Grid Adaptation with DuMuX

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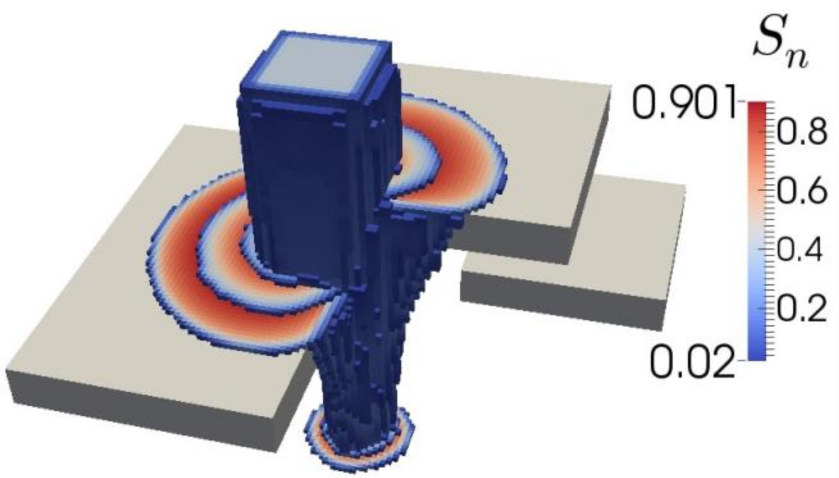
Motivation

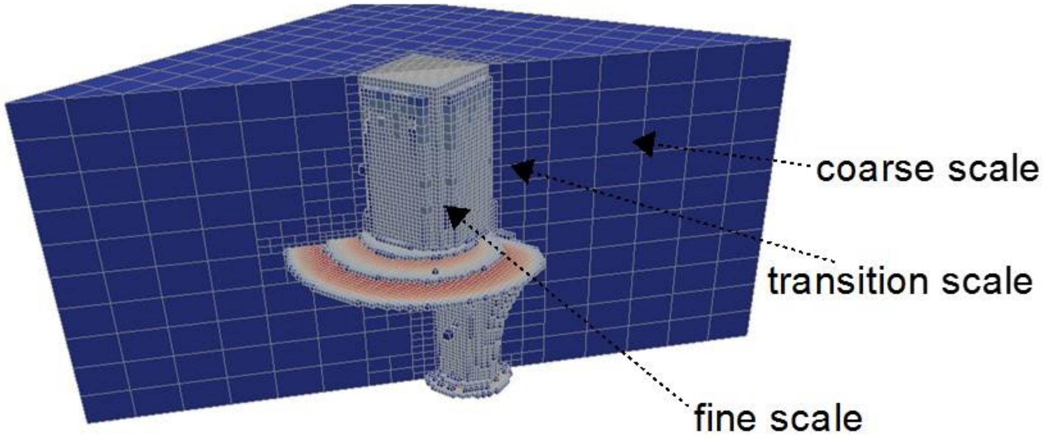
Infiltration process:

Injection in media with lenses



Decoupled Discretization:

- Adaptive Grid: 4.0e4 instead of 1.2e6 cells
- MPFA/TPFA with Adaptive Grid ~ hours
- TPFA with Non-Adaptive Grid ~ days
- MPFA with Non-Adaptive Grid ~ week



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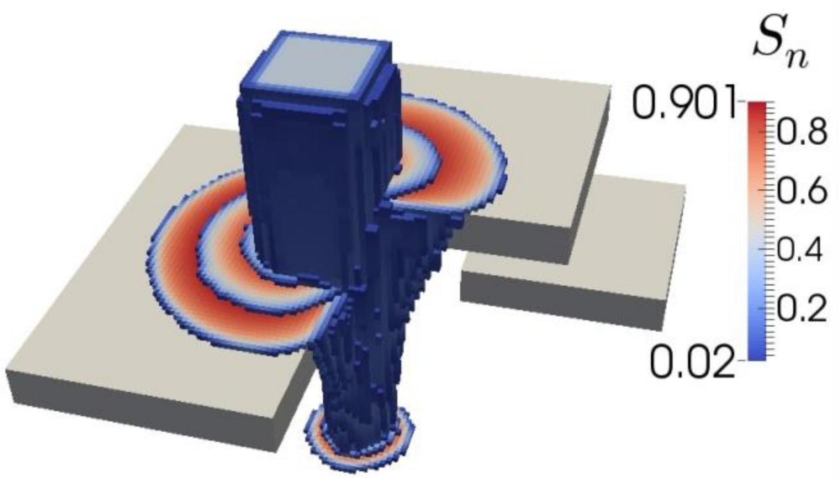
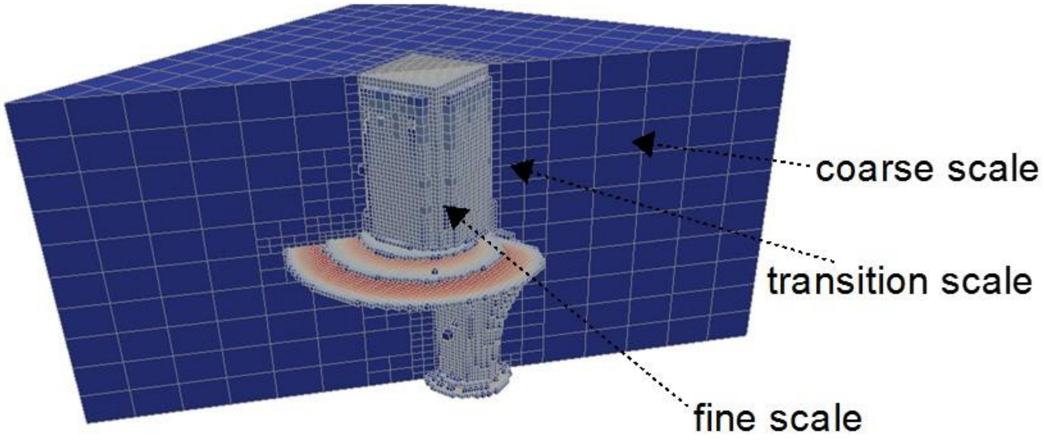


→ **Increase efficiency, same accuracy**

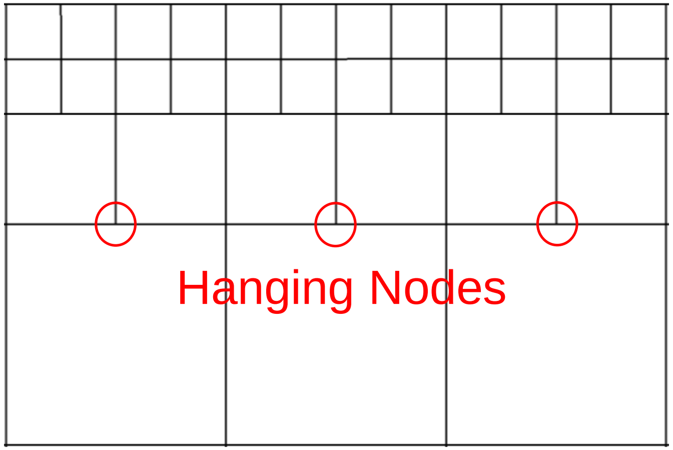


Grid Adaptation

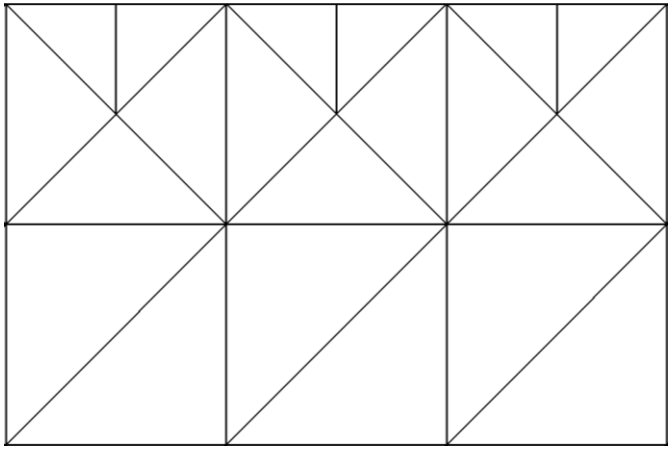
Dune grids supporting adaptation:
Alu, UG, Foam, …

No local adaptation possible:
Yasp, …

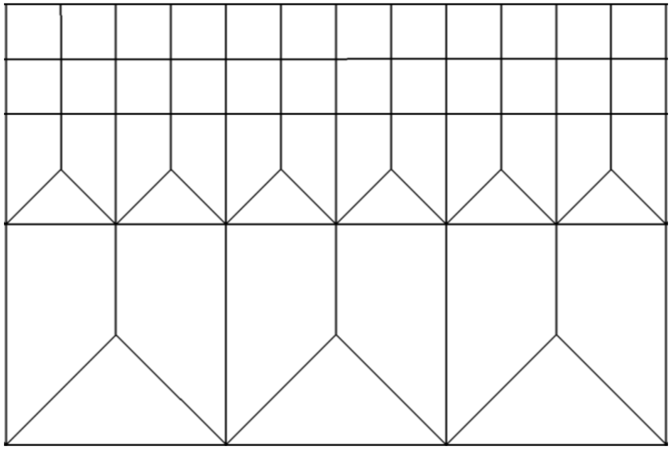
Nonconforming: (Alu)



Conforming: (Alu)

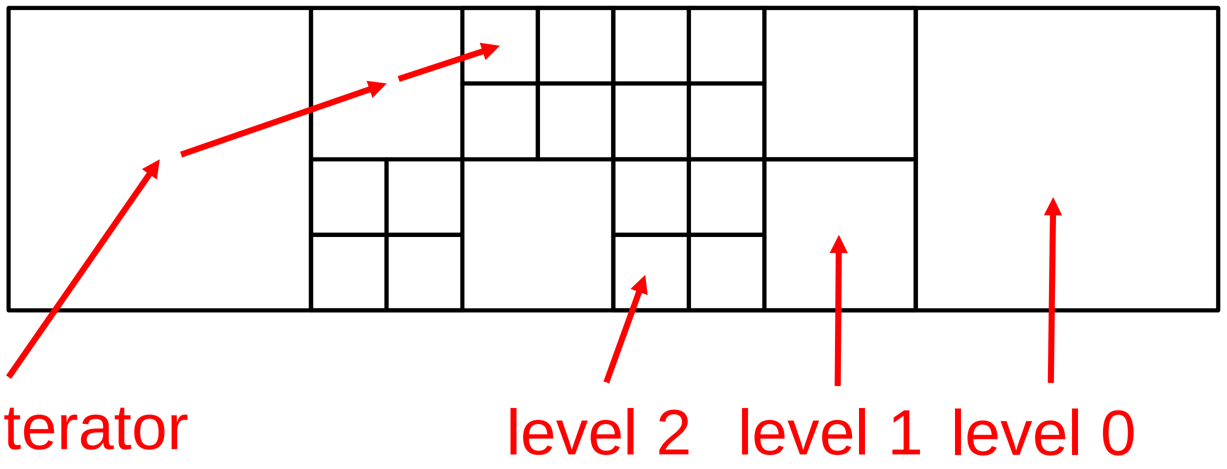


Conforming: (UG)



dune-grid LeafGridView

LeafGridView:



Leaf Iterator

level 2 level 1 level 0

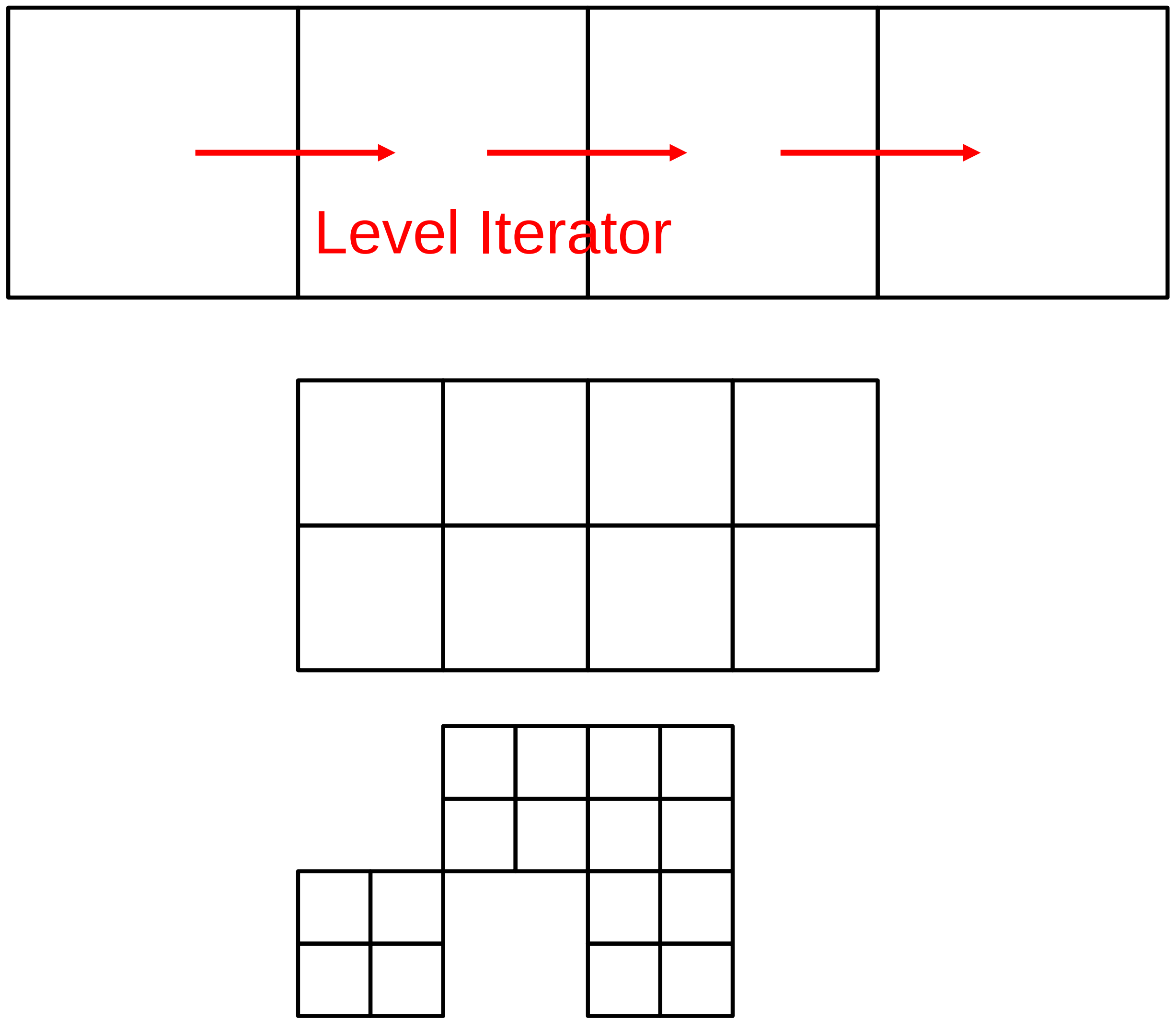
Mostly used in DuMuX

dune-grid Level View

Level 0:

Level 1:

Level 2:



Grid Adaptation

Most of the work is done by dune-grid

Basic routine for adaptation process:

1. Determine cells which should be coarsened or refined
2. Mark grid cells
3. Store primary variables
4. Adapt grid
5. Reconstruct primary variables

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Basic routine for adaptation process:

1. Determine cells which should be coarsened or refined
2. Mark grid cells *grid.mark(±1, entity)*
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4. Adapt grid *grid.adapt()*
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dune-grid

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dune-grid
basic routines in implicit/adaptive

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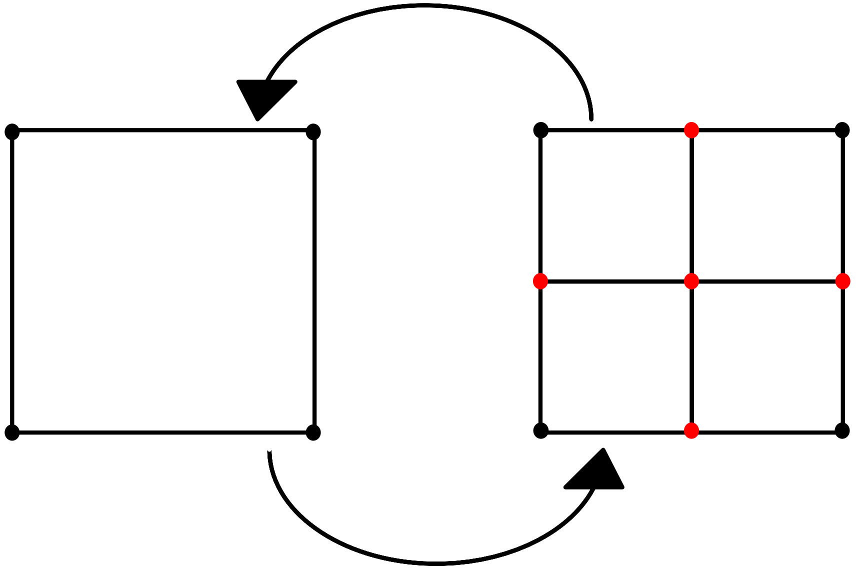
dune-grid
basic routines in implicit/adaptive
user: model specific, indicator for refinement / coarsening

Reconstruction of primary variables

Box method:

Nothing to do

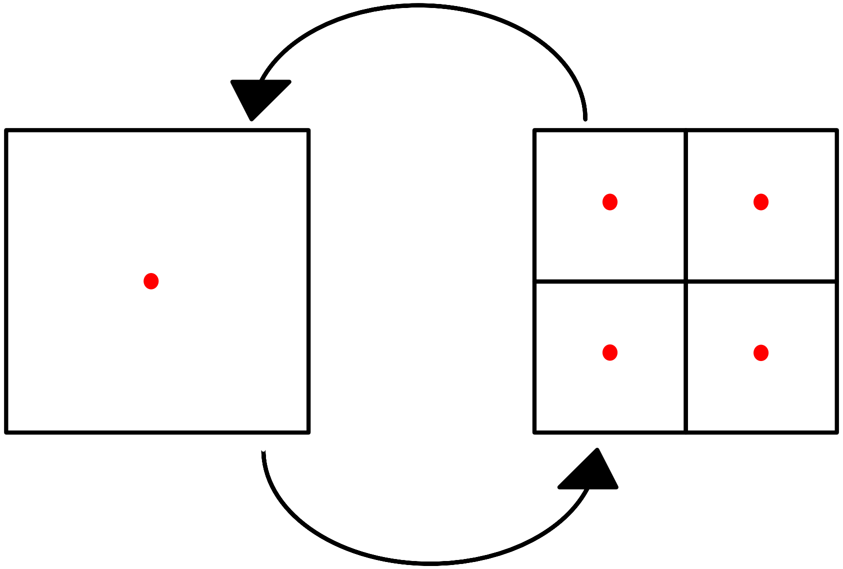


Calculate new values with Ansatz functions

Reconstruction of primary variables

CC FV method:

Averaging of values



Same value as father

Indicator

Two types of indicators:

- *Initialization Indicator* (refine at boundaries / source)
- *Runtime Indicator* (refine, coarse cells during runtime)

Example: Indicator for Saturation

$$\mathcal{I}(e_i) = \max_{j \in \mathcal{N}(i)} |S_i - S_j|$$

refine: $\mathcal{I}(e_i) > \mathrm{TOL}_{ref} |S^{\max} - S^{\min}|$

coarse: $\mathcal{I}(e_i) < \mathrm{TOL}_{coar} |S^{\max} - S^{\min}|$

Basic GridAdapt Properties

General Properties

- *AdaptiveGrid (true or false)*
- *AdaptionIndicator, AdaptionInitializationIndicator*

Initialization Indicator

- *RefineAtDirichletBC, RefineAtFluxBC, RefineAtSource*

Runtime Indicator

- *MinLevel, MaxLevel*
- *RefineTolerance, CoarsenTolerance*

Adaptation during runtime

Using adaptivity for the implicit model:

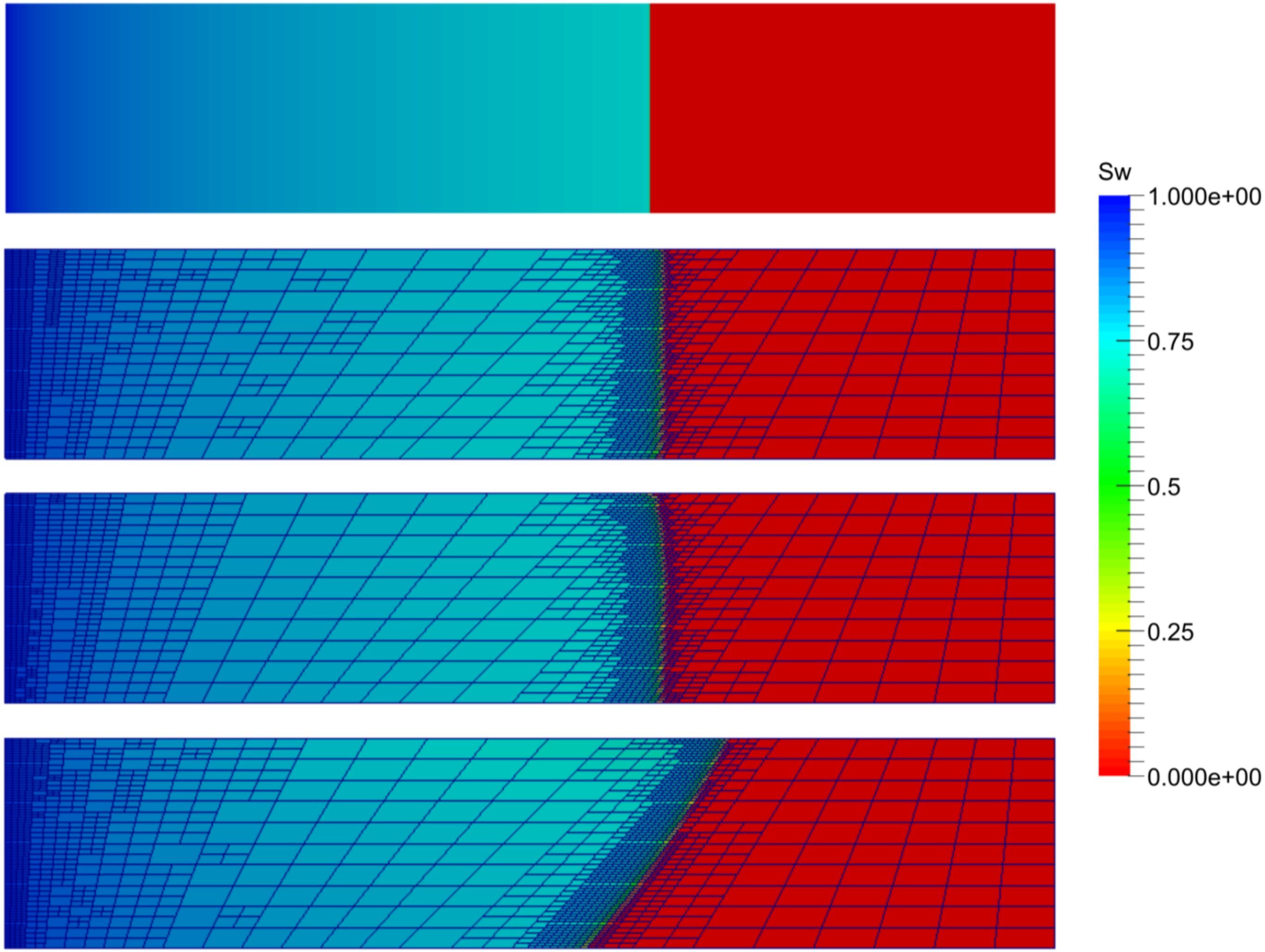
- Main routine is called in: *problem.preTimeStep()*

- Construction of new jacobian matrix in: *model.updateBegin()*

Important Facts

- Box method can not be used for nonconforming adaptation
- Cell Centered TPFA method may produce huge errors at hanging nodes
- This could influence convergence of Newton solver
- Adaptivity is not yet implemented for all solvers

Accuracy



Exact:

MPFA:

NLTPFA:

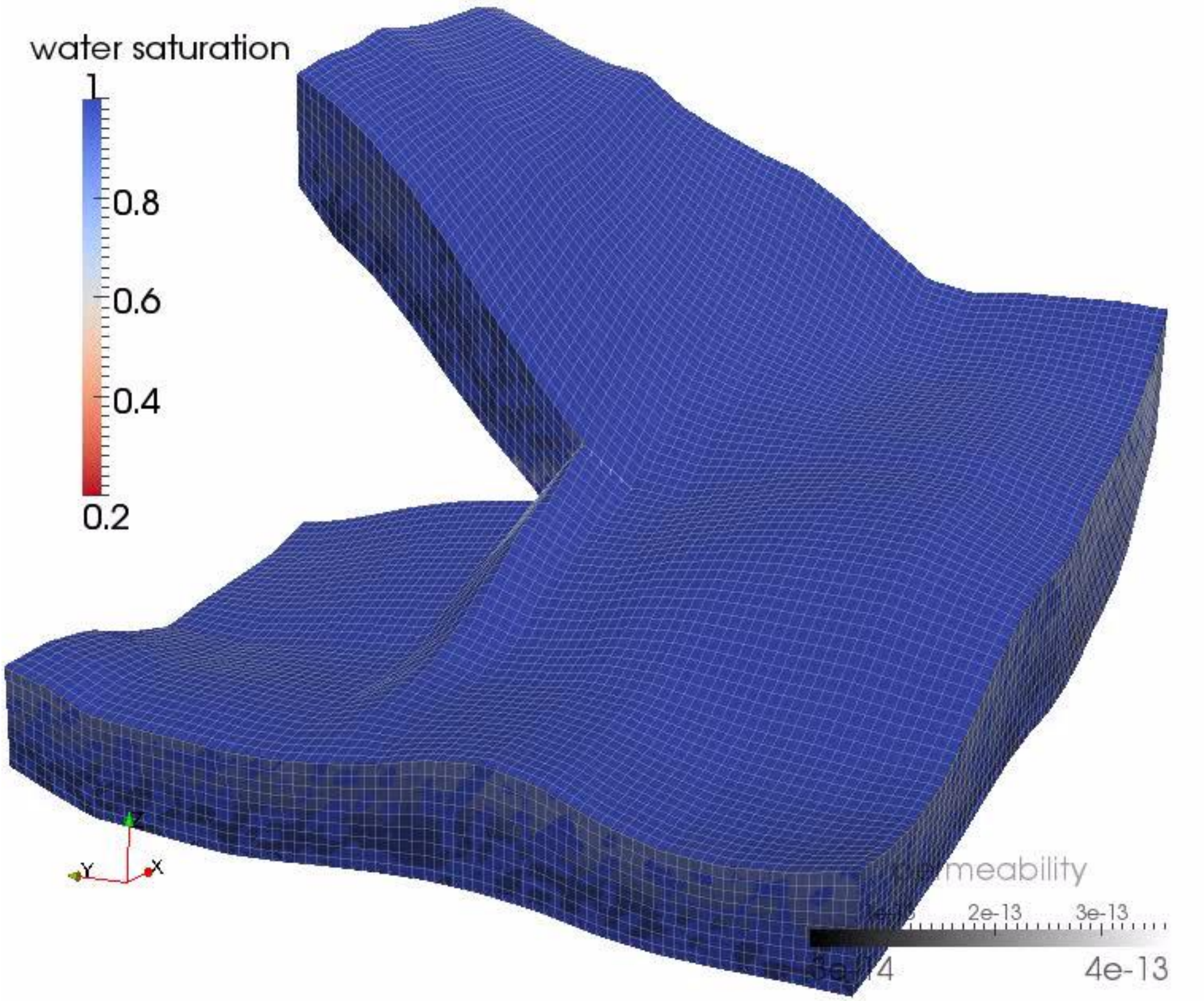
TPFA:

www.hydrosys.uni-stuttgart.de

Complex Example

CO_2 injection into

Johanson formation



(B. Faigle: Adaptive Multi-Physics)