Web of Simulation ontology (WoSO): Integration of Building Performance Simulations in IoT Systems

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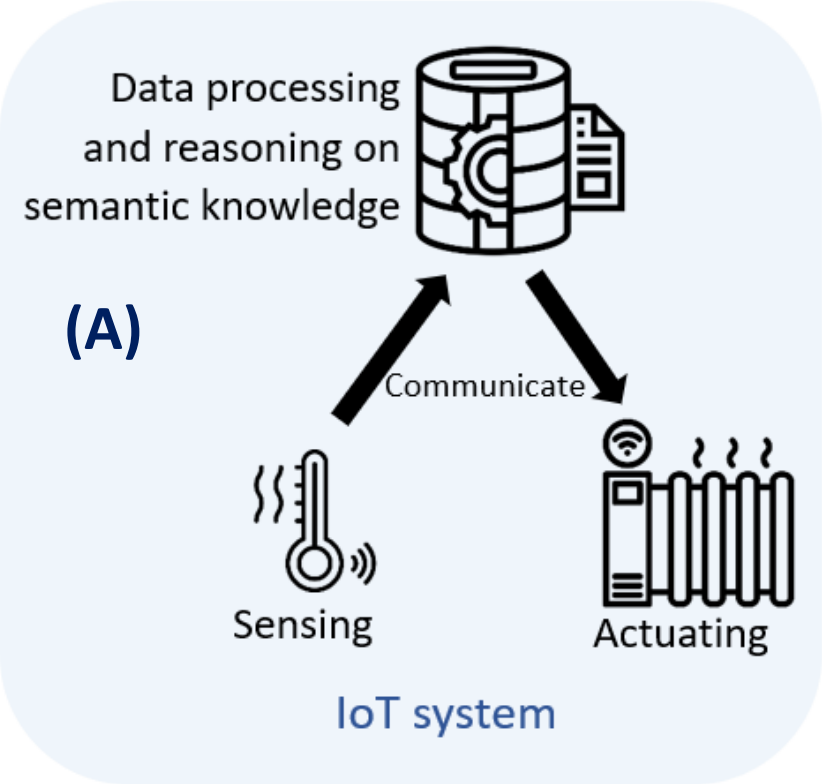
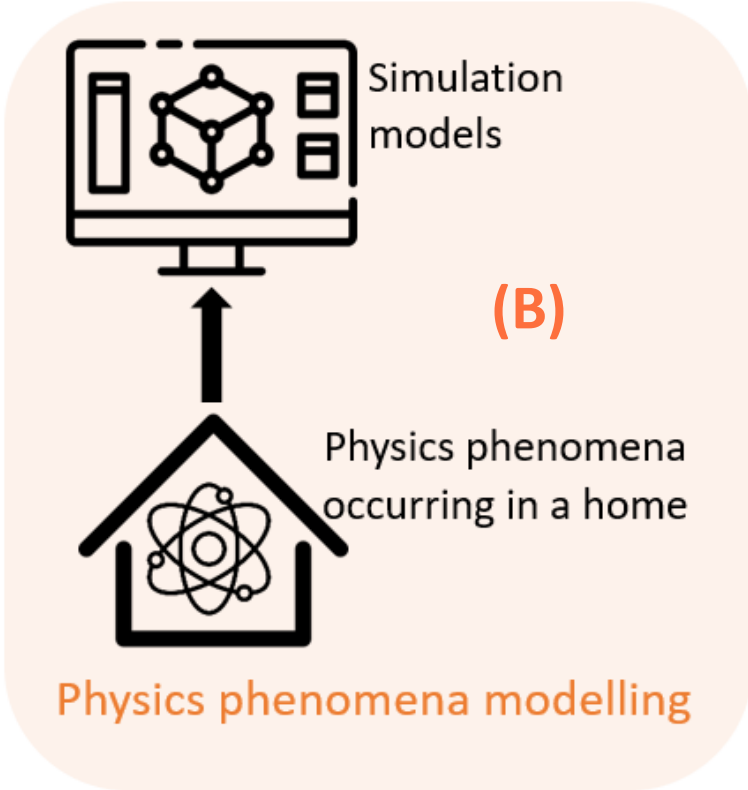
Context





(A) : in current IoT applications, physics phenomena occurring in a complex and heterogeneous cyber-physical system, such as a smart building, are poorly reflected

(B) : according to the conceptualization of digital twins, simulations of these physics phenomena allow to anticipate the temporal evolution of the cyber-physical system

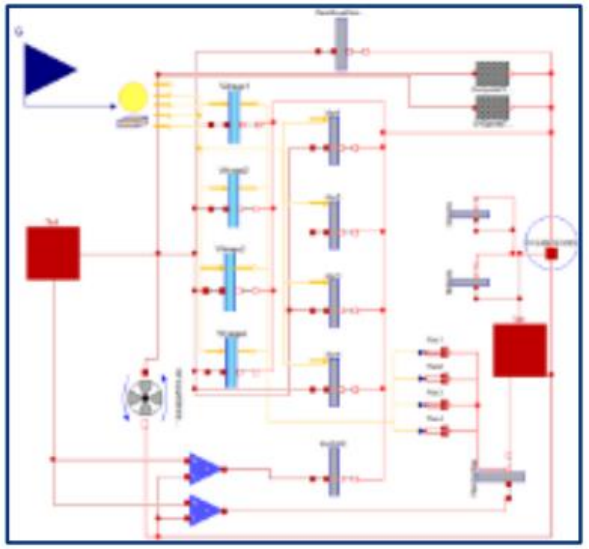
Motivation

Combination of simulation and semantic knowledge of the physics phenomena will improve decision-making process of IoT systems deployed in smart buildings.

Use case EDF R&D

Integrate the simulation models of an office building in EDF Lab into its building performance management system

buildSYSPRO



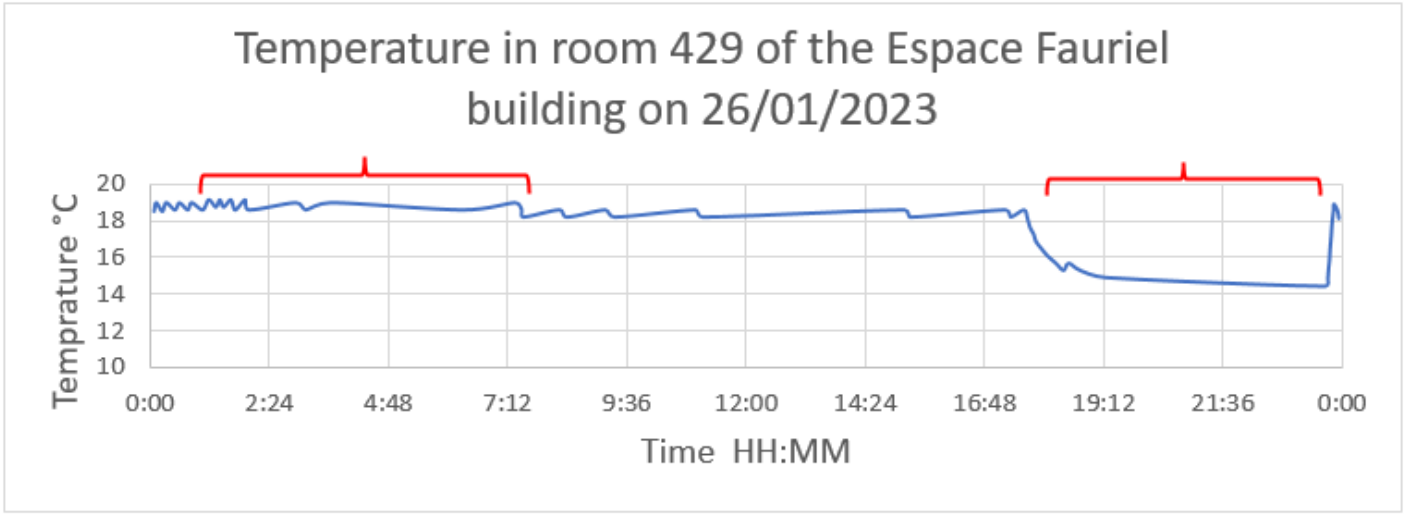
IoT devices

Use case Mines Saint-Étienne

Contribute to the improvement of the IoT control system in the DigitalTwin of the school building.

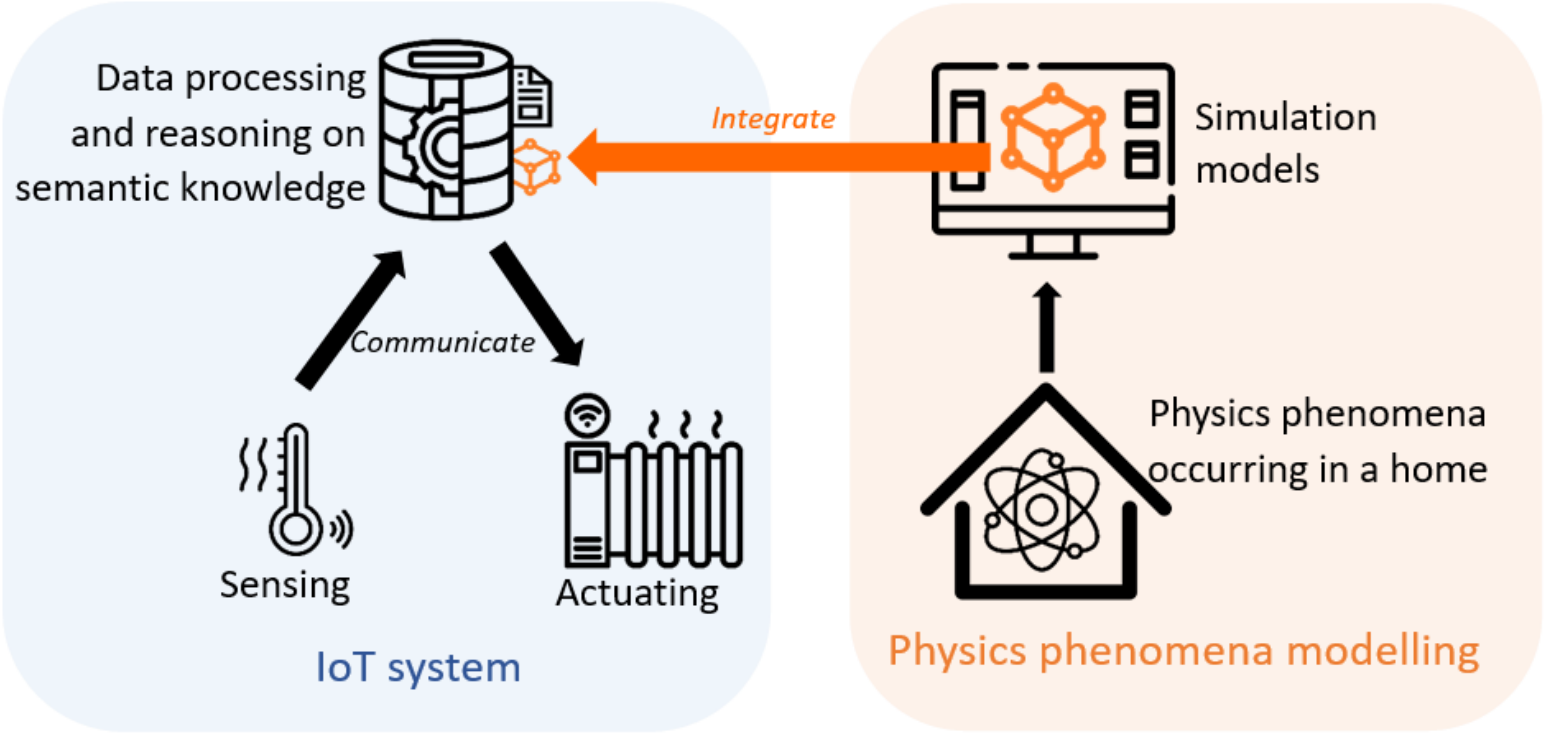
Figure : 3D model of the school building.

When to heat the building to reach the desired temperature at a given time?



Objective

Integrating physics phenomena simulation in IoT system

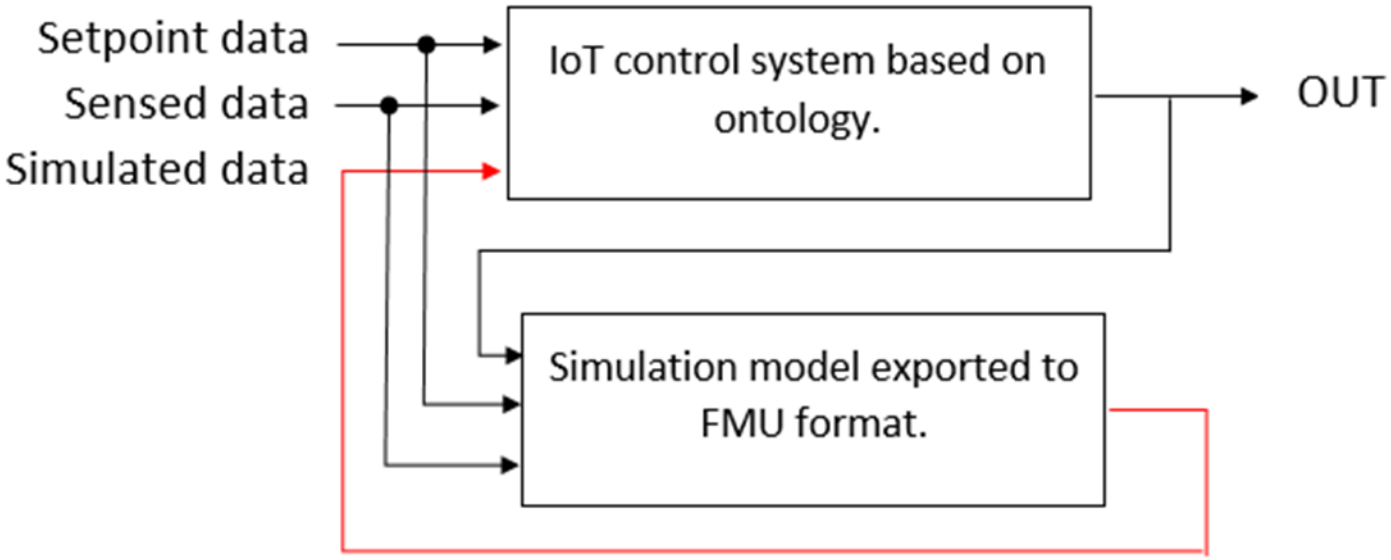


Hypothesis: Integrating physics phenomena simulation in IoT systems would improve the accuracy of the reasoning system and the energy efficiency.

Question: How to enable the interoperability between the simulation model and the reasoning system?

Approach

Proposed approach to integrate physics phenomena simulation in IoT system



We use the ontology to enhance knowledge representation by providing a shared vocabulary and data structure.

We propose to use the FMI standard to simulate the model and semantic web technologies to create a control loop between the simulation and the control system.

Requirements

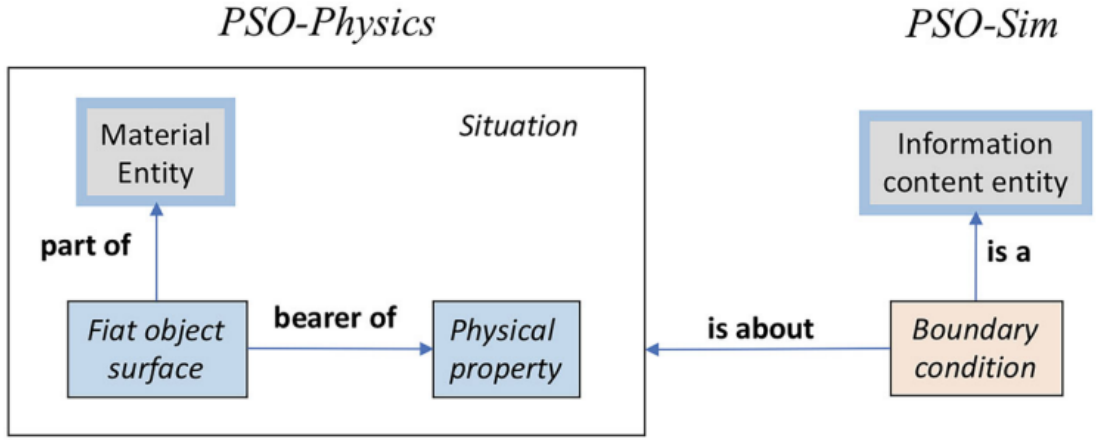
Req.1: The ontology module has to enable the representation of the simulations described by the FMI standard.

Req.2: The ontology module has to be compliant with the reference ontologies in IoT.

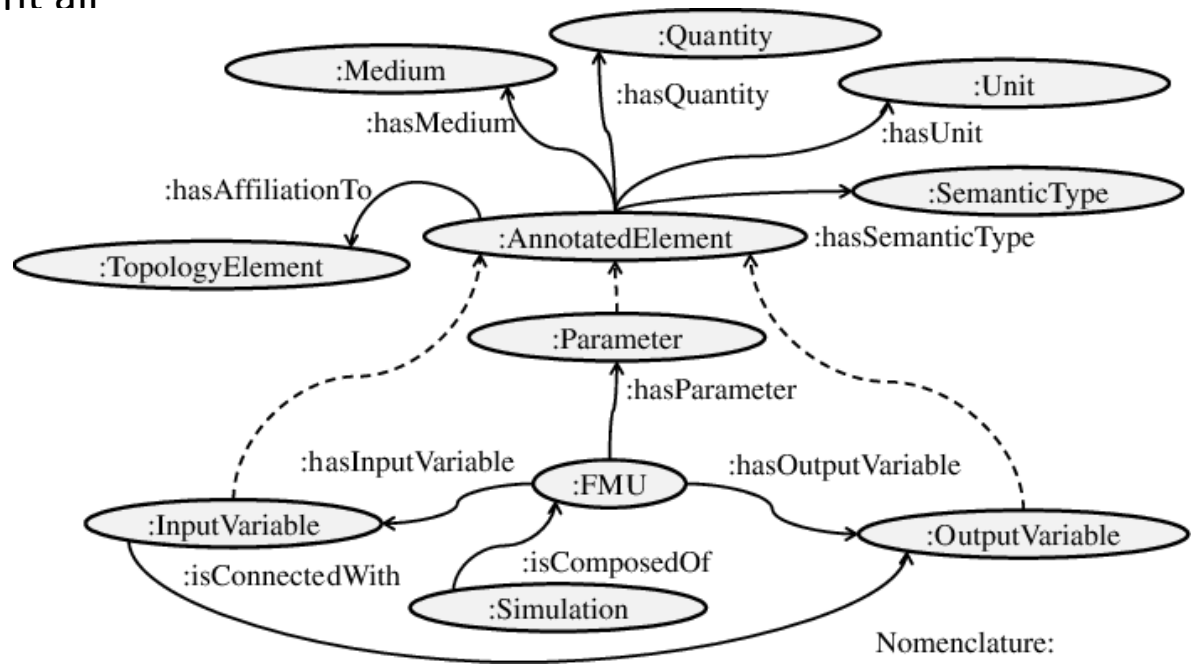
Req.3: The ontology module has to manage the data exchange between simulations.

State of the art

Frameworks [1,2] provide a single data model that represent all the data resources needed for simulation to be executed.



Physics-based Simulation Ontology (PSO) [3]



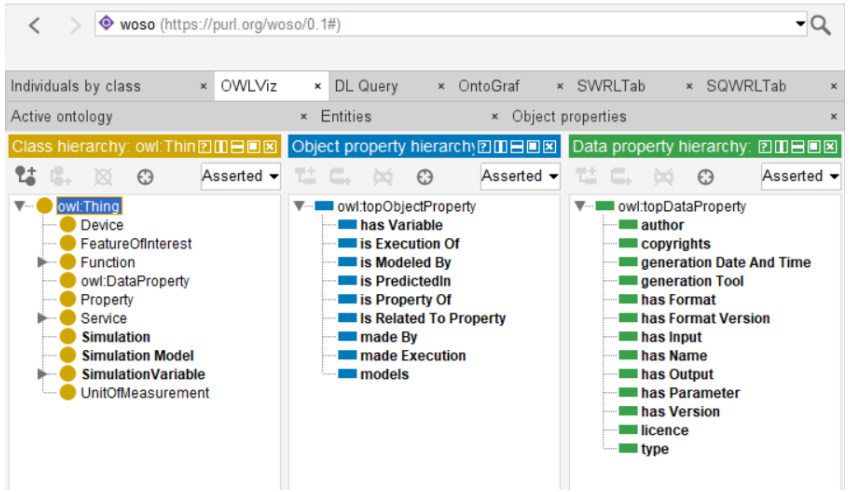
Overview of FMUont [4]

[1] Z. Wu, J. C. Cheng, Z. Wang, H. H. Kwok, An ontology-based framework for automatic building energy modeling with thermal zoning, Energy and Buildings (2023) 113267.
[2] J. Bjørnskov, M. Jradi, An ontology-based innovative energy modeling framework for scalable and adaptable building digital twins, Energy and Buildings 292 (2023) 113146.
[3] H. Cheong, A. Butscher, Physics-based simulation ontology: an ontology to support modelling and reuse of data for physics-based simulation, Journal of Engineering Design 30 (2019) 655–687.
[4] M. Mitterhofer, G. F. Schneider, S. Stratbücker, K. Sedlbauer, An FMI-enabled methodology for modular building performance simulation based on Semantic Web technologies, Building and Environment 125 (2017) 49–59.

Methodology

Overview of the methodology to develop and test WoSO methodology

Web of Simulations Ontology (WoSO) is a high-level description of simulations and IoT system that relies on the standard Functional Mock-up Interface (FMI) and extends a reference IoT ontology (SAREF).



CQ1 What is the model executed by a simulation?
SELECT * WHERE { $s woso:isExecutionOf ?m }

CQ2 What are the inputs, outputs, and parameters, of the simulation?
SELECT ?i WHERE {?s saref:hasIntput ?i}
SELECT ?o WHERE {?s saref:hasOutput ?o}
SELECT ?i WHERE {?s woso:hasparameter ?p}

CQ3 What are the start time, end time, and duration, of the simulation?
SELECT ?s ?st ?et ?d WHERE {?s woso:hasExecutionStartTime ?st.?s woso: hasExecutionEndTime ?et.?s woso:hasExecutionDuration ?d}

TURTLE

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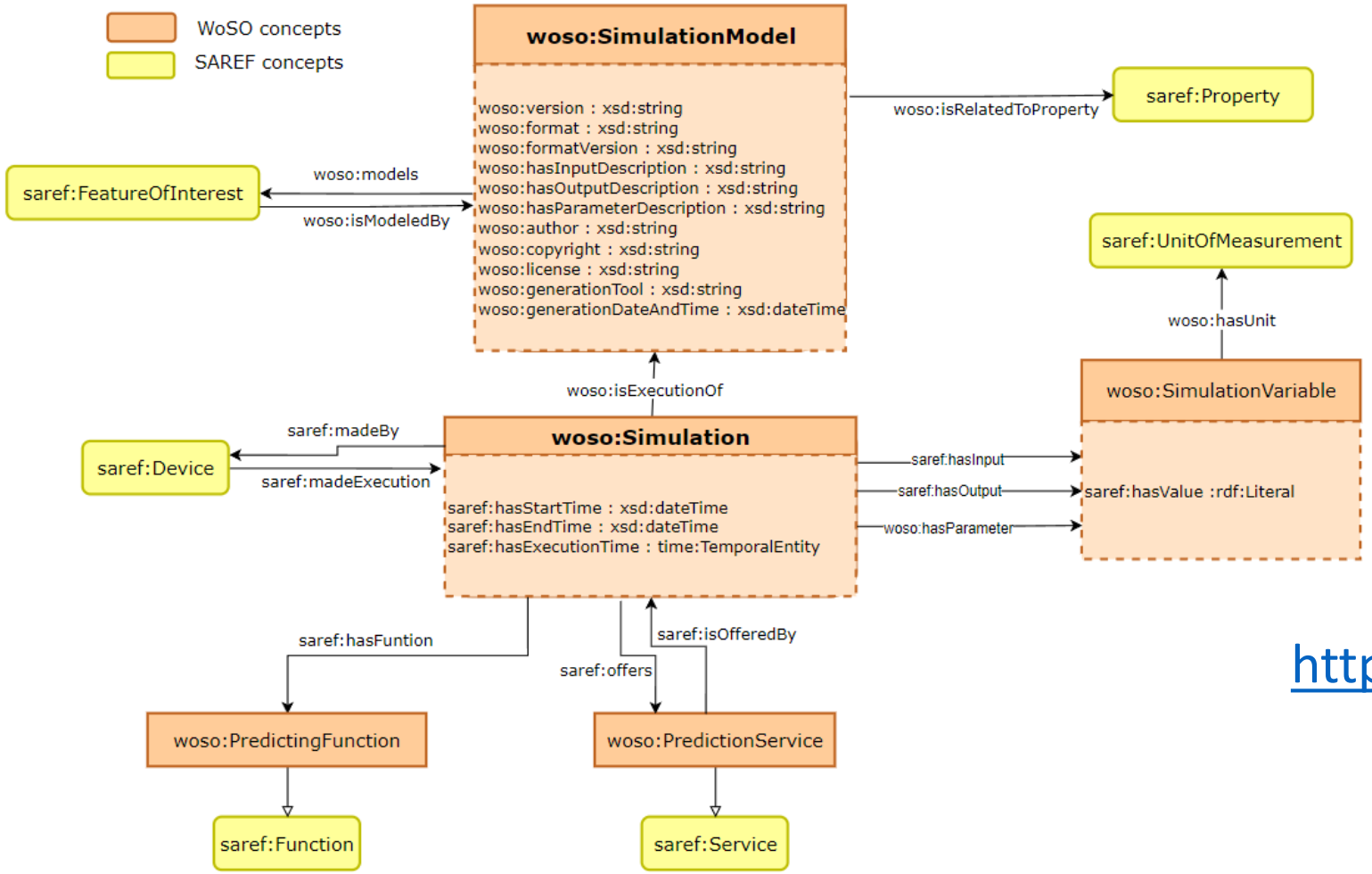
Overview of WoSO

Overview of the WoSO ontology using the Chowlk visual notation



https://purl.org/woso

Conclusion

We introduced the Web of Simulation Ontology (WoSO) as a foundational framework for integrating Building Performance Simulations (BPS) into Internet of Things (IoT) systems, with the aim of optimizing energy management in smart buildings.

We are working on the implementation of WoSO for the use case of building energy management efficiency. The building is a tertiary building located on EDF R&D site and is equipped with an IoT control system and a building thermal model.

https://purl.org/woso

Thank you. Any question?