TECHNISCHE UNIVERSITÄT DRESDEN

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

NANDRAD solver technology for multizone building performance simulation

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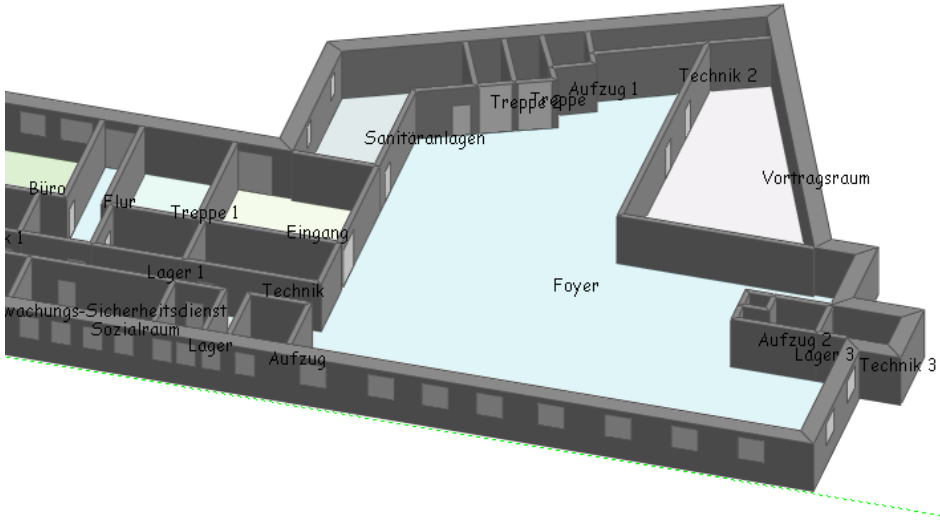
NANDRAD Solver concept

Thermal simulation and energy optimization of complex buildings



- designed for the transient simulation of large buildings
- transient + detailed wall calculation
- nonlinear technical equipment components
- semi-generic solver framework
- optimized numerical calculation for large nonlinear and sparse systems

NANDRAD Solver concept

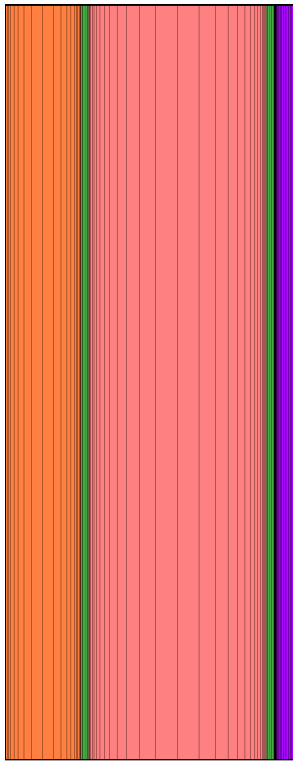
Predefined models (Implicit models)

- Building model: filled from BIM-data
  - Wall temperatures, Room temperatures, Climate model, solar radiation, window model
- Technical equipment models
  - Heat gains by heating, cooling, shading model
  - basic models for technical equipment components

User defined models (Generic models)

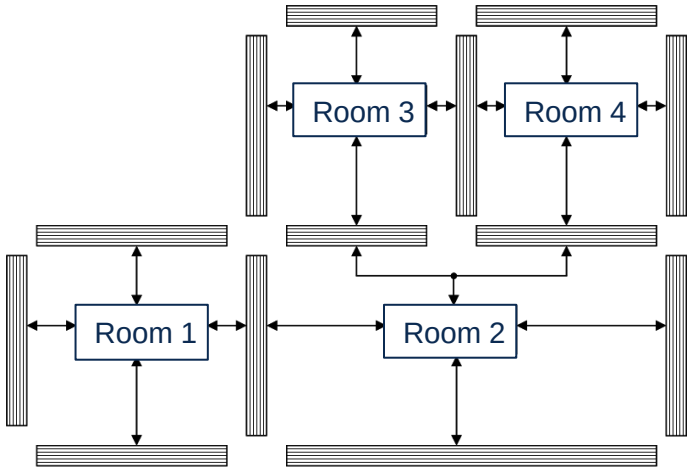
- allows modelling of complex technical equipment components
- filled from project file
- automatic coupling with building model

Implicit models



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
- Coupling to room balance



Implicit models

Room balance

- One node for each Room/Zone:

$$C\frac{dT}{dt} = \sum \dot{Q}$$

Wall balance

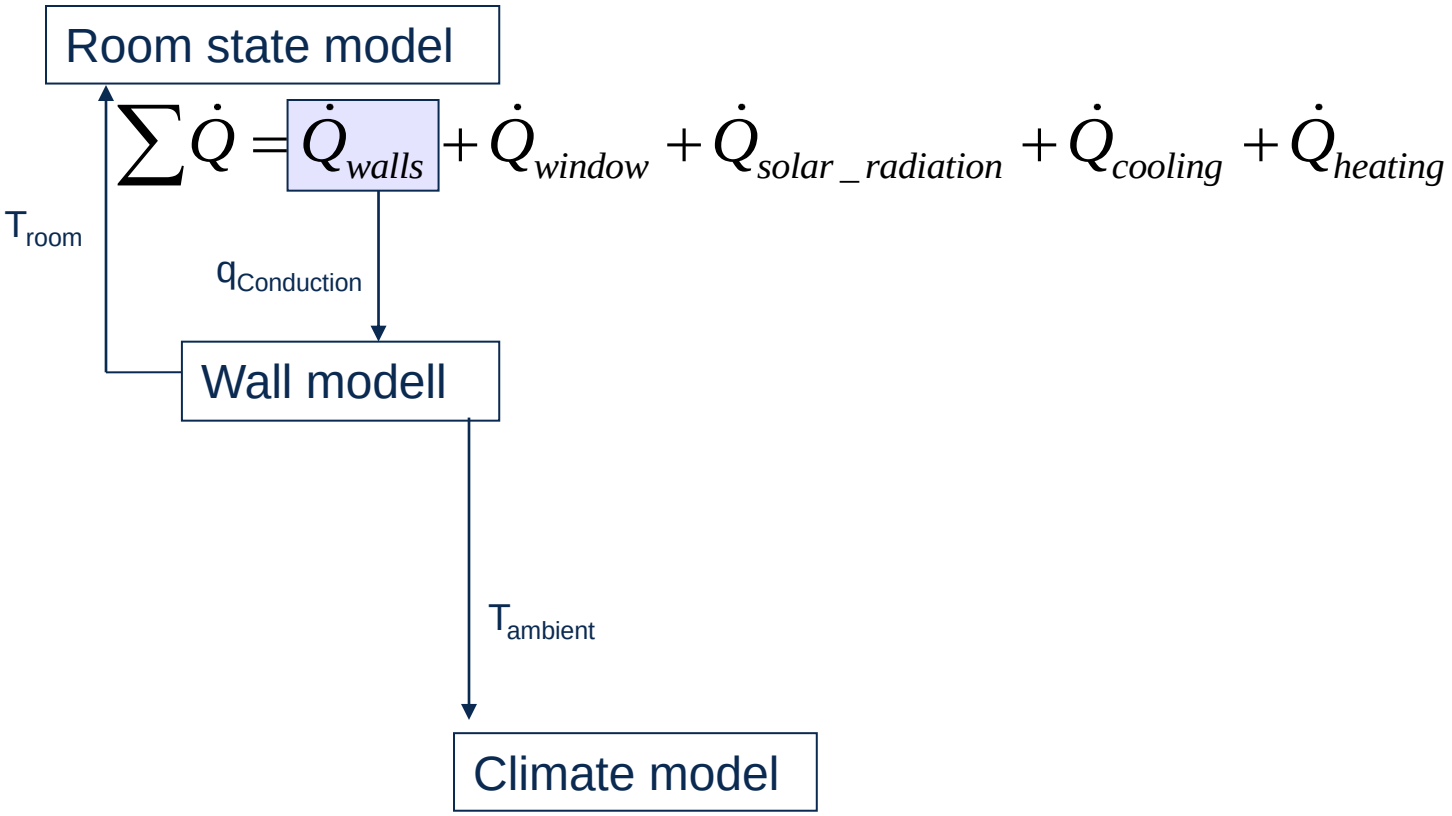
- Partial differential equation, 1D-discretization in time and space for *each* Construction (Wall,Ceiling,…)

$$\frac{du_i}{dt} = \frac{A}{V_i}\left(\lambda_{i-1/2} \frac{T_{i-1} - T_i}{\Delta x_{i-1/2}} - \lambda_{i+1/2} \frac{T_i - T_{i+1}}{\Delta x_{i+1/2}} \right)$$

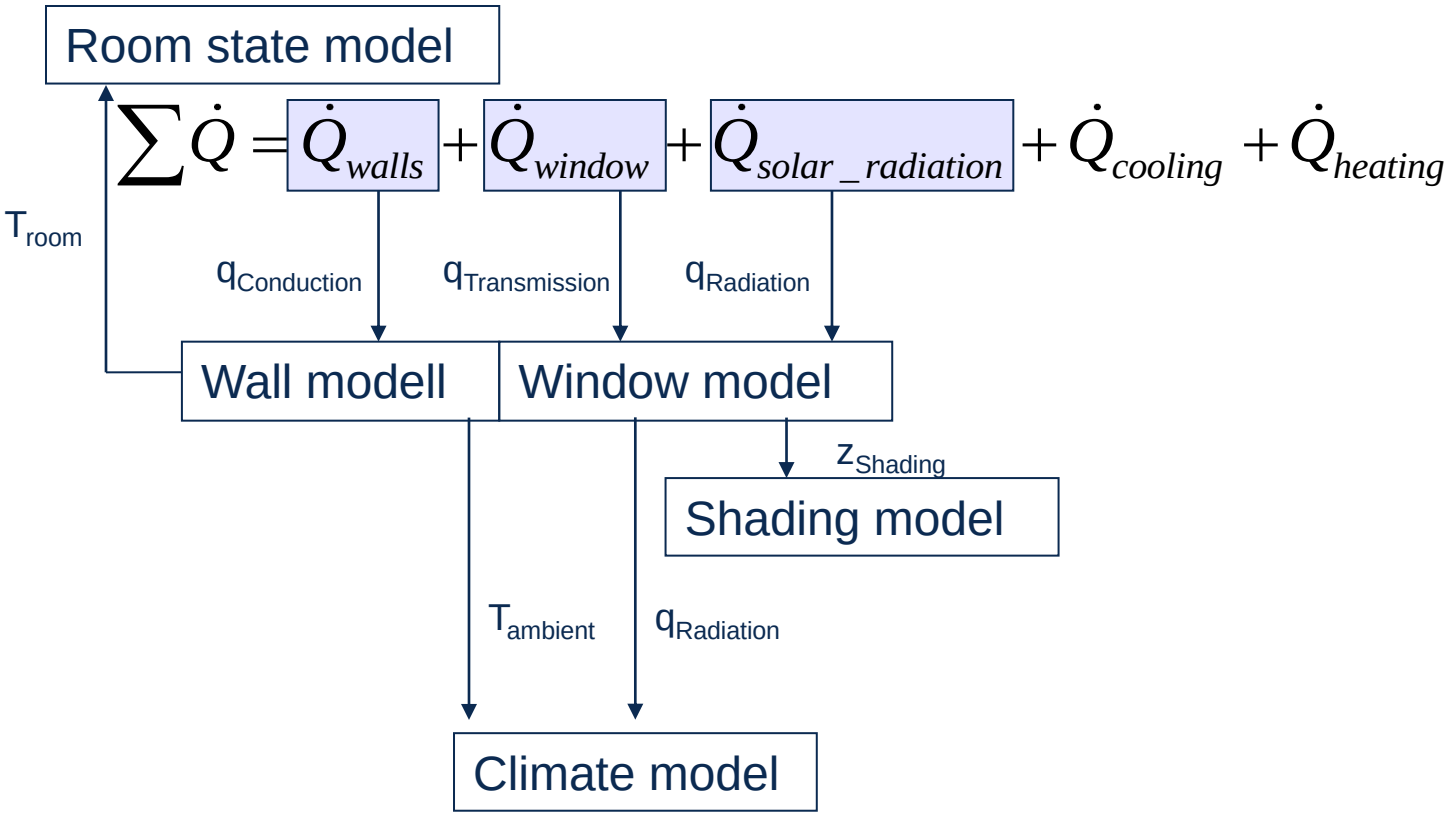
Implicit models

$$\sum \dot{Q} = \dot{Q}_{walls} + \dot{Q}_{window} + \dot{Q}_{solar\_radiation} + \dot{Q}_{cooling} + \dot{Q}_{heating}$$

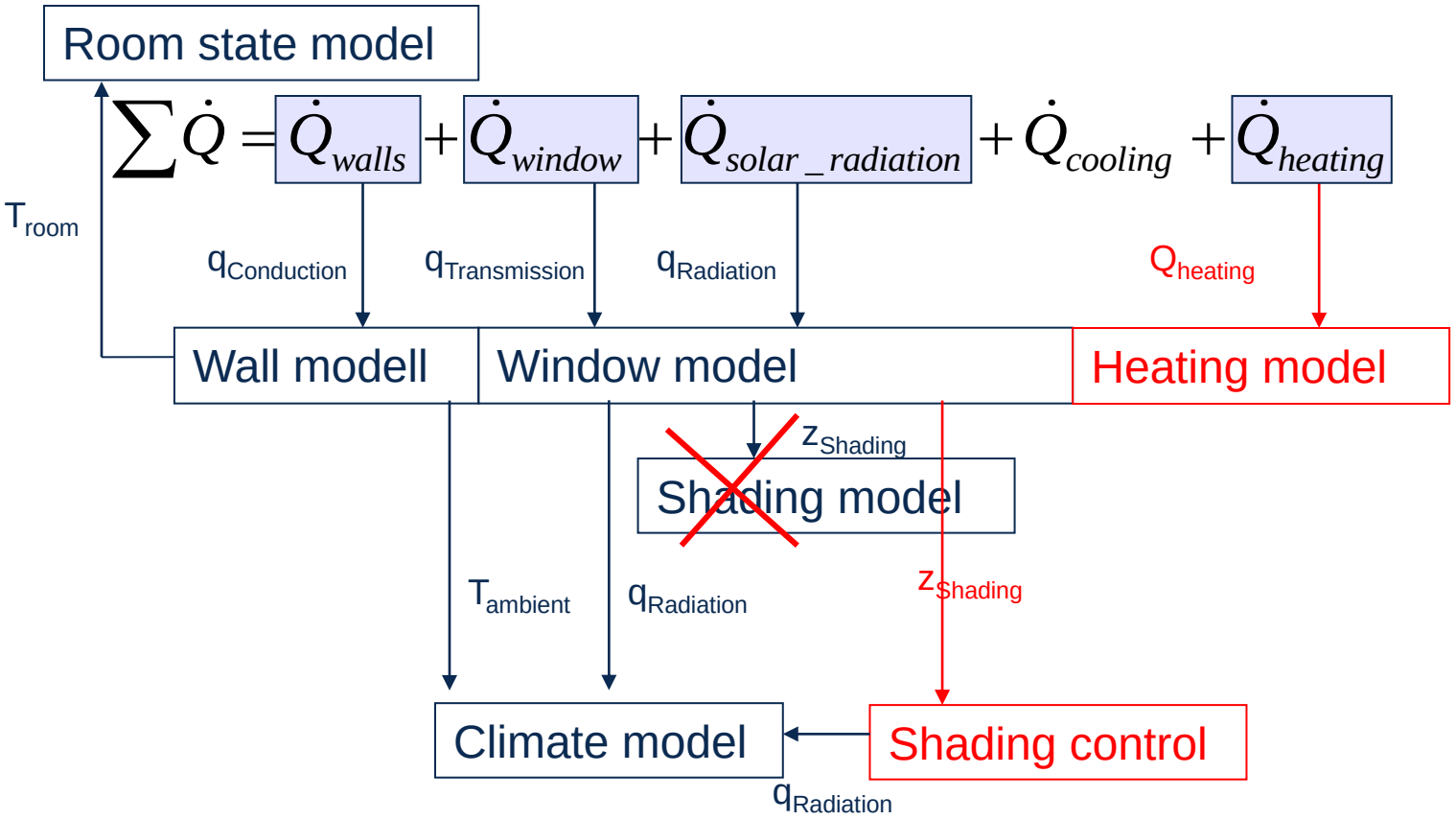
Implicit models



Implicit models

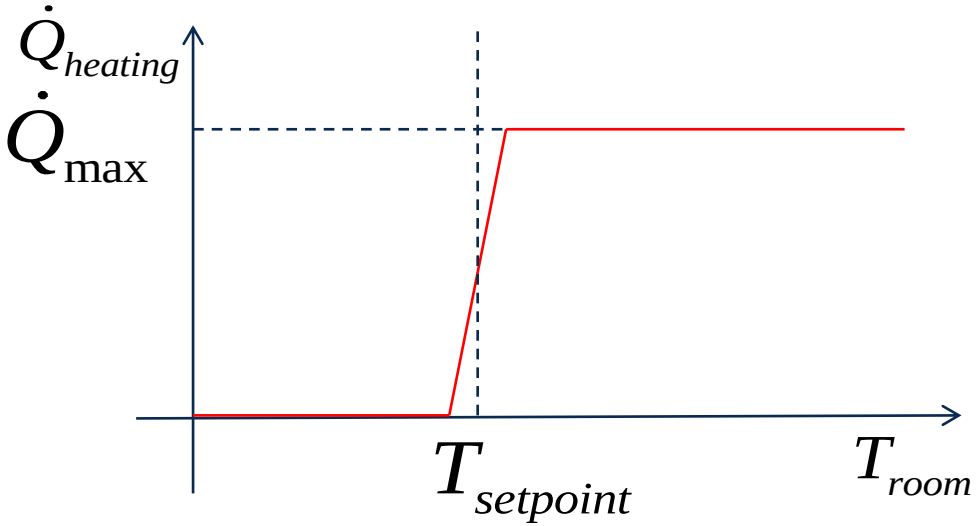


Generic Models



Generic Models

Ideal Heating model



Input signal:

$$e = T_{SetPoint} - T_{Room}$$

Heating load:

$$\dot{Q}_{heating} = \begin{cases} \min\left[K_p e, \dot{Q}_{max}\right] & T_{Room} < T_{Setpoint} \\ 0 & T_{Room} \geq T_{Setpoint} \end{cases}$$

Model evaluation

Completely coupled simulation

- Unknowns: references to other model results
- Results: model variables
- mixed transient and steady-state equations
- sparse system with unknown matrix pattern

Coupled room and wall balances

- Unknowns: room and wall temperatures
- Results: room and wall balances
- transient equations
- sparse system with characteristic matrix pattern

Model evaluation

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Model evaluation

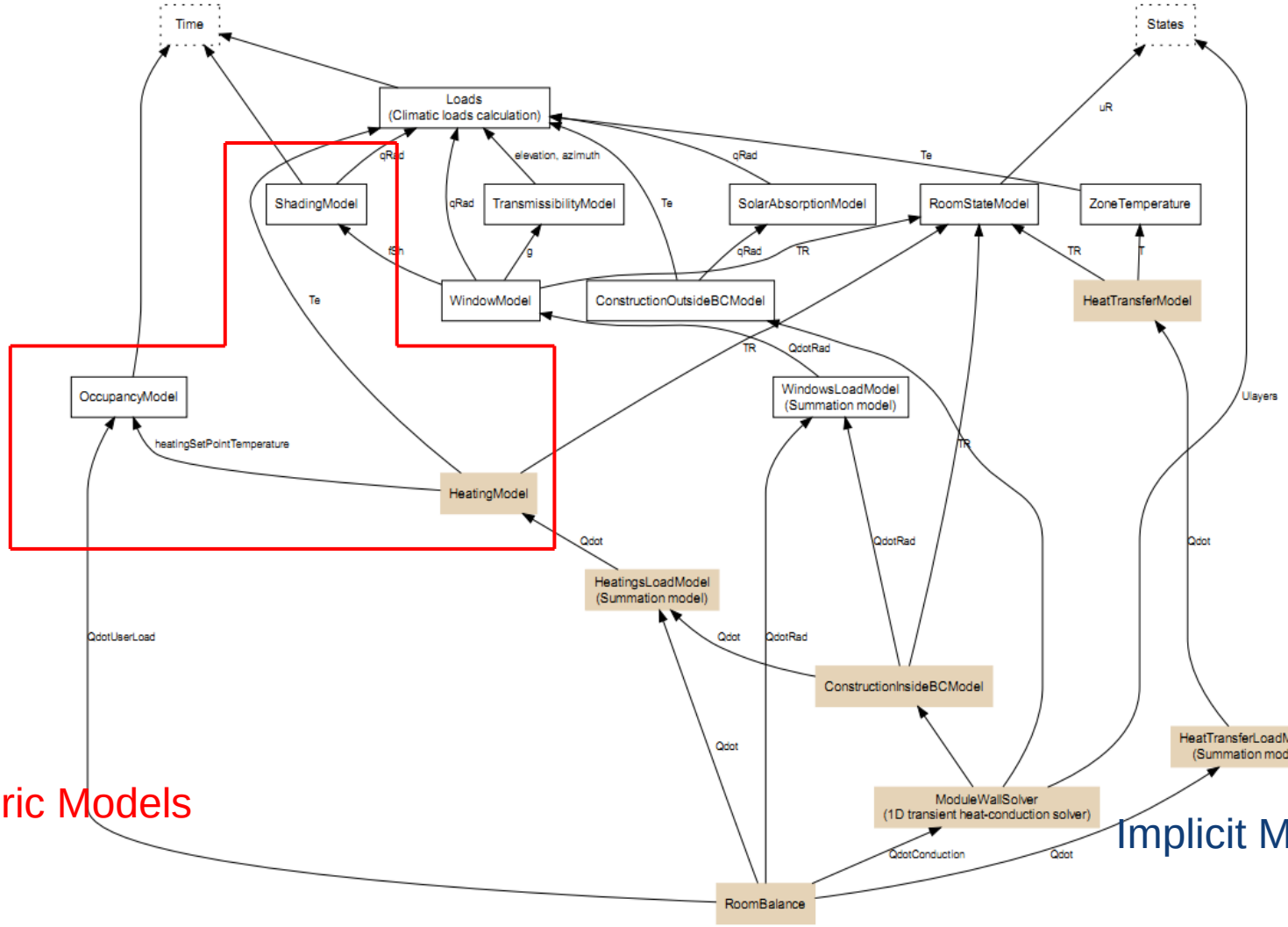
Problem: update of internal model results

- model results depend on each other
- model dependencies of generic models are known at run-time
- ordering of model calculation necessary

Update strategies

- Fixpoint iteration ⇒ bad convergence
- Completely coupled ⇒ inefficient
- Graph algorithms

Model evaluation

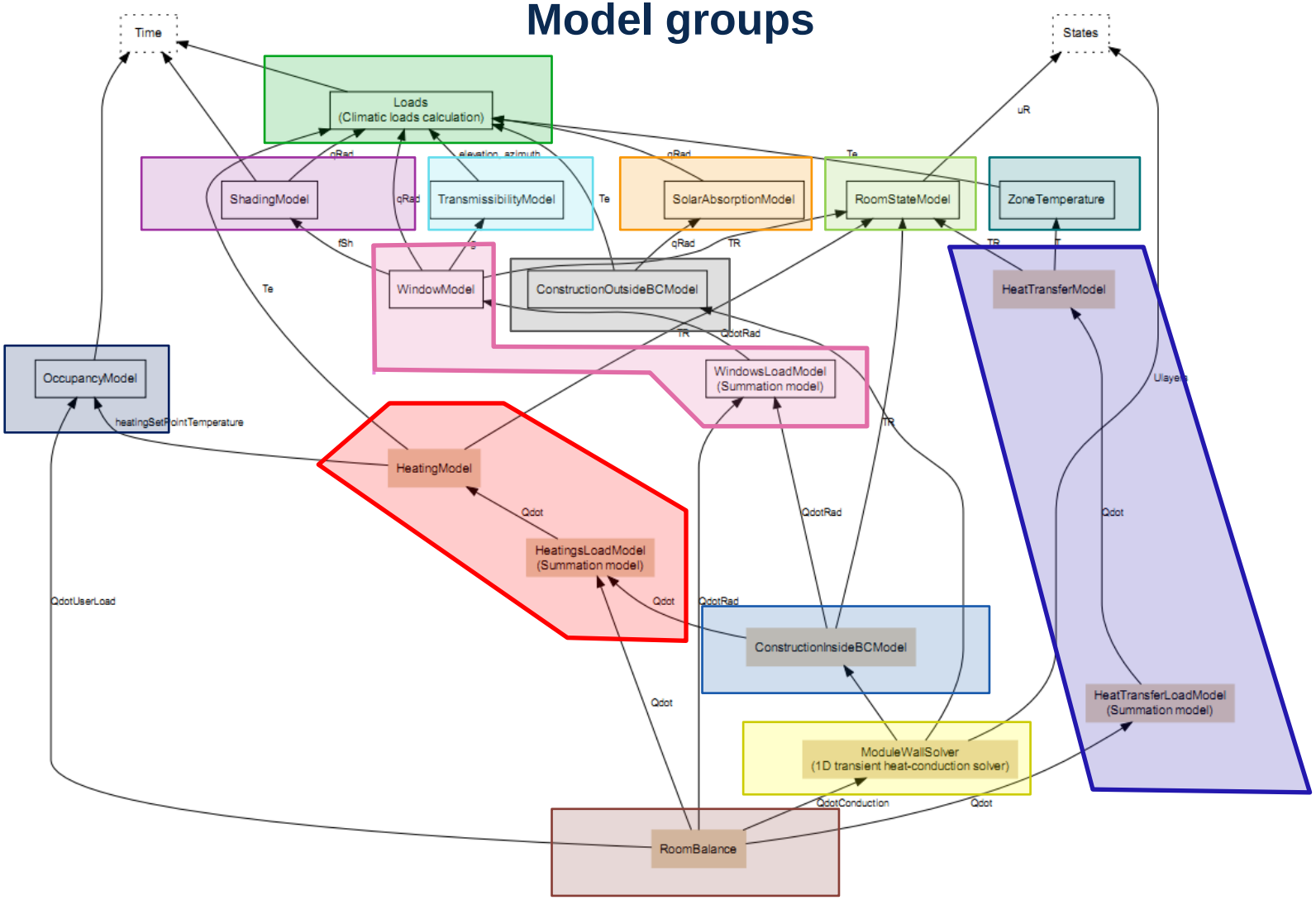


Generic Models

Implicit Models

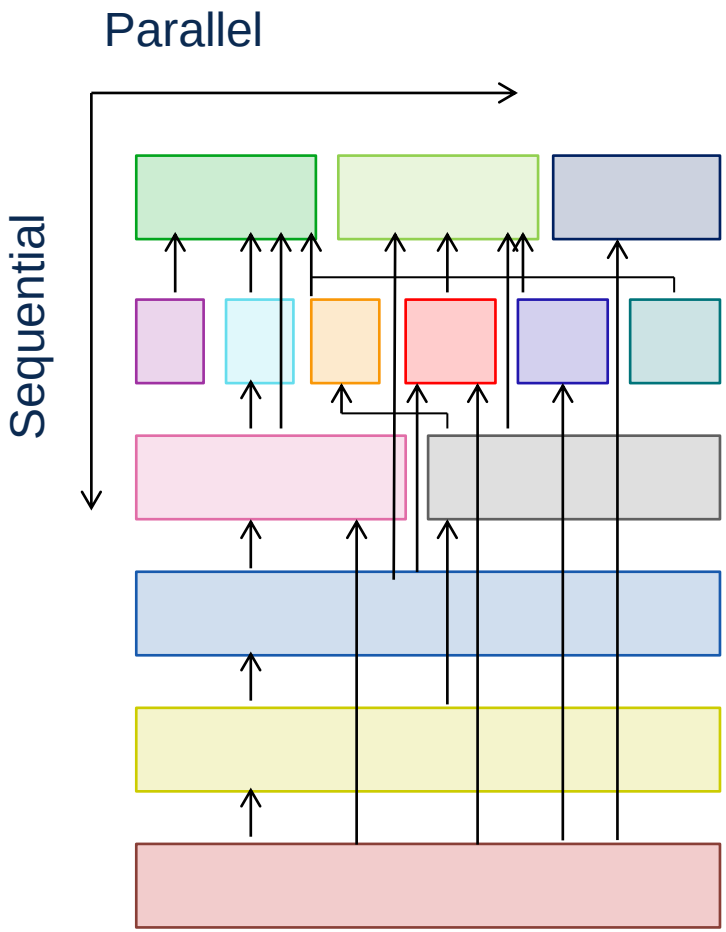
Model evaluation

Model groups



Model evaluation

Evaluation stack



Solution of the balance equations

Room balance model

$$C\frac{dT}{dt} = \sum \dot{Q}$$

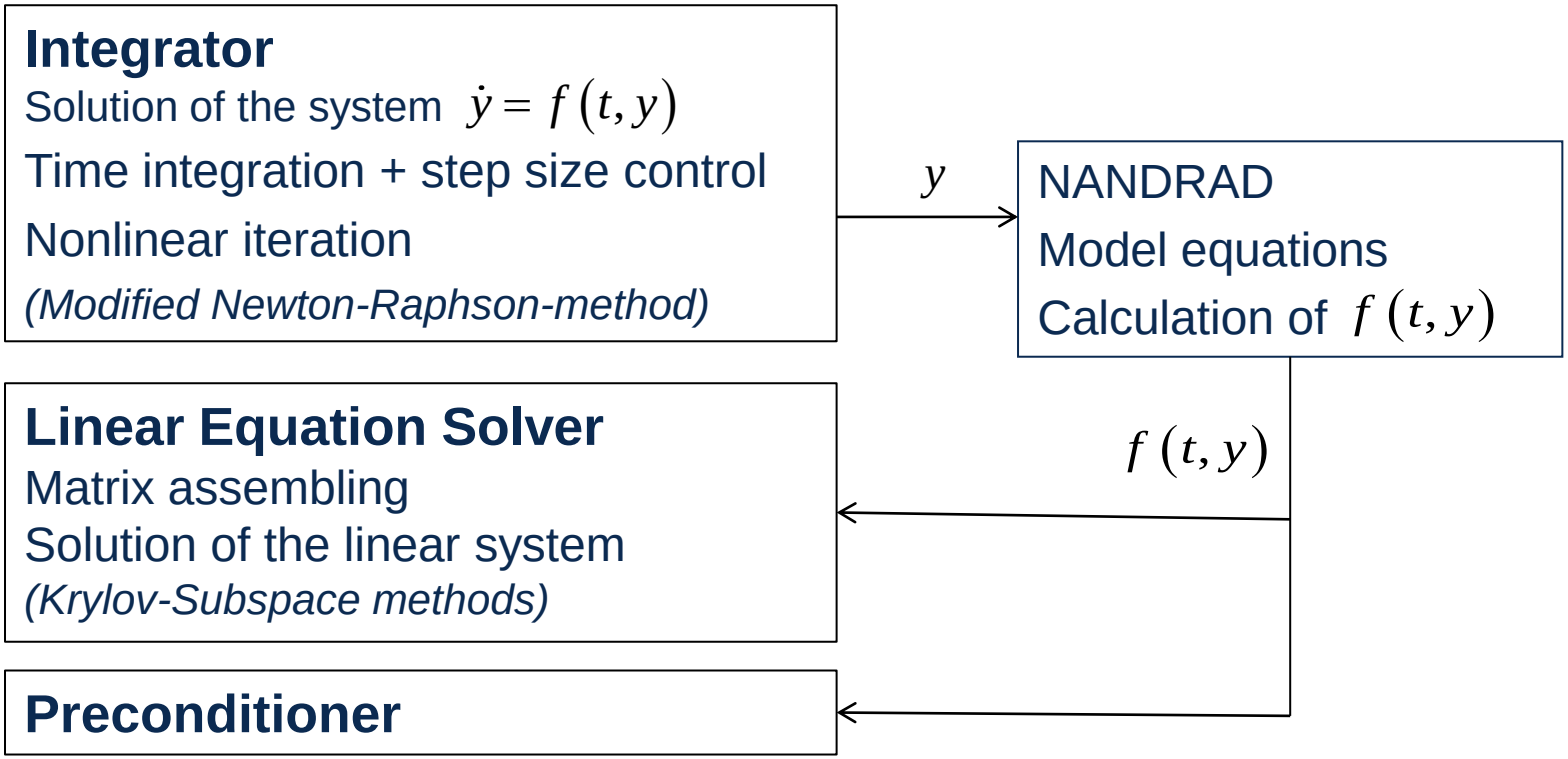
Wall model

$$\frac{du_i}{dt} = \frac{A}{V_i}\left(\lambda_{i-1/2}\frac{T_{i-1}-T_i}{\Delta x_{i-1/2}} - \lambda_{i+1/2}\frac{T_i - T_{i+1}}{\Delta x_{i+1/2}}\right)$$

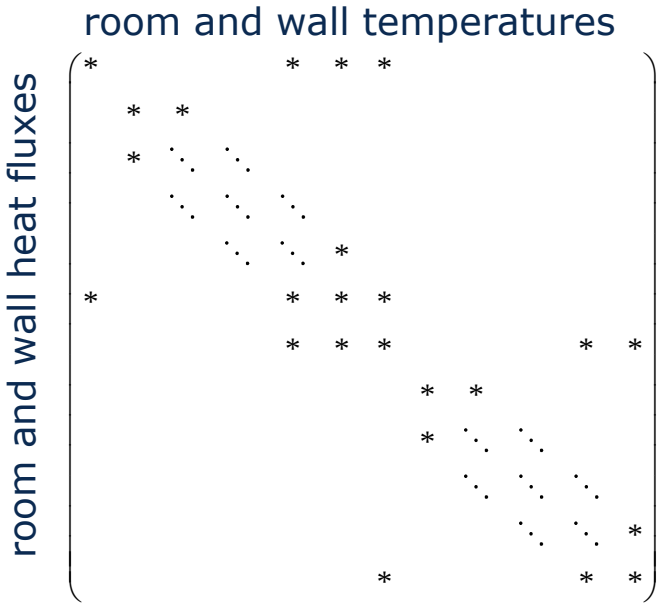
$$\dot{y} = f(t, y)$$

System of ordinary differential equations

Solution of the balance equations



Matrix assembling



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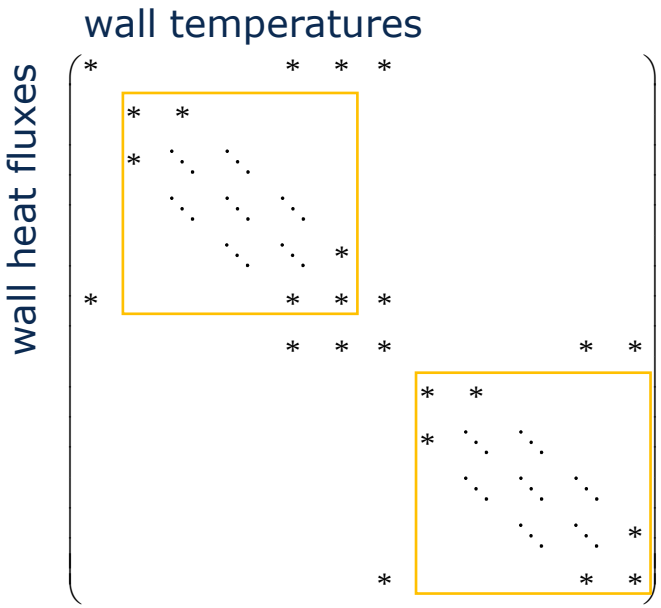

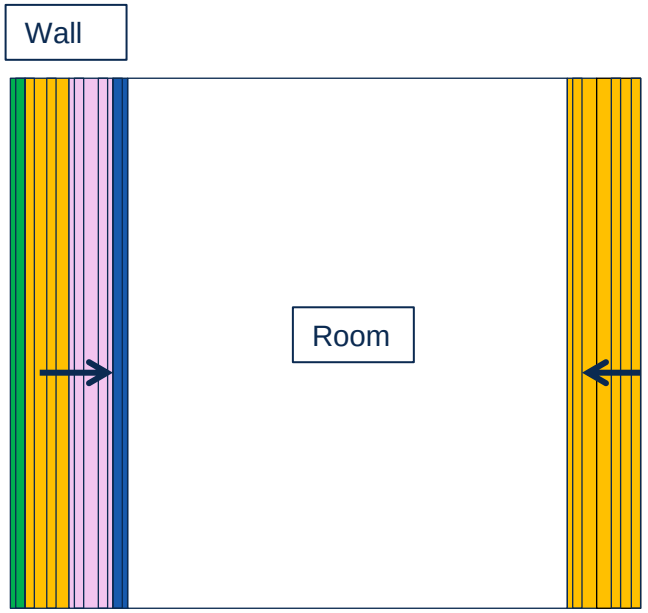

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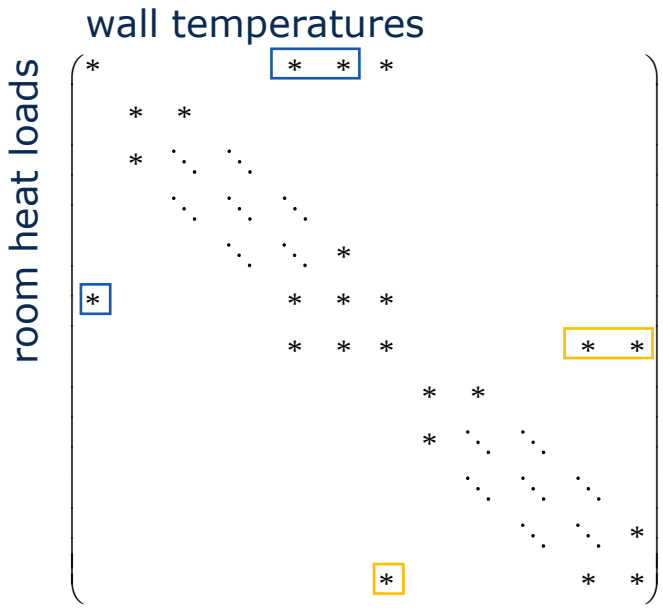

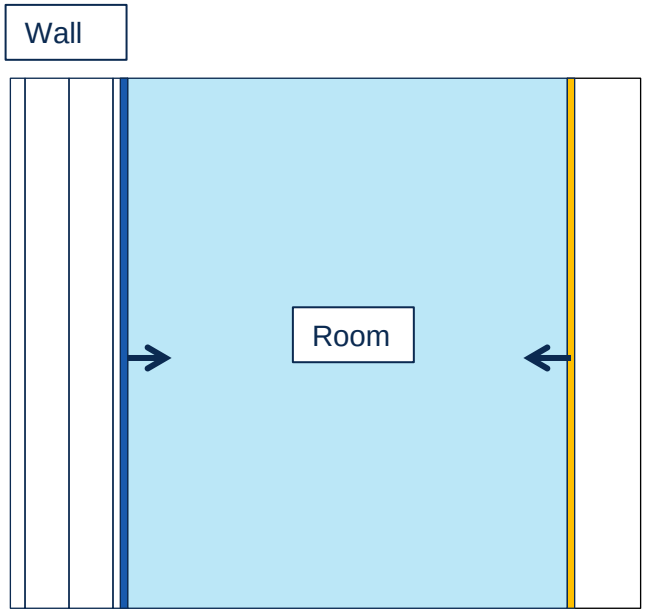

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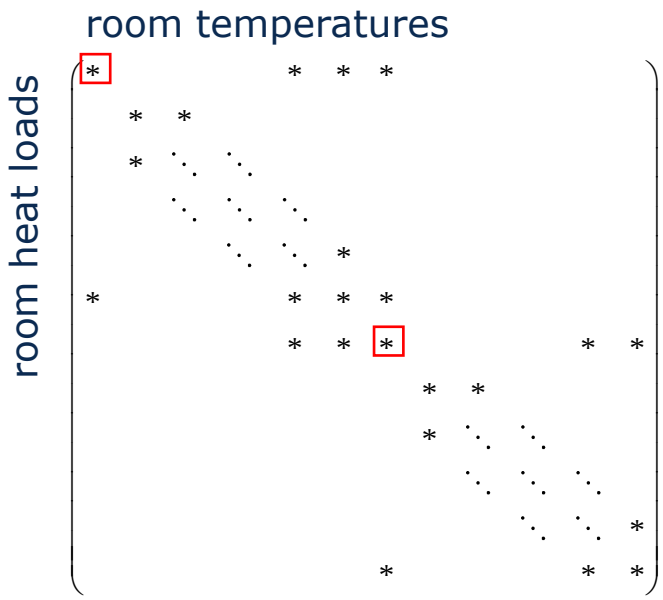
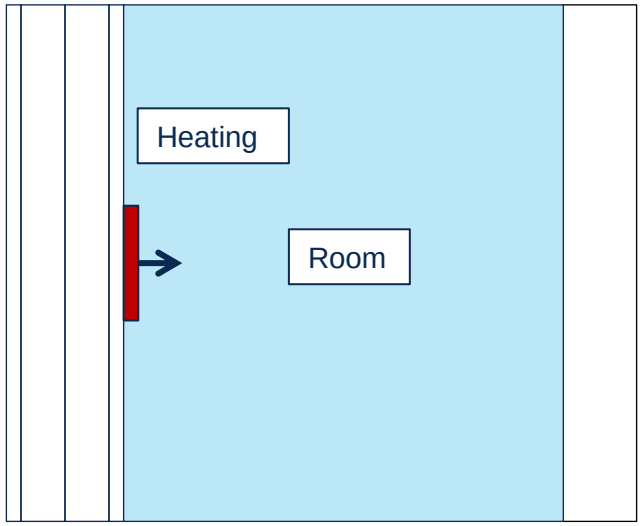
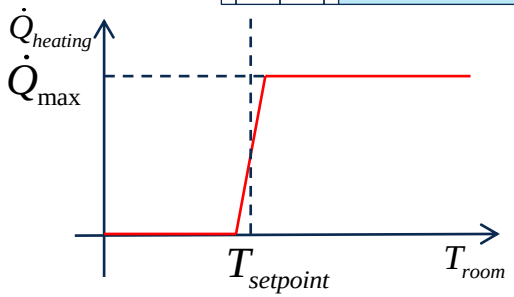
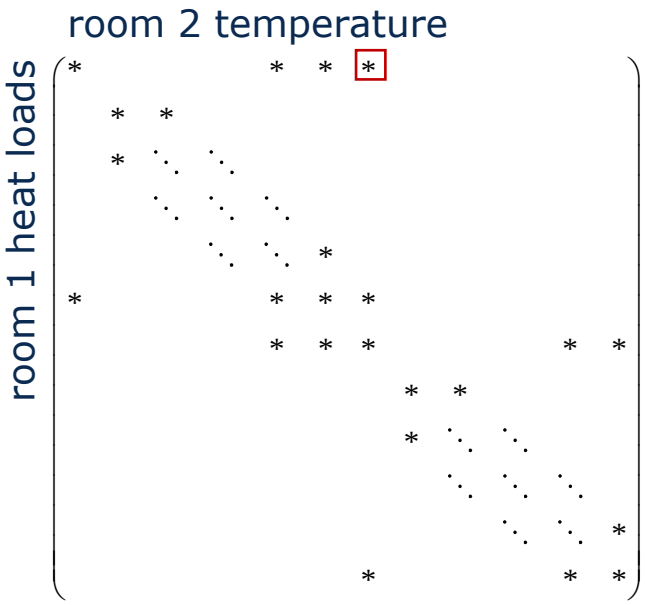
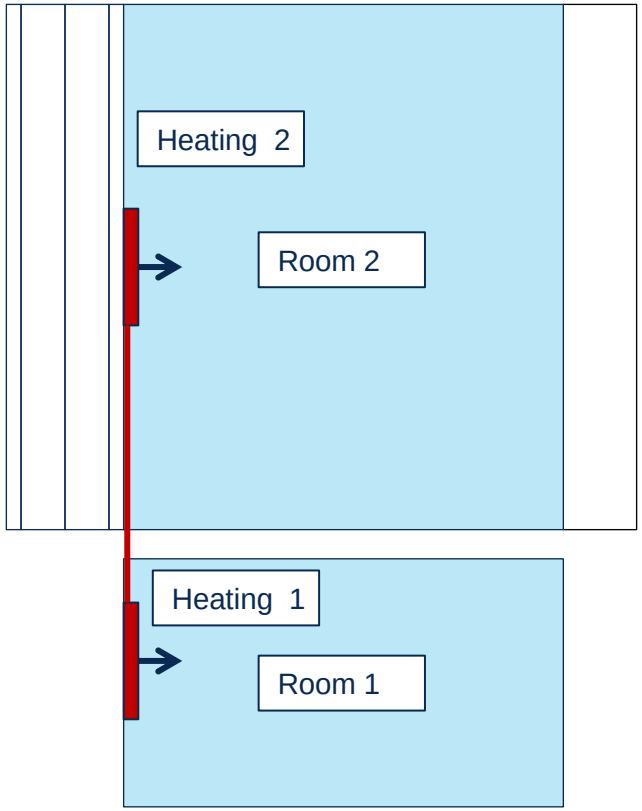




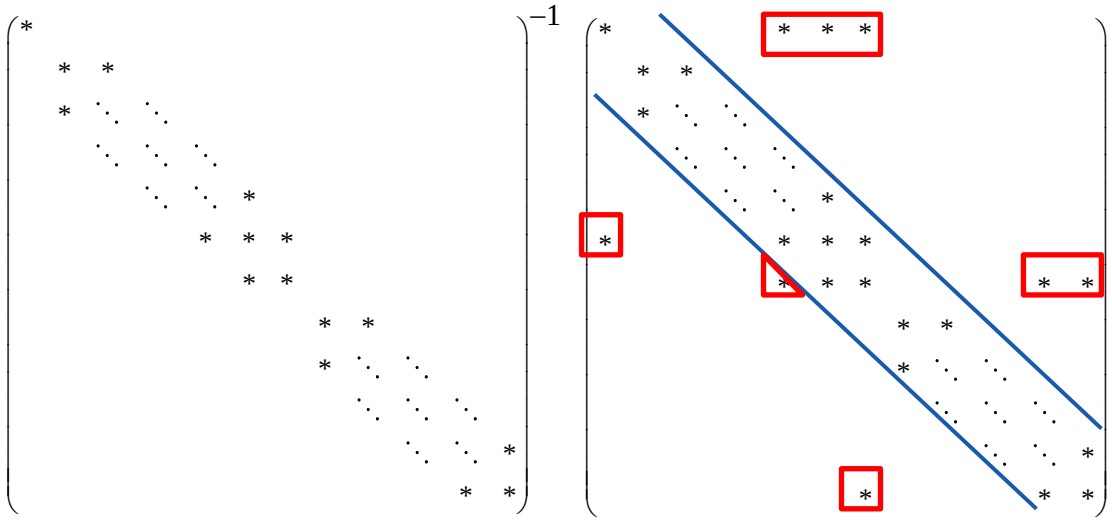


Matrix assembling





Solution of the linear system



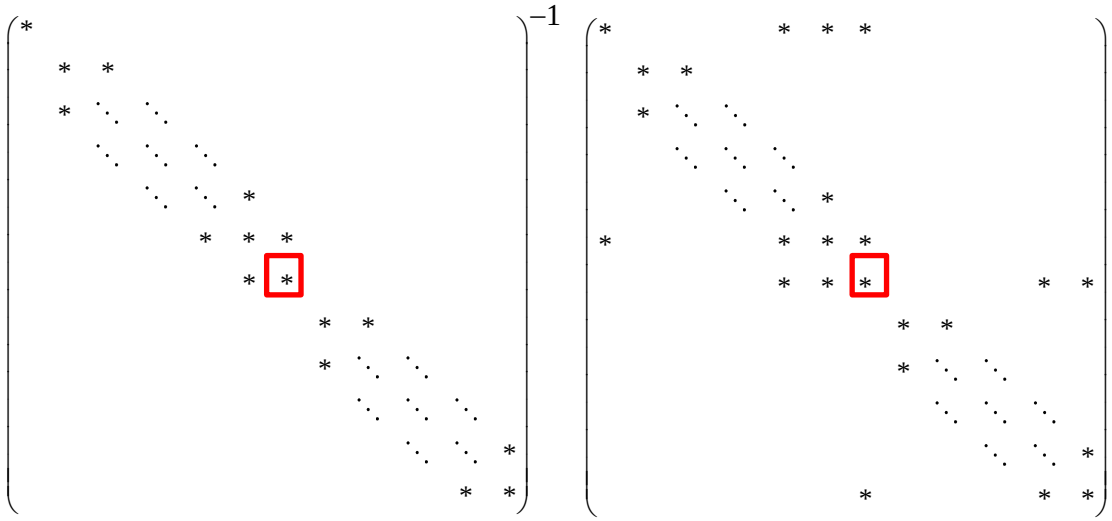
GMRES

- matrix-free: always updated data
- sparse matrix storage: Jacobian may be outdated (Modified Newton)

Preconditioning (Band-Preconditioner/ ILU)

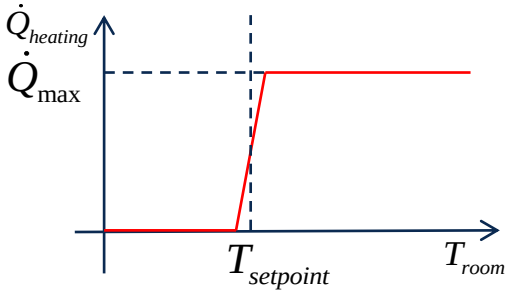
- sparse matrix storage

Solution of the linear system



Matrix-free GMRES

- bad performance for controled heating



GMRES with matrix storage

- exact matrix pattern is needed
- efficient matrix assembling

Conclusions

Passive Buildung

- Transient 1D-wall calulation
- Transient room balance
- Effivient numerical solution of the equations for large buildings

Technical equipment

- Basic model components (e.g. Heating and cooling control)
- Generic model extension by the user
- Model dependencies resolved using graph algorithms

Further Work

- Matrix pattern for generic model components
- Automatic entry of coupling terms into global solution matrix

Thank you for your attention!