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New approaches to solve the meshing problem

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Computing Research, Sandia National Laboratories

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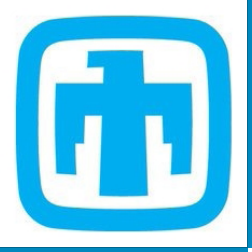


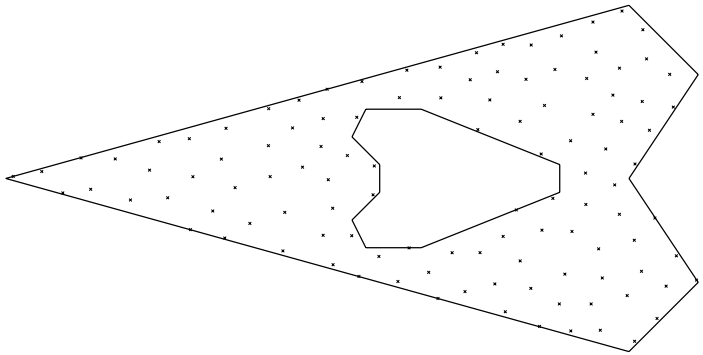
Collaborators

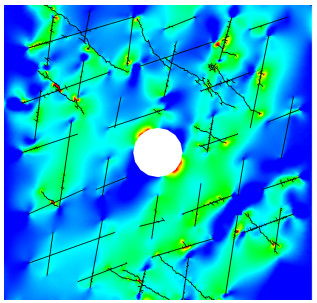
SNL

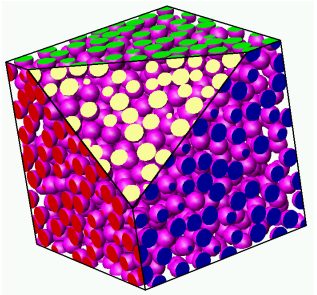
- P. M. Knupp
- V. J. Leung.
- J. E. Bishop
- M. J. Martinez

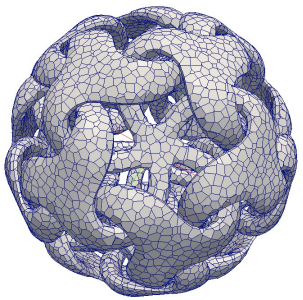
UCDavis:

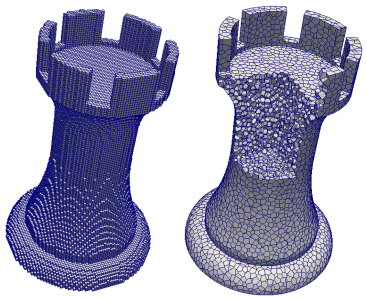
- A. Patney
- A. Davidson
- J. D. Owens

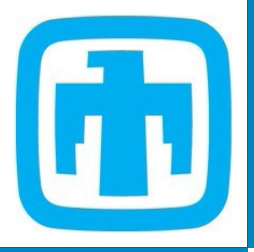










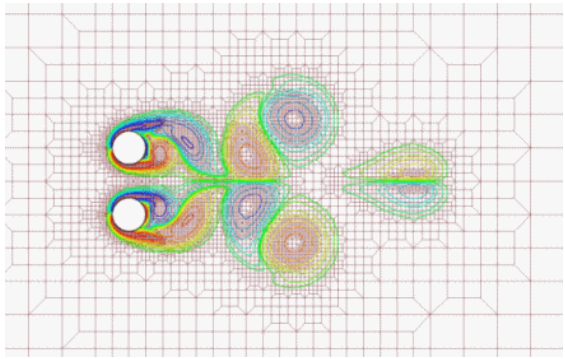


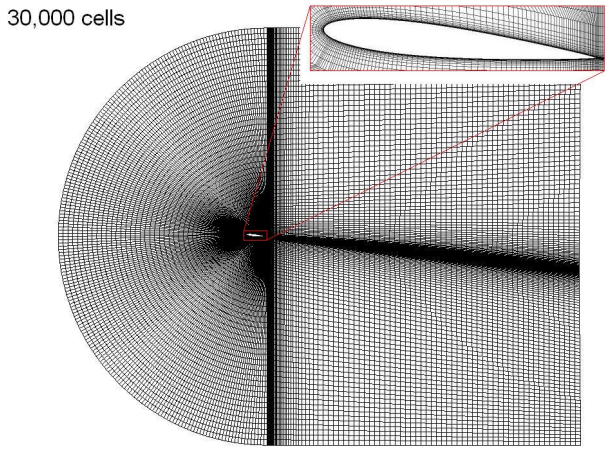
Overview

General Principals in Our Meshing Algorithms

Quality

- Point Clouds should adequately represent the associated geometry and physics.
- Extra points needed to improve quality / maintain certain connectivity should be kept at a minimum level.
- Moving points to non-deterministic locations should also be avoided for generating a provably good mesh.



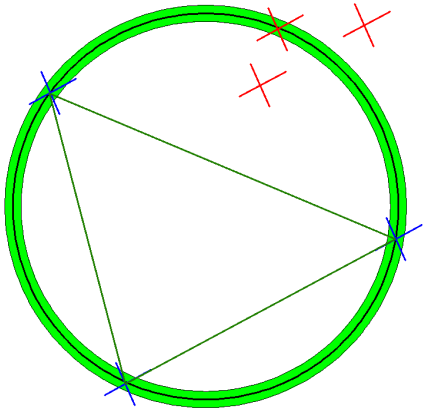


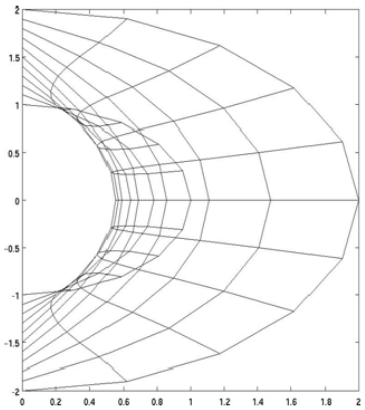
NACA0012 Image courtesy of http://www.cfd-online.com

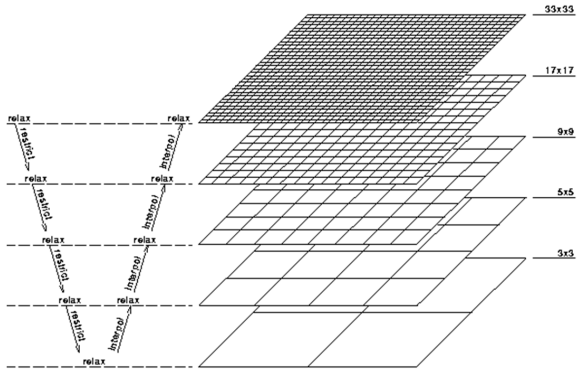
General Principals in Our Meshing Algorithms

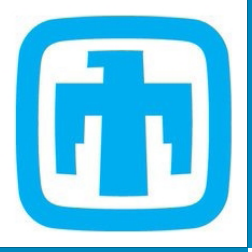
Efficiency, robustness and ... Multi-Grid!

- Local meshing operations is easier for parallel applications
- Provable robustness (meshing failure is NOT ACCEPTABLE in dynamic simulations).
- Meshing Operations should have minimum storage requirement.
- Geometric MG need to be considered.









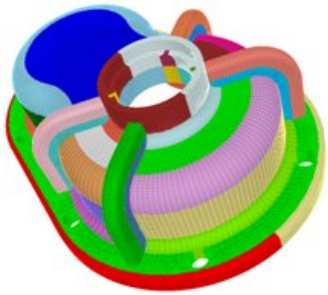
Existing Methods: Domain Decomposition

Pros

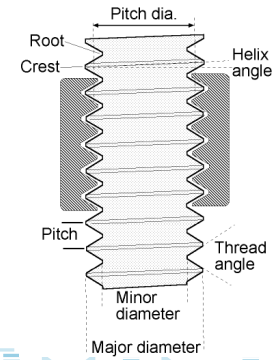
- High Quality.
- Complex geometries.
- Domains with multiple material.

Cons:

- Requires a lot of manual operations.
- Quality is not predicted.
- Number of regions in contact is limited.
- Retrieving a solution can be a challenging / time consuming process.



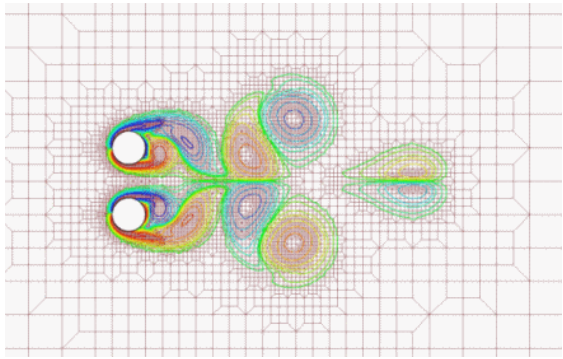
Images courtesy of
http://cubit.sandia.gov/



Existing Methods: Octree-based (projection)

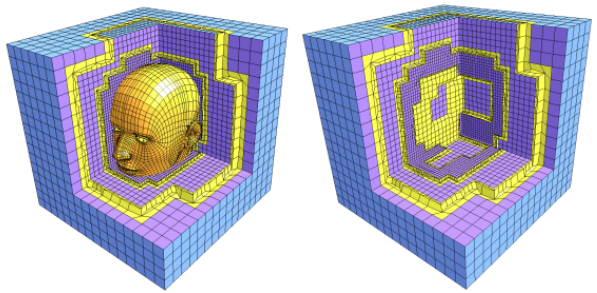
Pros

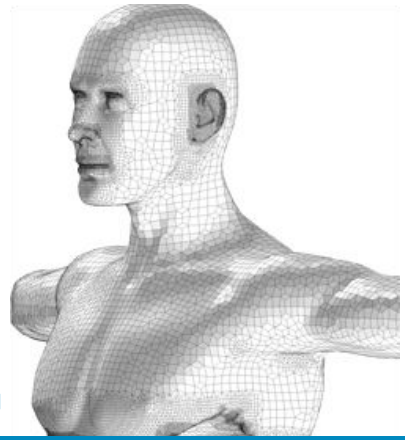
- Guaranteed quality
- Dynamic remeshing.
- Multigrid.

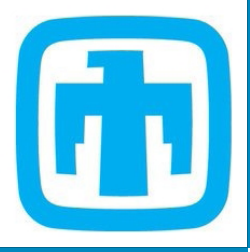


Cons:

- Domains with a single material only.
- Sharp Features may result in invalid elements.
- Sharp Features cannot be even represented
- Conforming refinement requires some propagation.



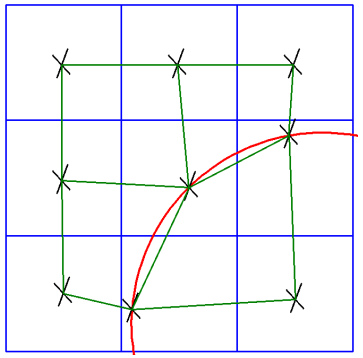




Existing Methods: Dual Contouring

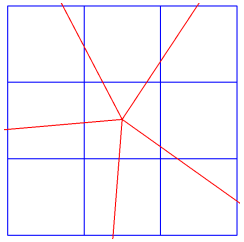
Pros

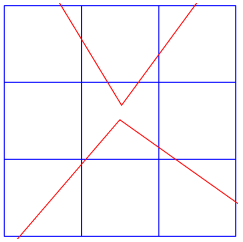
- Bounded radius for inscribed circles.
- Handles Multiple domains ?!

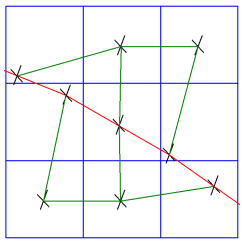


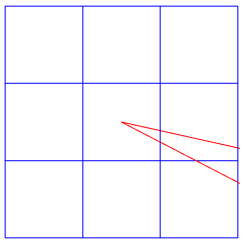
Cons:

- Not robust.
- Captures input geometry using uniform grids
- Sharp Features represent a BIG issue
- Narrow regions increase the output size significantly
- Invalid/low quality elements are generated even for some extremely nice geometries.









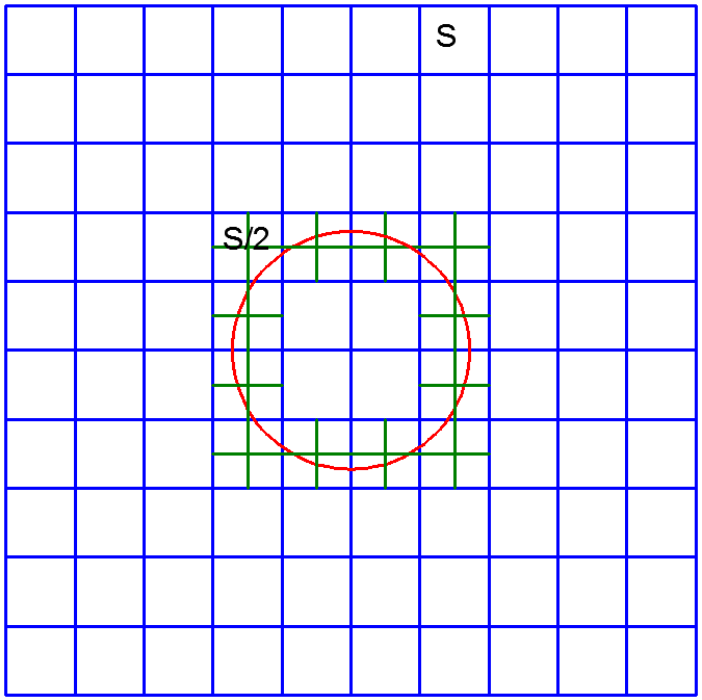
All-hex meshing: Main issues

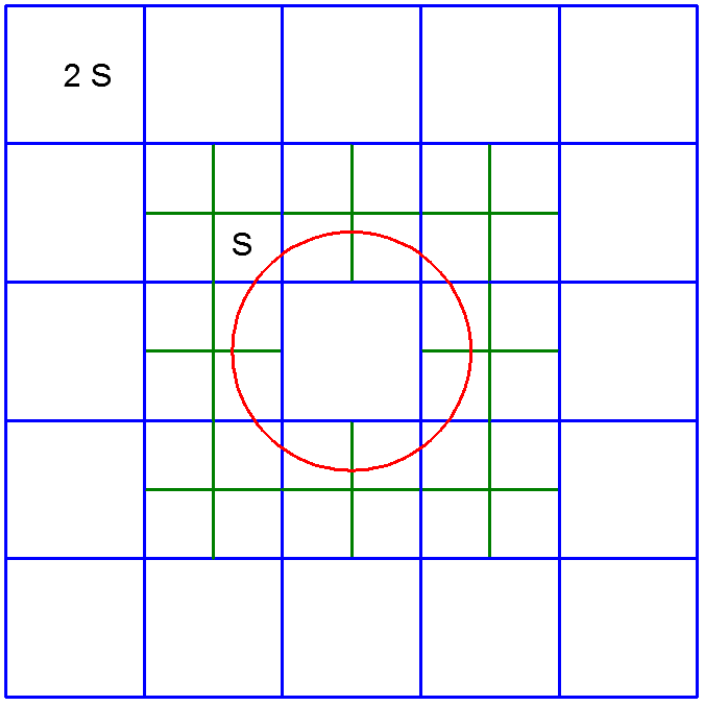
- Robust Automatic algorithm.
- Conforming Refinement THEN capturing geometry.
- Generation of boundary layers
- Guaranteed quality.
- Adequate mesh size.
- Handling of non-manifold surfaces.

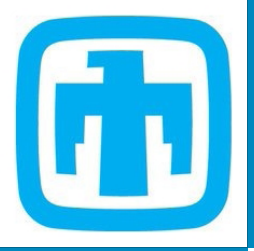
... Challenging Problems usually require a new Language!

Our All-hex meshing: The Alphabets

1. Refinement of all elements in a grid based method is not a bad idea.

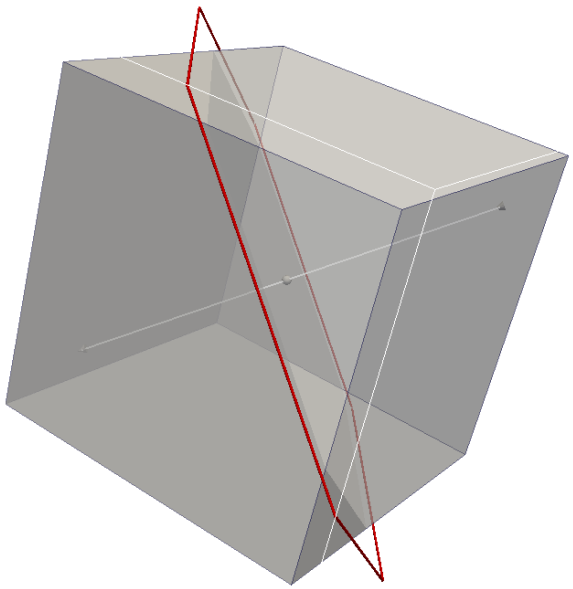


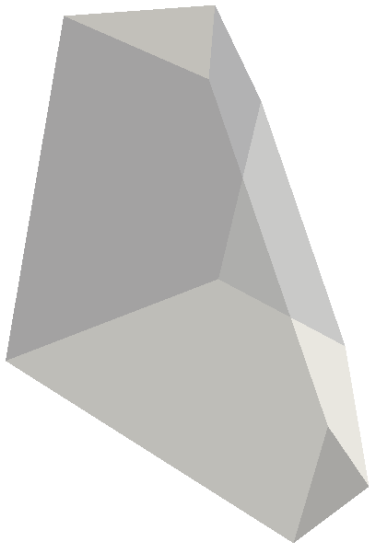


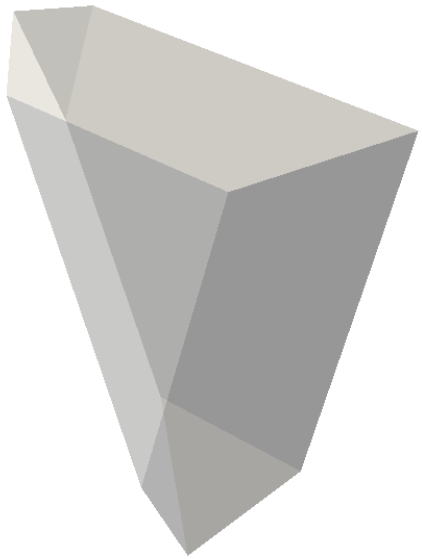


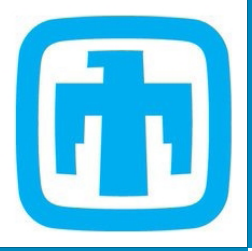
Our All-hex meshing: The Alphabets

2. Clipping of a region with tri-valent corners using a surface that does not pass through any of these corners will result in two region with tri-valent corners.



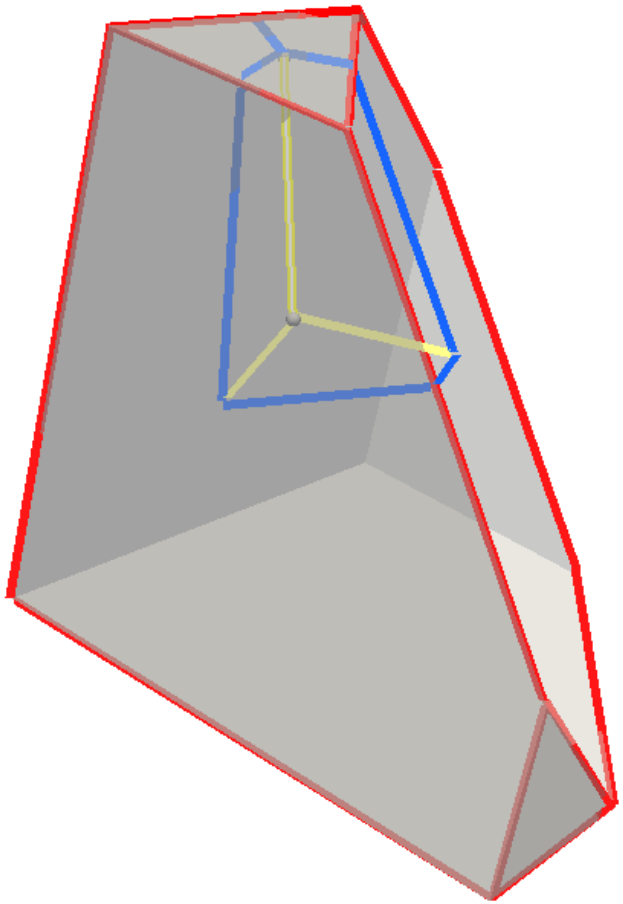




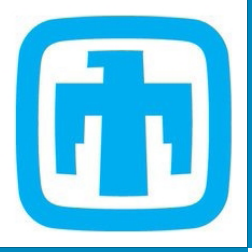


Our All-hex meshing: The Alphabets

3. Refinement of a region with tri-valent corners result in all-hex regions with an automatic generation of a boundary layer



1. Split each edge, add a face point to each face and a region point.
2. A Region point: 3 face points
3. A face point: 2 edge points and region point
4. An edge point: 2 face points and a corner
5. A corner: 3 edge points

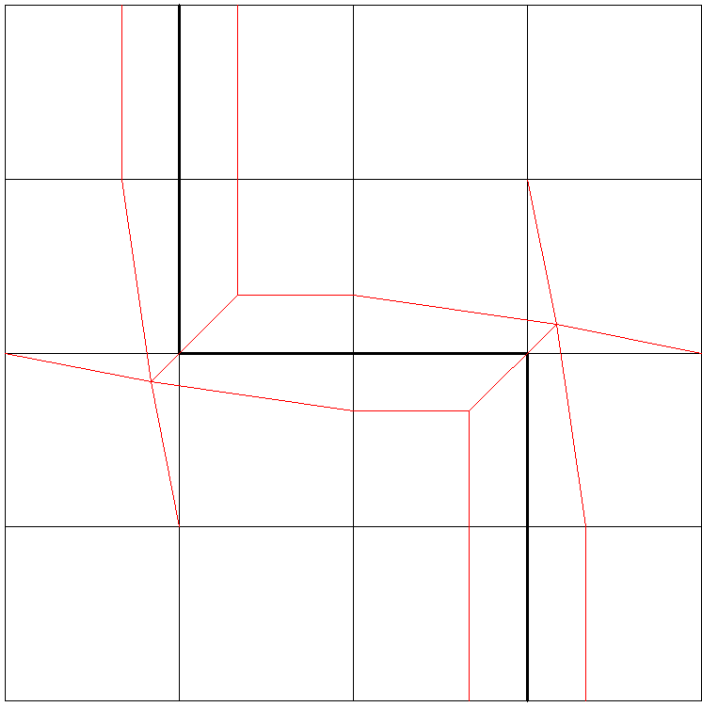


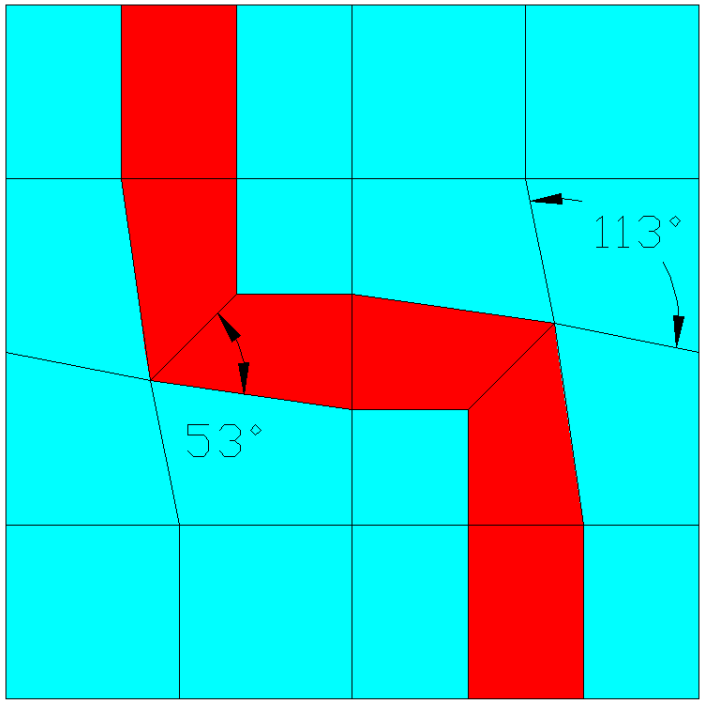
Our All-hex meshing: Representing two manifold smooth surfaces using a uniform grid

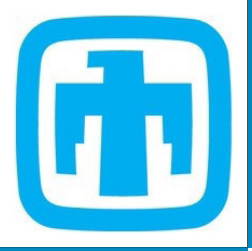
1. Generate a uniform grid covering the input geometry with an appropriate spacing.
2. Move grid points "away" from the boundaries.
3. Clip the regions intersecting with the geometry.
4. Refine all the elements resulting in an All hex mesh.
5. A boundary layer is generated around the input geometries.

Our All-hex meshing: The Alphabets

4. Pillowing can be achieved with guaranteed quality :

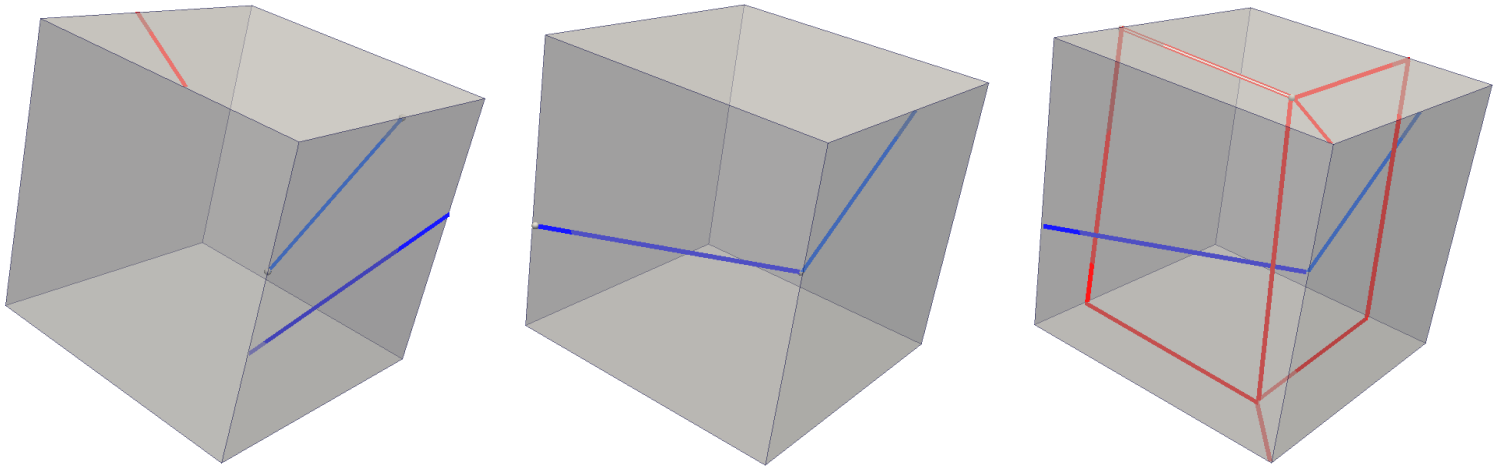






Our All-hex meshing: The Alphabets

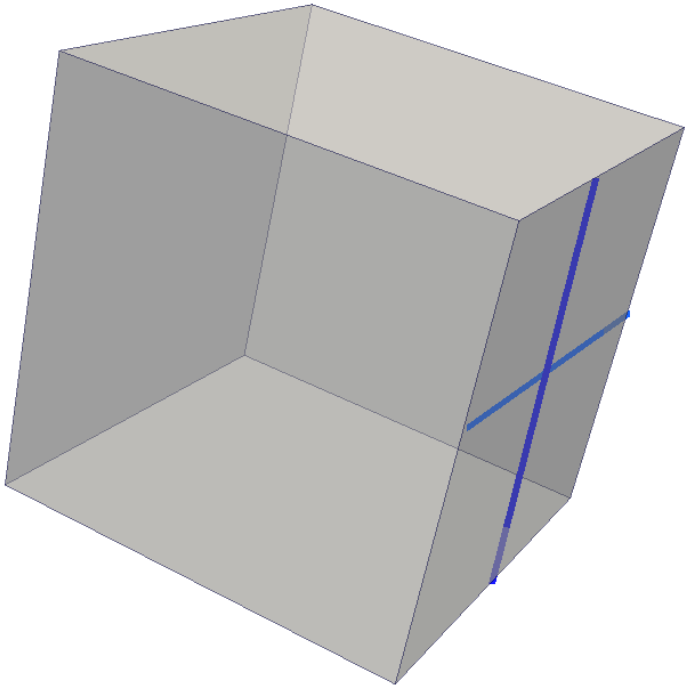
5a. Edge imprints may / may not result in a tri-valent region:

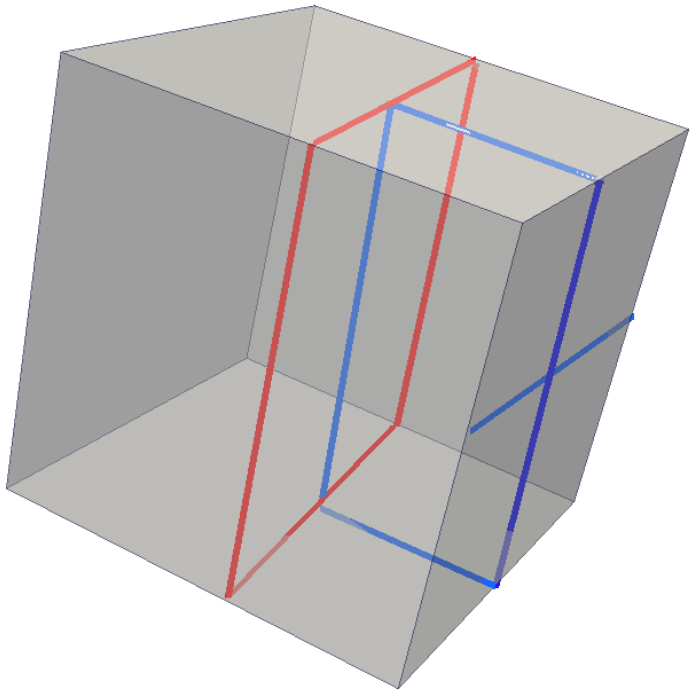


... sharp features would have edge imprint on some cells.

Our All-hex meshing: The Alphabets

5b. Edge imprints may / may not result in a tri-valent region:





... and this is how we generate a conforming octree.

Questions?!

Thank you!

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