

Keynote

Buildings and Semantics: Near Real-Time Access to your Building Data

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TU Eindhoven and Ghent University



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ATLAS LIVING LAB

The Atlas Living Lab is our newest and most sophisticated living lab, in which 10 years of experience with living labs accumulated in a flexible infrastructure and accompanying processes to conduct ground breaking research while respecting the privacy and comfort of the residents.

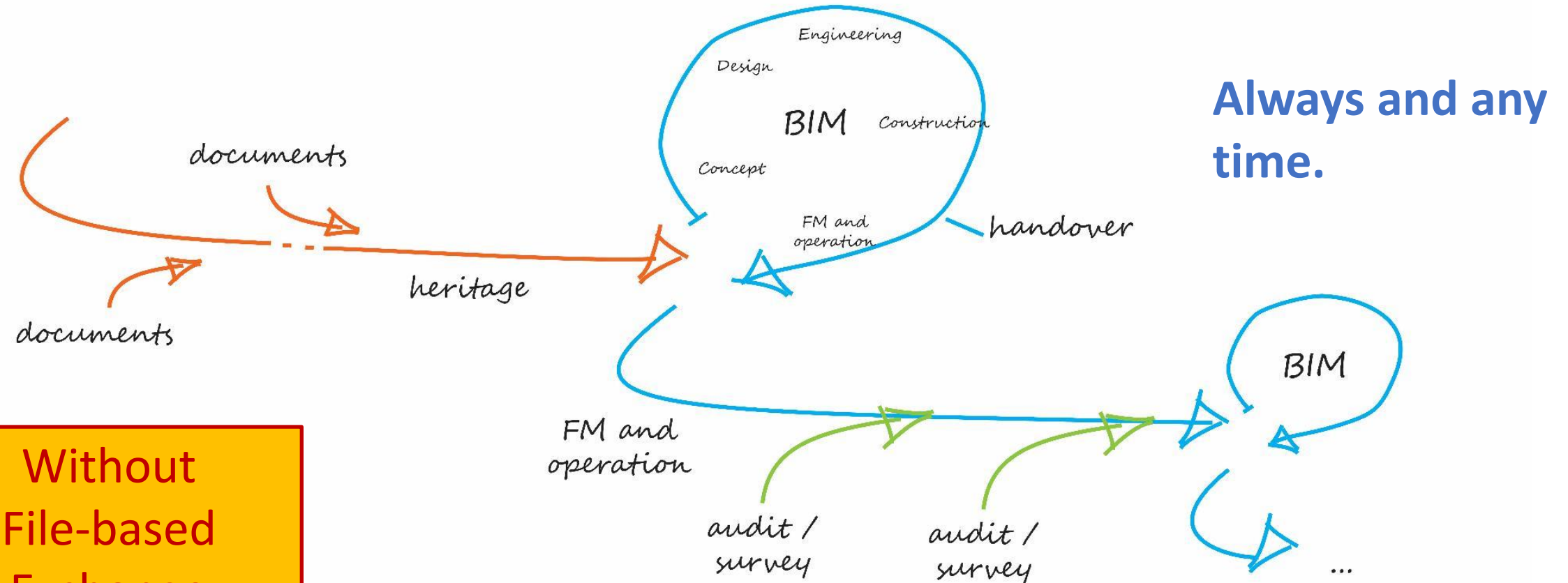
What brings the future?

B4B: Brains for Building's Energy Systems

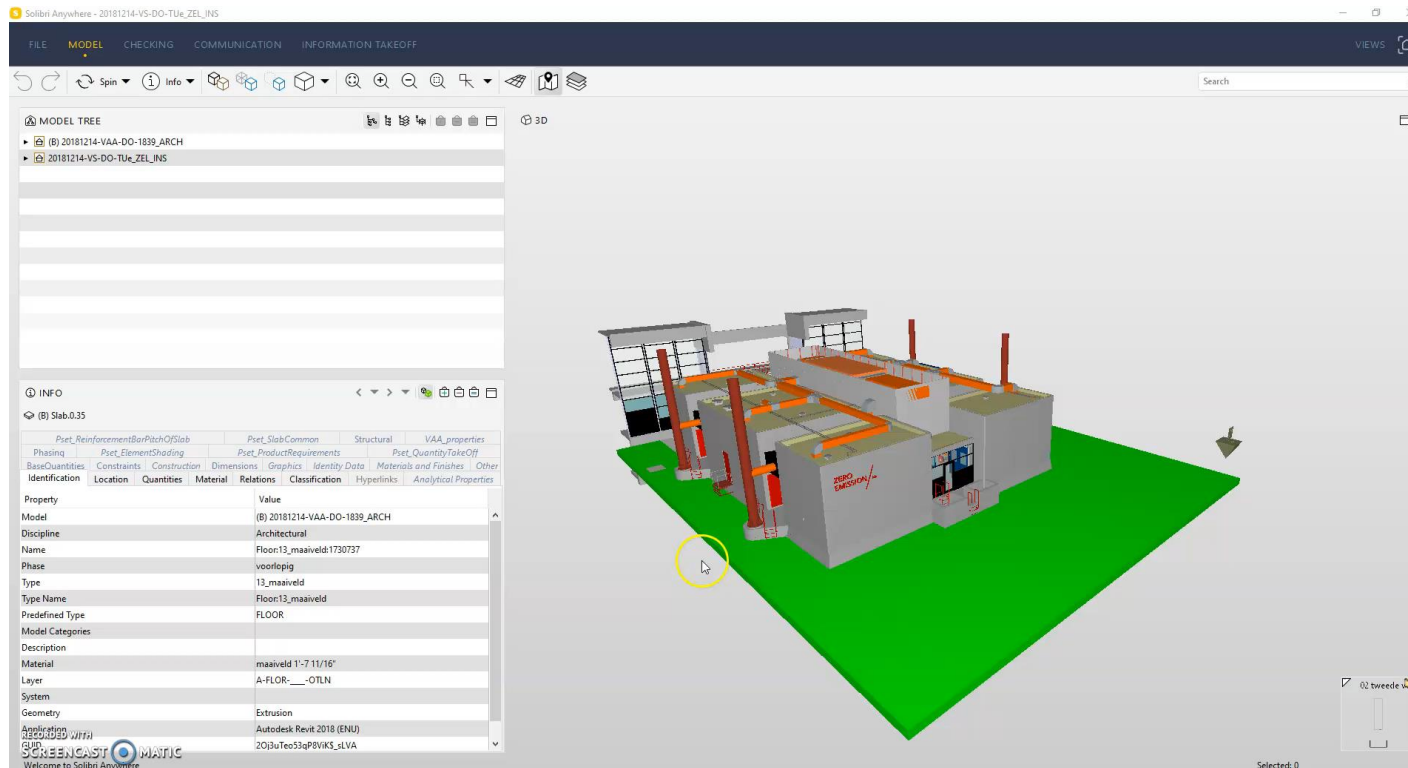


Content from tue-lighthouse.nl

Not only now....



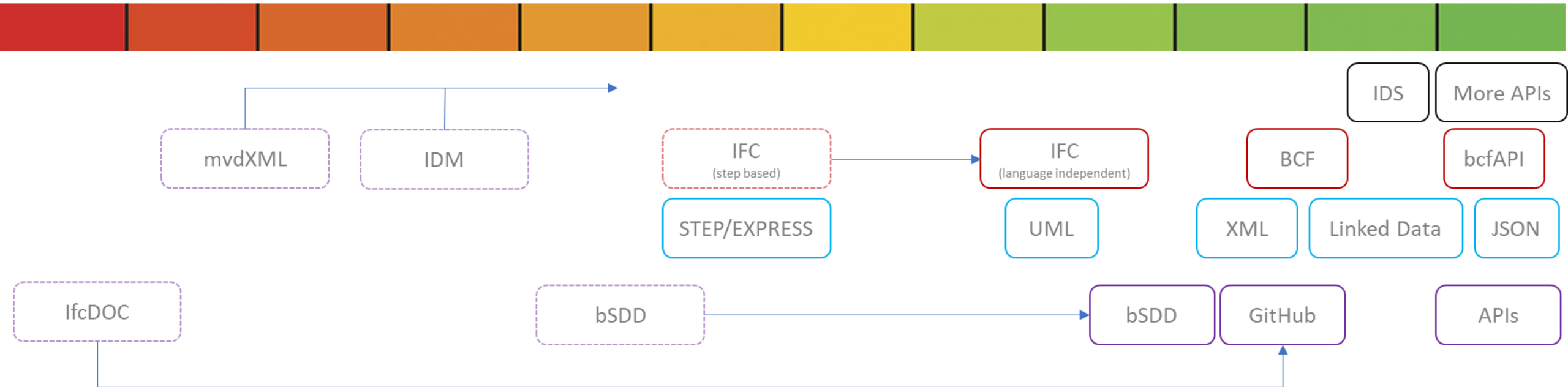
Without File-based Exchange



Building Information Model (BIM)
3D representation enriched with semantic information

Digital Twin (DT)
Digital counterpart for a physically existing object

Linked Building Data (LBD)
Set of interlinked web-based data about the built environment



<https://www.buildingsmart.org/about/technical-roadmap/>

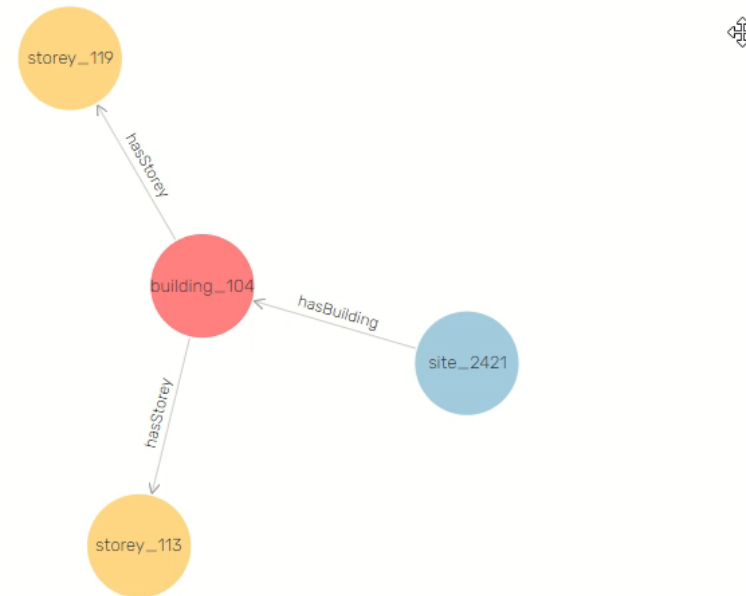
GraphDB FREE

- Import
- Explore
- Graphs overview
- Class hierarchy
- Class relationships
- Visual graph**
- Similarity
- SPARQL
- Monitor
- Setup
- Help

Visual graph ⓘ

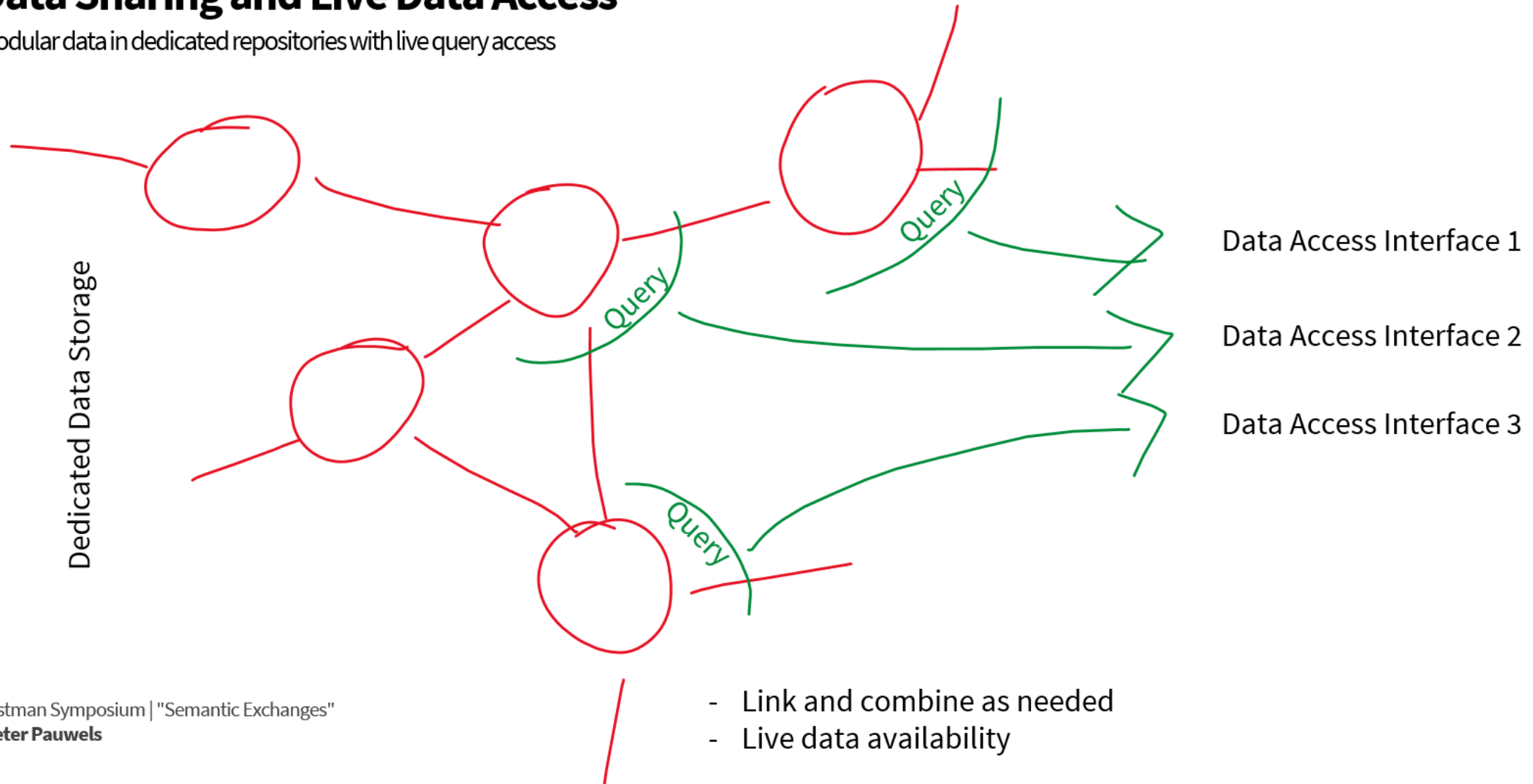
LBDDataFile ▾

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Data Sharing and Live Data Access

Modular data in dedicated repositories with live query access

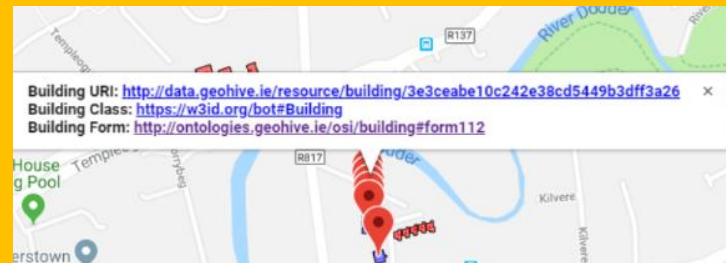
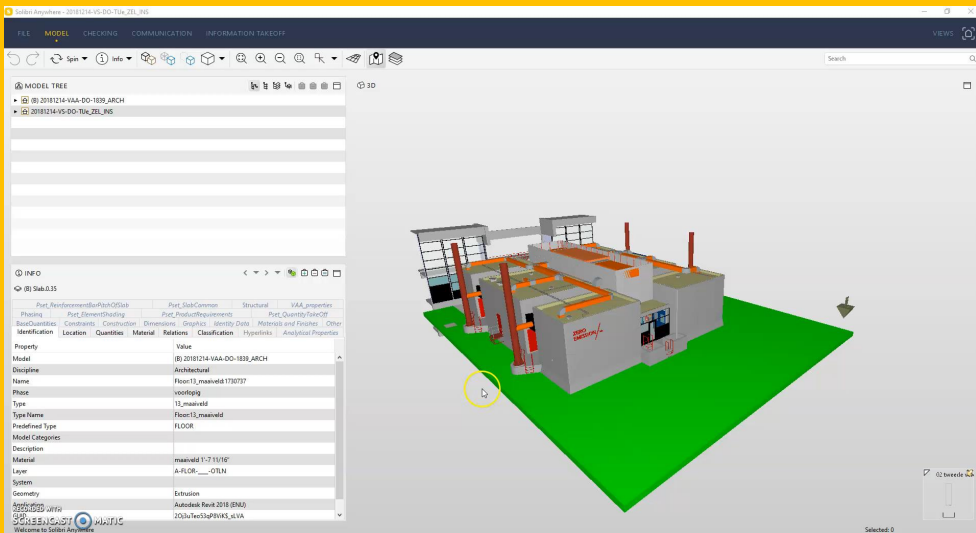
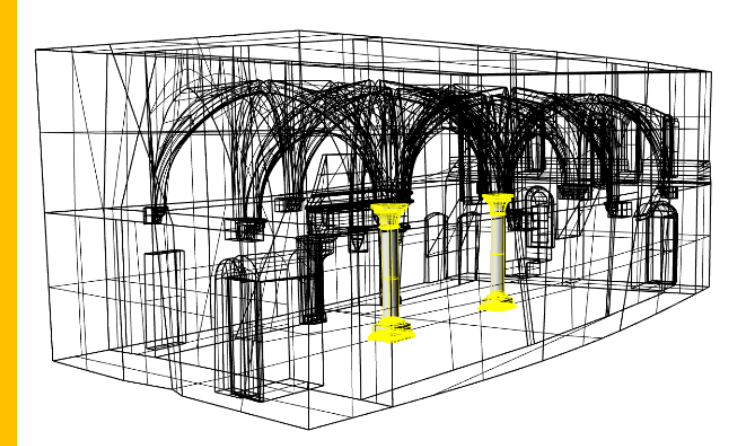
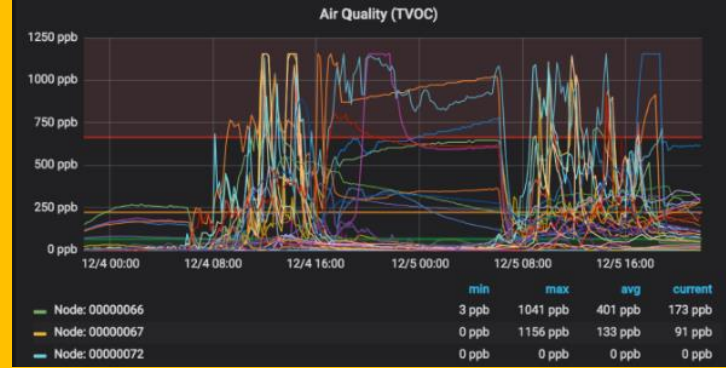


- Link and combine as needed
- Live data availability



A Cloud of Live Building Data

Range of data available



Categories of data?

- **Data streams:**
 - Ordered lists of values, typically floating point values
 - Large amount of data -> data lakes
 - Almost no semantics, at best a few labels for categorization
 - E.g. temperature measurements, system logs (e.g. triggering of actuators), etc.
- **Semantically rich and interconnected data:**
 - Seldom including large data streams
 - Long debates about the semantics of things -> standardisation
 - Complex and brittle (breaks easily)
 - Small amount of very important data
 - Easy to combine with rule-based and/or logic-based technologies (inference and query)
 - E.g. BIM models, semantic web ontologies, taxonomies, OTLs, etc.
- **Control models:**
 - Algorithms for control, parametric functions
 - Communication system, signal processing, direct control, low latency
 - Typically located on the edge (devices with embedded functions)
 - E.g. Control Description Language (CDL), modelica models
- **User data:**
 - Outside of the system
 - Different privacy and security requirements
- **Files:**
 - No semantically rich encodings, no data streams
 - Highly valuable, and seldom machine-processable
 - E.g. PDFs, Images, Geometry 'blobs'

Categories of data?

- **Data streams:**
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MACHINE LEARNING STATISTICAL AI METHODS



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- Communication system, signal processing, direct control, low latency
- Typically located on the edge (devices with embedded functions)
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- **User data:**
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 - Different privacy and security

- **Files:**
 - No semantically rich elements
 - Highly valuable, and so are the data

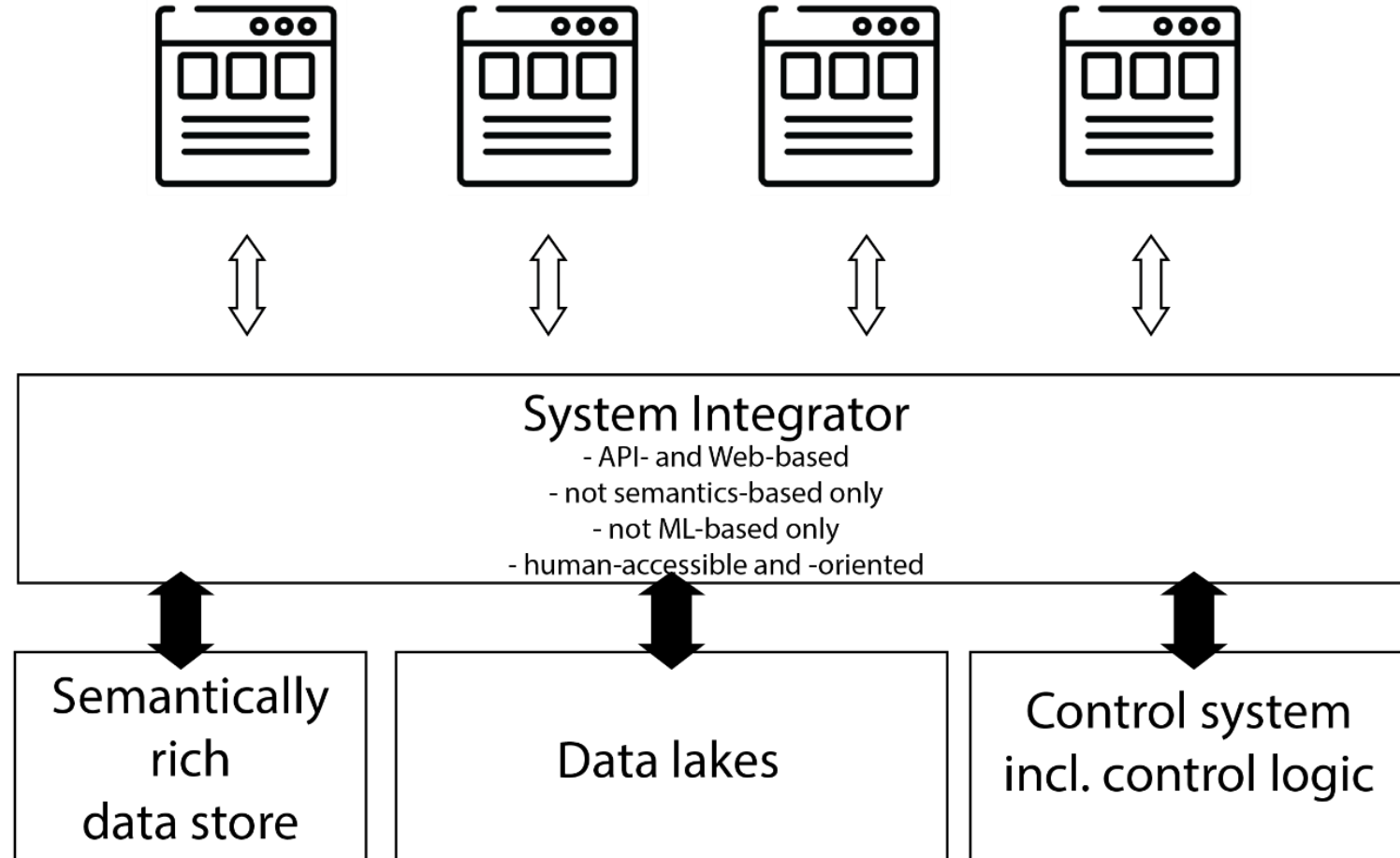


SEMANTICS SYMBOLIC AI METHODS

E.g. DfFs, Images, Geometric models

ams
isable

Targeted framework for AI-based smart buildings



SYMBOLIC AI



STATISTICAL AI



Important:

- Include access control (ACL)
- 'linking' of data on system integration level
- Agreement and standardization of labels and metadata tags
- Feed back into control systems!

Semantic graph of sensors

```

@prefix brick: <https://brickschema.org/schema/Brick#> .
@prefix inst: <http://linkedbuildingdata.net/ifc/resources20201208_005325/> .
@prefix ph: <https://project-haystack.org/def/ph/3.9.11#> .
@prefix phIoT: <https://project-haystack.org/def/phIoT/3.9.11#> .
@prefix phScience: <https://project-haystack.org/def/phScience/3.9.11#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

```

```

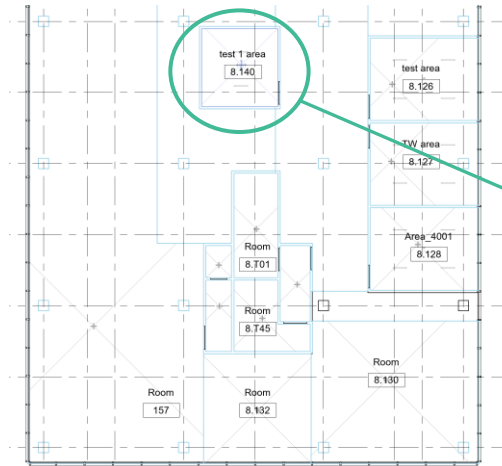
inst:11NR008LT-001PIRTM a brick:Occupancy_Sensor,
    phIoT:sensor ;
    rdfs:label "PRESENCE_8_128"^^xsd:string ;
    brick:hasLocation inst:space_892 ;
    ph:dis "PRESENCE_8_128"^^xsd:string ;
    ph:hasTag phIoT:his,
        phIoT:occupancy ;
    phIoT:spaceRef inst:space_892 .

```

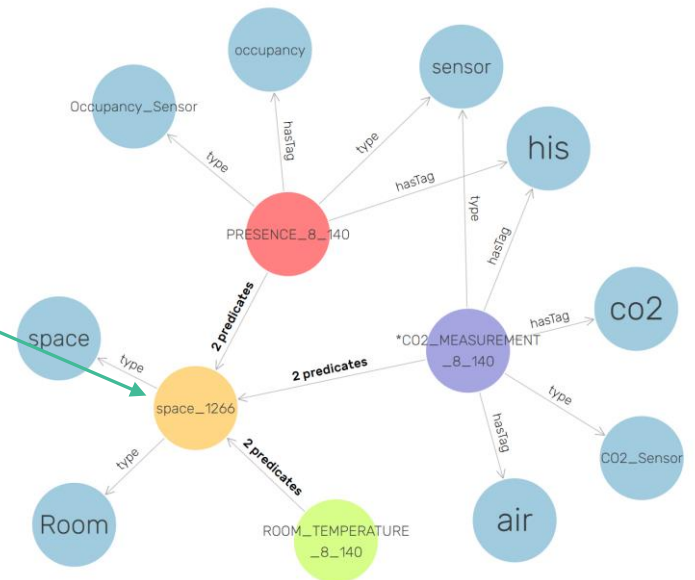
```

inst:11NR008LT-003PIRTM a brick:Occupancy_Sensor,
    phIoT:sensor ;
    rdfs:label "PRESENCE_8_127"^^xsd:string ;
    brick:hasLocation inst:space_1023 ;
    ph:dis "PRESENCE_8_127"^^xsd:string ;
    ph:hasTag phIoT:his,
        phIoT:occupancy ;
    phIoT:spaceRef inst:space_1023 .

```

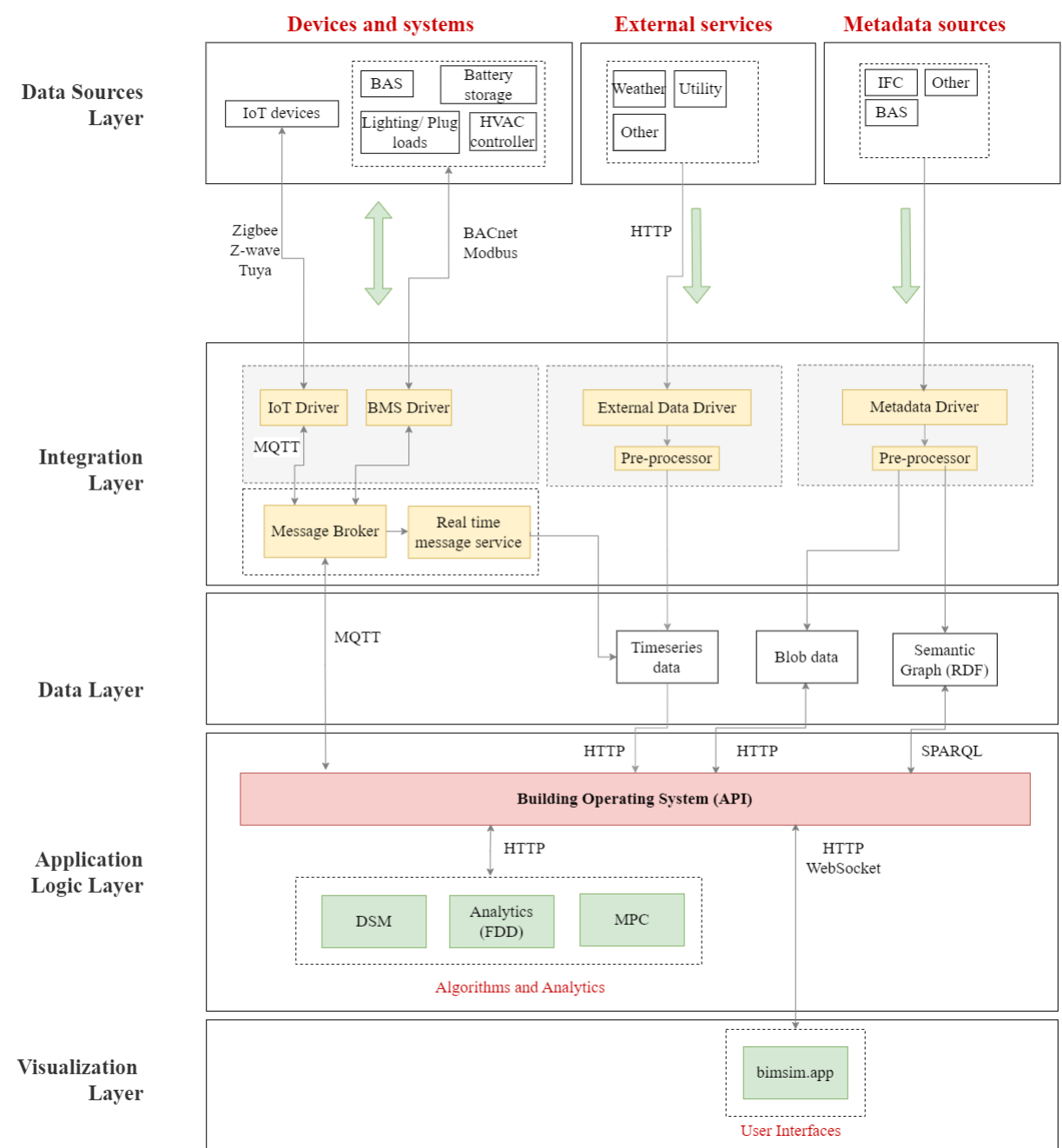


See presentation Lasitha Chamari on Wednesday 25 May.



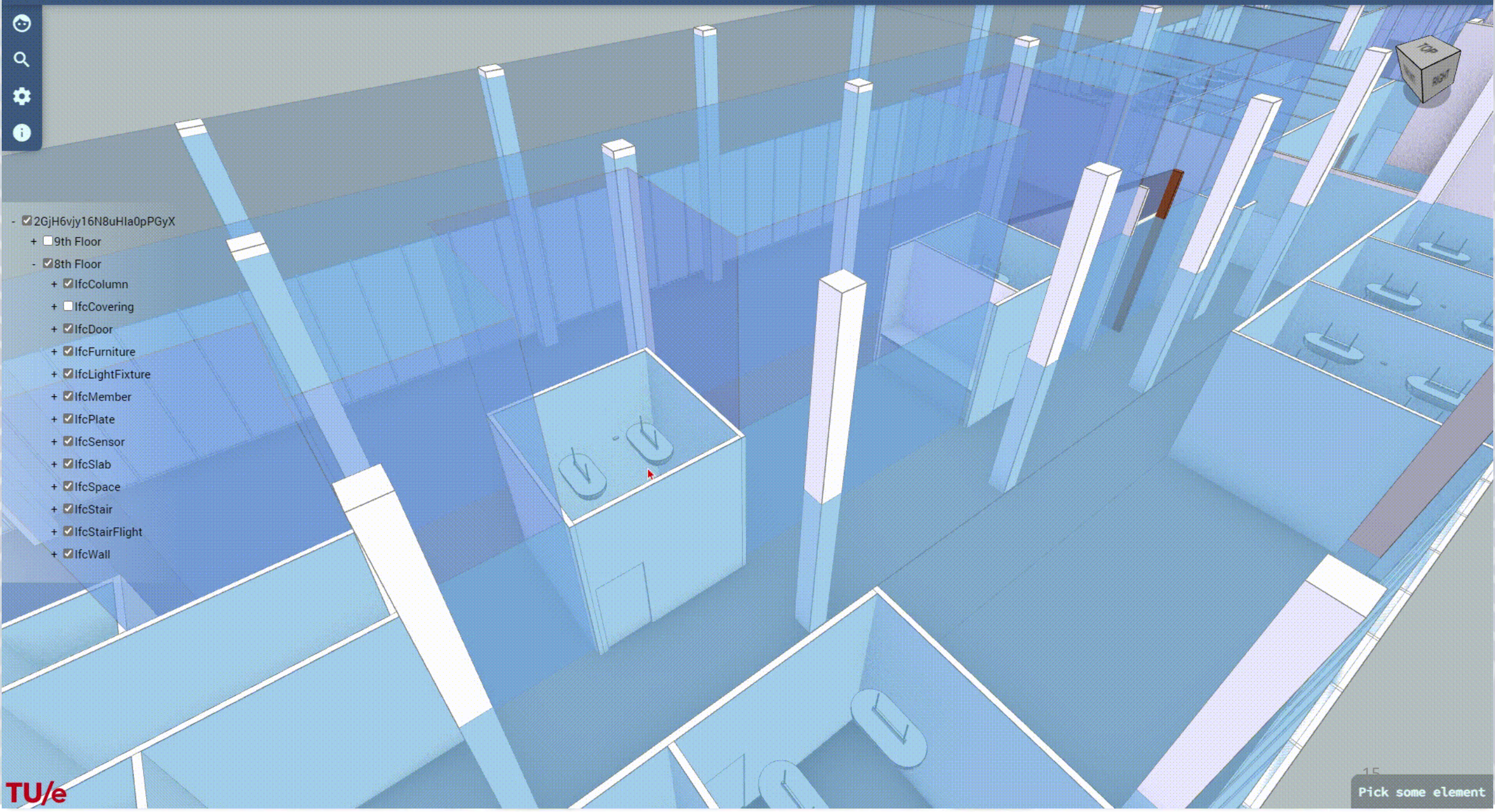
Brains4Buildings Reference System Architecture

- Web-compliant
- Connectors and transformers for external data sources
- Connected to IoT devices
- Central Building Operation System (API)
- Multiple Interfaces
- Be careful with security





- 2GjH6vjy16N8uH1a0pPGyX
- + 9th Floor
- 8th Floor
 - + IfcColumn
 - + IfcCovering
 - + IfcDoor
 - + IfcFurniture
 - + IfcLightFixture
 - + IfcMember
 - + IfcPlate
 - + IfcSensor
 - + IfcSlab
 - + IfcSpace
 - + IfcStair
 - + IfcStairFlight
 - + IfcWall



Can we use it
in more than 1
application?

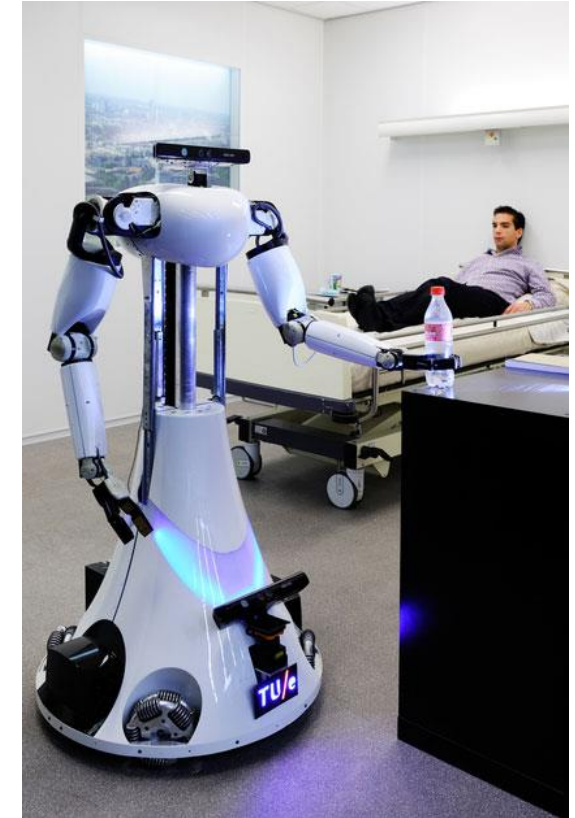
Does it scale?

Autonomous mobile robots are starting to be deployed in complex built environments where they need to navigate to complete the given tasks.

- Routing for last mile delivery (e.g. package delivery, hospital navigation)
- Emergency navigation and evacuation (e.g. fire)
- Navigation in risky environments (e.g. risk for diseases)
- Tasks in places that are difficult to reach (e.g. maintenance and inspection)

Autonomous mobile robots rely on environmental maps to do their navigation tasks:

- Topological map
- Metric map



Outline

Abstract

Keywords

1. Introduction

2. State of the art for robot world models and BIM

3. Method for evaluating data flows from BIM to r...

4. In-depth evaluation of data flows

5. Validation

6. Conclusion and future work

Declaration of Competing Interest

Data availability

References

Show full outline 








Advanced Engineering Informatics

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Full length article

Live semantic data from building digital twins for robot navigation: Overview of data transfer methods


Pieter Pauwels^a  , Rens de Koning^b , Bob Hendrikx^b , Elena Torta^b 


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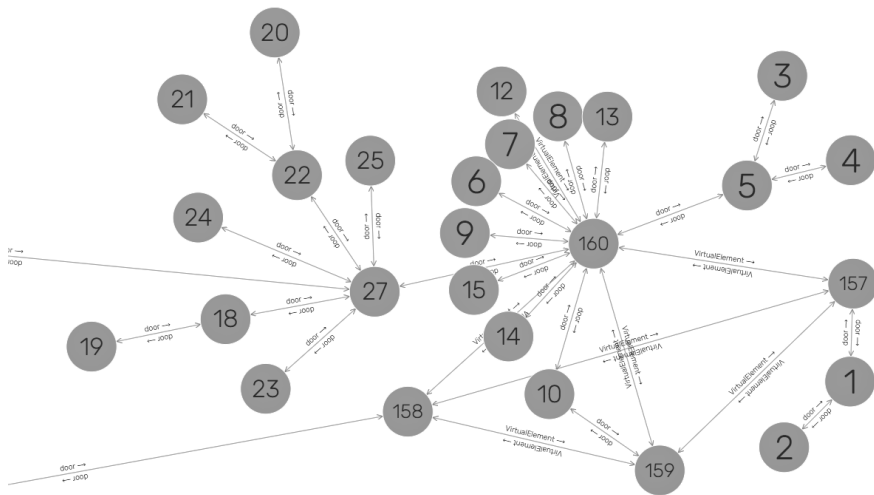
<https://doi.org/10.1016/j.aei.2023.101959> 

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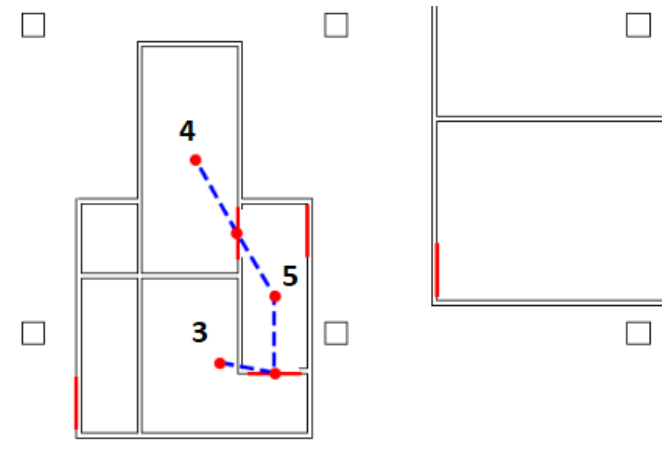
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- A **topological map** abstracts metric information and represents, in a bidirectional undirected graph (unlike the RDF graphs), how spaces are connected to each other.
- A **metric map** includes all metric information needed for path planning



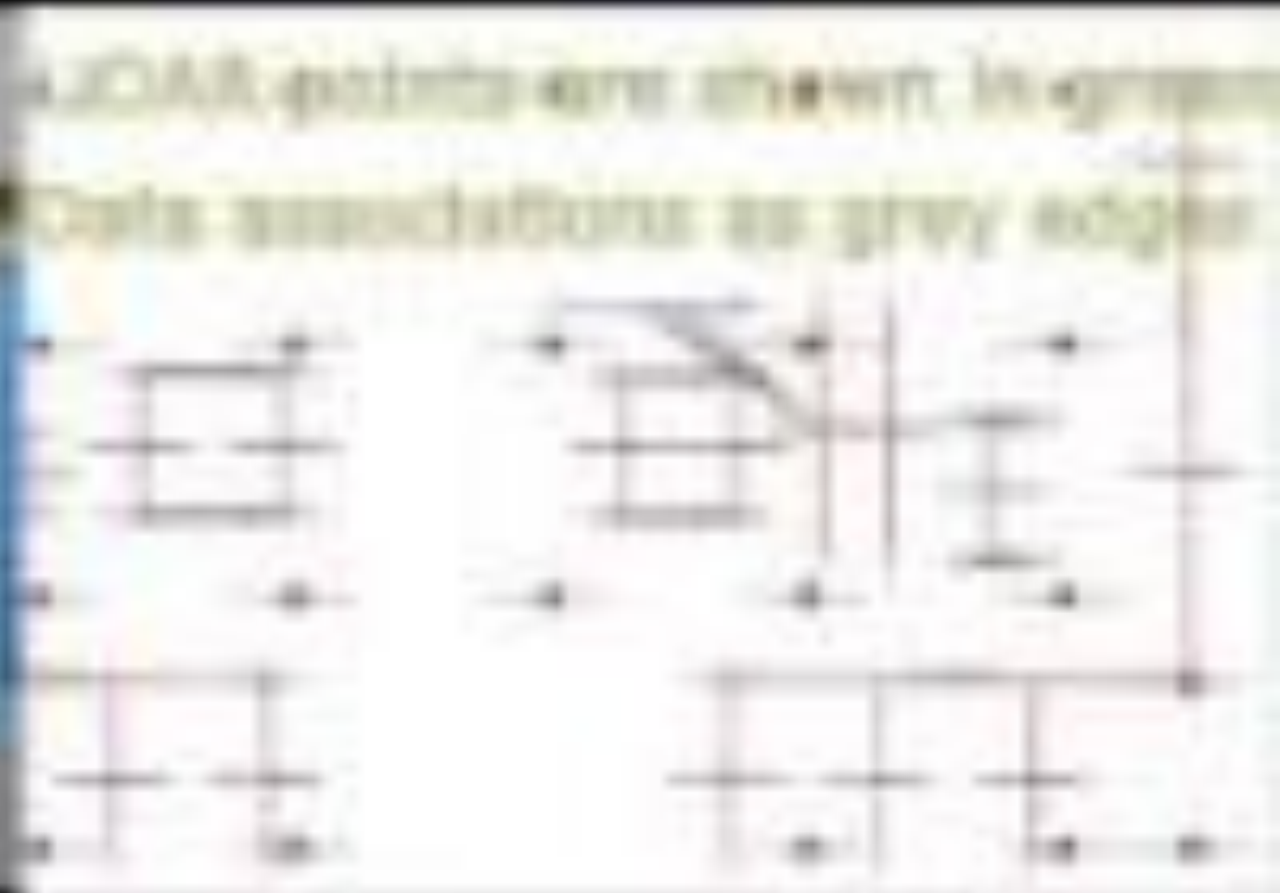
Topological map



Metric map

de Koning, R., Torta, E., Pauwels, P., Hendriks, R. W. M., & van de Molengraft, M. J. G. (2021). Queries on Semantic Building Digital Twins for Robot Navigation. In 9th Linked Data in Architecture and Construction Workshop (pp. 32-42). CEUR Workshop Proceedings; Vol. 3081. CEUR-WS.org.

<http://ceur-ws.org/Vol-3081/03paper.pdf>

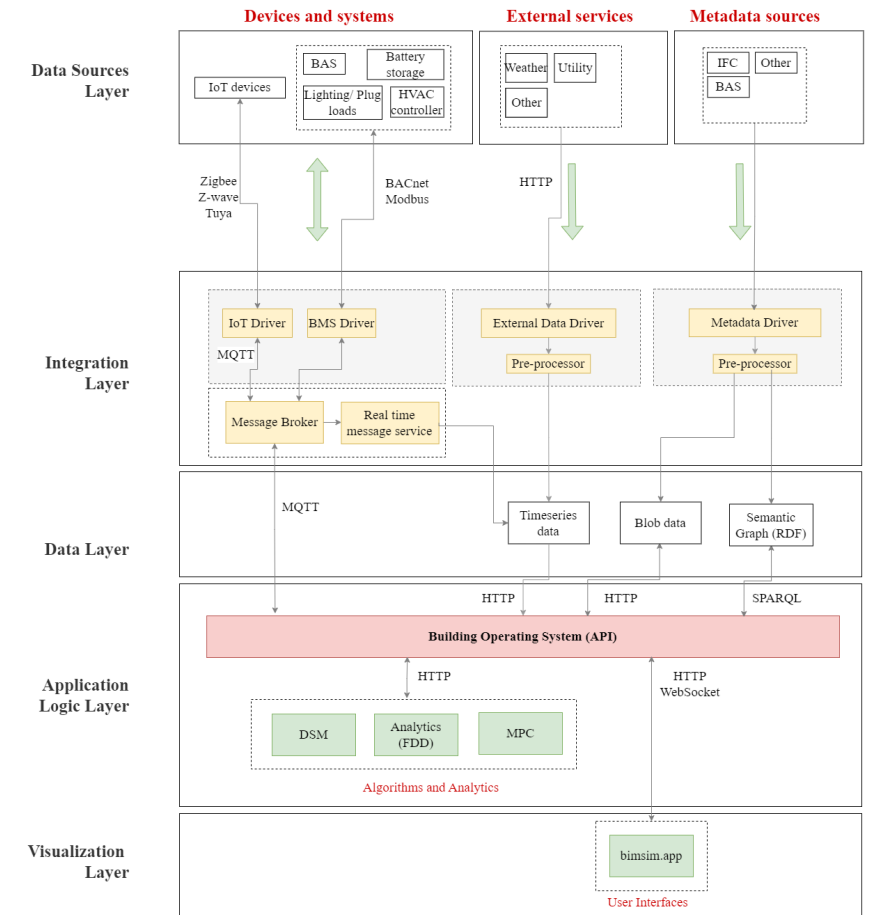


The Future is Now:

- Web-based Distributed Digital Twinning is becoming a reality
- High-quality data storage and access is possible
- Multiple interfaces to 1 Digital Twin System

So, what is in the Future?

- How well can large-scale distributed systems be maintained at scale?
- The 3D modeler challenge: how to keep geometry updated in a fast and cheap way?





3rd BUILDING DIGITAL TWIN
International Congress

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