



Project leader:
Prof. Shaofang Gong, LiU

Digitalization framework for energy optimization and smart maintenance of historic buildings

2020 - 2023



Goal

Cloud-based digitalization solution with artificial intelligence (AI) as a tool for energy optimization and maintenance of historic buildings. This is realized through definition and creation of a digitalization framework in which digital twins are generated for the chosen three historic buildings, i.e., the City Theater, the Auditorium and the City Museum in Norrköping. Widespread use of the solution is expected.



City Theater



Auditorium



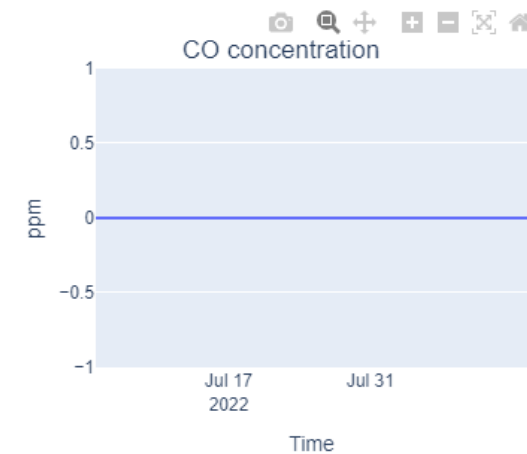
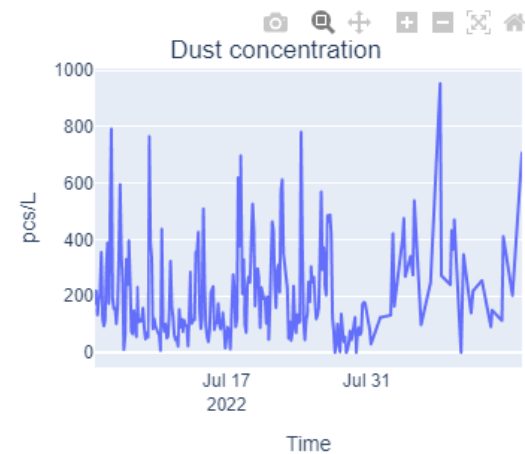
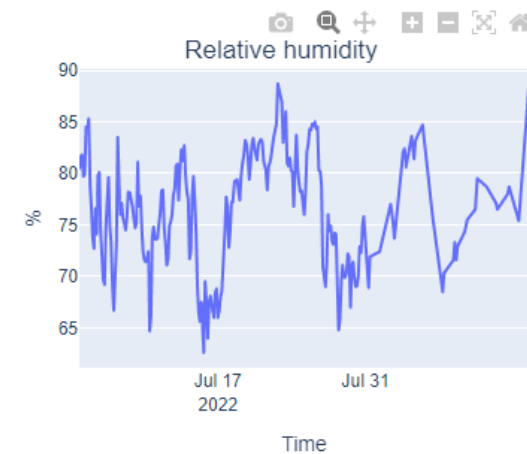
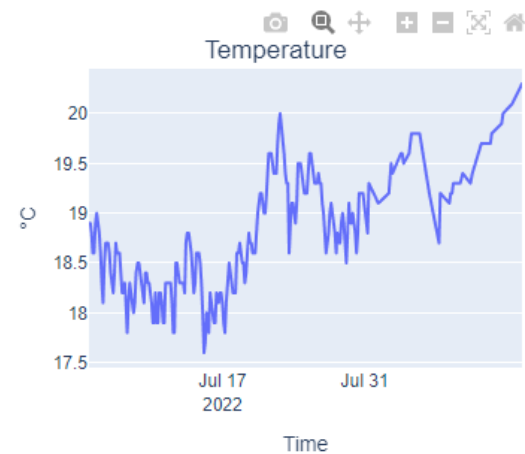
City Museum



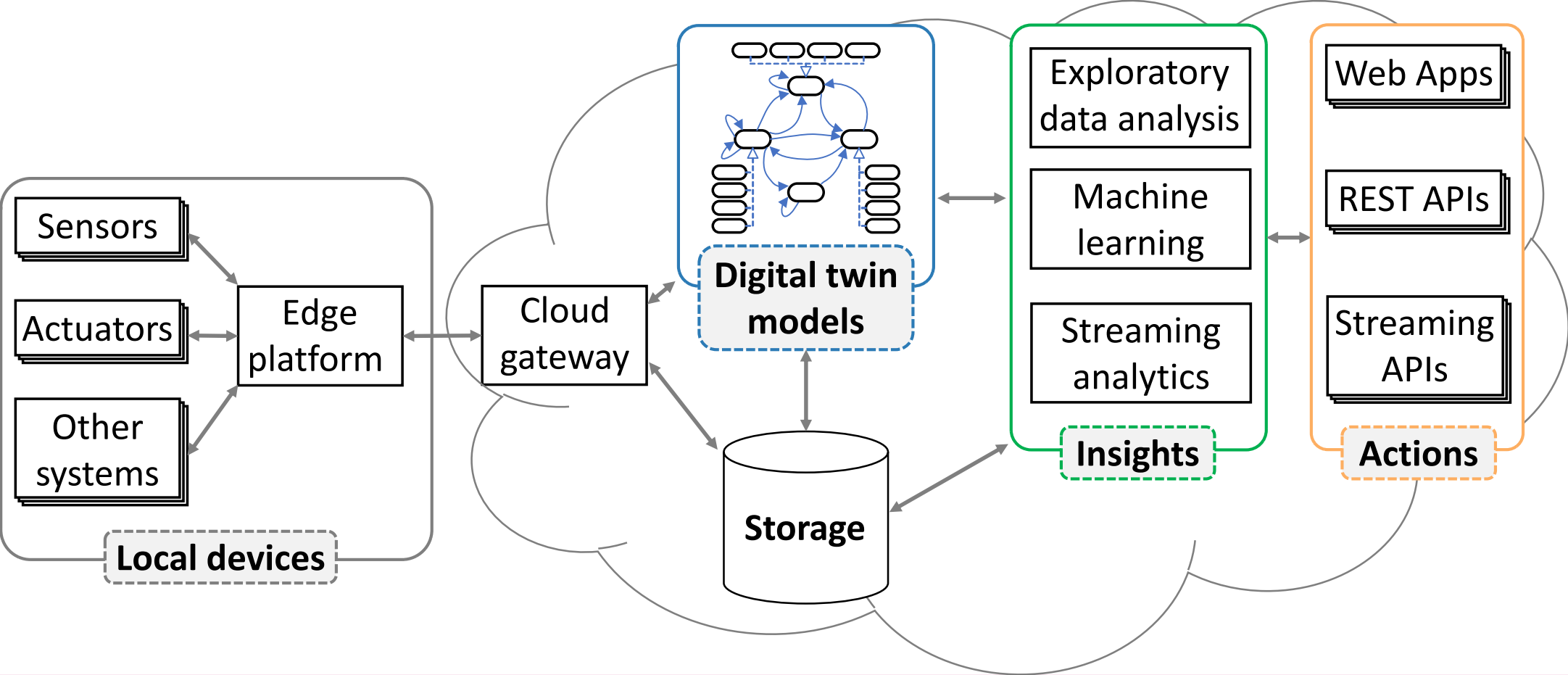
Löfstad palace

Room of Kokerskan in the Löstad palace

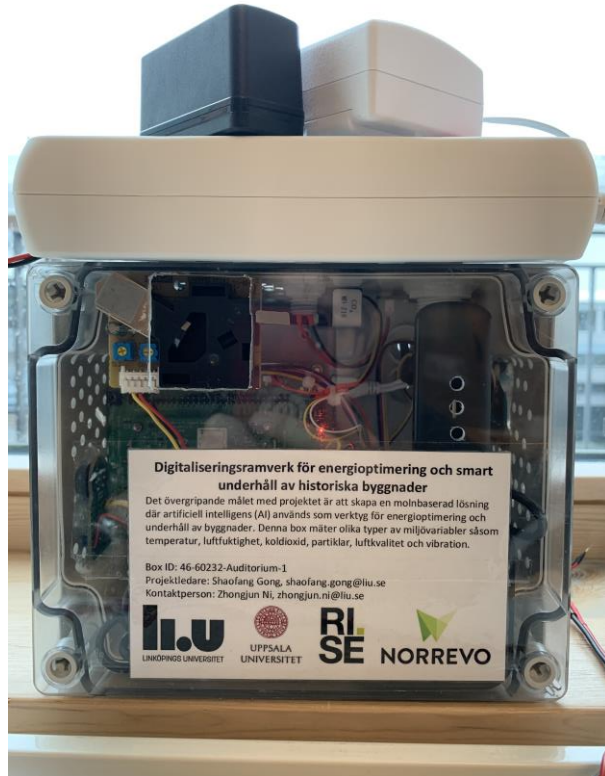
1 Hour 6 Hours 12 Hours 1 Day 7 Days 30 Days Custom date range



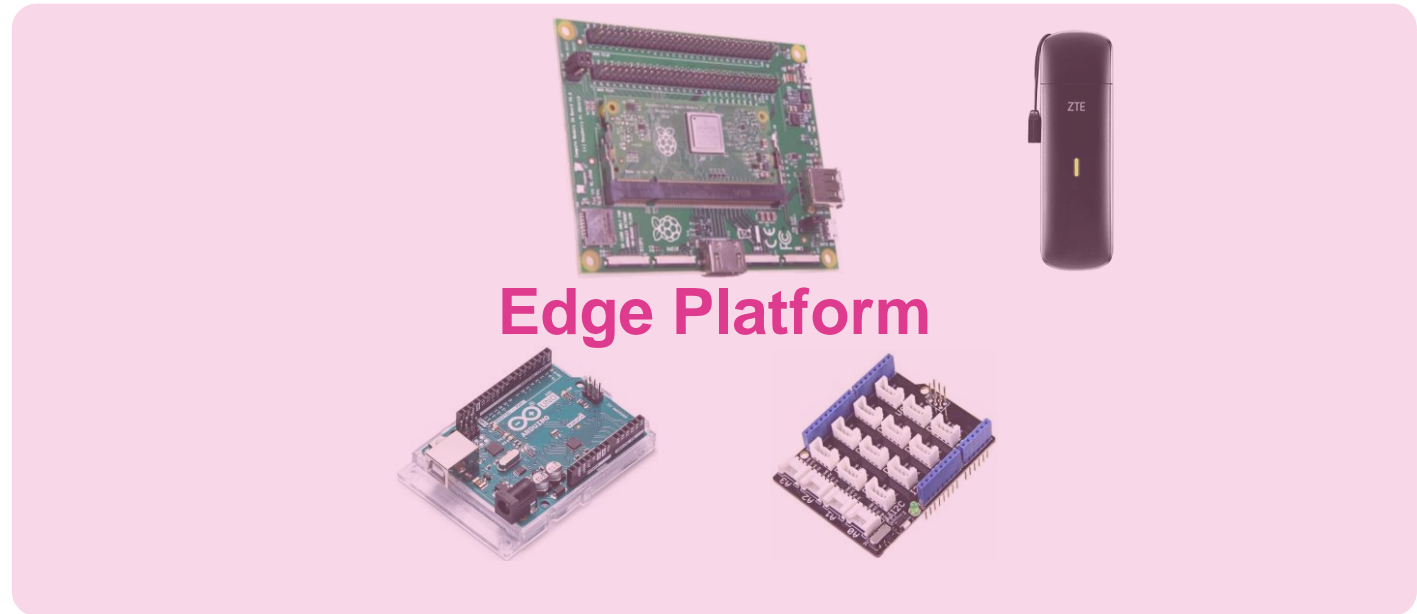
The overall digitalization framework



A multi-sensor box to collect indoor environment data



[Box size: 201x163x98 mm]



Edge Platform



Temperature & Relative humidity



CO₂



Micro-particles



Air quality



Vibration

A Web portal to provide applications

Indoor Environmental Data

Show data for building:

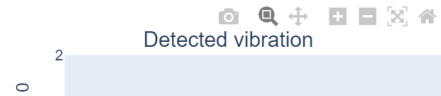
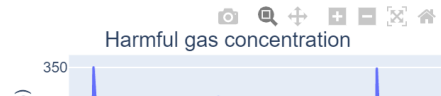
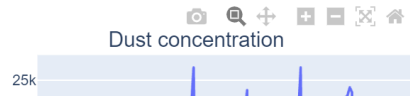
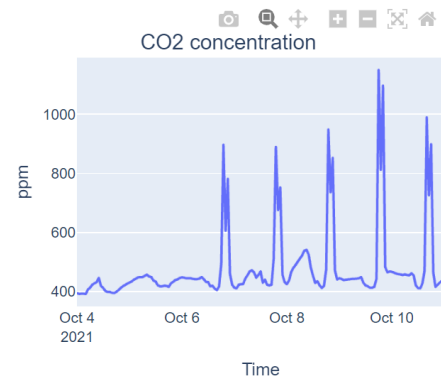
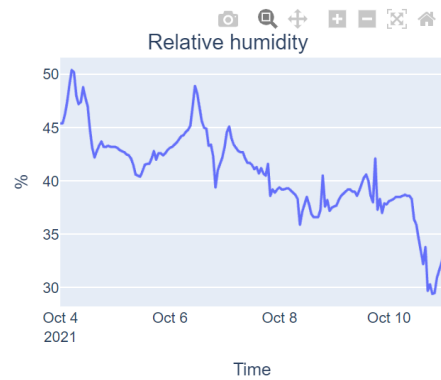
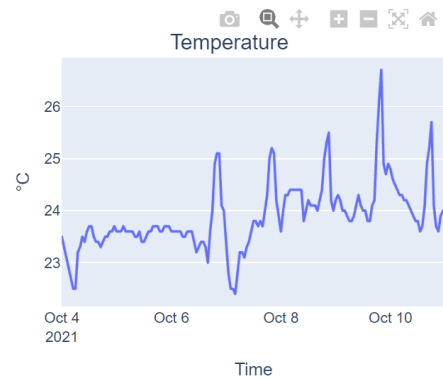
- The City Theatre The Auditorium The City Museum Lövstad Castle

Show data for (last):

- 1 Hour 6 Hours 12 Hours 1 Day 7 Days 30 Days Custom date range

10/04/2021 → 10/11/2021

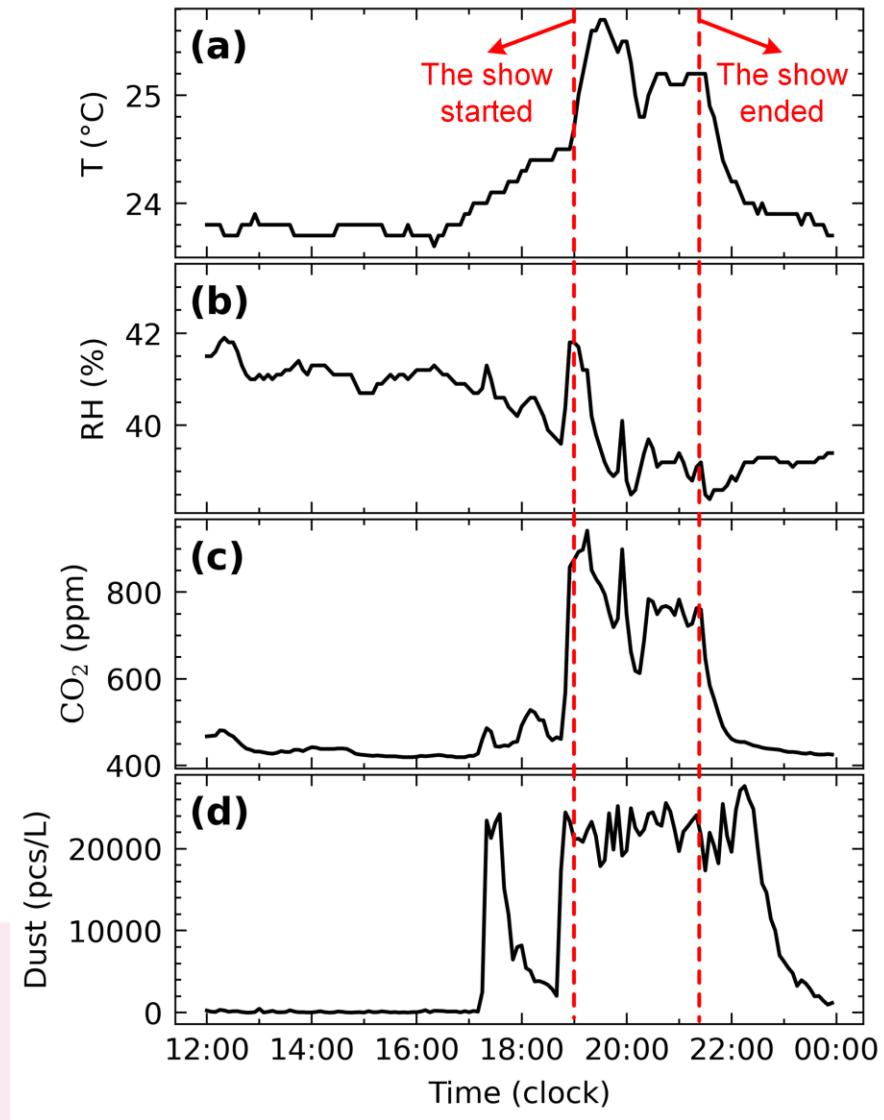
<https://historicbuildings.azurewebsites.net/dashboard>



Occupants' activities affect indoor environment

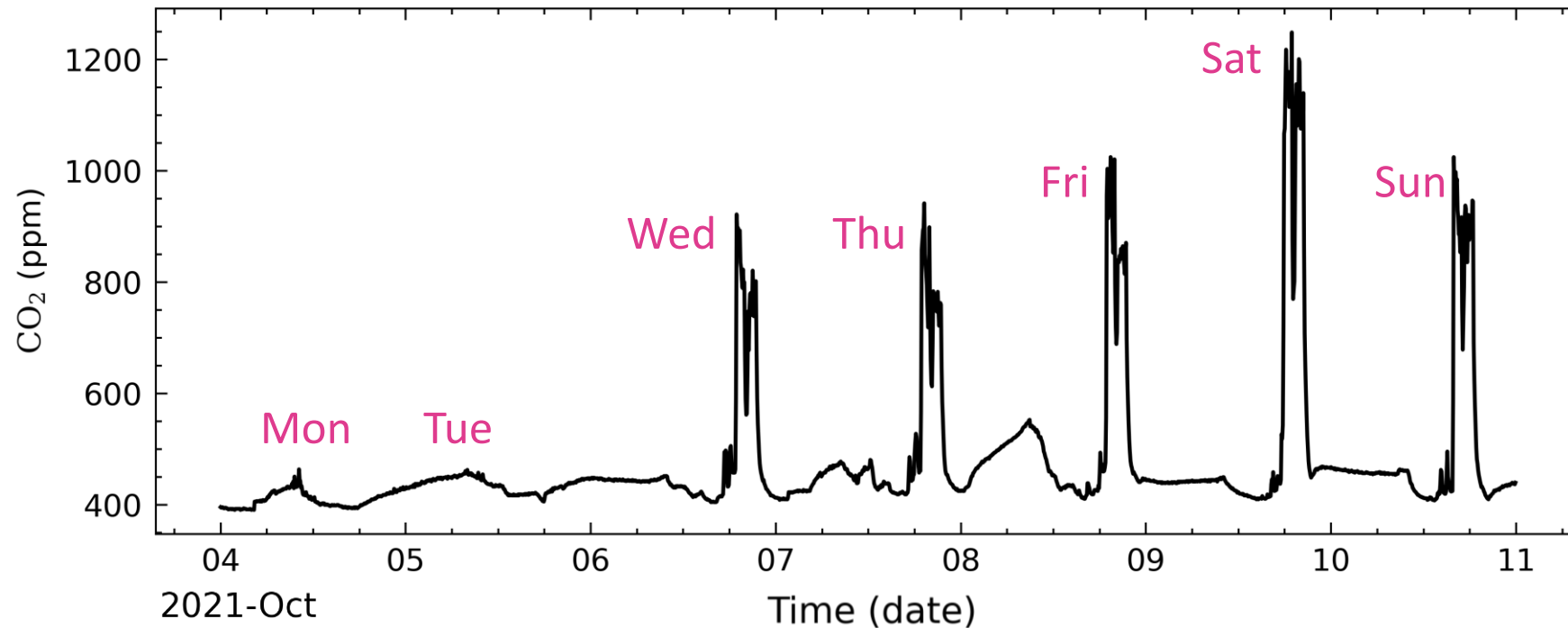
- A rise in temperature (T) and CO₂
- Fluctuations in relative humidity (RH)
- The ventilation system drives the movements of small particles

CO₂ is more sensitive to occupants' presence



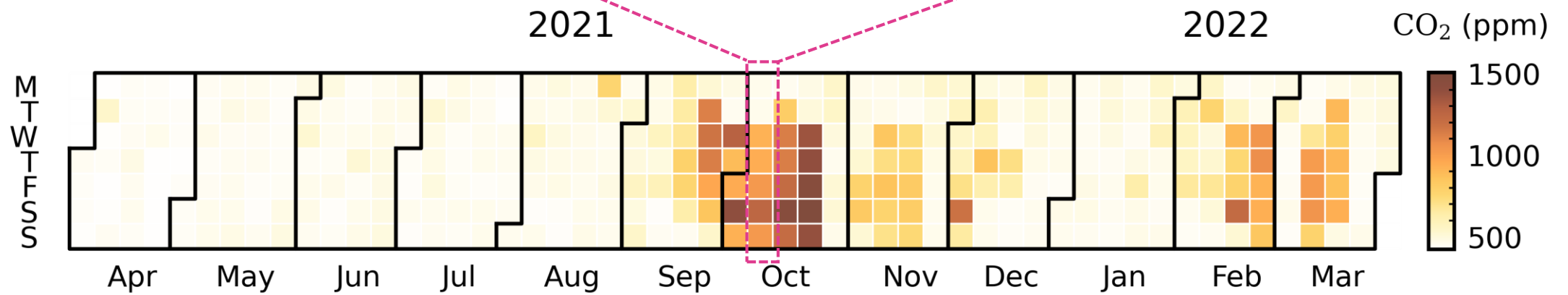
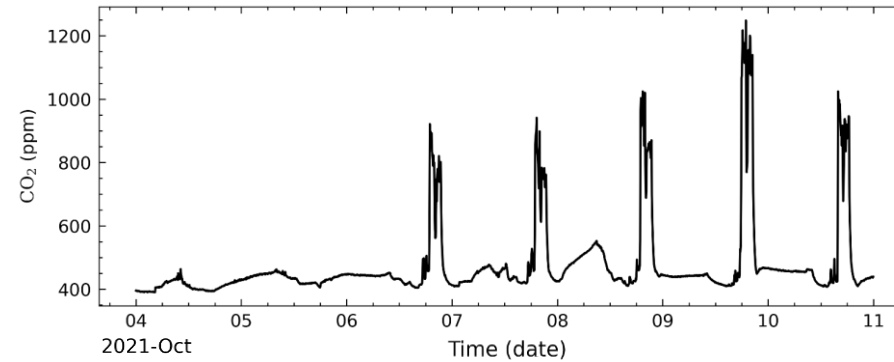
Historical indoor environment in the salon of the City Theatre from 12:00 to 23:59, October 7, 2021.

CO₂ concentrations reflect occupancy levels



Historical CO₂ concentrations in the salon of the City Theatre from October 4 (Monday) to 10 (Sunday), 2021.

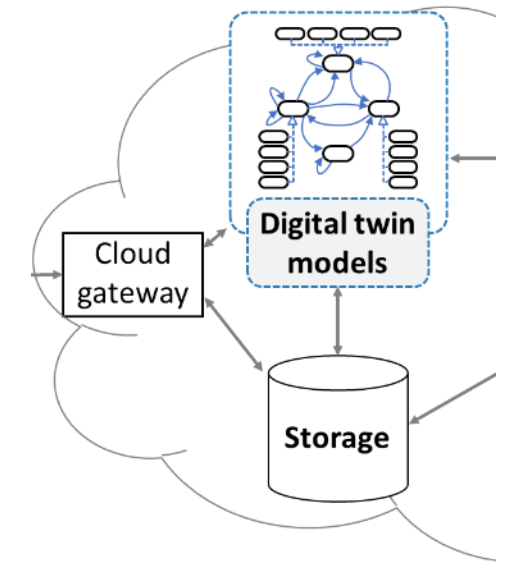
Occupancy levels in the City Theatre throughout the year



Daily maximum CO₂ concentrations in the salon of the City Theatre from April 1, 2021 to March 31, 2022.

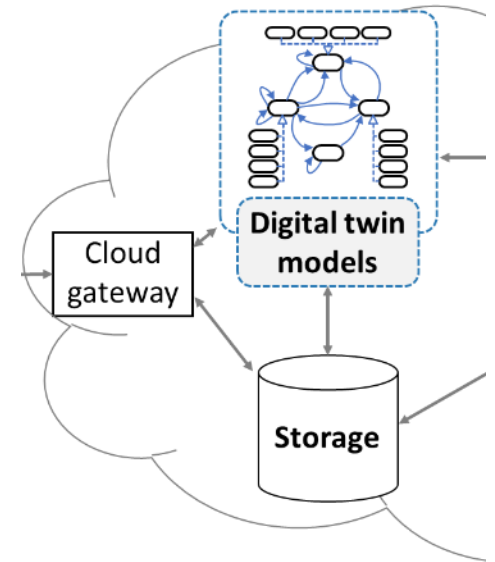
Digital Twins - Current status

- A wide range of solutions for modeling Digital Twins exist:
 - Each institution/company develops its own solution.
 - Only 2 open-source frameworks (Itwins & Ditto).
- The usage of ontologies to model a Digital Twin is not widespread:
 - Azure (property graph / possibility to convert ontologies)
 - Eclipse Ditto (property graph)
- Different frameworks for different usages:
 - Azure: DevOps tooling, real-time monitoring, analysis based on previous data.
 - Itwins: Advanced 3D modelization, real-time monitoring.
 - Simulink: Simulator
- Many Digital Twins frameworks can be/are supported by Azure.



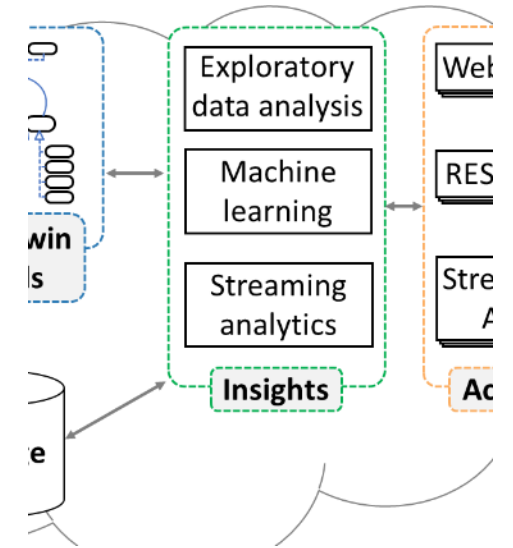
Relevant ontologies

- An ontology is;
 - a set of concepts and categories in a subject area or domain that shows their properties and the relations between them.
- Reason to use ontologies in the building sector
 - ontologies are a shared data model
 - facilitate data integration, sharing, discovery and reuse
 - enhanced search results
- Ontologies related to buildings
 - RealEstateCore: Description of smart buildings.
 - SAREF4CITY: Description of smart cities.
 - Schema.org: Description of civic structures (type, opening hours...).
 - SOSA/SSN (Sensor, Observation, Sampler, and Actuator/Semantic Sensor Networks)



Machine Learning & Artificial Intelligence

- Tasks done in this project;
 - Combining input from multiple sources
 - Weather, temperature, CO2 concentration, humidity and more to identify the trends
 - More correlated inputs improves model's accuracy
 - Doing data cleaning
 - The data consists of slow moving trends, the data can therefore be reduced before it is sent to the cloud
 - Exploring Machine Learning models
 - Multiple possible timeseries forecast models such as N-BEATS, SARIMA or CNN



Field study

- Field study in the case study buildings in Norrköping
- Specific conditions in heritage buildings – use and heritage values
- Interviews with managers and users

To be conducted fall 2022



Tack!

