

Elmer Parallel Computations

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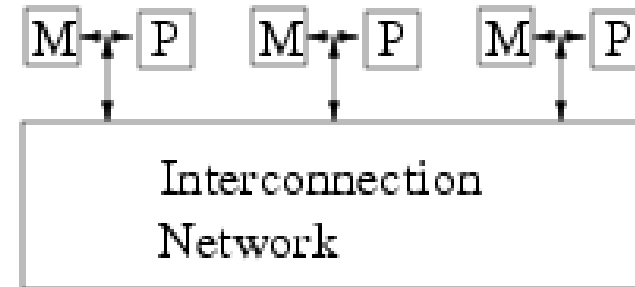
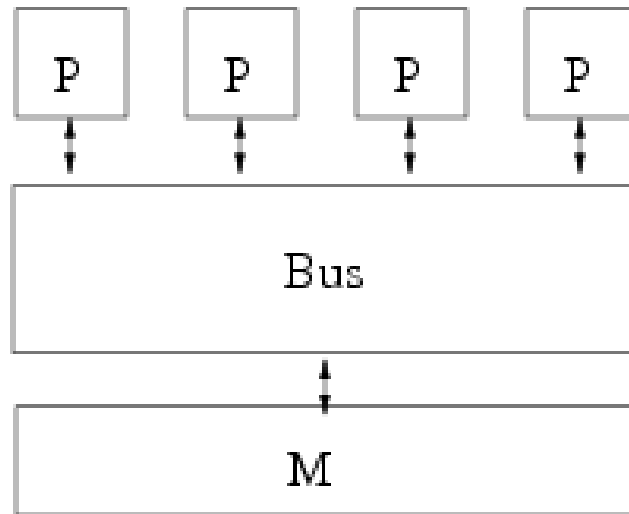
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CSC . IT Center for Science Ltd.

Motivation

- “ Current CPUs: 6 cores
(AMD Opteron *Shanghai*)
- “ Your PC is a
+supercomputer+
- “ Multi-threading (e.g.,
OpenMP) on shared
memory units
- “ HPC: Message passing

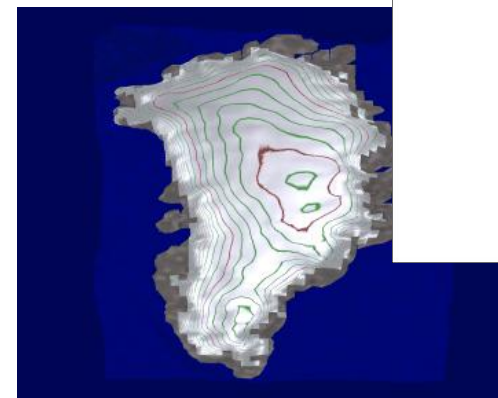
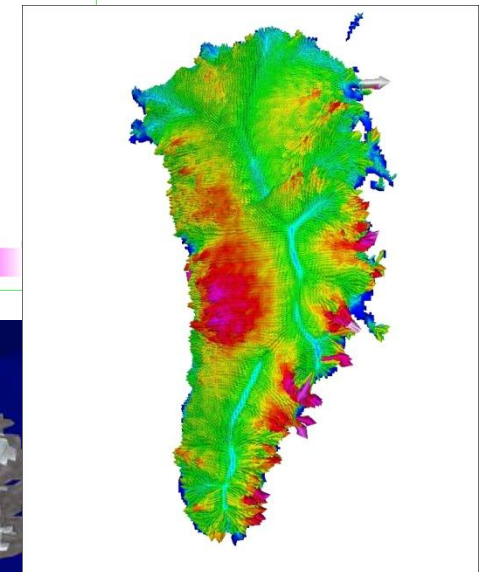
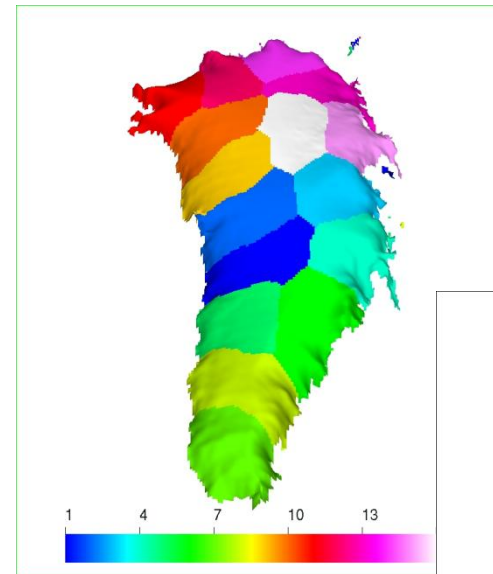


Motivation



Motivation

- “ Grand challenges
- “ Pre-processing:
 - . Automated meshing
- “ Post-processing:
 - . Parallel post processing:
ParaView

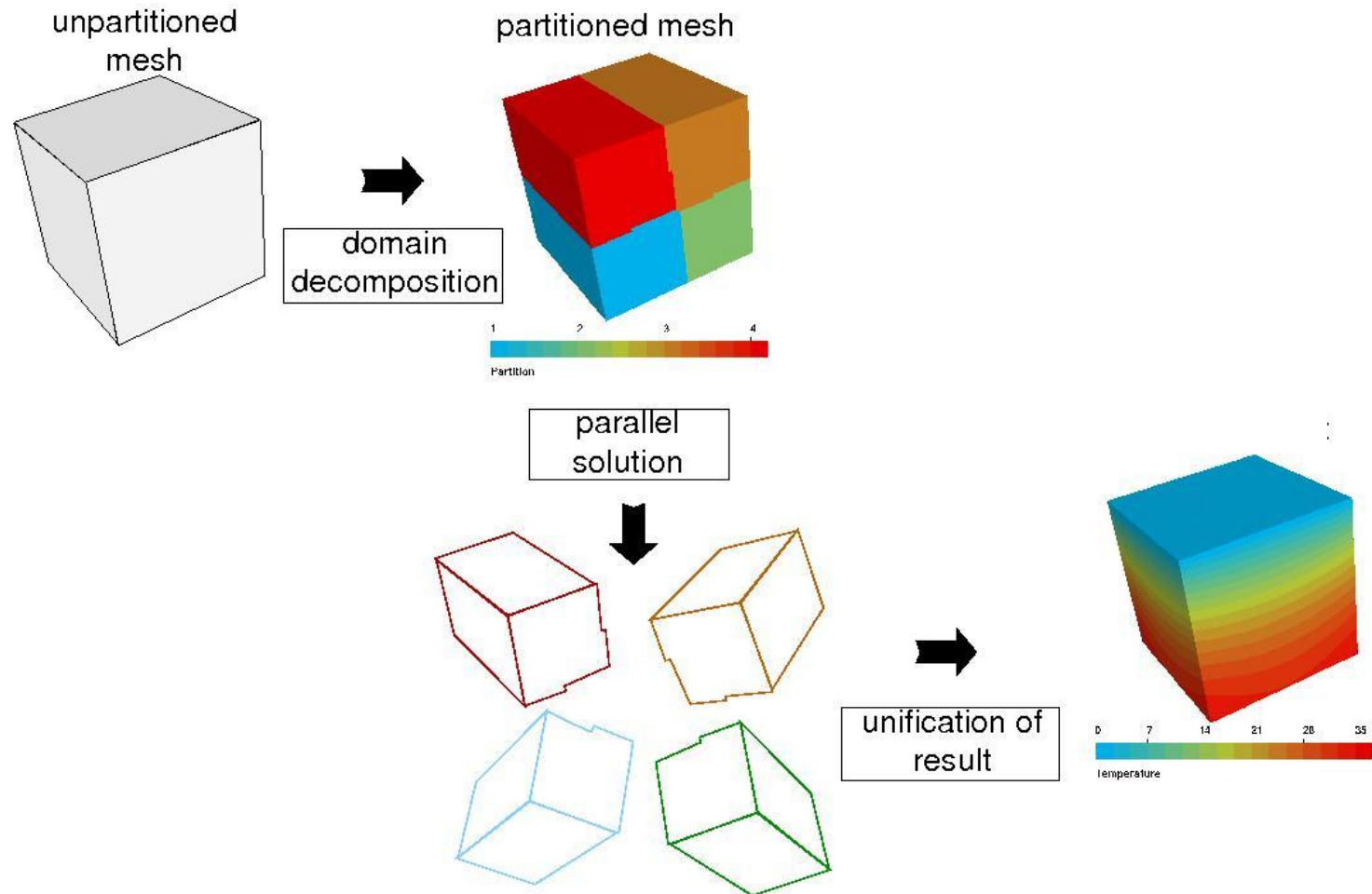


Parallel Concept of Elmer

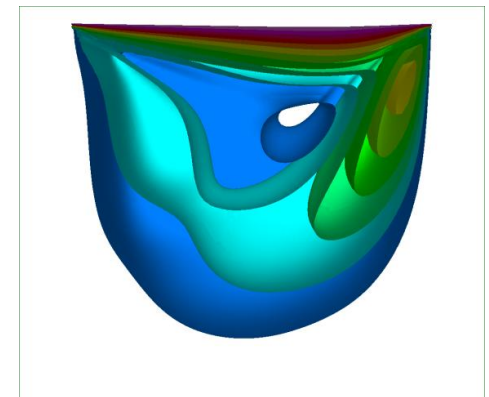
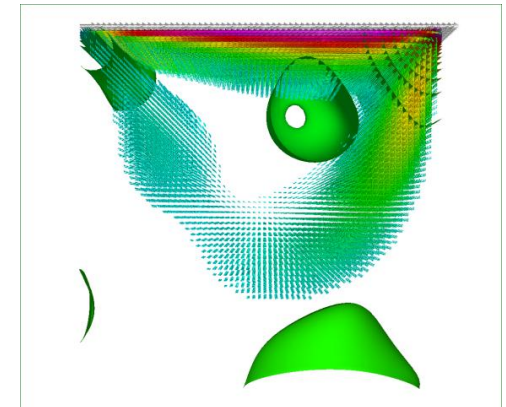
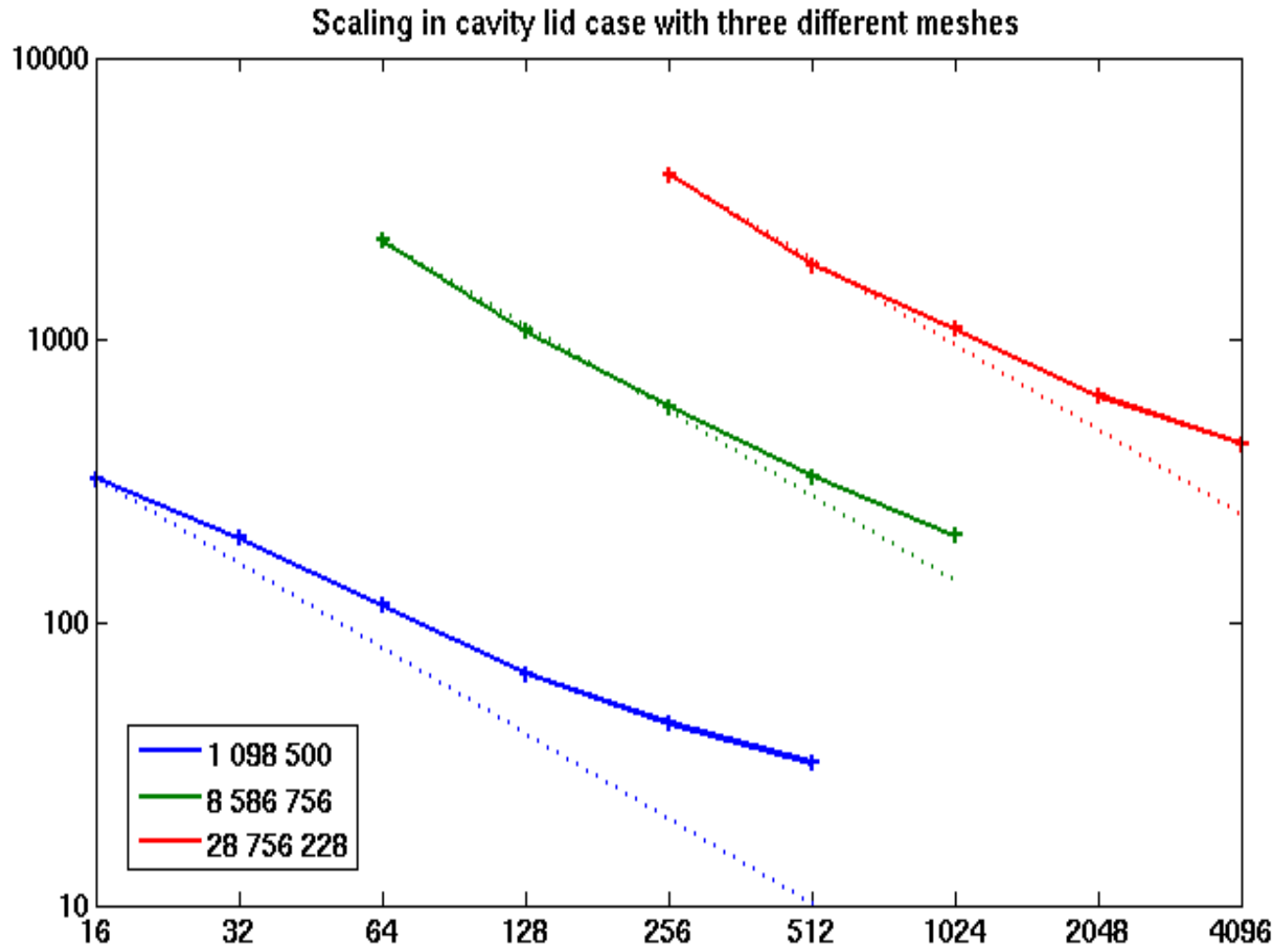


- “ Domain decomposition
- “ Additional pre-processing step (splitting)
- “ Every domain is running its own ElmerSolver
- “ Parallel process communication: MPI
- “ Slightly different strategies as serial
- “ Re-combination of ElmerPost output

Parallel Concept of Elmer



Parallel Concept of Elmer



Scaling of wall clock time with dofs in the cavity lid case using GMRES+ILU0. Simulation Juha Ruokolainen, CSC, visualization Matti Gröhn, CSC.

Elmer parallel mesh



” **Serial mesh structure:** `directoryname/`

- . **Header file** contains general dimensions: `mesh.header`
- . **Node file** contains coordinate and ownership of nodes:
`mesh.nodes`
- . **Elements file** contains composition of bulk elements and
ownerships (bodies): `mesh.elements`
- . **Boundary file** contains composition of elements and ownerships
(boundaries) and dependencies (parents) boundary elements:
`mesh.boundary`

Elmer parallel mesh



” Parallel mesh structure:

`directoryname/partitioning.N/`

- . **Header file:** `part.1.header, part.2.header, ... part.N.header`
- . **Nodes:** `part.1.nodes, part.2.nodes, ... part.N.nodes`
- . **Elements:** `part.1.elements, part.2.elements, ... part.N.elements`
- . **Boundary elements:** `part.1.boundary, part.2.boundary, ... part.N.boundary`
- . **Shared nodes between partitions:** `part.1.shared, part.2.shared, ... part.N.shared`

Elmer parallel mesh



” Best way to partition:

Serial mesh ElmerGrid parallel mesh

” General syntax:

```
ElmerGrid 2 2 existing [partoption]
```

” Principle 2 partitioning techniques:

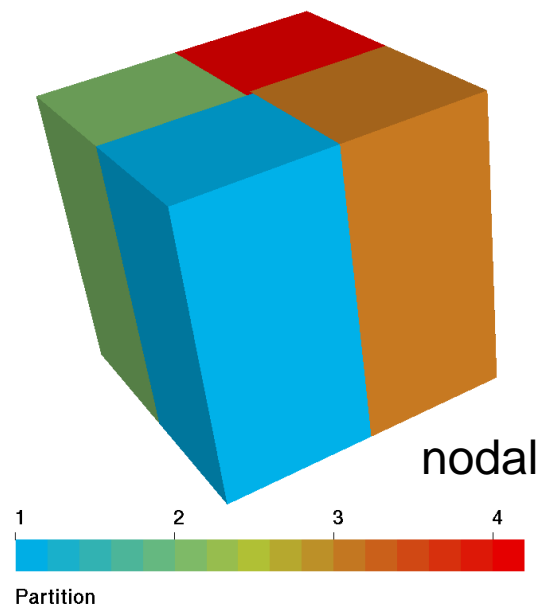
1. Along Cartesian axis (simple geometries/topologies)
2. Using METIS library

Elmer parallel mesh

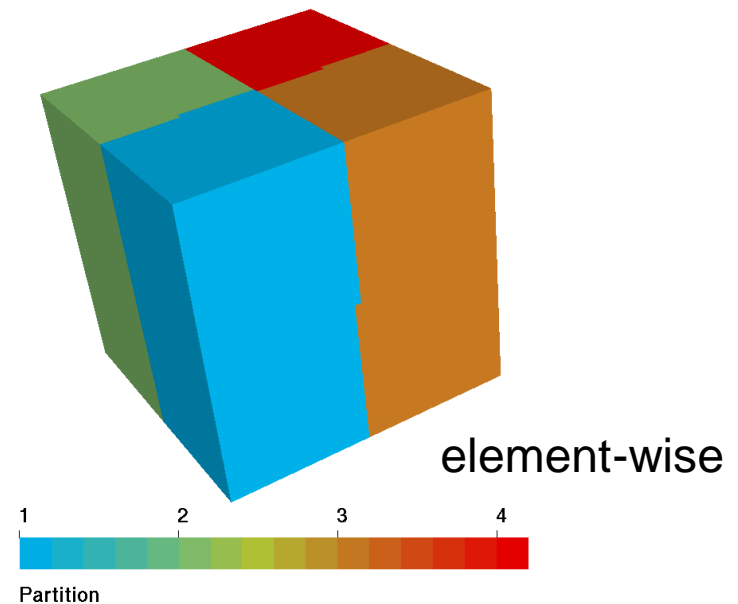


Directional decomposition:

```
ElmerGrid 2 2 dir -partition  $N_x$   $N_y$   $N_z$   $F$ 
```



```
-partition 2 2 1 0
```



```
-partition 2 2 1 1
```

Elmer parallel mesh



Directional decomposition:

```
ElmerGrid 2 2 dir -partition  $N_x$   $N_y$   $N_z$   $F$   
-partorder  $n_x$   $n_y$   $n_z$ 
```

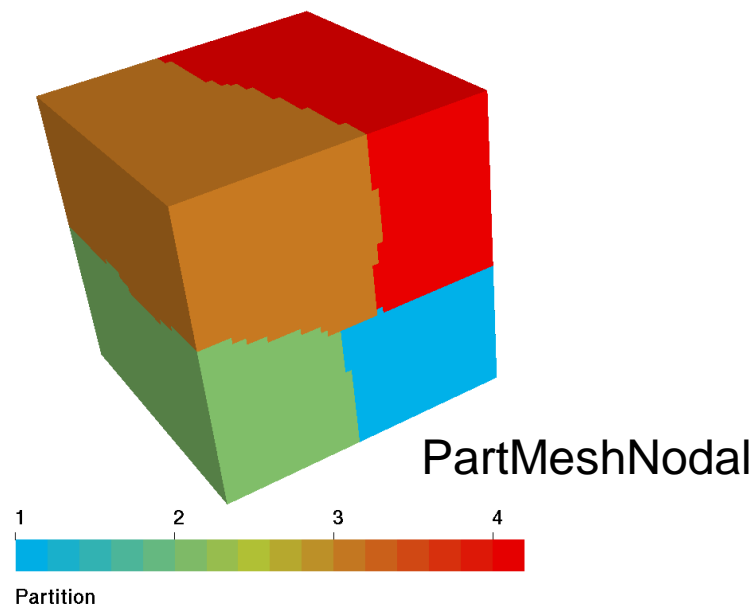
Defines the ordering direction (components of vector)

Elmer parallel mesh

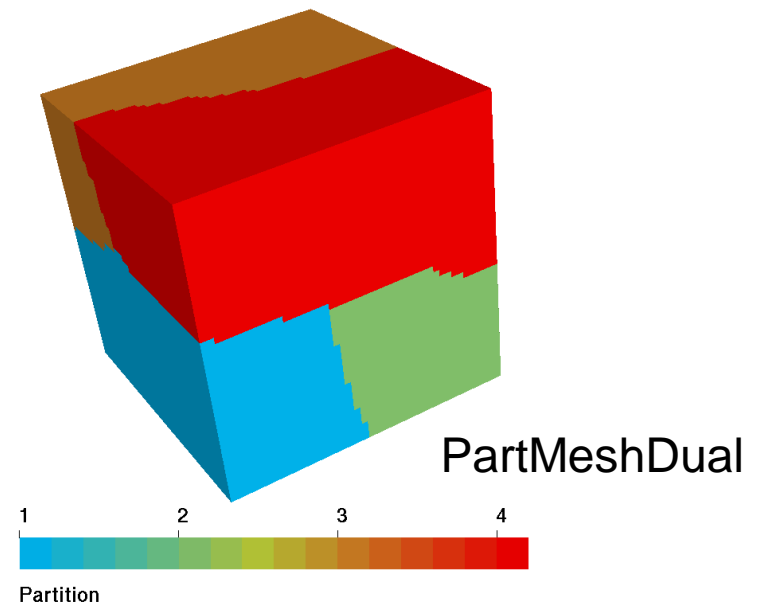


METIS:

```
ElmerGrid 2 2 dir -metis N Method
```



```
-metis 4 0
```



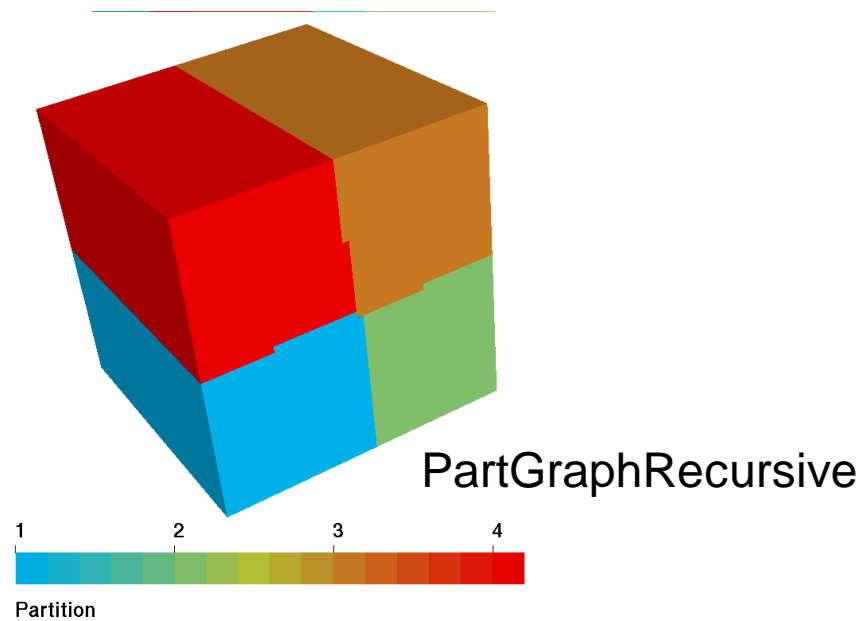
```
-metis 4 1
```

Elmer parallel mesh

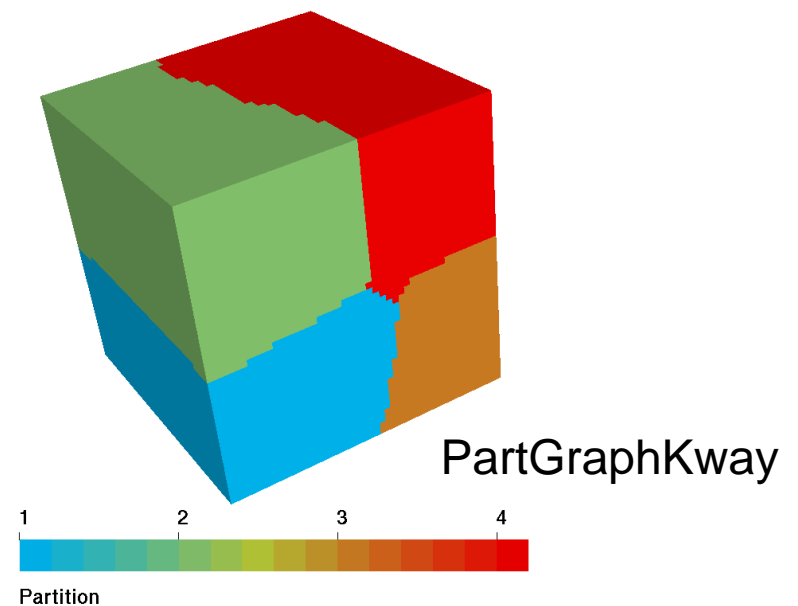


METIS:

```
ElmerGrid 2 2 dir -metis N Method
```



```
-metis 4 2
```



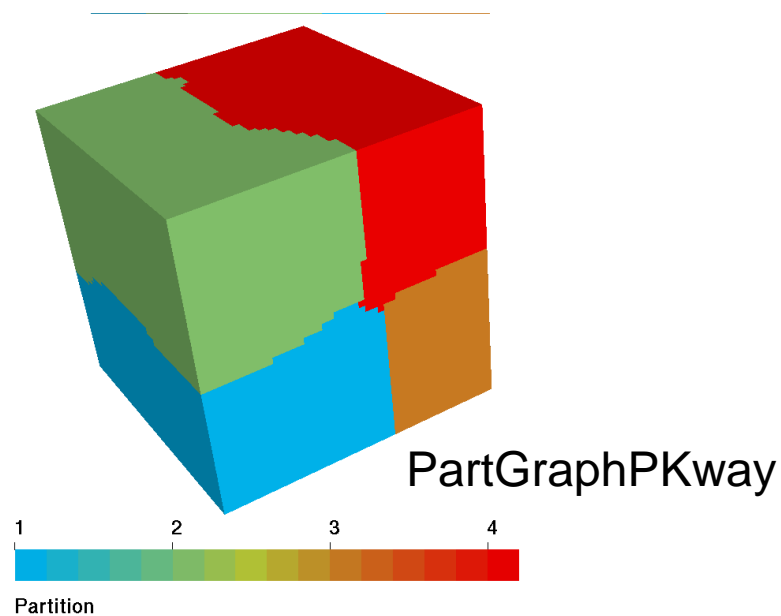
```
-metis 4 3
```

Elmer parallel mesh



METIS:

```
ElmerGrid 2 2 dir -metis N Method
```



```
-metis 4 2
```

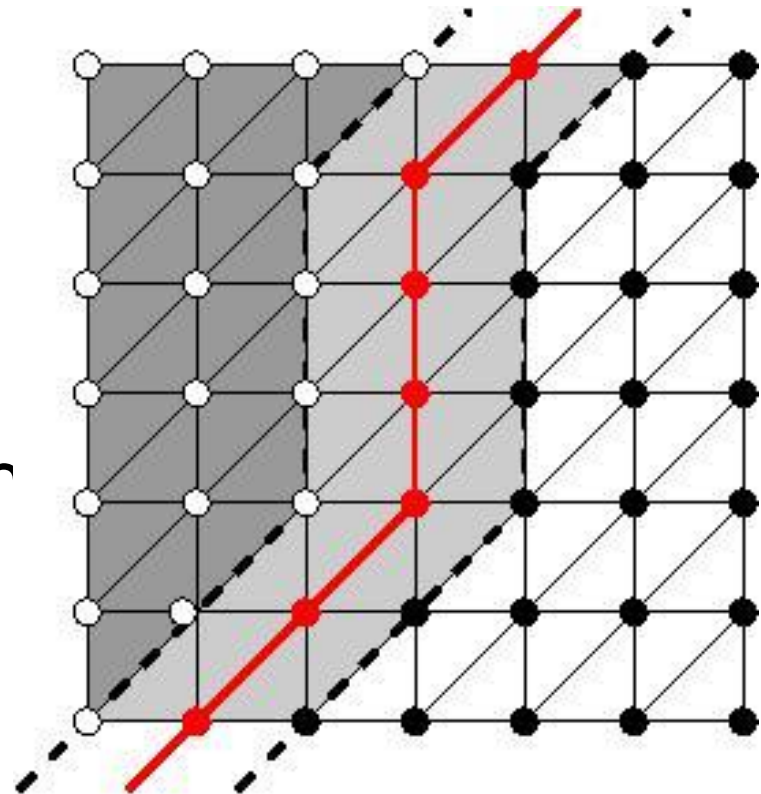
Elmer parallel mesh



Halo-elements:

```
ElmerGrid 2 2 dir -metis N Method -halo
```

- ” Necessary if using Discontinuous Galerkin
- ” Puts ghost cell on each side of the partition boundary



Elmer parallel mesh



More parallel mesh stuff...

- `indirect` create indirect connections
- `periodic Fx Fy Fz` declare the periodic coordinate directions for parallel meshes
- `partoptim` aggressive optimization to node sharing
- `partbw` minimize the bandwidth of partition-partition couplings

ElmerSolver parallel



- `mpirun -np N ElmerSolver_mpi`
- ” Might change on other platforms
- ” Might need a `hostfile`
- ” Needs a N -partition mesh
- ” Needs `ELMERSOLVER_STARTINFO` to contain the name of the command file
- ” Optional libraries: Hypre and MUMPS

ElmerSolver parallel



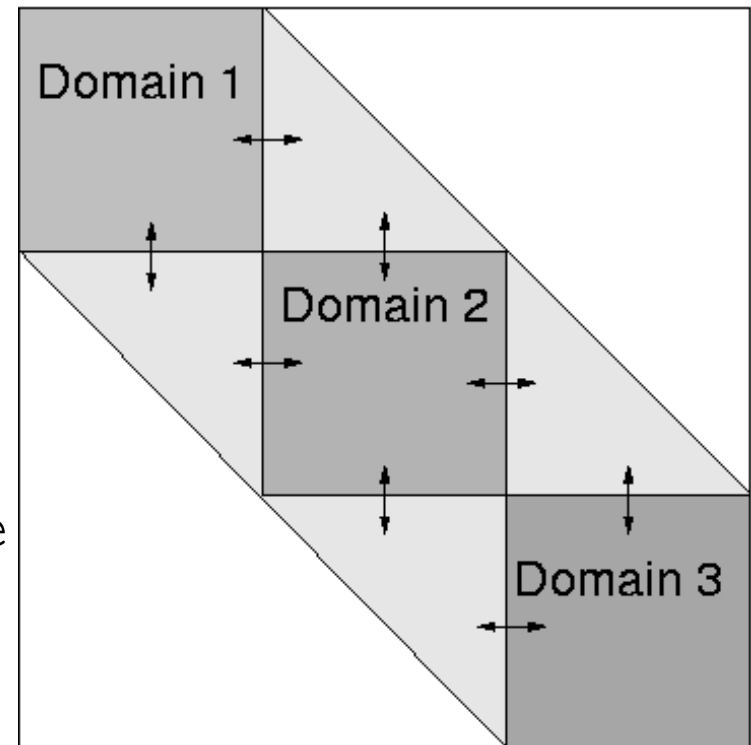
” Different behaviour of ILU preconditioner

” Not available parts at partition boundaries

” Sometimes work

” If not, use HYPRE:

```
Linear System Use HYPRE  
= Logical True
```



ElmerSolver parallel



” Alternative pre-conditioner in Hypre:

- . ParaSails (sparse approximate inverse preconditioner):

```
Linear System Preconditioning = String  
    "ParaSails"
```

- . BoomerAMG(Algebraic Multigrid):

```
Linear System Preconditioning = String  
    "BoomerAMG"
```

ElmerSolver parallel



” Alternative Solver:

- . **BoomerAMG(Algebraic Multigrid):**

```
Linear System Solver = "Iterative"
```

```
Linear System Iterative Method =  
"BoomerAMG"
```

- . **MUMPS (Multifrontal parallel direct solver):**

```
Linear System Solver = Direct
```

```
Linear System Direct Method = Mumps
```

Parallel postprocessing



“ Elmer writes results in parallel

`name.0.ep, name.2.ep, ..., name.N.ep`

“ ElmerPost: fusing into one file

```
ElmerGrid 15 3 name
```

fuses all timesteps (also non-existing) into a single file called `name.ep` (existing will be overwritten!)

. Special option for only partial fuse:

```
-saveinterval start end step
```