Air Quality Management: An Exemplar for Model-Driven Digital Twin Engineering

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Motivation

Creating and Maintaining Digital Twins is expensive

- MDE techniques can help
- But how (expensive to showcase applications)?

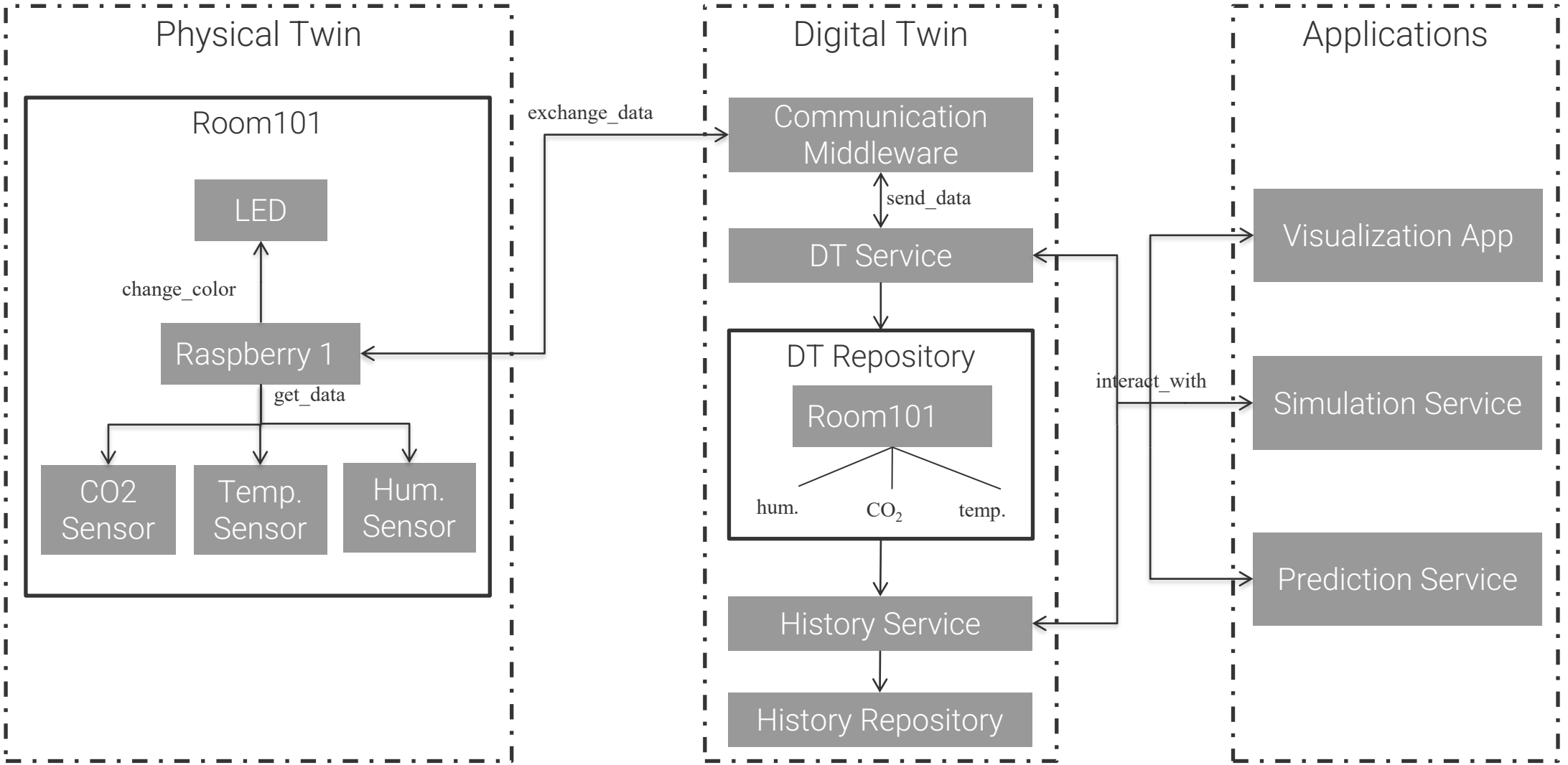
Contribution: **Cost-Effective Exemplar** to

- Identify challenges
- Showcase future solutions

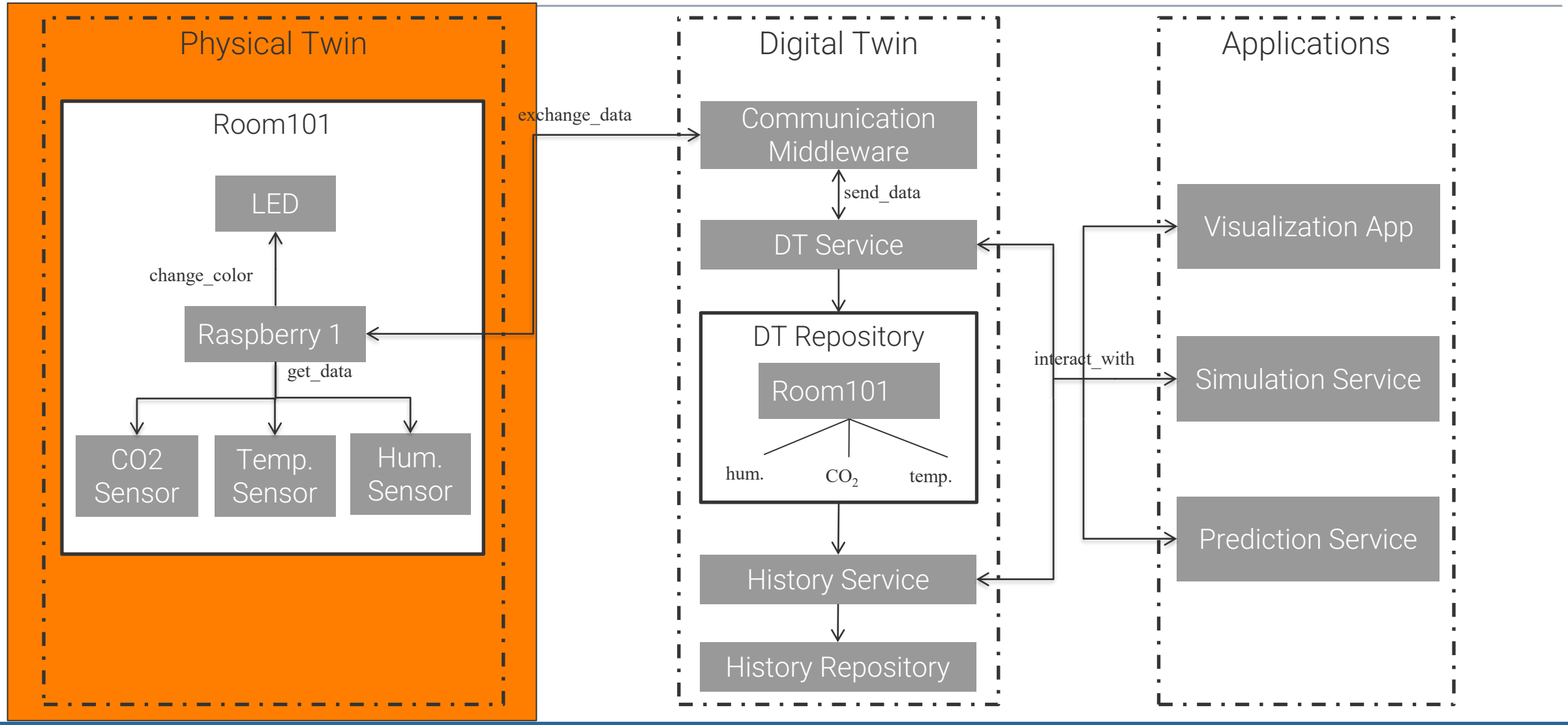
Exemplar provides

- Automation device (< 100 €) + historical data
- Different Digital Twin implementations
- 3 applications that make use of this DT

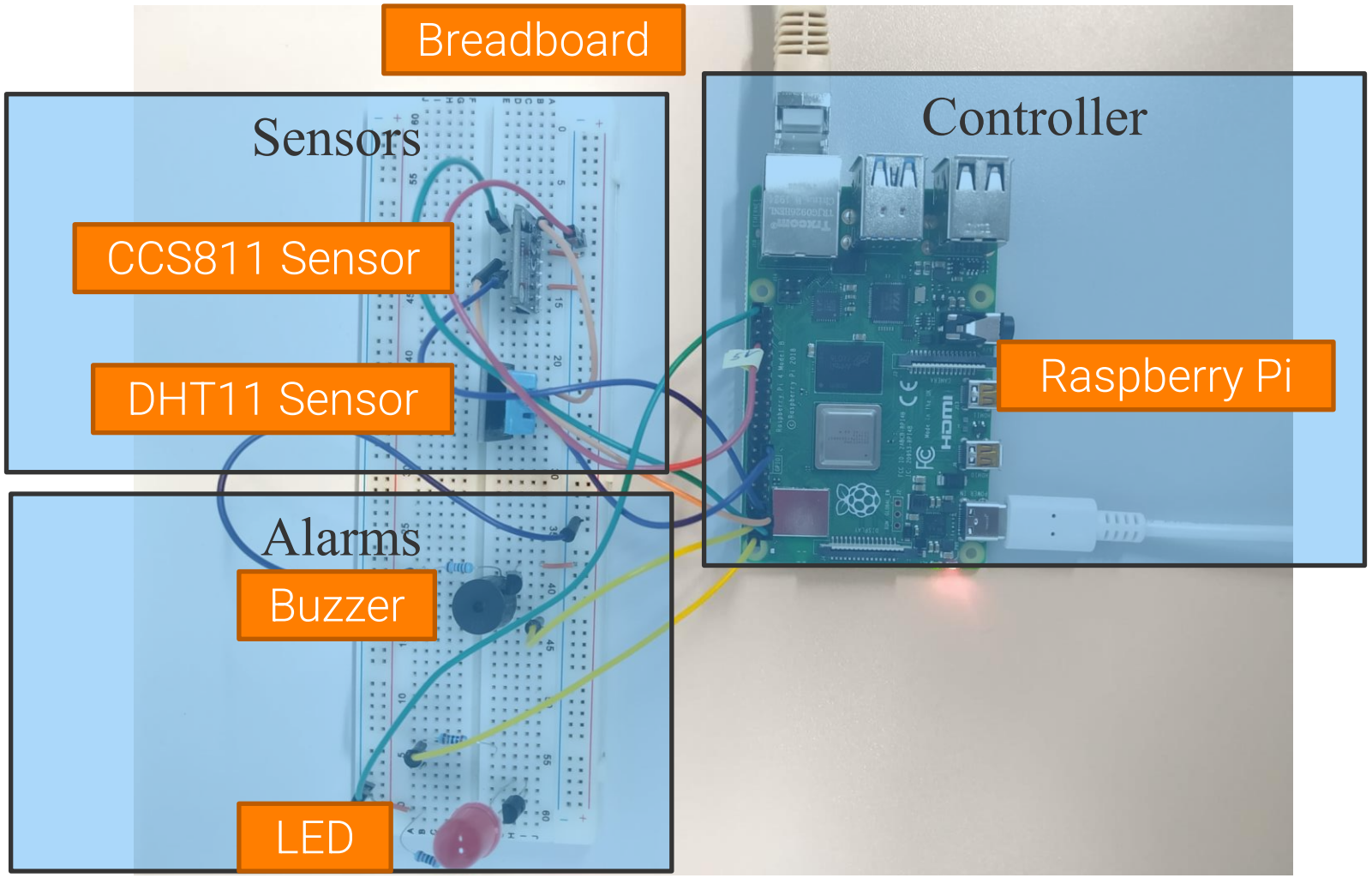
Digital Twin of a Room for Air Quality Management



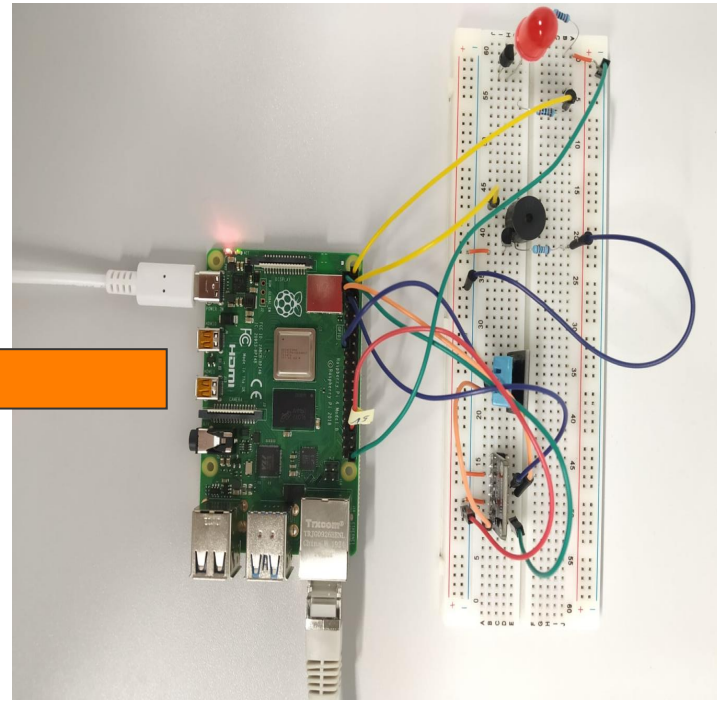
Digital Twin of a Room for Air Quality Management



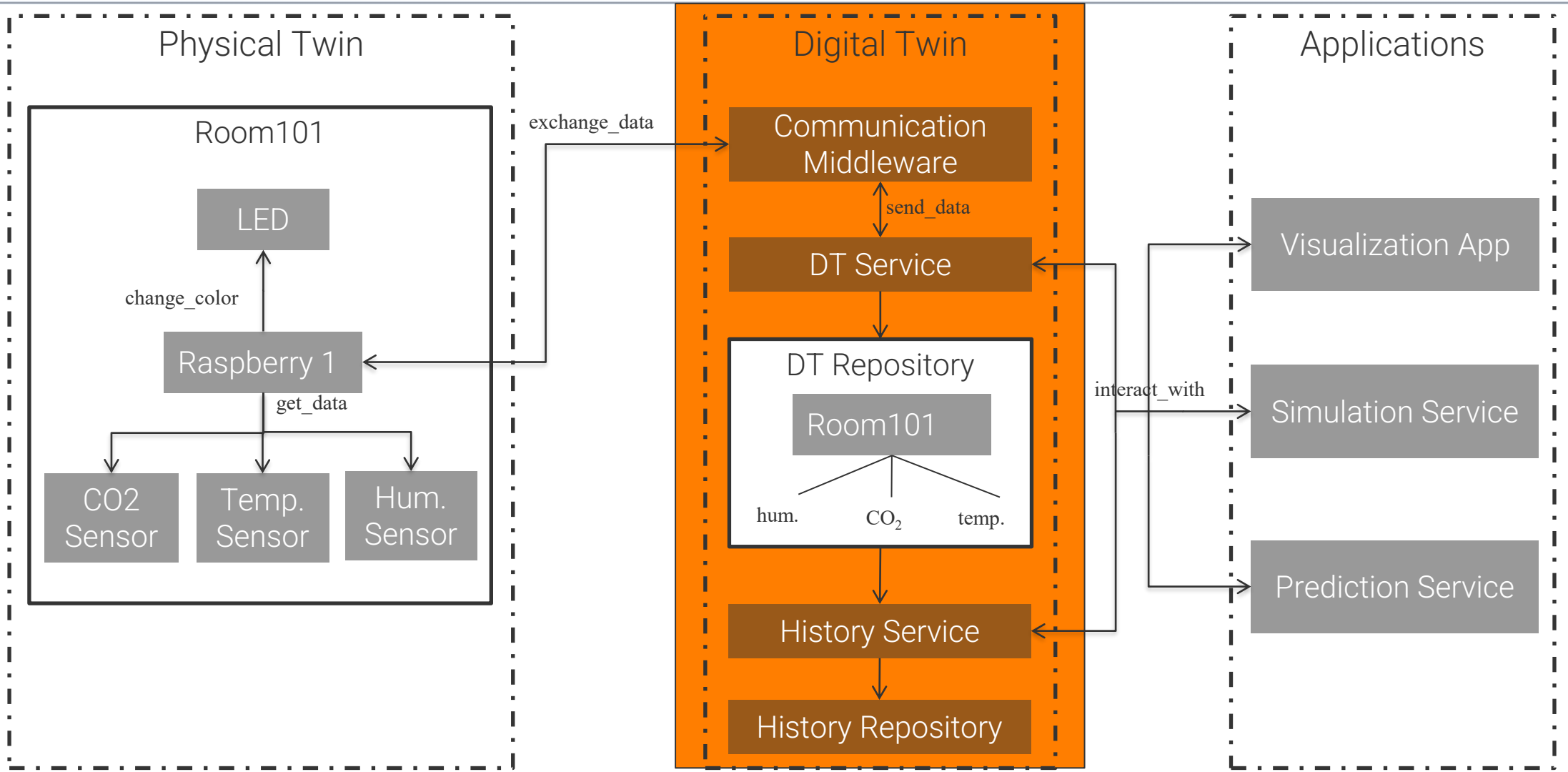
Automation Device



Physical Twin

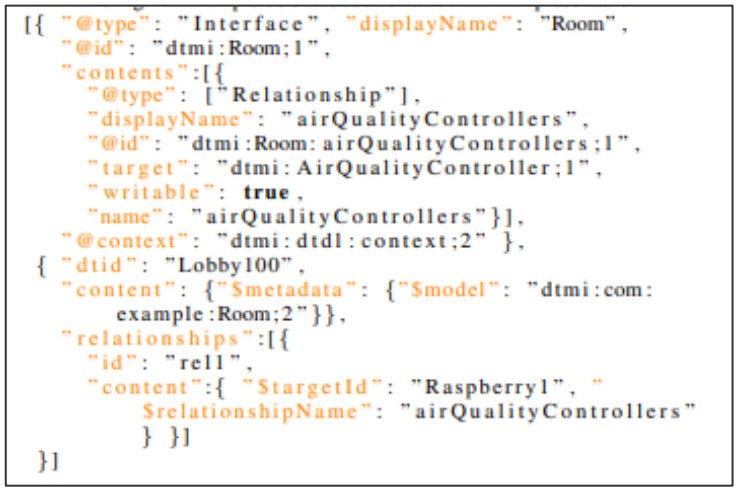


Digital Twin of a Room for Air Quality Management

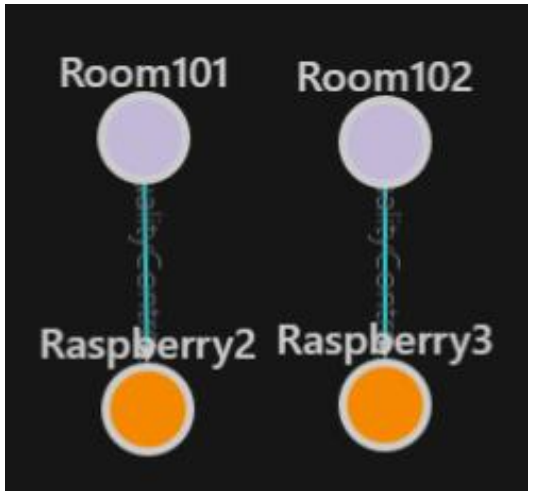


Digital Twin

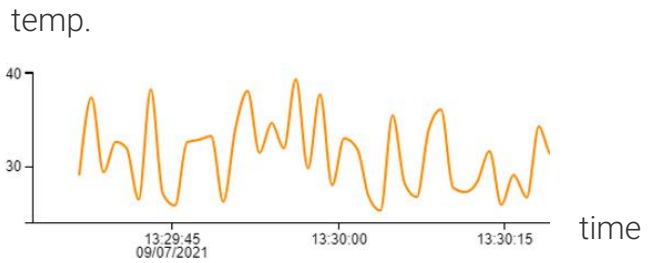
- Industry-Scale Implementation using Microsoft Azure [1]
- Open-Source Implementations [2]
  - Eclipse Hono/Ditto/Vorto
  - Runtime Monitoring Infrastructure from Academia [3]



Digital Twin Model



System Structure



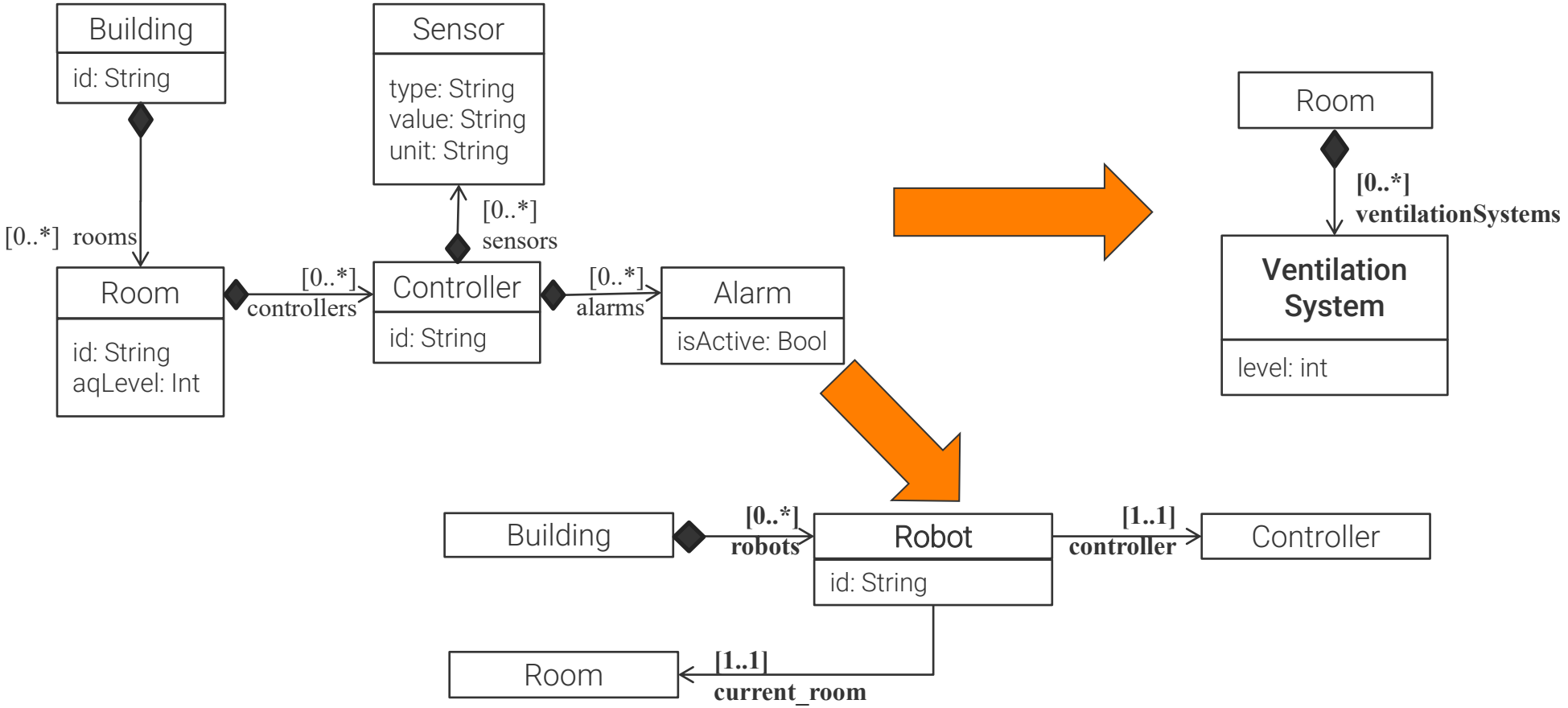
Historical Data

- **Challenge 1:** Platform-neutral modeling

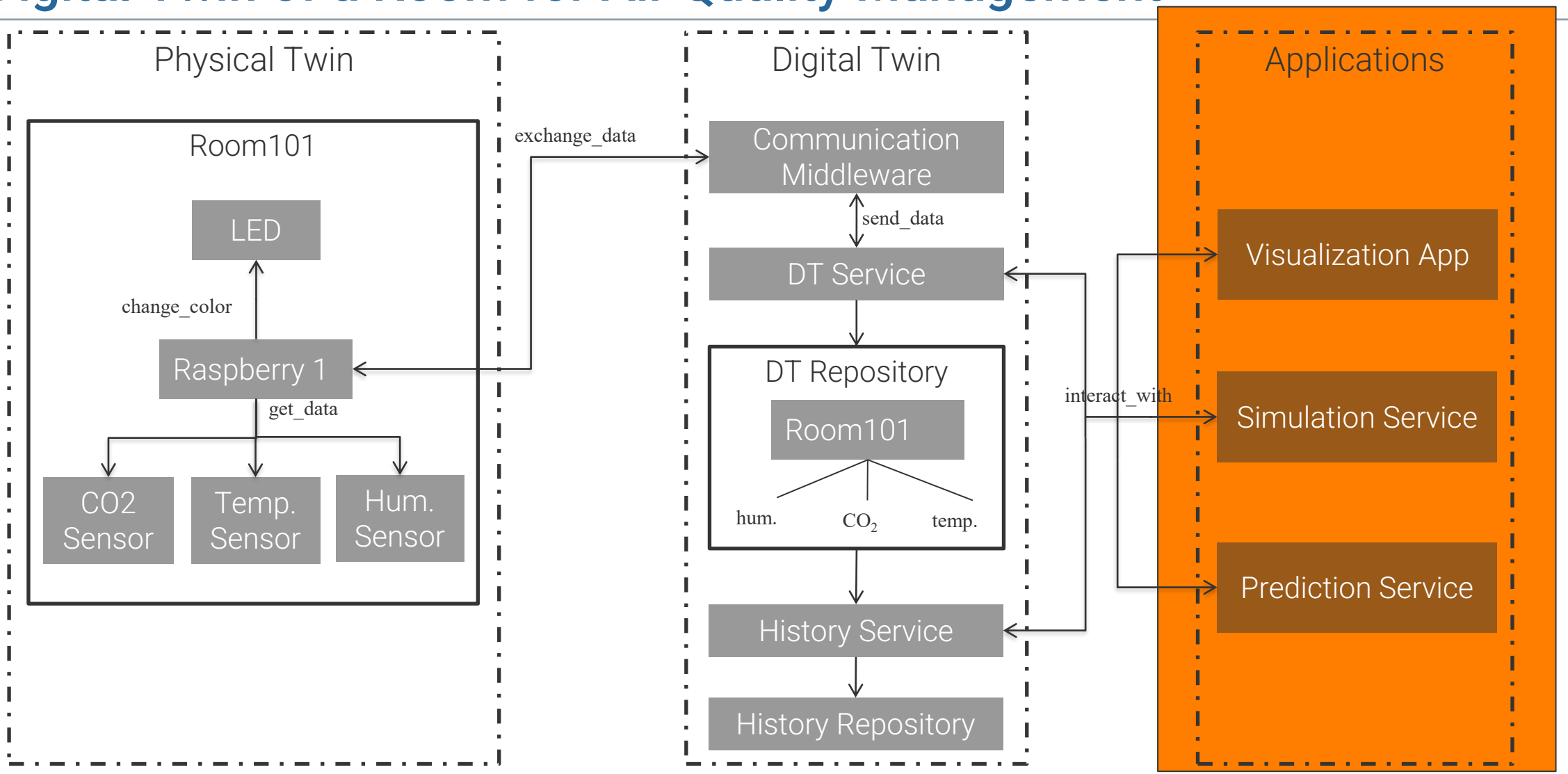
[1] https://github.com/derlehner/IndoorAirQuality_DigitalTwin_Exemplar/tree/main/digital_twin/azure
[2] https://github.com/derlehner/IndoorAirQuality_DigitalTwin_Exemplar/tree/main/digital_twin/open-source
[3] M. Vierhauser, H. Marah, A. Garmendia, J. Cleland-Huang, and M. Wimmer, "Towards a model-integrated runtime monitoring infrastructure for cyber-physical systems," in Proc. of ICSE-NIER, pp. 96–100, IEEE, 2021.

Digital Twin

Challenge 2: Dealing with model evolution [1]



Digital Twin of a Room for Air Quality Management



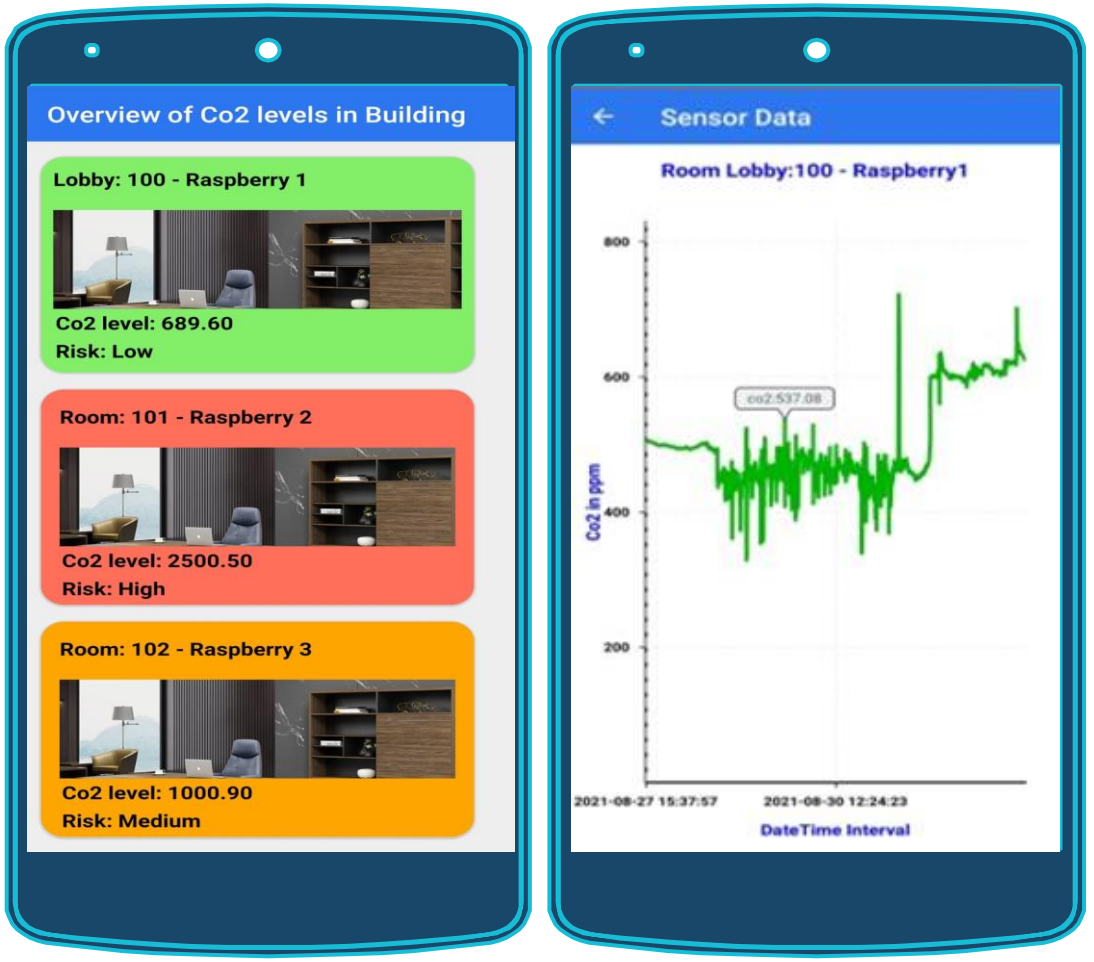
Advanced Visualization Application

Analyze air quality in a building

- Derive Actions for improving air quality
- Analyze the effect of actions on actual air quality values

Challenge 3: Runtime-Integrated Model Visualizations

- Effort for adapting a general Dashboard to specific user needs
- Visualization model and configuration model for auto-generation



Visualization Dashboards

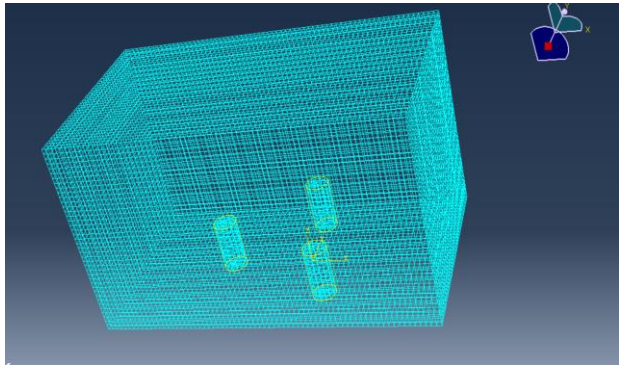
Physical Simulation Service

3D physical modelling of the flow of co_2 molecules

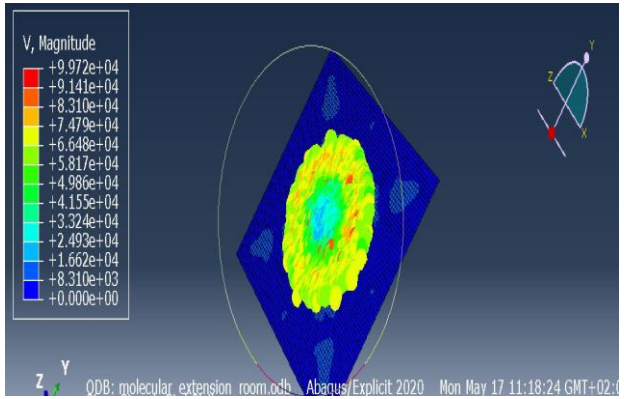
- Application: simulating different scenarios
- How does a ventilation system affect co_2 values?

Challenge 4: Integrating Physical Simulations

- Effort for creating simulation model
- Reuse information from existing models
- Generate simulation for new DTs



3D model of a room



flow of co_2 molecules for single source point

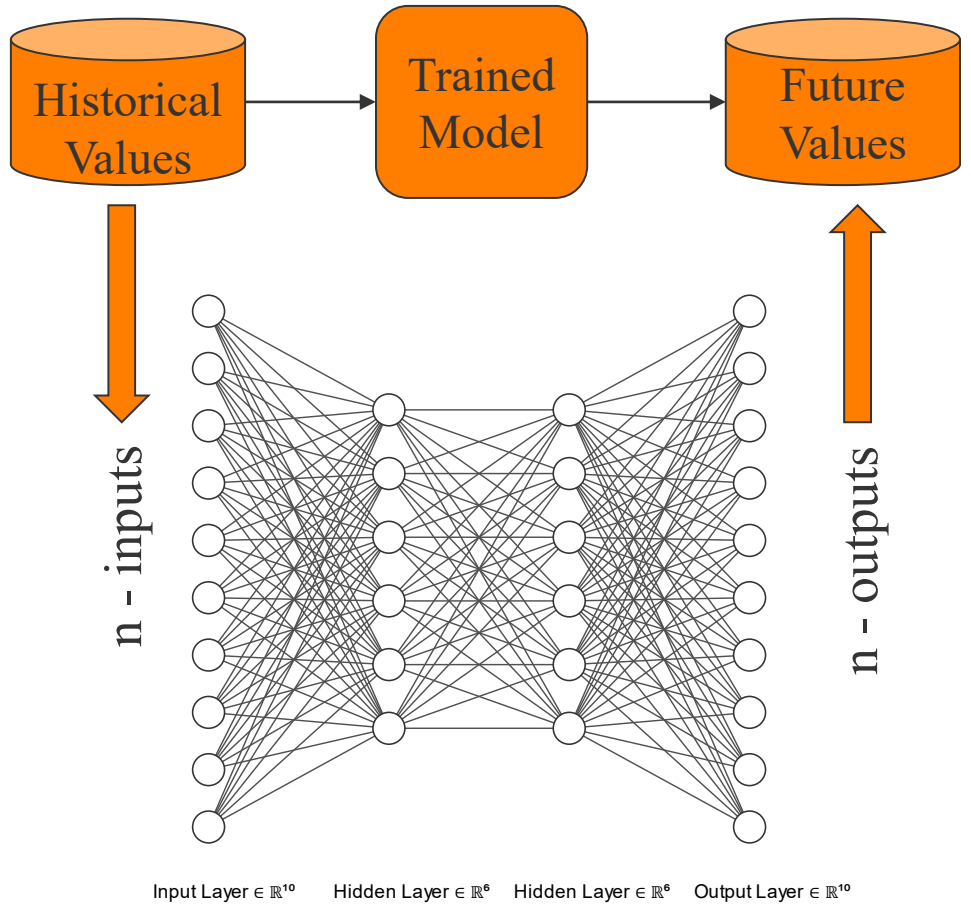
Prediction Service

Neural Network to prediction future Air Quality values

- Proactively influence values

Challenge 5: AI-integrated temporal models

- Integrate data from past and present with predictions for the future
- Query future values



Neural Network with 2 hidden layers

Summary and Future Work

Summary

- Digital Twin Exemplar for Indoor Air Quality Measurement
- Setup details for Physical, Digital Twin + Applications available on Github

Next Steps for Exemplar

- Vendor-Neutral Meta-Model
- More Digital Twin Implementations
- Adding heterogeniety on hardware side
- Providing implementation details for evolution cases

We‘re open for collaborations/contributions!

Thank You!

Comments? Questions? Feedback?

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Use Case
https://github.com/derlehner/IndoorAirQuality_DigitalTwin_Exemplar