IBPSA Project 1

International Building Performance Simulation Association

Building Energy Simulation in Virtual Reality environments

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State of the art - Building energy simulation with desktop applications

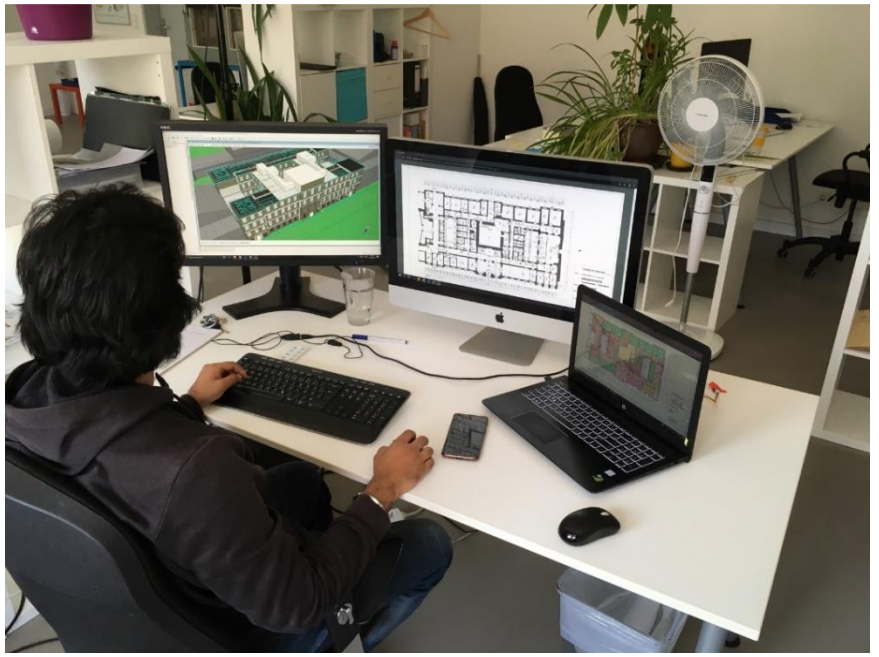
Tools

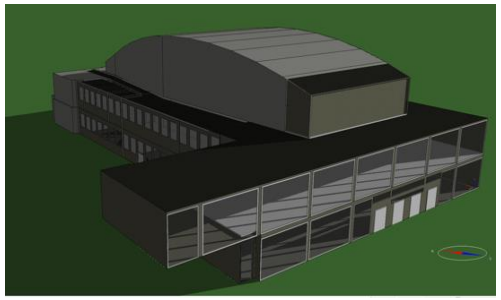
- EnergyPlus, IDA ICE, TRNSYS, …

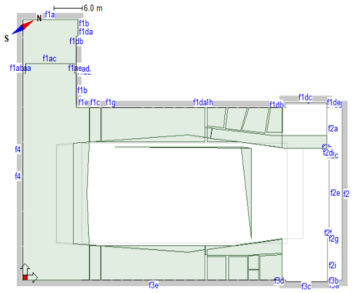
Working process and conditions

- Definition of the building geometry and topology, the building construction and user behavior with a desktop PC

- Physical distance of the user to the modeling and simulation process:
  → Input of actions via mouse and keyboard to the simulation tool
  → Observation of the progress of the modelling process and the simulation results on the screen





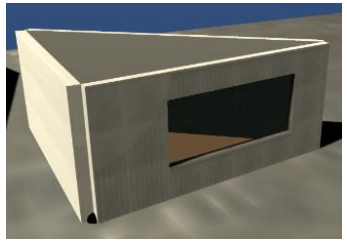


Modelling and simulation with IDA ICE on the Desktop

New approach - Interactive modelling and simulation within a VR environment

Modelling

- Geometry
- Building construction
- Boundary conditions

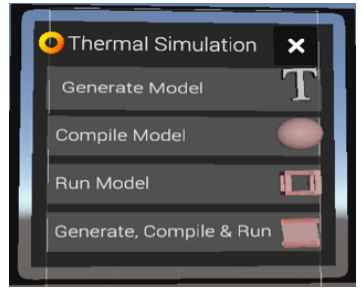


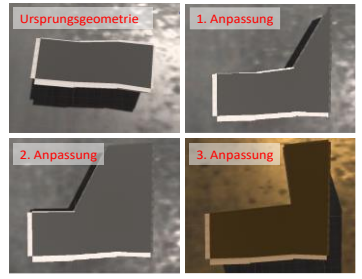
VR environment for interactive building energy simulation

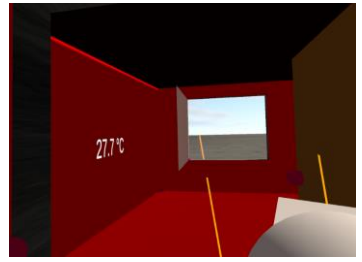
- Only one VR environment for modelling and simulation
- Immersive integration of the user into the workflow
- Modelling and simulation over VR controller

Simulation

- Model interaction
- Modification of the building geometry
- Model analysis

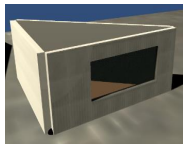




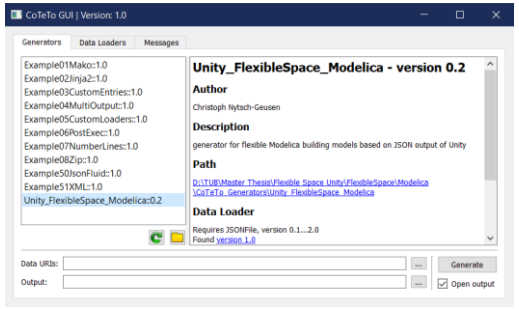


Software architecture and implementation of the VR simulation environment

Design Module
(Unity Editor and Editor XR)



Data storage and transfer
(epJSON format)



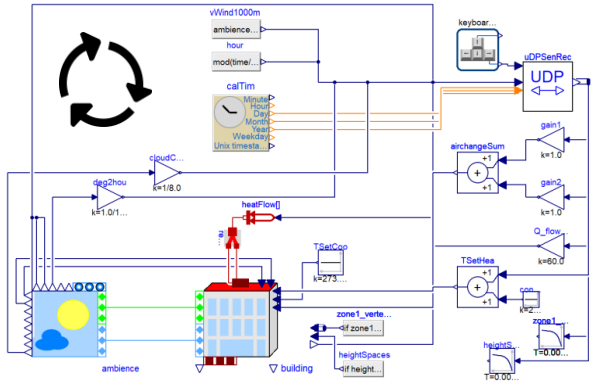
Code Template Module (CoTeTo)

Code generation
(Modelica building model)

Visualization and Interaction Module
(Unity Runtime and HMD)

Code generation
(Unity C# scripts)

Real time data exchange
(UDP sockets)

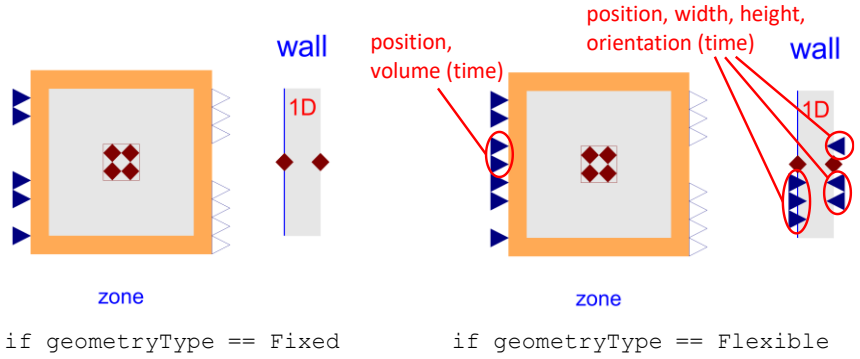


Physical building model and simulation core
(Modelica / Dymola)

Modelica building model

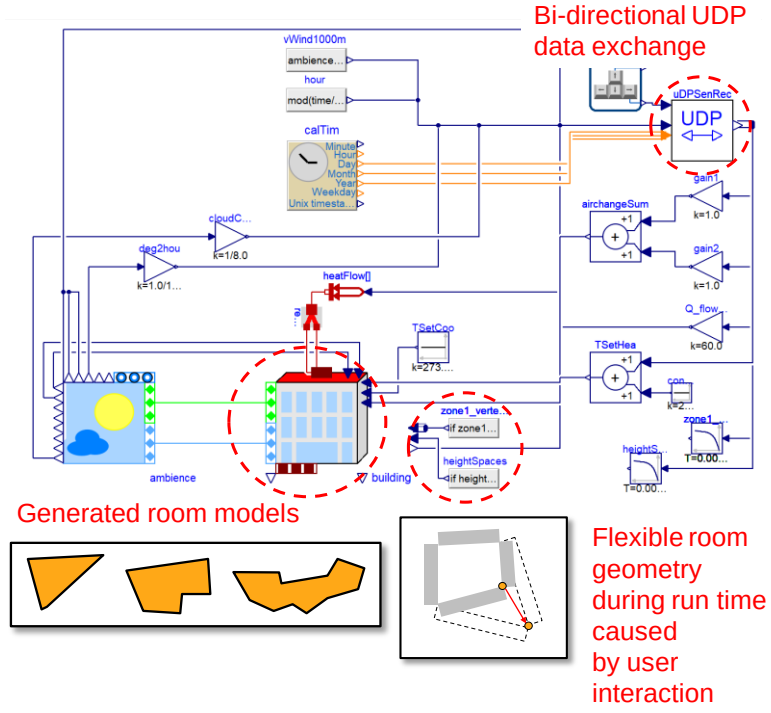
Extended model classes of the BuildingSystems library

- Optional flexible room geometry during runtime
  (flag `geometryType=Flexible`)
- Wall, door and window models
  → time dependent position, height, width, azimuth and tilt angle
- Zone models
  → time dependent position and volume



Modelica system model for real-time simulation

- Use of generated thermal room models (CoTeTo)
- Bi-directional data exchange to Unity via UDP data protocol
  (Modelica_DeviceDrivers library)
- Modelica → Unity: calculated model states
  (e.g. temperatures, moistures, heat fluxes)
- Unity → Modelica: user interactions
  (e.g. opening of a window or modification of the room geometry)



1st Example - Fixed building geometry

Modelling Mode

- Climate location Berlin
- Room with 8 outside walls with different thickness
- Inserting of a window and a door
- fixed building geometry
- Free floating temperature
- Simplified air change simulation:

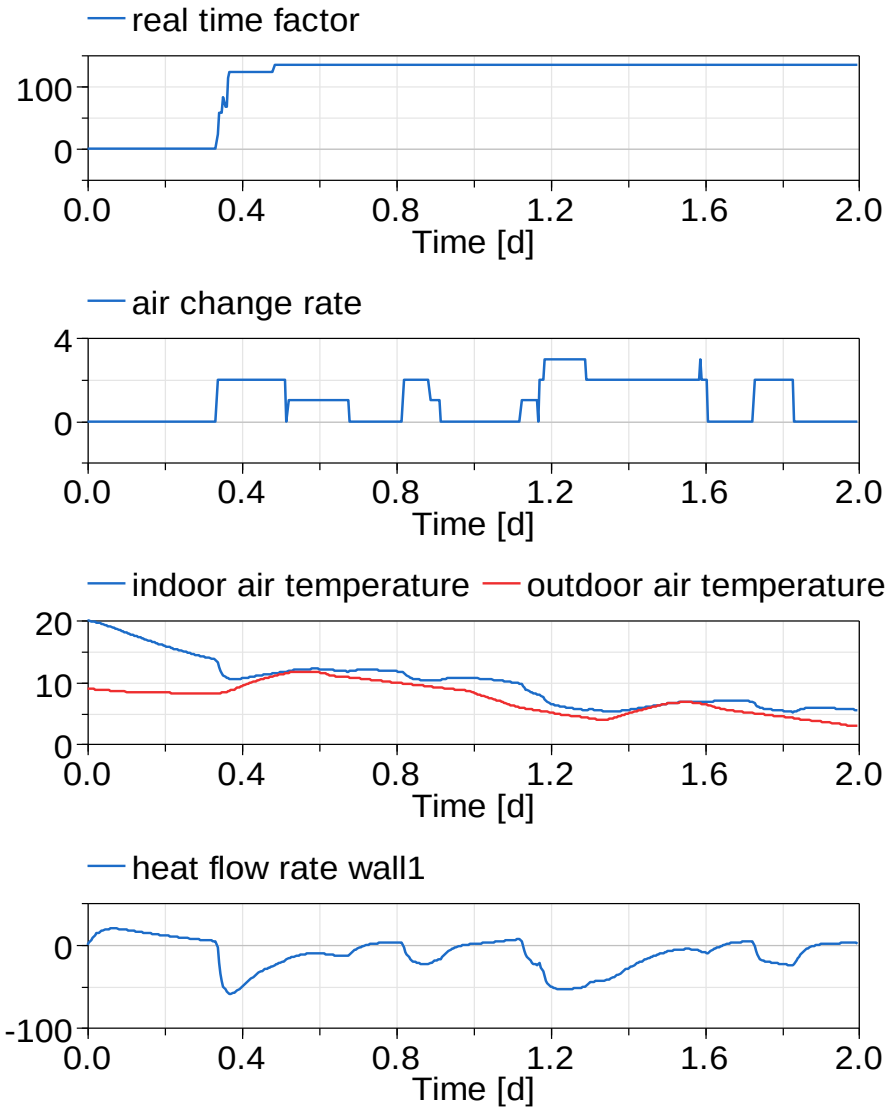
  → window closed/tilted/rotated or cross ventilation

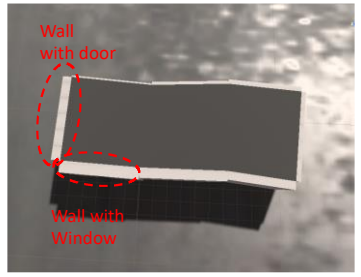
Simulation Mode

- 2 cold winter days (1st and 2nd of January)
- Interaction with door and window model
- Adaptation of real-time factor:

  acceleration of the simulation experiment

  → fast user behavior and slow thermal processes





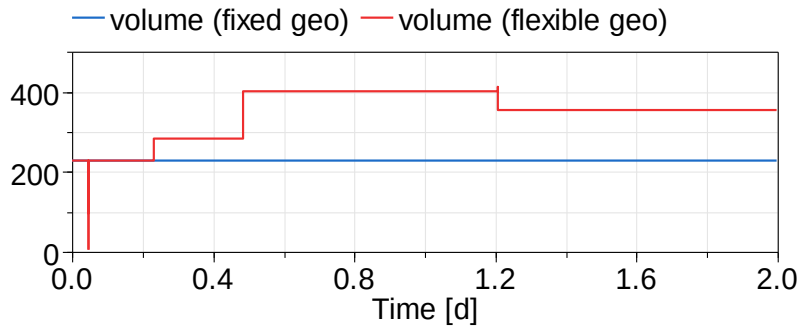
2nd Example - Flexible building geometry

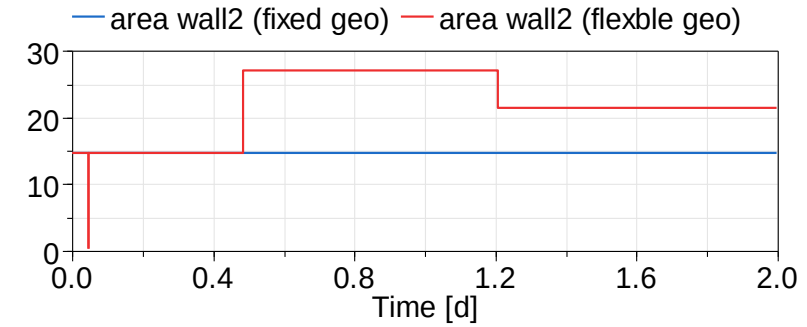
Modelling Mode

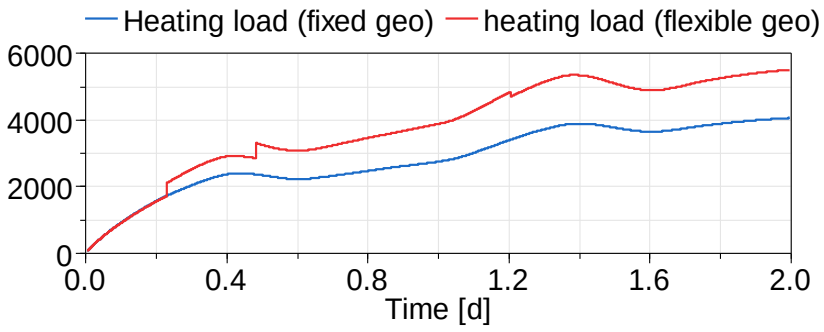
- Flexible building geometry
- Controlled air temperature (20 °C)
- Further assumptions as in 1st example

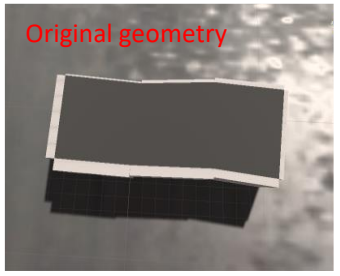
Simulation Mode

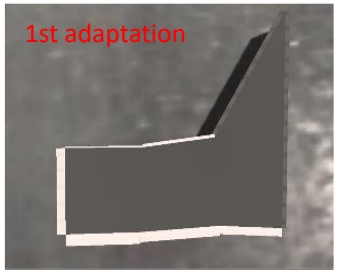
- 3 times adaptation of the floor plan during the simulation experiment
- Air volume and heat load of the room are immediately adapted related to the user interaction

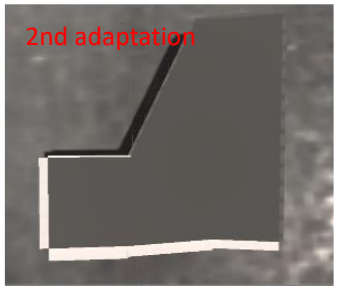


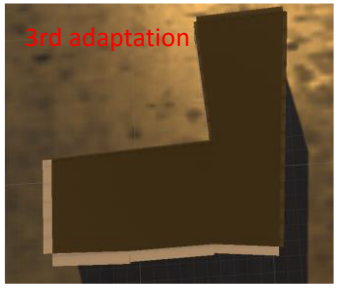




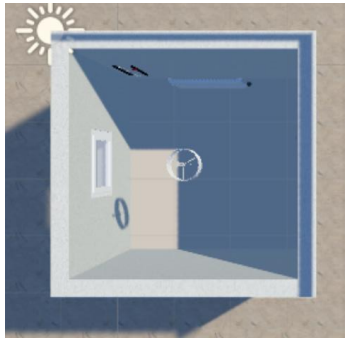


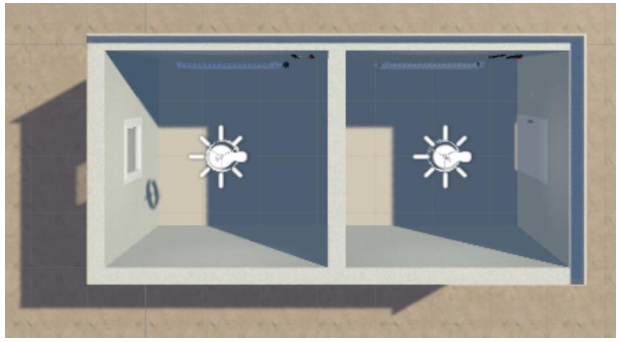






Consideration of different VR building models – Room, building, city quarter





Simple test models (door, window, thermostat, light …)

Rooftop building model (adaptable facades, sliding windows, comparison to a real building …)

Multi zone building models (more complexity, more collision detection …)

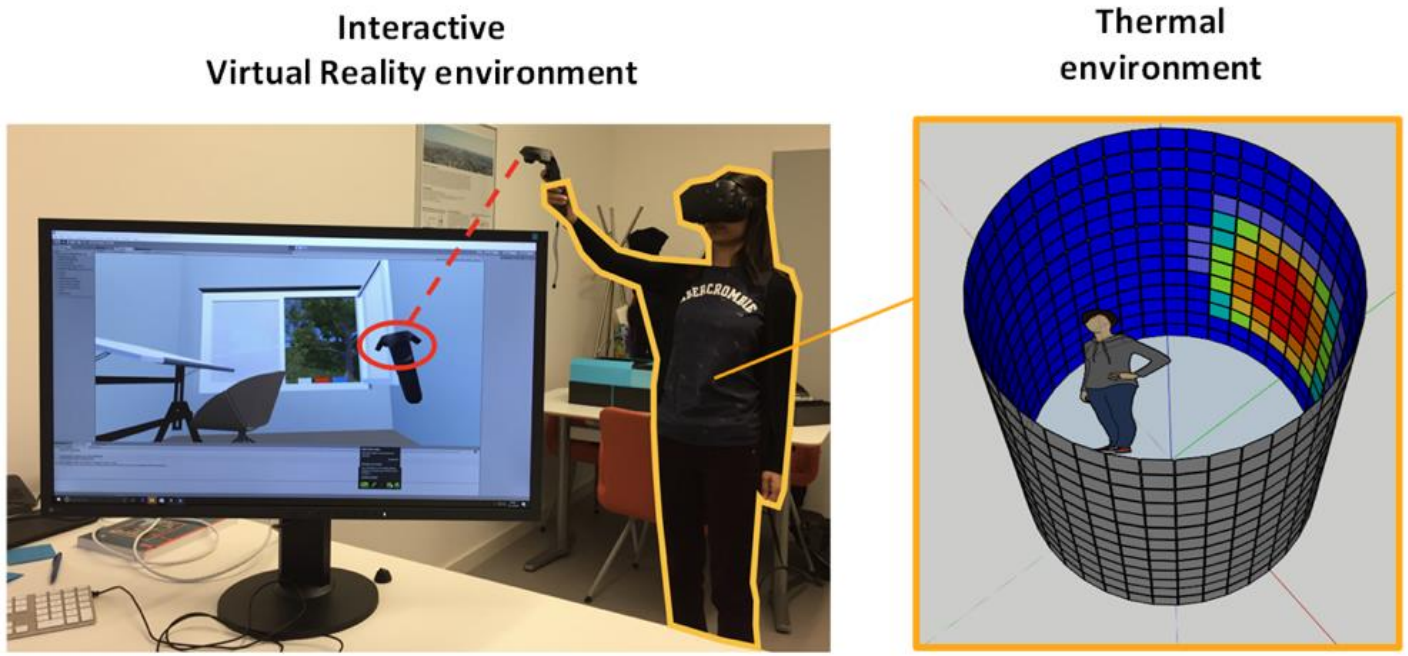
City quarter models (highest model complexity and immersion)

Please, explore the interactive city quarter model by yourself
http://www.solar-rooftop.de/RooftopDistrict/index.html

Outlook

Research project „EnOB: GEnEff: Neuartige Bewertung der Gebäude-Energie-Effizienz und innovative Demonstration mittels Simulationsmethoden und Virtual Reality“ (2020 bis 2023)

- Cooperation project with TU Berlin
- Realization of a climate chamber, in which the user have a thermal sensation of the simulated indoor climate (temperature, moisture, air movement etc.) for the space which is displayed in the VR environment
- Consideration of user interactions in the VR environment (e.g. window ventilation)



Contact

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