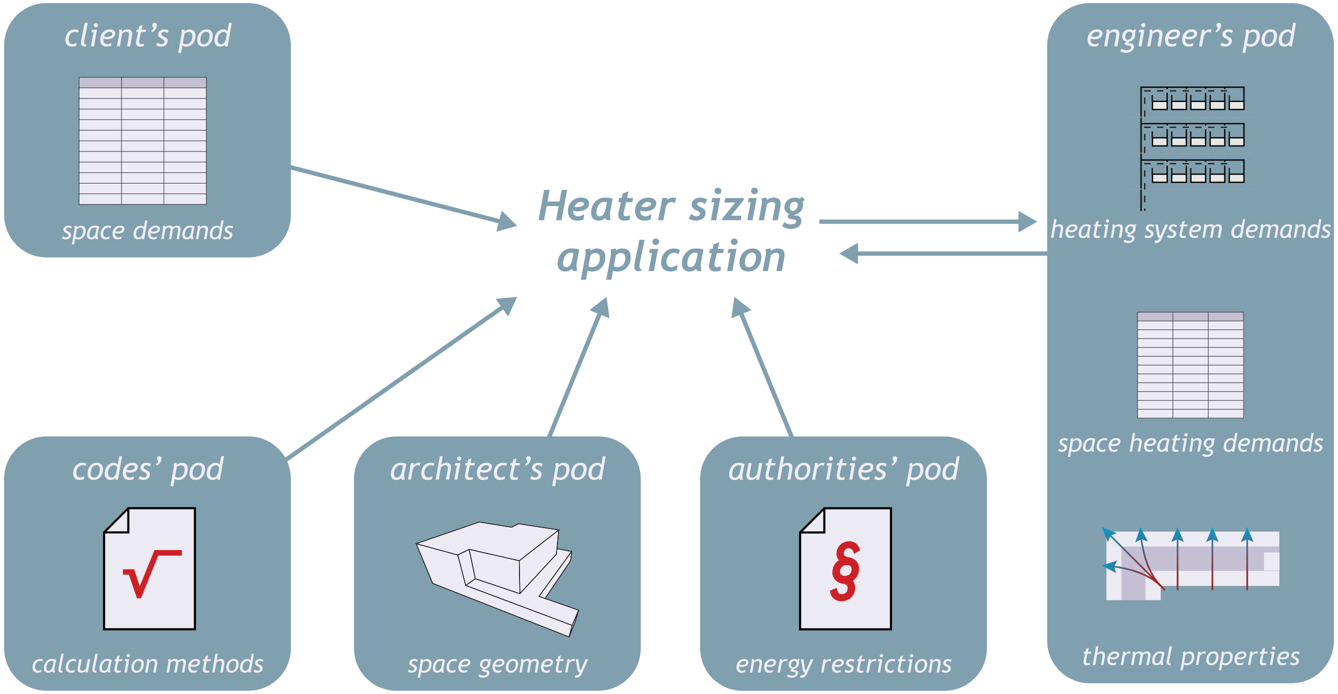
What could the system architecture look like?



Author’s name and latest profile picture
stored in author’s personal data pod
Work-related opinion about an article
stored in data pod of author’s company
Discussed article title and photo
stored in news website’s data pod
Likes on this post
each one in different individuals’ data pods
Comments on this post
each one in different individuals’ data pods


centralized Web applications
Facebook
my contact list 1
my pictures 1
my agenda 1
LinkedIn
my contact list 2
multiple
data silos
Doodle
my agenda 2
decentralized Web applications
photo
gallery
social
feed
meeting
scheduler
my agenda
my pictures
personal
data pod
my contact list


centralized ~~Web~~ applications
AUTODESK
REVIT
Geometry model
Plan drawings
room schemes
Rhinoceros
Special slab
multiple
data silos
SketchUp
Geometry model
decentralized Web applications
Facade
study tool
scheduling
tool
DFM/DFA
tool
Room schemes
Geometry
model
Architect's
data pod
Plan drawings


client's pod
space demands
Heater sizing application
engineer's pod
heating system demands
space heating demands
thermal properties
codes' pod
calculation methods
architect's pod
space geometry
authorities' pod
energy restrictions

Small, task-specific applications rather than large monolitic systems

Who should define the terminology?

Dansk standard

DS/EN 15251

1. udgave

2007-06-22

Input-parametre til indeklimaet ved design og bestemmelse af bygningers energimæssige ydeevne vedrørende indendørs luftkvalitet, termisk miljø, belysning og akustik

Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics

DANSK STANDARD
Danish Standards

Kollegievej 6
DK-2920 Charlottenlund
Tel: +45 39 96 61 01
Fax: +45 39 96 61 02
dansk.standard@ds.dk
www.ds.dk

EN 15193		*Energy performance of buildings — Energy requirements for lighting*
EN 15241		*Ventilation for buildings — Calculation methods for energy losses due to ventilation and infiltration in commercial buildings*
EN 15242		*Ventilation for buildings — Calculation methods for the determination of air flow rates in buildings including infiltration*
prEN 15255		*Thermal performance of buildings — Sensible room cooling load calculation — General criteria and validation procedures*
prEN 15265		*Thermal performance of buildings — Calculation of energy needs for space heating and cooling using dynamic methods — General criteria and validation procedures*
EN ISO 7726		*Ergonomics of the thermal environment — Instruments for measuring physical quantities (ISO 7726:1998)*
EN ISO 7730		*Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria (ISO 7730:2005)*
EN ISO 8996		*Ergonomics of the thermal environment — Determination of metabolic rate (ISO 8996:2004)*
EN ISO 9920		*Ergonomics of the thermal environment — Estimation of the thermal insulation and evaporative resistance of a clothing ensemble (ISO 9920:1995)*
EN ISO 13731	2001	*Ergonomics of the thermal environment — Vocabulary and symbols (ISO 13731:2001)*
EN ISO 13790		*Thermal performance of buildings — Calculation of energy use for space heating (ISO 13790:2004)*
ISO/TS 14415		*Ergonomics of the thermal environment — Application of International Standards to people with special requirements*
CIE 69		*Methods of characterizing illuminance meters and luminance meters; performance, characteristics and specifications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 12792:2003, EN ISO 13731:2001, EN 12464-1:2002 and the following apply.

3.1
adaptation
physiological, psychological or behavioural adjustment of building occupants to the interior thermal environment in order to avoid discomfort

NOTE In naturally ventilated buildings these are often in response to changes in indoor environment induced by outside weather conditions.

3.2
active cooling
see mechanical cooling

3.3
buildings, very low-polluting
buildings where an extraordinary effort has been done to select low-emitting materials and activities with emission of pollutants are prohibited and no previous emitting sources (like tobacco smoke) was present

NOTE Criteria are listed in Annex G.

3.4
buildings, low-polluting
buildings where an effort has been done to select low-emitting materials and activities with emission of pollutants are limited or prohibited

NOTE Criteria are listed in Annex G

3.5
buildings, not low-polluting
old or new buildings where no effort has been done to select low-emitting materials and activities with emission of pollutants not prohibited

NOTE Previous emissions (like tobacco smoke) may have taken place.

3.6
buildings without mechanical cooling
buildings that do not have any mechanical cooling and rely on other techniques to reduce high indoor temperature during the warm season like moderately-sized windows, adequate sun shielding, use of building mass, natural ventilation, night time ventilation etc. for preventing overheating

3.7
cooling season
part of the year during which (at least parts of the day and part of the building, usually summer) cooling appliances are needed to keep the indoor temperatures at specified levels

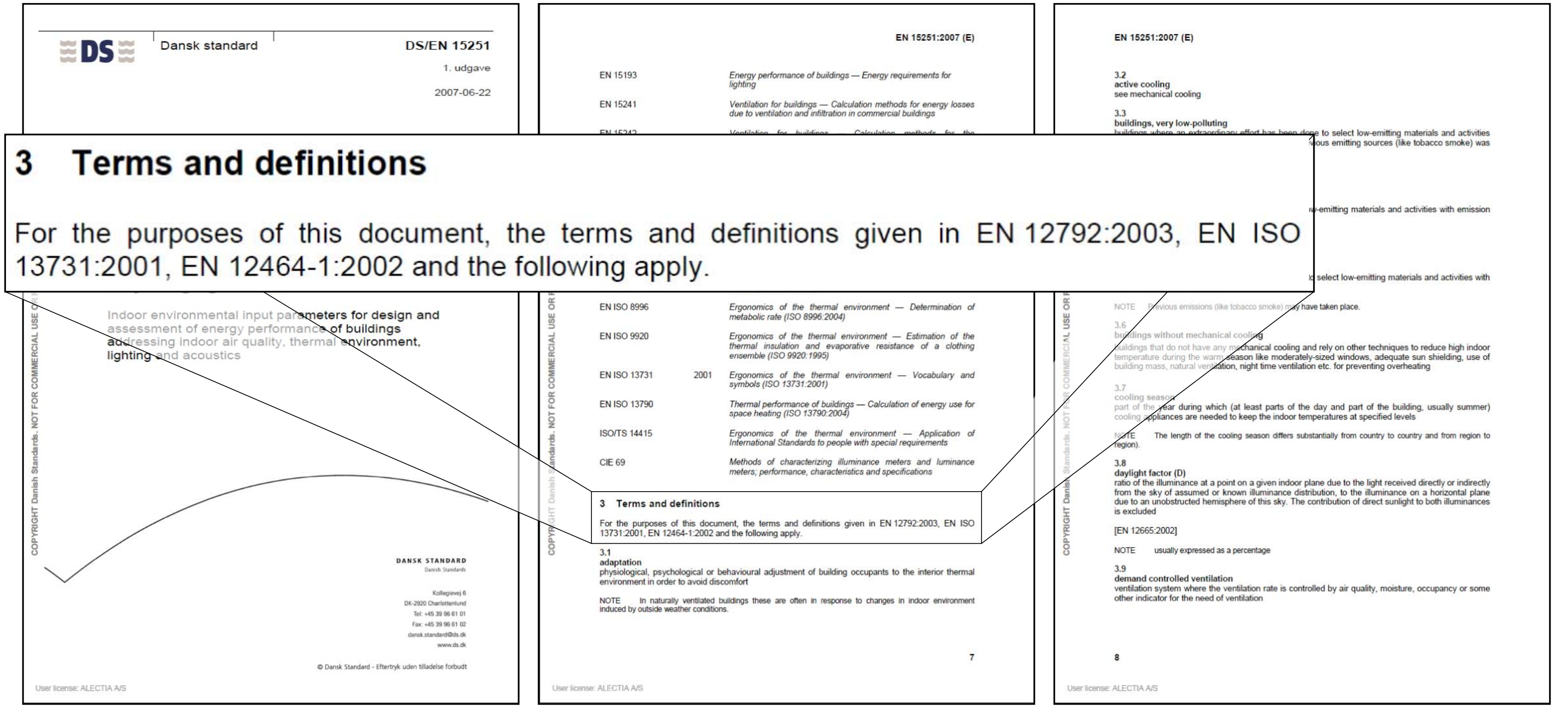
NOTE The length of the cooling season differs substantially from country to country and from region to region).

3.8
daylight factor (D)
ratio of the illuminance at a point on a given indoor plane due to the light received directly or indirectly from the sky of assumed or known illuminance distribution, to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky. The contribution of direct sunlight to both illuminances is excluded

[EN 12665:2002]

NOTE usually expressed as a percentage

3.9
demand controlled ventilation
ventilation system where the ventilation rate is controlled by air quality, moisture, occupancy or some other indicator for the need of ventilation



Dansk standard
DS/EN 15251
1. udgave
2007-06-22
3 Terms and definitions
For the purposes of this document, the terms and definitions given in EN 12792:2003, EN ISO 13731:2001, EN 12464-1:2002 and the following apply.
Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics
DANSK STANDARD
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User license: ALECTIA A/S
EN 15251:2007 (E)
EN 15193
Energy performance of buildings — Energy requirements for lighting
EN 15241
Ventilation for buildings — Calculation methods for energy losses due to ventilation and infiltration in commercial buildings
EN ISO 8996
Ergonomics of the thermal environment — Determination of metabolic rate (ISO 8996:2004)
EN ISO 9920
Ergonomics of the thermal environment — Estimation of the thermal insulation and evaporative resistance of a clothing ensemble (ISO 9920:1995)
EN ISO 13731
2001
Ergonomics of the thermal environment — Vocabulary and symbols (ISO 13731:2001)
EN ISO 13790
Thermal performance of buildings — Calculation of energy use for space heating (ISO 13790:2004)
ISO/TS 14415
Ergonomics of the thermal environment — Application of International Standards to people with special requirements
CIE 69
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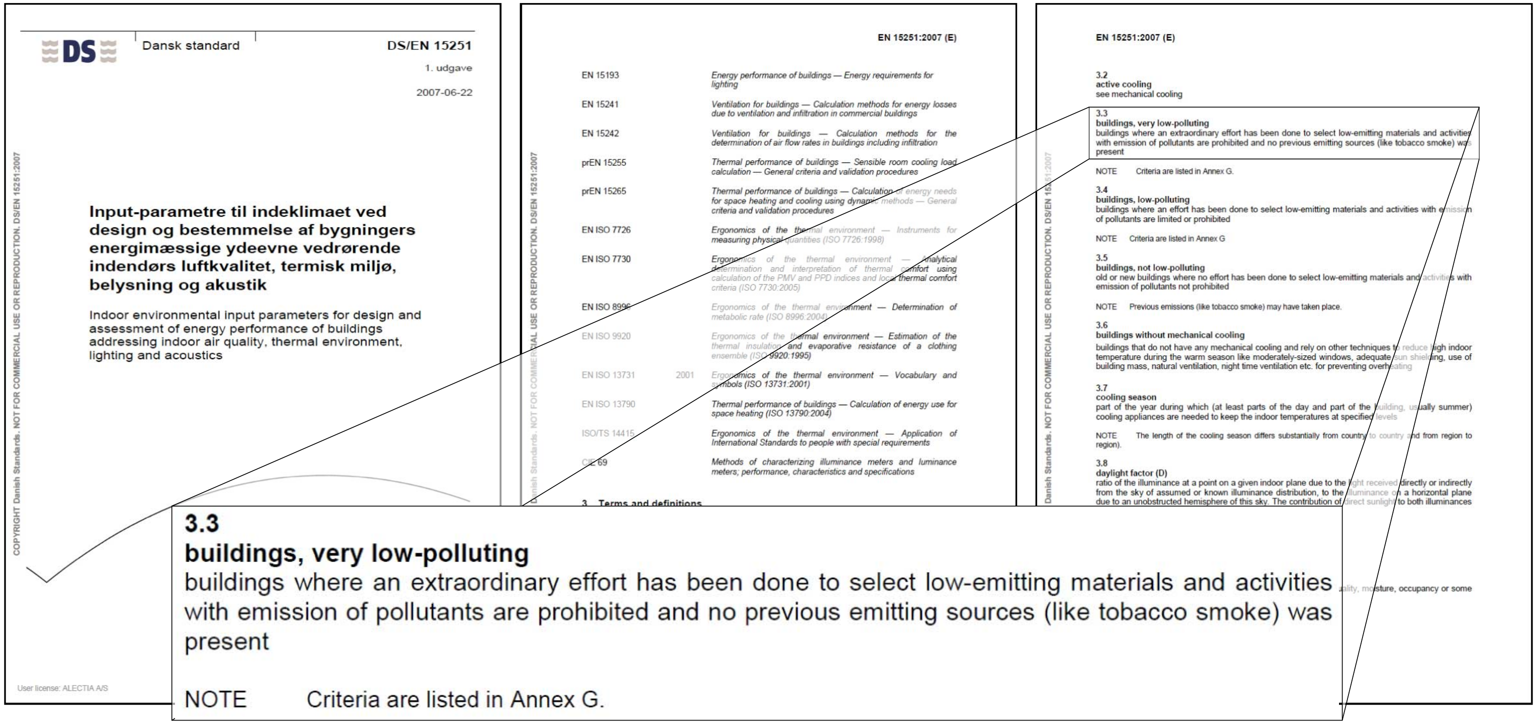
adaptation
physiological, psychological or behavioural adjustment of building occupants to the interior thermal environment in order to avoid discomfort
NOTE In naturally ventilated buildings these are often in response to changes in indoor environment induced by outside weather conditions.
7
3.2
active cooling
see mechanical cooling
3.3
buildings, very low-polluting
3.8
daylight factor (D)
ratio of the illuminance at a point on a given indoor plane due to the light received directly or indirectly from the sky of assumed or known illuminance distribution, to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky. The contribution of direct sunlight to both illuminances is excluded
[EN 12665:2002]
NOTE usually expressed as a percentage
3.9
demand controlled ventilation
ventilation system where the ventilation rate is controlled by air quality, moisture, occupancy or some other indicator for the need of ventilation
8


Dansk standard
DS/EN 15251
1. udgave
2007-06-22
Input-parametre til indeklimaet ved design og bestemmelse af bygningers energimæssige ydeevne vedrørende indendørs luftkvalitet, termisk miljø, belysning og akustik
Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics
COPYRIGHT Danish Standards. NOT FOR COMMERCIAL USE OR REPRODUCTION. DS/EN 15251:2007
User license: ALECTIA A/S
EN 15251:2007 (E)
3.3
buildings, very low-polluting
buildings where an extraordinary effort has been done to select low-emitting materials and activities with emission of pollutants are prohibited and no previous emitting sources (like tobacco smoke) was present
NOTE Criteria are listed in Annex G.

```
@prefix cen15251:   <https://www.cen.eu/en/15251-2007#> .
@prefix owl:        <http://www.w3.org/2002/07/owl#> .
@prefix rdf:        <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs:       <http://www.w3.org/2000/01/rdf-schema#> .

cen15251:VeryLowPolutingBuilding
          rdf:type          owl:Class ;
          rdfs:label        "Buildings, very low-polluting"@en ,
                            "Bygninger, meget lavt-forurenende"@da ;
          rdfs:comment      """Buildings where an extraordinary effor
                            to select low-emitting materials and acti
                            of pollutants are prohibited and no previ
                            (like tobacco smoke) was present."""@en ,
                            """Bygninger hvor der er gjort en ekstror
                            udvælge lavt-udledende materialer og hvor
                            aktiviteter er forbudt og ingen tidligere
                            (såsom tabaksrøg) har været til stede."""
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                            cen15251:NotLowPolutingBuilding ;
          rdfs:subClassOf   cen15251:BuildingPollutionCategory .
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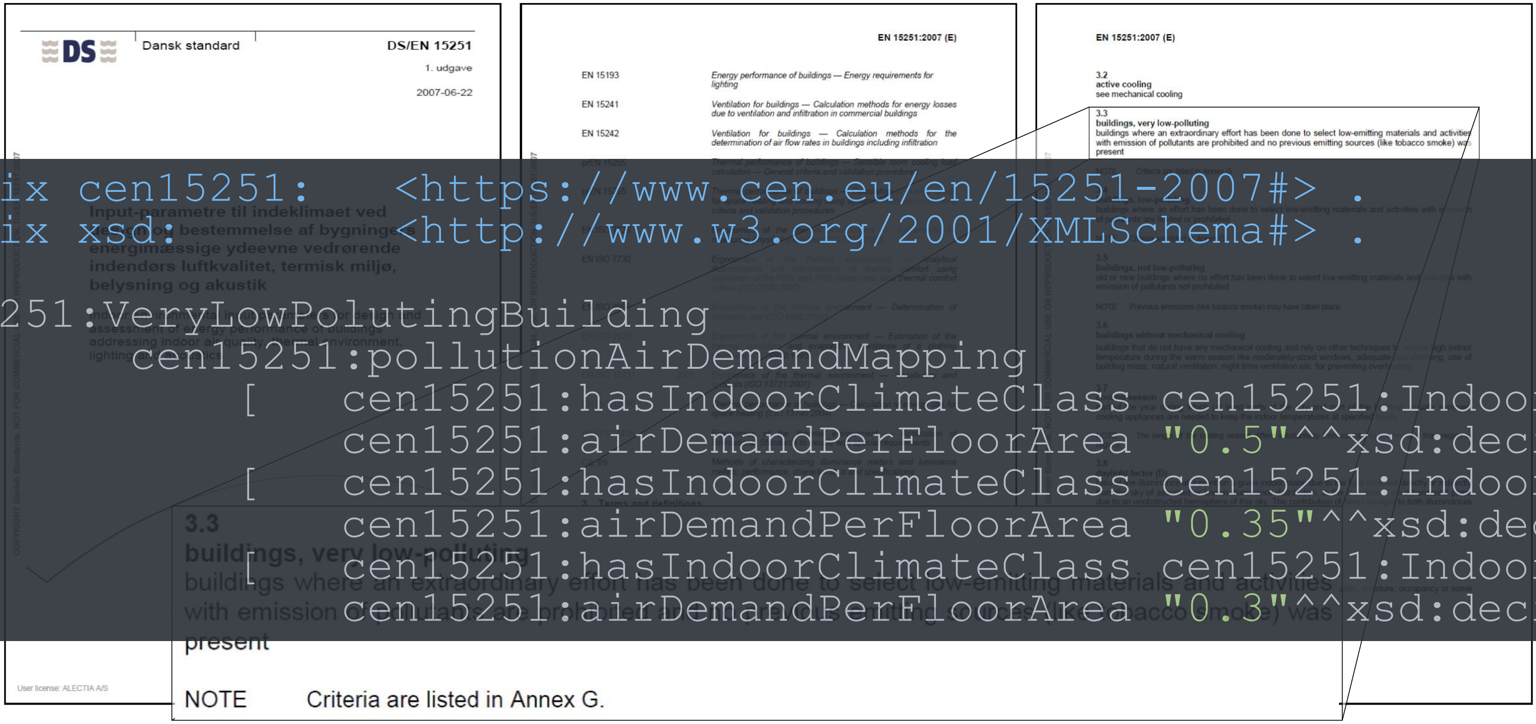


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@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .

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        [   cen15251:hasIndoorClimateClass cen15251:IndoorClima
            cen15251:airDemandPerFloorArea "0.3"^^xsd:decimal ]
```

NIRAS approach

- Use what is already out there
- Extend with Niras-specific terminology when needed
- Encourage standardisation organisations to publish RDF
- Link and align own terminology as standards become available in RDF

Other cool stuff...

There exists a standars rule language called SHACL

With RDFa it can be embedded directly inside HTML-pages

The technologies are widely used in other industries
and are therefore continuously being developed

There are both commercial and open source triplestores available

Let's dream a bit!

Imagine **material properties automatically being inherited** simply by describing the material as <https://materialDB/concrete2300> instead of just "concrete"

Imagine that the placeholder product used in the design model can be automatically matched against what is available on the market. Like a

Skyscanner for building products

Imagine if building regulations were published as SHACL rules such that **compliance checking** could be automated.

Imagine if manufacturers could **publish LCA data** on their products. Innovative production methods yield lower climate impact but designers depend on data from generic databases.

Let's give the manufacturers an extra incentive to make better products!

What if the controls and systems used in indoor climate simulations were transfered to the actual systems?

What if all contexts of a sensor (what room, what system, where in the system) were modeled in the design stages and therefore directly available for the Digital Twin?

Embrace the technology and go innovate the industry!

Tak for opmærksomheden 😊