Constructing a Volume Geometry Map For Hexahedra With Curved Boundary Geometries

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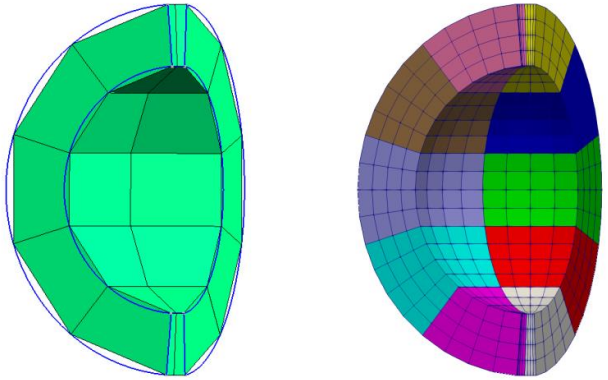
Dirk Reith[2]



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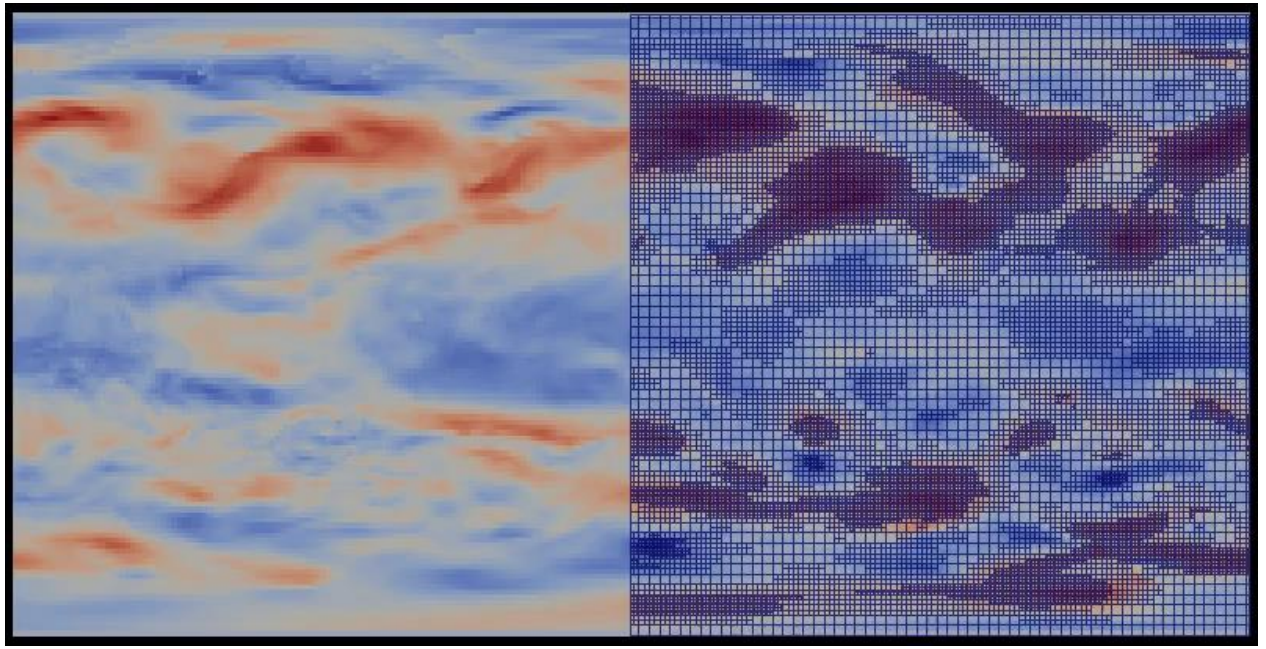
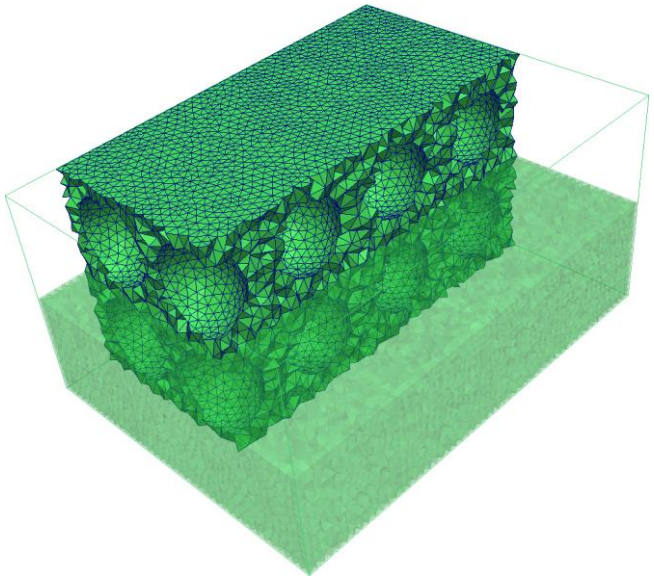
Institute of Technology, Resource and Energy-Efficient Engineering
Electrical Engineering, Mechanical Engineering and Technical Journalism

Dynamic adaptive mesh refinement (AMR) with t8code

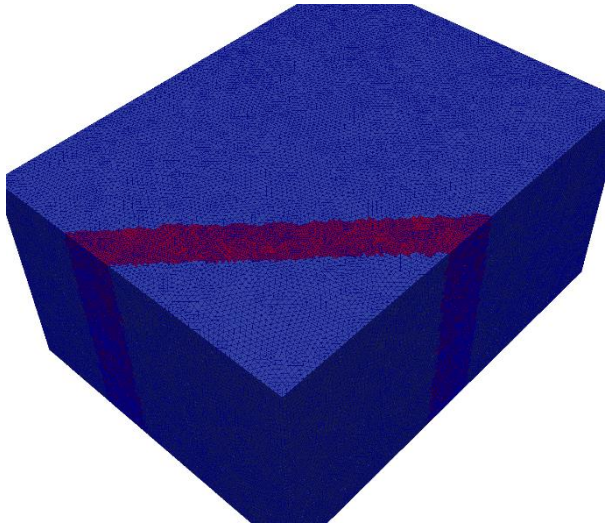
- t8code is a library for parallel (dynamic) adaptive mesh refinement
- During the simulation the mesh is arbitrarily refined and coarsened
- Algorithms for mesh adaptation, load-balancing, ghost elements, mesh iteration, search, etc.



Our work starts when the mesh generation is finished

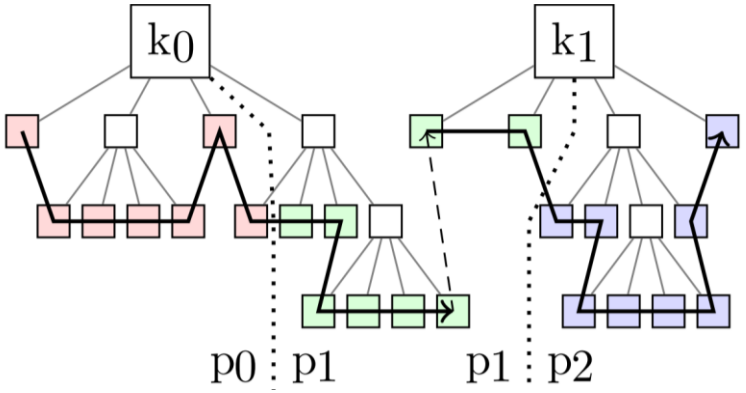


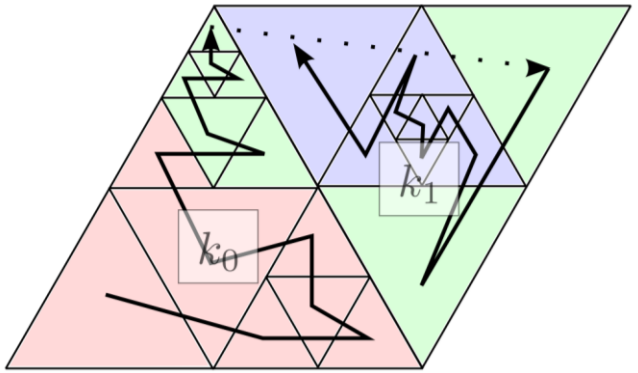
„Coarse“ input mesh from mesh generator

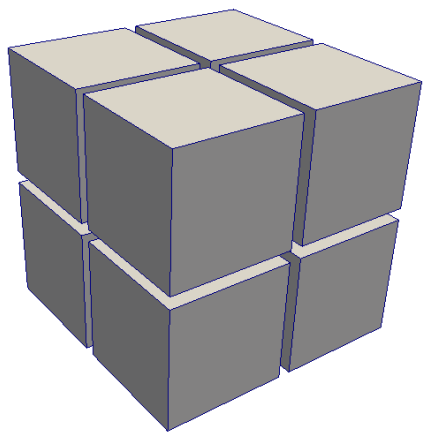


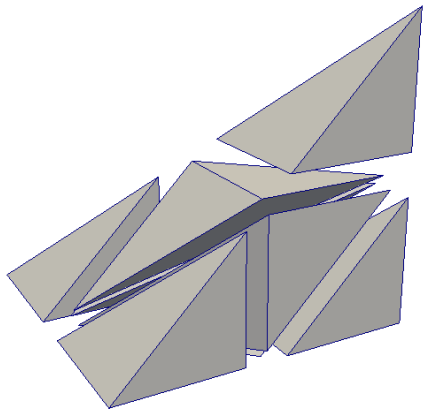
Adaptively refined during simulation

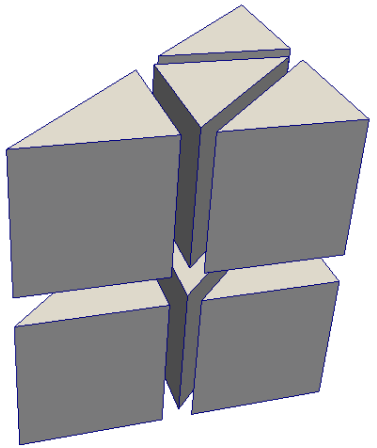
Space-filling curve

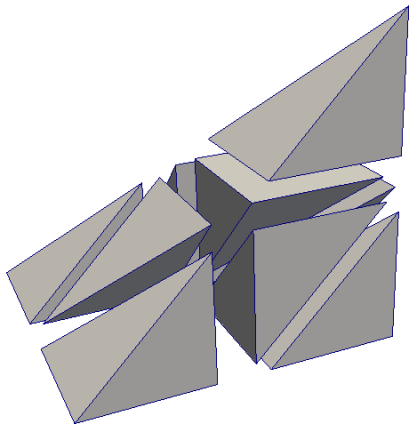




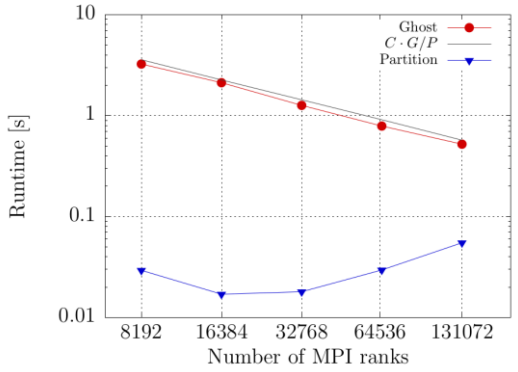




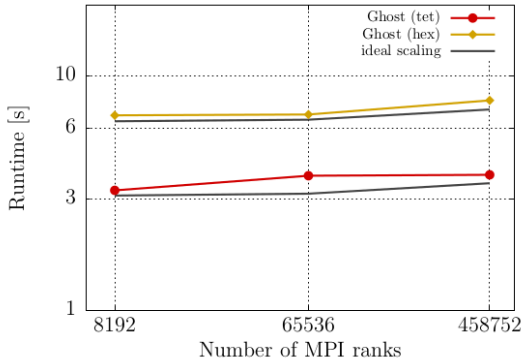




These methods are very efficient and massively scalable



Strong scale 1.9 billion tets



Weak scale, up to 142 billion elements

Recent milestone **1 Trillion element mesh:**

#processes	#Elements	#Elements/process	Ghost	Partition
98,304	1,099,511,627,776 ≅ 1.1e12	11,184,811	1.43s	0.33s

Geometry

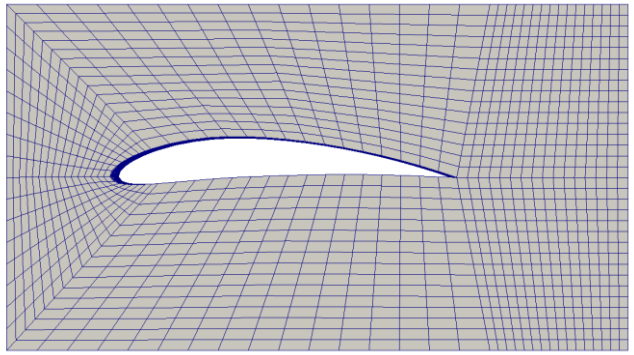
All information on the geometry lies in the coarse mesh

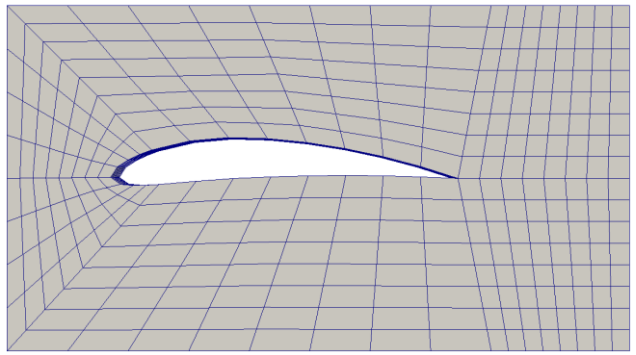
The smaller the coarse mesh, the better

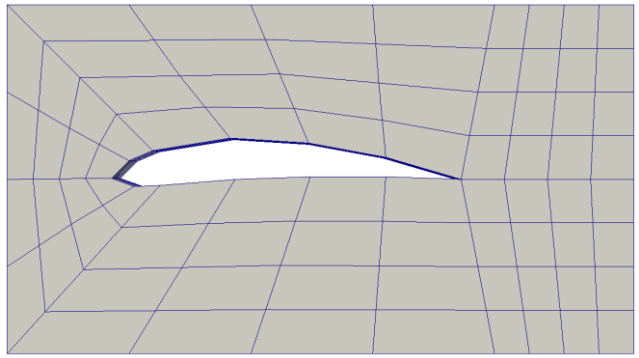
- Less memory
- Faster computation
- More hierarchy levels
- Less pre-processing overhead

Refinement without geometry information looses information

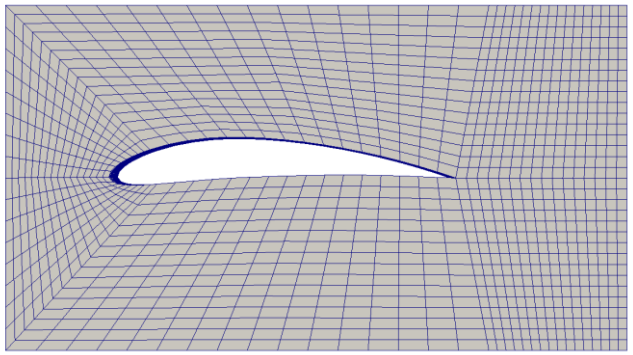
Coarse mesh

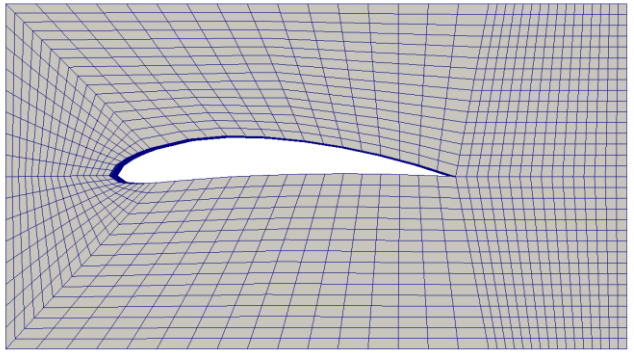


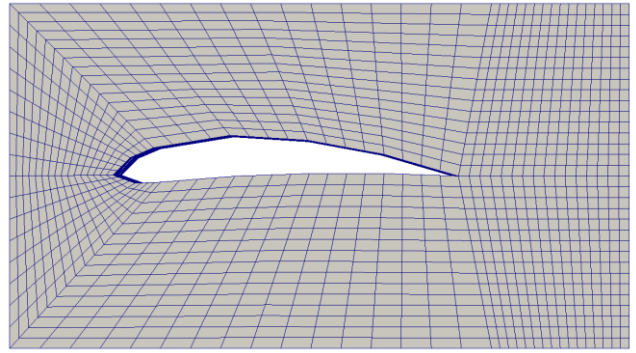




Fine mesh



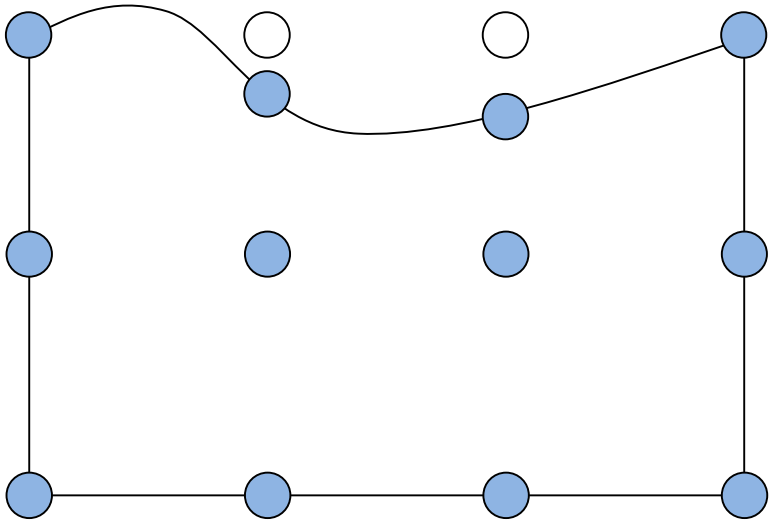




Common approach

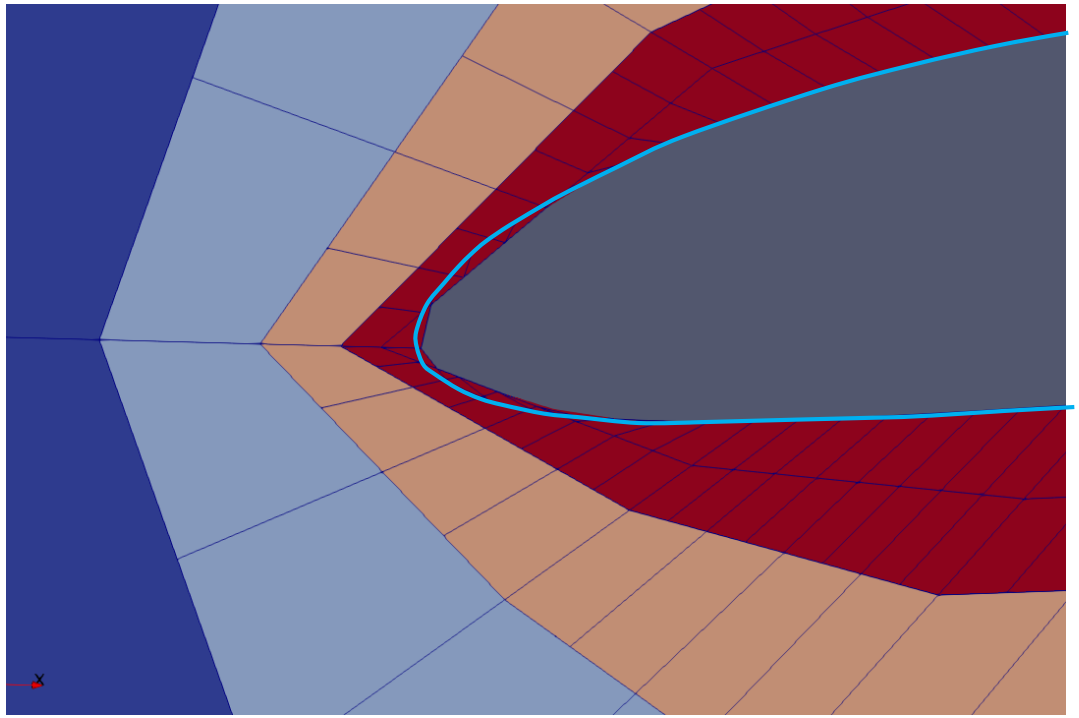
⇨ Equip the coarse mesh with additional geometry information (High-order, CAD, etc.)
Use this information to evaluate geometry for fine mesh elements

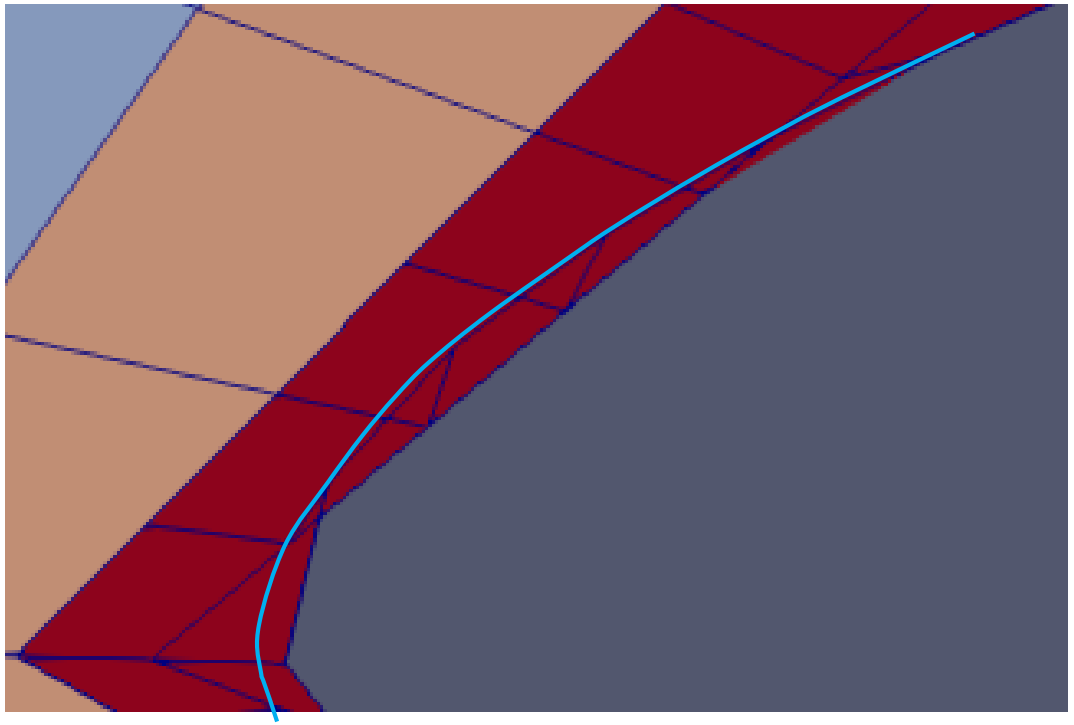
Common approach: Surface projections



Why it fails

- We have **no a priori knowledge** of where fine mesh elements will arise
- Only projecting the elements closest to the surface will **distort the mesh** and may introduce **self intersections**

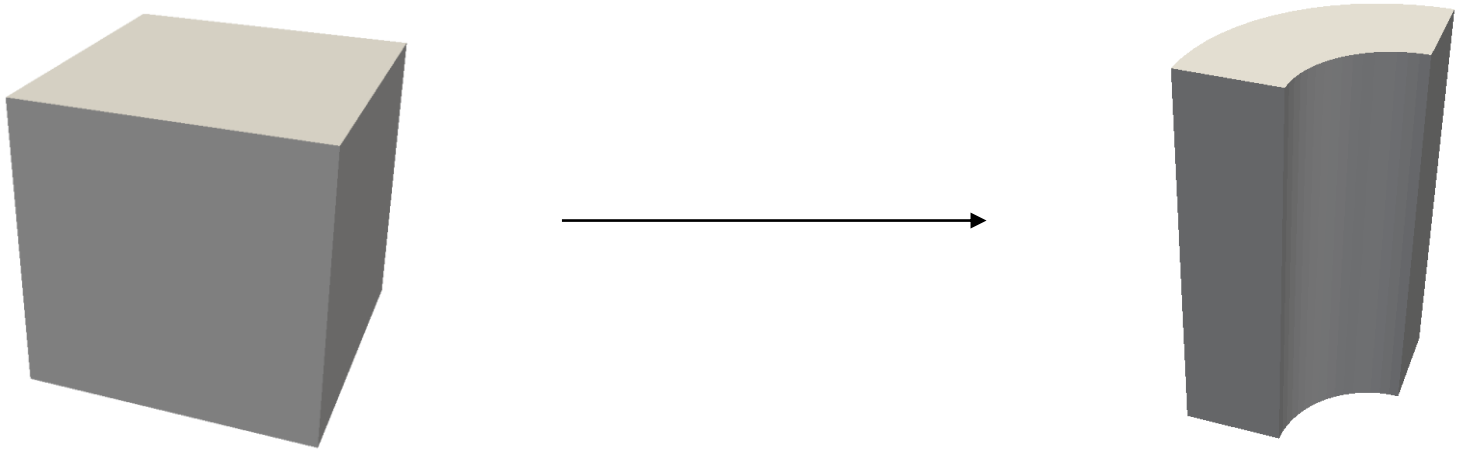




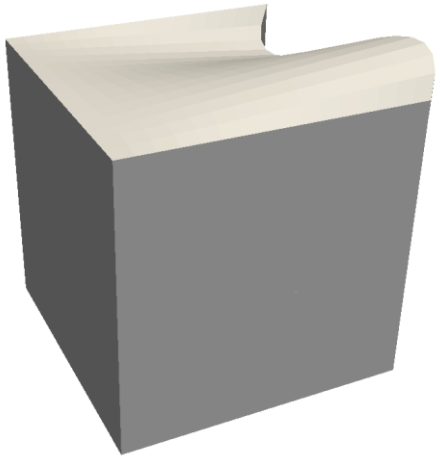
A volume geometry map

- We need to be able to evaluate the geometry **for every possible element** at **every possible position** in the original volume
- Therefore, we require a volume map

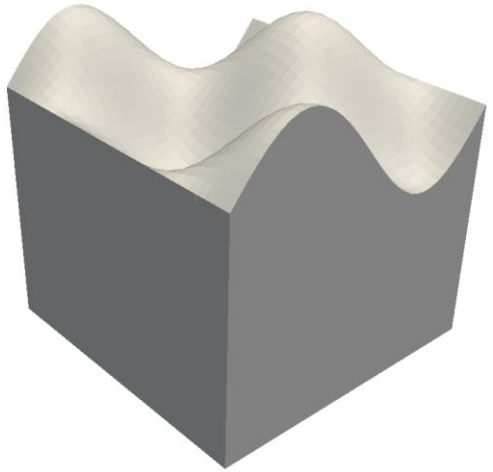
$$G: \text{Reference volume} \longrightarrow R^3$$



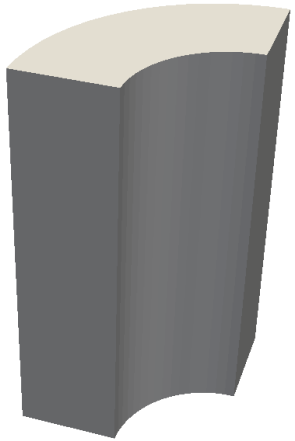
Possible cases



Curved edges



Curved surfaces

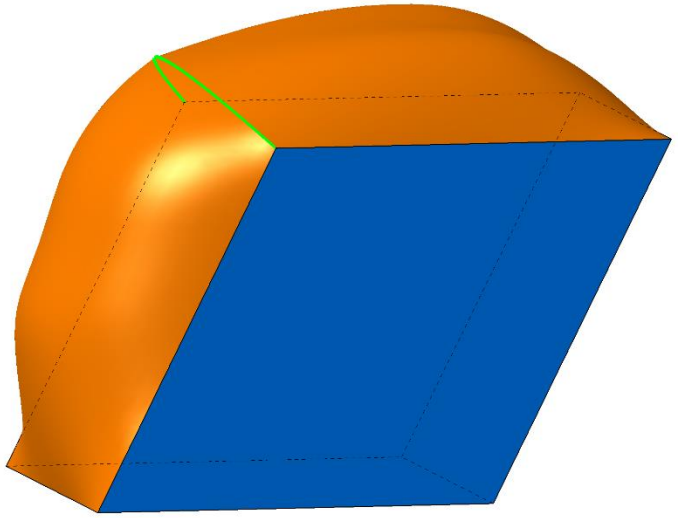


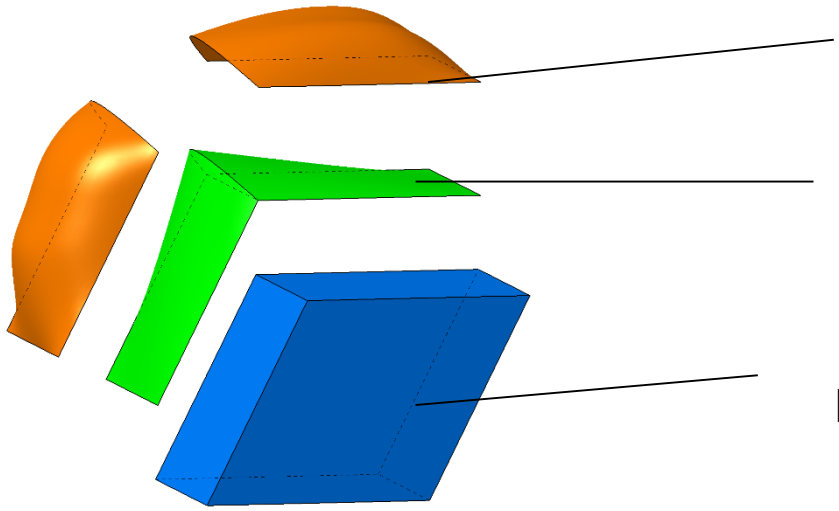
Any combination

Outline

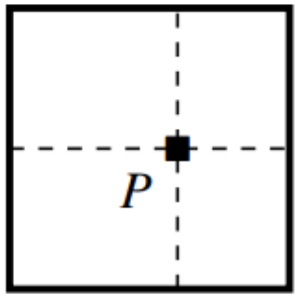
Input:

- Coarse mesh Cell
- Curved edges and surfaces
  with parameter space

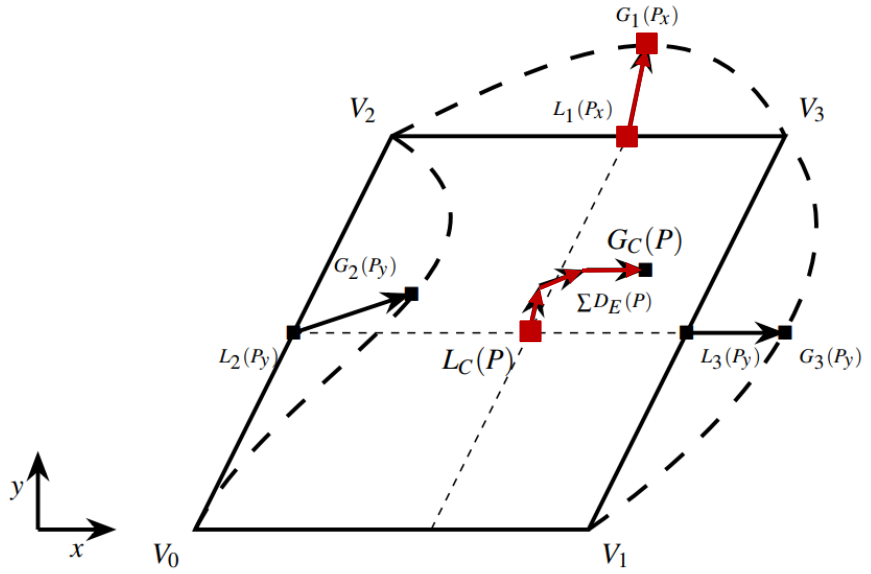




The volume map

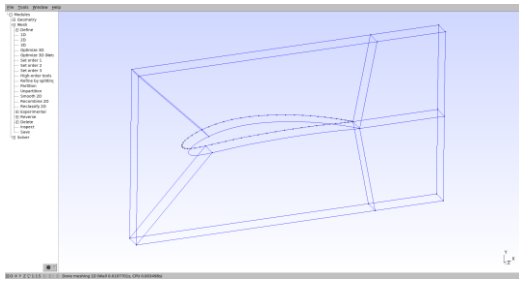


$G_C()$

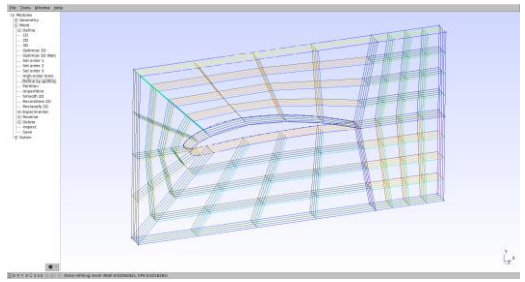


$$G_C(P) = L_C(P) + \sum_{\substack{\text{linked} \\ \text{edges } E}} D_E(P) + \sum_{\substack{\text{linked} \\ \text{faces } F}} D_F(P)$$

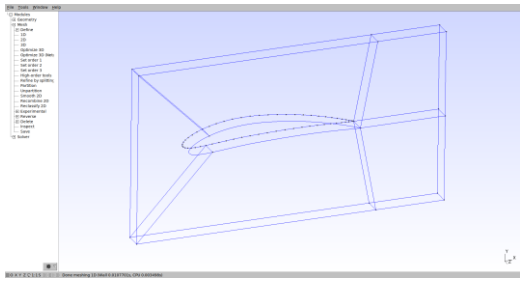
Workflow with Gmsh



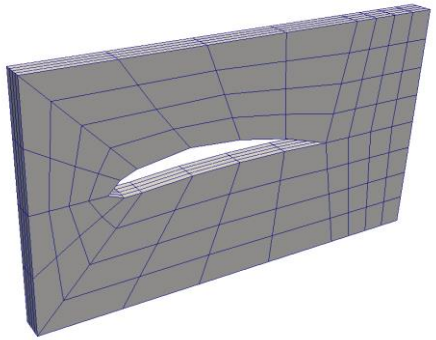
Gmsh



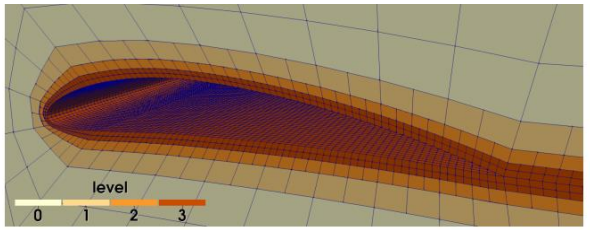
.msh file



.brep file

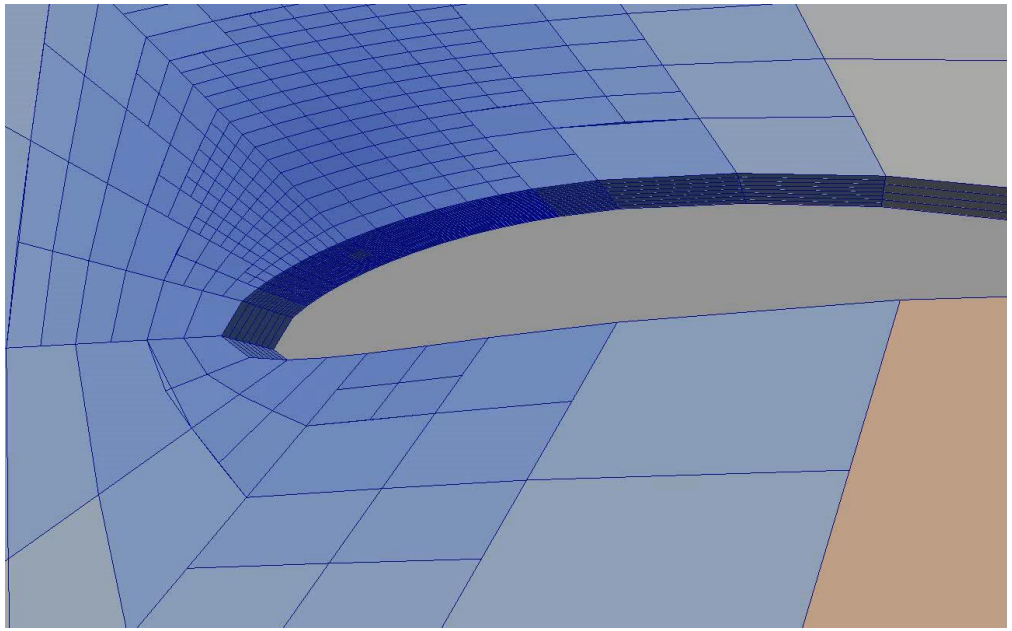


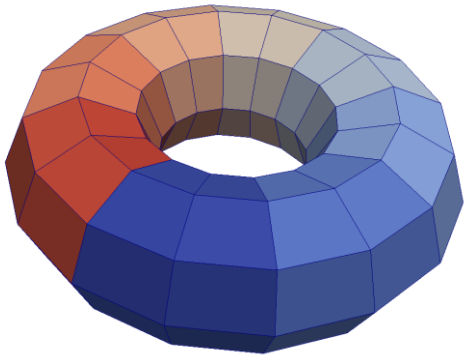
t8code coarse mesh + geometry info

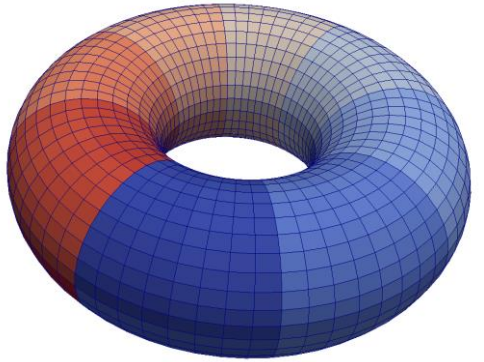


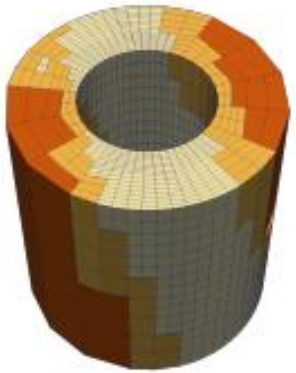
Adaptive mesh with accurate geometry

Some more examples









References

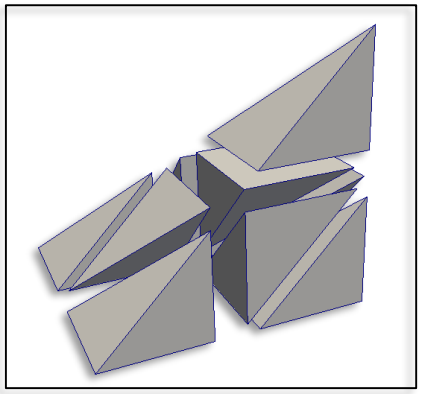
Checkout t8code at: www.github.com/holke/t8code
(Work in progress on https://github.com/sandro-elsweijer/t8code/tree/feature-brep_geometry_2)

Holke J. *Scalable algorithms for parallel tree-based adaptive mesh refinement with general element types*
PhD thesis, Rheinische Friedrich-Wilhelms-Universitat, Bonn, 2018

Holke J., Knapp D., Burstedde C. *An Optimized, Parallel Computation of the Ghost Layer for Adaptive Hybrid Forest Meshes*
SIAM Journal on Scientific Computing, Vol. 43 (6), https://doi.org/10.1137/20M1383033

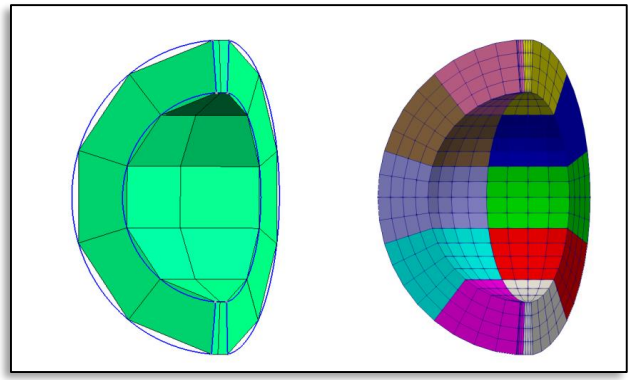
Elsweijer S. “Curved Domain Adaptive Mesh Refinement with Hexahedra.” Tech. rep., Hochschule Bonn-Rhein-Sieg, Jul. 2021. URL https://elib.dlr.de/143537/

t8code @ SIAMPP22



MS28 Thursday, 24th, 11:45 UTC-8 / 19:45 GMT

A space-filling curve for pyramids
David Knapp, J. Holke, C. Burstedde



IMR22, Thursday, 24th, 17:10 GMT / 09:10 UTC-8

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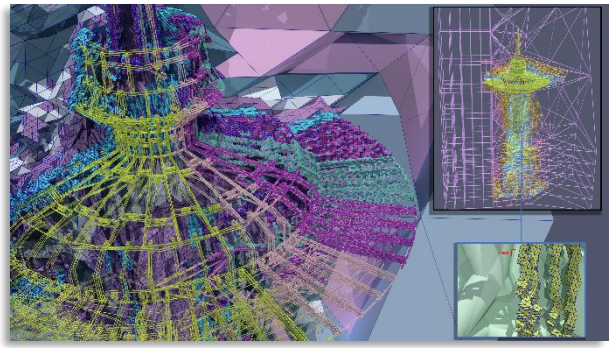

Meshing contest @IMR22