Narrowing the Gap

Connecting Simulation Models to Physical Buildings for Real-time Monitoring and Fault Diagnosis

EQUA
SIMULATION TECHNOLOGY GROUP

Motivation

- All models are inherently wrong - often initial building design models do NOT perform as intended
- Calibration is required to be (legally) useful
  - ASHRAE G14 (NMBE < 5/10% and CV(RMSE)<15/30% monthly/hourly)
- This can be problematic for performance oriented contracts, cases of energy certification requirements, passive houses, net zero energy projects, etc…
- Manual model calibration is costly!
- Optimizing a well calibrated model can translate in savings up to 40%. Something we see all too often at EQUA…

TRIBUTE

"Take the energy bill back to the promised building performance"

- Time line (2014 - 2018)
- Objectives
  - Self-tuning iBPS
  - Improved occupancy modeling
  - Real-time visualization
  - Auto/Manual Fault detection and diagnosis
  - Short and long term forecasting
  - Retrofitting and optimal control options

TRIBUTE

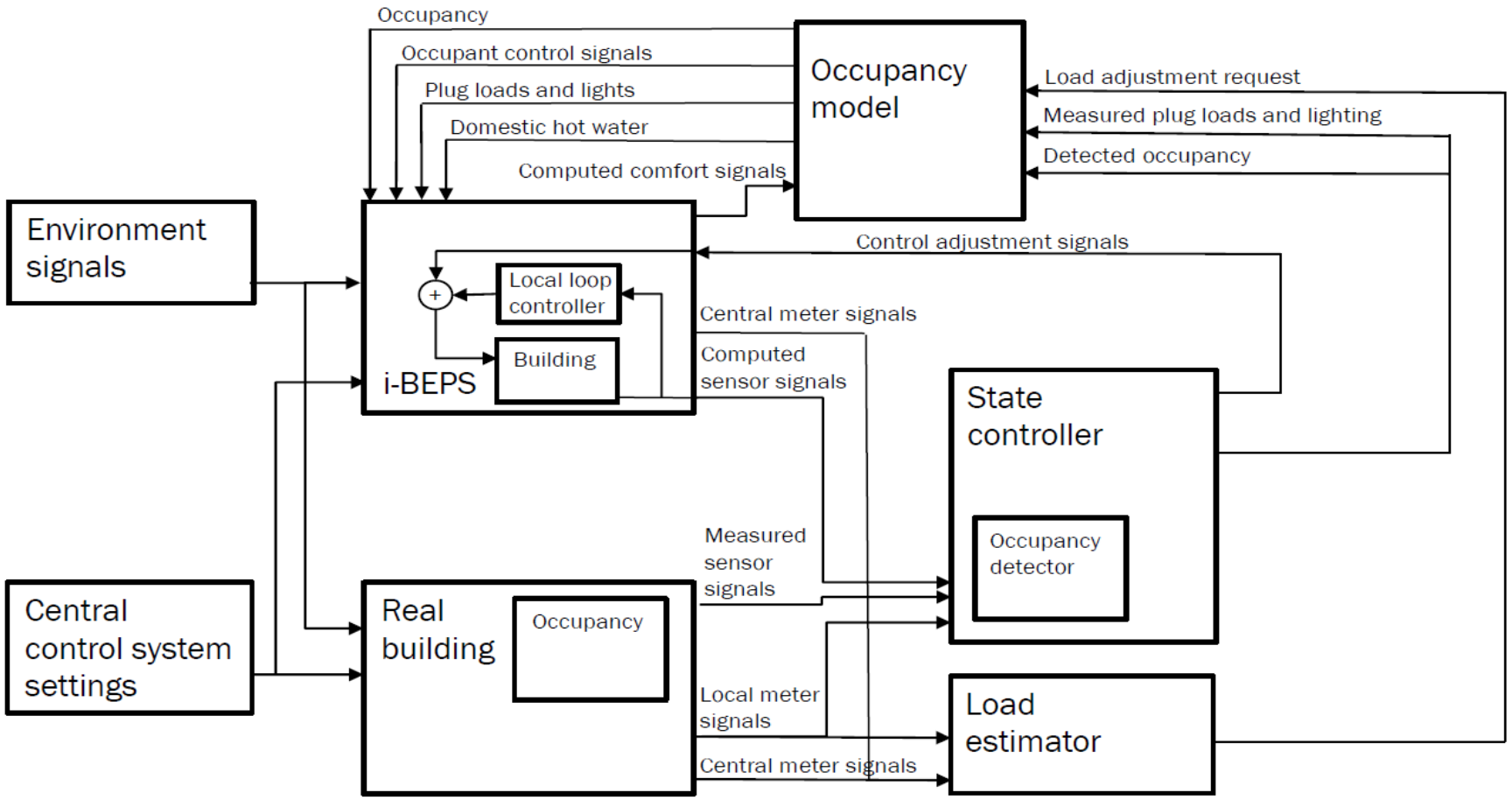
- Partners
  - Schneider Electric, Grenoble:
    - Project leader
  - IBM, Cork:
    - Occupancy modeling
  - NXP, Eindhoven:
    - Wireless sensors
  - Centre Suisse d'Electronique et de Microtechnique:
    - Algorithm development
  - IREC, Spain:
    - Model component development
  - EQUA Simulation:
    - Simulation and modeling
  - Many more: Nimbus embedded systems, La Rochelle University, Politecnico di Torino, Zed factory, etc...

Related Work

- Autotune
  - Oak Ridge National Laboratory
  - U.S. Department of Energy

- Tuning 156 EnergyPlus inputs
  - over 96 outputs with 15 min resolution
  - over 8 million E+ simulations
  - 267 TB
  - 1024-core shared memory Nautilus, 2048-core Frost, 224,256-core Jaguar, 299,008-core Titan. (30¢/day/core)

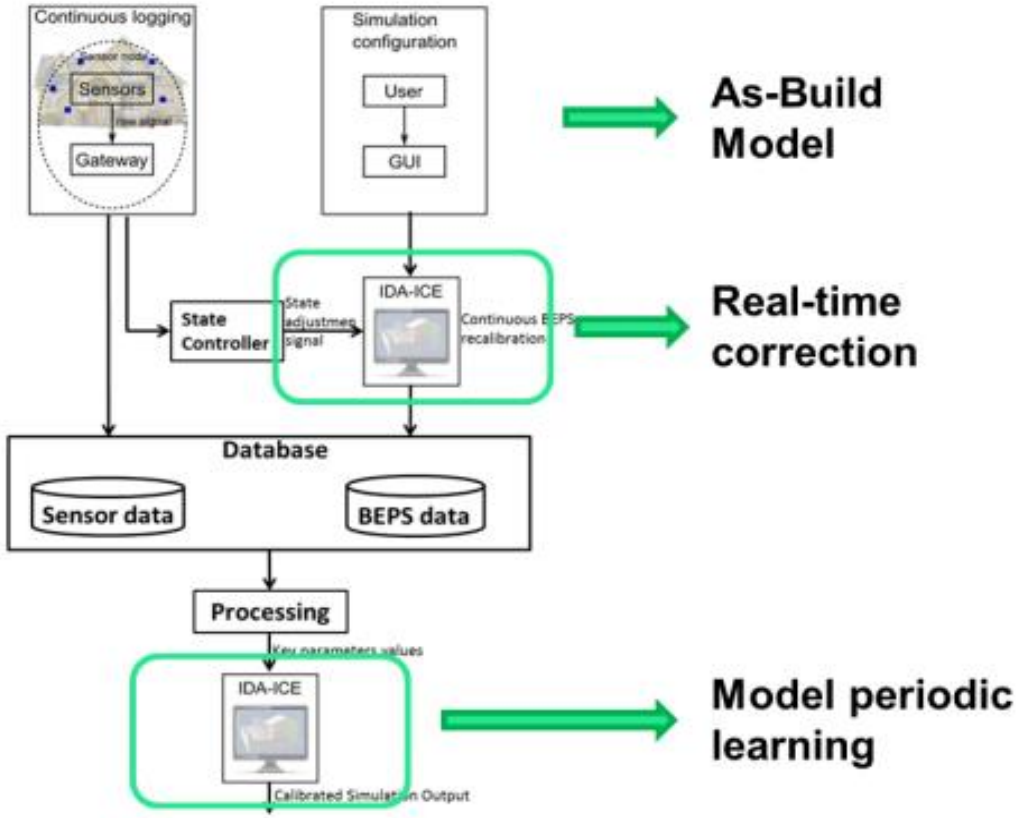
Outline



EQUA
SIMULATION TECHNOLOGY GROUP

Three Stage Approach

- Real-time, Online, and Offline
  - Initial calibration
  - Real-time tuning through CAS
  - Online tuning through optimizing KPMs
  - Offline calibration and model adjustment

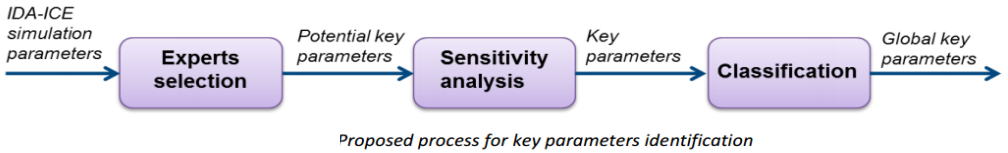


EQUA
SIMULATION TECHNOLOGY GROUP

Key Parameter Modifiers and Control Adjustment Signals – Room Level

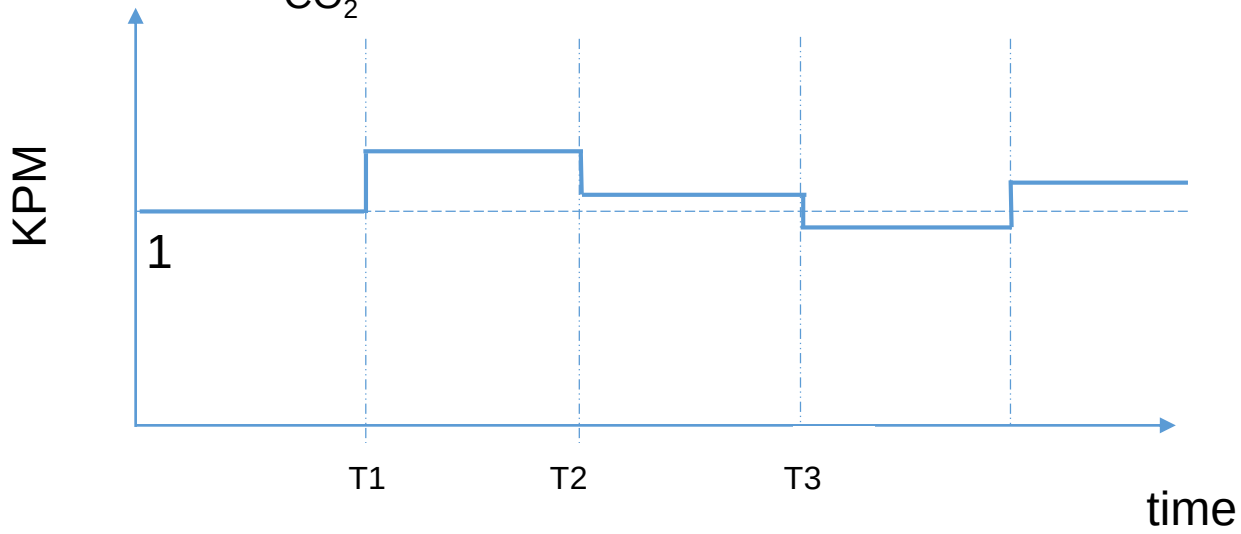
- Control adjustment signals (CAS):
  - Heating
  - Cooling
  - Outdoor air exchange
  - Light

- Key parameter modifiers (KPM):
  - Envelope conduction
  - Thermal mass
  - Envelope leakage
  - Solar aperture
  - Moisture storage
  - Heating capacity
  - Cooling capacity
  - Mechanical ventilation capacity
  - Artificial lighting capacity



Proposed process for key parameters identification

- Sensor priority list:
  - Temperature
  - Motion
  - Light
  - Humidity
  - CO_2

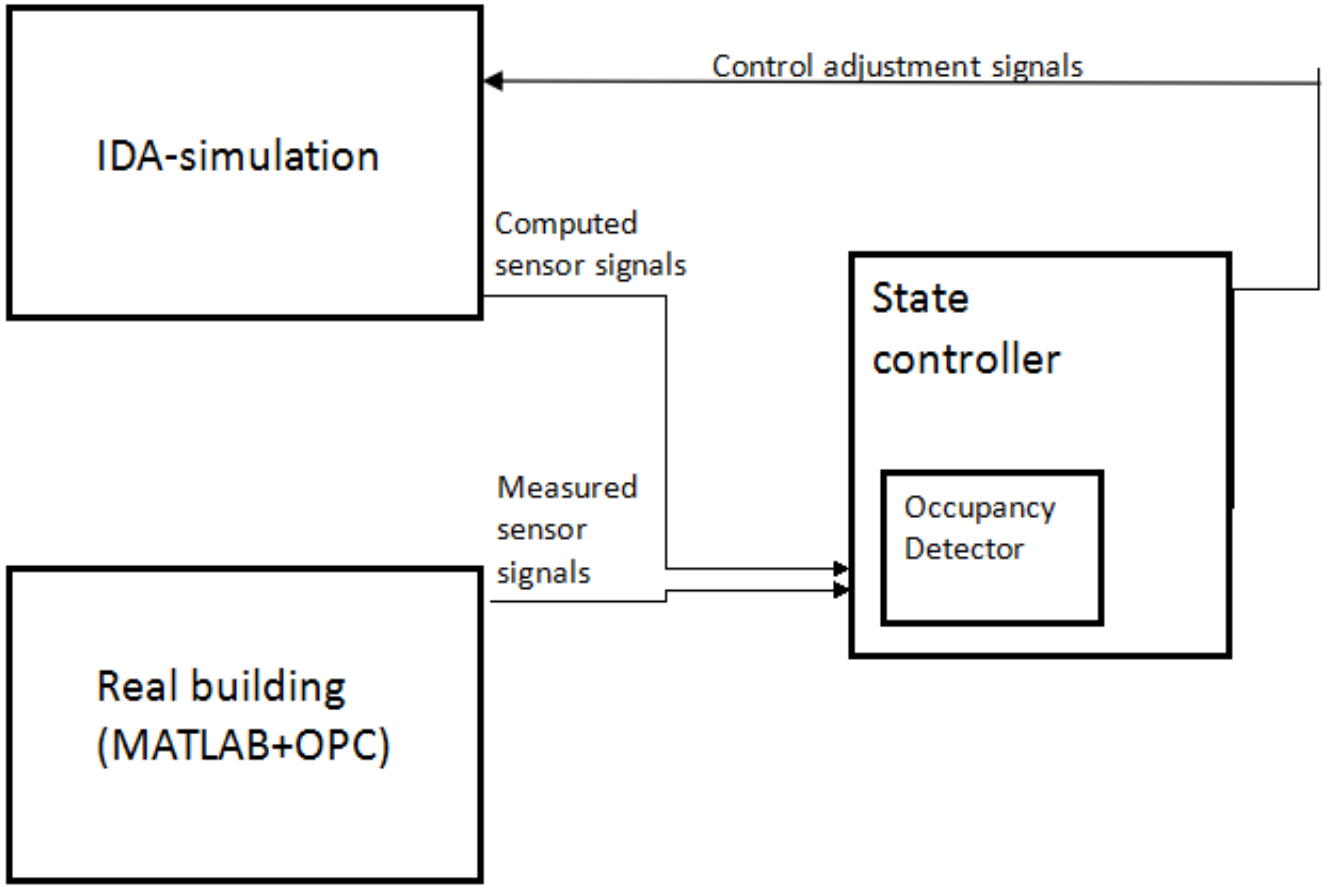


EQUA
SIMULATION TECHNOLOGY GROUP

Significance

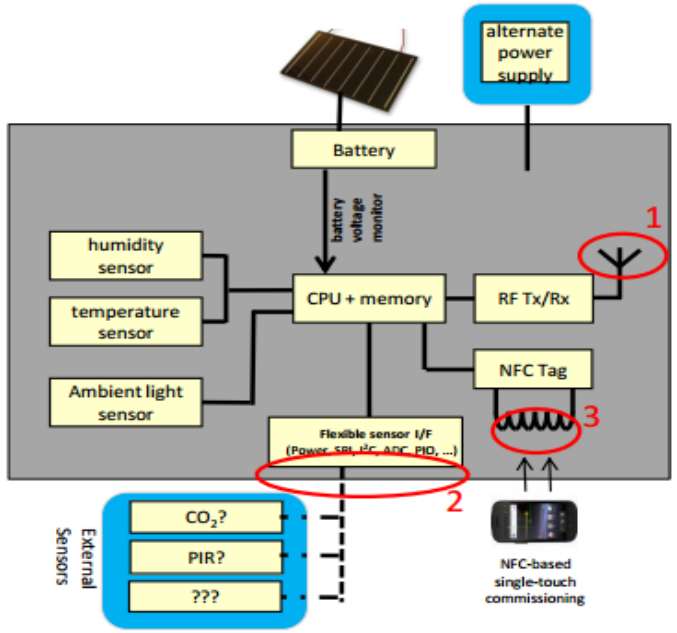
- KPMs serve as a key indicator as to what might be wrong in the model or building, as well as gives us an insight as to how the building is evolving in time
- CAS analysis can also contribute to pin pointing faults and diagnosis
- This framework serves as a diagnostic tool necessary for consultants and building operators in performing manual fault detection.

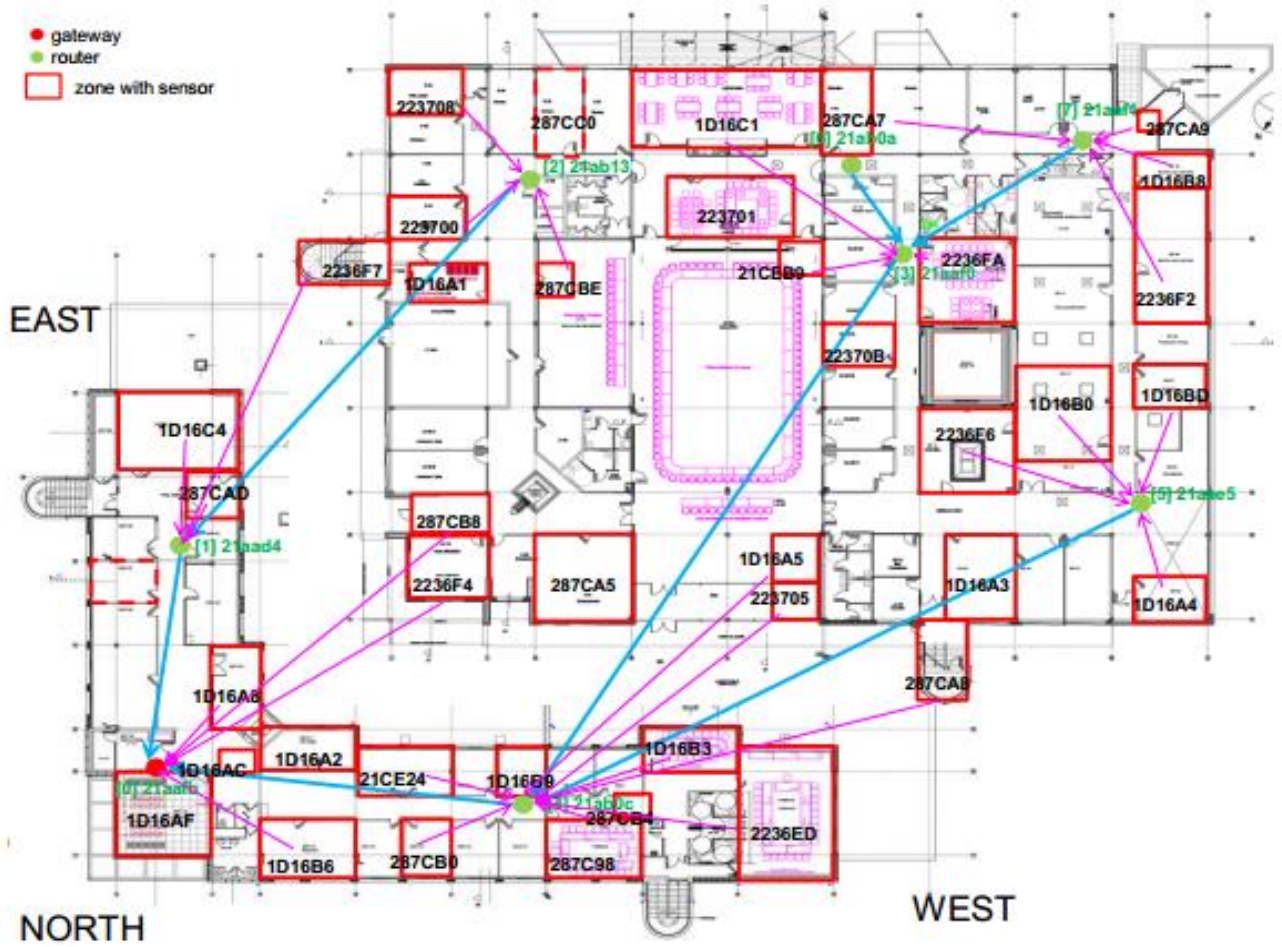
Connecting a Physical Building with IDA ICE in Real-Time



EQUA
SIMULATION TECHNOLOGY GROUP

Instrumentation

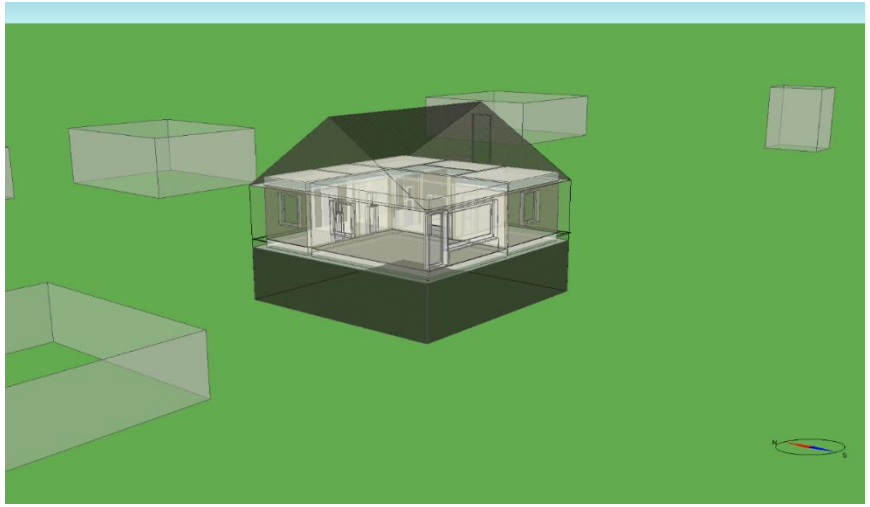




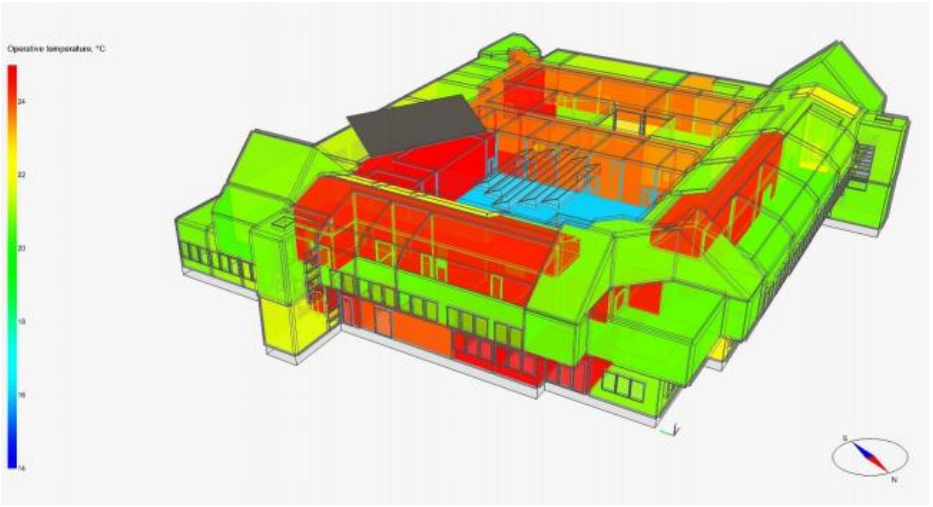
An actual topology of prototype sensor network at Vaucanson

EQUA
SIMULATION TECHNOLOGY GROUP

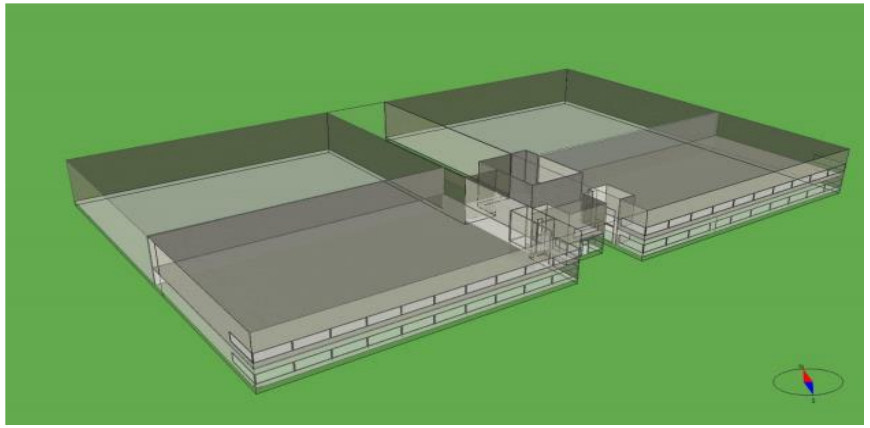
Case Studies



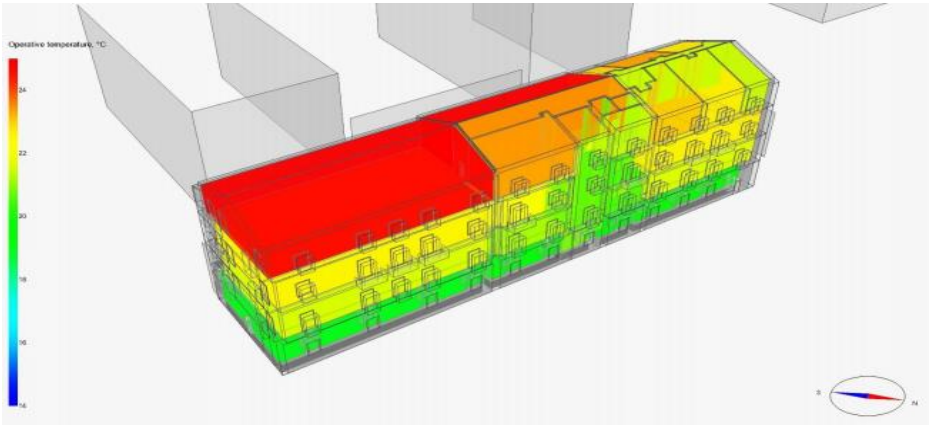
Single Family house IEA Annex 58 (Fraunhofer, Germany)



Municipality building Vauconson (La Rochelle, France)



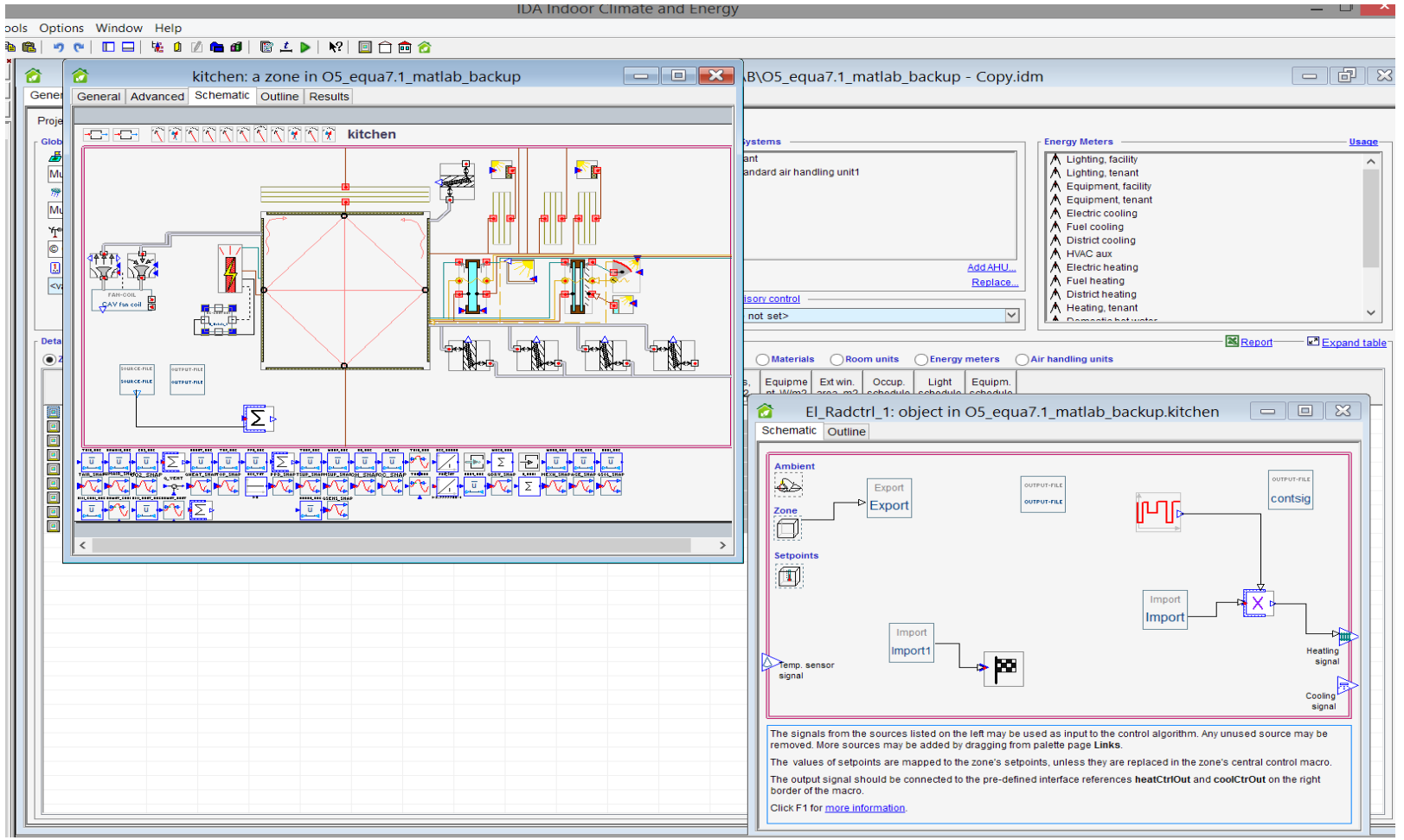
IBM HQ (Cork, Ireland)



Public Library (Torino, Italy)

EQUA
SIMULATION TECHNOLOGY GROUP

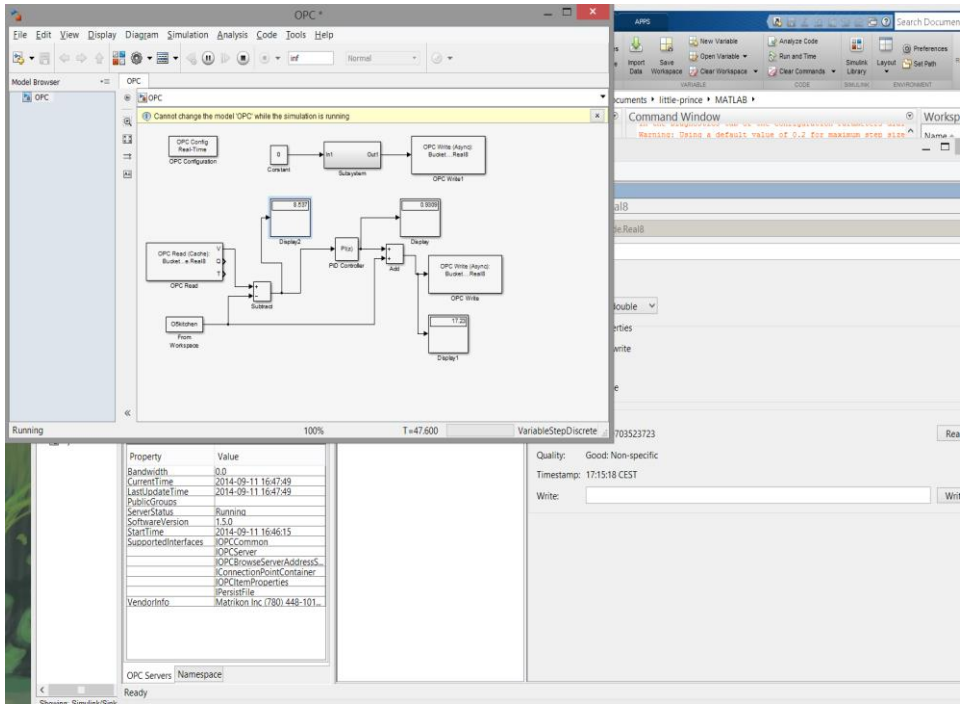
Using the Object Linking and Embedding Process Control (OPC) with IDA



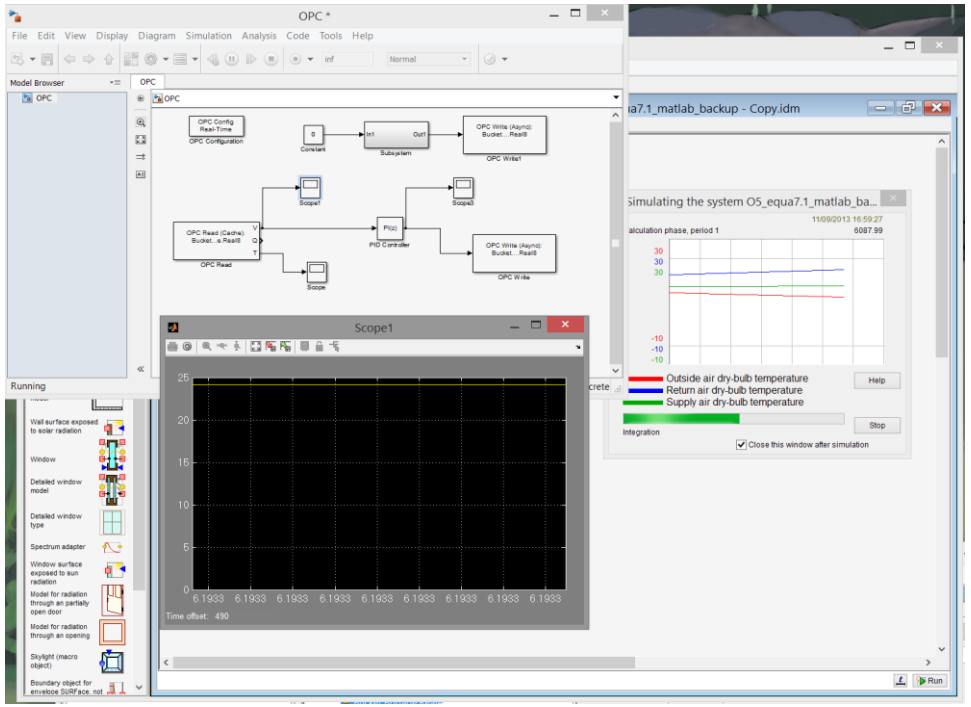
Setting IDA ICE Annex 58 model to import/export variables to/from OPC server

EQUA
SIMULATION TECHNOLOGY GROUP

Matlab-IDA ICE-OPC



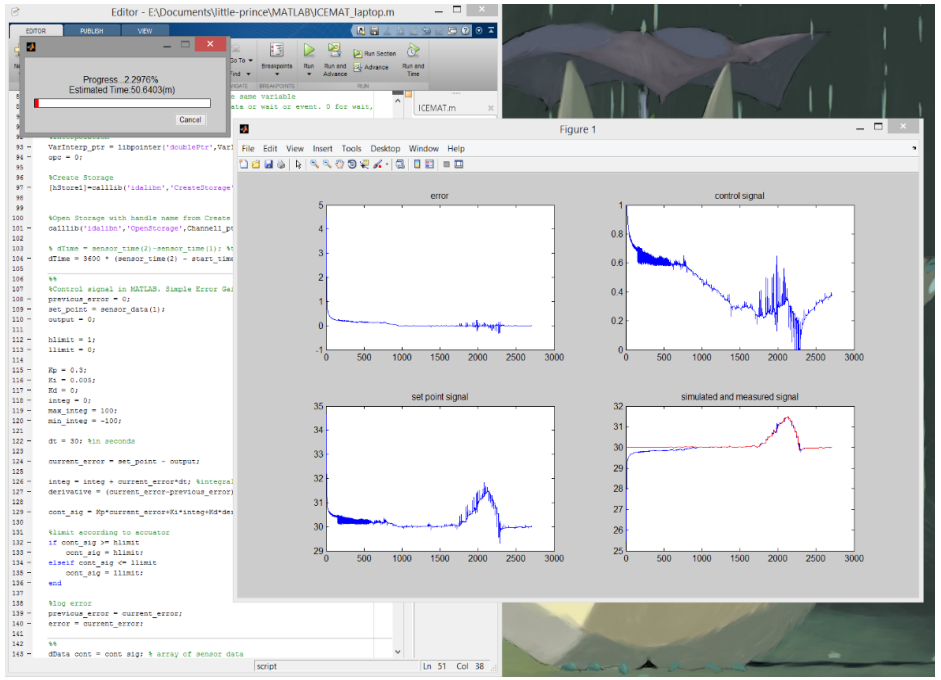
Setting up Matlab to communicate with IDA ICE & OPC server

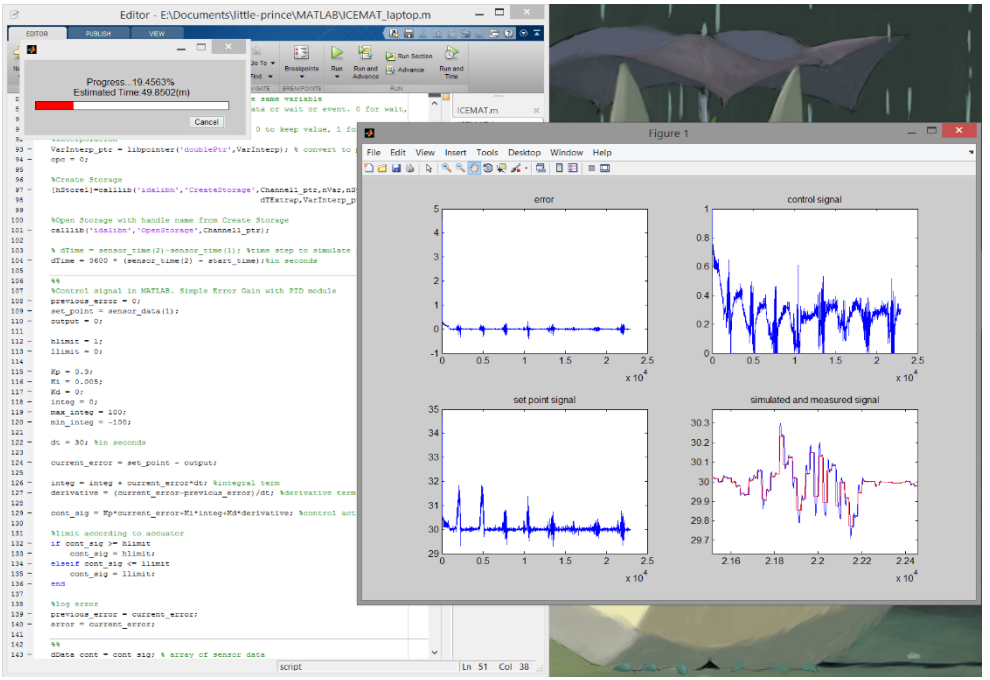


Running IDA ICE in real-time with an OPC server

EQUA
SIMULATION TECHNOLOGY GROUP

Results Real-time coupling

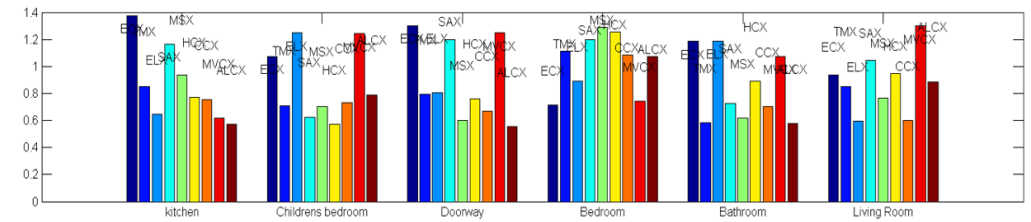


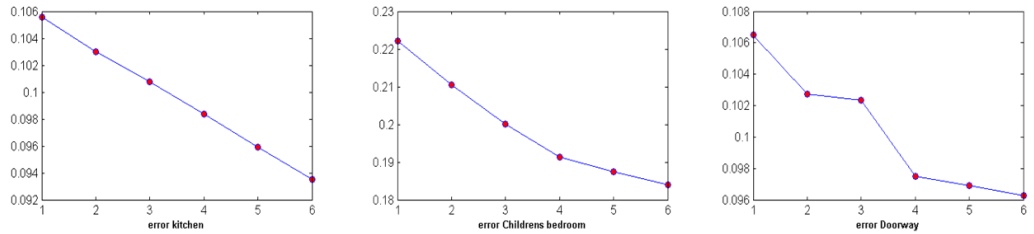


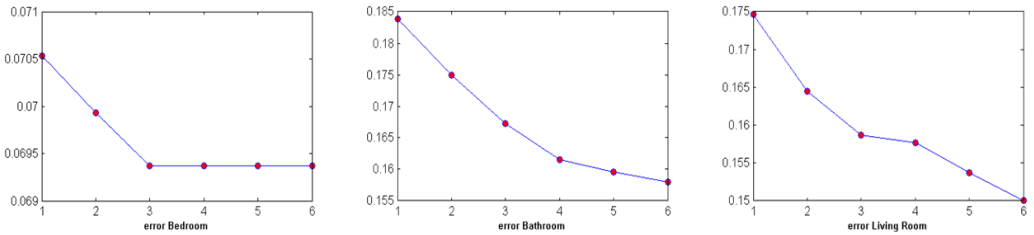
Self-tuning PID controller using fuzzy logic in Matlab
Run-time penalty observed

EQUA
SIMULATION TECHNOLOGY GROUP

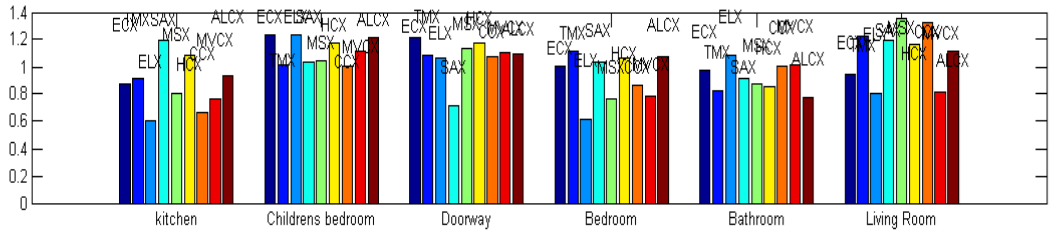
Results KPM optimization

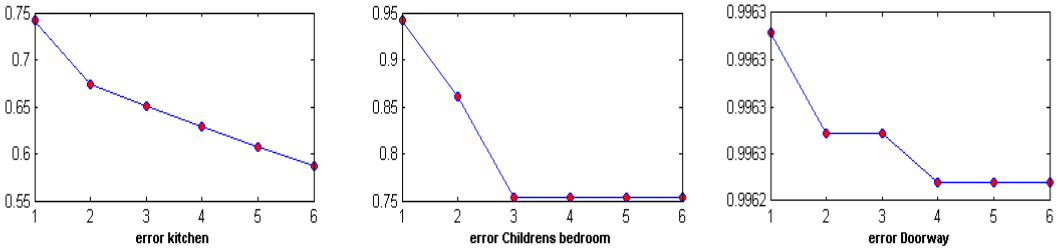


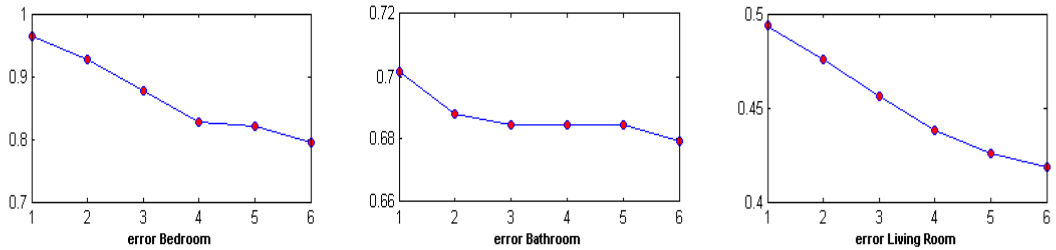




Stop Pause







Stop Pause

EQUA
SIMULATION TECHNOLOGY GROUP

Summary

- We are building a diagnostic tool that will allow building experts, designers, and operators to efficiently detect faults in the operation and performance of a building.
- It also opens the door for testing innovative control strategies and retrofitting options.
- As well as allows for an efficient and automated way to tune a building design model, ensuring that the end product will perform exactly as intended.

EQUA
SIMULATION TECHNOLOGY GROUP

Q & A

EQUA
SIMULATION TECHNOLOGY GROUP