SAND2014-18464C

Exceptional service in the national interest

Sandia National Laboratories

LayTracks3D: Hex Meshing using MAT

William Roshan Quadros

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND NO. 2011-XXXXP

Goal of LayTracks3D

- Handle General Solids & Assemblies
- Orientation Insensitive
- Boundary Sensitive
- Preserves Imprints and Sharpe Features
- Geometry Adaptive
- Fast Remeshing
- Morphable Meshes
- Parallel Friendly
- Potential All-Hex

Advantages of MAT

- Orientation Insensitive:
  - MA of a solid does not change with orientation of the solid
- Boundary Sensitive:
  - AFM fronts meet at MA, i.e., structured mesh along the boundary
- Robust Geometry Decomposition:
  - Medial branch points represent critical singularity regions
- Dimension Reduction:
  - Hex meshing can be reduced to surface meshing
- Geometry Adaptive:
  - Medial radius function provides local feature size to control mesh size.
- Symmetric Skeleton:
  - Simplifies interval assignment and restricts irregular nodes at MA
- Homotopy Equivalence:
  - Preserves sharp boundary features

Medial Axis Transform

Two-Way Mapping

f: p → Mp

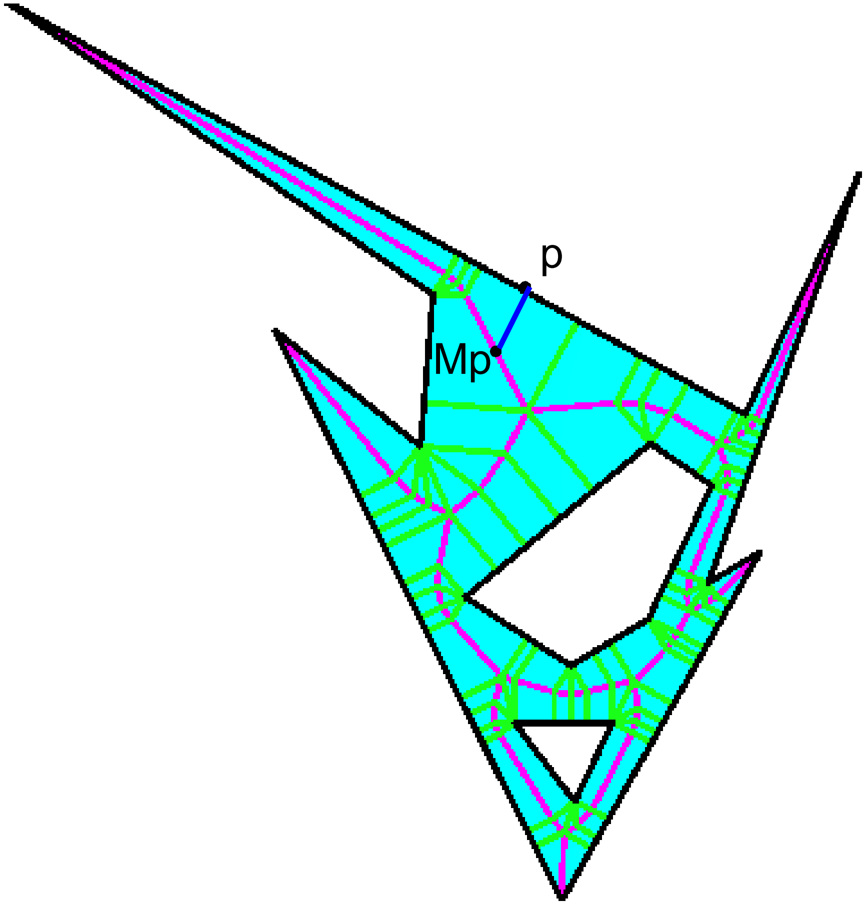
g: Mp → p

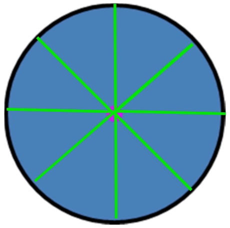
Types of Mapping

1-to-1 Map

1-to-N Map

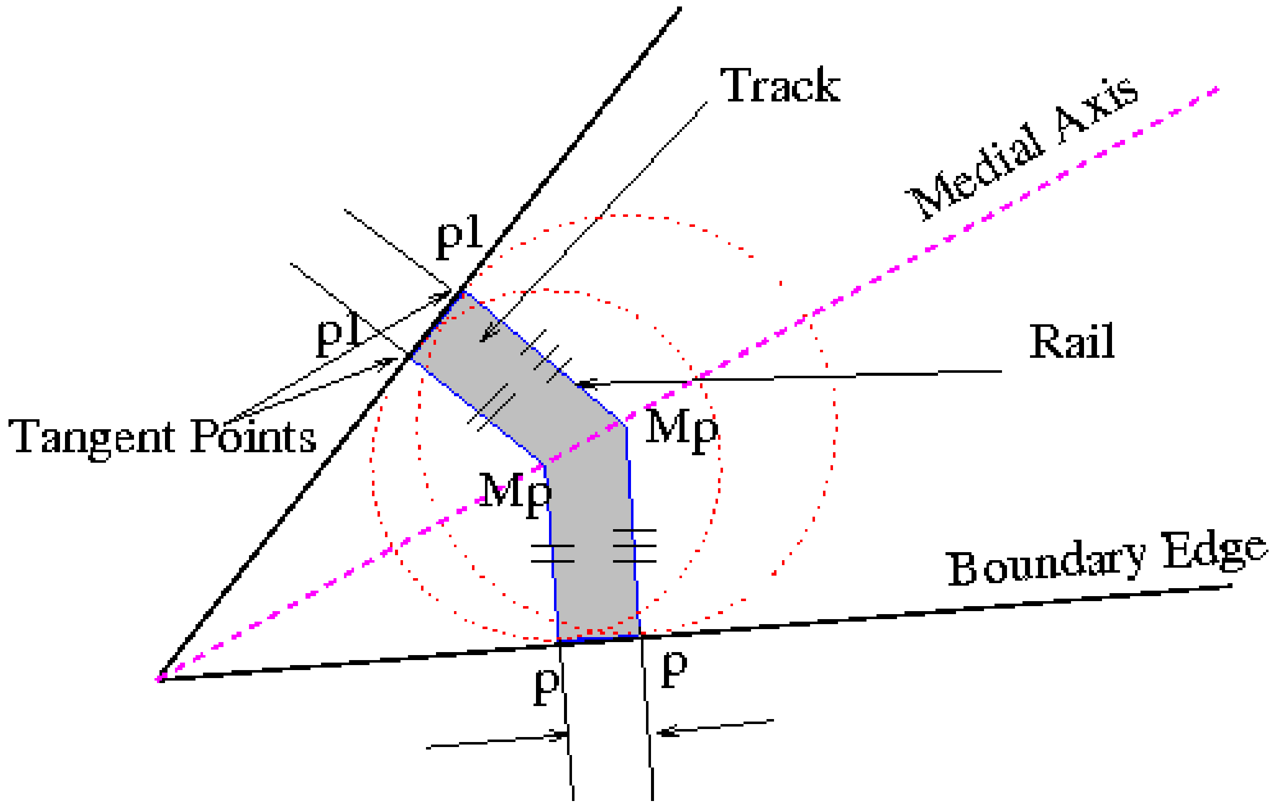
N-to-1 Map





Projection Operator

- Uses map *f* to connect p -> Mp
- Uses map *g* to connect Mp -> p1

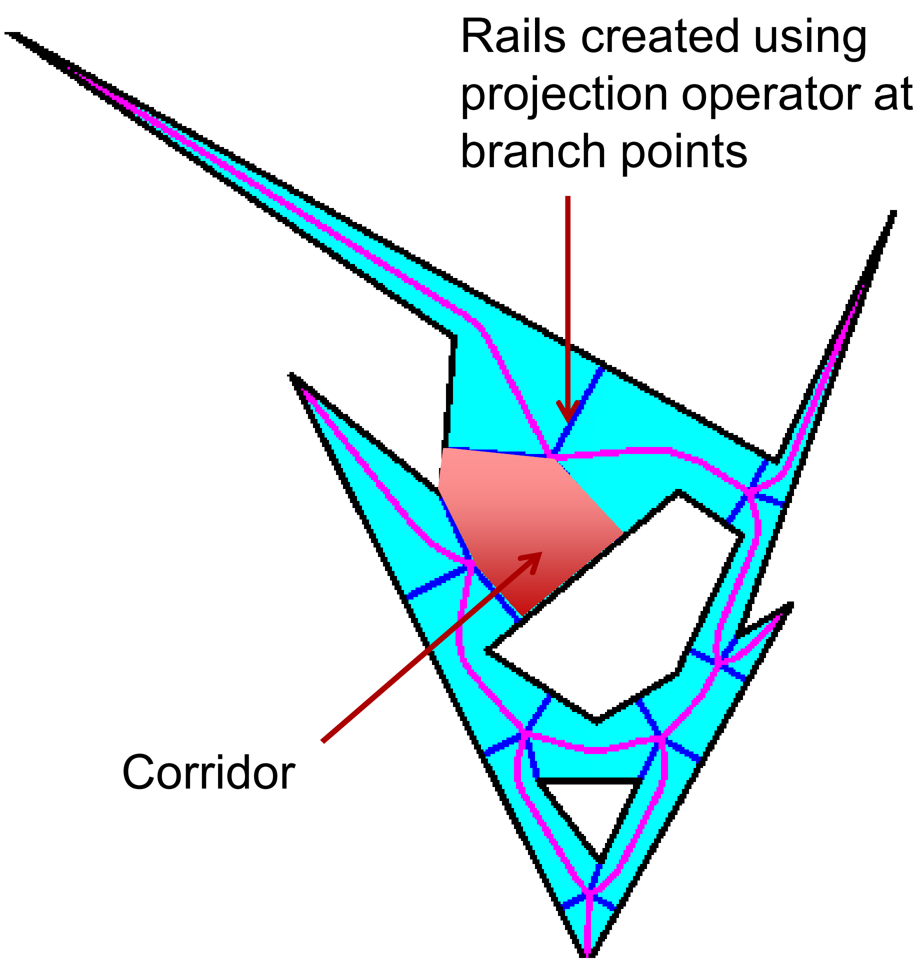


LayTracks: All-Quad Meshing, 9th IMR, 2000

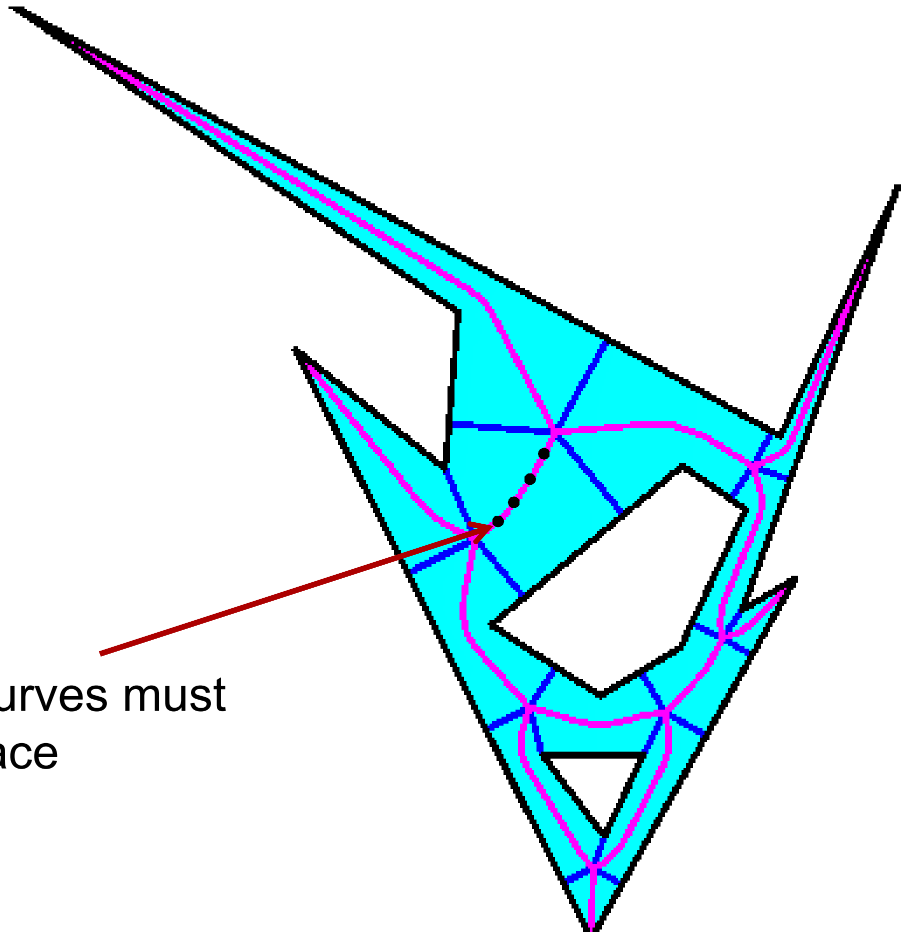
Combines merits of decomposition and advancing front methods

- Generate MAT: establish two-way map between domain boundary and medial
- Generate Corridors: decompose domain using medial branch points and projection operator
- Mesh Medial: surface meshing is reduced to curve meshing. Medial radius function can be used to control mesh size.
- Generate Tracks: further decompose the domain/Corridors into simpler/meshable Tracks using projection operator
- Mesh Tracks: generate all-quad in each track using symmetric property of the medial

Generate Corridors: Domain Decomposition

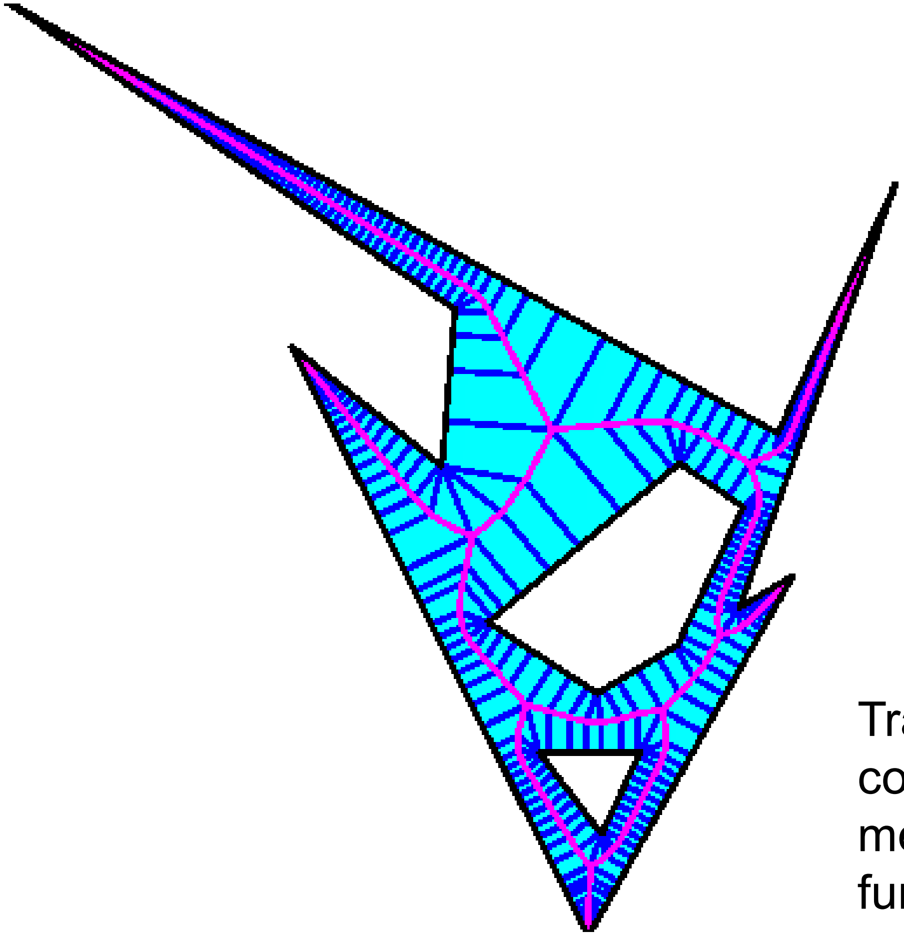


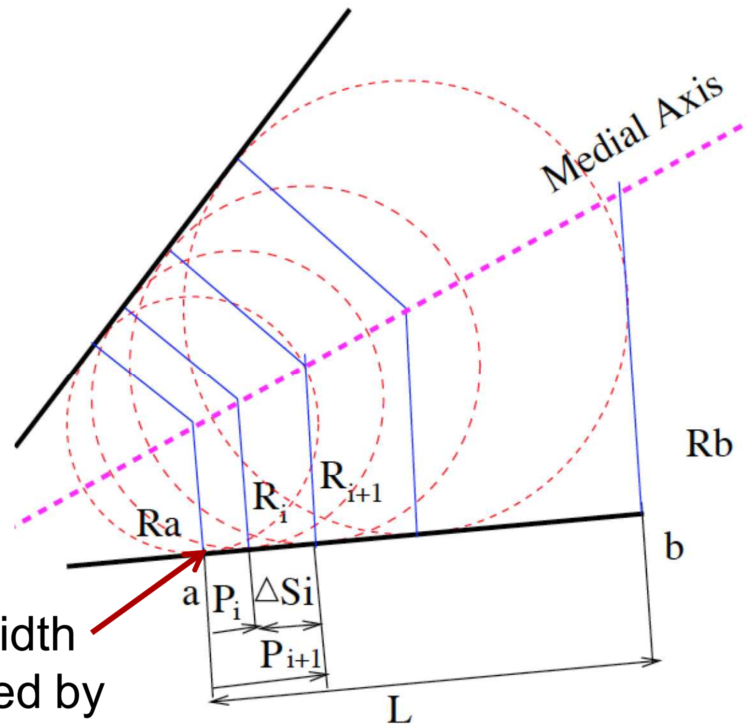
Mesh Medial: Surface meshing is Reduced to Curve Meshing



Meshing all medial curves must cover the entire surface

Generate Tracks: Projection Operator Connects MA Nodes to Boundary

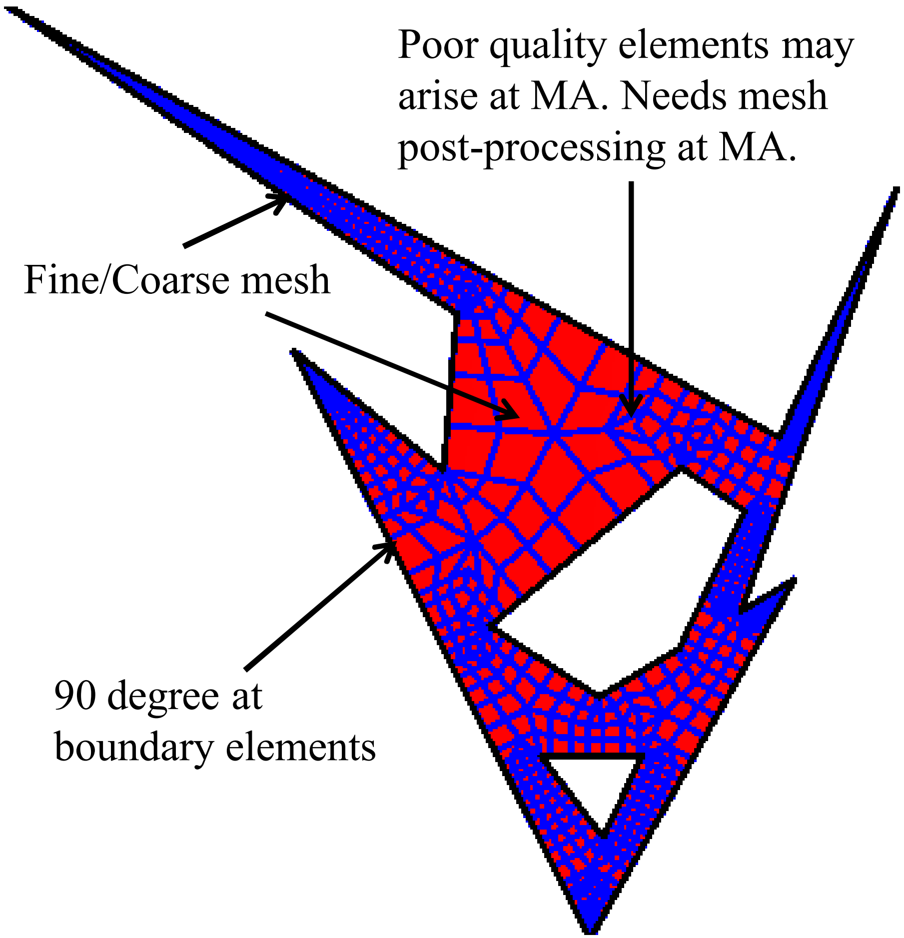


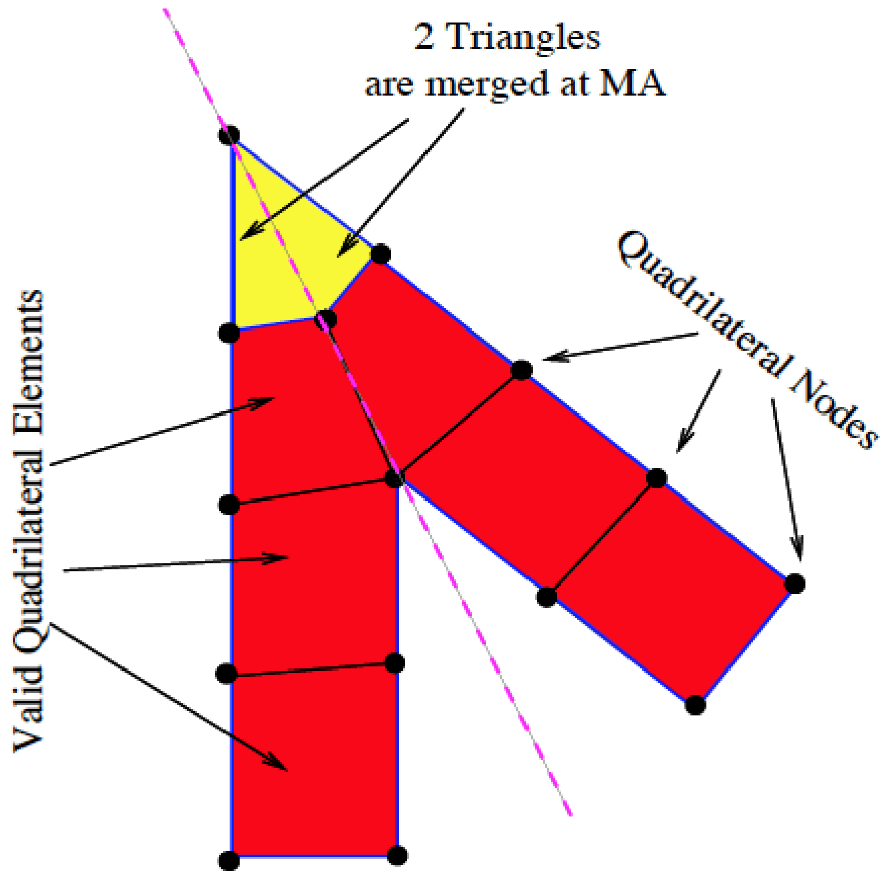


Track width controlled by medial radius function

Mesh Tracks: All-Quad Mesh can be Generated in 2D

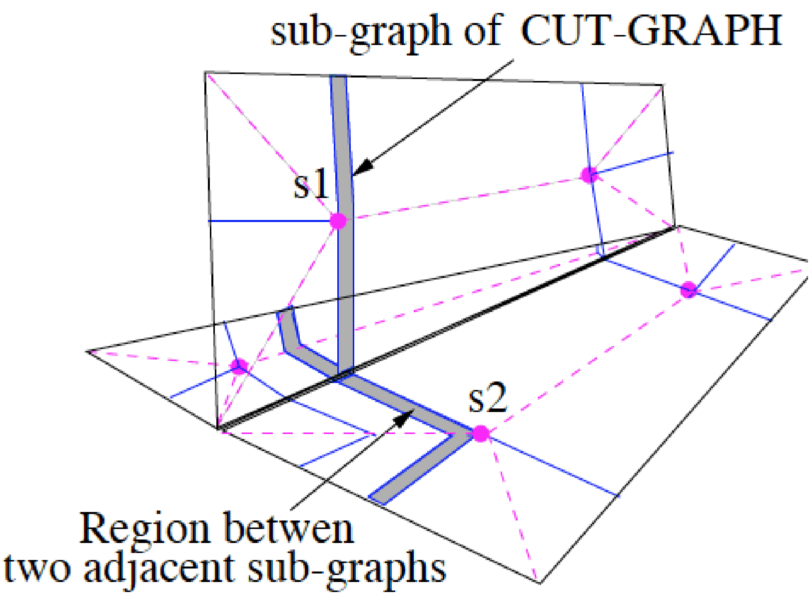
Sandia National Laboratories

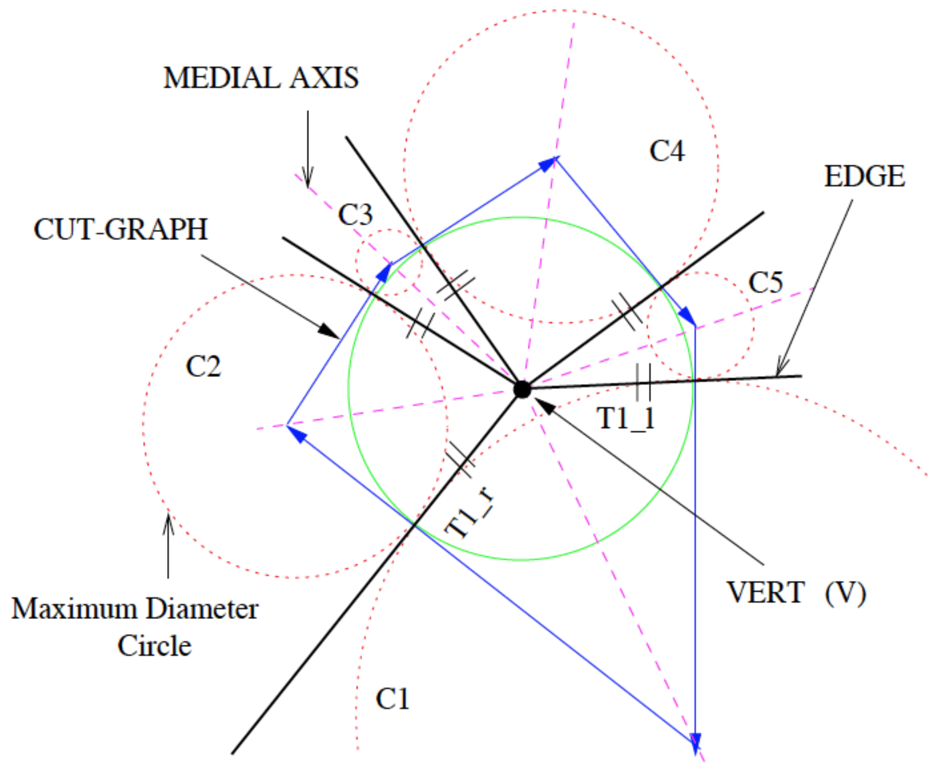




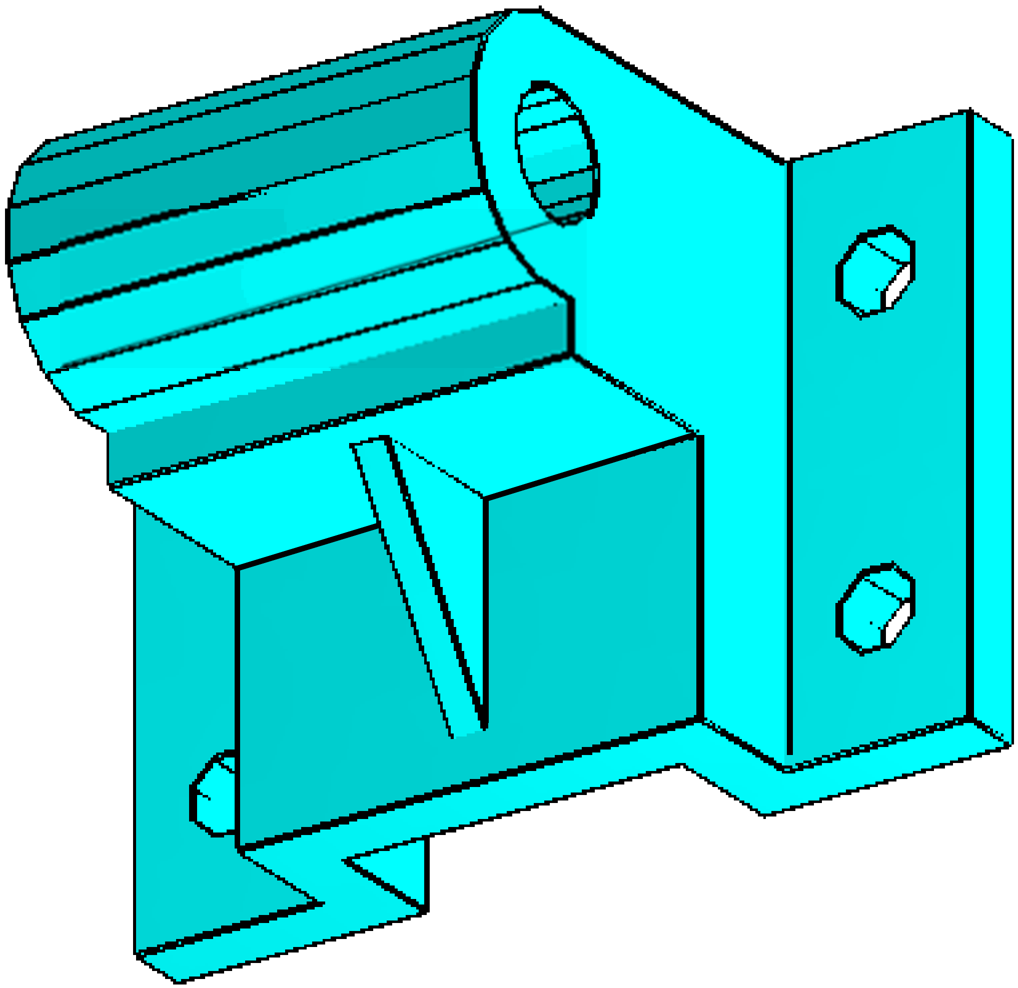
All-Quad: A track is bounded by even number of edges via symmetric property

LayTracks on Multiple Surfaces

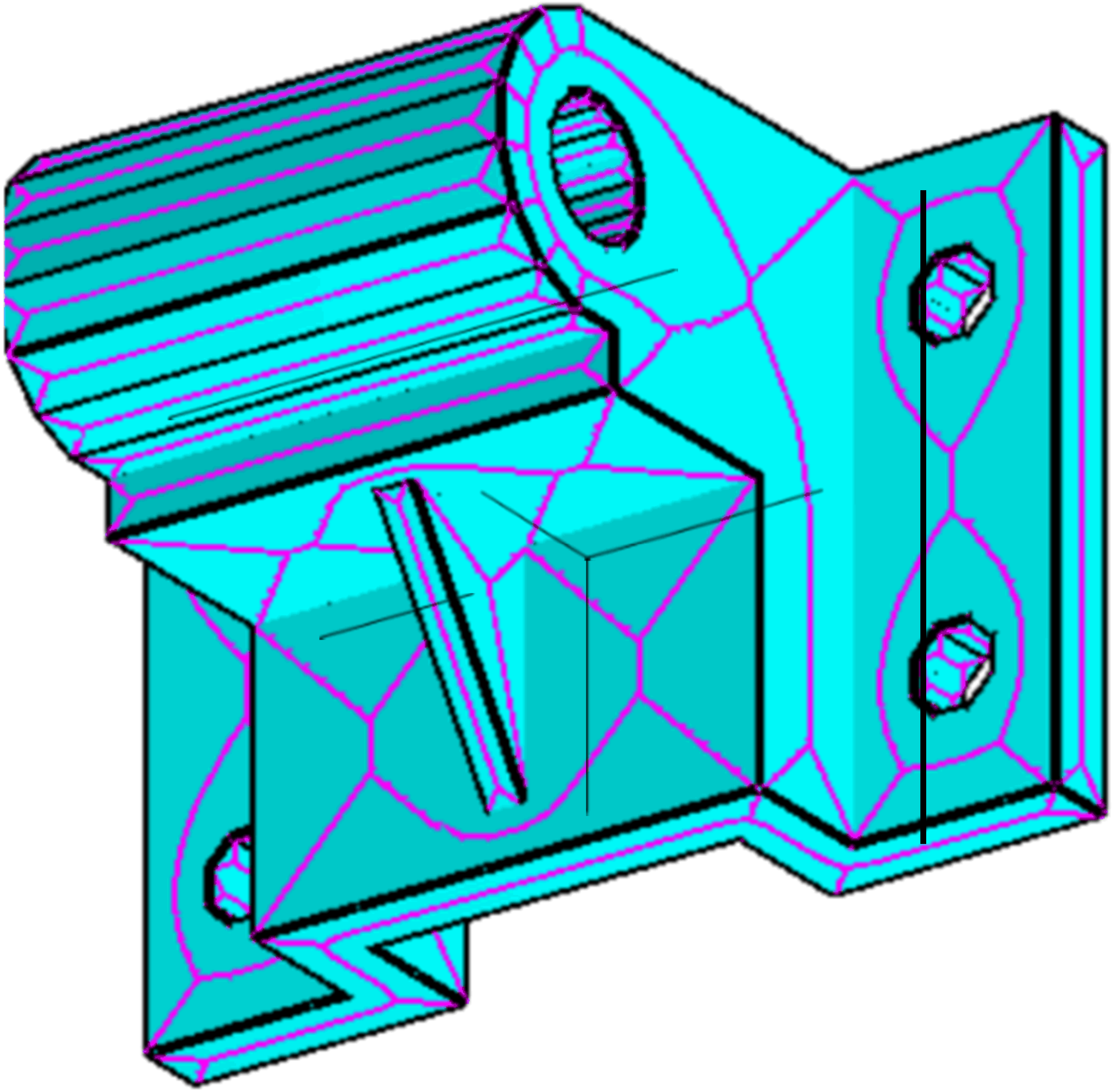




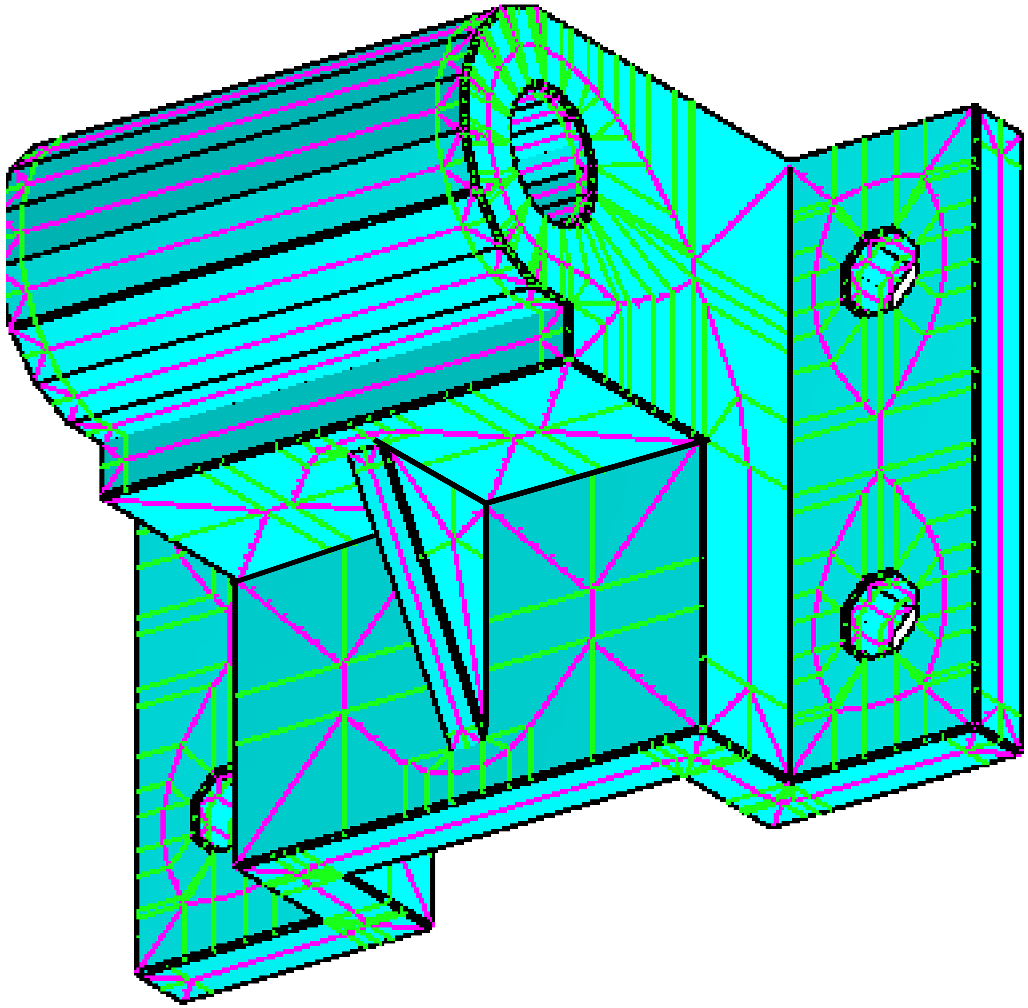
Assembly of Surfaces



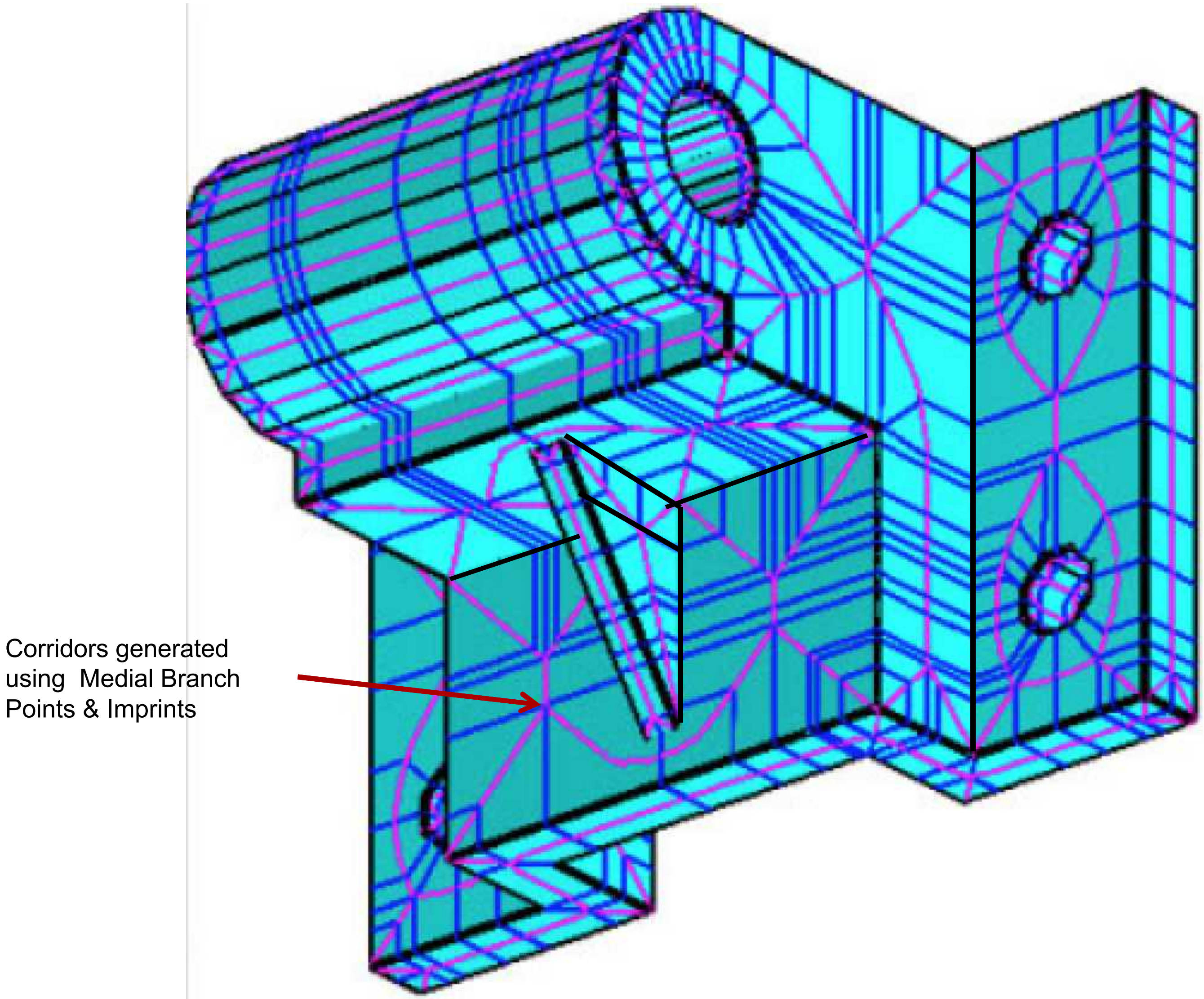
Medial of Multiple Surfaces



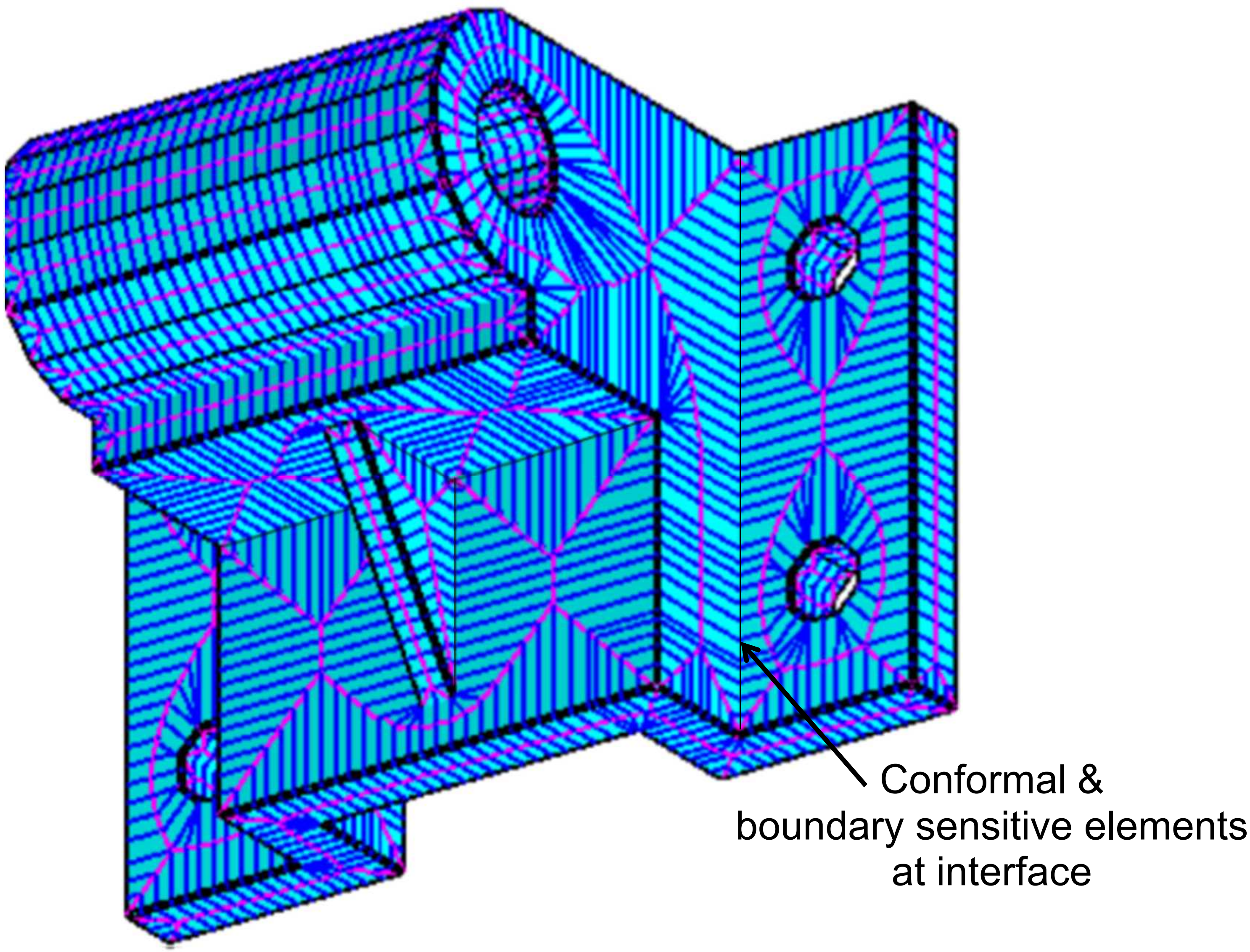
Two-Way Map on Multiple Surfaces



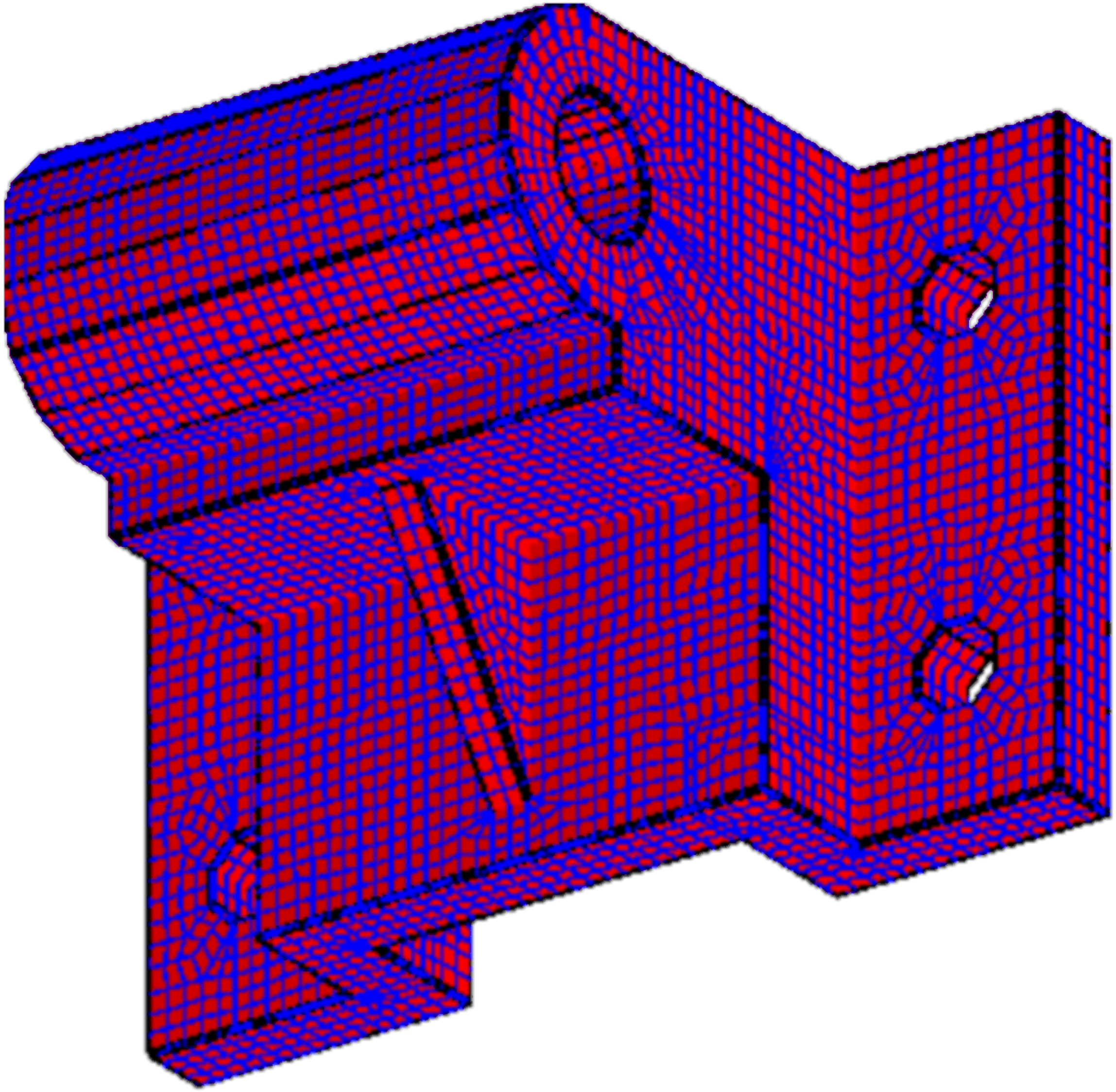
Automatic Geometry Decomposition



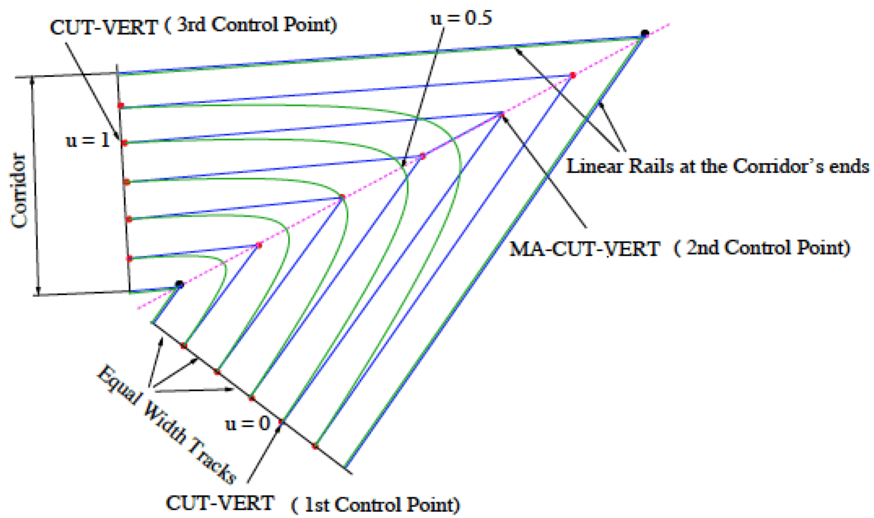
Tracks on Multiple Surfaces

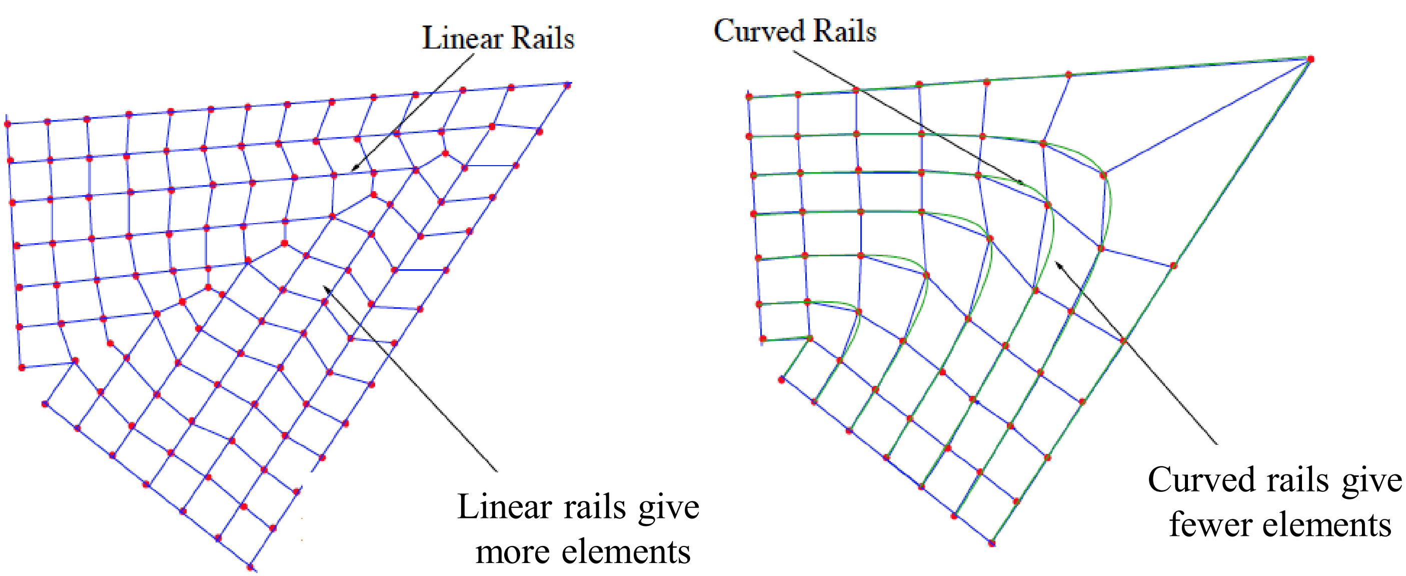


Quad Mesh on Multiple Surfaces
(with no post-meshing operations)



LayTracks with Curved Rails & Tracks



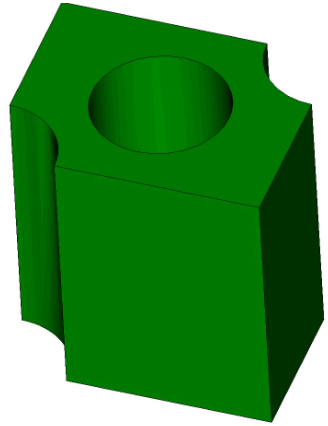


LayTracks3D:
Extension of LayTracks to 3D

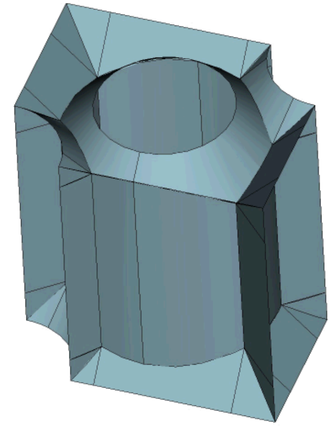
Overview of LayTracks3D

Sandia National Laboratories

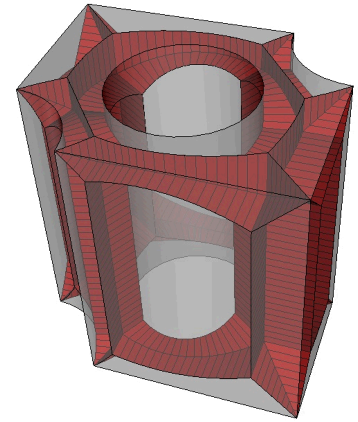
- Solid or Assembly
- Step 1: Generate MAT
- Step 2: Geometry Decomposition -Generate Corridors using MA junctions & Imprints
- Step 3: Mesh all Medial or Boundary Surfaces of Corridor
- Step 4: Generate Tracks by Propagating Rails in Corridors
- Step 5: Mesh Tracks
- Mesh



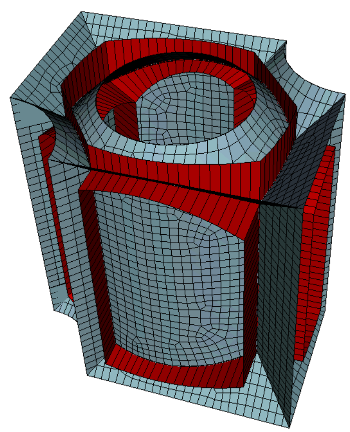
Input solid



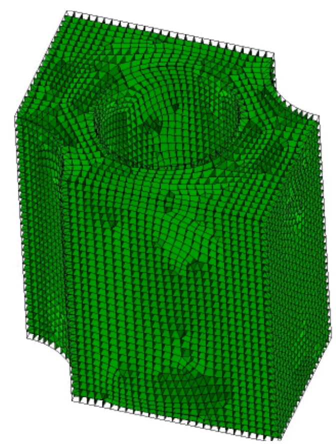
(1) Medial surface



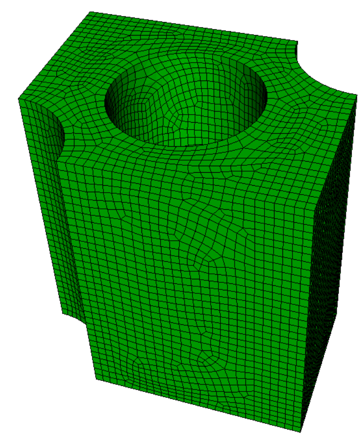
(2) Corridors



(3) Mesh on medial in corridors

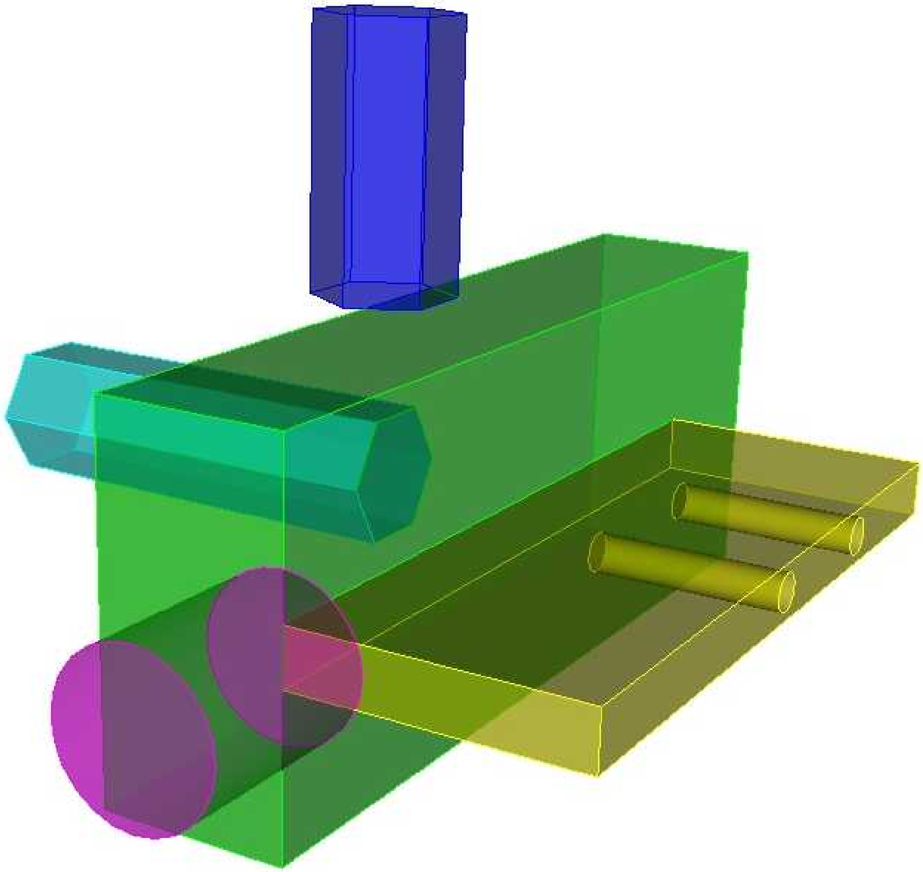


(4) Tracks in 3D

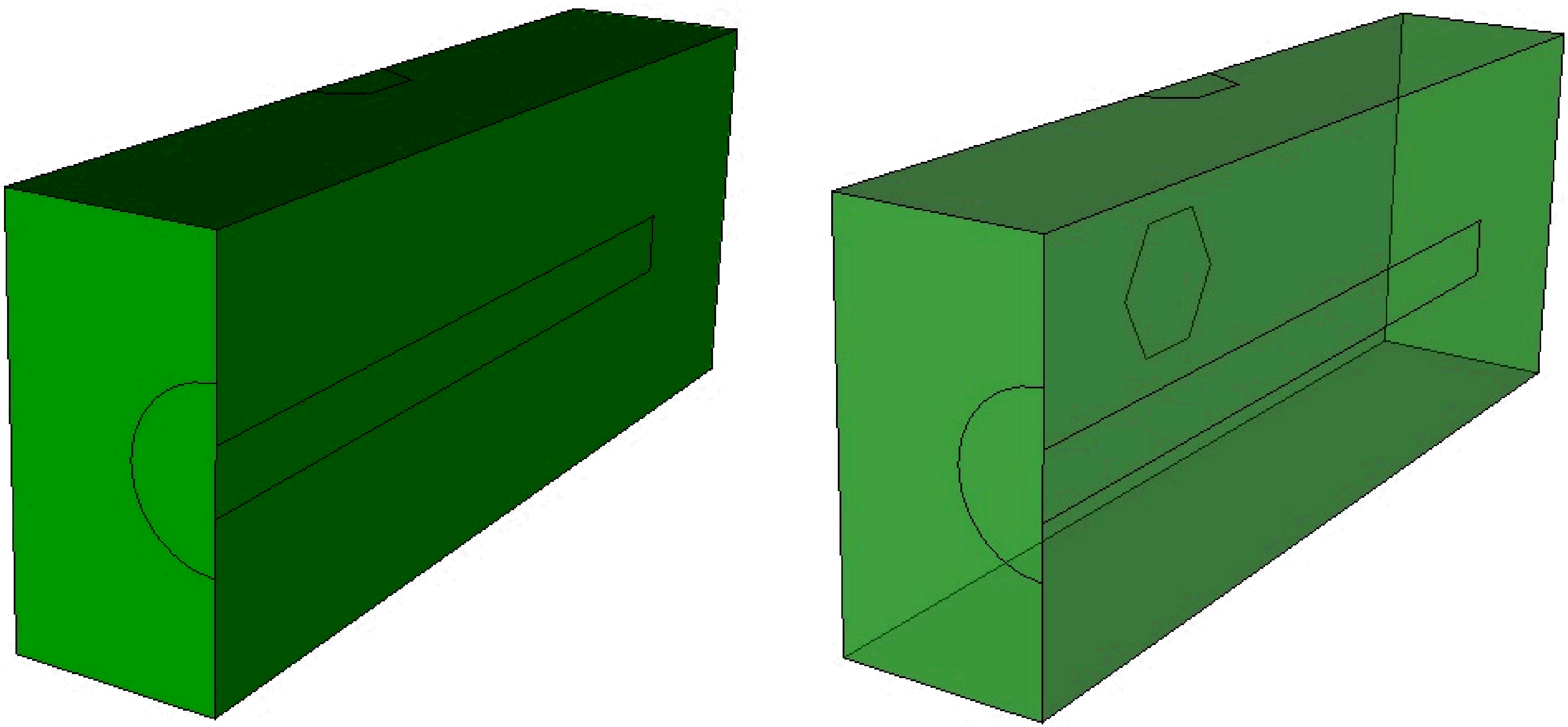


(5) Hex dominant Mesh

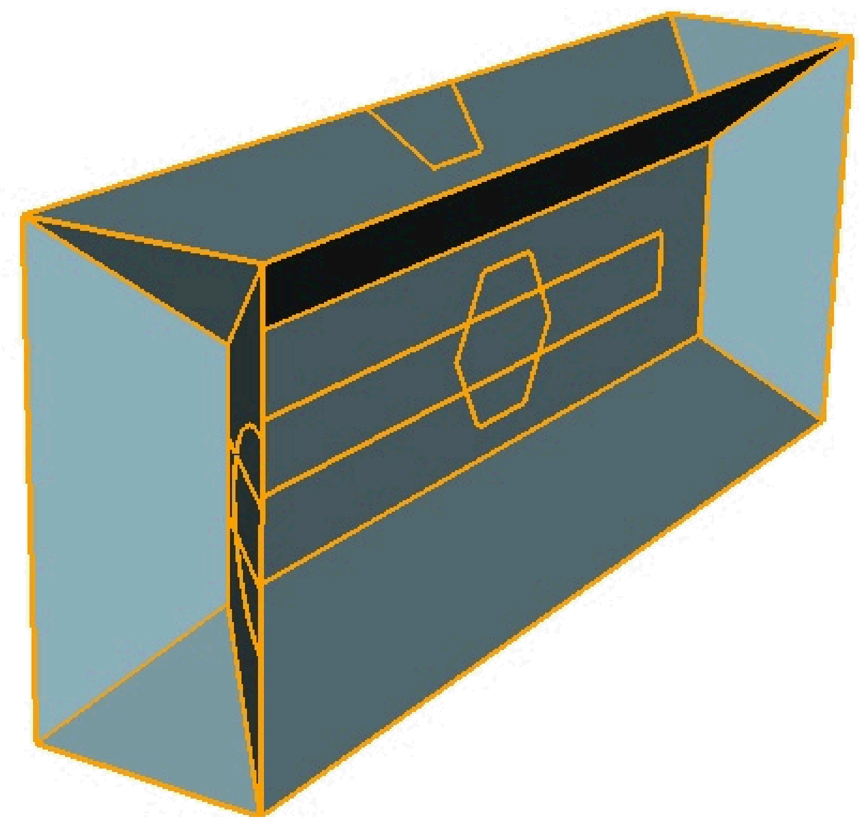
Extension to Assembly Model



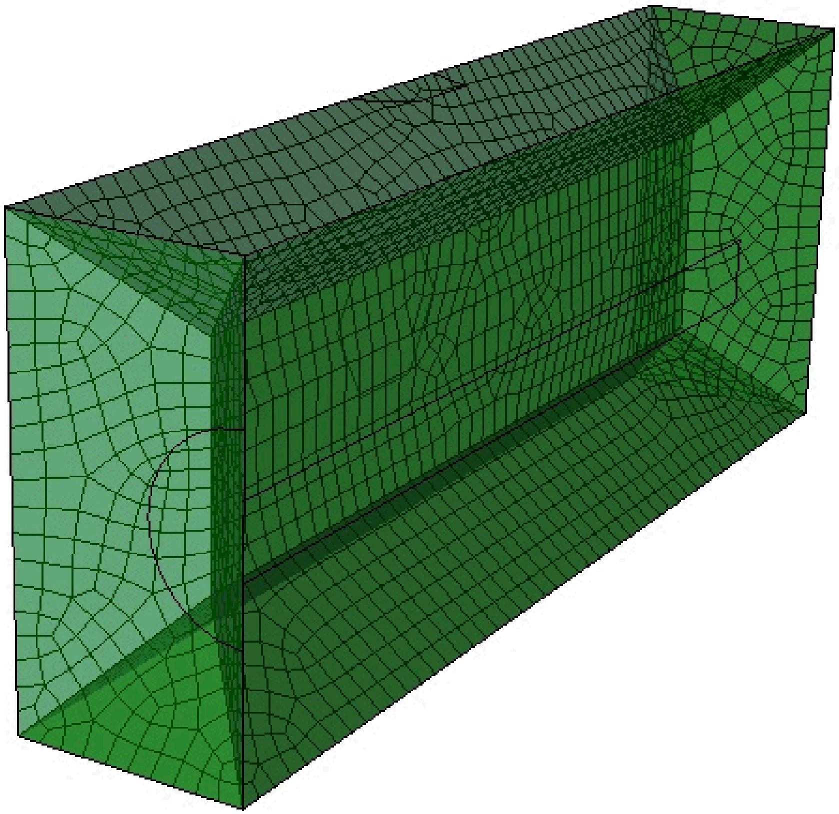
Imprints on Top, Bottom, and Sides

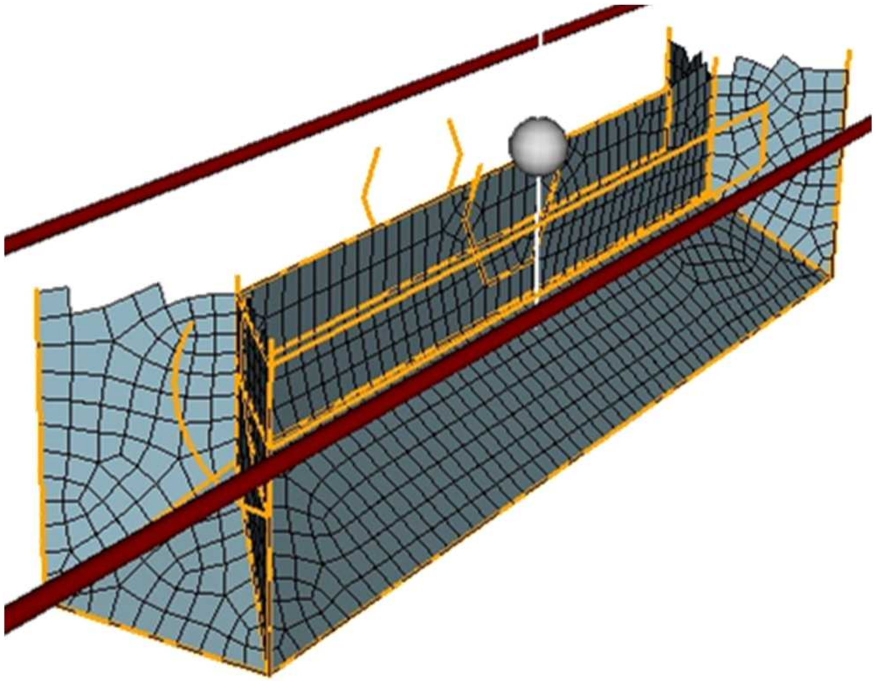


All Imprints Resolved at MA using Projection Operator

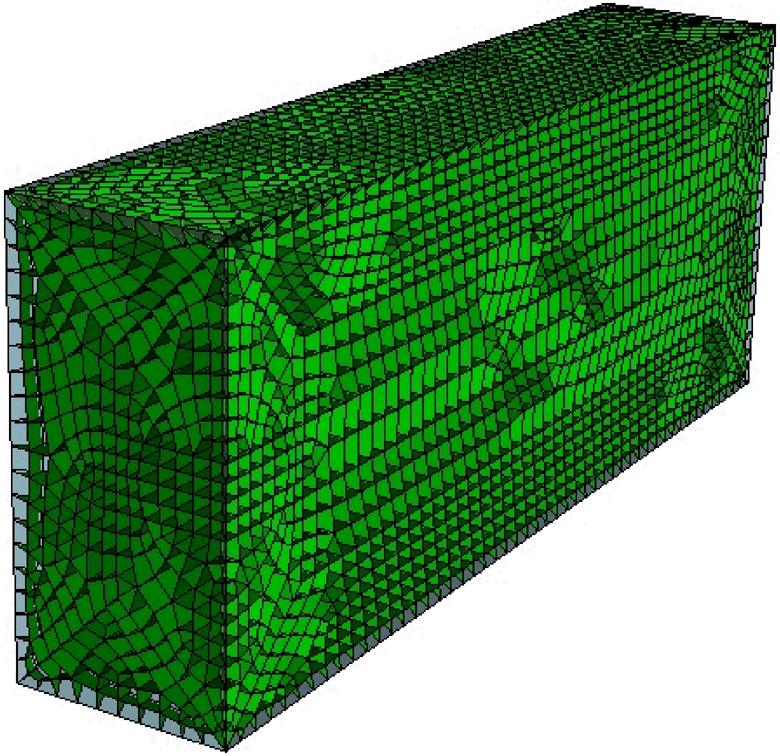


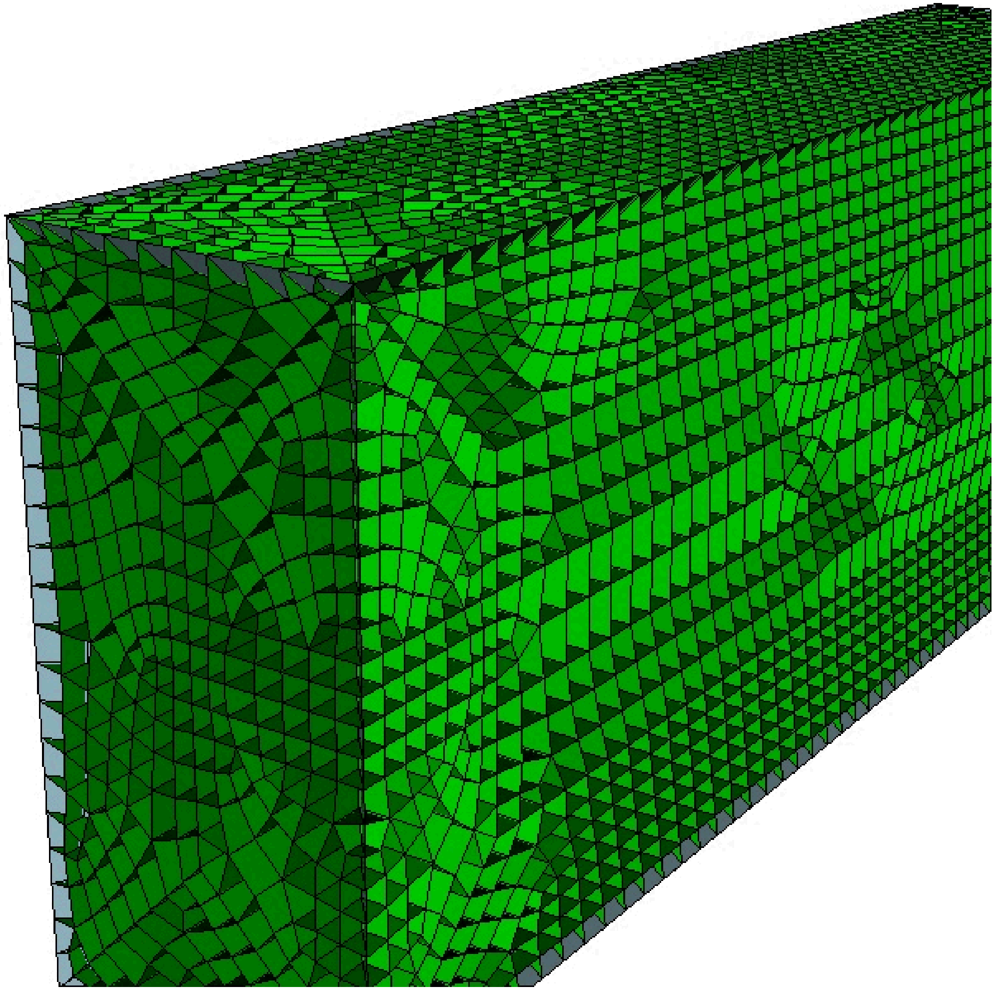
Quad Mesh on Imprinted Medial



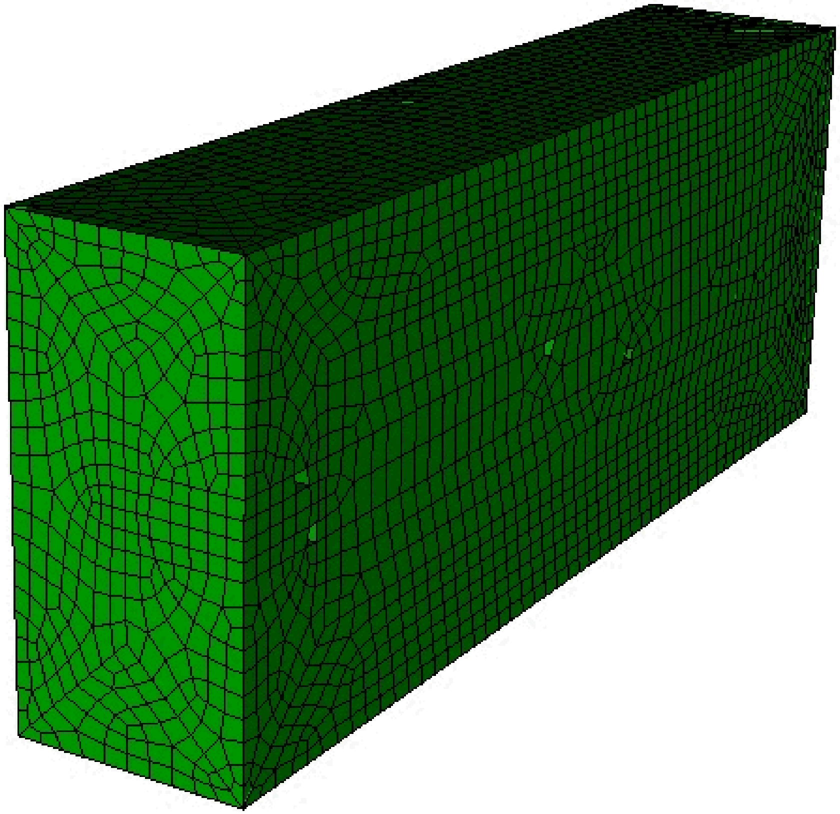


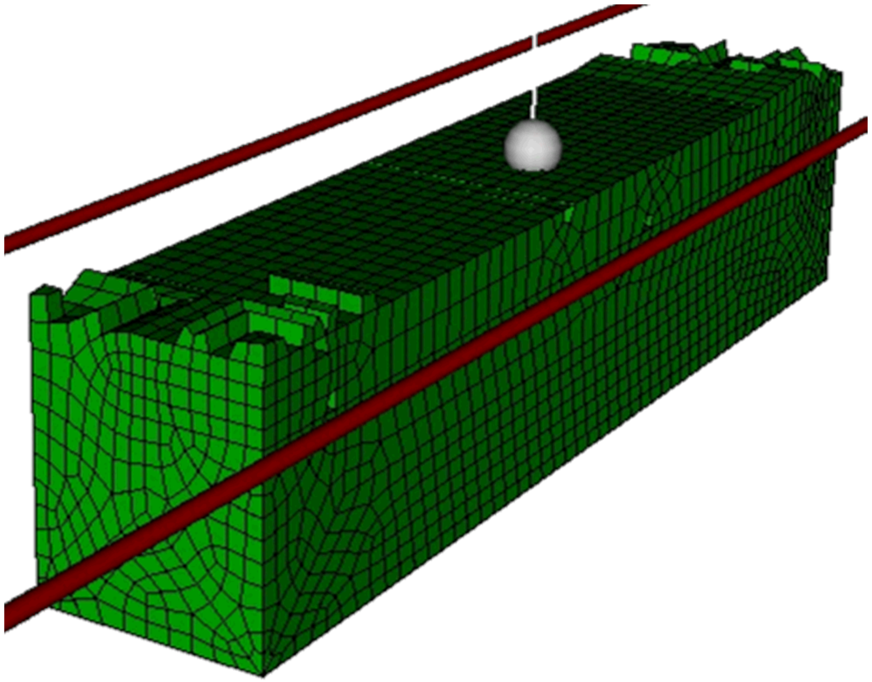
Tracks in 3D



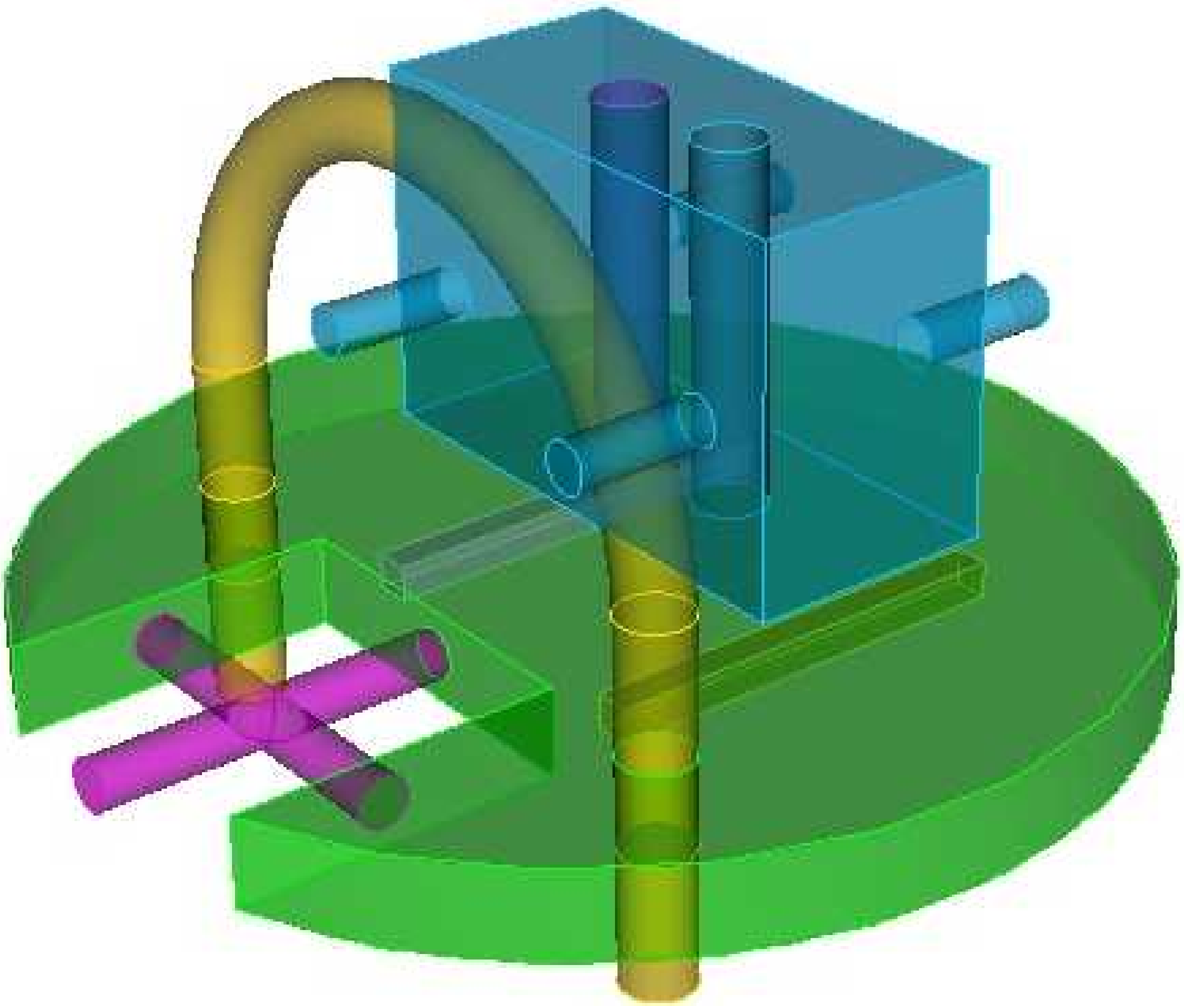


Hex-dominant Mesh

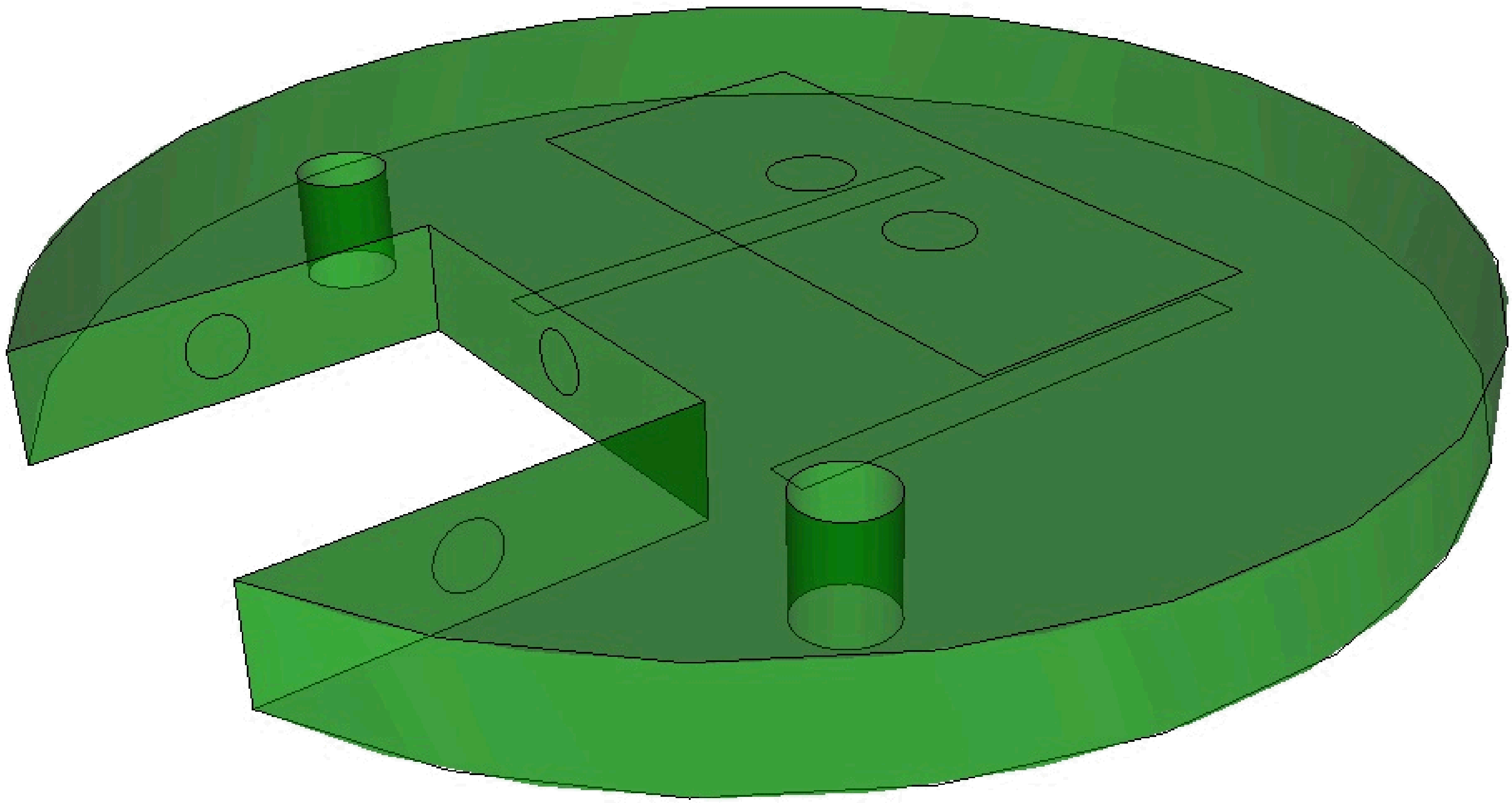




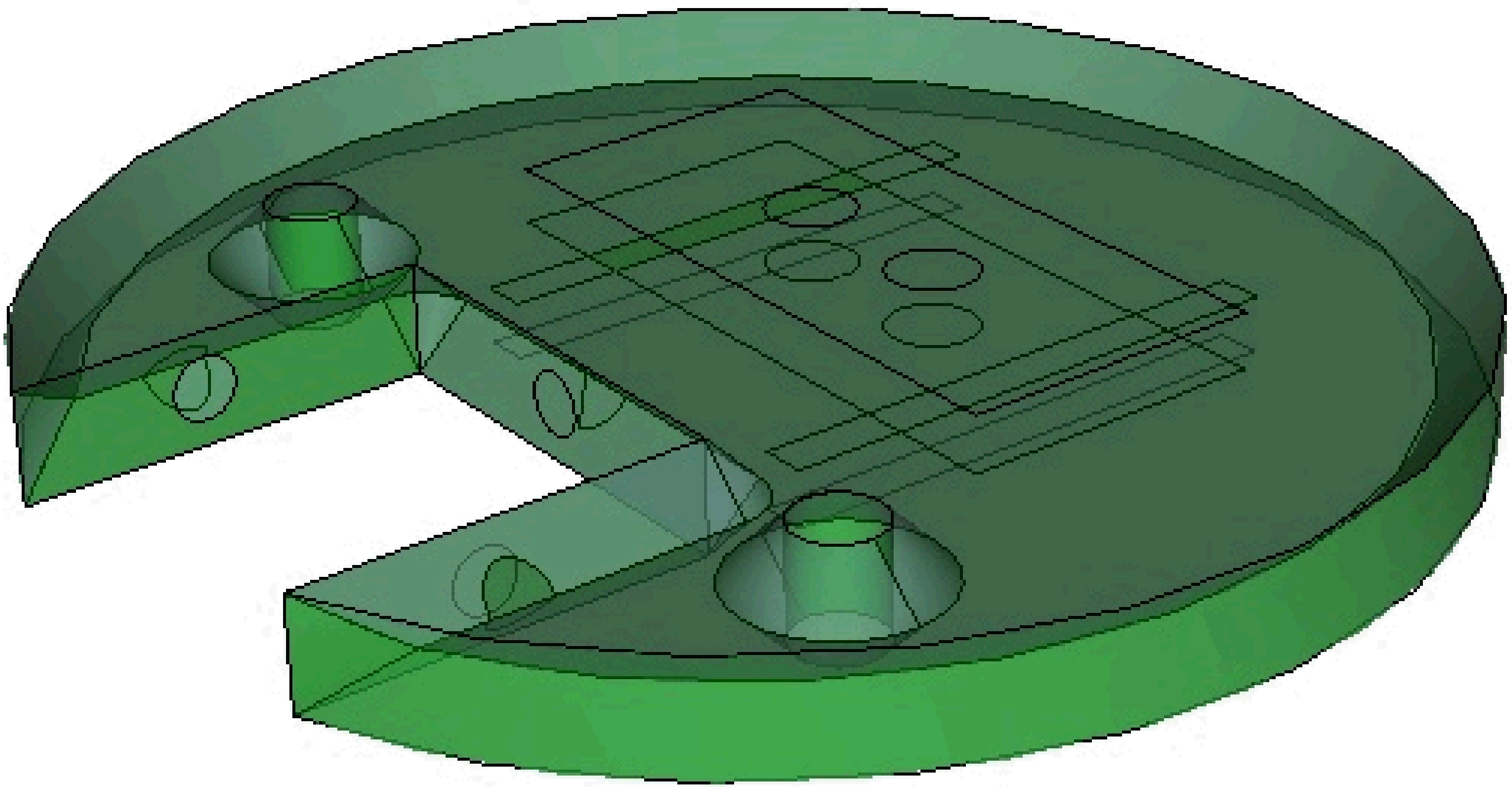
Extension to Assembly Model



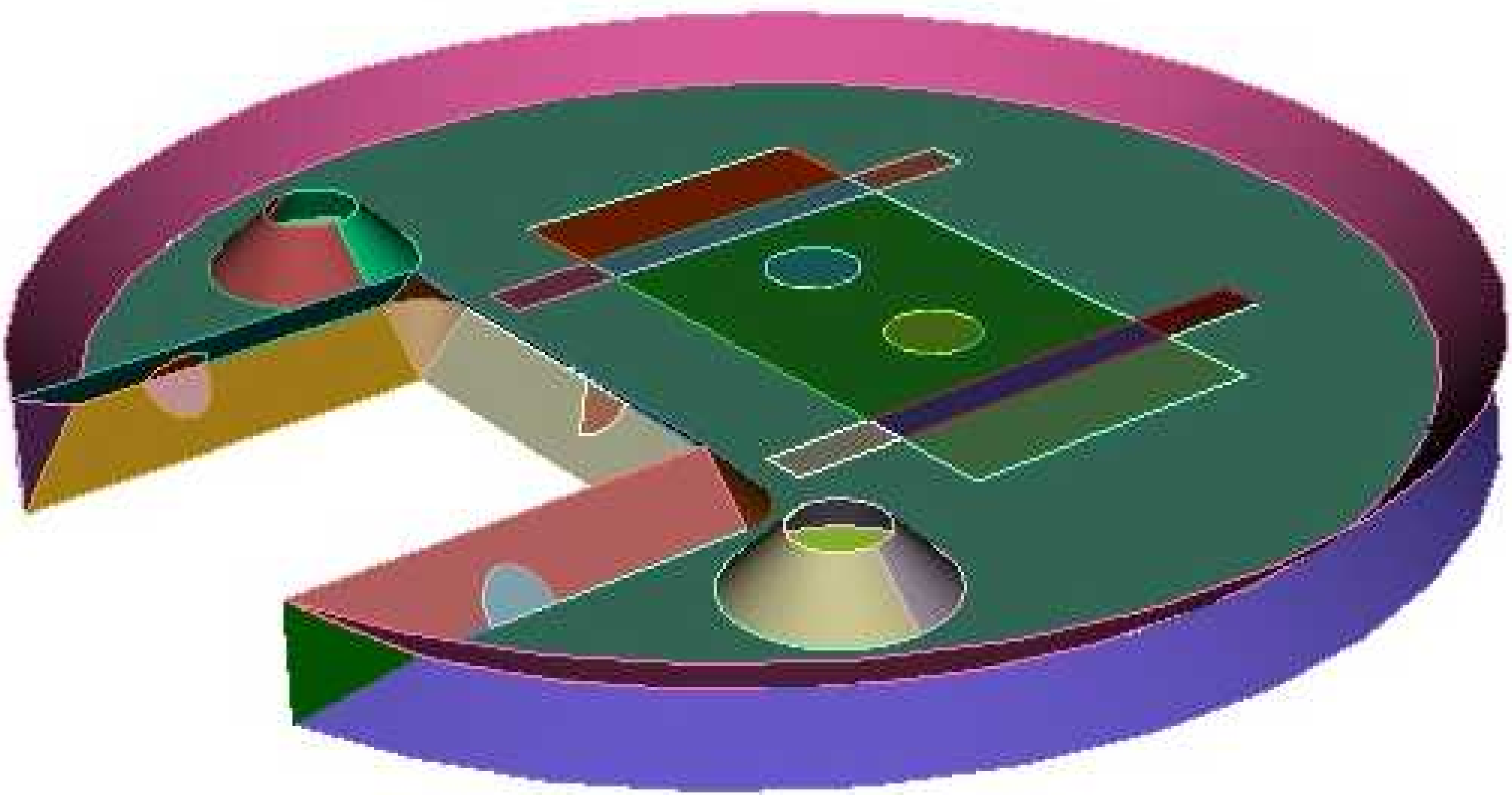
Imprints on Top, Bottom, and Sides



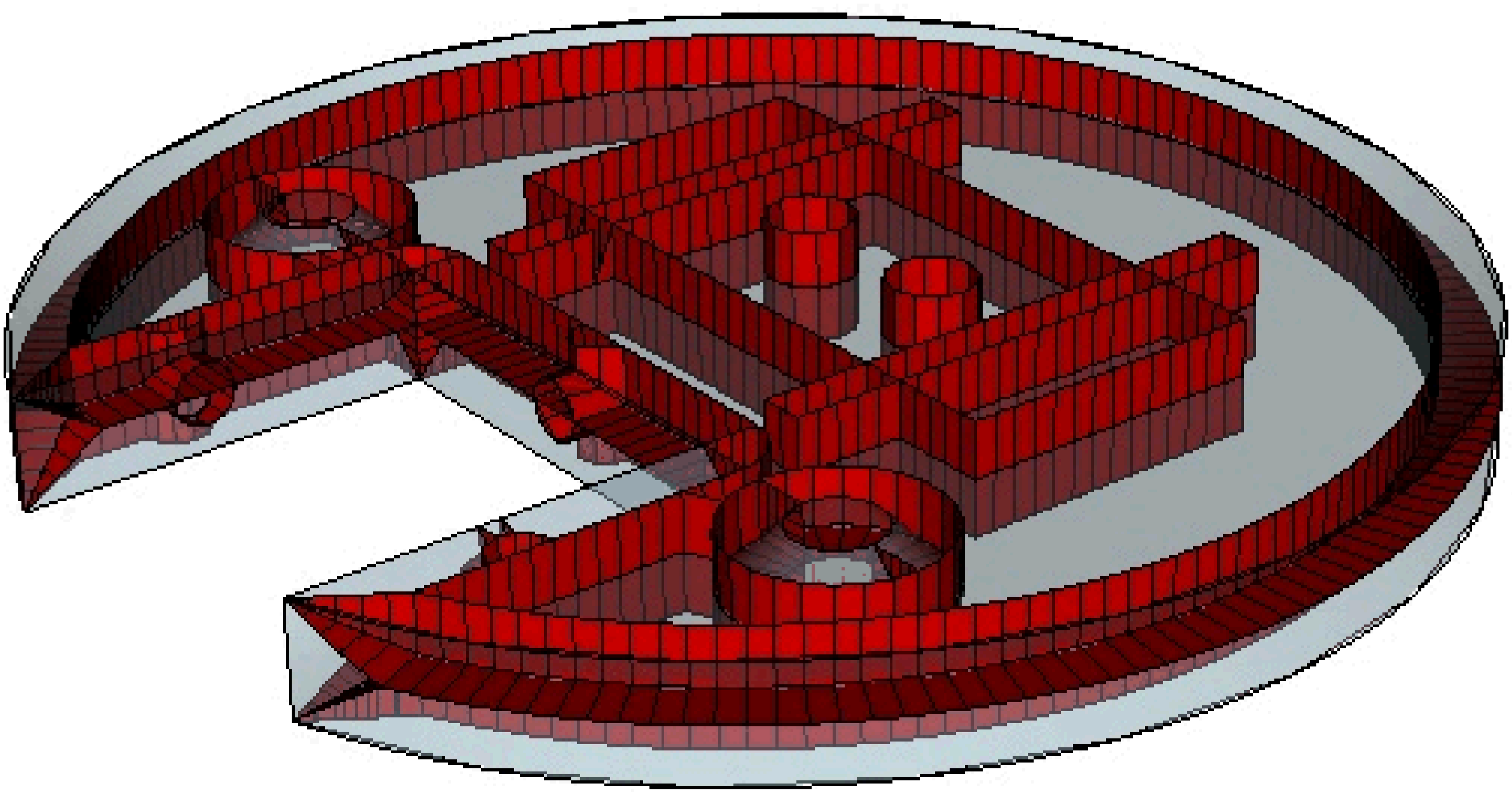
Resolve Boundary Imprints on Medial using Projection Operator



Medial Resolves Imprints from All Directions

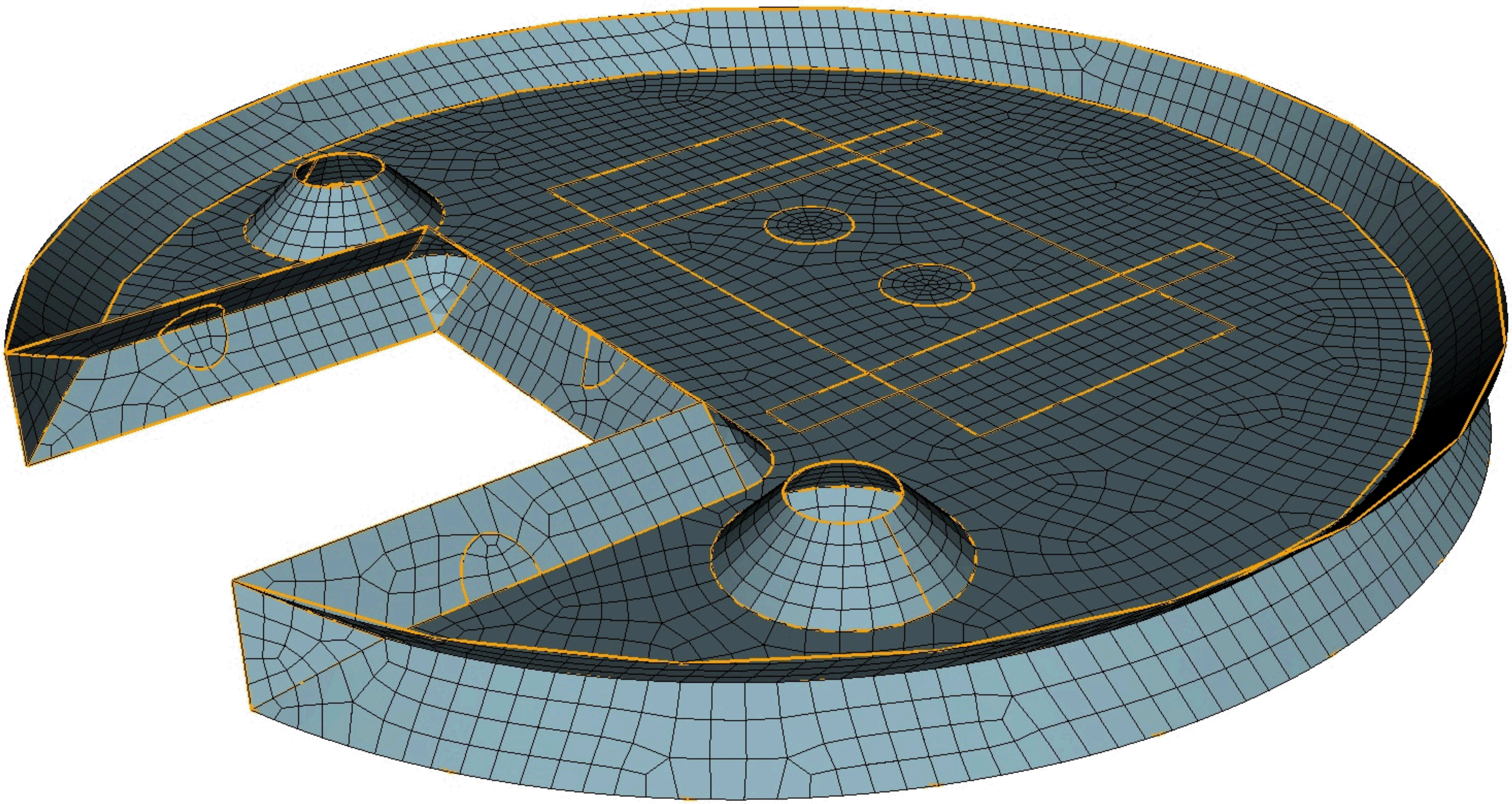


Automatic Geometry Decomposition using Imprints and Medial Junctions

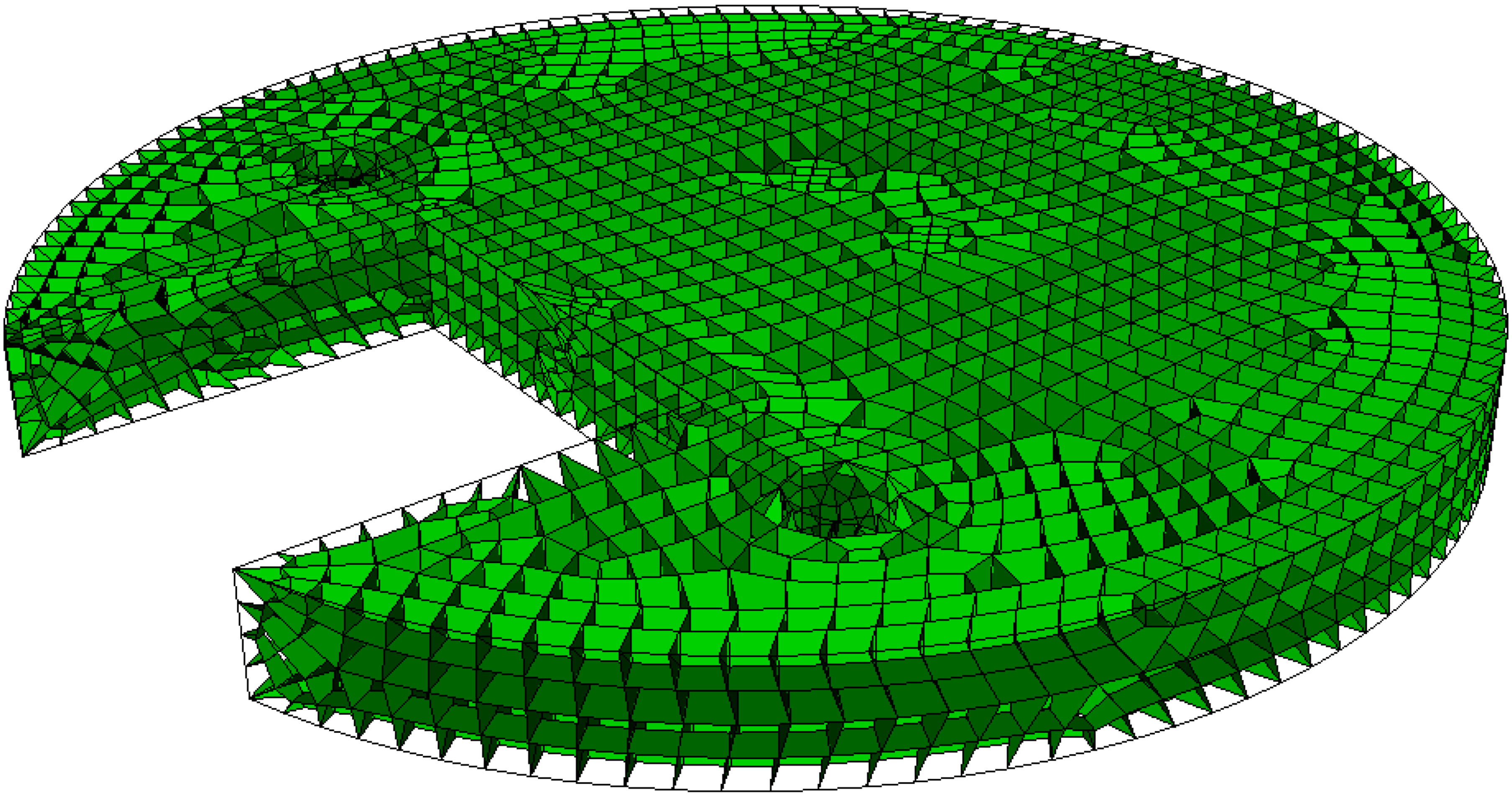


Corridors

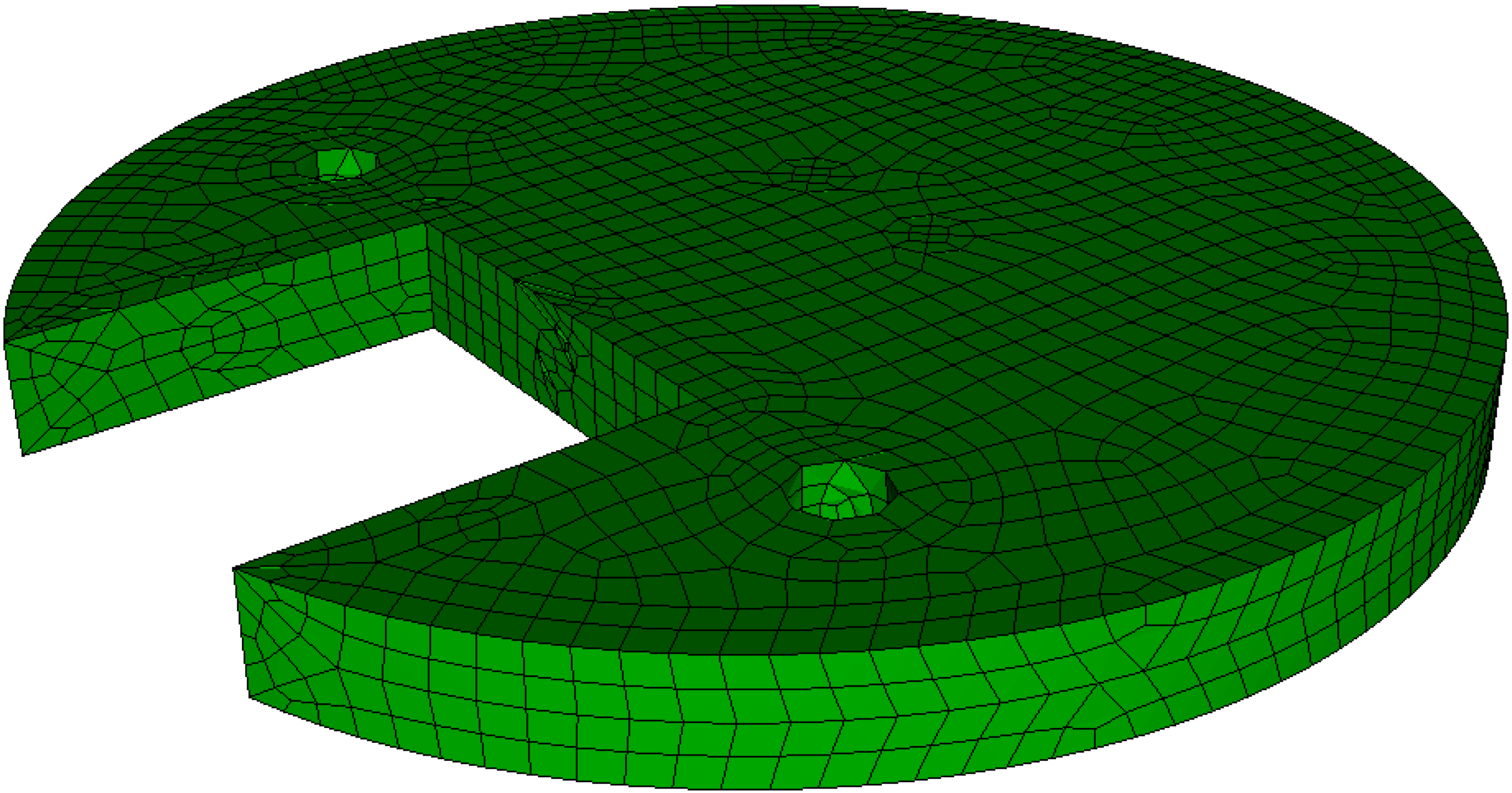
Quad Mesh on Imprinted Medial



Tracks in 3D

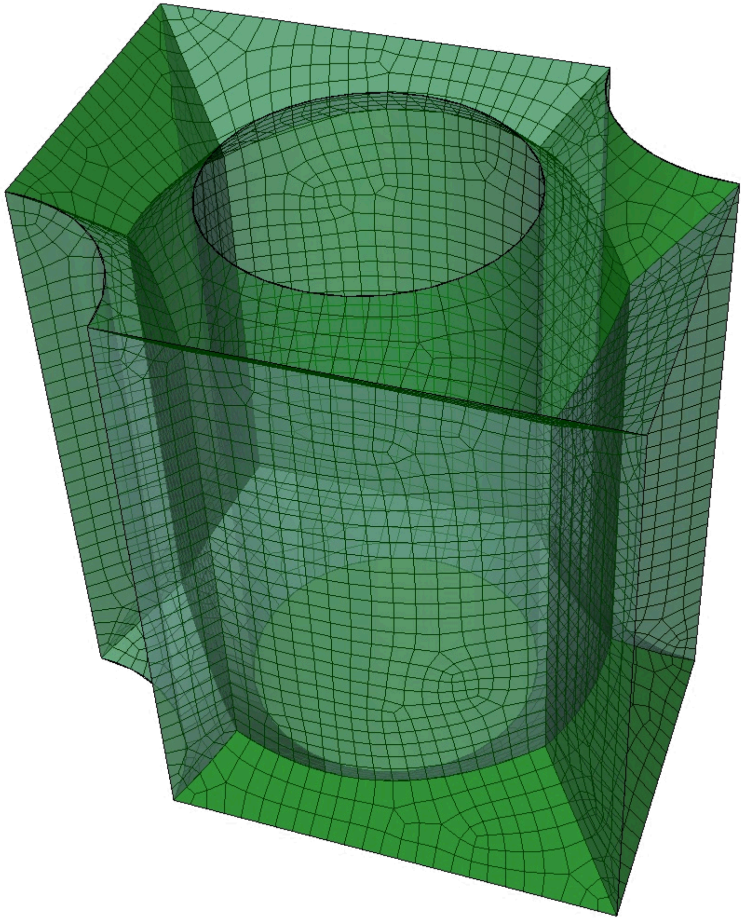


Hex-Dominant Mesh

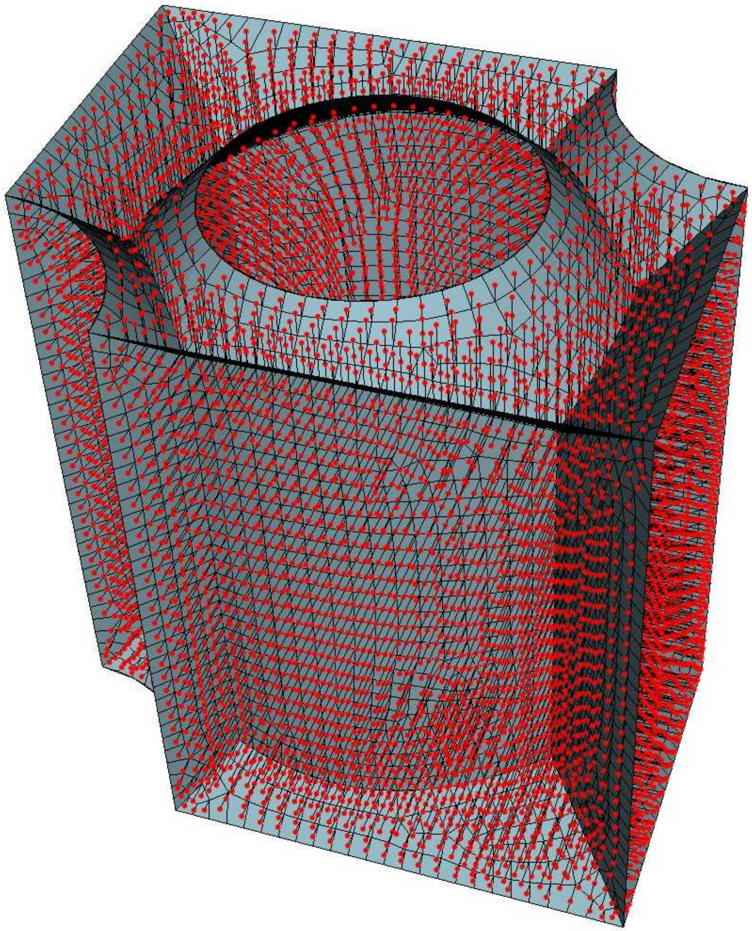


Improve Quality at Common 3-manifold MA Curve

All-Quad Mesh on Medial is not Ideal!

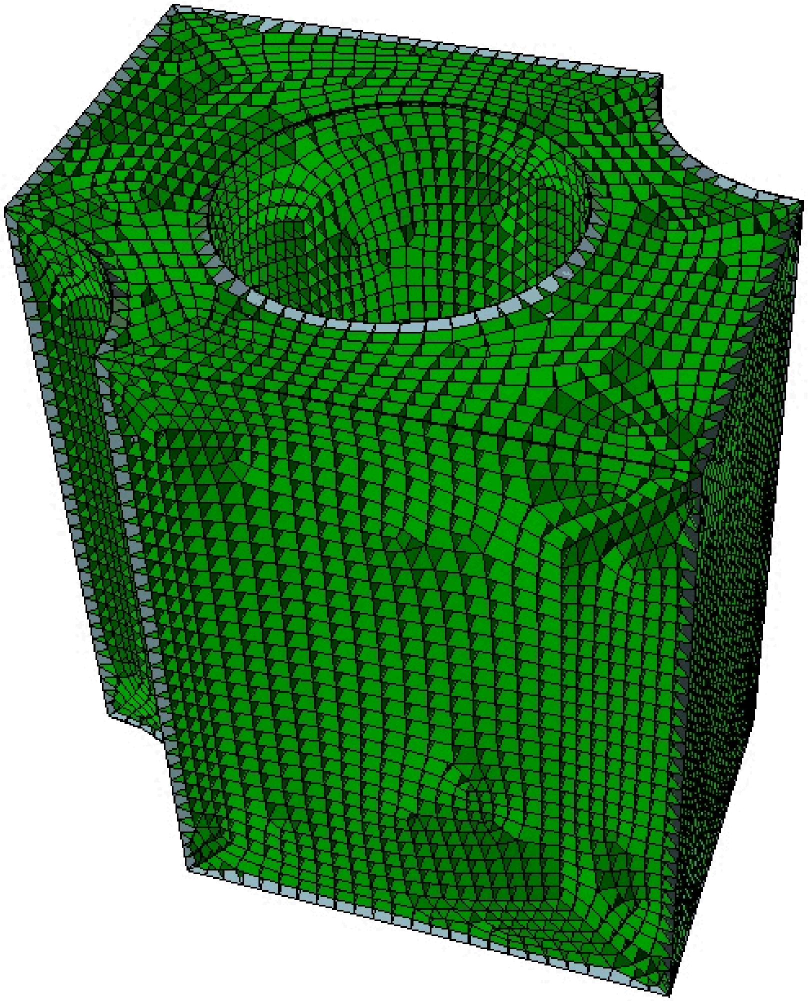


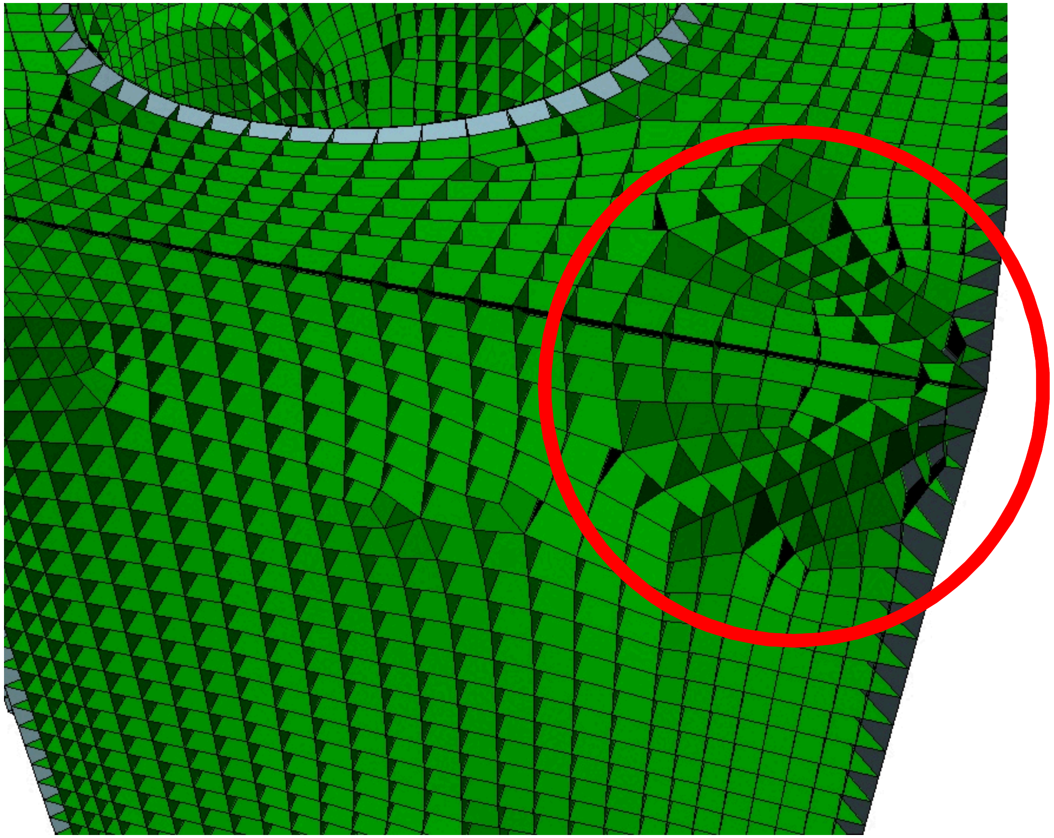
All-Quad Mesh on Medial Surface



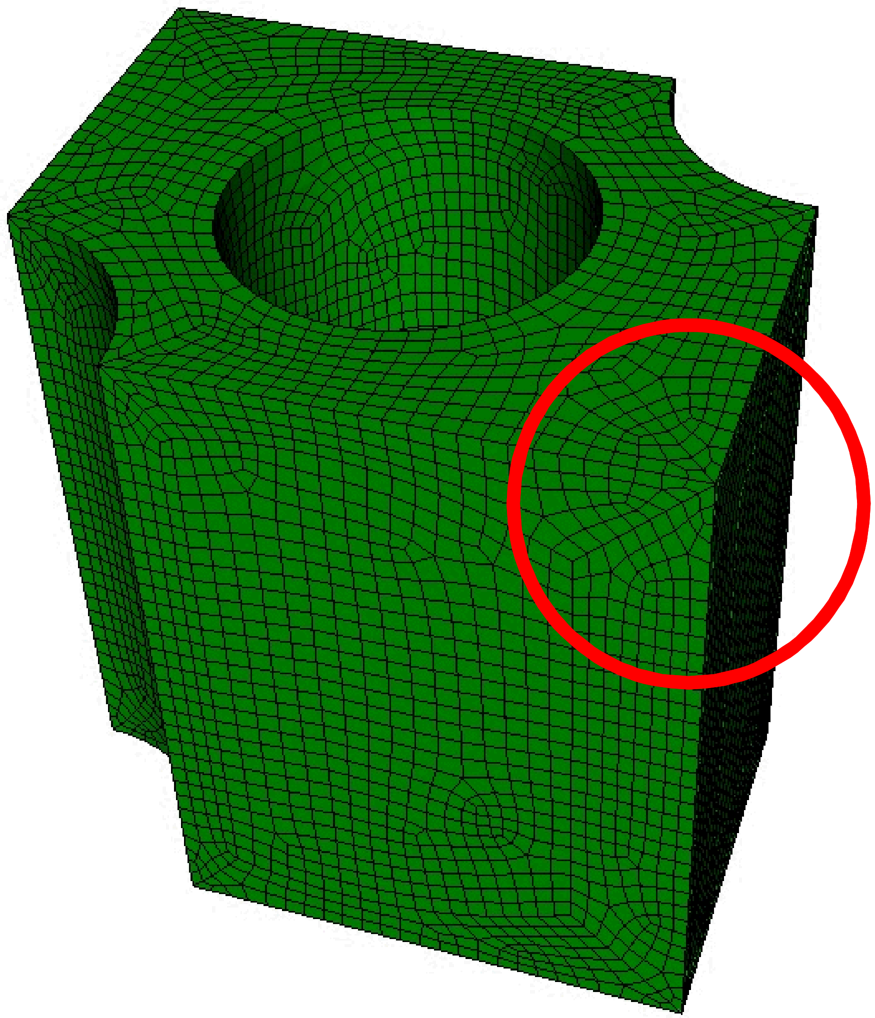
Rails Generated using Projection Operator

Complex Tracks at a Convex Vertex



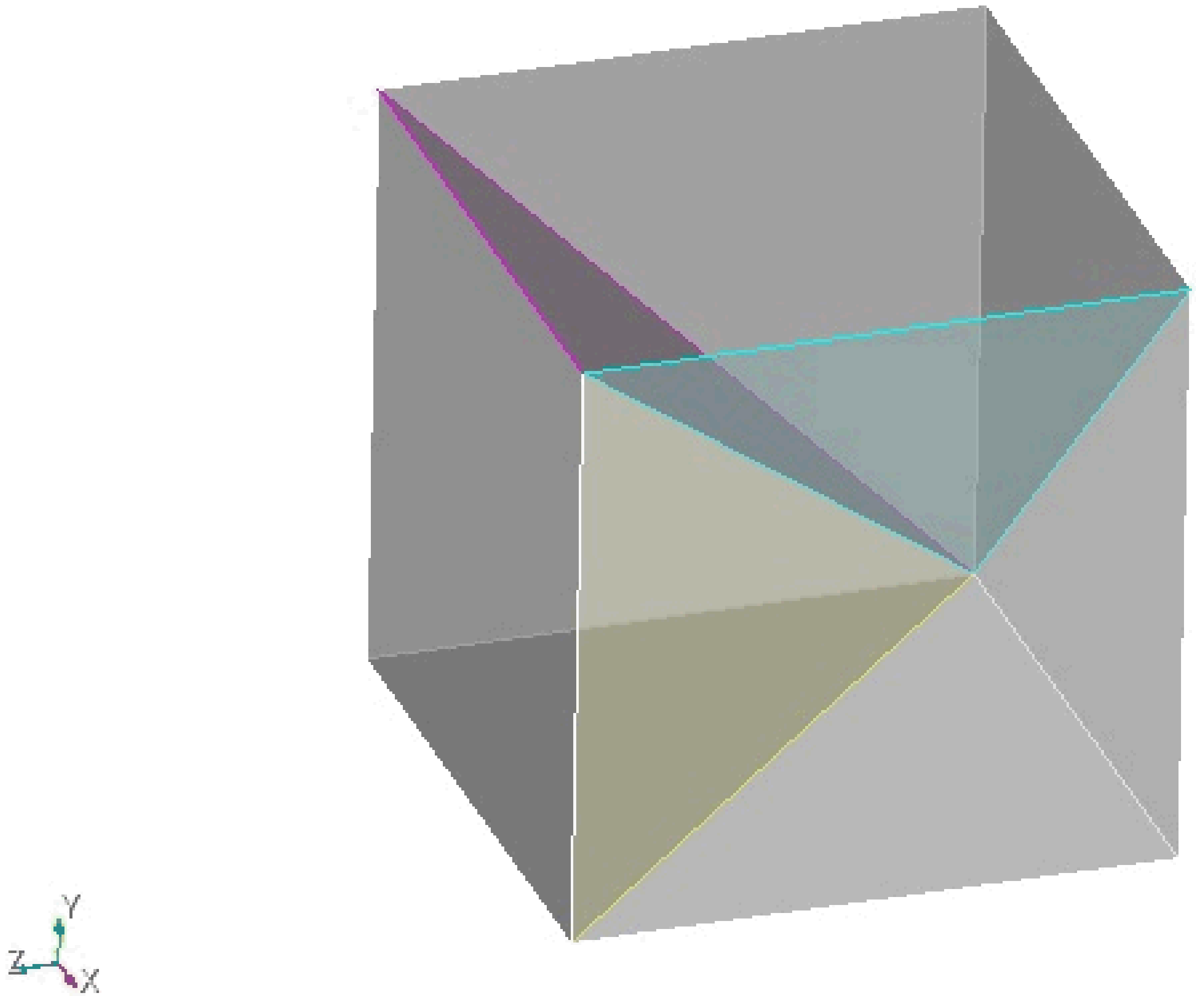


Hex-dominant Mesh at Convex Vertex

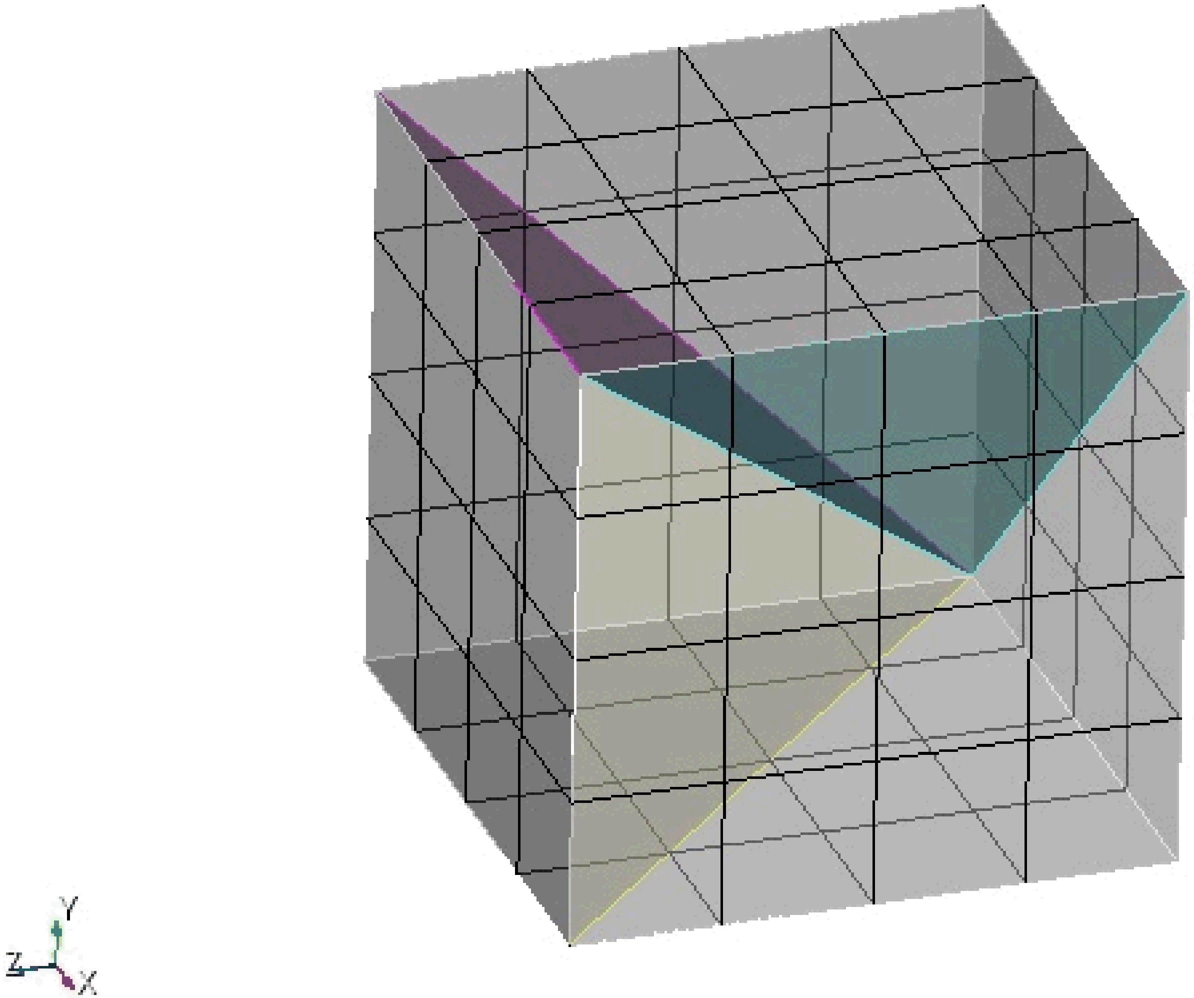


How to Improve Hex Quality at Convex Vertex?

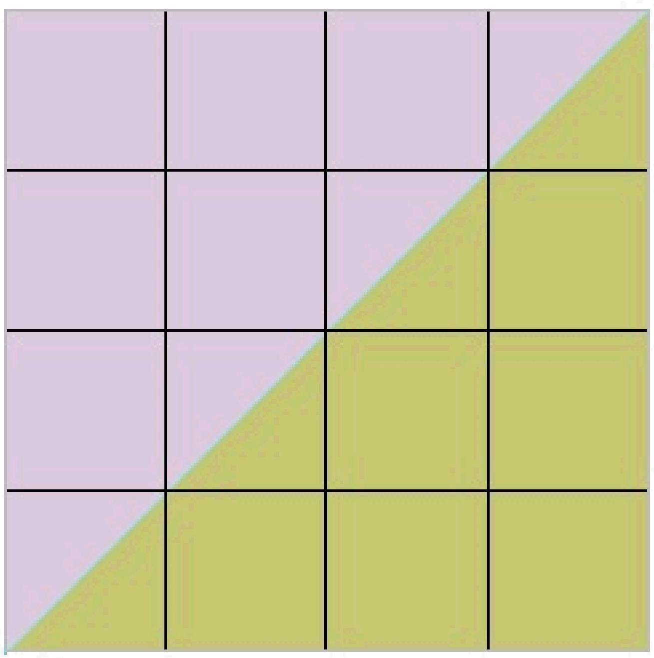
Typical 3-manifold Medial at a Convex Vertex

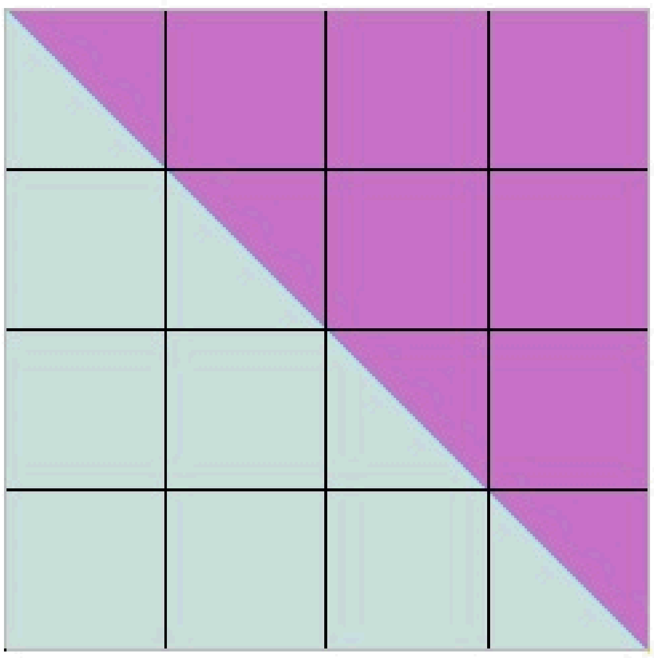


Ideal Hex Mesh at a Convex Vertex

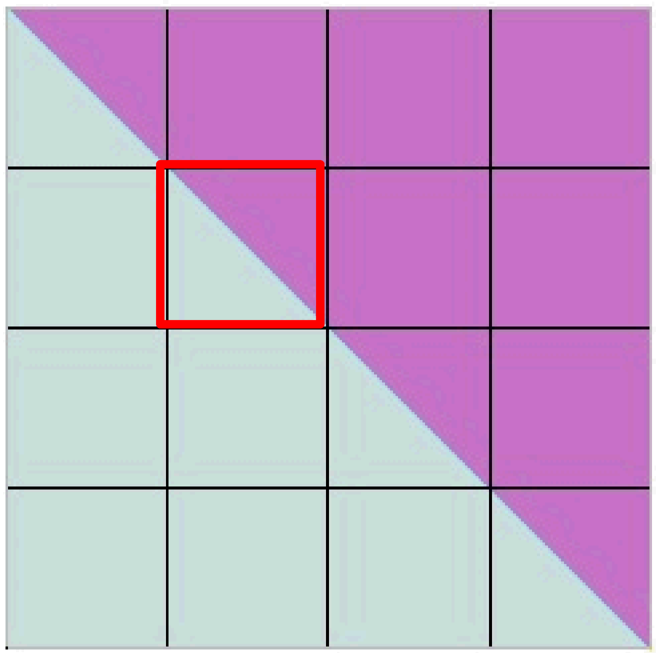


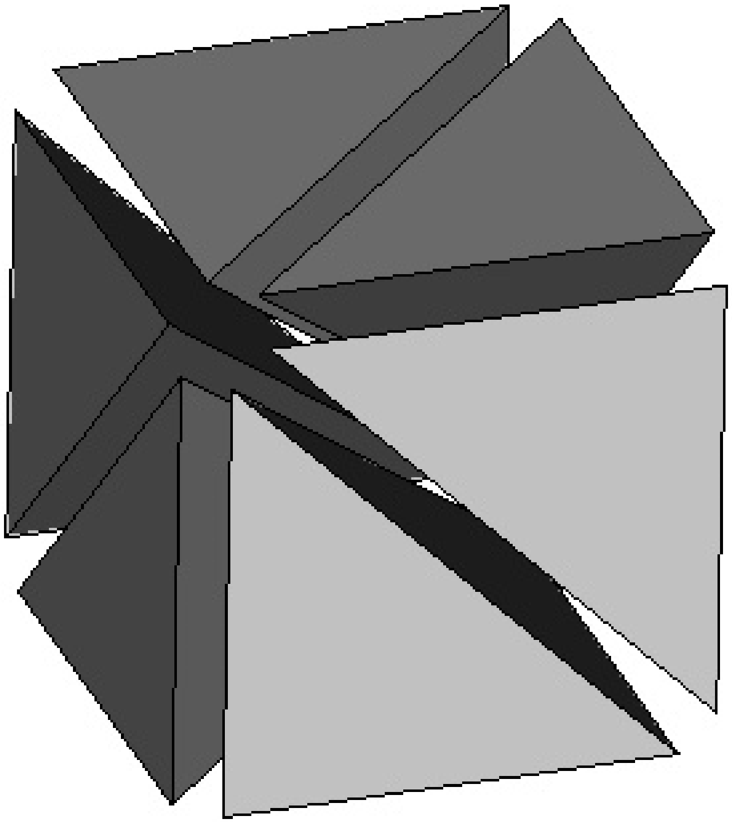
Ideal Mesh Should Contain Tri Along 3-manifold Medial Curve!!!



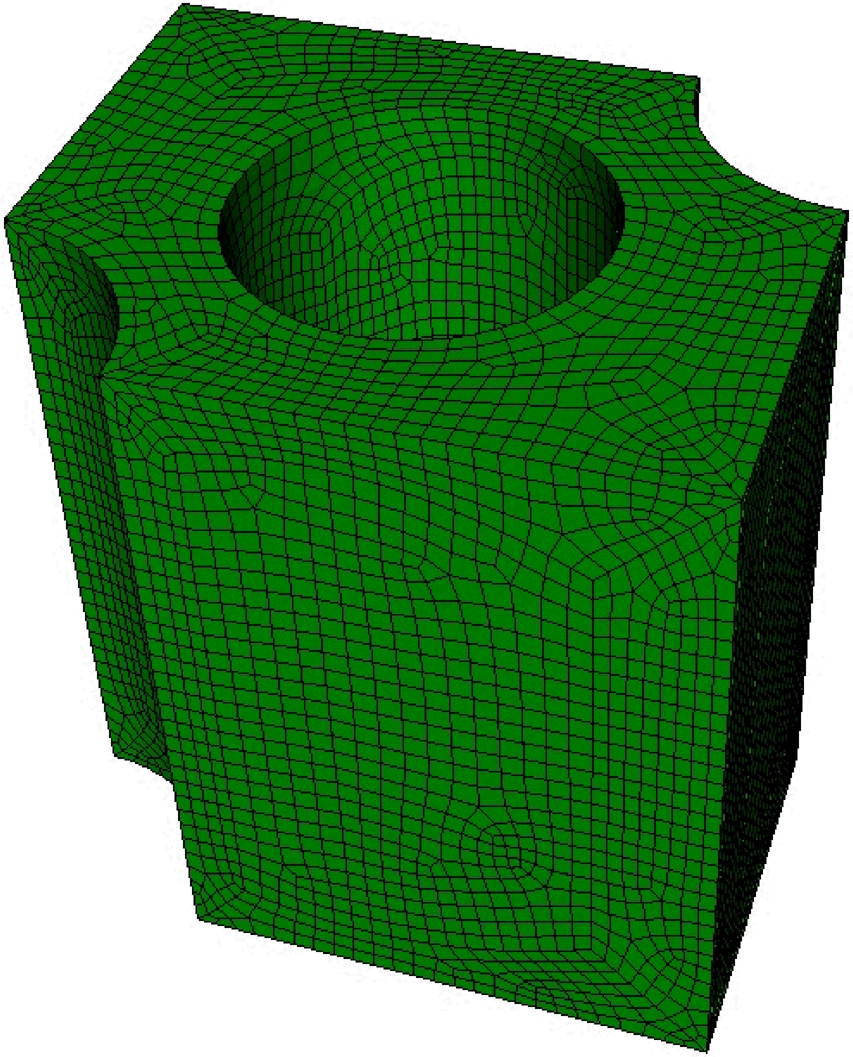


Merge Six Tets to form a Hex along 3-Manifold Medial Edge!!!

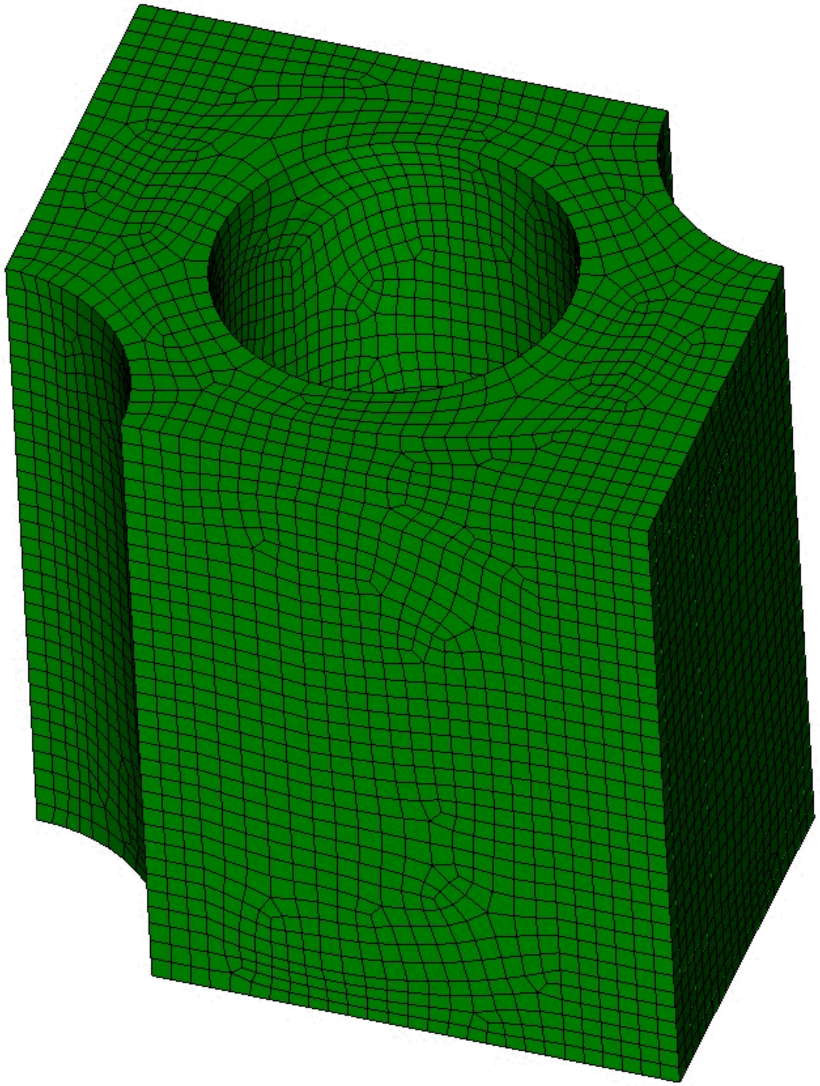




Improved Hex-dominant Mesh

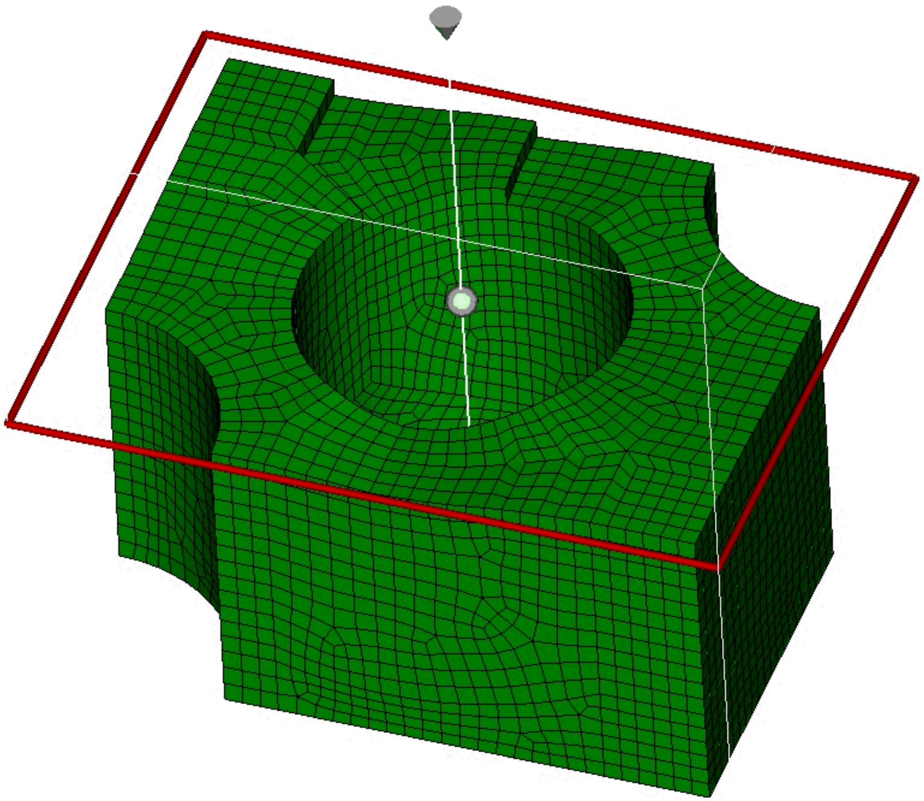


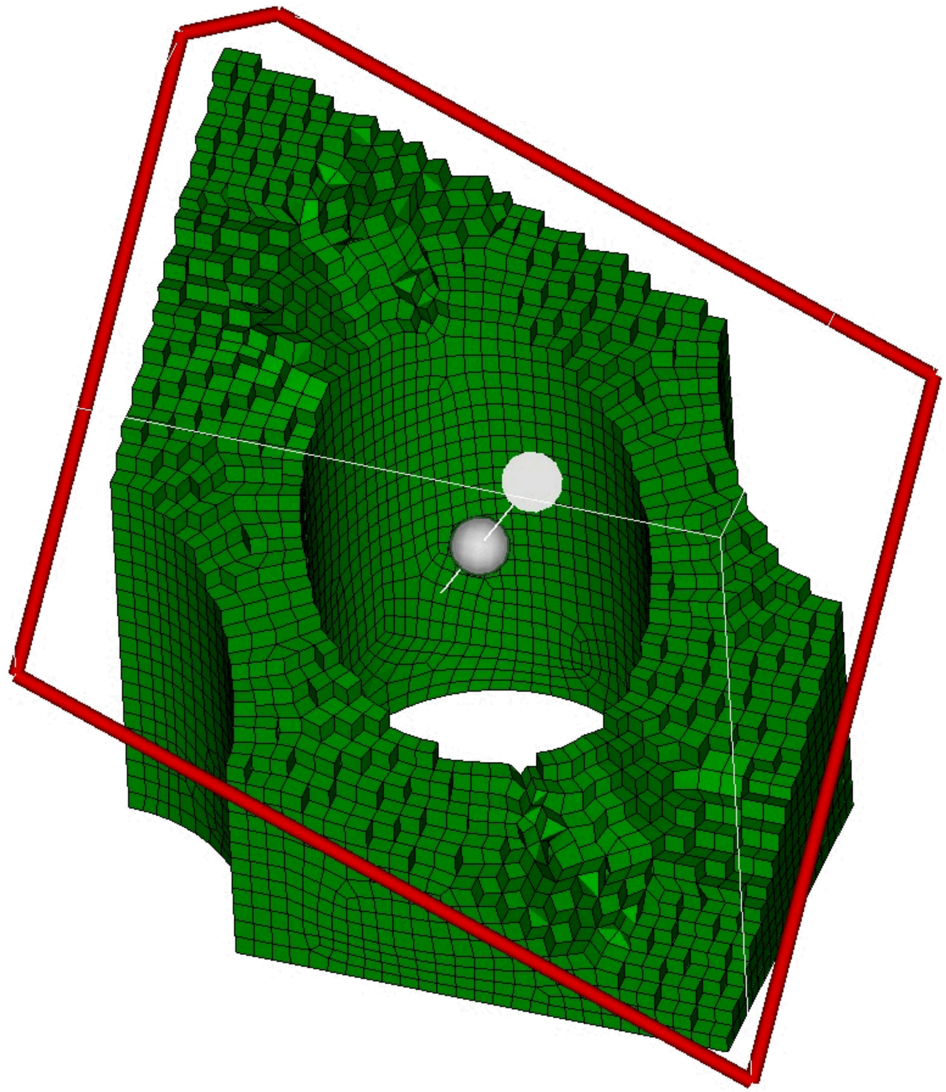
All-Quad Mesh on Medial



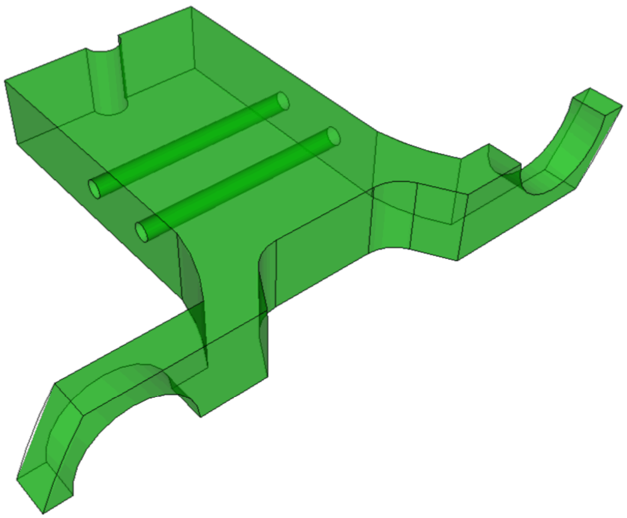
Tri at 3-Manifold Medial Curve

Sectional View

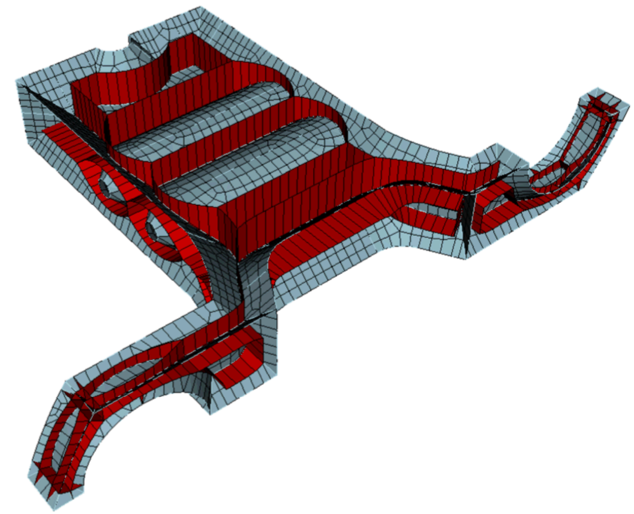




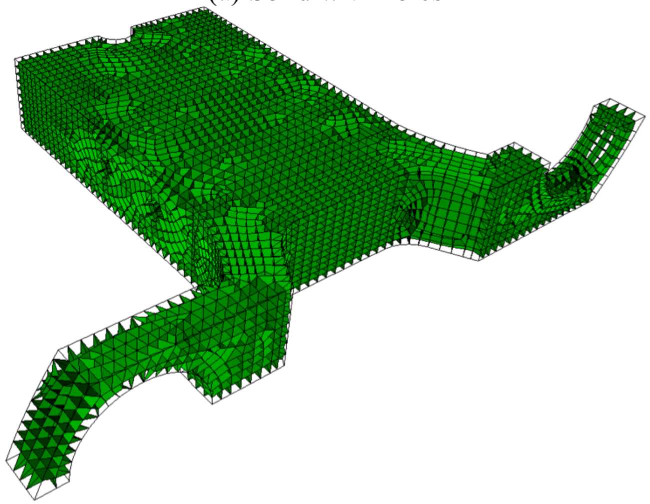
Demo



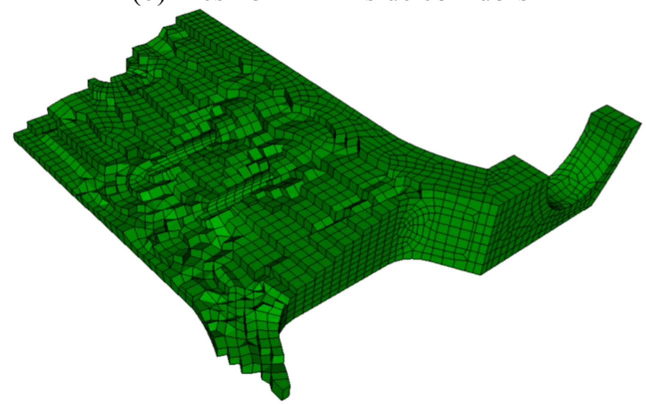
(a) Solid with holes



(b) Mesh on MA inside corridors

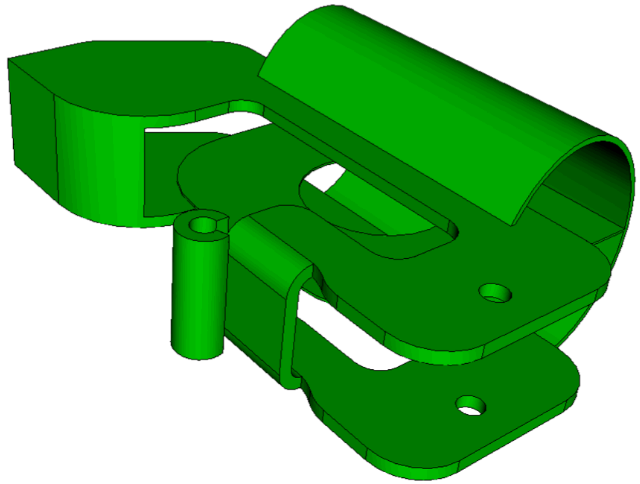


(c) Tracks in 3D

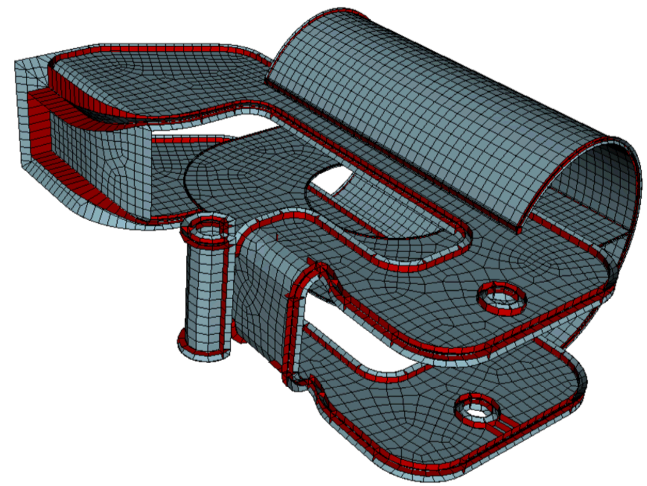


(d) Mesh cross section

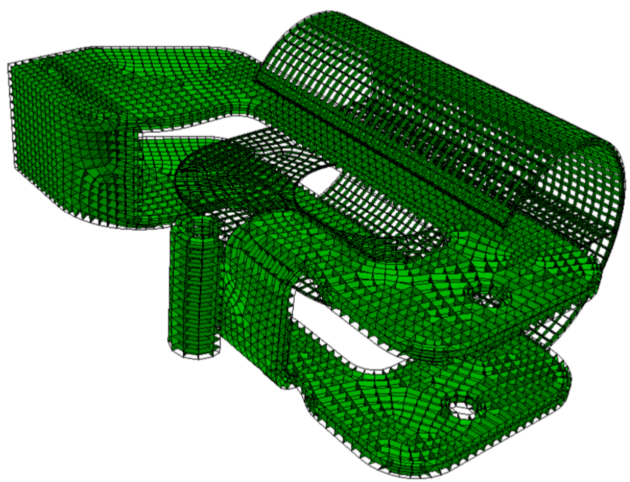
Demo



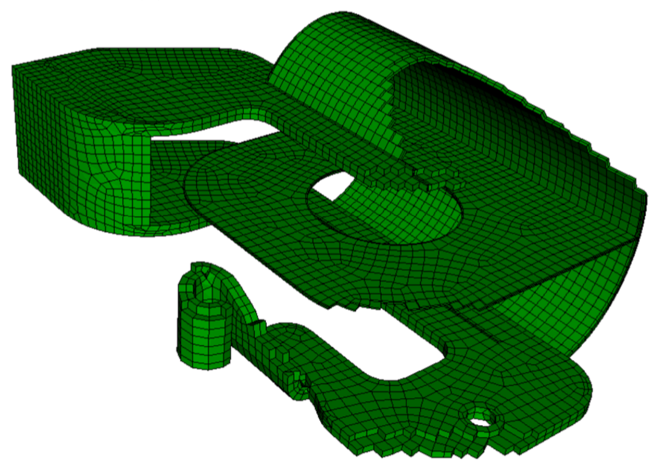
(a) Thin-wall solid



(b) Mesh on MA inside corridors



(c) Tracks in 3D



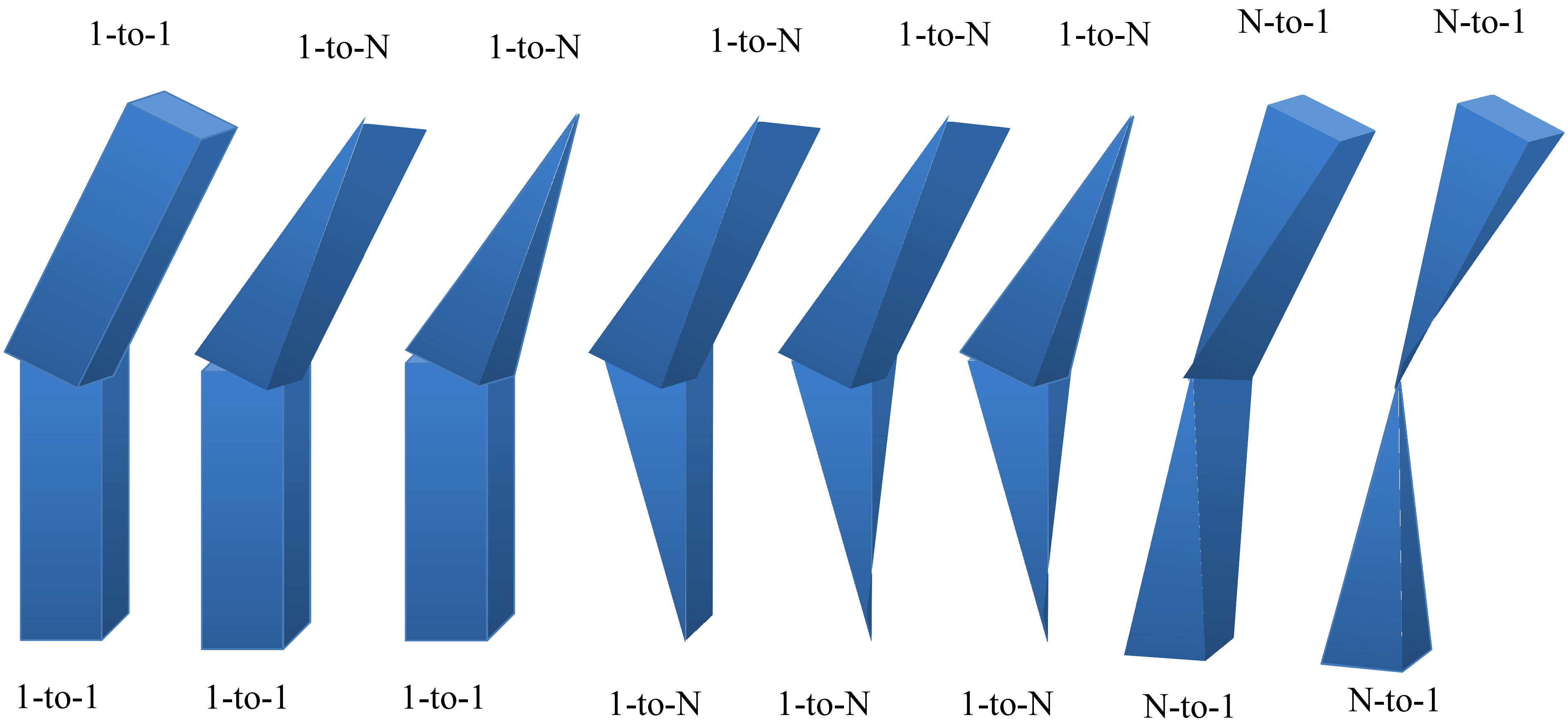
(d) Mesh cross section

Extension to All-Hex Meshing

Claim 1: A general solid can be decomposed into a set of connected quad cross-section 3D tracks

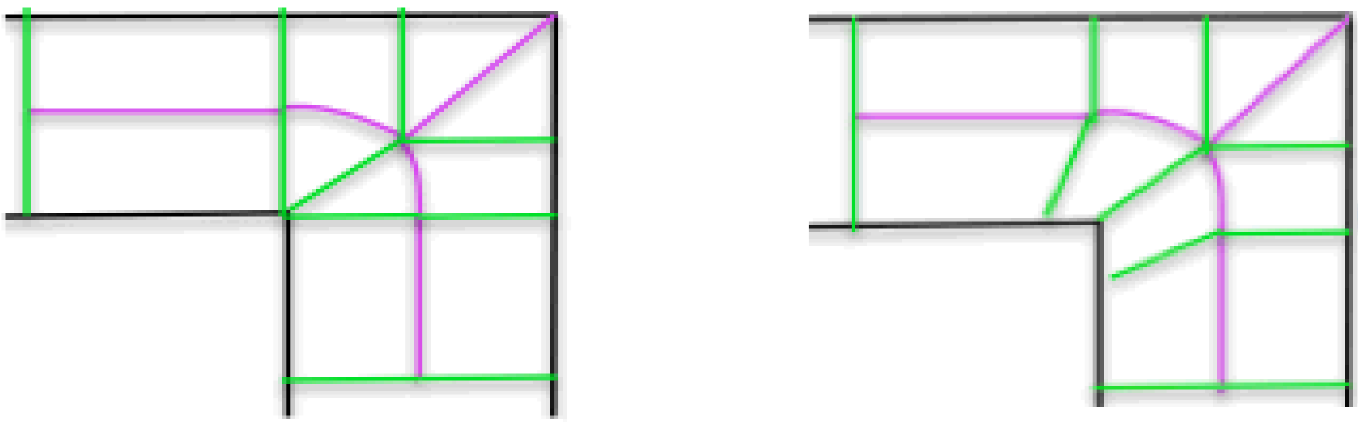
Claim 2: A quad cross-section 3D track can be meshed with all-hex elements

Claim 1: A general solid can be decomposed into a set of connected quad cross-section 3D tracks

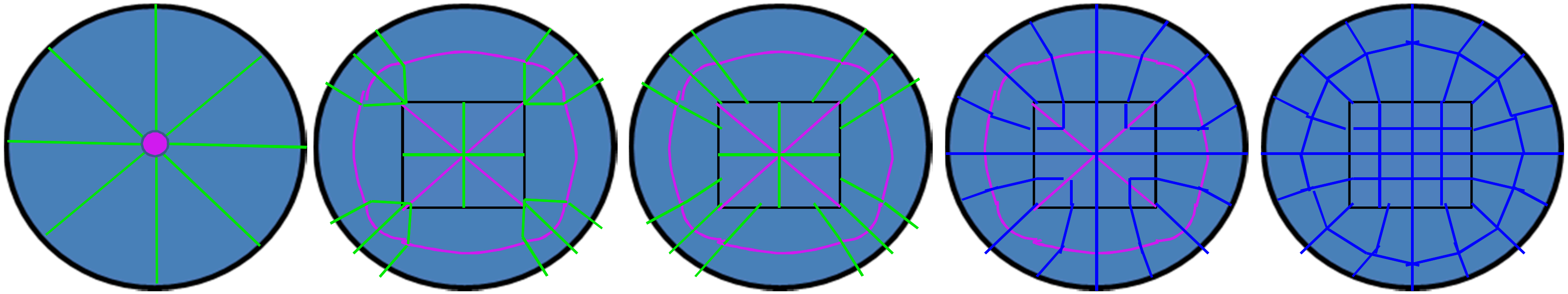


Types of Tracks in 3D

1-to-N Track Transformed to Quad Cross-Section 1-to-1 Track



N-to-1 Track Transformed into Quad Cross-Section 1-to-1 Track



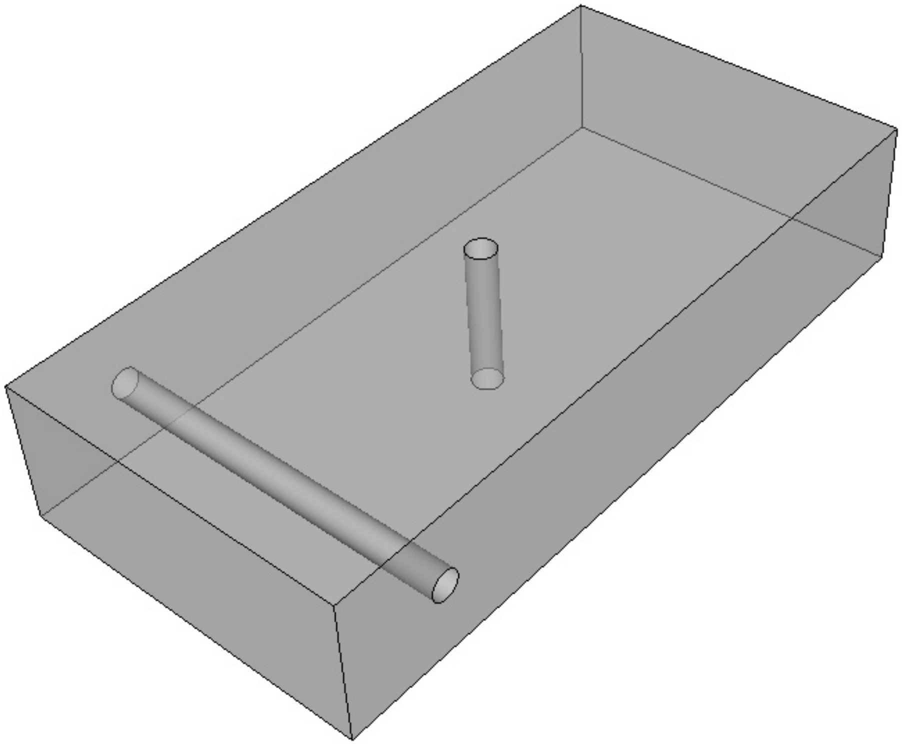
(a)N-to-1 (b)1-to-N (c)1-to-1 (d)Tracks (e)Mesh

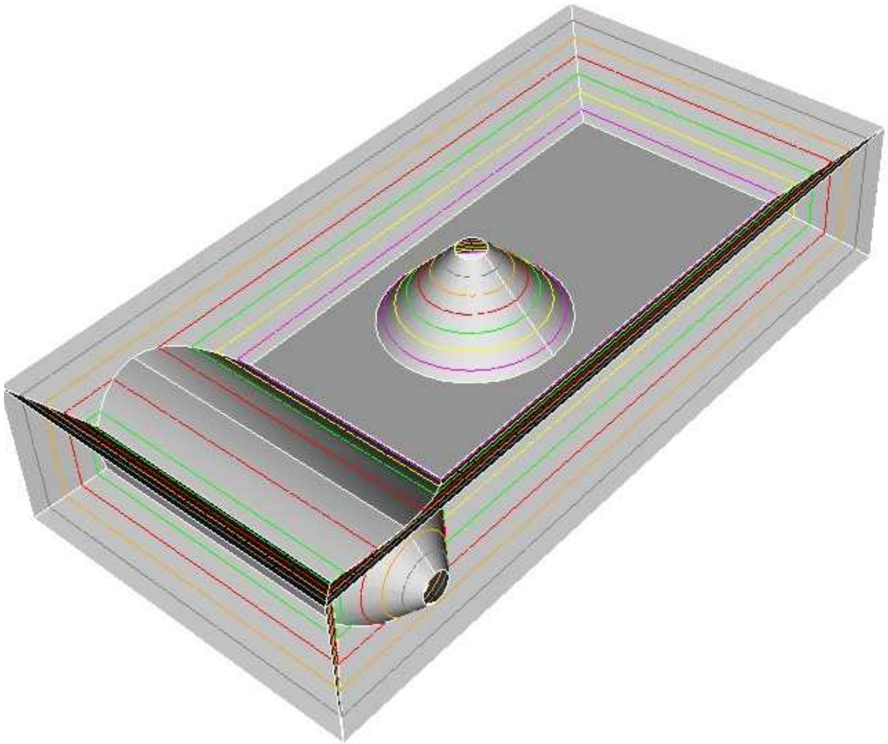
Claim 2: A quad cross-section 3D track can be meshed with all-hex elements

In order to obtain an all-hex mesh inside a quad cross-section track,
Case 1: all four rails must have the same intervals or Case 2: two rails must have 2N intervals and the other two rails must have 2(N+1) intervals.

With Case 1, equal number of hex elements are generated on both sides of MA and
with Case 2, two wedges at the MA are merged to form a hex.

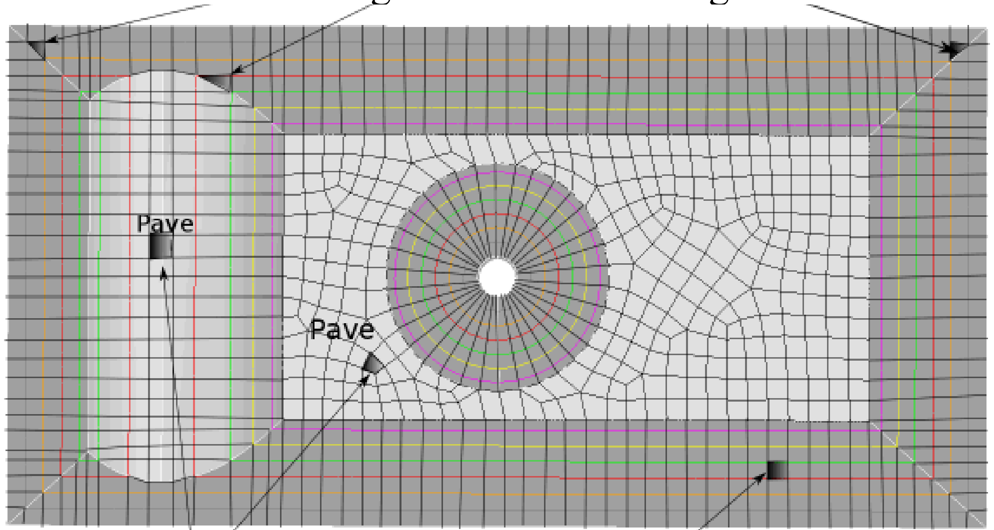
Isocontours of Medial Radius Function Controls Mesh Intervals on Rails





All-Hex Mesh Topology Visualization on Isocontours of MA

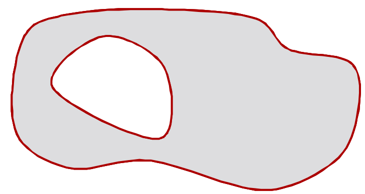
Tri along 3-manifold MA edges



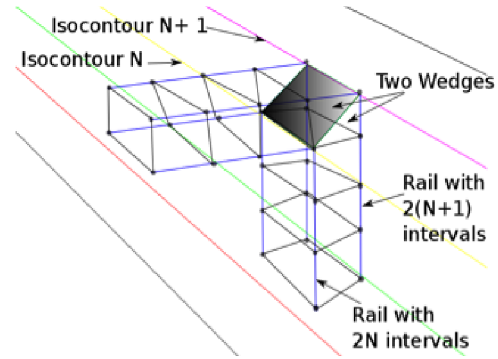
Case1: quad in region bounded by one isocontour

Case 2: quad incident on N & N+1 isocontours

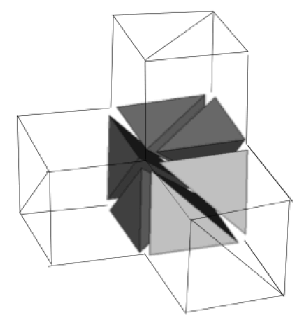
(c) Meshing MA using isocontours guarantees correct intervals on rails to satisfy Case 1 or Case 2 in each track



(a) Case1: equal num of hexes exist on both sides of MA



(b) Case 2: two wedges form a hex at a quad lying on N & N+1 isocontours



(d) Six tets form a hex at 3-manifold MA

Acknowledgements

Sandia National Laboratories

Thanks to Henry Bucklow, Robin Fairey, and Mark Gammon at ITI TranscenData Europe Ltd for providing the CADfix medial object library.

Thank You

Questions?

wrquadr@sandia.gov