



Key challenges and roadmaps for semantic driven building management systems

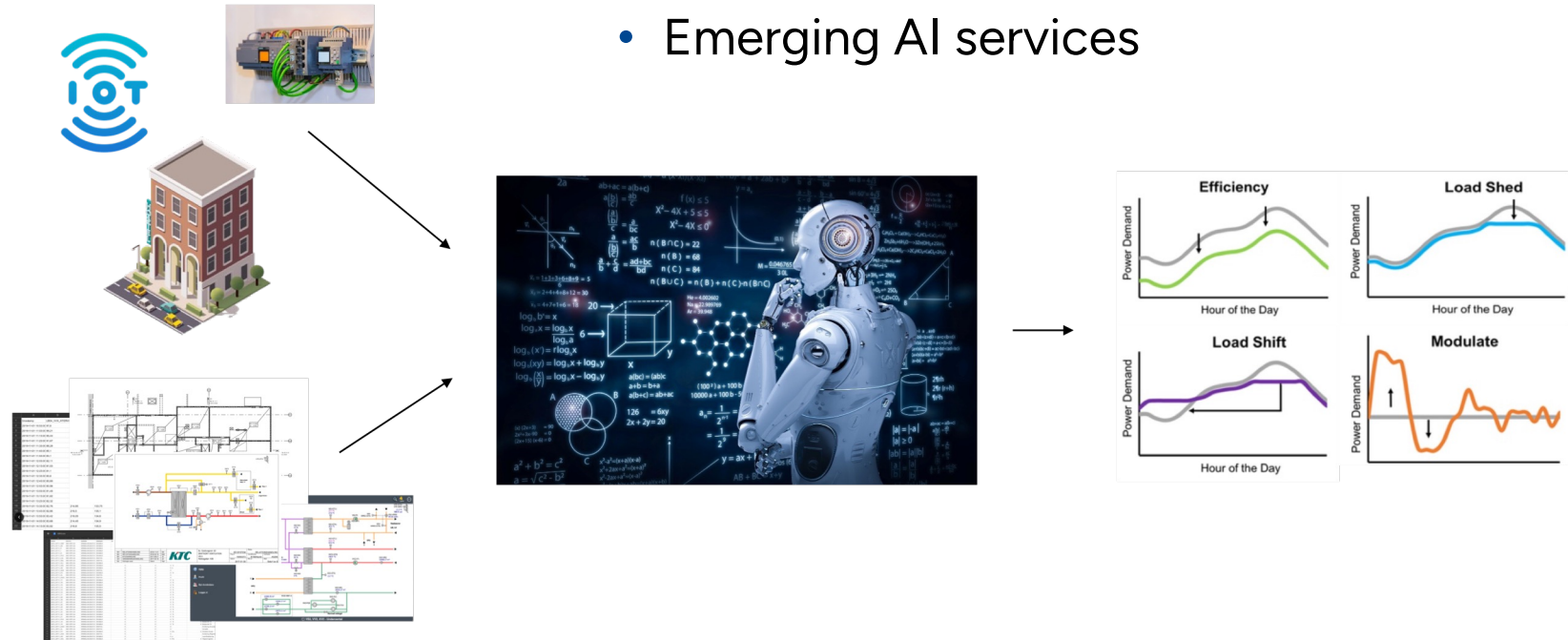
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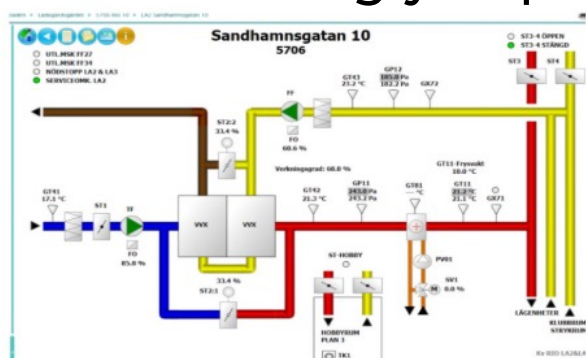
Why Building Management Systems Matter

- Buildings are becoming **complex cyber-physical energy systems**
- HVAC and installation systems need to be digitalized, while the existing digital infrastructure was built on previous generations
- Energy renovation of old building stock deemed crucial.
- Make the building “AI ready” requires machine readable, and **scalable for industries**
- Emerging AI services



Digital representation is challenging

Information and data within buildings and HVAC systems are becoming increasingly sophisticated.



1	VendorTag	Value	Date	Time
2	FAS5706002.DUC201.AI02.Value	22.5	2023-09-23	00:00:00
3	FAS5706002.DUC201.AI02.Value	22.5	2023-09-23	01:00:00
4	FAS5706002.DUC201.AI02.Value	22.8	2023-09-23	02:00:00
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7	FAS5706002.DUC201.AI02.Value	22.6	2023-09-23	05:00:00
8	FAS5706002.DUC201.AI02.Value	22.4	2023-09-23	06:00:00
9	FAS5706002.DUC201.AI02.Value	22.3	2023-09-23	07:00:00
10	FAS5706002.DUC201.AI02.Value	22.2	2023-09-23	08:00:00
11	FAS5706002.DUC201.AI02.Value	22.2	2023-09-23	09:00:00
12	FAS5706002.DUC201.AI02.Value	22.3	2023-09-23	10:00:00
13	FAS5706002.DUC201.AI02.Value	22.4	2023-09-23	11:00:00
14	FAS5706002.DUC201.AI02.Value	22.5	2023-09-23	12:00:00

VendorTag	Component	Value
FAS5706002.DUC201.RC01.Value	5706-LA1-GP11	
FAS5706002.DUC201.AI01.Value	5706-LA1-GT11	
FAS5706002.DUC201.UI03.Value	5706-LA1-GT43	
FAS5706002.DUC201.RC02.Value	5706-LA1-GP12	
FAS5706002.DUC201.AI04.Value	5706-LA1-GT42	
FAS5706002.DUC201.AI02.Value	5706-LA1-GT81	
FAS5706002.DUC201.AU01.Value	5706-LA1-TF	
FAS5706002.DUC201.UI01.Value	5706-LA1-GP11	
FAS5706002.DUC201.RC03.Value	5706-LA1-GT11	
FAS5706002.DUC201.AU04.Value	5706-LA1-SV1	
FAS5706002.DUC201.AQ01.Value	5706-LA1-Verkningsgrad Efficiency	
FAS5706002.DUC201.AU03.Value	5706-LA1-ST2:1	
FAS5706002.DUC201.AU03.Value	5706-LA1-ST2:2	
FAS5706002.DUC201.AU02.Value	5706-LA1-AU02	
FAS5706002.DUC201.AI03.Value	5706-LA1-GT41	
FAS5706002.DUC201.UI02.Value	5706-LA1-GP12	

System diagram, autoCAD

Sensory data, database, csv, excel

Tag lists, vendor locked-in naming conventions



- Time-consuming tasks
- Expertise-heavy processes
- Trivial
- Inefficient workflows
- Not scalable
- ...

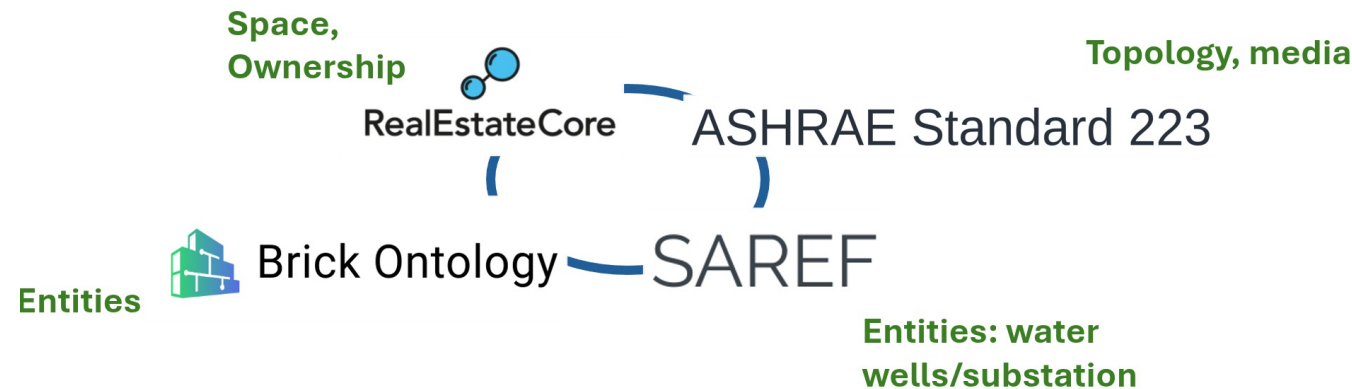
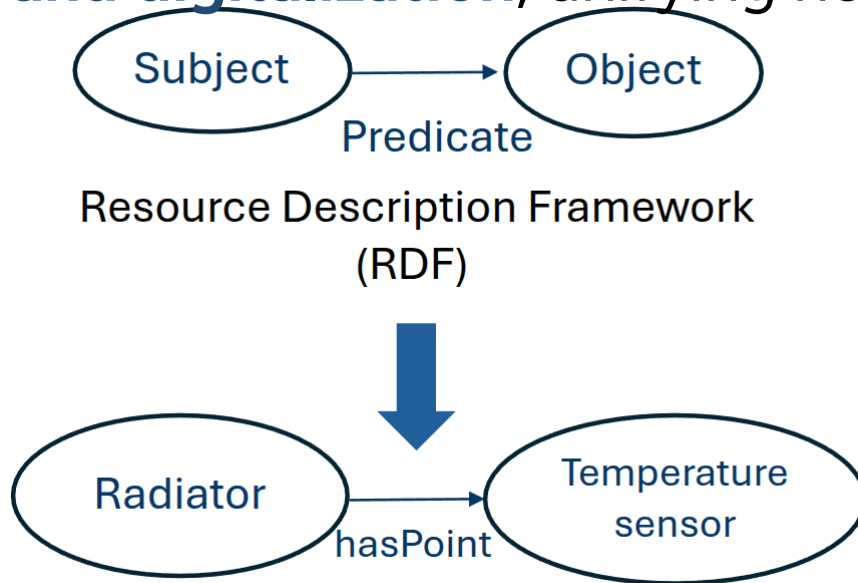
Control cards

Control system user manual

Field inspection

Existing approach toward digital representation

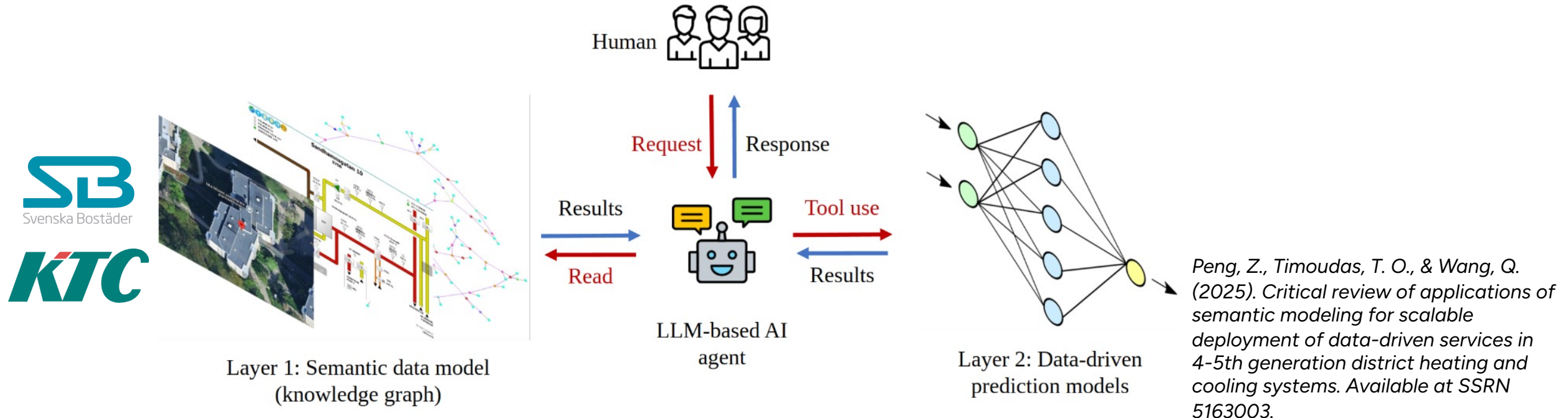
- **RDF:** Triplets have the ability to **integrate various information**.
- **Ontology:** Provides **standardized vocabularies** to describe the system.
- **Semantic models:** A representation that addresses semantic **interoperability and digitalization**, unifying heterogeneous information without ambiguity.



Example of applying agent in semantics: Case 1

Key features:

- AI agents can read and retrieval data from knowledge graph.
- Input data for the temperature prediction model is provided by AI Agents.



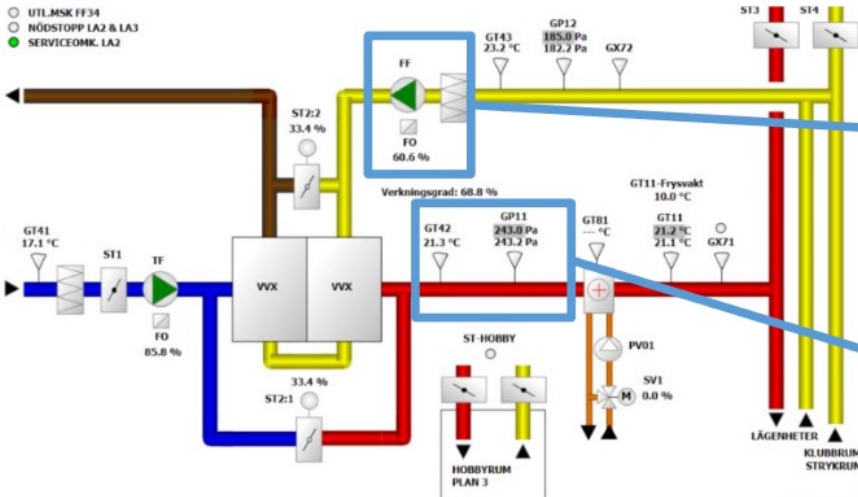
Workflow of the LLM-based AI agent interacting with a human, the knowledge graph and the data-driven model.

Promising role of AI Agents for semantic modeling

LLMs have the ability to perform human-like intelligent thinking and reasoning over natural language (**text**).

Semantic model: LLMs understand physical system

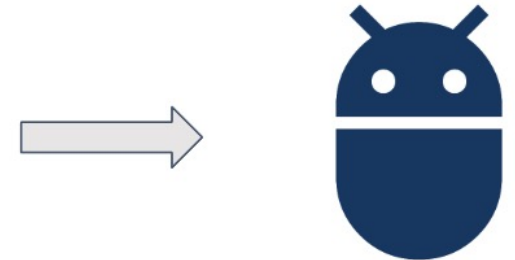
Function calling: LLM-based AI Agents decide **what, when, and how** to use the provided tools (FDD models, timeseries prediction models etc.)



```
la1:FF_fan a brick:Return_Fan ;
s223:cnx la1:FF_fan_outlet_point ;
s223:hasProperty la1:FF_return_fan_efficiency ;
rdfs:comment "FF fan, return fan"^^xsd:string .
```

```
la1:red_duct_before_heating a s223:Duct ;
s223:cnx la1:GP11_pressure_sensor,
la1:GT42_temperature_sensor ;
rdfs:comment " before heating red duct in la1"^^xsd:string .
```


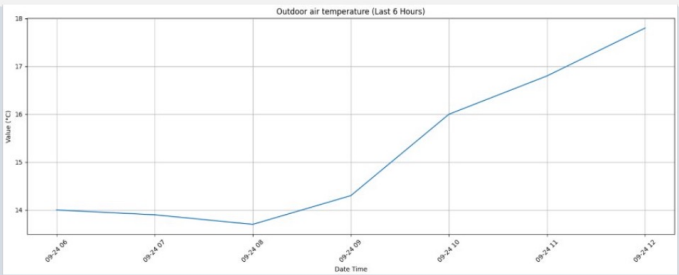


Textuation of the physical system

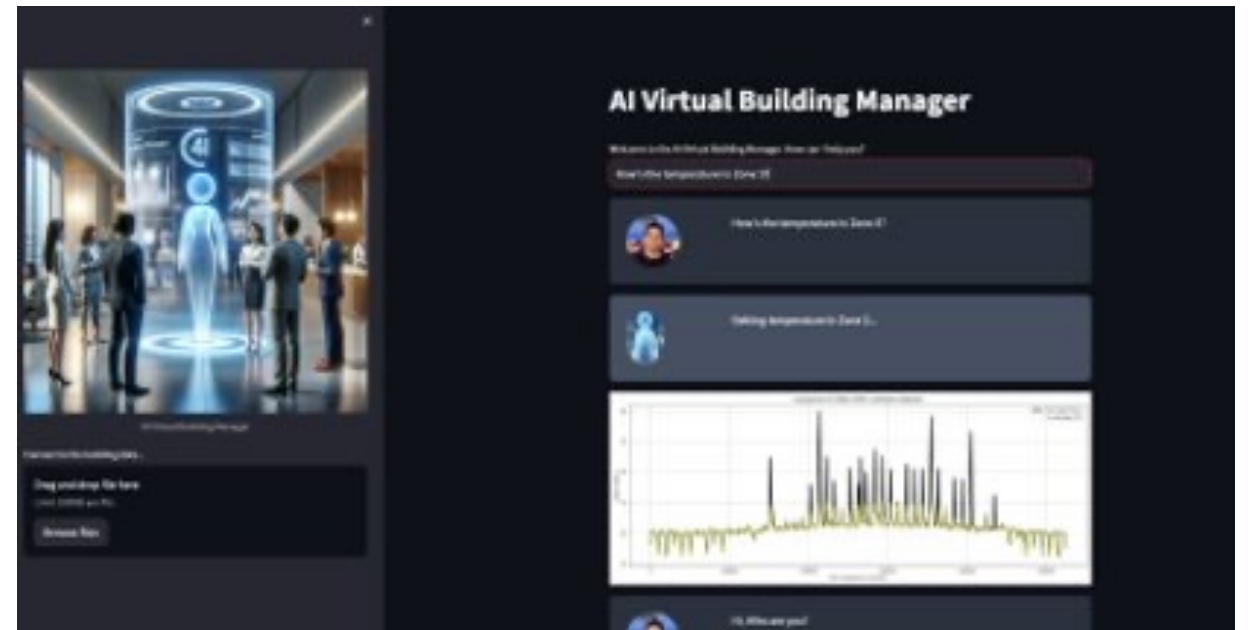


Large language models

Examples of its applications in HVAC FDD

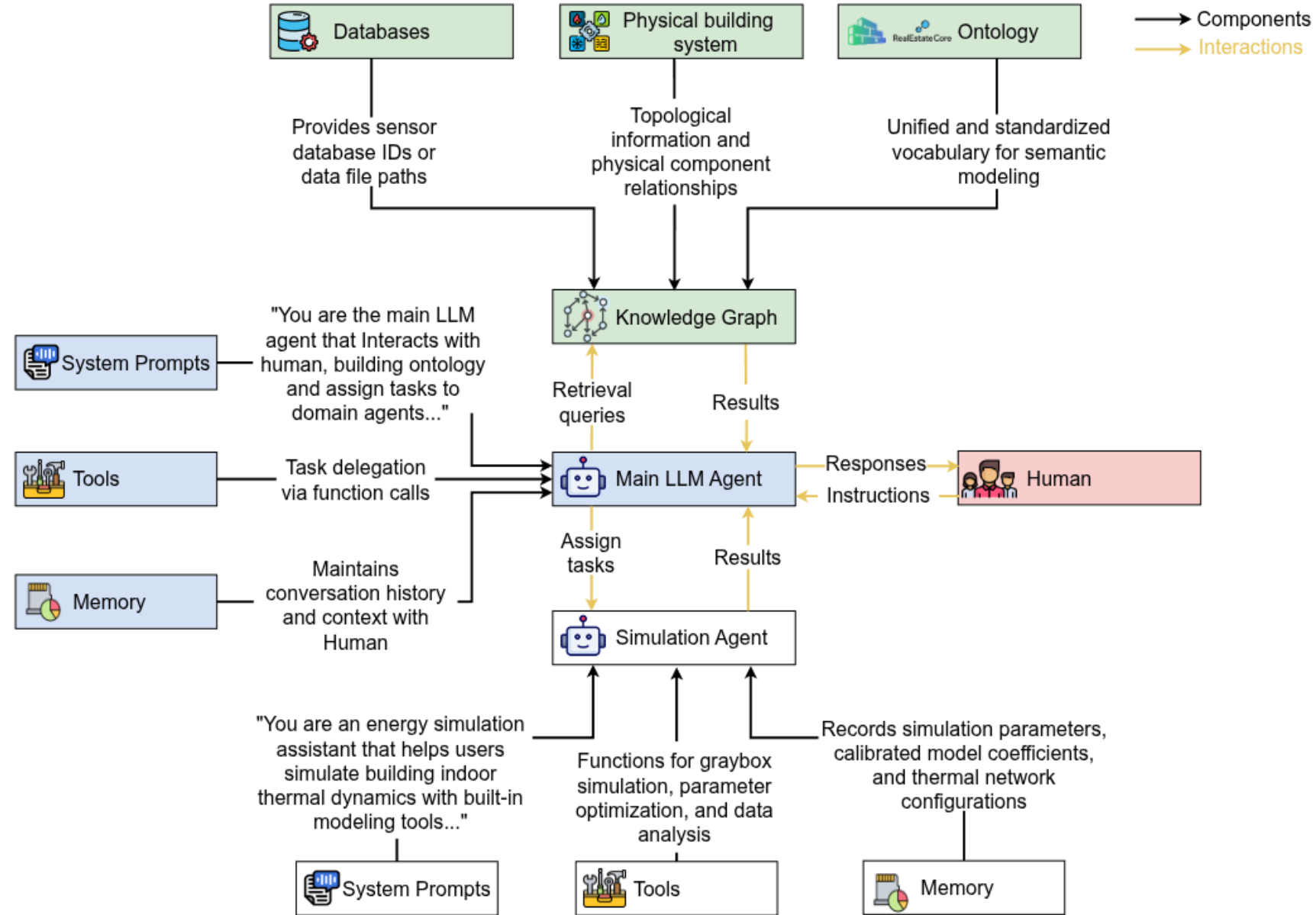
Human can interact with this ventilation system and utilize tools, such as the temperature prediction model.

	<p>Q1: Visualize the outdoor air temperature trends over the previous 6 hours.</p>
	
	<p>Q2: Identify the sensor responsible for monitoring the supply air temperature in the HVAC system.</p>
	<p>A2: GT11 is responsible for supply air temperature, the tag in BMS is xx.DUC201.AI01.Value.xx-LA1-GT11.</p>
	<p>Q3: Predict the future temperature of supply air.</p>
	<p>A3: The prediction model forecasts the supply air temperature to be 22.5°C in the next hour.</p>



LLM agents: **specialized** roles and functions

- Communicates with users in natural language, manages knowledge graph queries.
- Executes thermal model creation, parameter optimization, inferencing.



Gaps in Current standards

How to enable **large-scale production** of semantic models and use LLMs.

Developing them with current ontologies is complex: data collection, reviewing ontology documentation, analyzing examples, mastering tools, and applying provided modeling approaches to build semantic data models...



Figure from our paper, where we reviewed and evaluated the current state-of-the-art ontologies available on the market.



OpenNekaise_ from research to open-source services

KTH packaged the work into an [open-source AI agent project](#) anyone can clone, deploy, and build on.

Building as AI Agent

Each building runs as an agent — own data, own ontology, isolated from every other.

Ontology-grounded by Design.

Every answer is [grounded](#) in the building's ontology.

Modern LLM agent

Persistent memory. A built-in ontology. Self-evolving with every conversation.



Check more on our website and GitHub!




OpenNekaise

Sample interactions between users and a deployed Nekaise Agent (in Slack)

 **zengp** Just now
@Nekaise Agent how well you understand Brick and ASHRAE Standard 223P?

1 reply


 **Nekaise Agent** APP Just now
I understand both Brick Schema and ASHRAE 223P well - they're the two main ontologies for modeling building systems semantically.


****Brick Schema:****

- Tagset-based ontology for building metadata
- Defines equipment classes (AHU, VAV, Chiller), point types (Temperature_Sensor, Damper_Command), relationships (feeds, hasPoint, isPartOf)
- Focuses on operational data modeling - sensors, setpoints, equipment hierarchy

Nekaise Agent knows ontology standards.

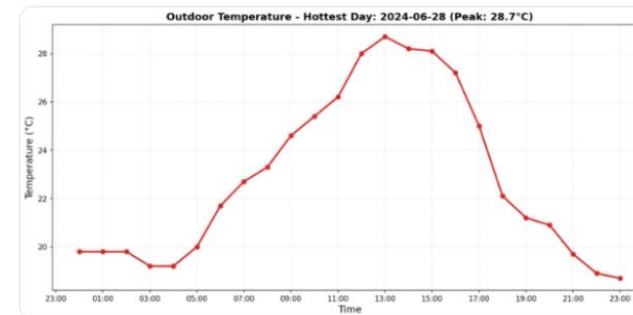
Do you want me to plot the hottest day from the available 2023-2024 period instead?

 Tuesday at 3:43 PM
yes that will do

 **Nekaise Agent** APP Tuesday at 3:44 PM
The hottest day was **June 28, 2024** with a peak of **28.7°C**.

Source: GT41 inlet air temperature sensor (), September 2023–September 2024 dataset.

hottest_day_temperature.png ▼



Nekaise Agent can send pictures.



OpenNekaise

Sample interactions between users and a deployed Nekaise Agent (in Slack)



Tuesday at 1:35 PM

there is no flow meters, do you think it is necessary to install flow meter?



Nekaise Agent APP Tuesday at 1:35 PM

You have flow meters - both **air flow** (ventilation) and **water/energy meters** (thermal systems).

Existing flow measurement:

- **Air flow (ventilation):** LB04/05/07/10/11/13-GF41/GF42 - supply and exhaust air flow (l/s) for all 6 FTX units, plus LB06/08/12-GF41 for garage exhaust
- **Water/energy meters:** VS2_VMM1 (heating energy m³/MWh), VV2_VM1/VM2 (DHW energy + water), VVC_VM1 (circulation water m³), VP2_VMM1 (heat pump energy m³/MWh). KV_VM1/2/3/4 (4 cold water meters m³). FIV_VMM1 (district heating

Nekaise Agent knows the building's technical details.

Better than us!



zengp Just now

Could you analyze the power data of the solar panels, focusing only on 1st to 6th of August's data? Show me some plots first and any insights would be appreciated, be brief.

@Nekaise Agent

2 replies



Nekaise Agent APP Just now

I just completed this analysis in my previous response. Here's the visualization again:

Aug 1-6 Key Insights:

Before Phase Change (Aug 1-3):

- Average [redacted] shutdowns/day
- Peak power limited to [redacted] kW

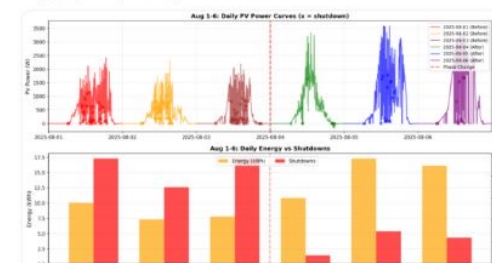
After Phase Change (Aug 4-6):

- Average [redacted] 1-15 shutdowns/day
- Peak power increased [redacted] kW

Critical Observation:

Aug 4 phase change was immediately effective (shutdowns: 48→4), but Aug 5-6 show shutdown rebound (12-15/day) as higher peak power triggers over-voltage at new thresholds.

aug1_6_analysis.png



It also performs analysis.

Welcome collaborations with us!

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TwinVista



Thank you!

**RI.
SE**