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Generating building performance simulation models using semantic graphs and sensor measurements

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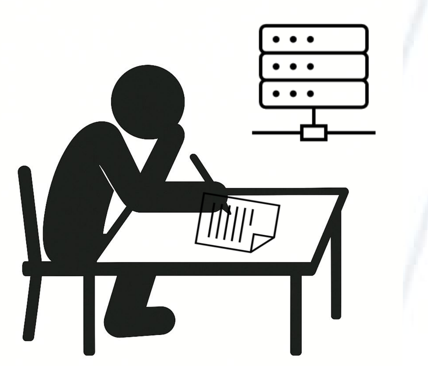
Background and Motivation

Heating, Ventilation, and Air-Conditioning (HVAC) systems account for approximately 40% of the energy consumption in the building sector. To optimize their performance, **Building Performance Simulation (BPS)** models are essential but efforts-intensive to create. Recent studies[1,2] have focused on translating the **Building Information Model (BIM)**, primarily **Industry Foundation Classes (IFC)**, into executable thermal simulation models. Yet, creating models of building coupled with HVAC systems, which can be used for validating the building operations, still demands significant manual work. This is mainly due to limitations from the following perspectives:

- IFC schema lacks sufficient vocabulary to represent technical equipment, control sequences, and sensor data systematically;
- Additional effort is required to extract measurement data from **Building Management Systems (BMS)** for simulation use.



Proposed RDF-Based Workflow

Using **Resource Description Framework (RDF)** graphs to describe building, HVAC systems, and sensor metadata, the **Graph2SIM** package retrieves firstly required data from graph database and measurements in timeseries database, then instantiates predefined templates into executable Modelica code automatically.

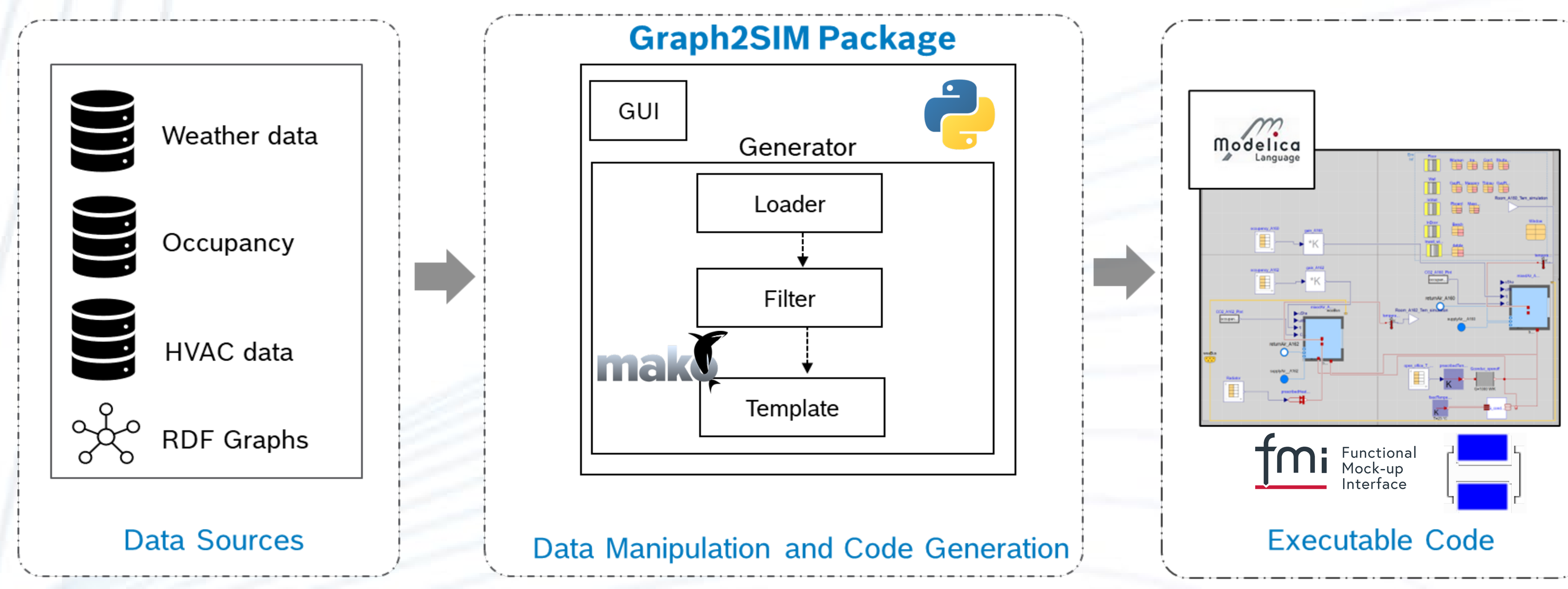
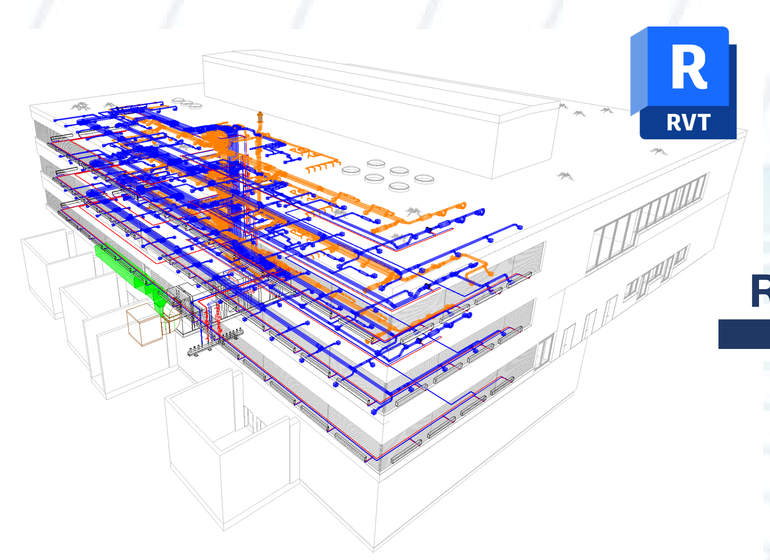
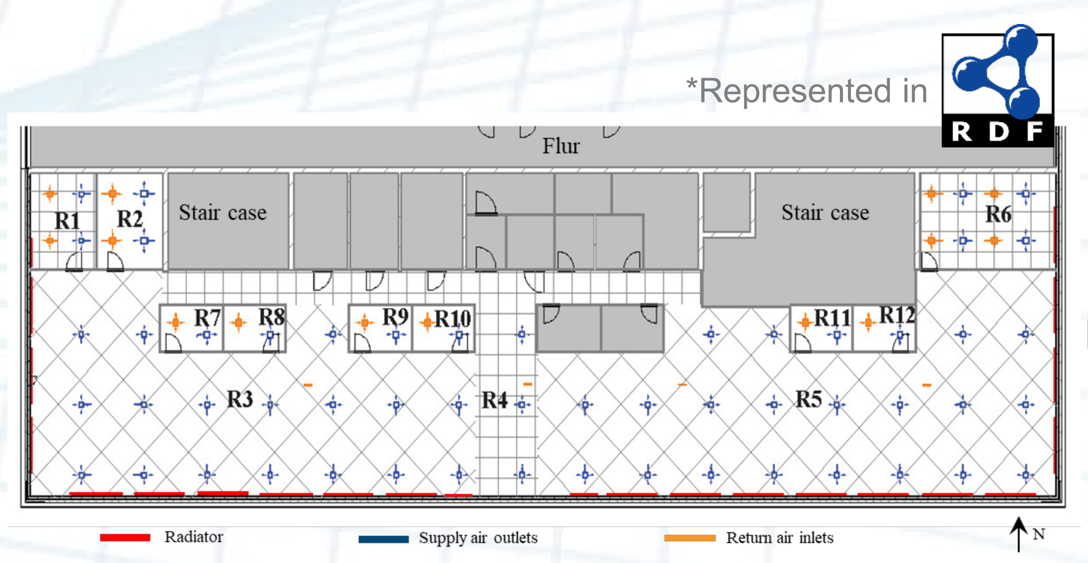


Fig. 1: Illustration of the proposed RDF-based BPS generation workflow.

Case Study: Multi-zone Building at Bosch Research Campus



Revit2RDF



Graph2SIM

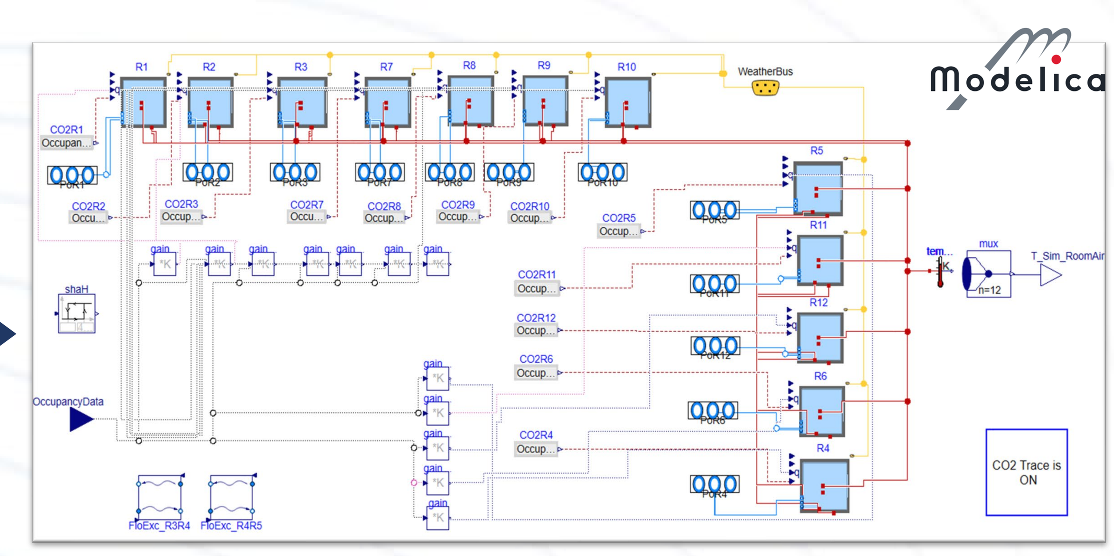


Fig.2: BIM of office building RNG 111

Fig. 3: Floor plan of RNG 111/1

Fig. 4: Generated base model of RNG 111/1

Description of Metadata

We describe the metadata with BOT, FSO, Brick, SOSA/SSN as detailed in [3].

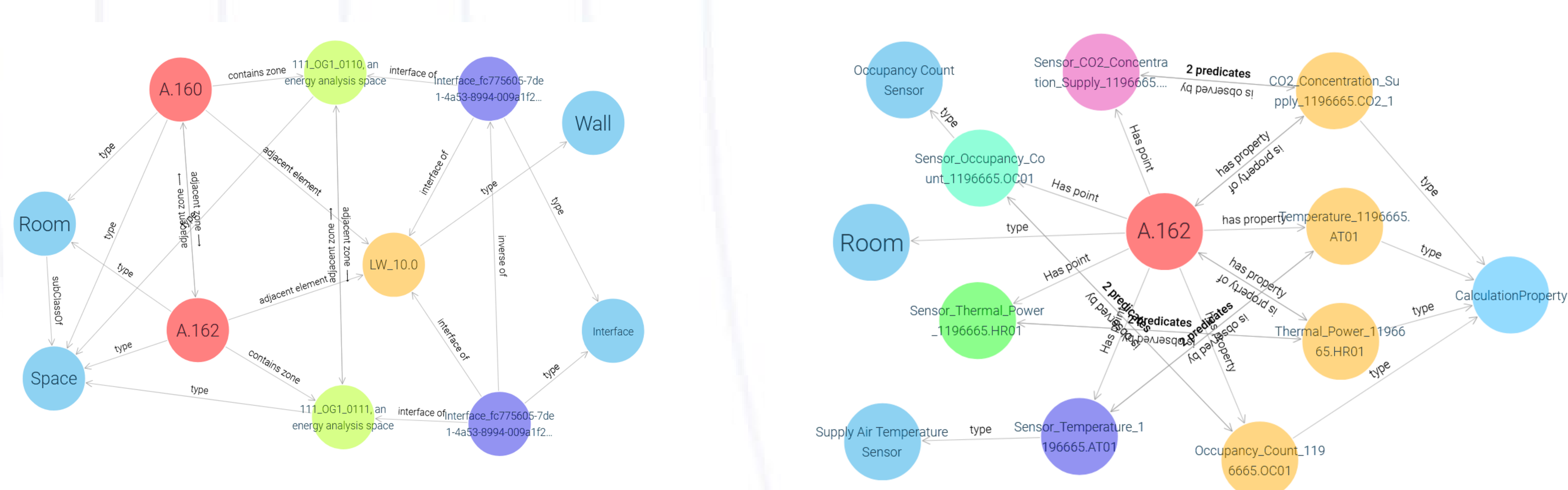


Fig. 5: Metadata of R1 (A.162) for the geometry (left) and sensor datapoints (right)

Results and Conclusion

The 12-zone BPS model of the studied story was successfully created. With a boundary condition of measurements, the model is simulated from year 2022 to 2023. The simulated CO_2 and room temperature are compared with measured value. Maximal **Root Mean Square Error (RMSE)** for temperature and CO_2 are 1.97 ℃ and 49 PPM, respectively.

Our study confirms that semantic graphs streamline BPS model generation by linking metadata with real sensor data. Future work will expand system templates, such as AHU, and support diverse HVAC configurations to enhance real-world usage.

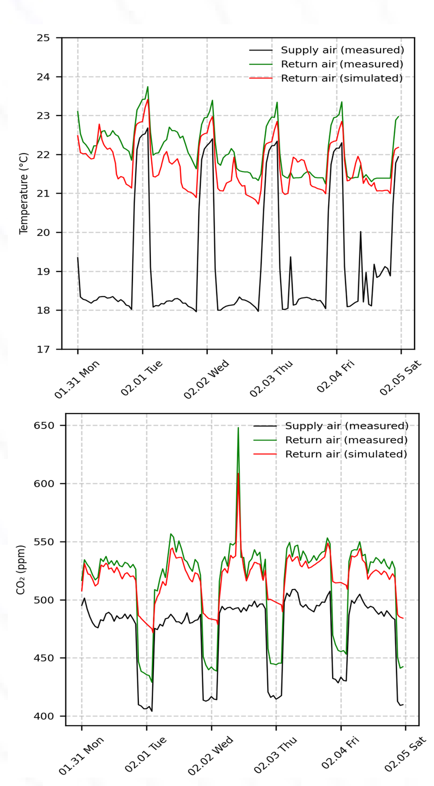


Fig. 6: Simulation in Feb. 2022

Query and Templates

For multi-zone simulation, three templates are developed: A *Base Model* template declares the thermal envelope coupled with simplified HVAC, two *Test Model* templates extend the *Base Model* with FMU connection and standalone simulation, respectively. **SPARQL** is used to query the metadata, and the results are utilized to parameterize the templates. **Influx** query is used to fetch historical measurements.

Listing 1 Excerpts of the template for defining exterior window instances

```
%if len(ConExtWin)!=0: # Loop through the exterior wall elements of the thermal zone
    datConExtWin(
    layers={\
        %for i in range(len(ConExtWin)): # Loop through the window elements on the exterior wall
            ${ConExtWin[i].Boundary}${'},' if loop.last else ','}\
        %endfor
    A={\ %for i in range(len(ConExtWin)): # Check the area of window
    ${ConExtWin[i].area}${'},' if loop.last else ','}\ %endfor
```

References

[1] Jansen D, Mehrfeld P, Müller D, Fichter E, Richter V, Barz A, et al. BIM2SIM - Development of semi-automated methods for the generation of simulation models using Building Information Modeling. Proc. Build. Simul. 2021 17th Conf. IBPSA, vol. 17, Bruges, Belgium: IBPSA; 2021, p. 1244–5.
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[3] Wan L, Rossa F, Welfonder T, Petrova E, Pauwels P. Enabling scalable Model Predictive Con-trol design for building HVAC systems using semantic data modelling. Autom Constr 2025;170:105929.

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