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

Hari Shankar Govindasamy, Ramya Jayaraman, Burcu Taspinar, Daniel Lehner, Manuel Wimmer
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

Physical Twin

Room101

- LED
  - change_color
- Raspberry 1
  - get_data
- CO2 Sensor
- Temp. Sensor
- Hum. Sensor

Digital Twin

- Communication Middleware
- DT Service
  - DT Repository
    - Room101
      - hum.
      - CO2
      - temp.
- History Service
- History Repository

Applications

- Visualization App
- Simulation Service
- Prediction Service
Automation Device

Breadboard

Sensors
- CCS811 Sensor
- DHT11 Sensor

Alarms
- Buzzer
- LED

Controller
- Raspberry Pi
Physical Twin
Digital Twin of a Room for Air Quality Management

Physical Twin

Room101

- LED
- Raspberry 1
  - CO2 Sensor
  - Temp. Sensor
  - Hum. Sensor

Digital Twin

- Communication Middleware
- DT Service
- DT Repository
  - Room101
    - hum.
    - CO2
    - temp.

Applications

- Visualization App
- Simulation Service
- Prediction Service

Applications

- exchange_data
- get_data
- send_data
- interact_with
- history_service
- history_repository
Digital Twin

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

```
[  {
    "@type": "Interface",
    "displayName": "Room",
    "@id": "dtmi:Room:1",
    "content": {
      "@type": "Relationship",
      "displayName": "airQualityControllers",
      "@id": "dtmi:Room:airQualityControllers:1",
      "target": "dtmi:AirQualityController:1",
      "writable": true,
      "name": "airQualityControllers"},
      "@context": {"dtmi:dtcl:context:2"},
      {"did": "Lobby100",
      "content": {"5mctdata": {"Smodel": "dtmi:com:example:Room:2"}},
      "relationships": [{
      "id": "ref1",
      "content": {"Smodel": "Raspberry1", "RelationshipName": "airQualityControllers" } }
      ]}
```
Digital Twin

Challenge 2: Dealing with model evolution [1]

Digital Twin of a Room for Air Quality Management

Physical Twin

Room101
- LED
  - change_color
- Raspberry 1
  - get_data
  - CO2 Sensor
  - Temp. Sensor
  - Hum. Sensor

Digital Twin

Communication Middleware
- send_data
- DT Service
- DT Repository
- Room101
  - hum.
  - CO2
  - temp.
- History Service
- History Repository

Applications

Visualization App
- Simulation Service
- Prediction Service
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
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 predict 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 heterogeneity on hardware side
• Providing implementation details for evolution cases

We’re open for collaborations/contributions!
Christian Doppler Laboratory for Model-Integrated Smart Production
CDL-MINT

Thank You!
Comments? Questions? Feedback?

Daniel Lehner, Hari Govindasamy
daniel.lehner@jku.at
http://github.com/derlehner
hari.govindasamy@jku.at
CDL-MINT
https://cdl-mint.se.jku.at/

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