Local grid refinement in OPM

Antonella Ritorto

Dr. Blatt HPC-Simulation-Software & Services

antonella.ritorto@opm-op.com

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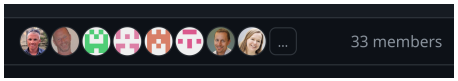
Dresden

About OPM OPEN POROUS MEDIA

- **Who are we?**
  Collaborative software developers

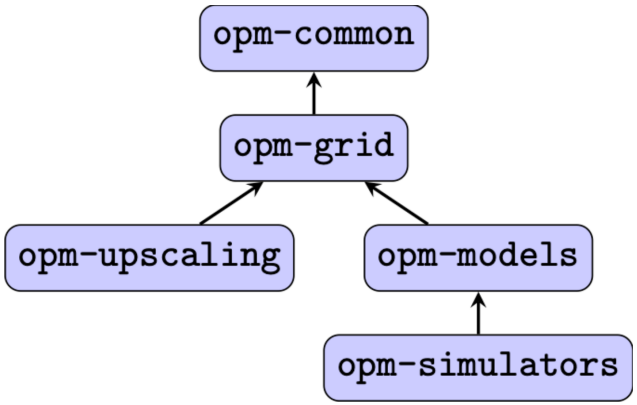


- **What do we do?**
  Modeling and simulation of porous media processes
  - CO_2 sequestration
  - Oil recovery

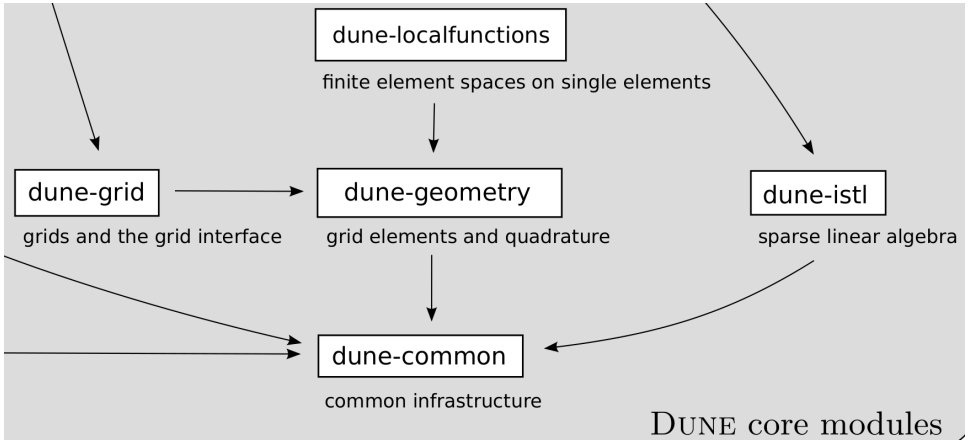
- **What do we provide?**
  Open-source software and open data sets
  Tools to create/customize solvers and simulators:
  - OPM Flow
    Reservoir simulator for three-phase black-oil problems
  - Upscaling
    Flow-based upscaling of (relative) permeability and capillary curves
  - ResInsight
    Visualization tool for reservoir simulation

Modules

OPM core modules



DUNE core modules (⋆)



- opm-common
  - build system
  - Eclipse deck parser, Eclipse binary format I/O
- **opm-grid**
- opm-simulators
  - OPM Flow
  - automatic differentiation library
  - solvers: IMPES, 2-phase incompressible transport, ...

(⋆) from **DUNE-The distributed and Unified Numerics Environment, Oliver Sander**.

Corner-**p**oint **Grid**

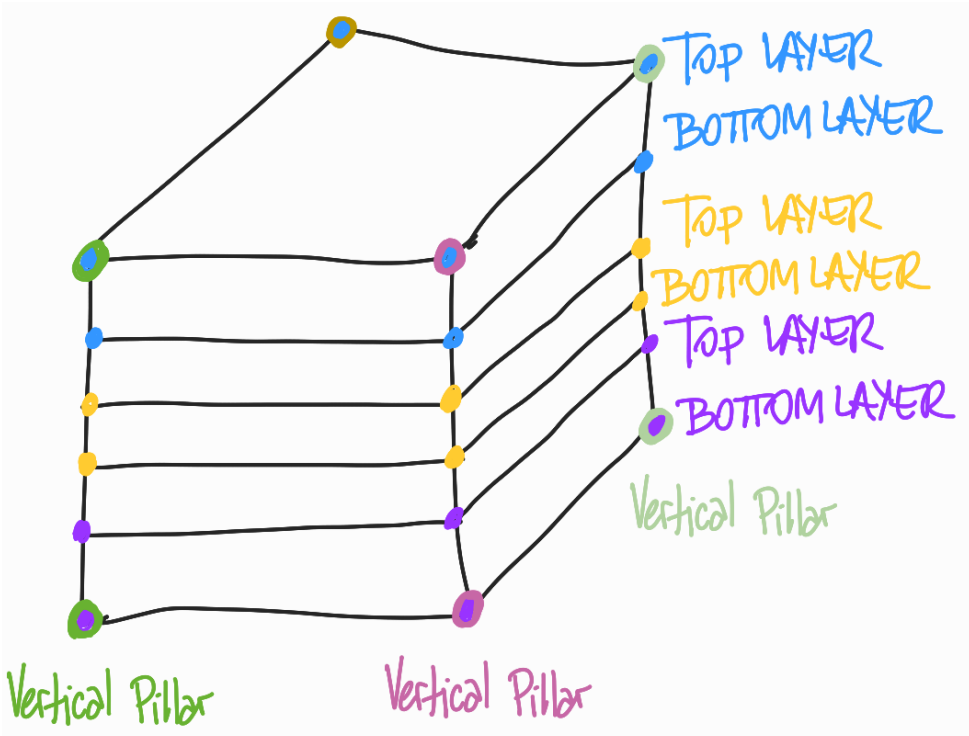
opm-grid

DUNE module supporting

- CpGrid → corner-point grid
- PolyhedralGrid → fully unstructured grid

CpGrid defined by **vertical pillars** and **layers** (might vanish/collapse!)

```
RUNSPEC
DIMENS
1  1  5 /
GRID
COORD
--- Vertical pillar
0 0 0
0 0 1
--- Vertical pillar
1 0 0
1 0 1
--- Vertical piller
0 1 0
0 1 1
--- Vertical pillar
1 1 0
1 1 1 /
ZCORN  --- depth of each corner point
4*0  --- top layer 1
8*1  --- bottom layer 1
8*2  --- top layer 2
8*3  --- bottom layer 2
8*4  --- top layer 3
4*5  --- bottom layer 3 /
ACTNUM
5*1  --- all 5 cells active /
PORO
5*0.15
```



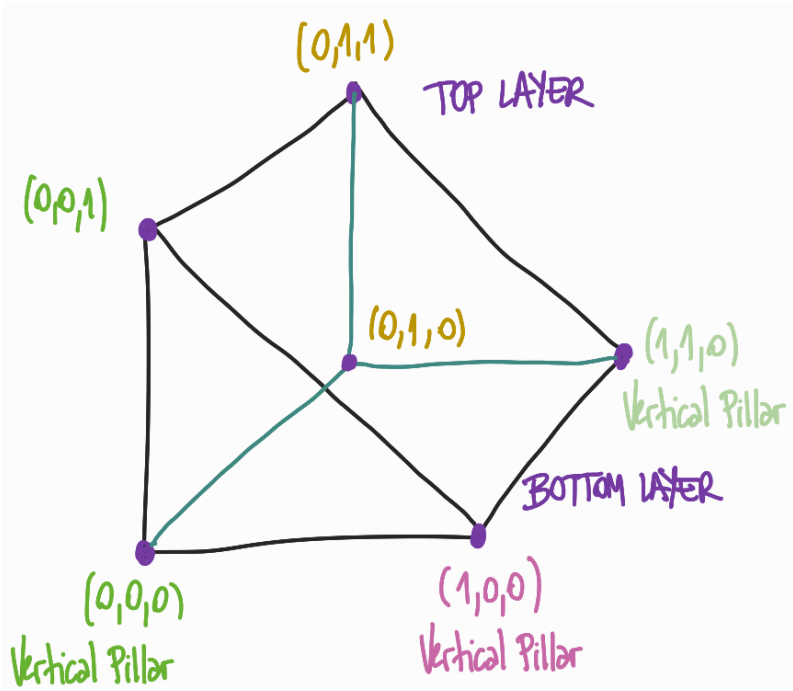
opm-grid

DUNE module supporting

- CpGrid → corner-point grid
- PolyhedralGrid → fully unstructured grid

CpGrid defined by **vertical pillars** and **layers** (might vanish/collapse!)

```
RUNSPEC
DIMENS
1  1  1 /
GRID
COORD
--- Vertical Pillar
0 0 0  0 0 1
--- Vertical Pillar
1 0 0  1 0 0
--- Vertical Pillar
0 1 0  0 1 1
--- Vertical Pillar
1 1 0  1 1 0
/
ZCORN
4*0  --- top layer
4*1  --- bottom layer
/
ACTNUM
1*1
```



(Regular) Cartesian grid example - SPE1

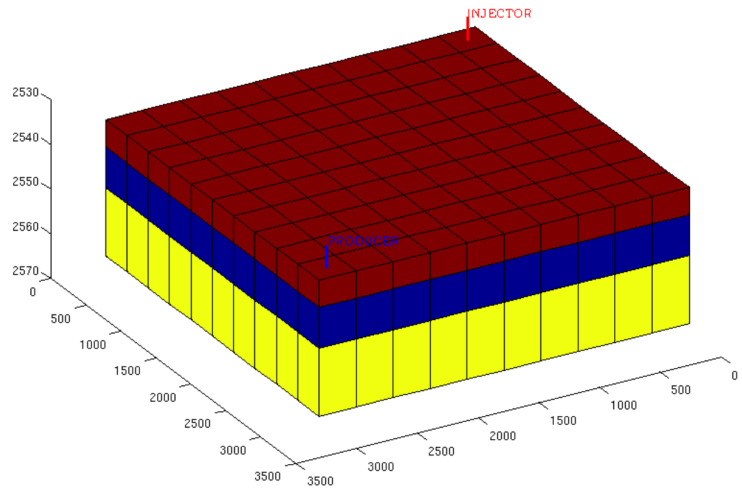
Reservoir model from the **1st** **S**ociety of **P**etroleum **E**ngineers Comparative Solution Project

Designed for bench marking 3D black-oil simulators

- Three-layer permeability structure
- Injection well
- Production well

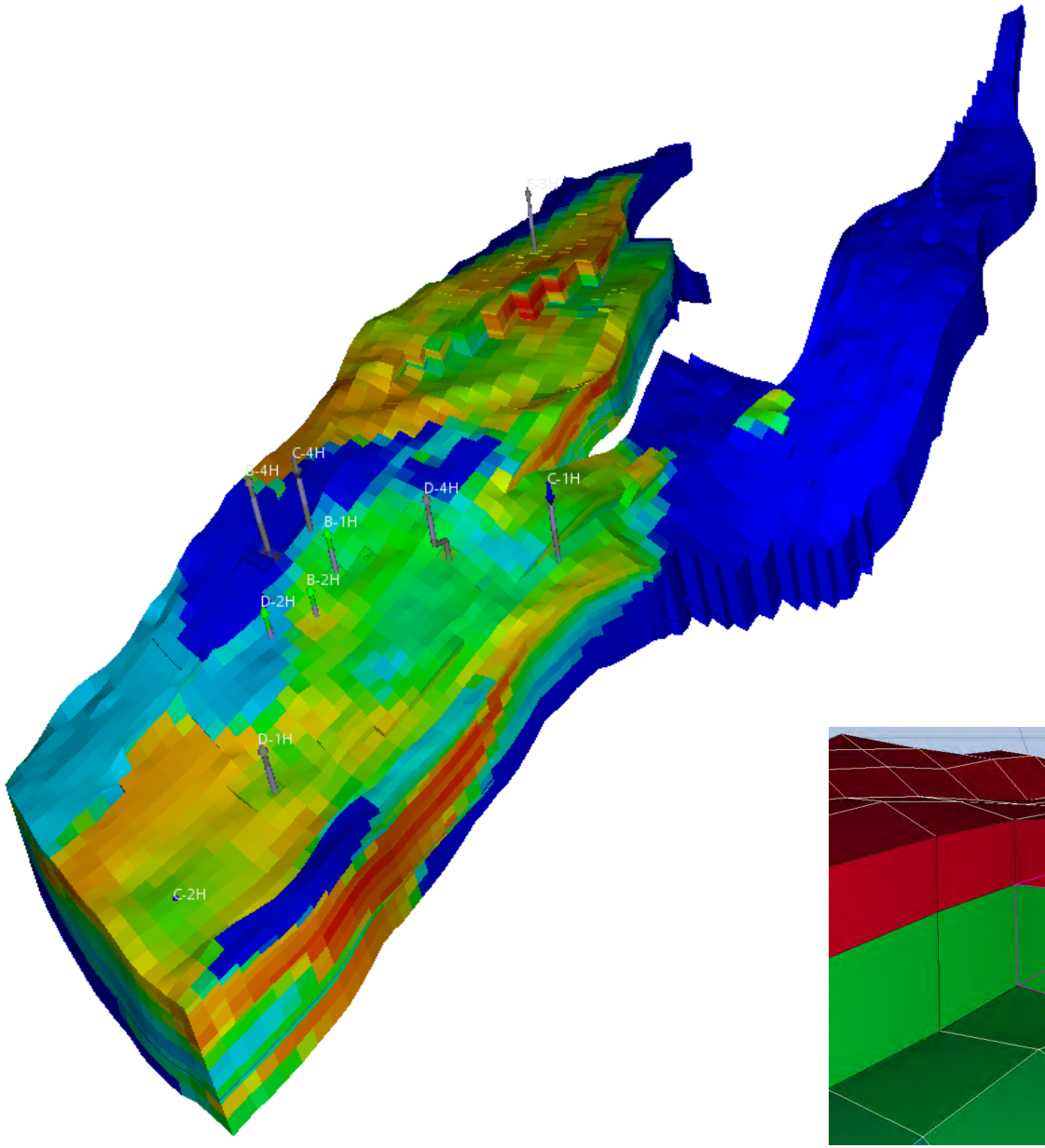
The reservoir is filled in with **oil** and **water**
Gas is injected thought the injection well

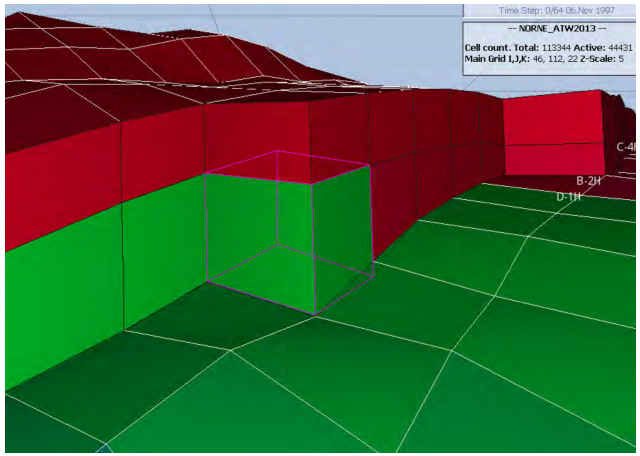
```
RUNSPEC
DIMENS
   10 10 3 /

GRID
DX
-- There are in total 300 cells with length 1000ft in x-direction
      300*1000 /
DY
-- There are in total 300 cells with length 1000ft in y-direction
      300*1000 /
DZ
-- The layers are 20, 30 and 50 ft thick, in each layer there are 100 cells
      100*20 100*30 100*50 /

TOPS
-- The depth of the top of each grid block
      100*8325 /
```



OPM Flow manual, David Baxendale

(Irregular) Corner-point Grid example - Norne oil field

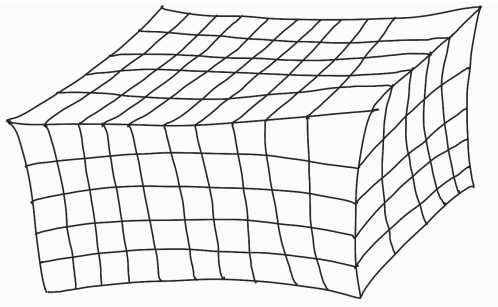




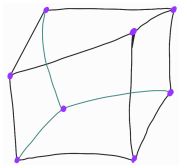
OPM Flow manual, David Baxendale

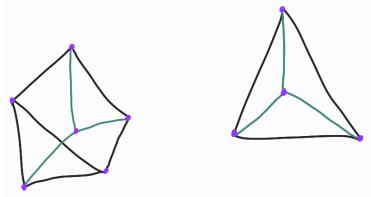
Corner point grid

Corner point grid $\rightsquigarrow$ degenerated and distorted **Cartesian grid**



Degenerated/distorted cells





It provides mappings from cells to the underlying **Cartesian Index**

Each cell can be **ACTIVE** or **INACTIVE**

Dune::CpGrid::createCartesian method

```
void createCartesian(const std::array<int, 3>& dims,
                     const std::array<double, 3>& cellsize,
                     const std::array<int, 3>& shift = {0,0,0});
```

- dims $\rightsquigarrow$ number of cells in each Cartesian direction
- cellsize $\rightsquigarrow$ size of each cell in each direction
- shift $\rightsquigarrow$ origin of the grid
  $\rightsquigarrow$ corner of the cell with Cartesian Index $(0, 0, 0)$

Local **G**rid **R**efinement

Local Grid Refinement in OPM

Cooperation between

TNO

SINTEF

Dr. Blatt - HPC-Simulation-Software & Services

Local Grid Refinement in OPM

LGR project is a cooperation between

TNO

Bård Skaflestad
SINTEF

Dr. Blatt-HPC-Simulation-Software & Services

How it was one year ago

LGR ACTIVITIES

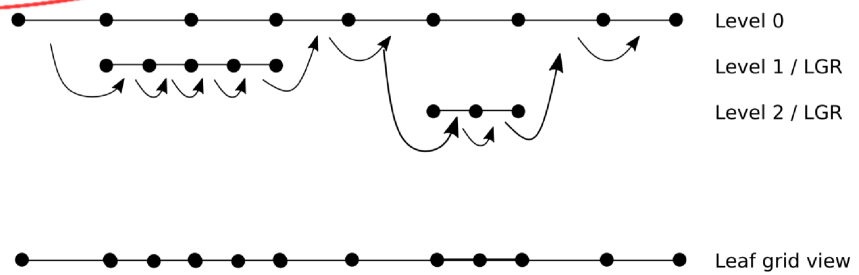
~~CURRENT STATUS~~ one year ago

- Literature and simulators reviewed: Eclipse, CMG, MRST, papers...
- Tests cases created and pushed to opm-tests
- Designing plan for code implementation to support the following aspects of LGR functionality (in cooperation with SINTEF and OPM-OP AS)
- Requires code changes in several repositories: opm-common, opm-grid and opm-simulators
- Challenges:
  - Allow wells to cross over grids (means solving the all
  - Output and restart of models with LGR
  - Extensive code refactoring in opm-grid needed

Cíntia Machado et al. (TNO) – Recent OPM Devel

- Changes to opm-grid:
  - Store multiple level grids in CpGrid
  - Identify Mother-Child relationships
  - Store/Compute/Iterate over leaf grid view

!

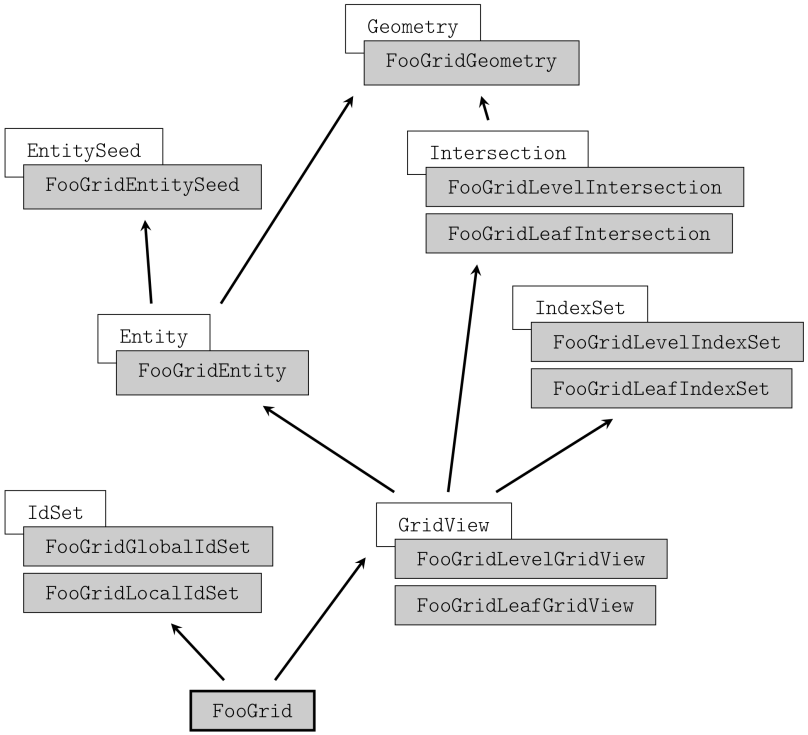



```
           std::vector<Geometry<3, cdim>> refine(const std::array<int, 3>& cells_per_dim,
                                                 std::vector<EntityVariable<Geometry<0, 3>, 3>>&
corner_storage,
                                                 std::vector<std::array<int, 8>>& indices_storage)
```

OPM Summit 2022

What has been done in opm-grid

Using DUNE's adaptive grid interface($\star$)

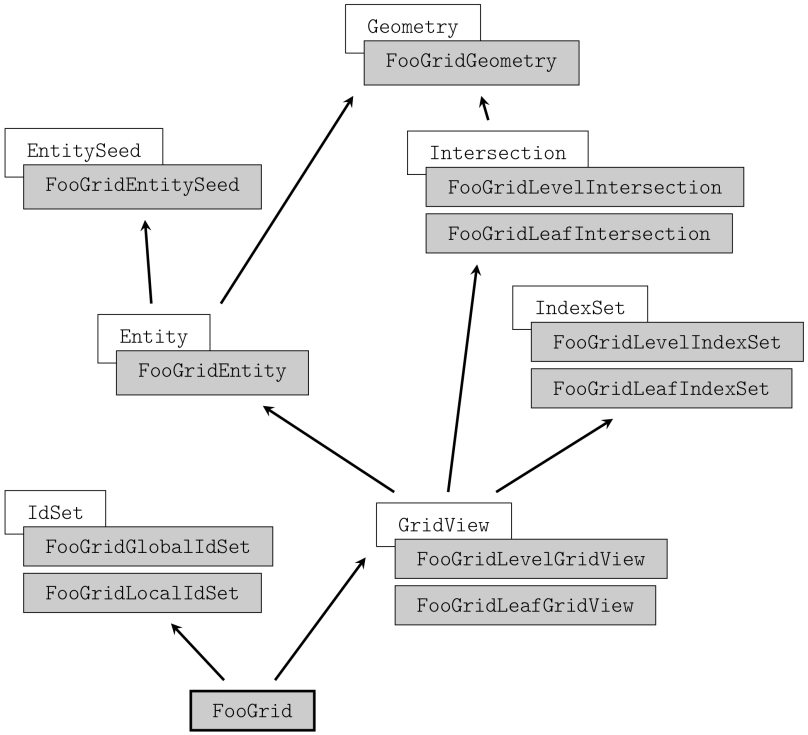


- Create and store multiple level grids in CpGrid ✓
- Identify Parent-Child relationships ✓
- Store/compute/iterate over leaf grid view ✓

($\star$) from **DUNE-The distributed and Unified Numerics Environment, Oliver Sander**.

What has been done in opm-grid

Using DUNE's adaptive grid interface($\star$)

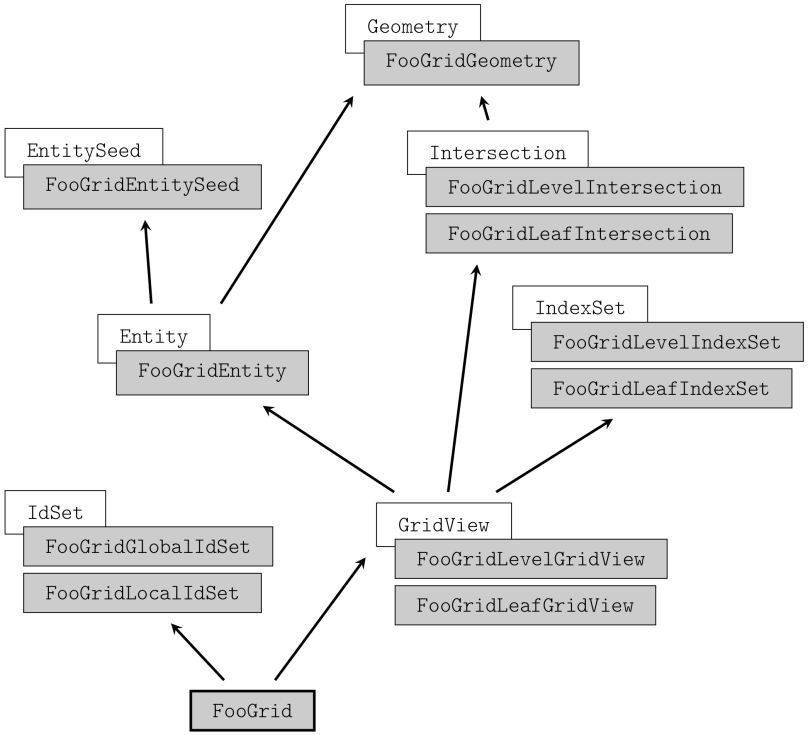


- Create and store multiple level grids in CpGrid ✓
- Identify Parent-Child relationships ✓
- Store/compute/iterate over leaf grid view ✓ **How?**

($\star$) from **DUNE-The distributed and Unified Numerics Environment, Oliver Sander**.

What has been done in opm-grid - How?

Using DUNE's adaptive grid interface($\star$)

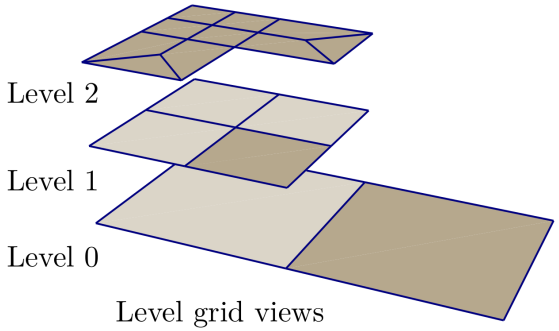



```
void addLgrsUpdateLeafView(const std::vector<std::array<int,3>>& cells_per_dim_vec,
                           const std::vector<std::array<int,3>>& startIJK_vec,
                           const std::vector<std::array<int,3>>& endIJK_vec,
                           const std::vector<std::string>& lgr_name_vec);
```

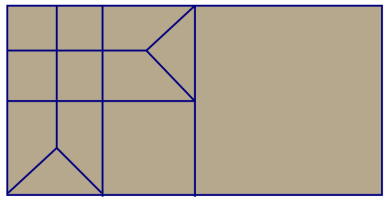
- **Hierarchical Grids** (refinement; geometrical and topological features)
- **Entity::father(), hasFather(), geometryInFather(), ...**
- **Hierarchical Grids and Leaf Grid View** (iterators, ...)

Hierarchical grids and grid views in OPM - **Now!**

DUNE(⋆)

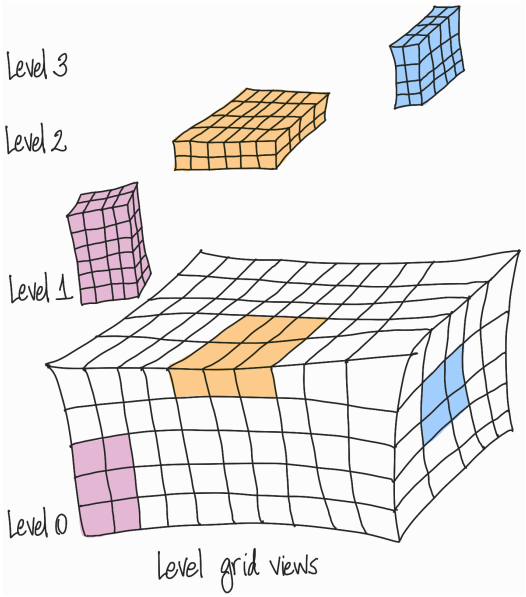


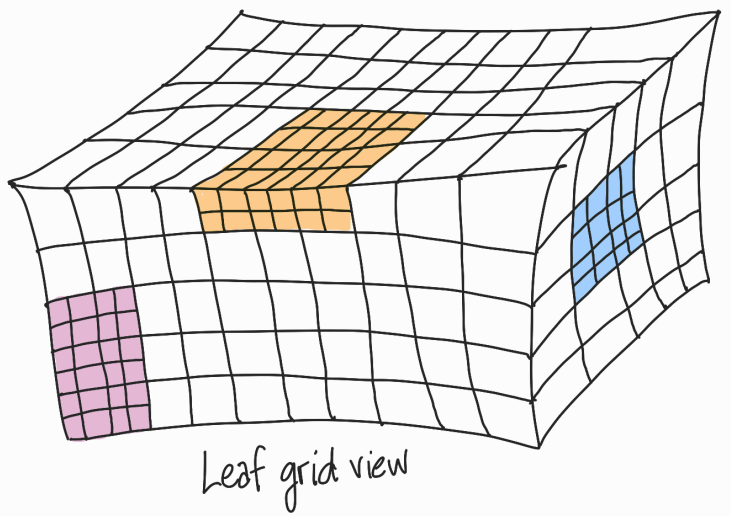
Level grid views



Leaf grid view

OPM - **Now!**

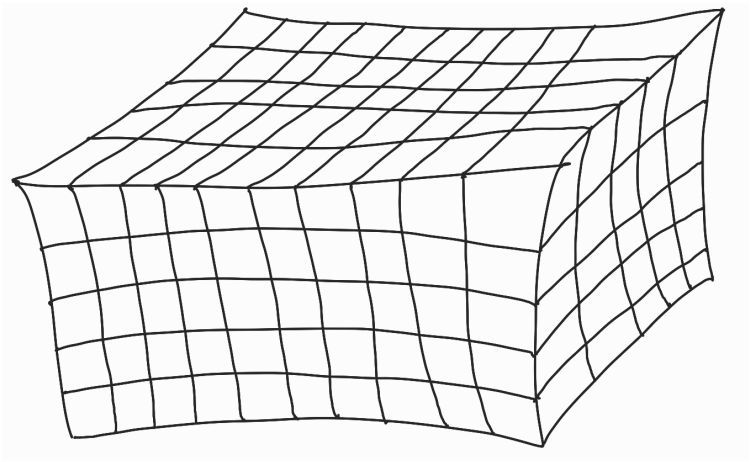


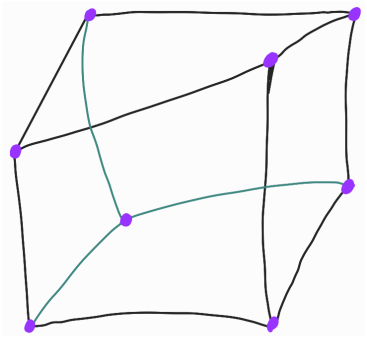


(⋆) from **DUNE-The distributed and Unified Numerics Environment, Oliver Sander**.

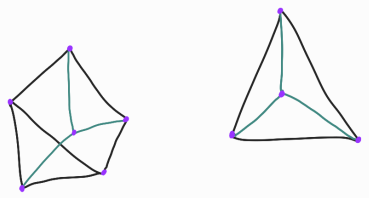
Technical (temporary!) limitations

1. **Corner point / Cartesian grid** $\rightarrow$ cells with 8 corners





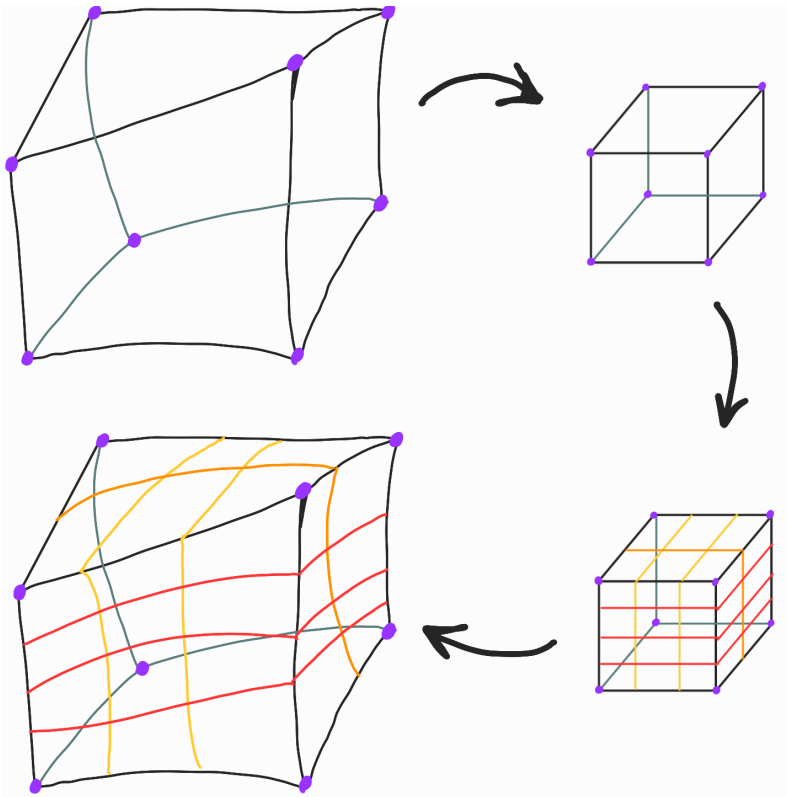
Non (yet) supported cells:



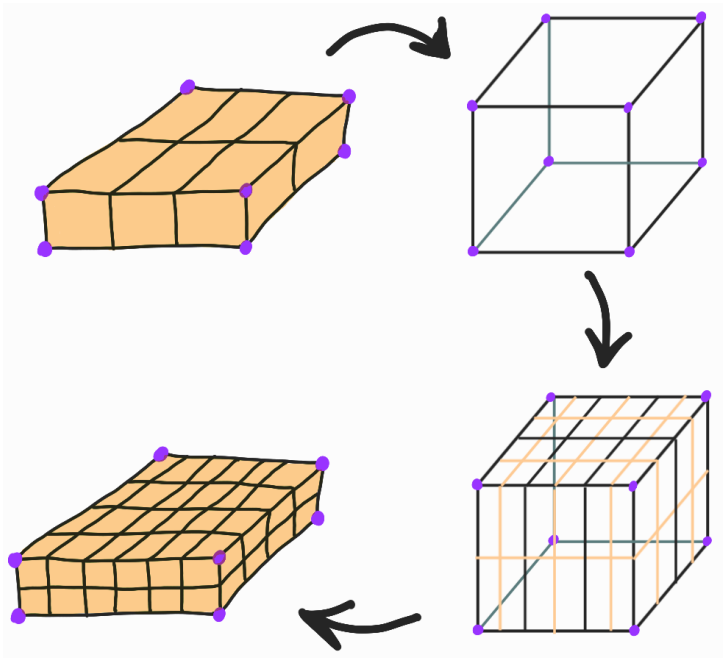
2. All cells are **ACTIVE**

Local grid refinement in OPM

Refine single cell

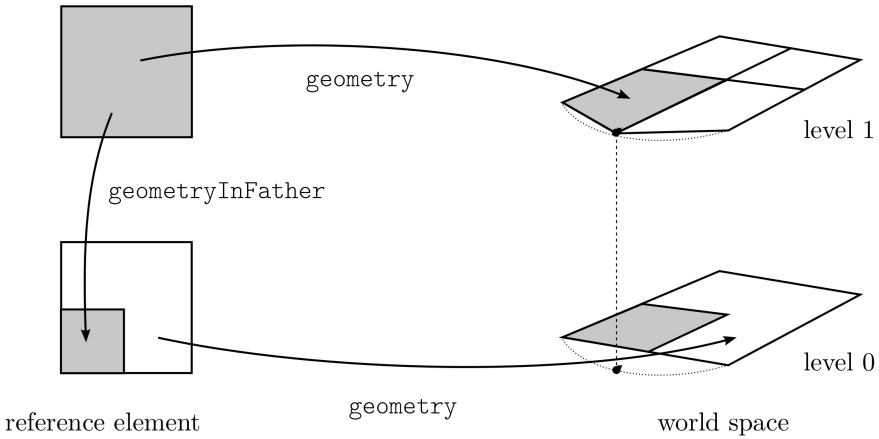


Refine block-shaped patch

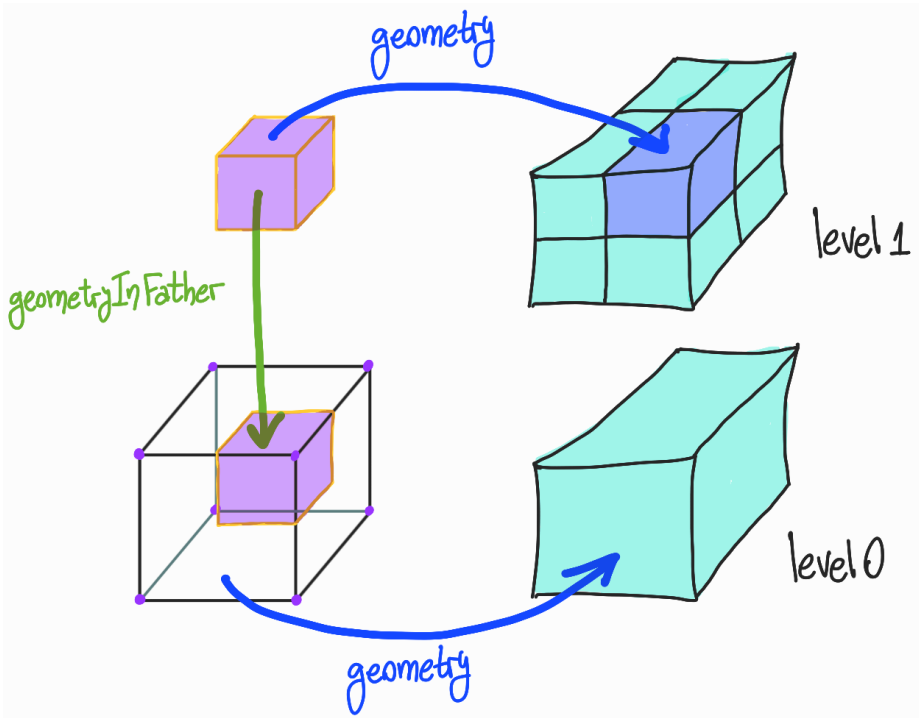


Entity::geometryInFather()

DUNE(⋆)



OPM

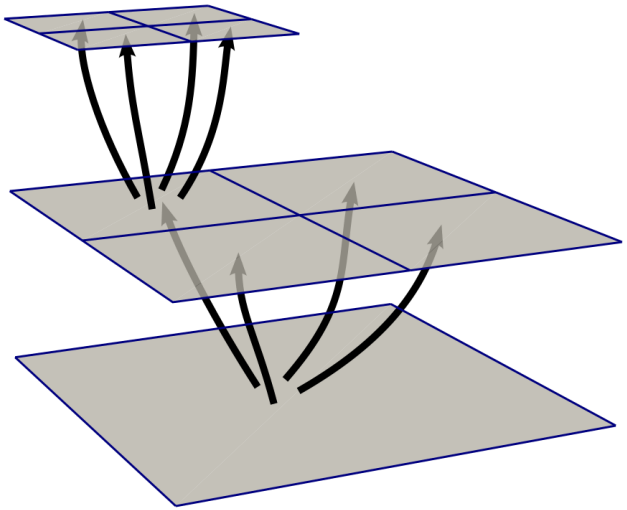


(⋆) from **DUNE-The distributed and Unified Numerics Environment, Oliver Sander**.

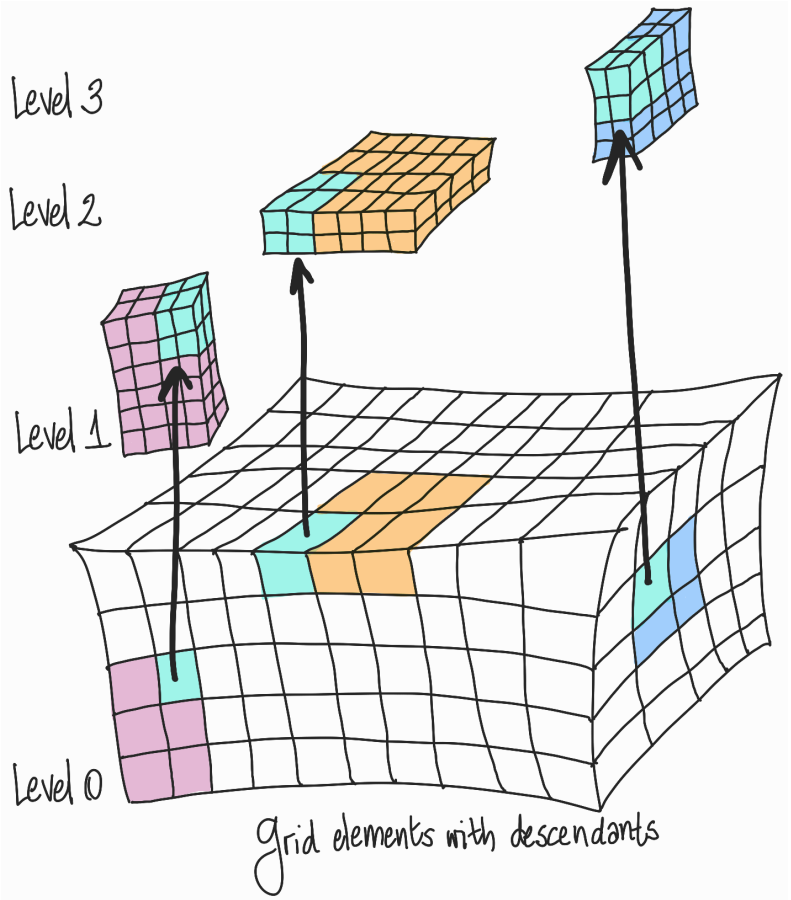
Entity::hasFather(), father()

Grid elements with descendants

DUNE($\star$)



OPM



($\star$) from **DUNE-The distributed and Unified Numerics Environment, Oliver Sander**.

When do LGRs appear in the simulation?

OPM

LGRs in (oil) simulation

- are defined at the
beginning of the simulation

- can be **switched on and off during the simulation**

DUNE

Decide which cells should be
- refined
- coarsened
during simulation

After that,
simulation continues

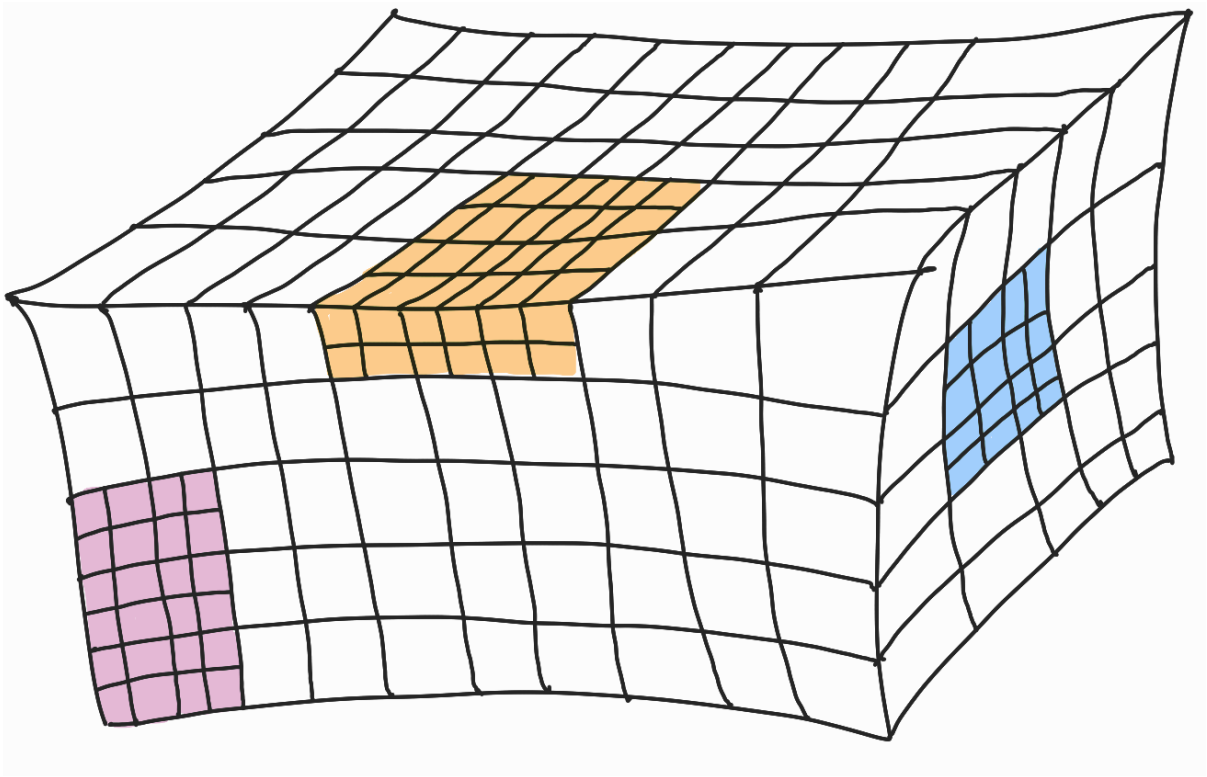
Refine/coarsen
takes place again

Wrapping up

One year ago...	**Now!**	**What's next?**
• Level 0 = Leaf Grid View • *Incomplete* Geometry::refine single cell	• Multiple level grids • Parent-Child relations • Update Leaf Grid View	• Mark subset of leaf grid elements - to refine - to coarsen • Call - adapt() - preAdapt() - postAdapt()

Further...

- Remove *temporary* constrains:
  - allow **INACTIVE elements in the LGRs**
  - allow **elements with fewer corners** (8 currently)



Thank you for your attention!

Dr. Blatt HPC-Simulation-Software & Services

OPM
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Check our GitHub repository OPM/opm-grid!