Brains for buildings: where to find all the relevant smart building data?

TUESDAY 13 APRIL 2021 – WEBINAR – BIG DATA, IAQ AND VENTILATION – PART 1

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TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

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Who am I?

GHENT UNIVERSITY · W3C® · buildingSMART

Associate Professor TU Eindhoven (2019)

Assistant Professor Ghent University (2016-2019)

Postdoc Ghent University (2014-2016)

Postdoc University of Amsterdam (2012-2014)

Master & PhD in Civil Engineering – Architecture @Ghent University (2008, 2012)

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Presentation Outline

1. Brains 4 Buildings: why?
2. Building Data Semantics: BIM, IFC, LBD, BRICK, etc.
3. System Integration for scalability and feasibility

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End aims and user stories

- Fault detection (improved building management systems – BMSs)
    - understanding what goes wrong in a system
    - predicting when faults occur and having clues about the why
    - live detection
- User-centered systems
    - comfort levels per individual user
    - learning from user interaction
- Flexible Energy (interfaces):
    - consumption of energy where it is being created
    - creation of energy where it is consumed
    - load balance in the local and regional grid, including the appliances used

DATA INTEGRATION

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Data Integration for Smart Buildings
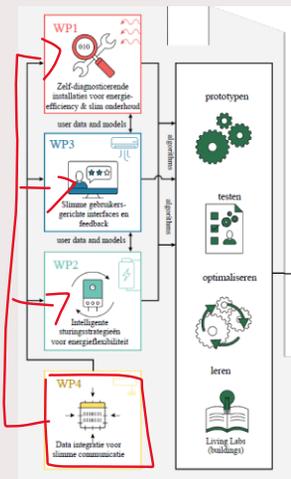
To enable making our buildings smarter, advanced data integration is needed (among several other matters):

- Ensure **data connectivity** between applications

- Ensure security, **ethical use and privacy of data**

- **Standardise** data sets and approaches

- Aim for **system integration at API level**, between individual systems of diverse manufacturers

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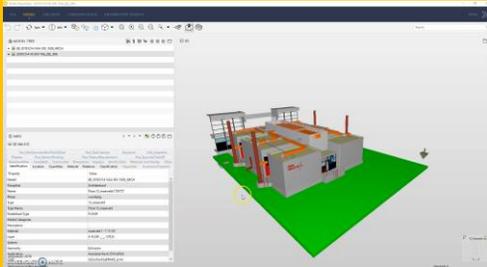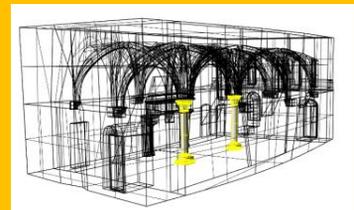
1. Brains 4 Buildings: why?
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All sorts of data available …

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BIM Data

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BIM data: Revit, modelling guidelines, agreements, 3D modelling, and IFC
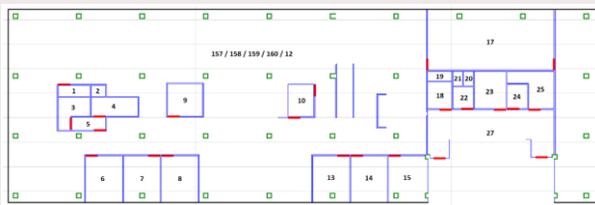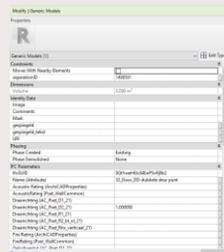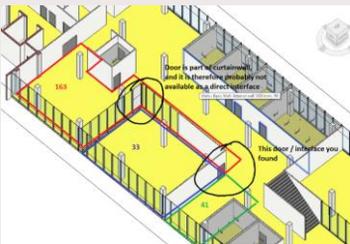
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Data in the Industry Foundation Classes (IFC)

- Overall building shape and topology easy
- Classification of elements possible, but not many classes => extension with bSDD classes and properties possible
- Difficult (not impossible) to include sensor data (timeseries data)
- Availability in STEP, XML, RDF, and JSON
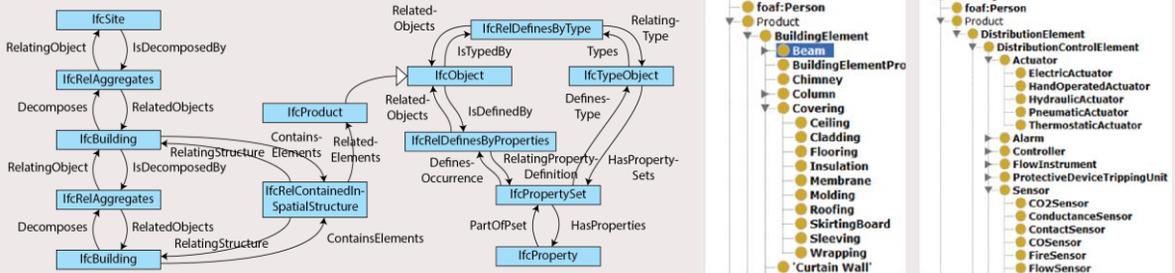
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W3C Linked Building Data

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Emergence of W3C LBD Community Group: Mission Statement

Bring together experts in the area of Building Information Modeling (BIM) and Web of Data technologies to:

1. define existing and future use cases and requirements for Linked Data based applications across the life cycle of buildings.
2. discuss best practices for publishing building data on the Web propose ontology models to describe:
    1. Buildings and building elements (topology, associate values to properties)
    2. Products and product properties
3. discuss how they can be used together with other specifications:
    1. existing standards (IFC, GeoSPARQL, Semantic Sensor Network, …)
    2. separate initiatives (schema.org, Haystack, BRICK, …)

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Scope of BOT: just the start, allowing to extend

- Limited set of classes
- Extensible and easy to combine with other ontologies and data sets
- Comprehensible

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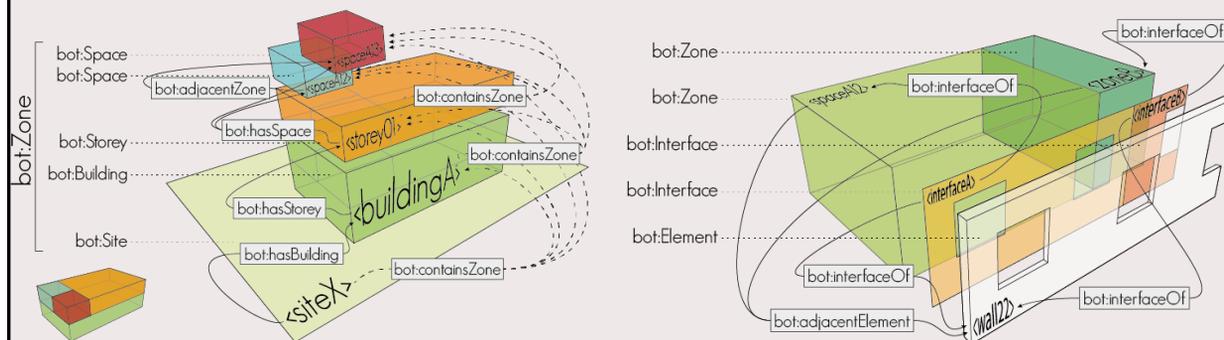
Modular ontology modelling advocated by LBD group
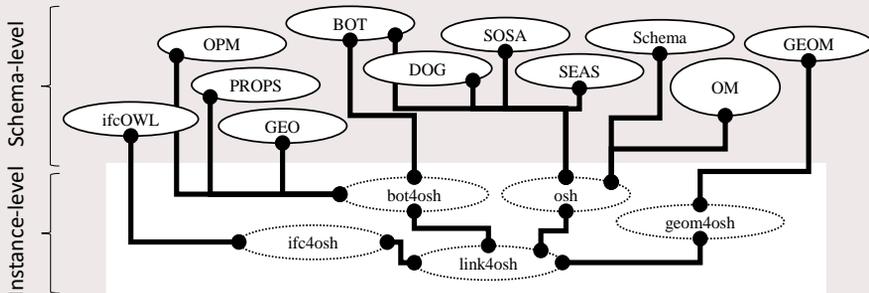
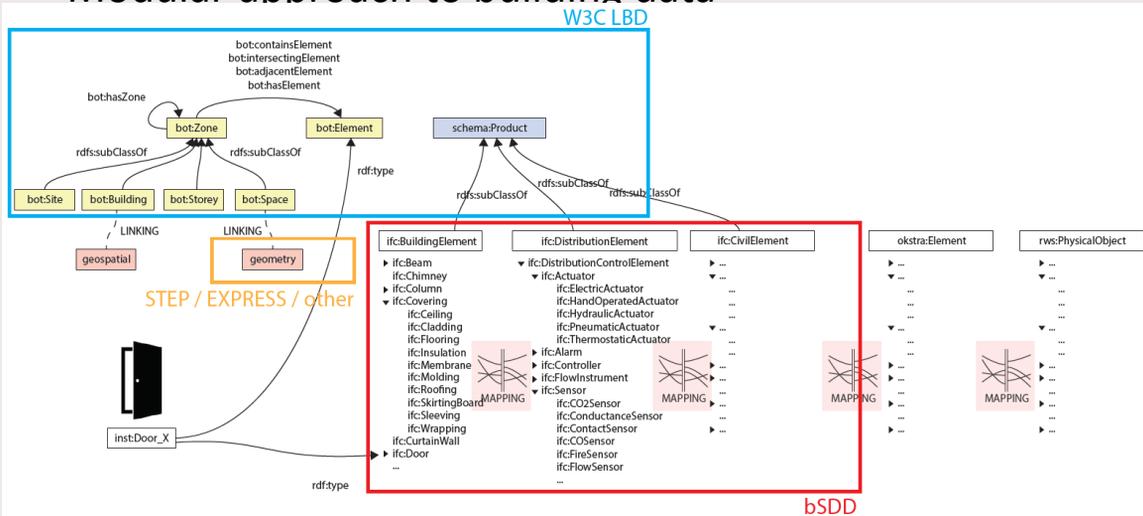- Implemented using Semantic Web Technologies -> <u>Web-scale</u>, <u>queryable</u>
- Reuse of existing ontologies -> <u>Modular</u>
- <u>Linking at instance level</u> -> Multi-model method

Sample dataset available at:
https://github.com/TechnicalBuildingSystems/OpenSmartHomeData

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Modular approach to building data

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Reference ontologies

BOT	https://w3id.org/bot#
BEO	https://pi.pauwel.be/voc/buildingelement/
MEP	https://pi.pauwel.be/voc/distributionelement/
OMG	https://w3id.org/omg#
FOG	https://w3id.org/fog#
BPO	https://www.w3id.org/bpo#
OPM	https://www.w3id.org/opm#

Revit to LBD exporter: on demand
IFC to LBD converter: on demand

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BRICK, HTO, SAREF, and REC

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BRICK, HTO, SAREF, REC, etc.

- Developments are rather disconnected from any BIM- or building-related area
- Focus on systems, incl. operation and control
- Focus on the sensor Point and Equipment types

- Beware of biased overview tables

Modeling Support	Brick	Project Haystack	IFC	BOT	SAREF
HVAC Systems	yes	yes	yes	no	no
Lighting Systems	yes	partial	yes	no	no
Electrical Systems	yes	yes	yes	no	no
Spatial Information	yes	no	yes	yes	no
Sensor Systems	yes	yes	generic	no	yes
Control Relationships	yes	no	generic	no	no
Operational Relationships	yes	no	generic	no	no
Formal Definitions	yes	no	yes	yes	yes

https://brickschema.org/

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BRICK - A uniform metadata schema for buildings

https://brickschema.org/

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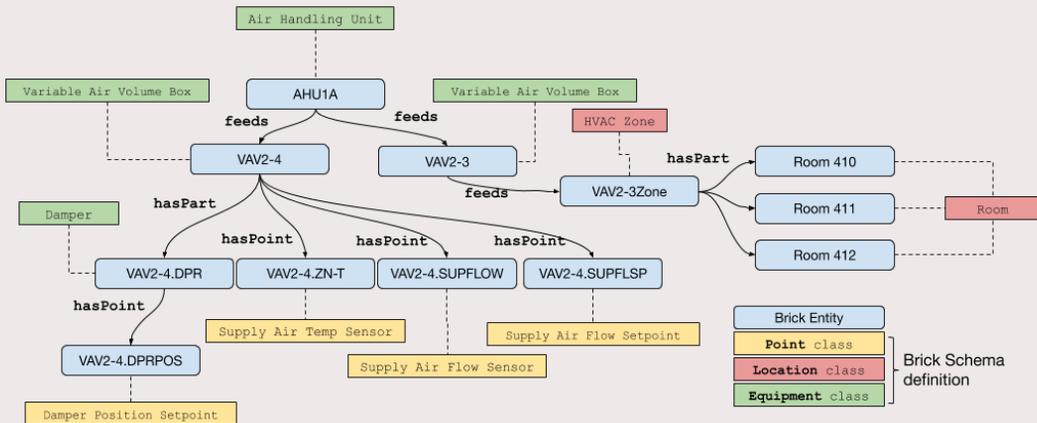
BRICK, HTO, SAREF, REC, etc.

BRICK
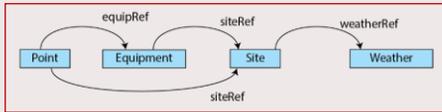
SAREF4BLDG
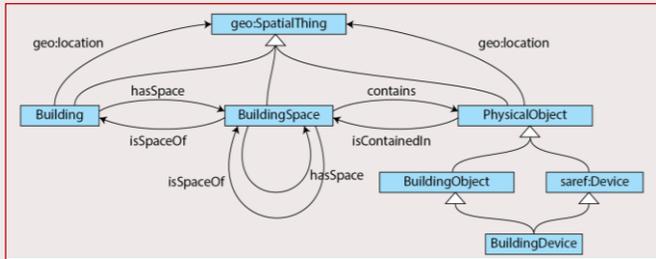
Real Estate Core
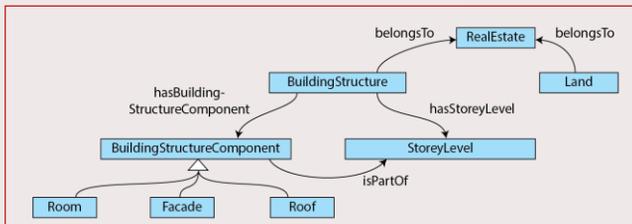
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In short

Nothing that cannot be included in a modular linked building data (LBD) cloud.
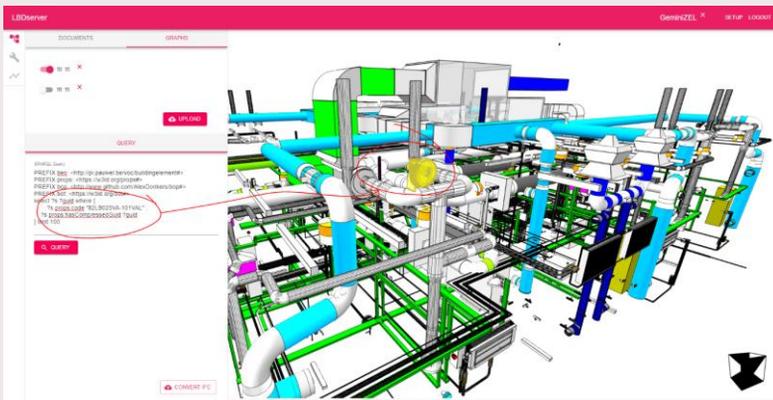
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Mapping all into RDF

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Available options for integration for software

OPTION 1: Transform all into semantic graphs (e.g. R2RML or custom data transformers) and do data integration
- Plus: all in same format
- Plus: inference possible
- Minus: unfit storage
- Minus: disconnect from origin
- Minus: no ML algorithms nor procedural code possible
- Minus: how to handle privacy and security (trust?)

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Native data format

Native data format

Native data format

ETL procedure

Linking data

RDF stores

RDF stores

Data management in application back-end

End user application development

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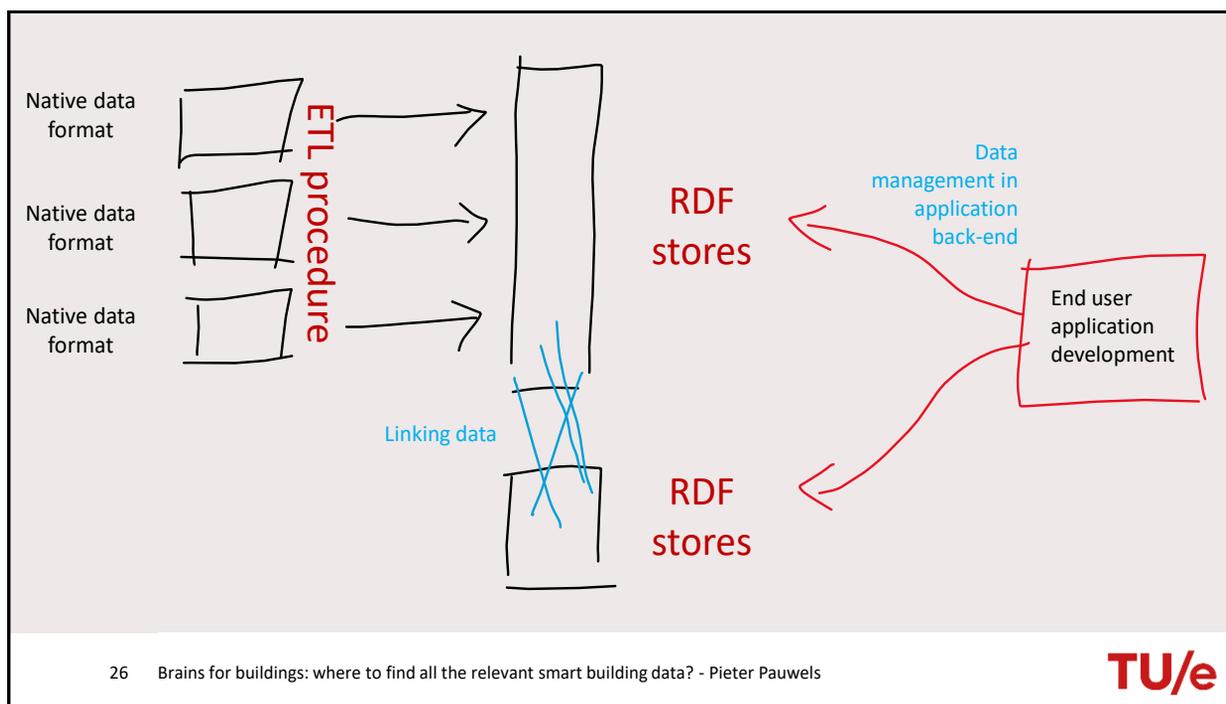
We intend to Leverage a Standard Conceptual Overview of Information Silos and Data Aggregation
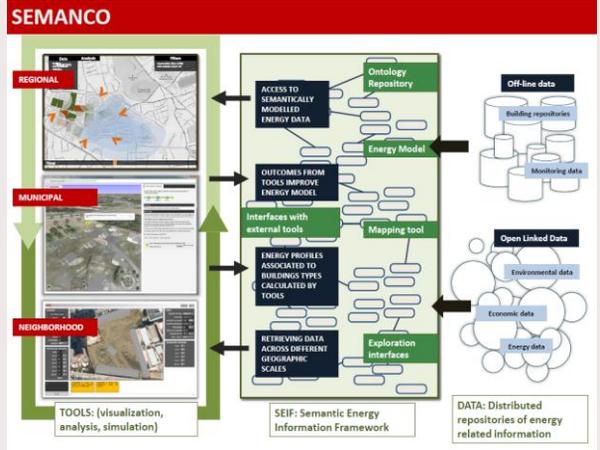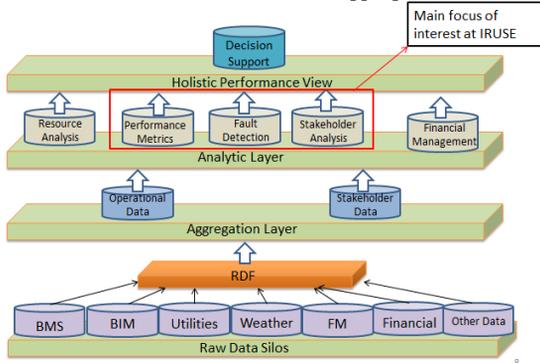
Gonçal Costa, Alvaro Sicilia, Leandro Madrazo. Energy efficiency of buildings. 1st Intl. Workshop on Linked Data in Architecture and Construction. Ghent, BE, 2012.

James O'Donnell, Edward Corry, Edward Curry, Marcus Keane. Building and using multi-domain data. 1st Intl. Workshop on Linked Data in Architecture and Construction. Ghent, BE, 2012.

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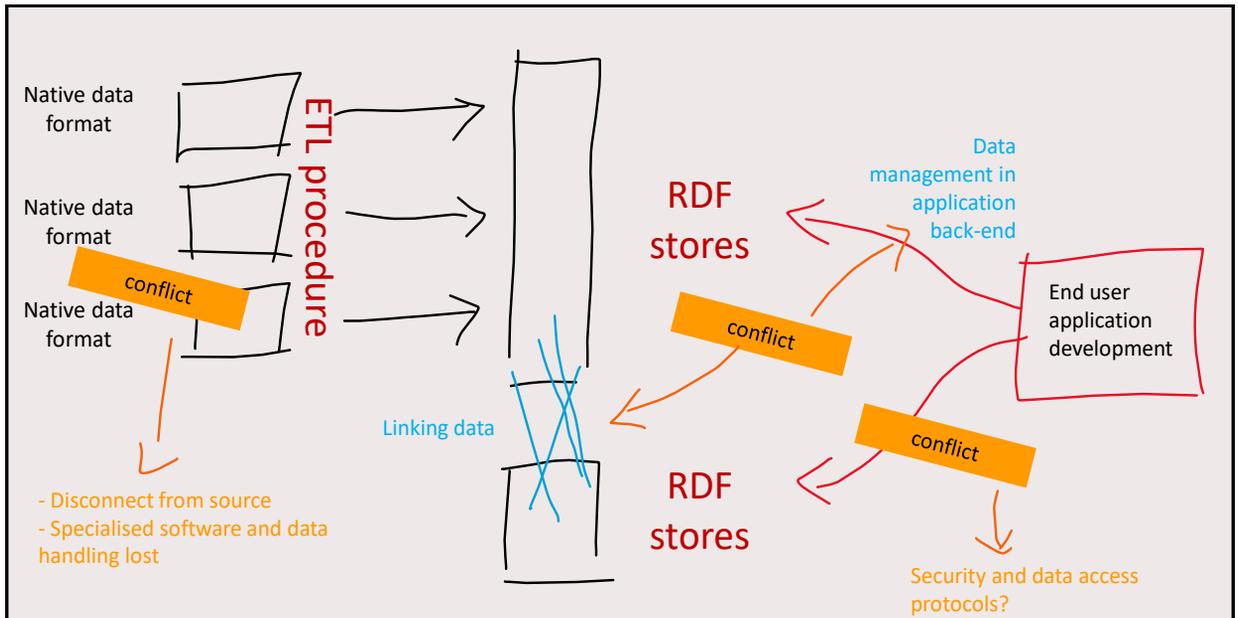
Maintaining specialized data stores and deploying web technologies

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Available options for integration in trustworthy manner

OPTION 2: Store all in well-fit data stores (KV stores, graphDBs, relational DBs, timeseries stores, etc.) and perform data integration (also) on a system and API level (system integration)

- Plus: apt data storage
- Plus: data stays at source -> web-based connections needed
- Plus: ML algorithms and procedural algorithms not blocked
- Plus: Privacy and security can be easily handled at the gates of APIs and DBs.
- Minus: multitude of systems requires lots of diverse software and expertise

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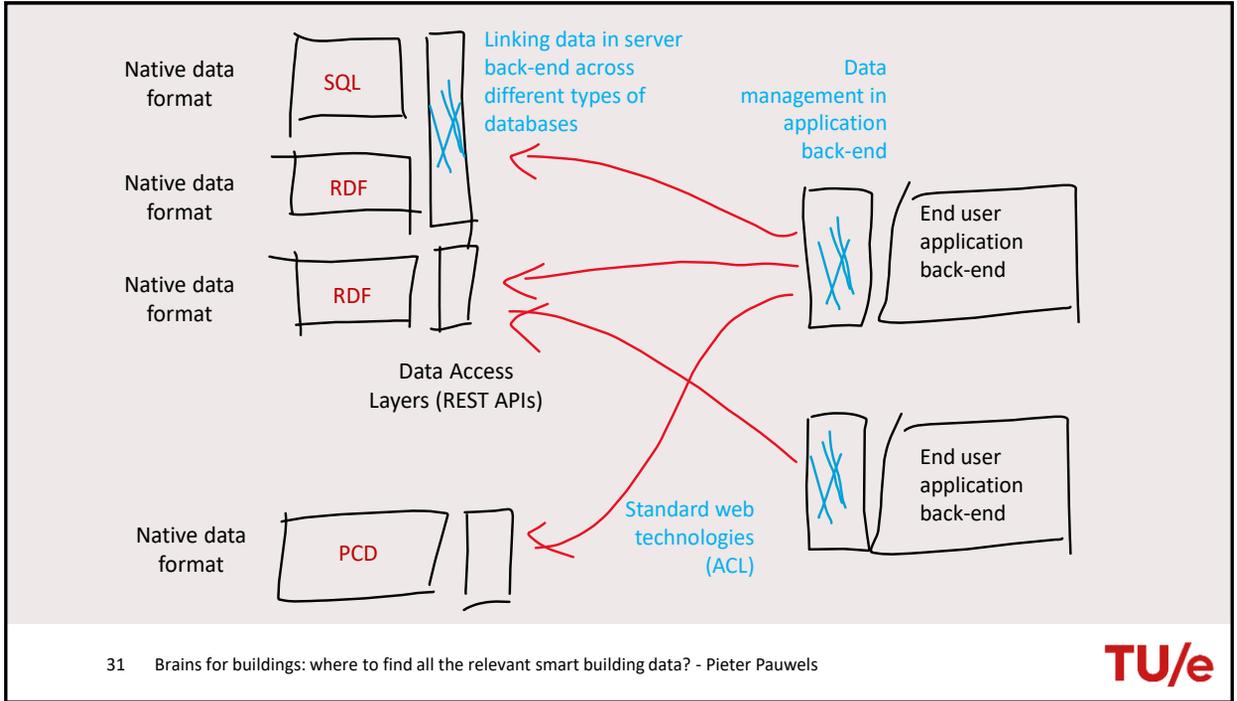
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SENSOR DATA EXAMPLE: GIGANTIUM IOT LIVING LAB AALBORG

▸ 35 sensor nodes monitoring Temperature (°C), Relative Humidity (%), Air Pressure (hPa), Indoor Air Quality (Total Volatile Organic Compounds ((TVOC), ppb) and CO_2 (ppm)), illuminance (lux) and motion

▸ Data storage in SQL database
▸ Data monitoring and visualization in Grafana

Source: Rodriguez et al. (2018)

Grafana

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SEMANTIC GRAPH ENRICHED WITH PERFORMANCE PATTERNS AND WEB REFERENCE TO SENSOR DATA

```
inst:room_16
    rdf:type bot:Space ;
    gig:hasSensorNode inst:sensorNode_0000014 ;
    gig:spaceType "Cafe" ;
    rdfs:label "Cafe" .

inst:sensorNode_00000014
    rdf:type gig:SensorNode ;
    rdfs:label "00000014" ;
    gig:observation "Indoor climate" ;
    gig:purpose "Thermal comfort in the lobby during big events when there is a gathering of a lot of people." ;
    sosa:hosts inst:sensor_00000014_1, inst:sensor_00000014_2, inst:sensor_00000014_3, inst:sensor_00000014_4, inst:sensor_00000014_5,
inst:sensor_00000014_6 ;
    gig:placement "Placed on a column in the cafe without direct sunlight." .

inst:sensor_00000014_1 ;
    rdf:type sosa:Sensor ;
    sosa:madeObservation inst:observation_1 ;
    sosa:observes inst:obsProperty_1 ;
    rdfs:label "00000014_1" .

inst:result_1 rdf:type sosa:Result ;
    rdfs:label "Result of observation of Relative Humidity";
    gig:values "https://gigantium.dk/Gigantium2018instances?orgId=1&datastream=true" .
```
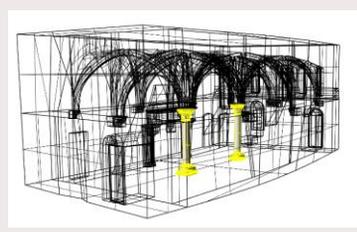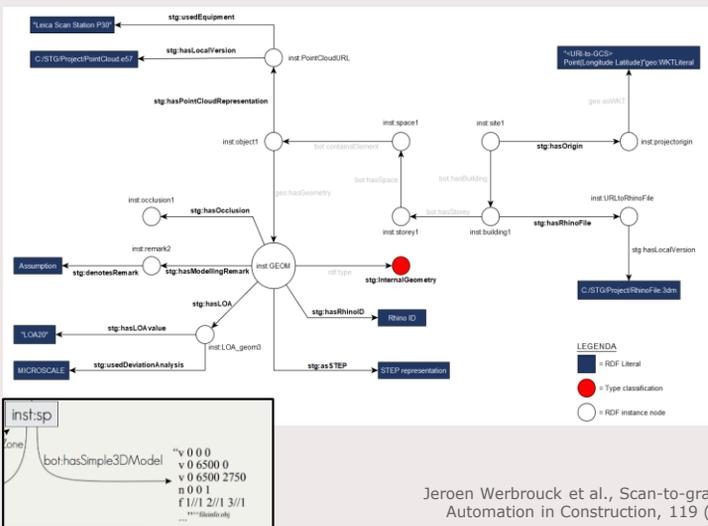
Petrova, E., Pauwels, P., Svidt, K., Jensen, R.L. (2018) From patterns to evidence: Enhancing sustainable building design with pattern recognition and information retrieval approaches. Proceedings of the 12th ECPPM conference, pp. 391-399.

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Abox linking to point cloud data and geometry

Jeroen Werbrouck et al., Scan-to-graph: Semantic enrichment of existing building geometry, Automation in Construction, 119 (2020). https://doi.org/10.1016/j.autcon.2020.103286.

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Increase simplicity, preserve semantics

Simplicity →

SCADA system

Digital Twin System (DTLab)

InfluxDB / ...

API

Topological map of floor 8

Physical building

Semantic 3D model (BIM)

Knowledge graph

GraphDB / Neo4J / ...

API

Event broker

Metric map of floor 8

Full simulated world

- Security -
- Authentication -
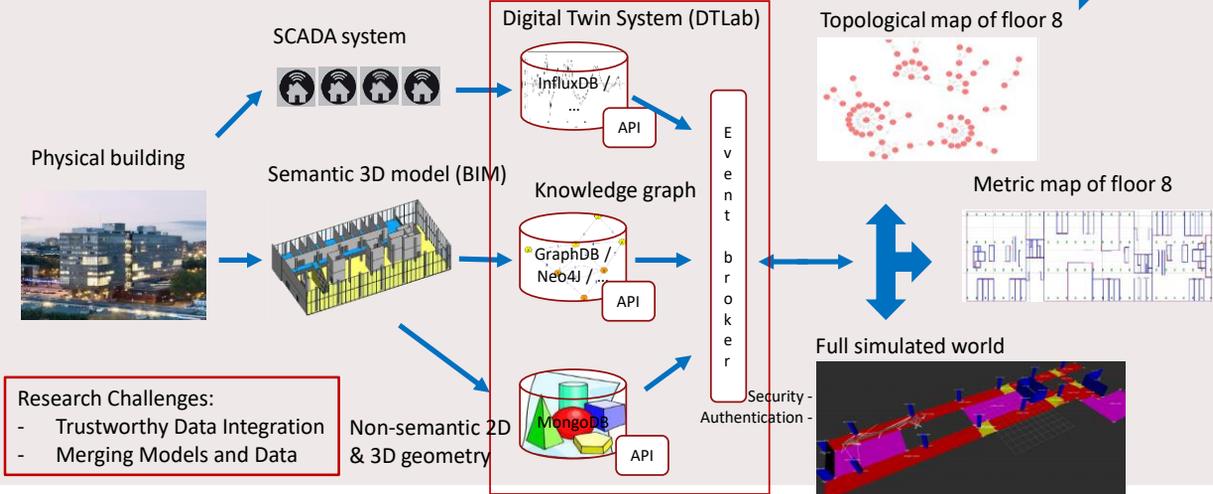
Research Challenges:
- Trustworthy Data Integration
- Merging Models and Data

Non-semantic 2D & 3D geometry

MongoDB

API

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LBDserver

GeminiZEL ✕   SETUP LOGOUT

DOCUMENTS   GRAPHS

UPLOAD

QUERY

SPARQL Query
PREFIX beo: <http://pi.pauwel.be/voc/buildingelement#>
PREFIX props: <https://w3id.org/props#>
PREFIX bop: <http://www.github.com/AlexDonkers/bop#>
PREFIX bot: <https://w3id.org/bot#>
select ?s ?guid where {
    ?s props:code "82LB025VA-101VAL" .
    ?s props:hasCompressedGuid ?guid
} limit 100

QUERY

CONVERT IFC

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