TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Architecture, Institute for Building Climatology, Chair of Building Physics

HAJAWEE and NANDRAD - New thermal room and multizone models

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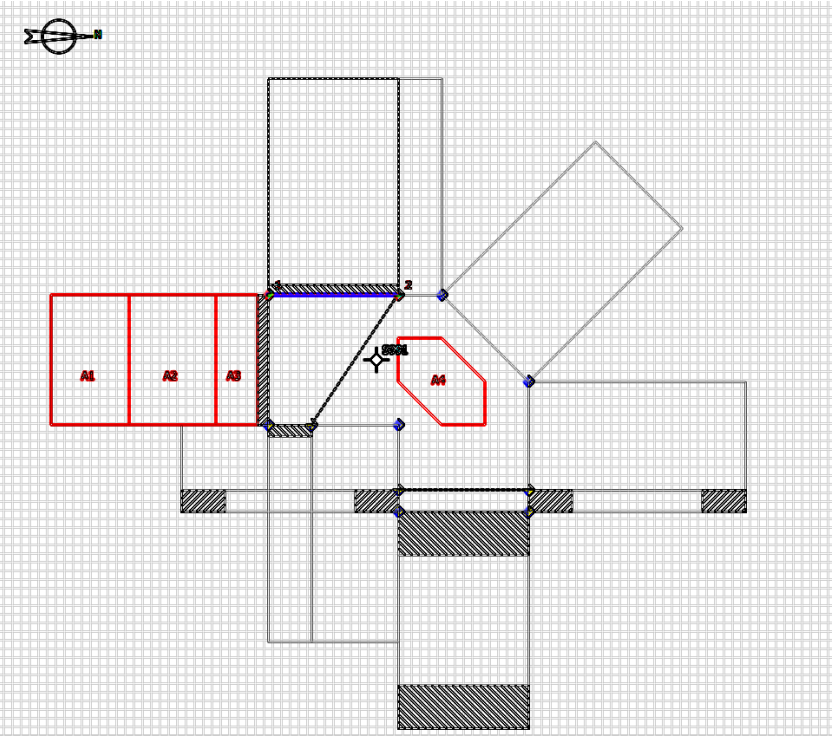
Dresden, 13.06.2013

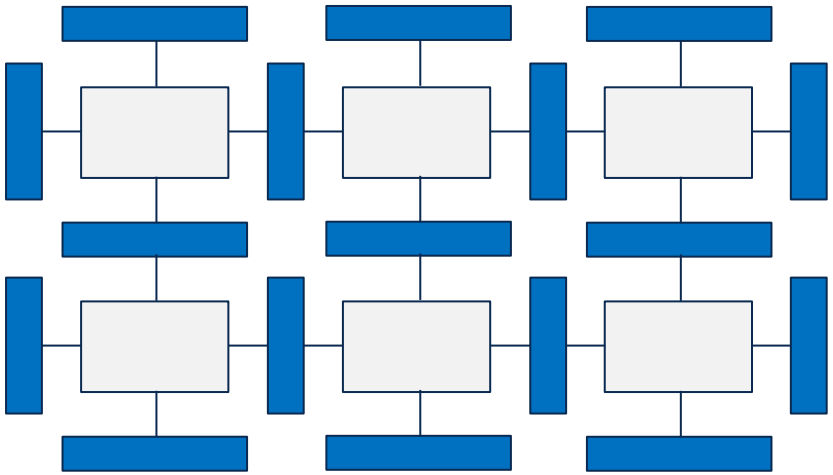
Thermal comfort simulation of single rooms
(B. Glück)



- detailed long wave radiation exchange
- detailed wall simulation
- planed: air convection simulation
- technical equipment components

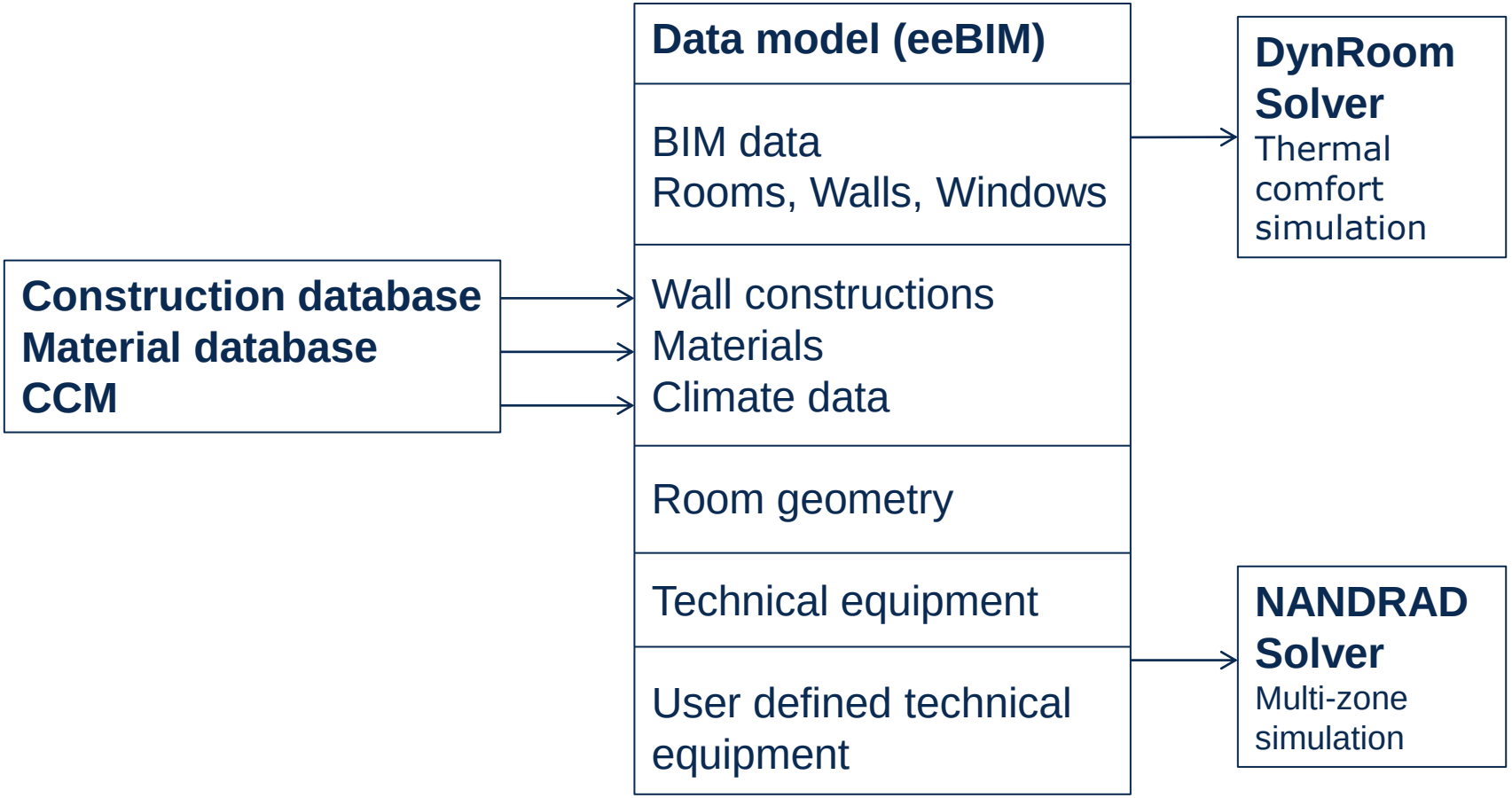
Geometric modelling and simulation of the room + room enclosing

Multi-zone simulation of complex buildungs

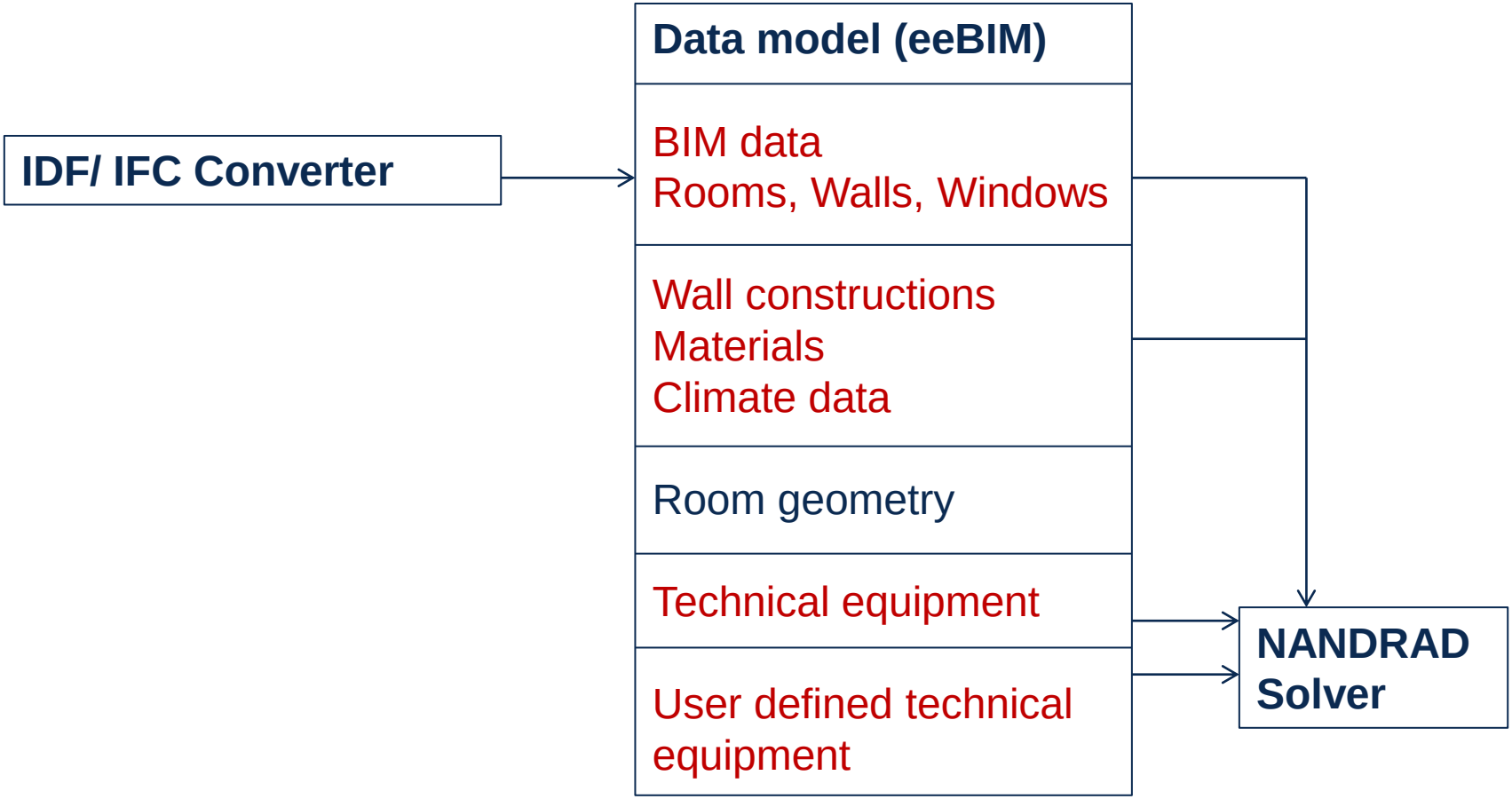


- transient simulation of large buildings
- basic nonlinear technical equipment components
- user defined model extension possible
- numerical methods for large and sparse systems

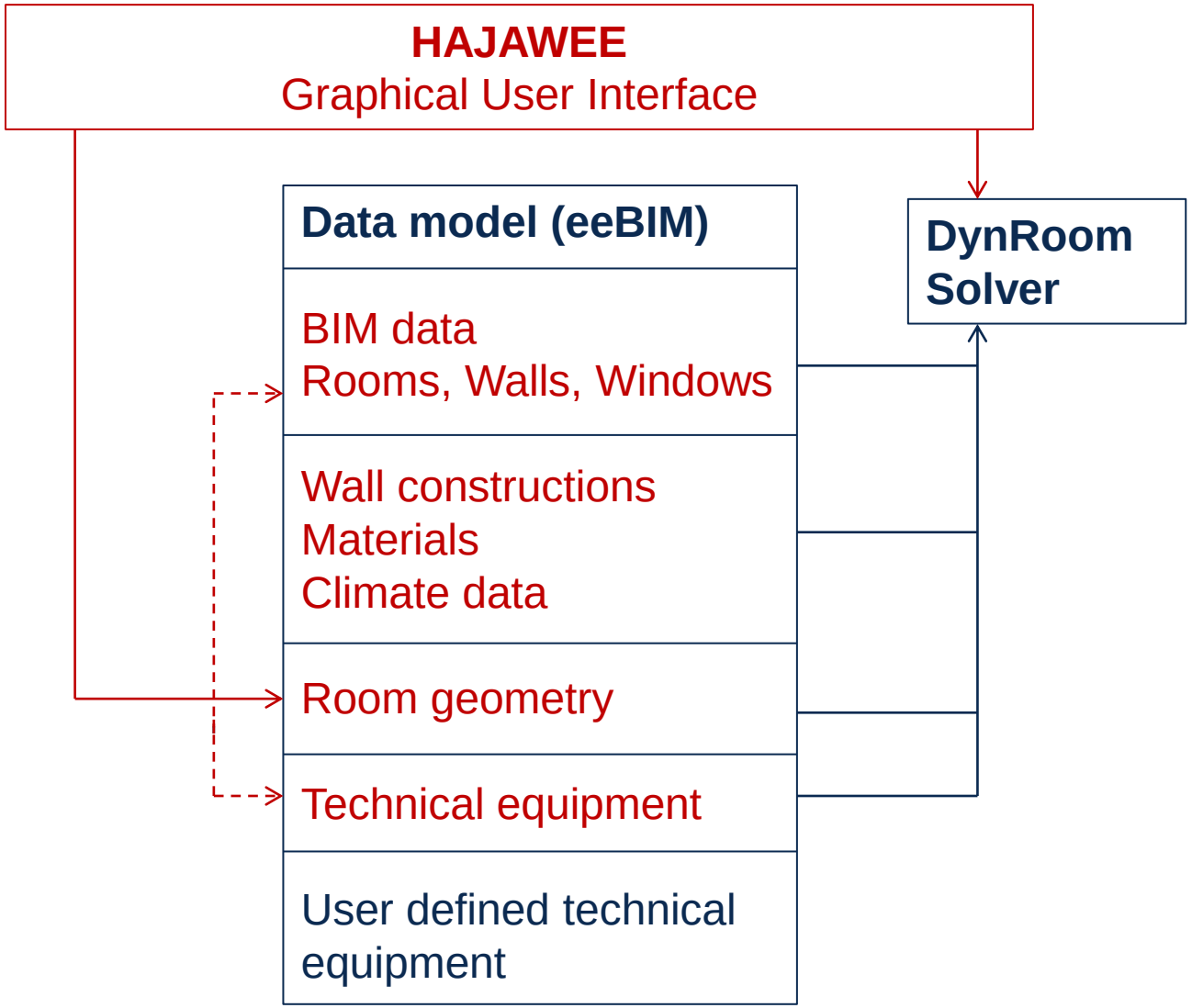
Data model


Data model (eeBIM)
BIM data
Rooms, Walls, Windows
Wall constructions
Materials
Climate data
Room geometry
Technical equipment
User defined technical equipment
Construction database
Material database
CCM
DynRoom Solver
Thermal comfort simulation
NANDRAD Solver
Multi-zone simulation

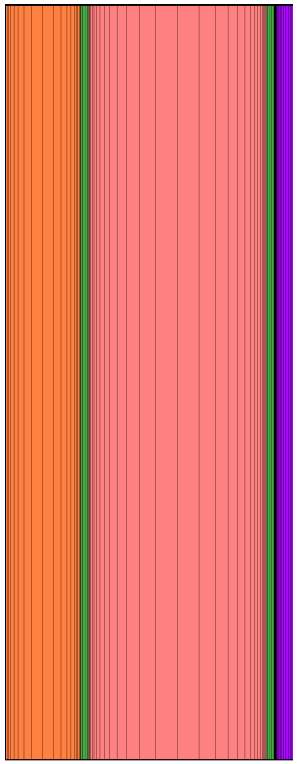
Data model


Data model (eeBIM)
IDF/ IFC Converter
BIM data
Rooms, Walls, Windows
Wall constructions
Materials
Climate data
Room geometry
Technical equipment
User defined technical equipment
NANDRAD Solver

Data model

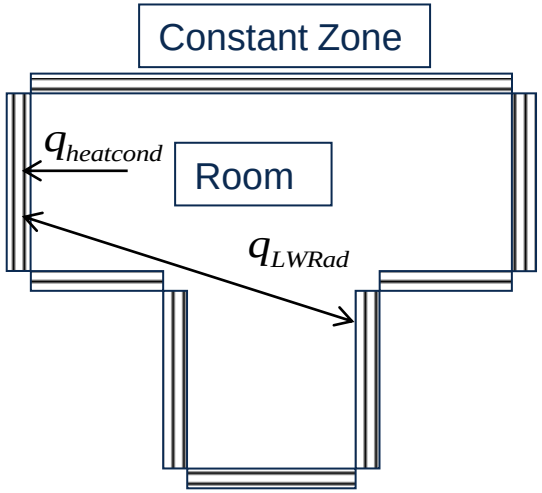

HAJAWEE
Graphical User Interface
Data model (eeBIM)
BIM data
Rooms, Walls, Windows
Wall constructions
Materials
Climate data
Room geometry
Technical equipment
User defined technical equipment
DynRoom Solver

Wall model

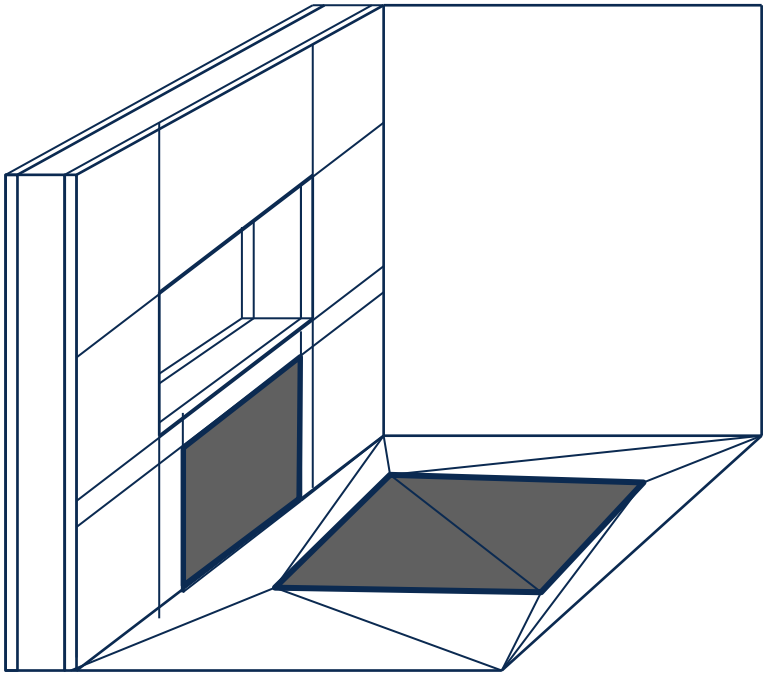


1	Historical Brick
2	Lime cement plaster
3	Calcium silicate
4	Glue mortar
5	Clay mortar
6	Foam glass
7	Clinker

- Transient Wall model for detailed 1-dimensional Construction using Finite-Volume discretization
- Numerical calculation of heat flux + Temperatures in time and space
- Heat exchange to room and long-wave radiation exchange between all walls



DynRoom Room model



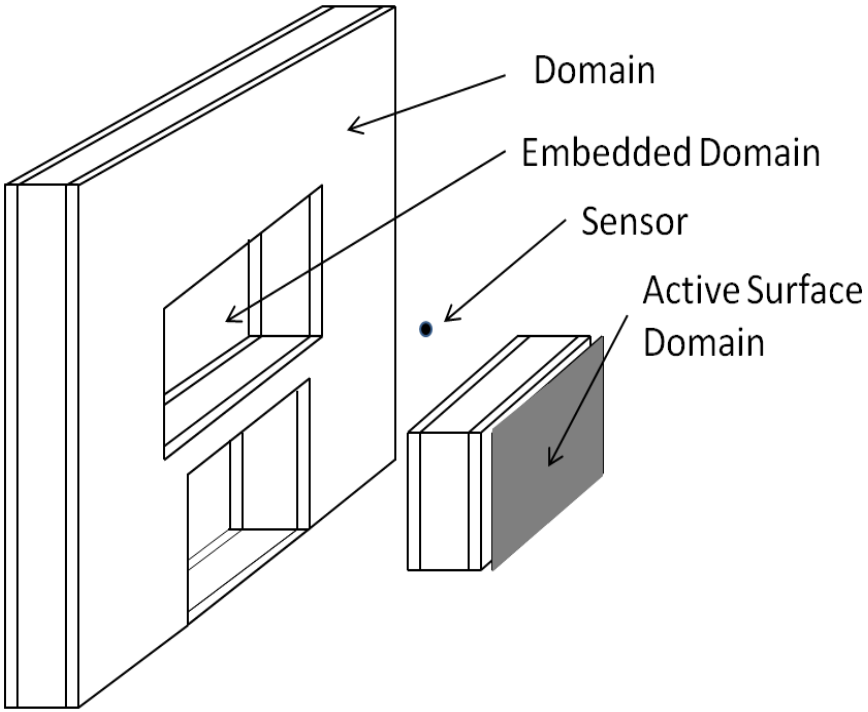
Geometry

- Polygon shaped floor and ceiling
- Rectangular enclosing walls

Discretization

- Plane elements: wall surface discretization, triangles or rectangles

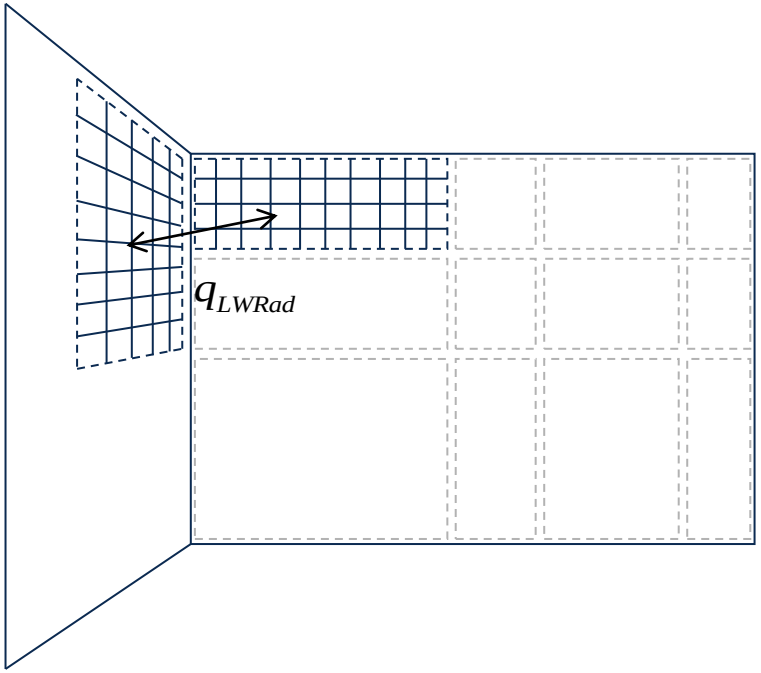
DynRoom Room model



Model geometry

- Groups of plane elements
- Domain: wall with passive surface
- Active domain: wall with thermal active surface
- Embedded domain: wall opening with window or door model
- Sensor: passive point objects inside the room

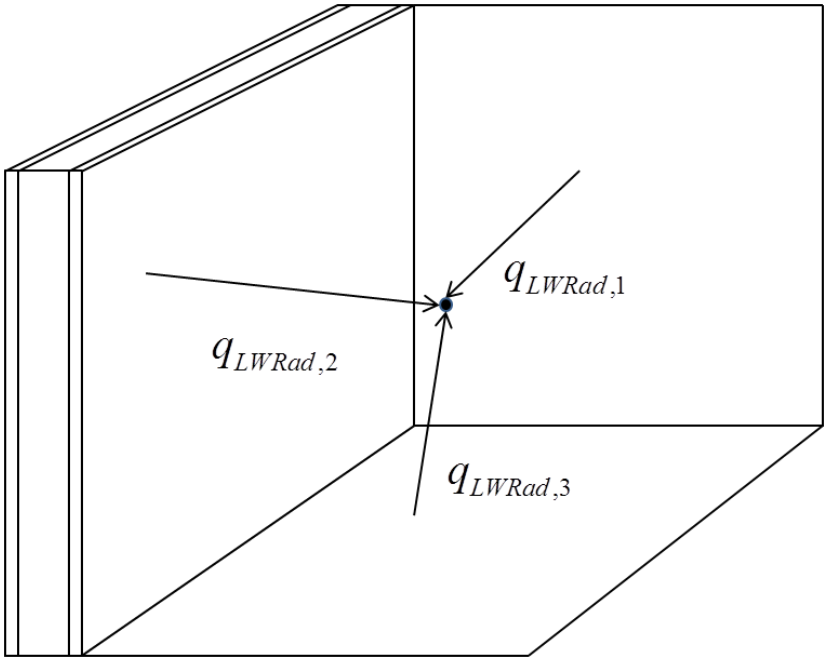
DynRoom Radiation model



- Geometric thermal radiation model
- Long wave radiation exchange between passive domain surfaces
- Long wave radiation from radiant heating
- Calculation of radiant temperatures for active surfaces

DynRoom Thermal comfort model

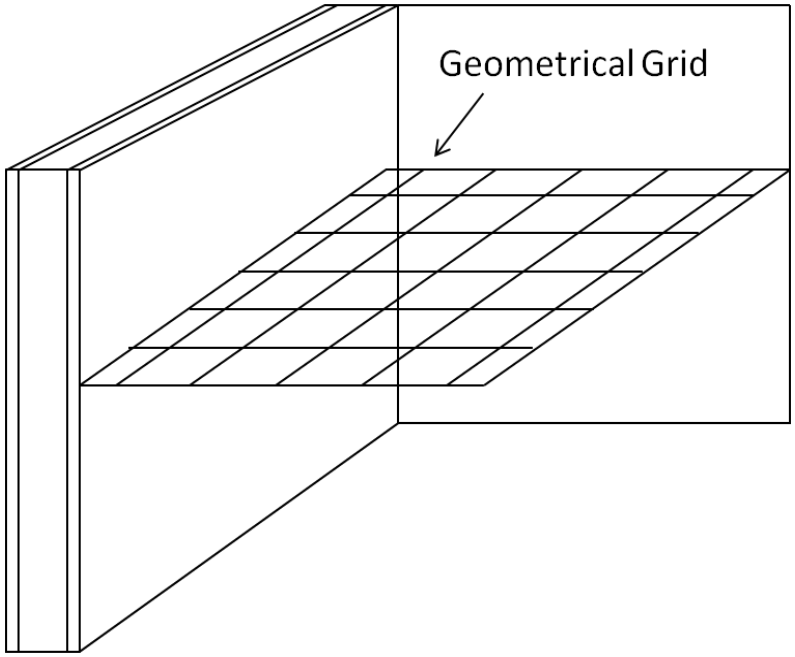
Room radiant and operative temperatures



Spacial distributed Quantities:

- Radiant temperature:
  T_{LWRad}
- Operative temperature:
  $T_{operative} = \alpha T_{LWRad} + (1-\alpha) T_{room}$
- Radiant temperature asymmetry

DynRoom Thermal comfort model



- Two dimensional discretization grid of a horizontal room plane
- Calculation of symmetric and asymmetric view factors for each grid point
- Calculation of operative temperatures and temperature asymmetry for each grid point

DynRoom Windows and HVAC models

Window models

- located at an embedded domain

Heating models

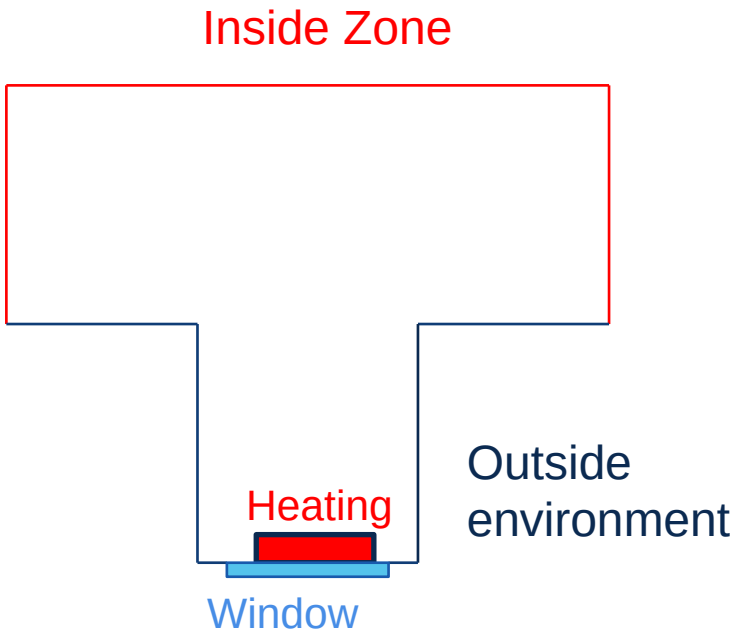
- Thermal active wall panels: located inside the wall
- Heater: located at an active domain surface
- Room heat source
- Heating with ideal P-control

HVAC Control

- External HVAC-control library (Ebök GmbH)
- Heating control, shading control, natural ventilation

Simulation results

Simulation example



- T-shaped room with heating and window
- Heating model with ideal P-control, mixed convective and radiant heating
- Control quantity: operative temperature
- Scheduled set point temperature:

  20°C at day

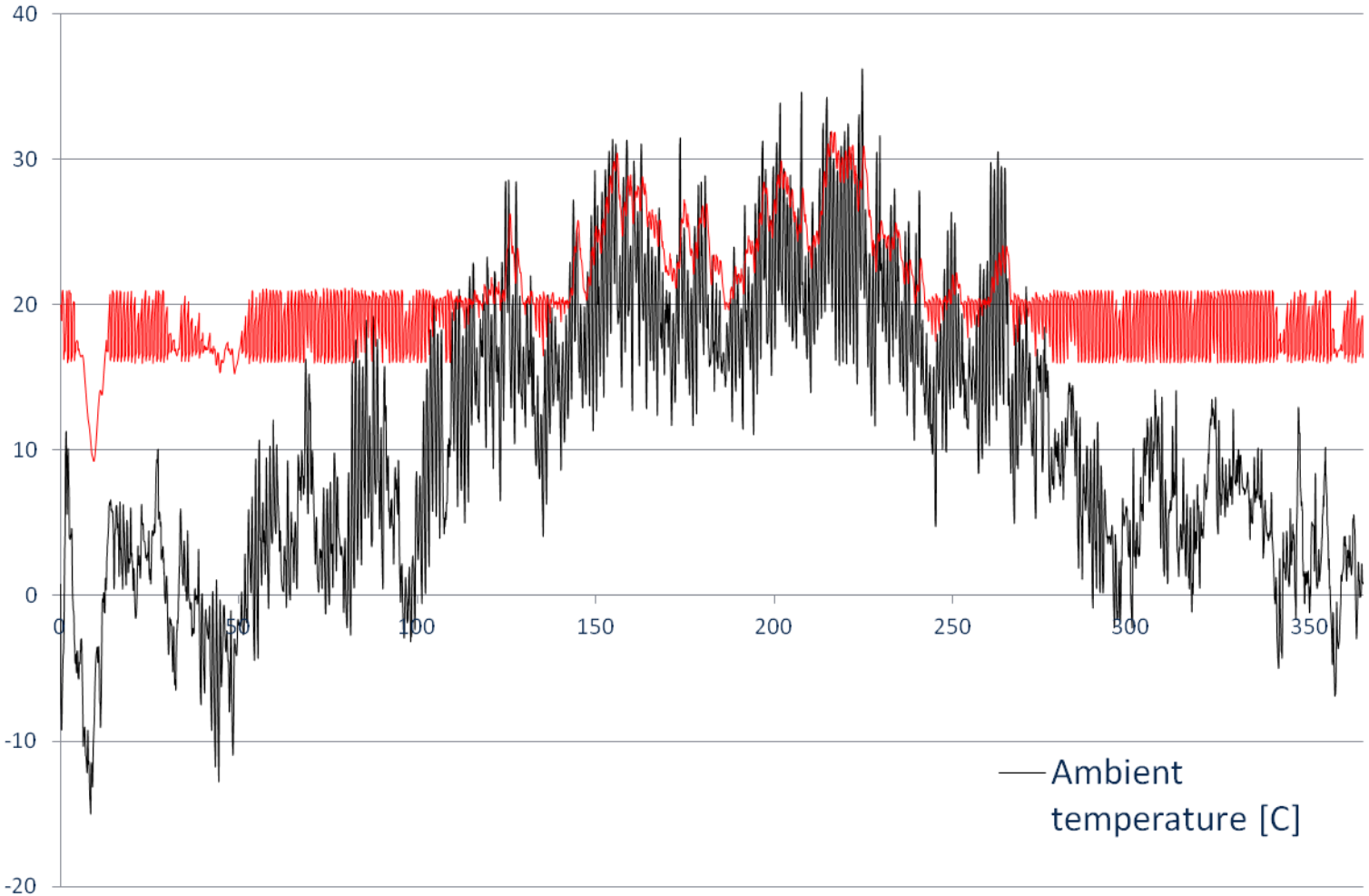
  16°C at night
- Simulation time: 1 year

Simulation results

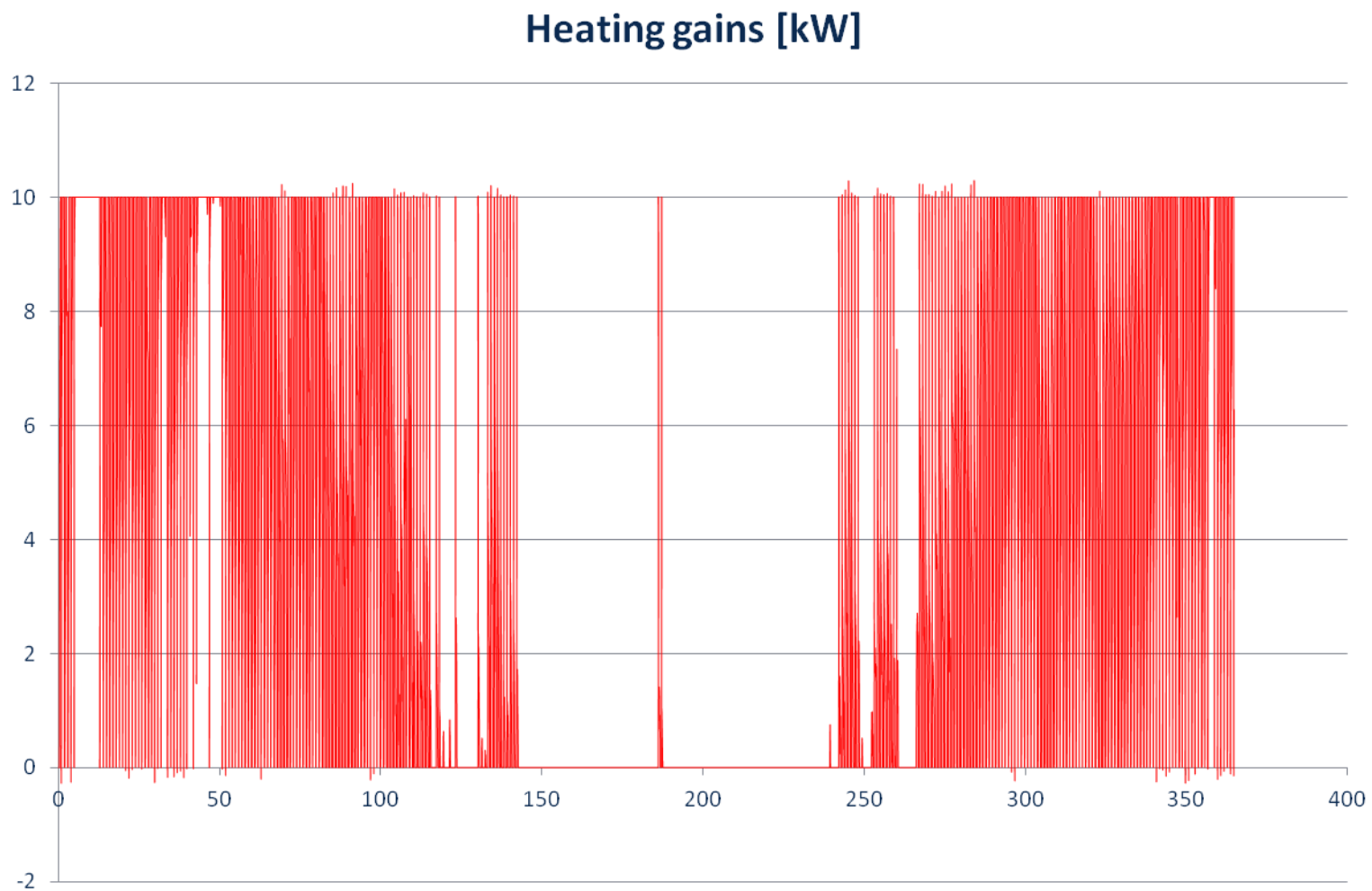
NANDRAD model

- detailed model of the wall constructions
- non-geometric model of the room
- single room temperature
- average operative temperature
- heat gains due to solar radiation and heat losses due to thermal transmission through the windows
- no long wave radiation exchange between the walls
- heating model with ideal P-control
- area-weighted distribution of long wave radiation heat gains to the walls

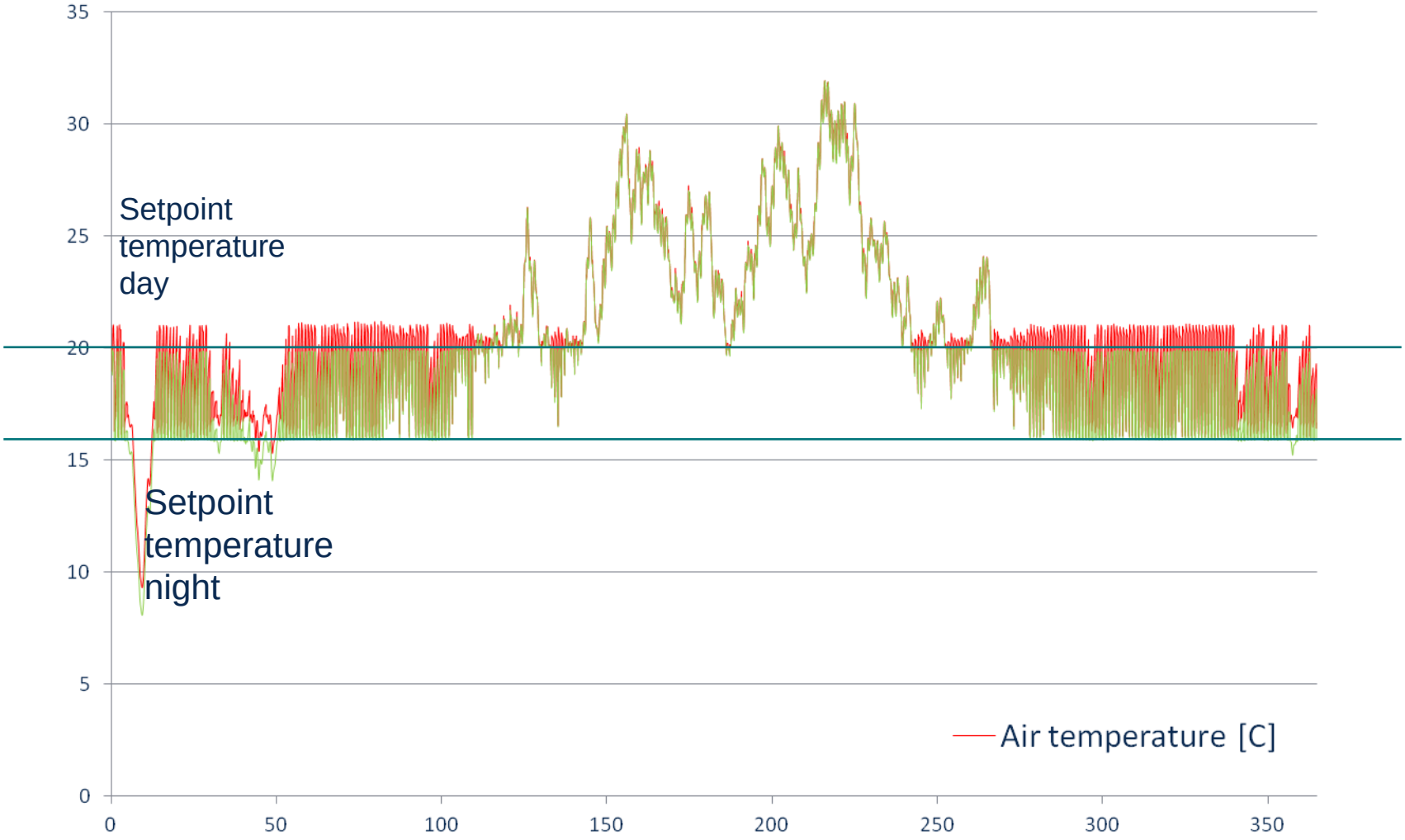
NANDRAD solver results



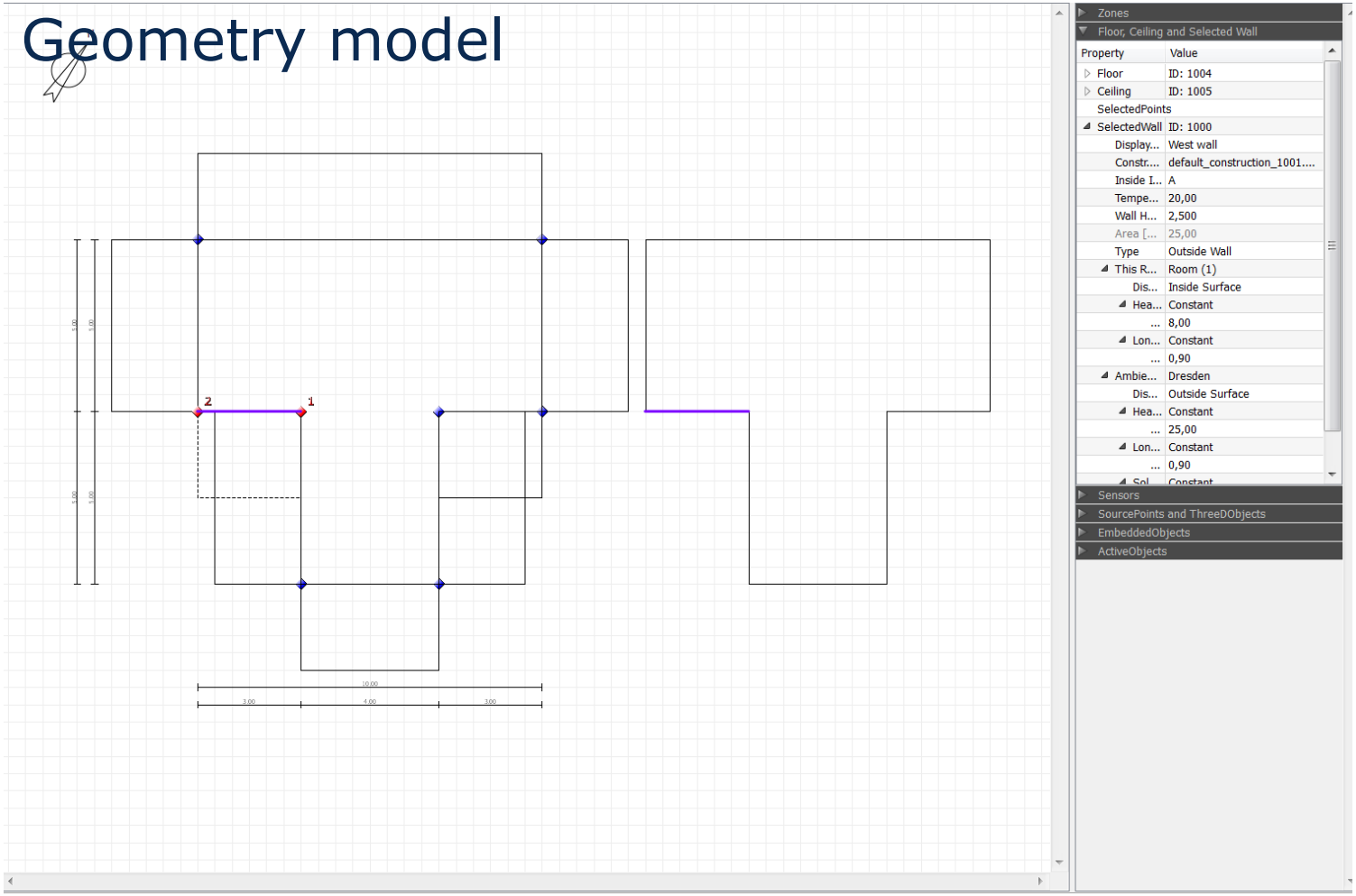
NANDRAD solver results



NANDRAD solver results

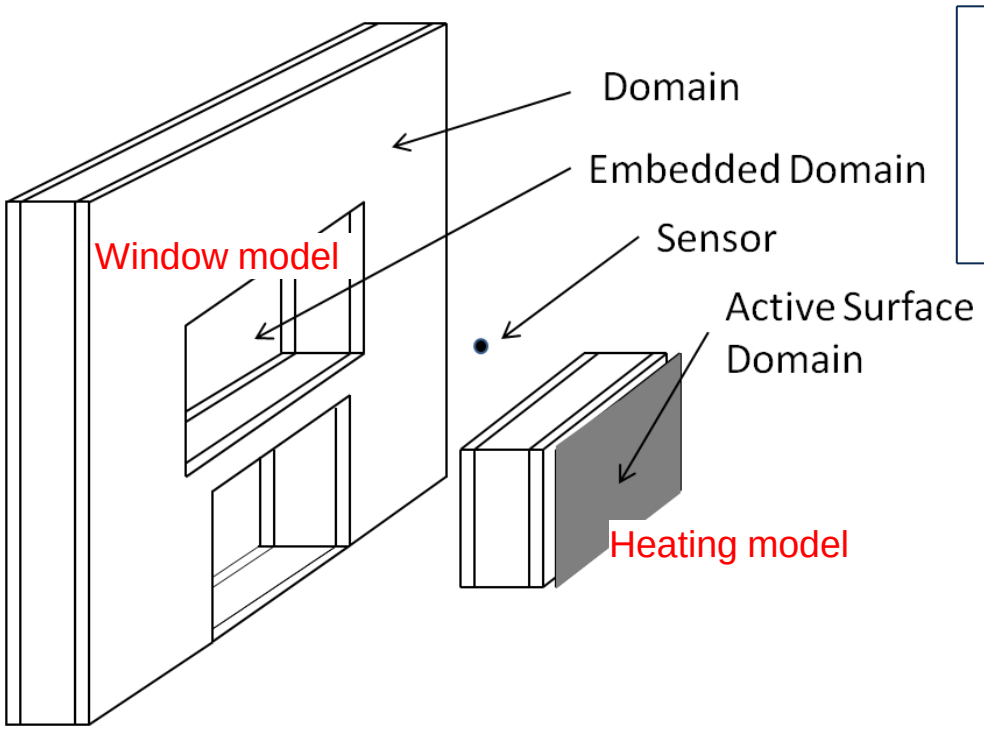


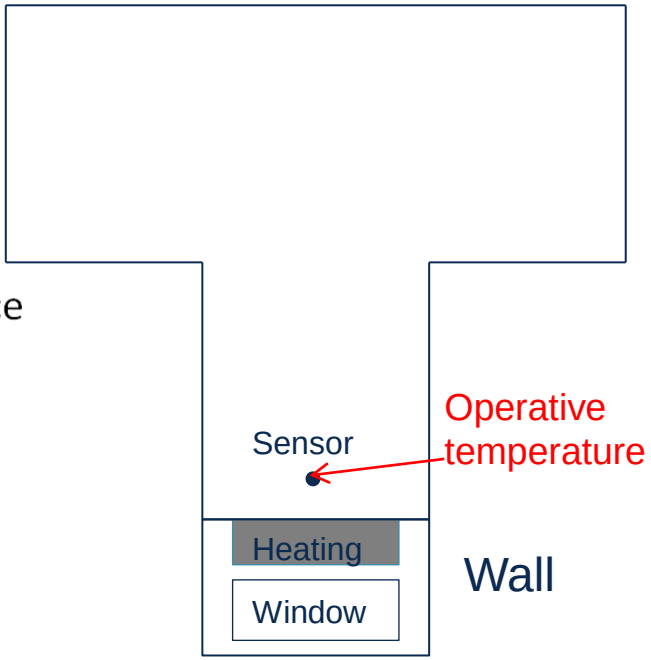
DynRoom Solver results



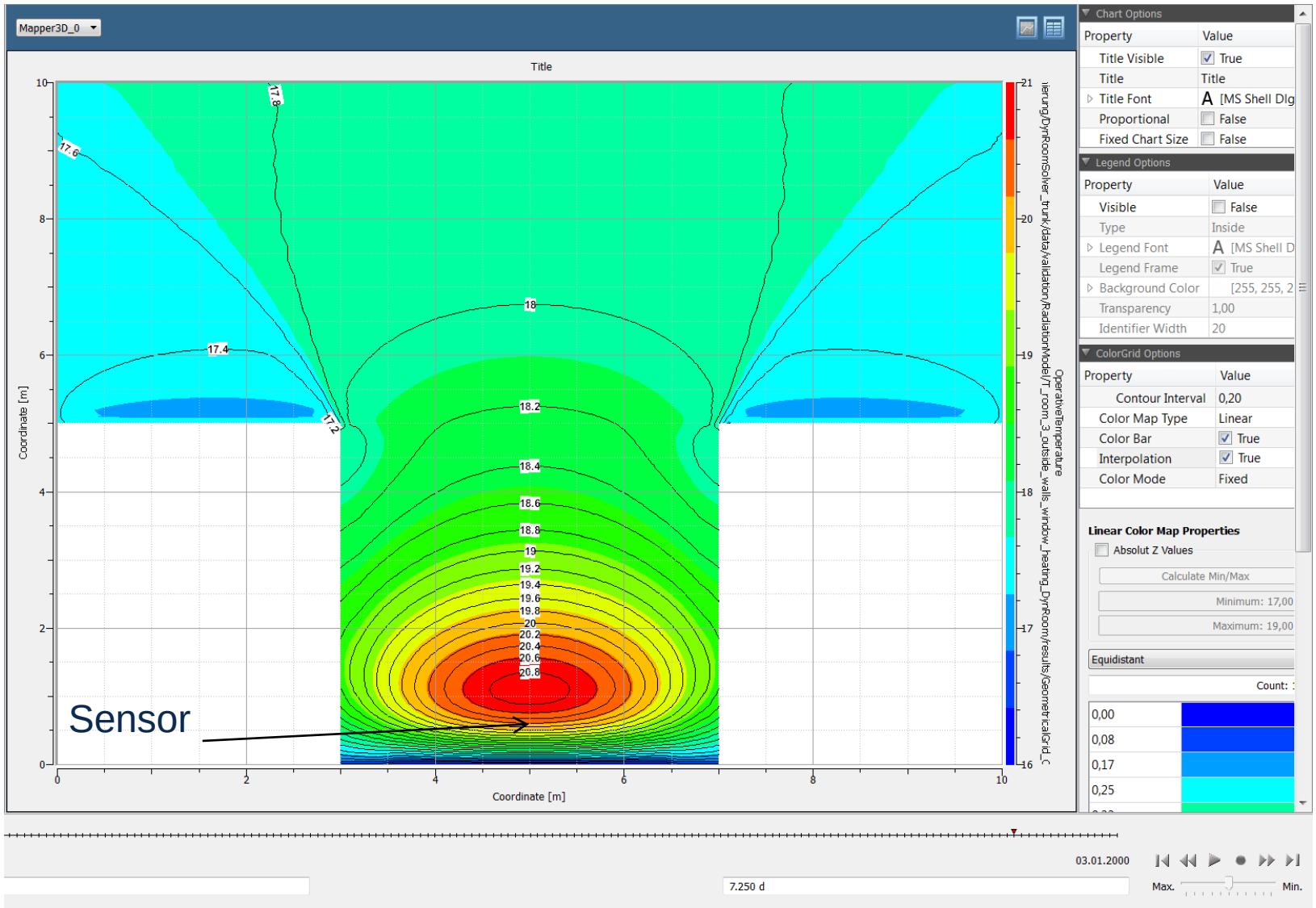
DynRoom Solver results

Geomety model + discretization

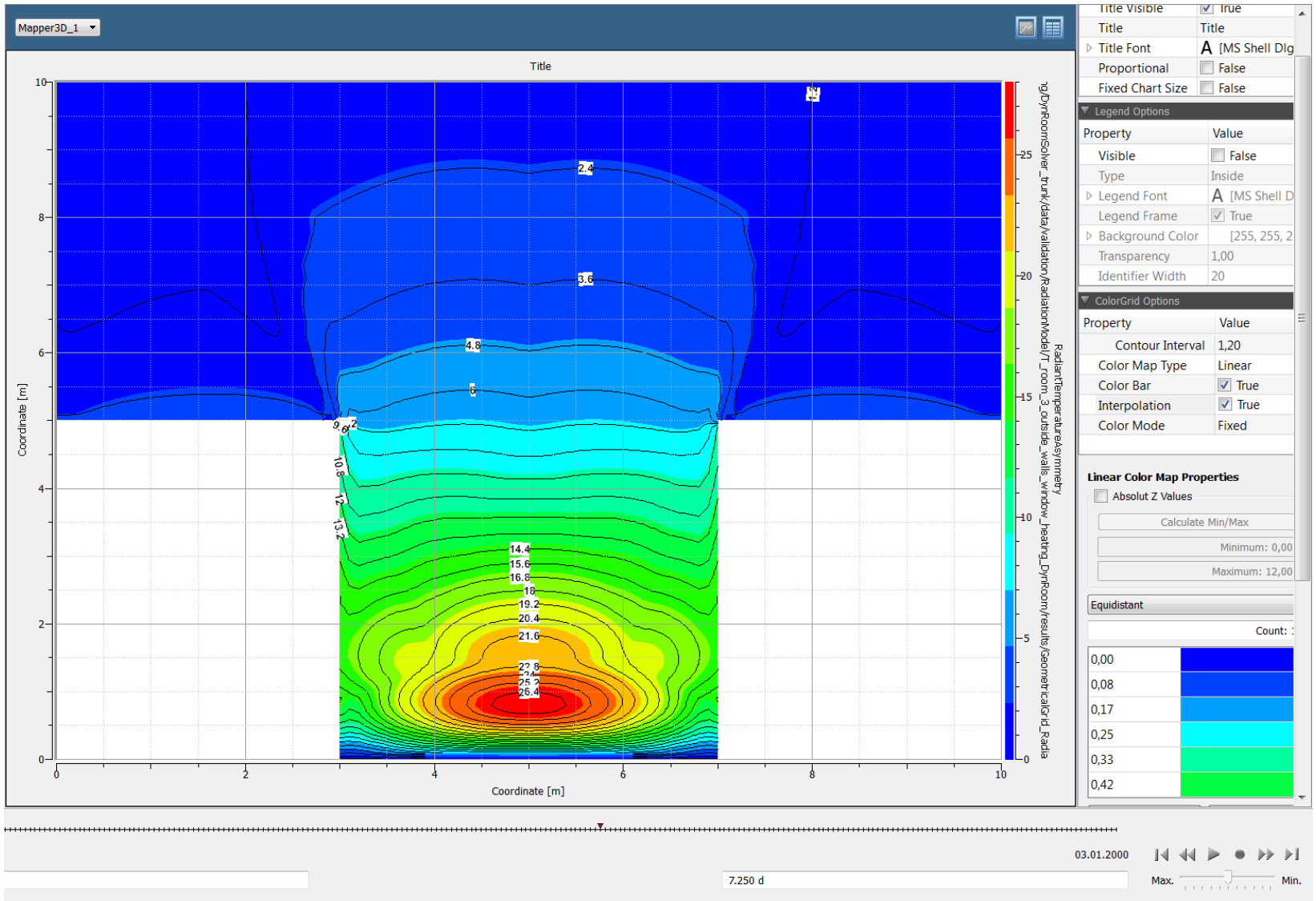




DynRoom Solver results



DynRoom Solver results



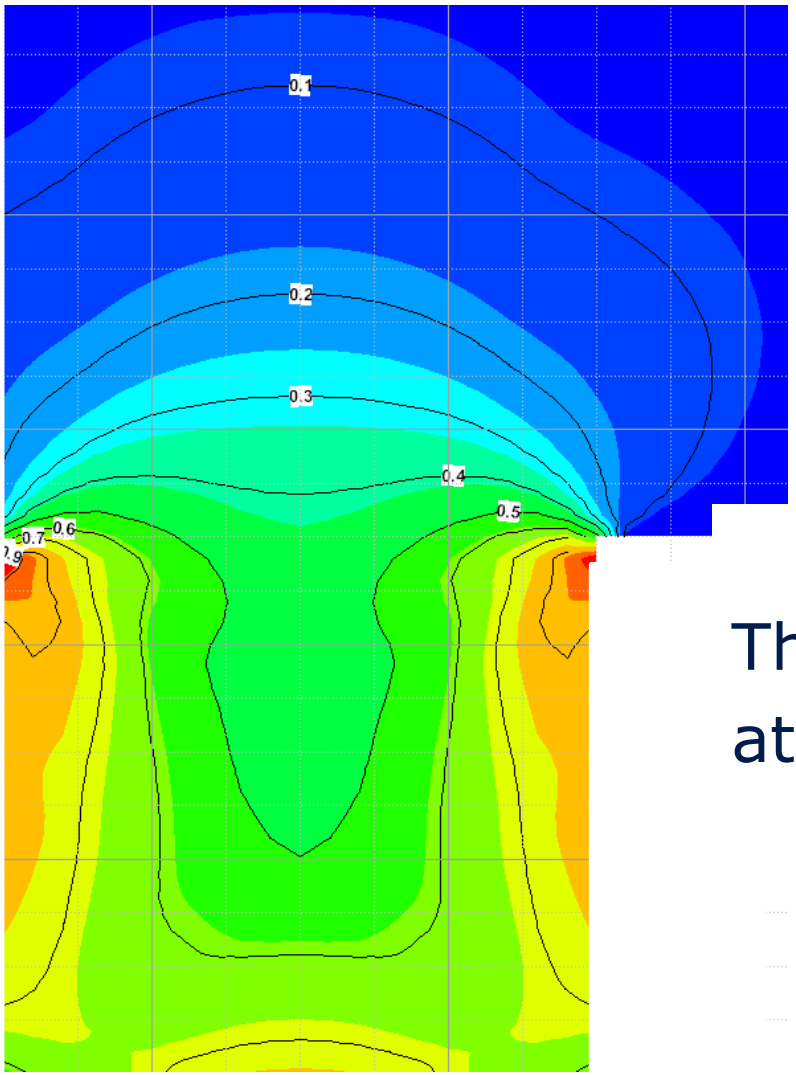
Conclusions

HAJAWEE/ DynRoom Solver

- Thermal comfort simulation: basic functionality (passive building + technical equipment models)
- Data model
- In progress: HAJAWEE GUI development, moisture and CO_2 calculation, HVAC control models, simulation test cases
- Still unsolved: air convection simulation for complex rooms

NANDRAD Solver

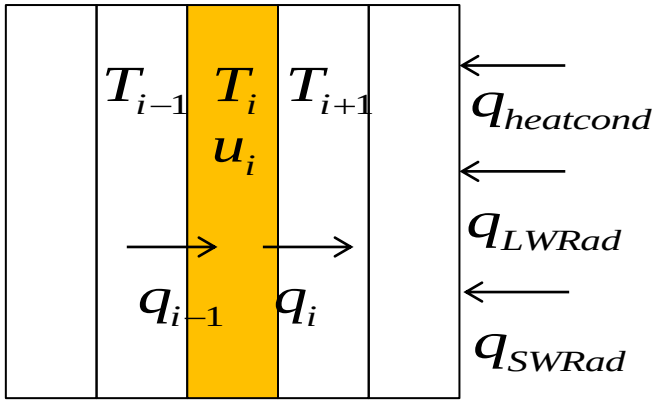
- Transient multi-zone simulation: basic functionality (passive building + technical equipment models)
- Data model
- Generic model interface
- In progress: IFC/IDF converter, optimization of numerical algorithms, simulation test cases



Thank you for your attention!

Appendix: Wall model

- Partial differential equation
- 1D-discretization in time and space for *each* Construction (Wall,Ceiling,…)



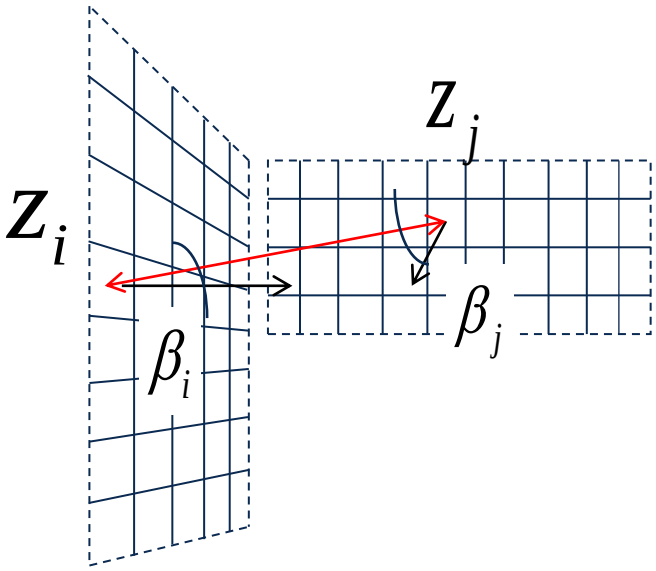
$$\frac{du_i}{dt} = -\frac{A}{V_i}\left(q_i - q_{i-1}\right)$$

$$q_i = -\lambda_{i-1/2}\frac{T_i - T_{i-1}}{\Delta x_{i-1/2}}$$

- Boundary condition: heat fluxes by heat conduction, long wave radiation, short wave radiation

Appendix: DynRoom Radiation model

View factor calculation



- View factor $\Phi_{i,j}$:

  fraction of the outgoing radiation from surface i that strikes surface j
- Numerical integration for each wall segment:

  Tiles z_i, z_j
- Expensive: check for obstacles for each tile pair

Appendix: DynRoom Radiation model

Radiation balance for wall surface i

- Radiosity $\dot{f}_i$: sum of emitted and reflected radiant fluxes
- Emitted radiation: Stefan-Boltzmann $\dot{e}_i = \varepsilon_i \sigma T_i^4$
- Incoming radiation: $\dot{h}_i = \sum_j \Phi_{ij} \dot{f}_j$
- Outgoing radiation: $\dot{f}_i = \dot{e}_i + (1 - \varepsilon_i) \dot{h}_i$
- Heat flux towards the wall due to long wave radiation:

$$q_{LWRad,i} = \dot{h}_i - \dot{f}_i$$

- Active surfaces: calculation of radiant temperature