SAND2013-6301P

LayTracks3D: Hex & Hex-dominant Meshing Via MAT

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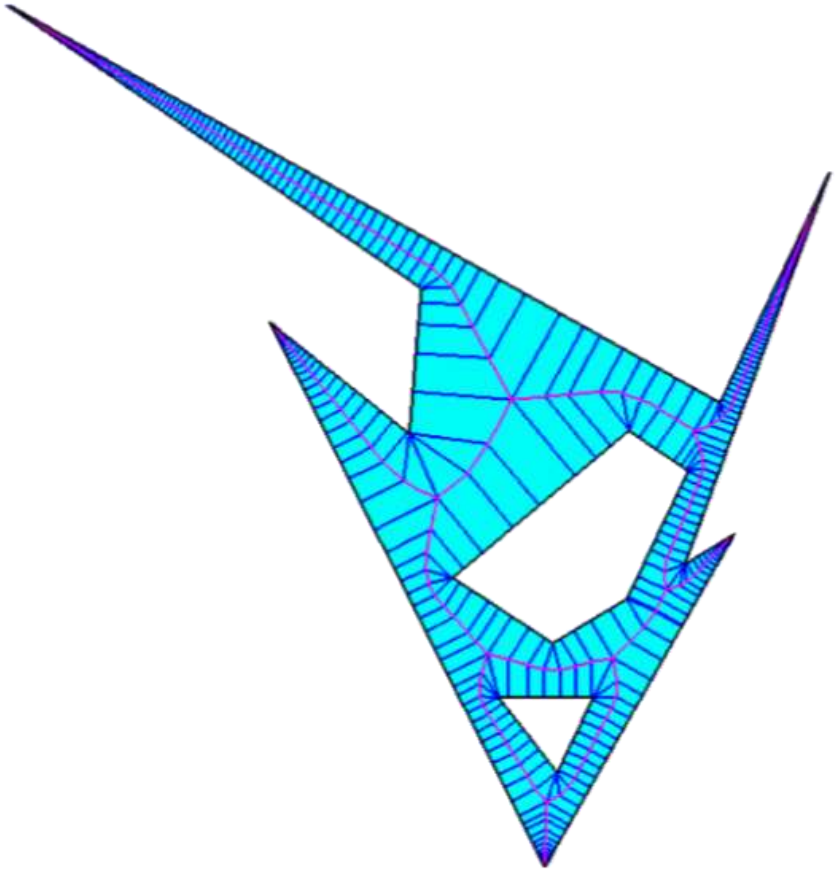
Layout of Presentation

- Goal
- LayTracks
- LayTracks3D Overview
- Rails in 3D
- Tracks in 3D
- All-Hex
- Results
- LayTracks3D for Assembly Model
- Future Work
  - All-Hex
  - Size & Anisotropy Control
  - Geometry Adaptive
  - Non-Linear Tracks
  - Mesh Morphing
  - Parallel Meshing

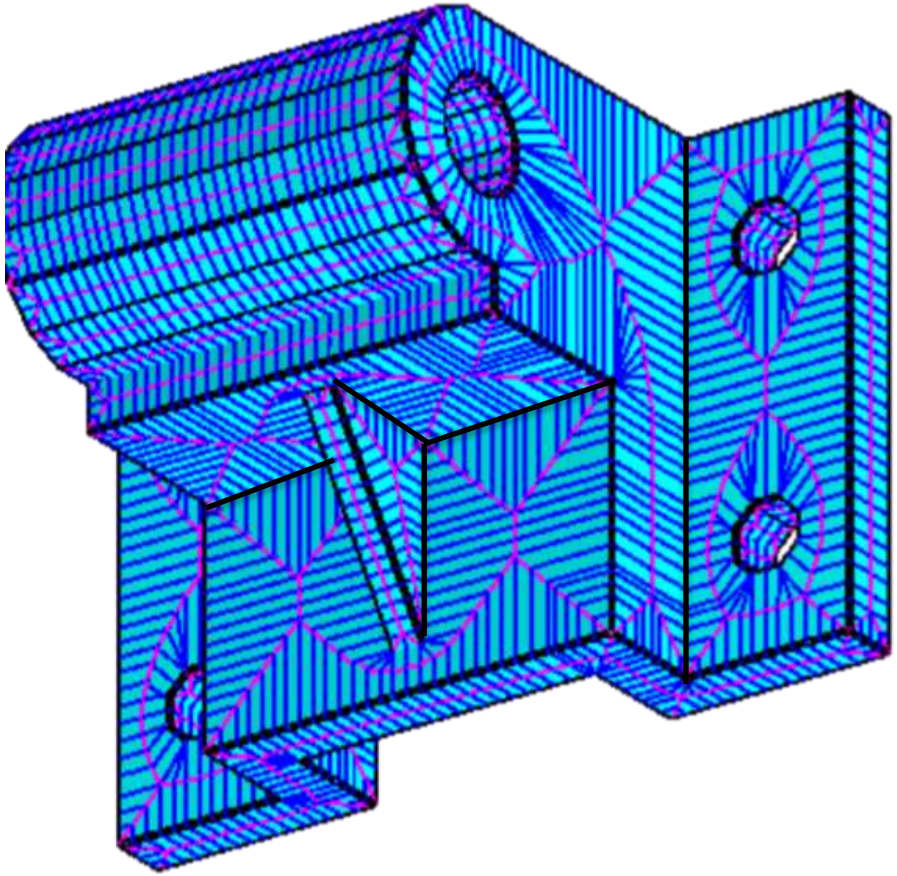
Goal

- **Handles General Solids:**
- **Boundary Sensitive:** Elements at the boundary are near cube shape. This is essential requirement for many boundary conditions.
- **All-Hex :** MAT is a mathematically well studied symmetric skeleton and may provide theoretical proof for guaranteed all-hex. Special treatment is needed where mapping between boundary and medial is not one-2-one (e.g. one-2-many map at concave regions and many-2-one map at finite contacts).
- **Orientation Insensitive:** Gives same output for all orientations of input model.
- **Respects B-Rep:** Mesh aligns with boundary curves and surfaces. Thus captures sharp boundary features.
- **Respects External Mesh Sizing/Intervals:** The mesh size/interval specified by the user on boundary entities (vertex/curve/surface) is mapped to corresponding medial entities before meshing the medial surface.
- **Handles Assembly Models:** Map between the boundary and the medial enables resolving all the boundary imprints on medial. Tracks cut interface of assembly orthogonally and gives automatic conformal mesh.
- **Geometry Adaptive Meshing**: Radius function of MAT can be used to control element size, anisotropy, and orientation.
- **Fast Remeshing:** Once the MAT is calculated for a given input solid, obtaining multiple meshes with varying mesh size ‘h’ for V&V is significantly fast without any collision checks.
- **Mesh Morphing:** Old meshes can be morphed easily to new deformed geometry if MA topology does not change.
- **Parallel Friendly:** Decomposition-based method is parallel friendly. Node placement on all rails and laying hex elements inside all tracks can be parallelized.

LayTracks3D:
Extension of LayTracks, 9th IMR, Oct 2000



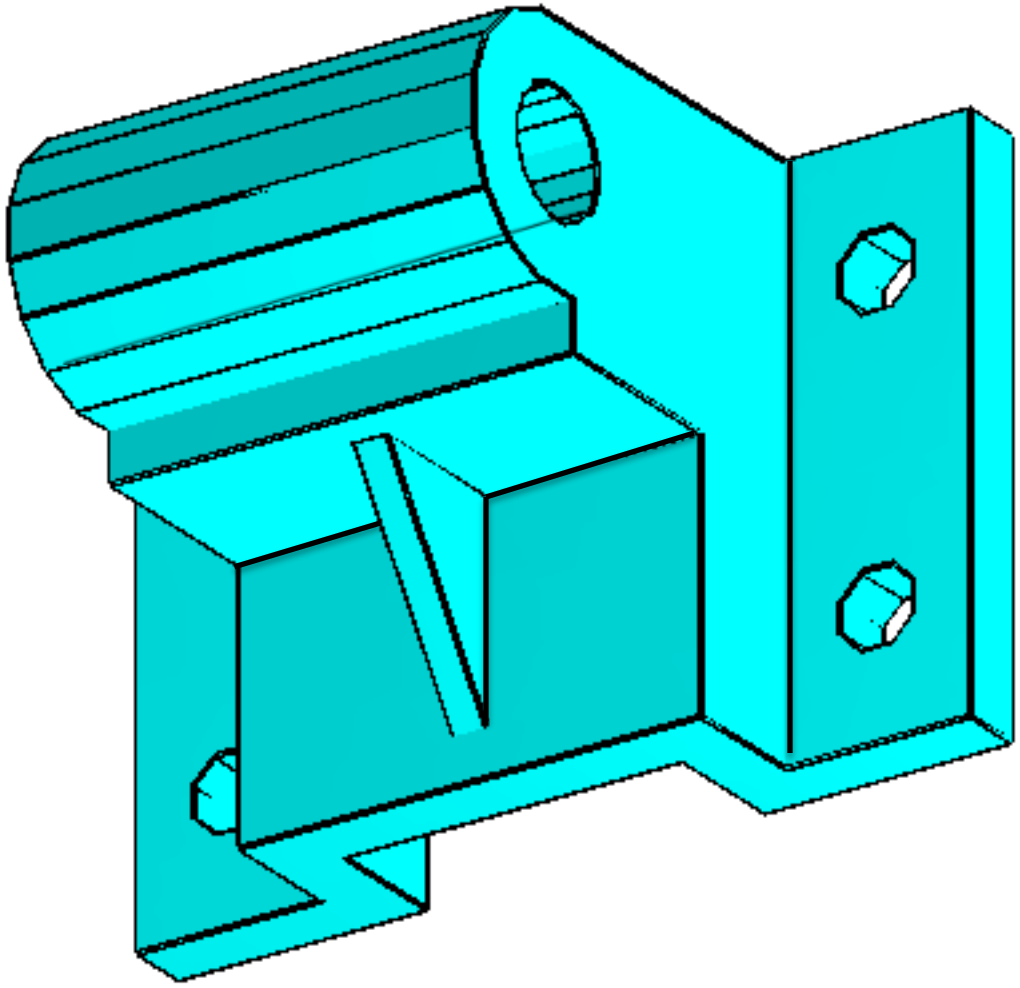
LayTracks decomposes general complex domain into simpler non-intersecting tracks



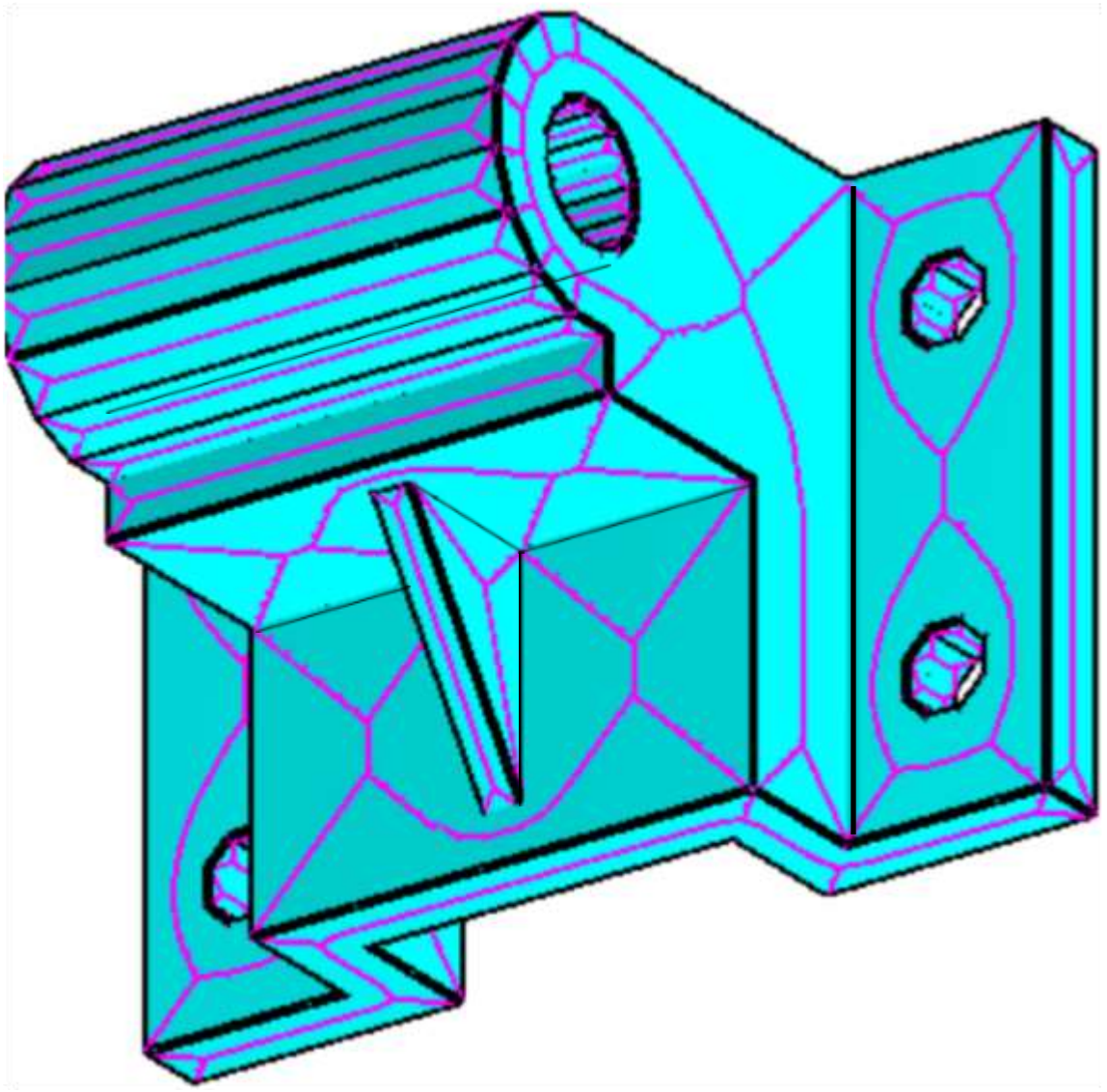
Tracks propagate orthogonally at the interface of multiple surfaces

Quadros, W. R., et al. "LayTracks: A New Approach To Automated Quadrilateral Mesh Generation using MAT", Proceedings, 9th International Meshing Roundtable, pp.239-250, October 2000.

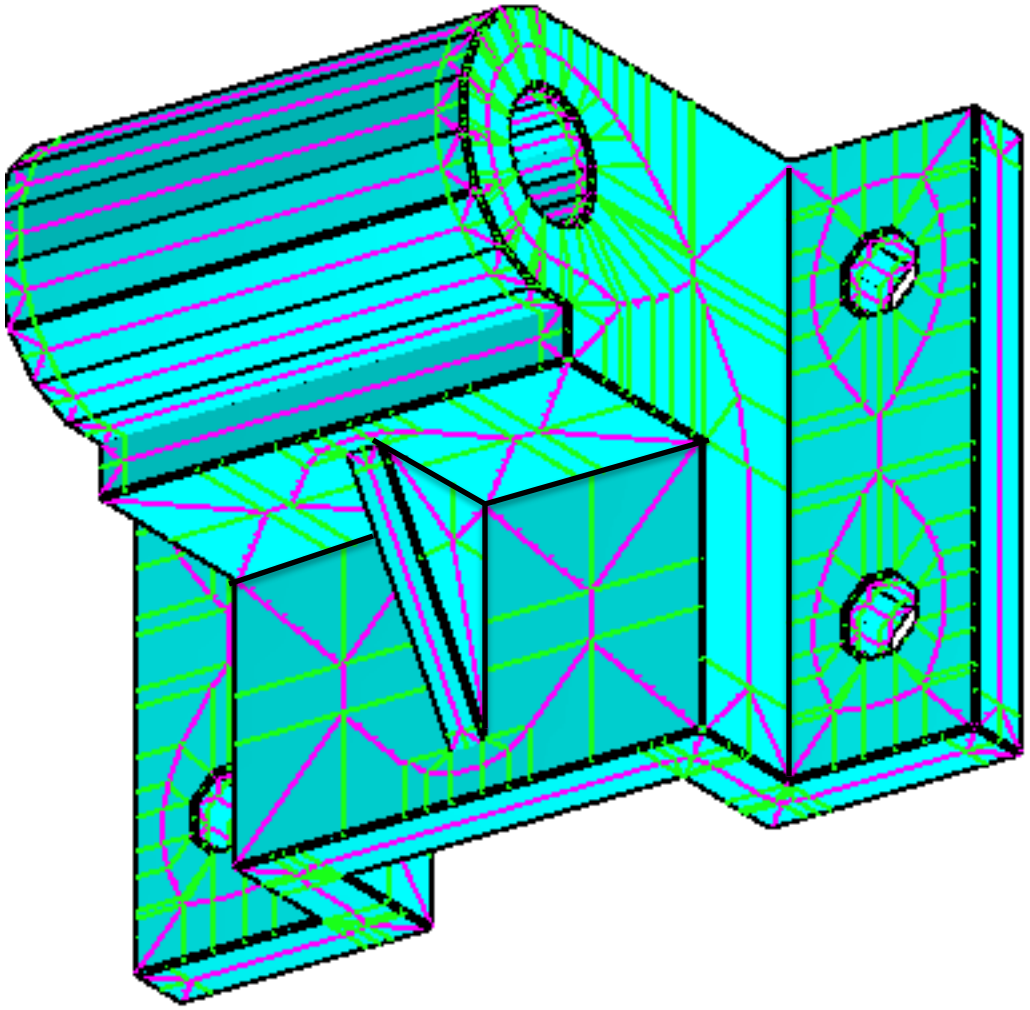
Set of Surfaces



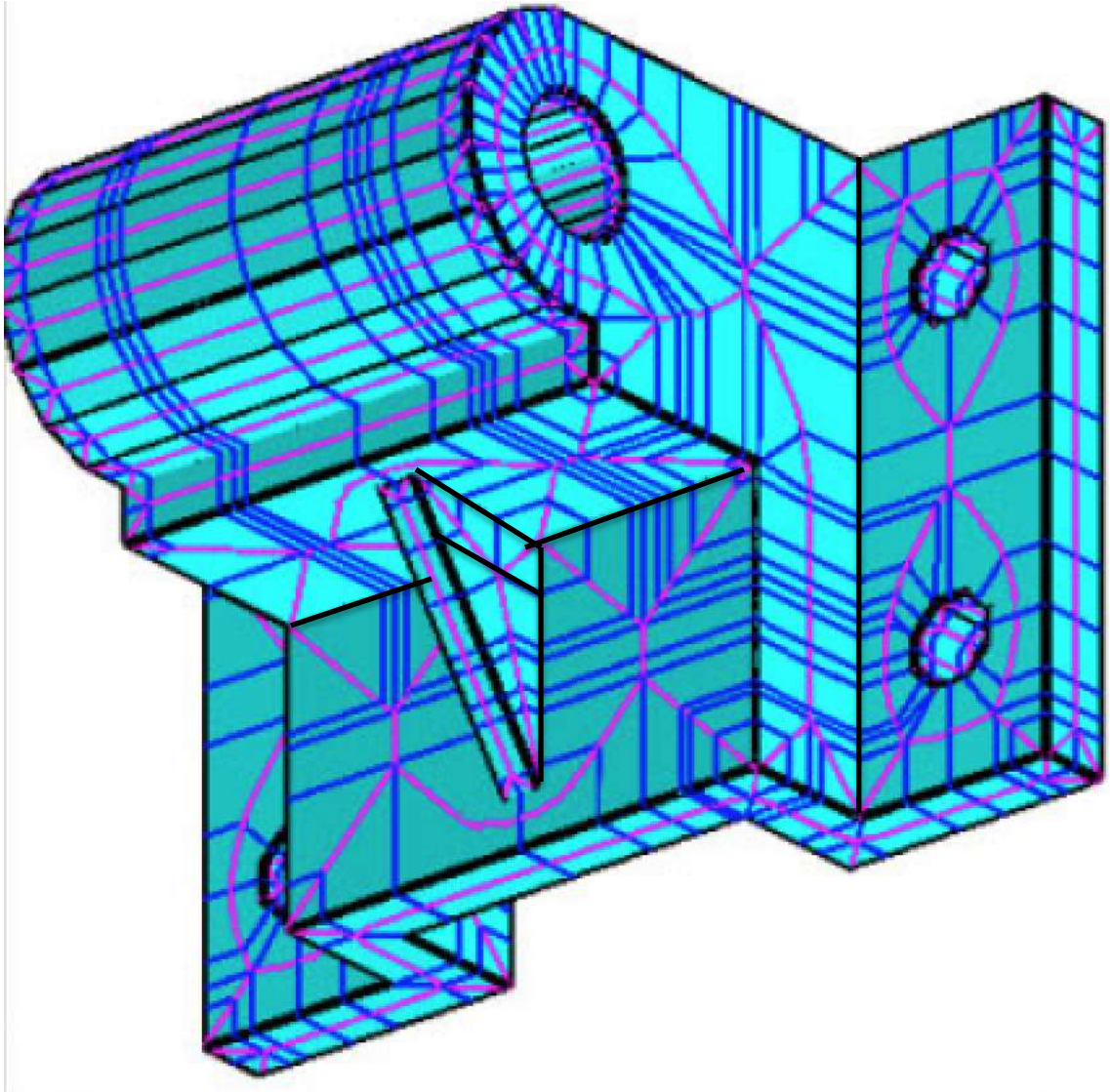
Medial of Multiple Surfaces



2-Way Map of Multiple Surfaces

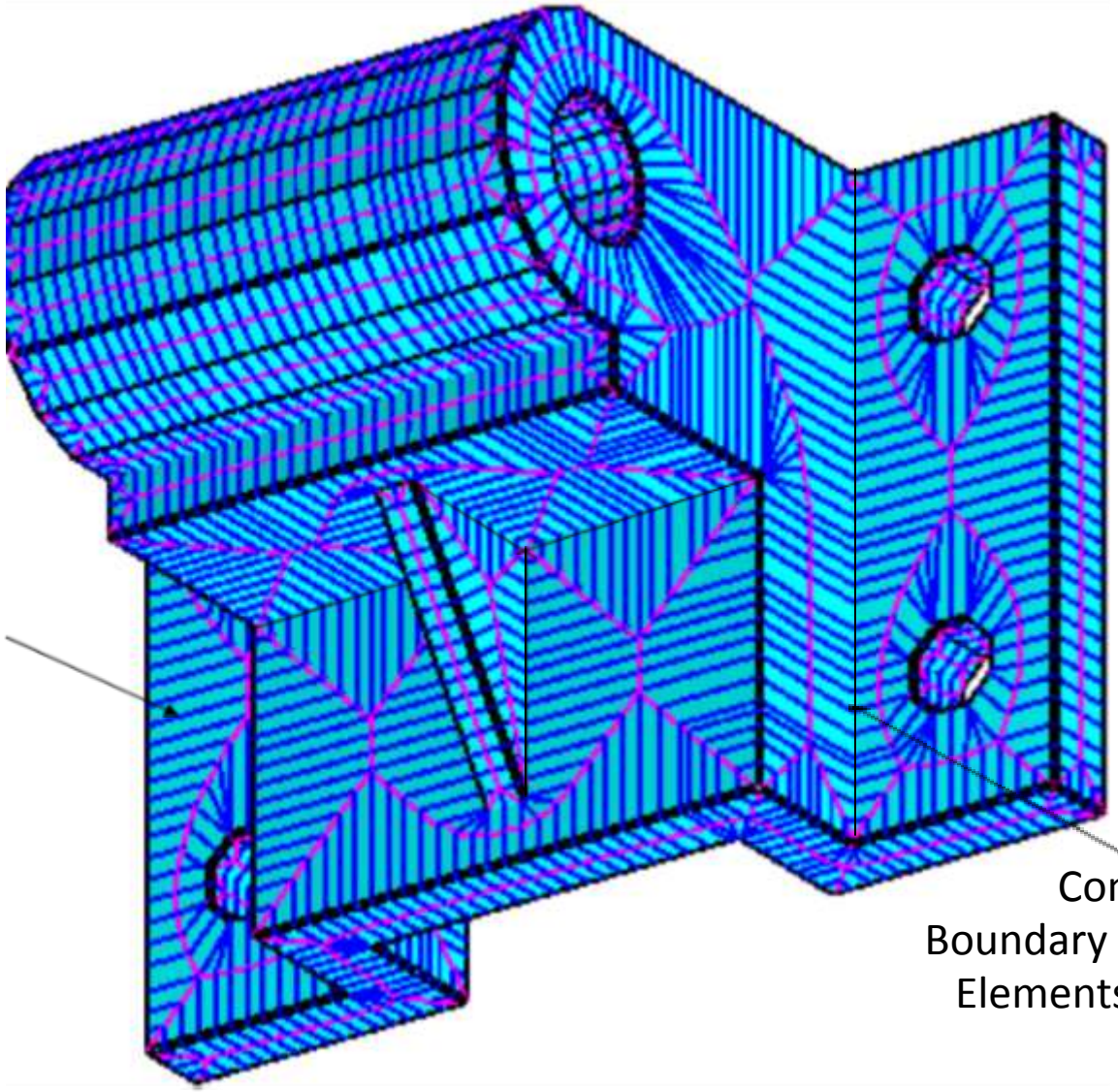


Automatic Geometry Decomposition



CORRIDORS using Medial Branch Points & Imprints

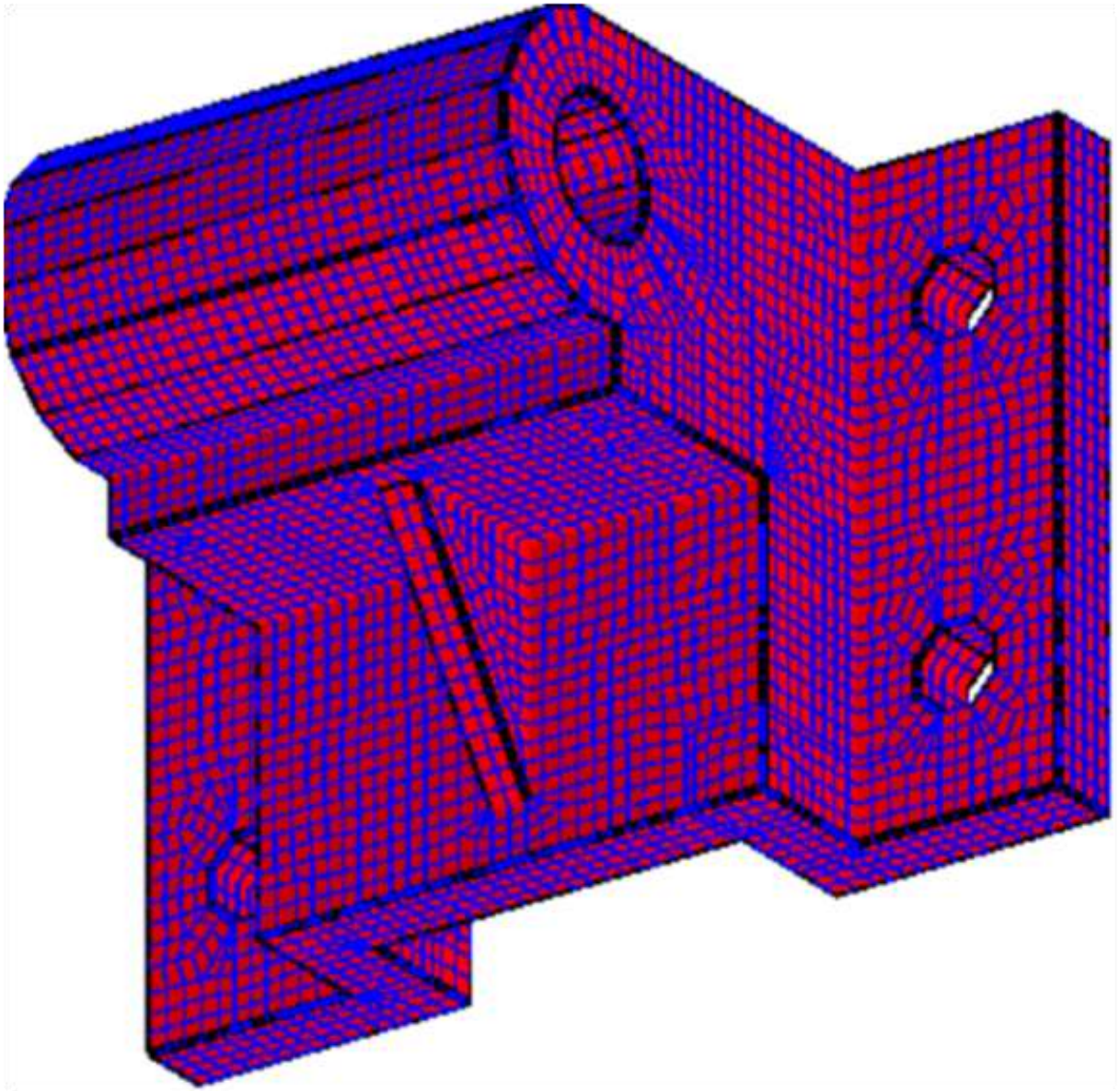
Tracks Across Multiple Surfaces



Element Size Controlled by Track Width

Conformal Boundary Sensitive (90°) Elements at Interface

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



Overview of LayTracks3D

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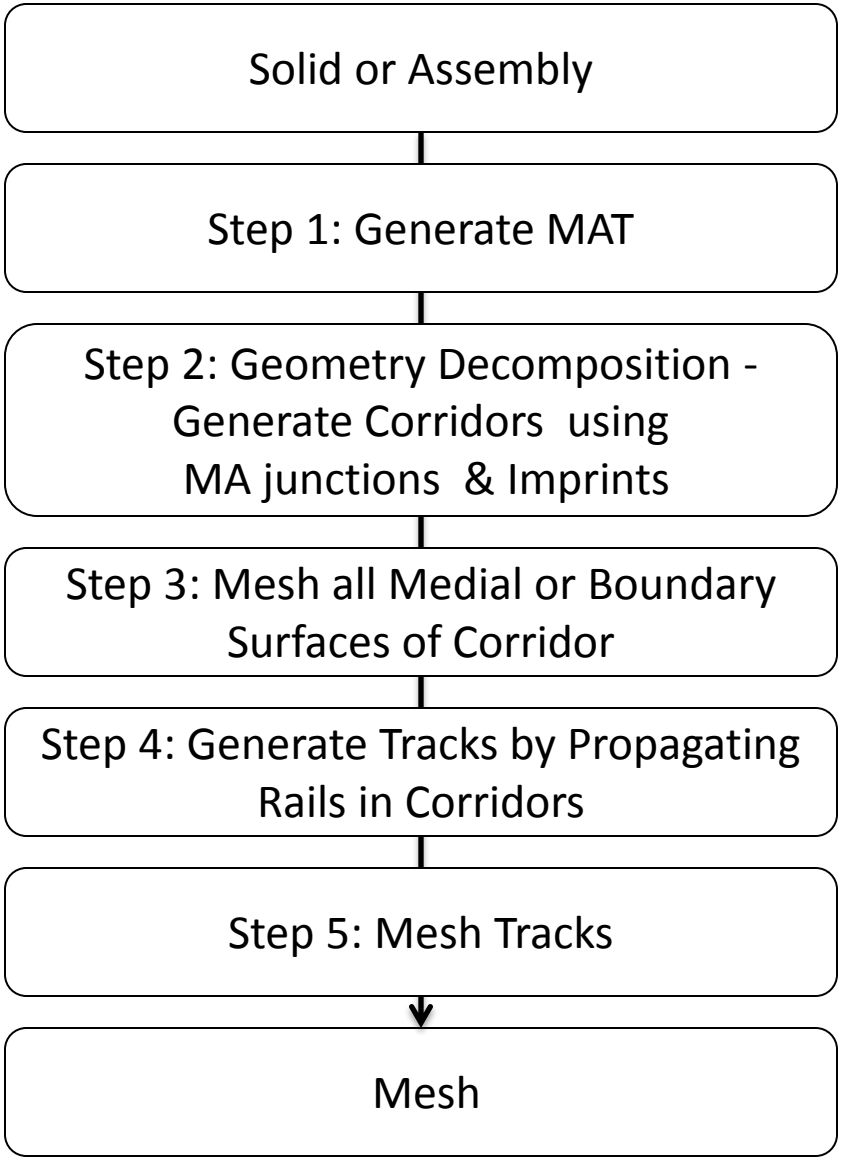
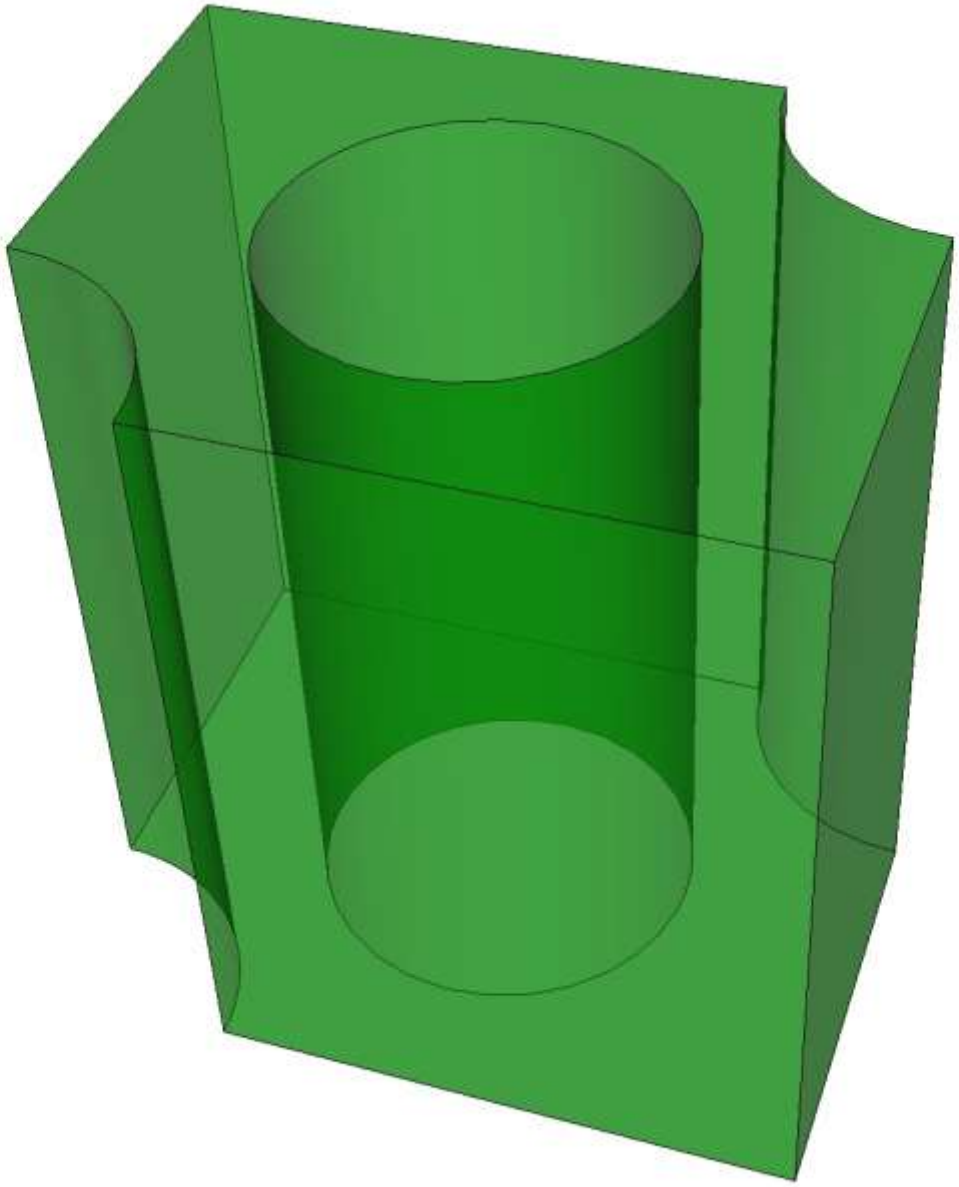
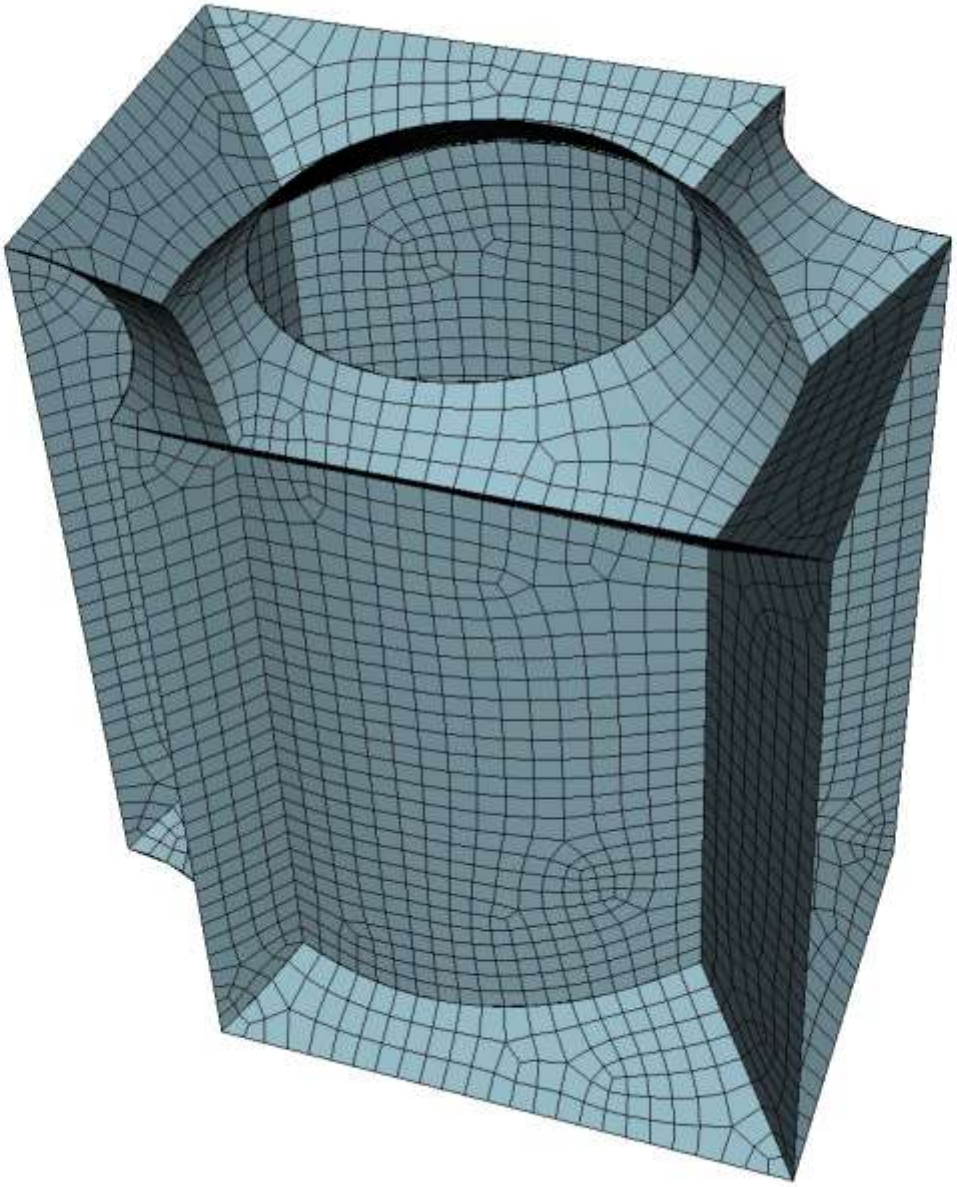


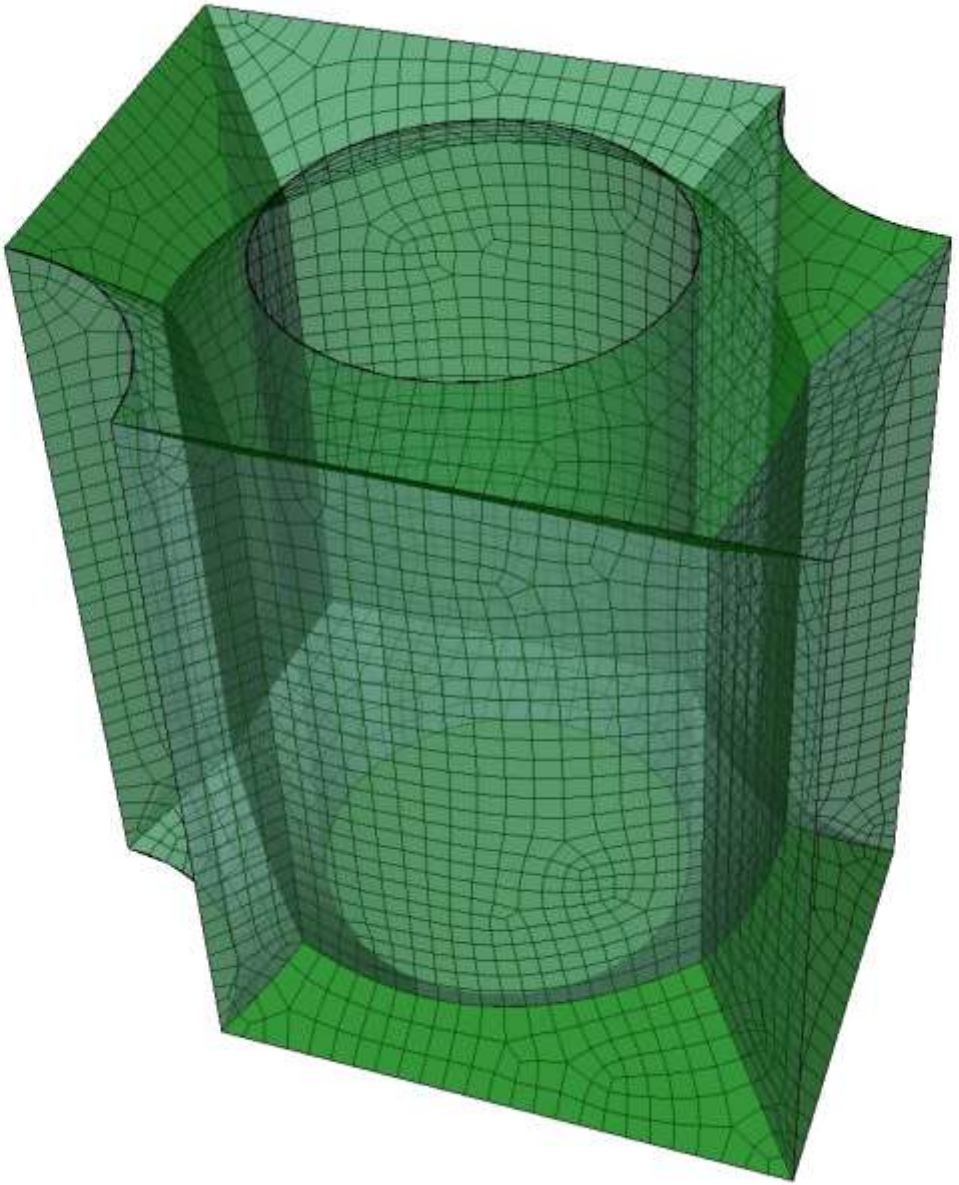
Input Solid



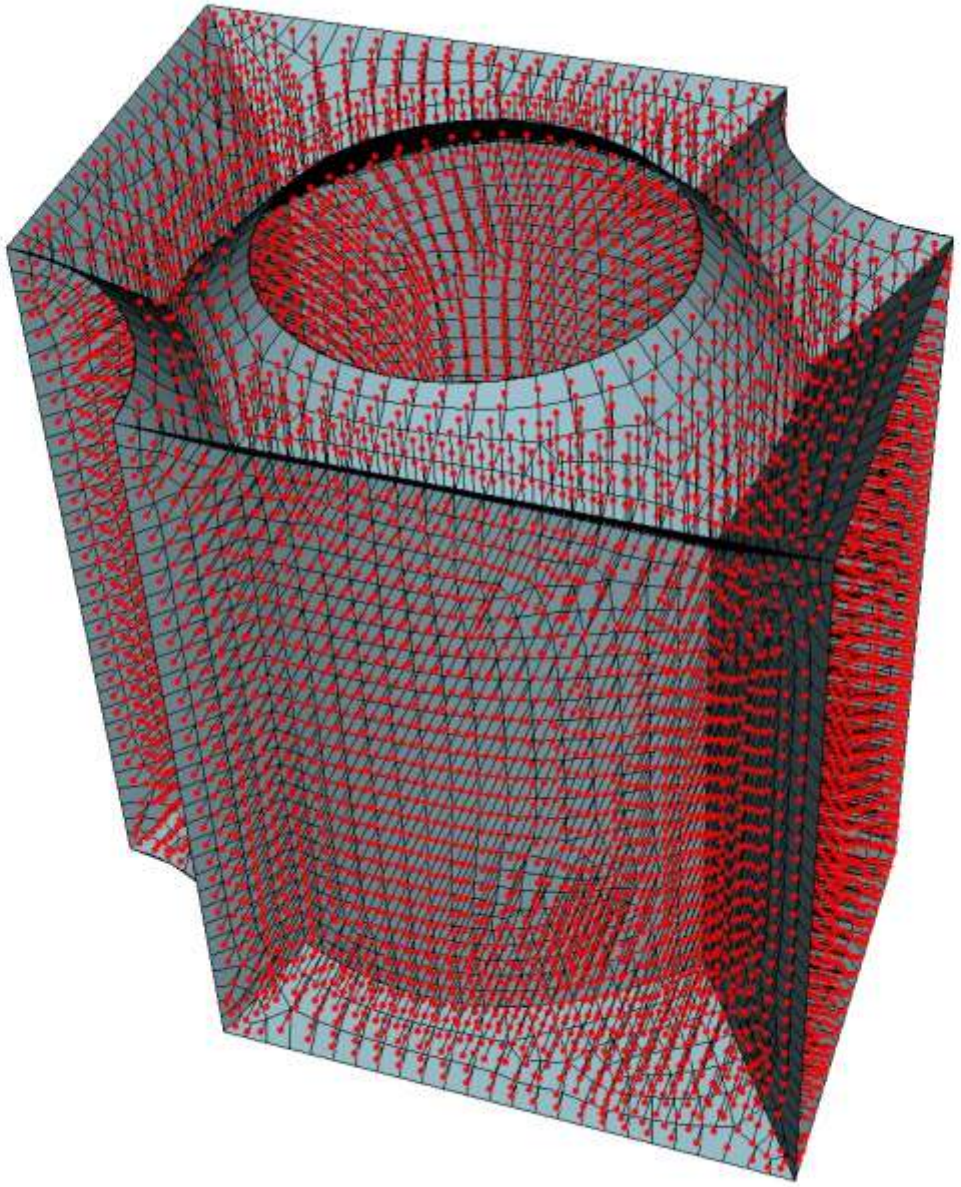
All-Quad Mesh on Medial



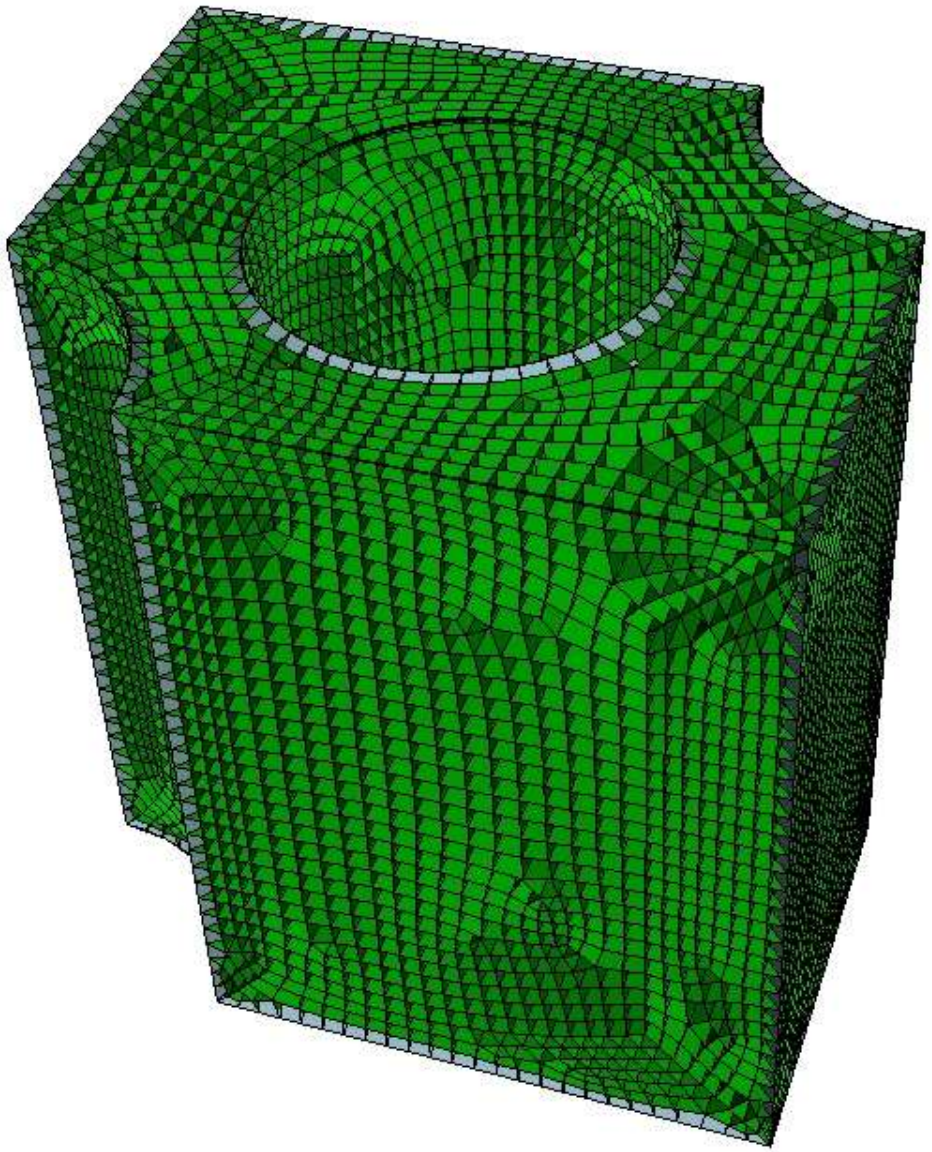
Medial Mesh inside Solid



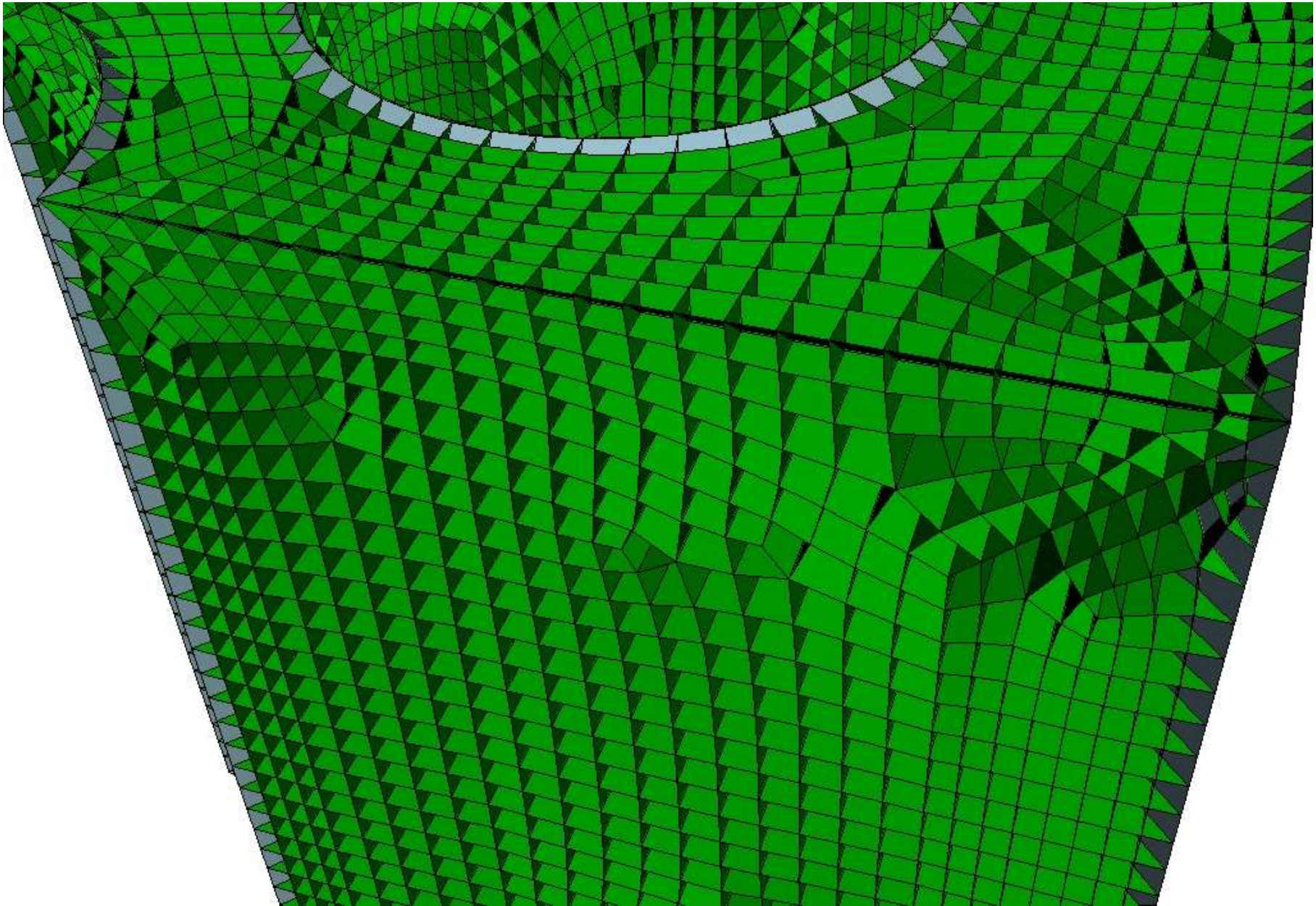
Nodes Along Rails



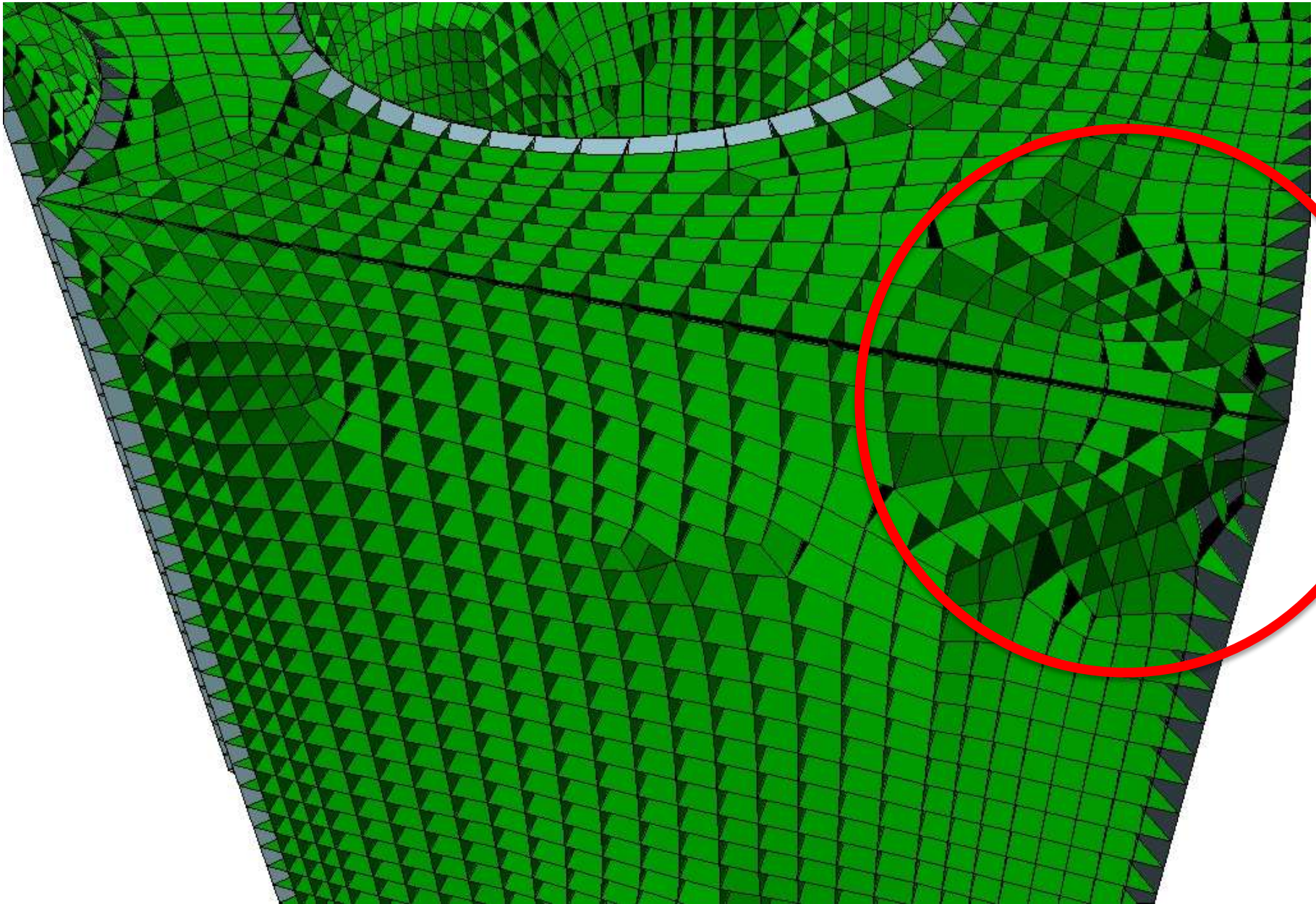
Tracks in 3D



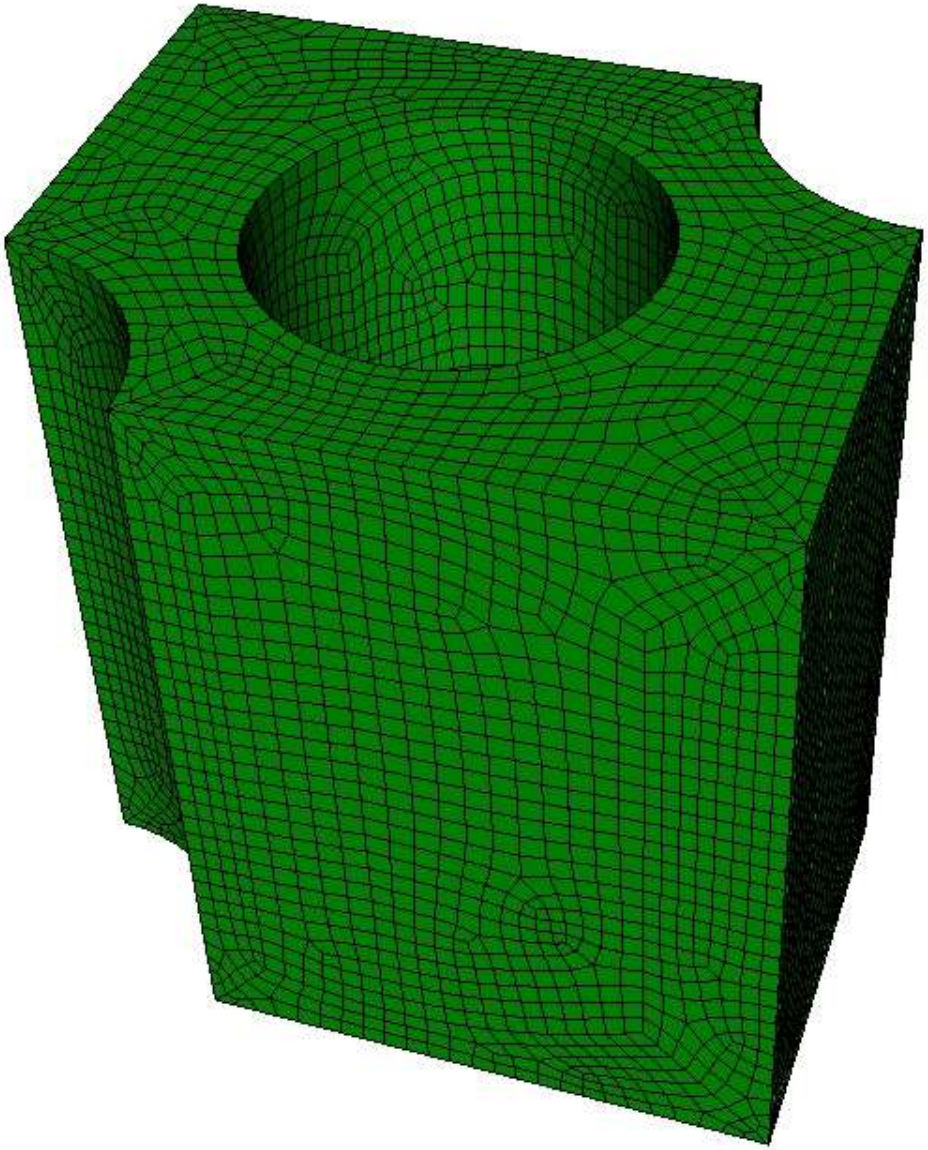
Tracks in 3D



Complex Tracks at All Convex Vertex

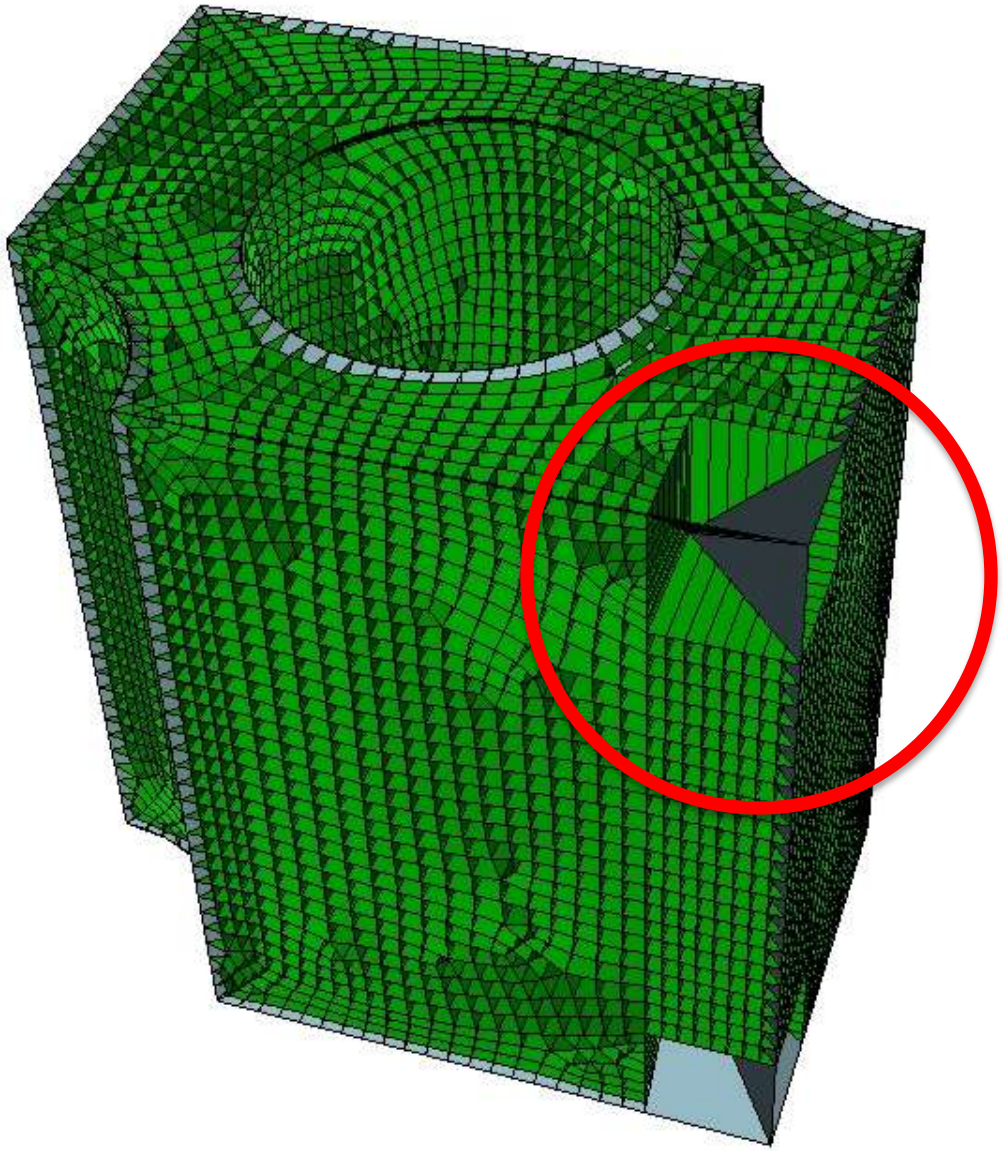


Hex Mesh

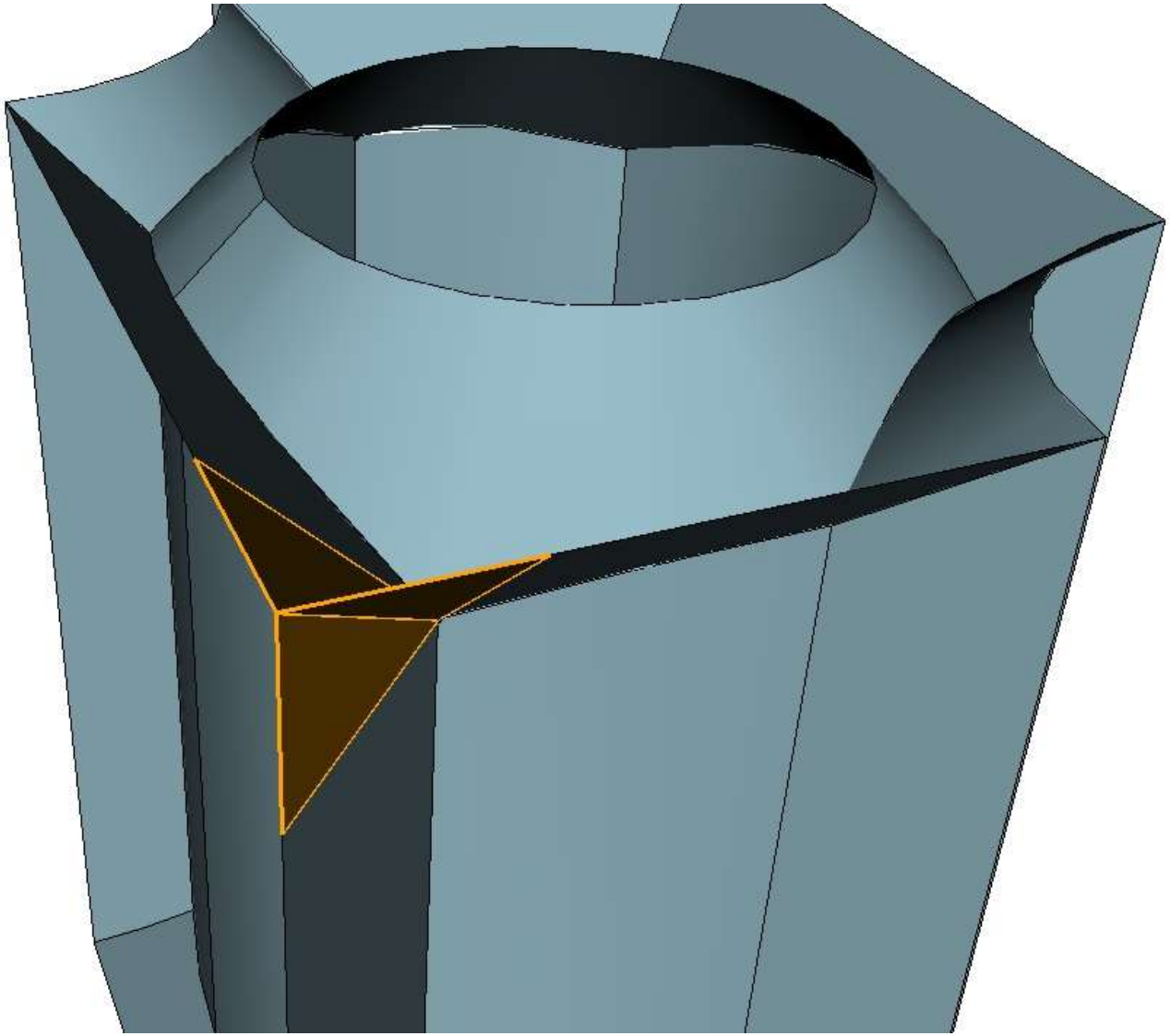


How to Improve Hex Quality at Convex Vertex?

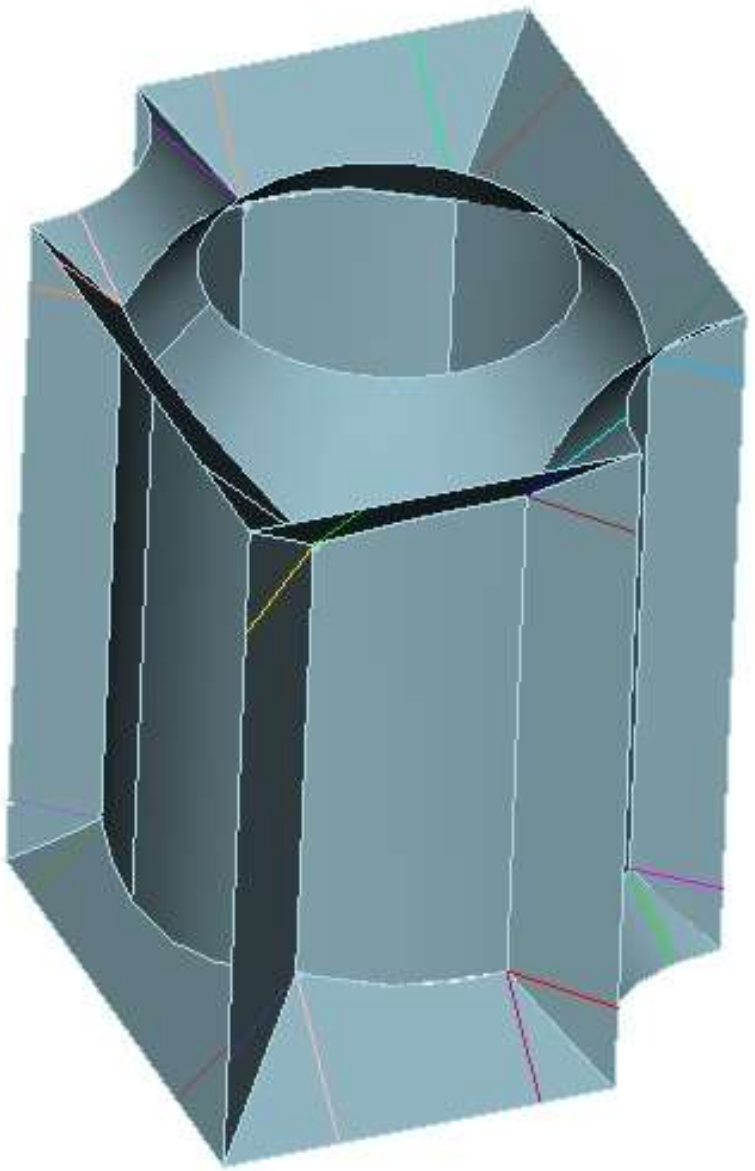
No Tracks at a Convex Vertex Topological Cube



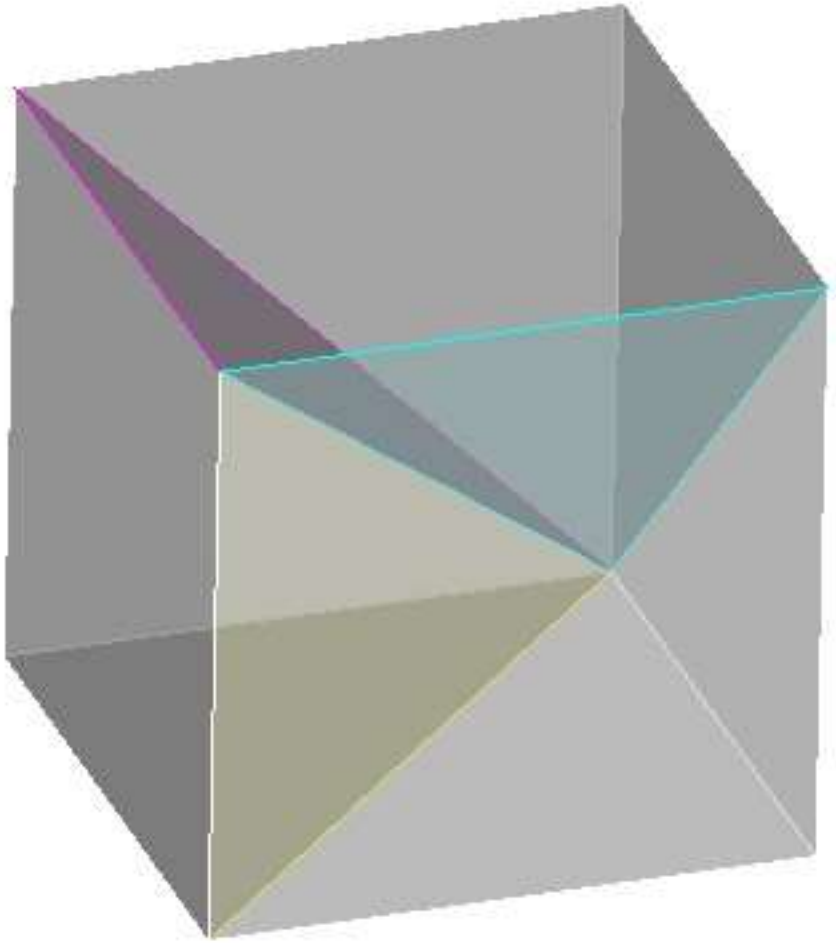
Split Medial Surfaces at Topological Cube of a Convex Corner



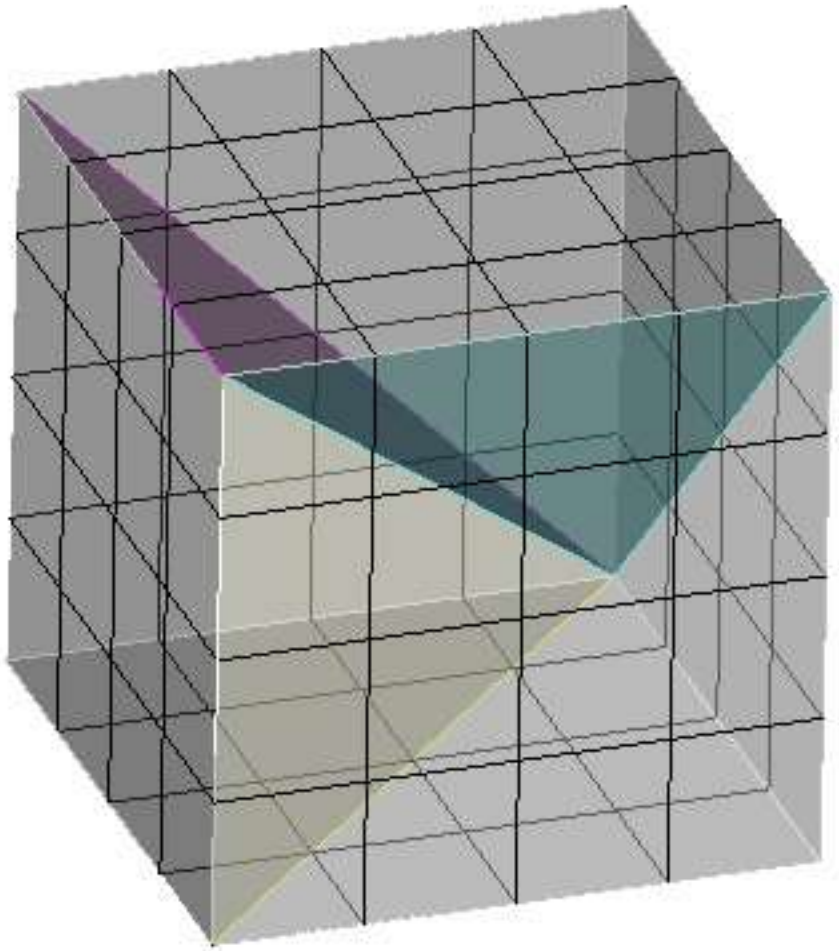
Split Medial Surfaces at Topological Cube of Convex Corners



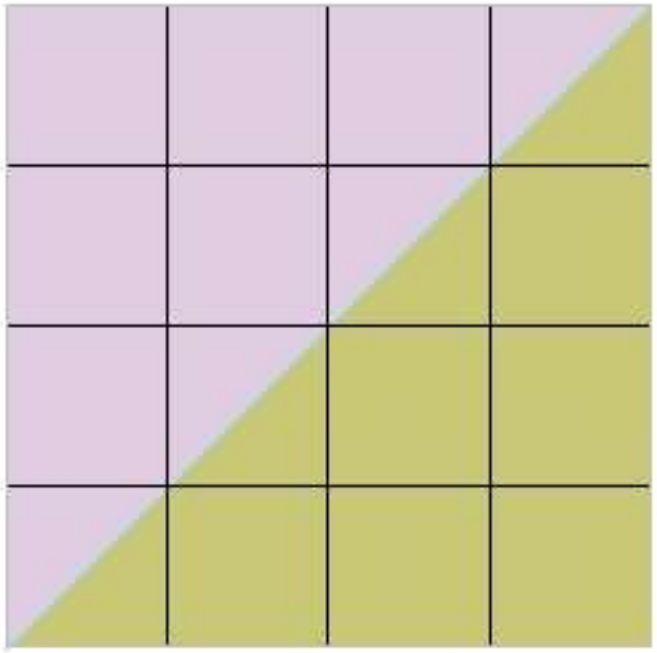
Typical Non-manifold Medial at Topological Cube of a Convex Vertex

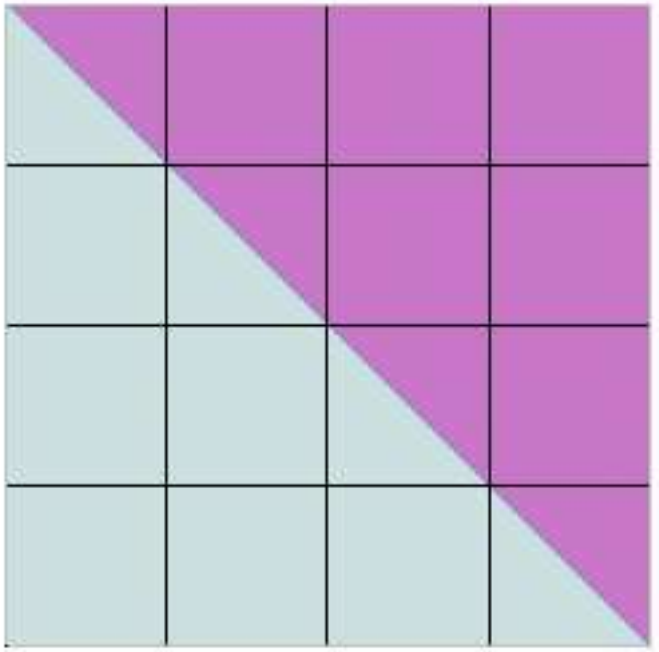


Ideal Hex Mesh of a Topological Cube at a Convex Corner

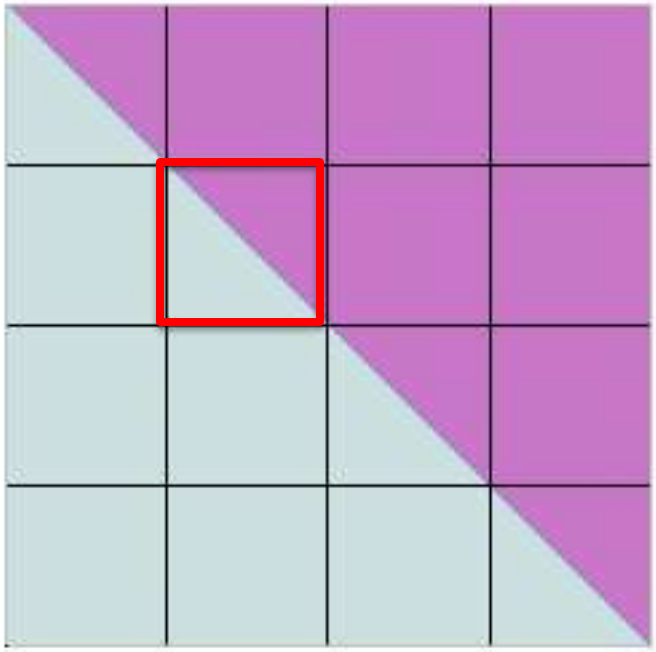


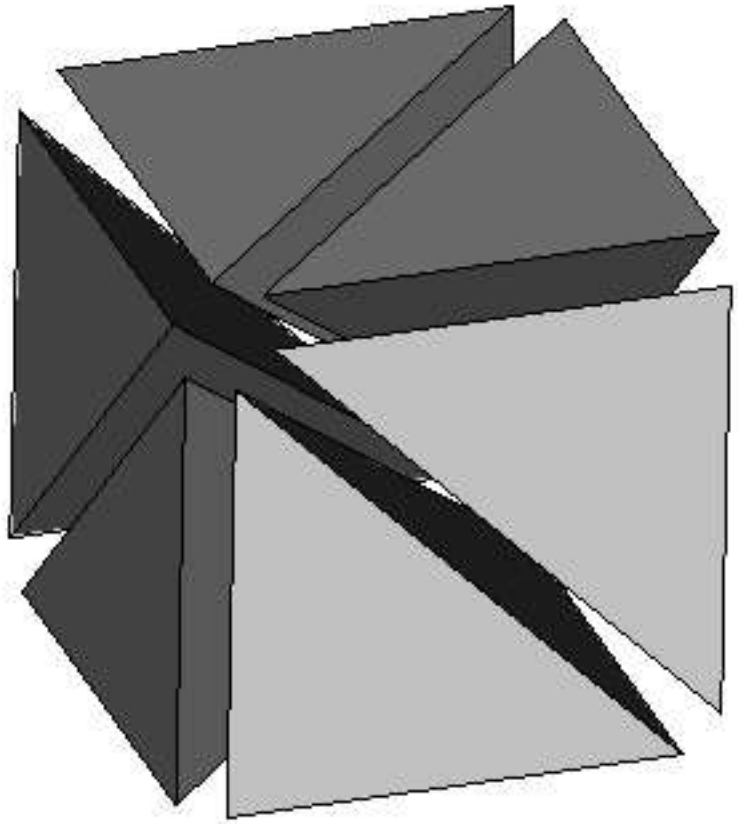
Ideal Mesh on Triangular Medial Surfaces at Convex Vertex



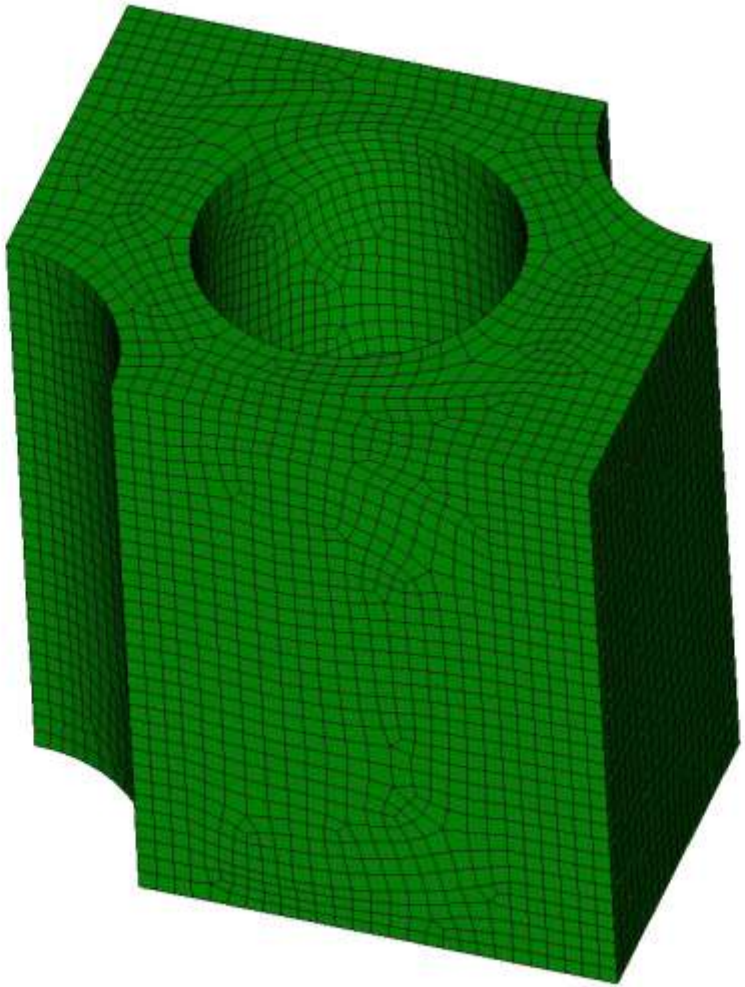


Merge Six Tets Along Medial Edge Incident at Convex Vertex

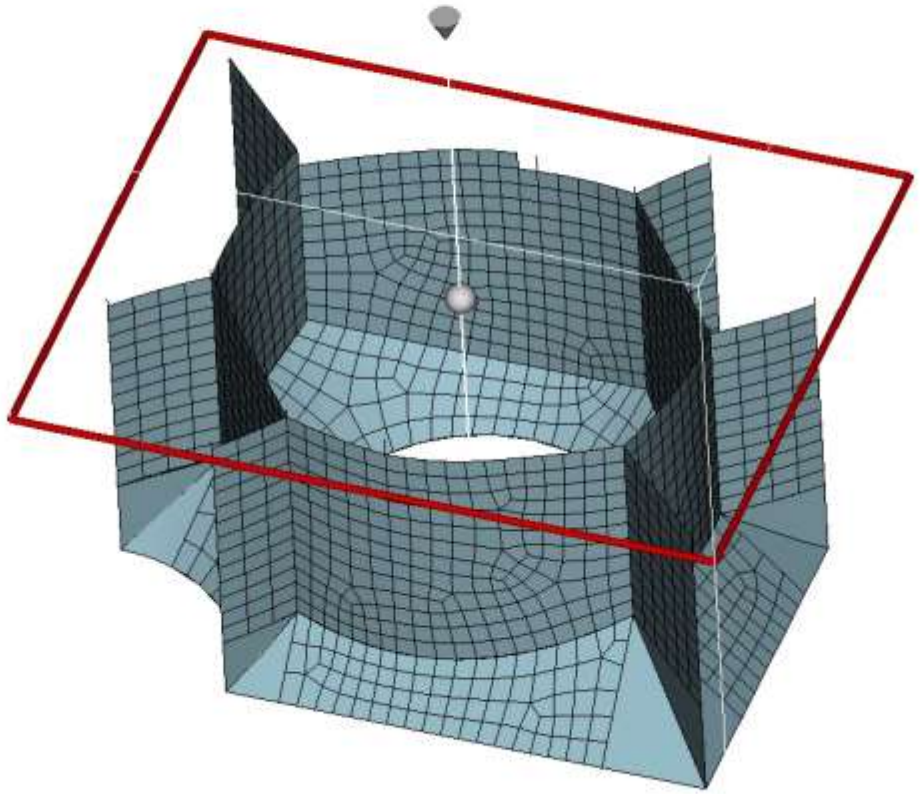




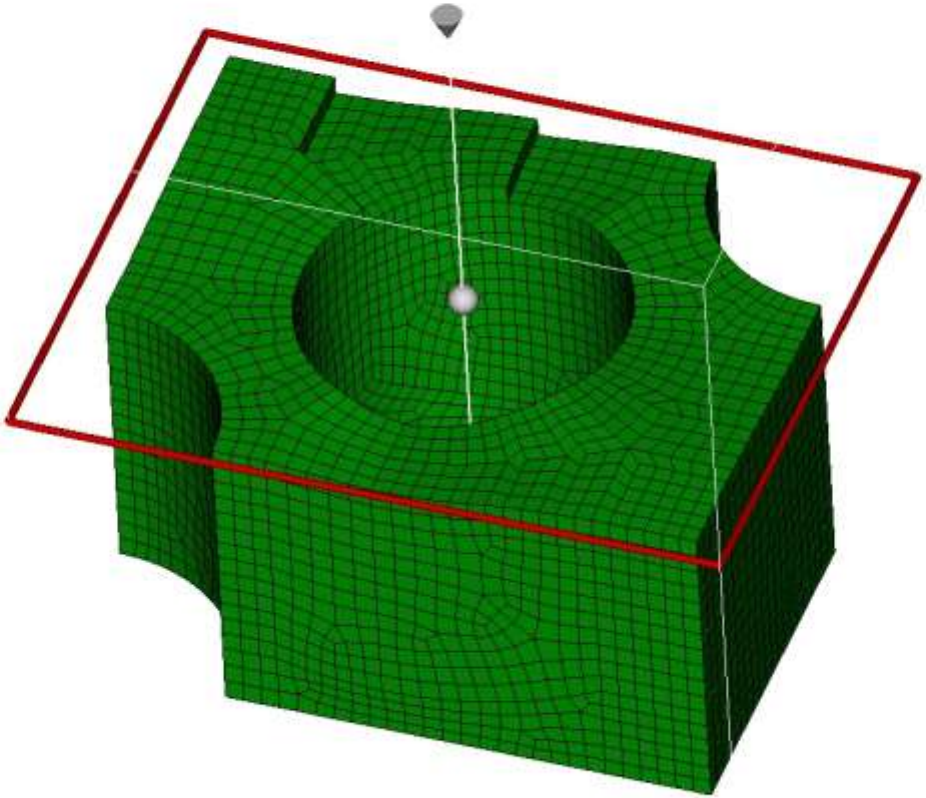
Hex Mesh



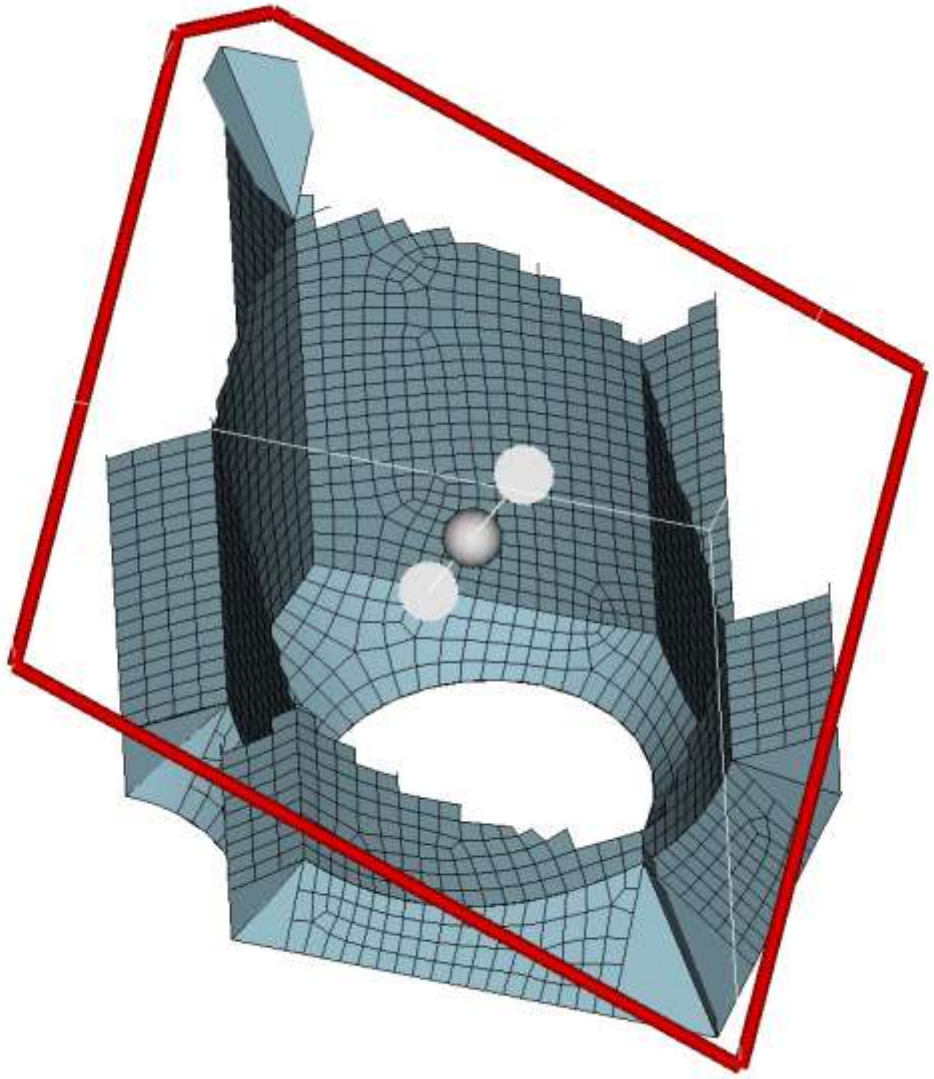
Sectional View



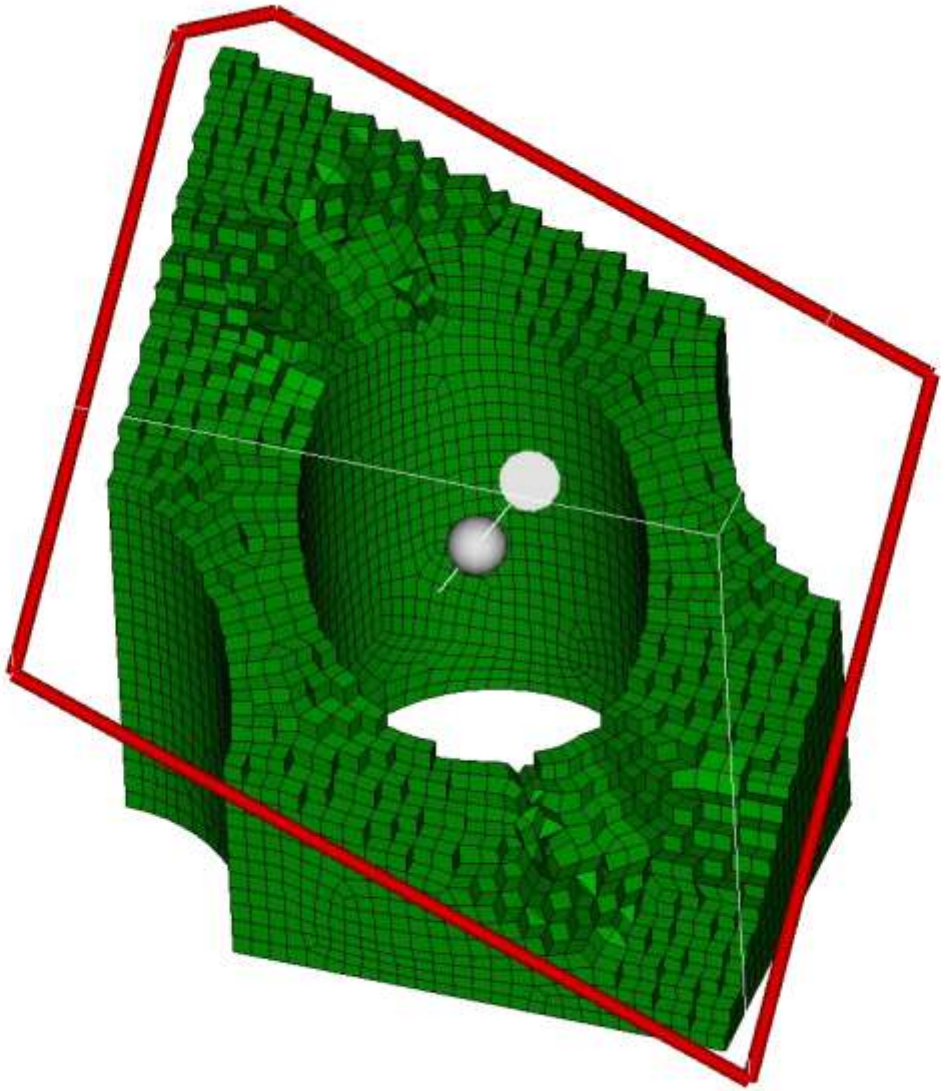
Sectional View



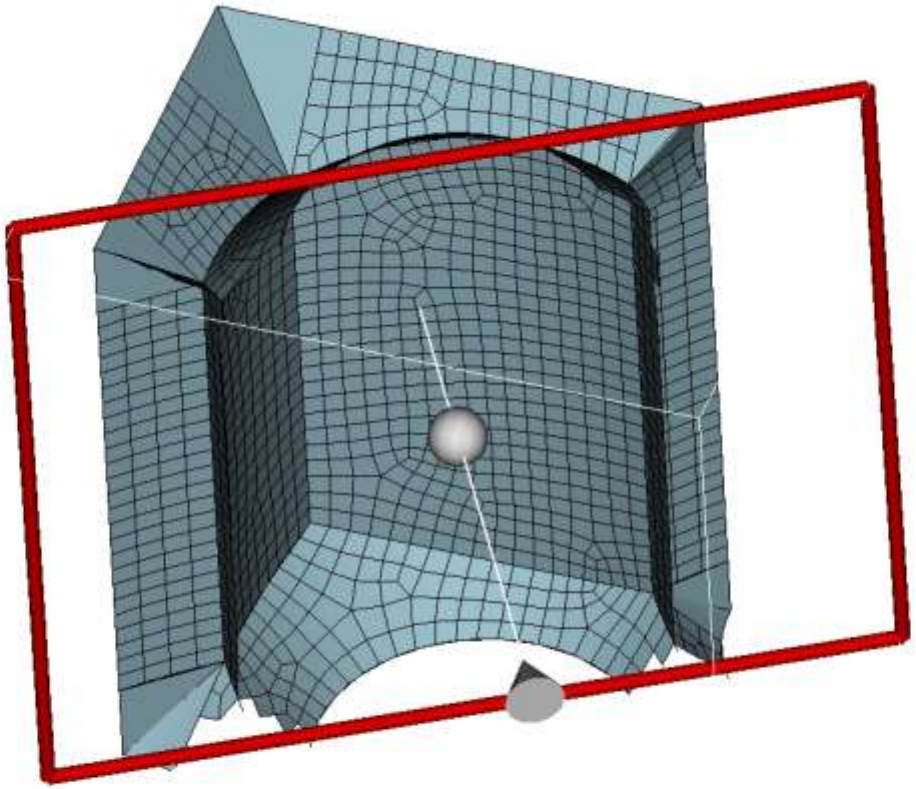
Sectional View



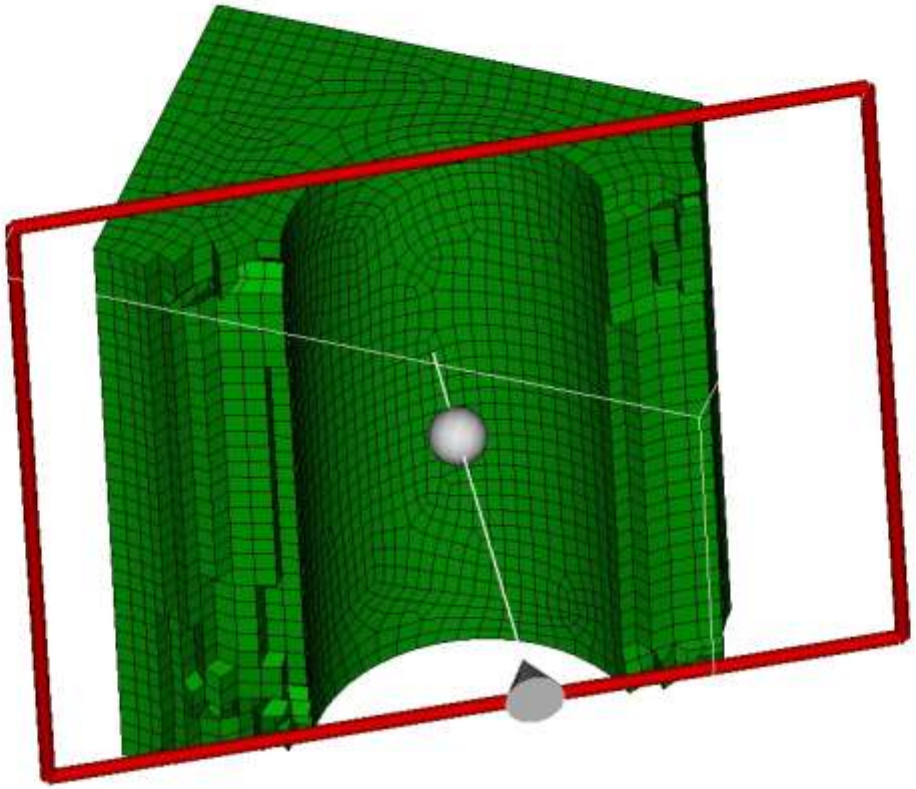
Sectional View



Sectional View



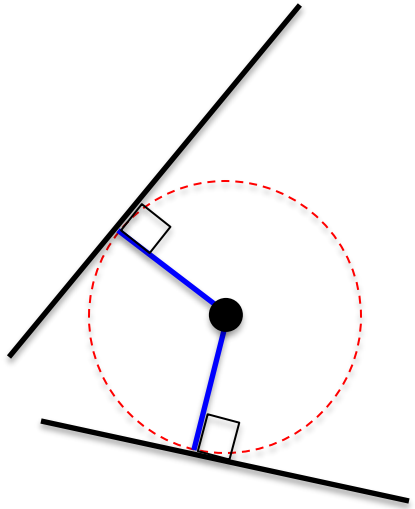
Sectional View



Demo

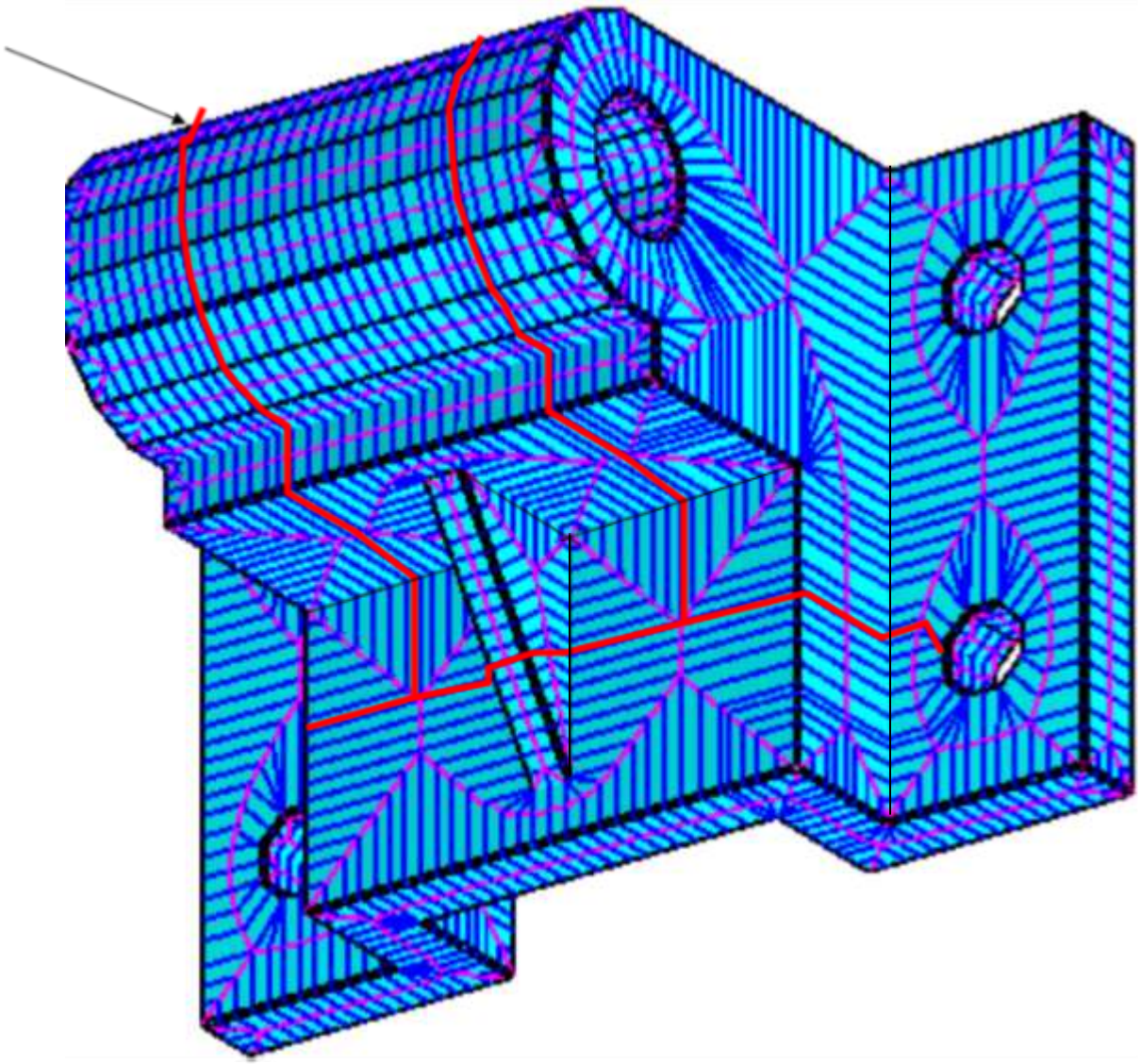
Rails in 3D

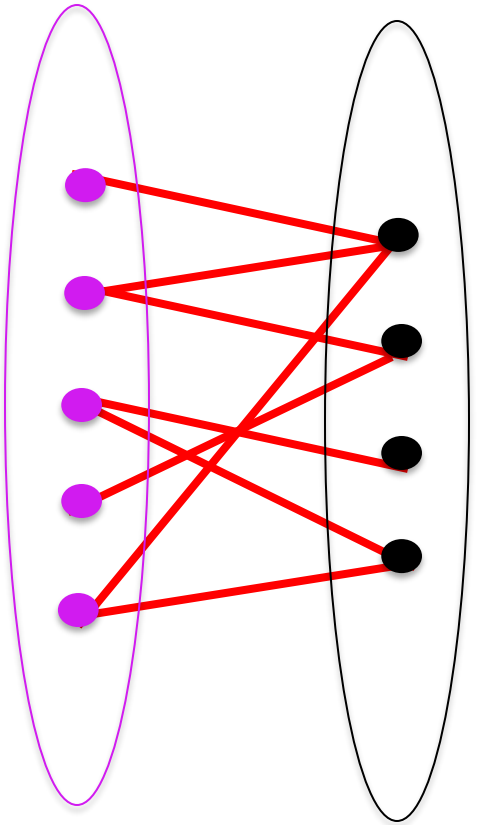
Rails in 3D: Radius



- 90 degrees at Boundary
- Symmetric
- Shortest Distance from MA to Boundary

Rails in 3D: Bi-partite Graph





Narrow Corridor Removal

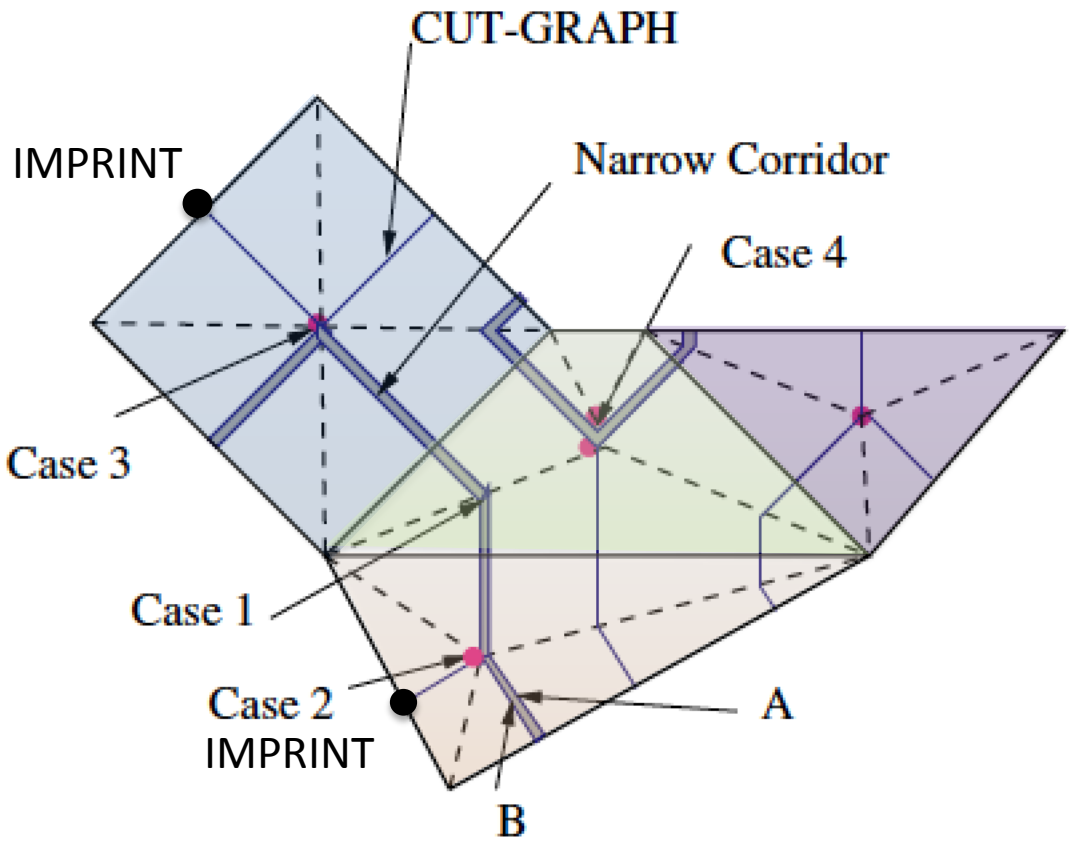


Figure 6. Four cases of narrow corridor.

Narrow Corridor Removal

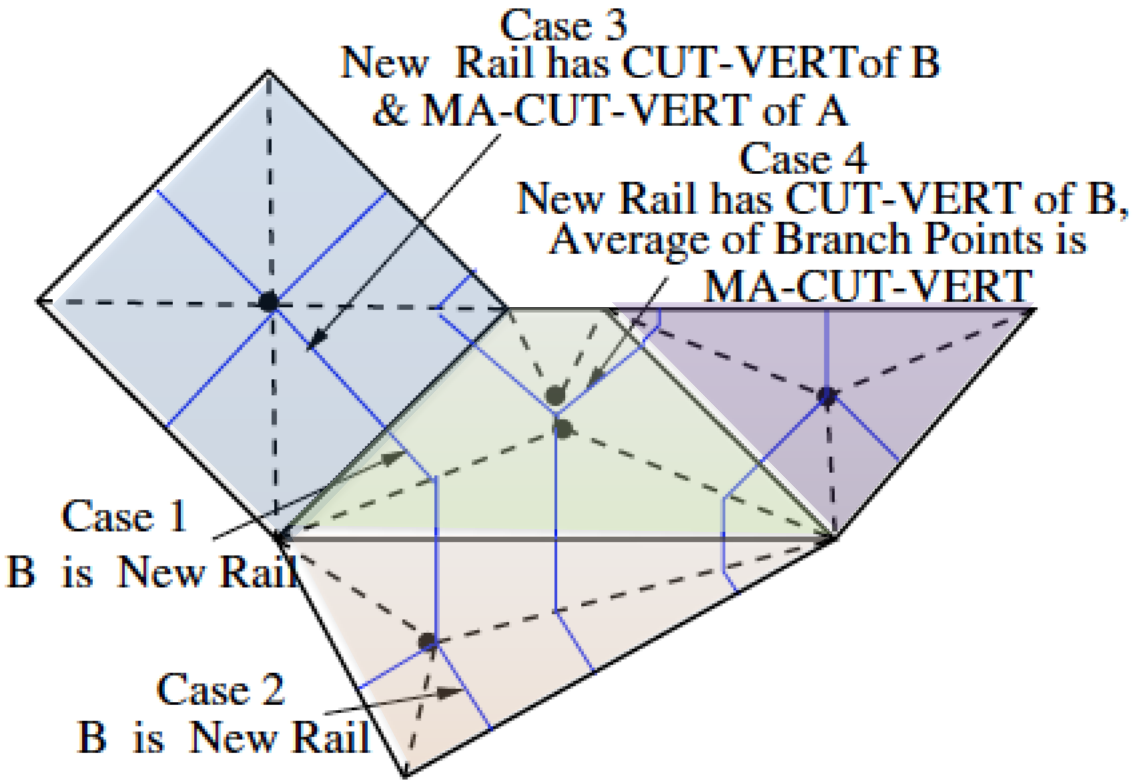
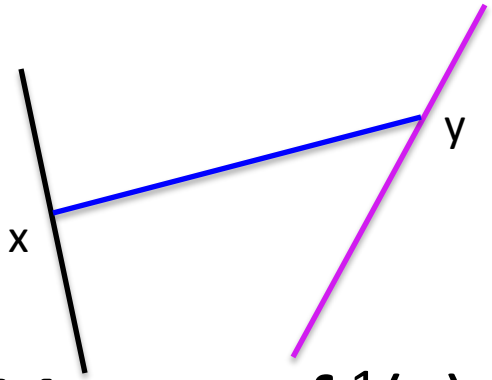


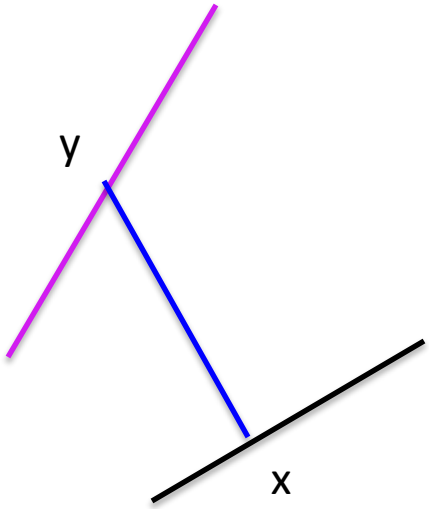
Figure 7. Removal of narrow corridor.

Rails in 3D: Connects Elements of Sets

- Forward Map: $y = f(x)$



- Reverse Map: $x = f^{-1}(y)$



Rails in 3D: Control Polygon

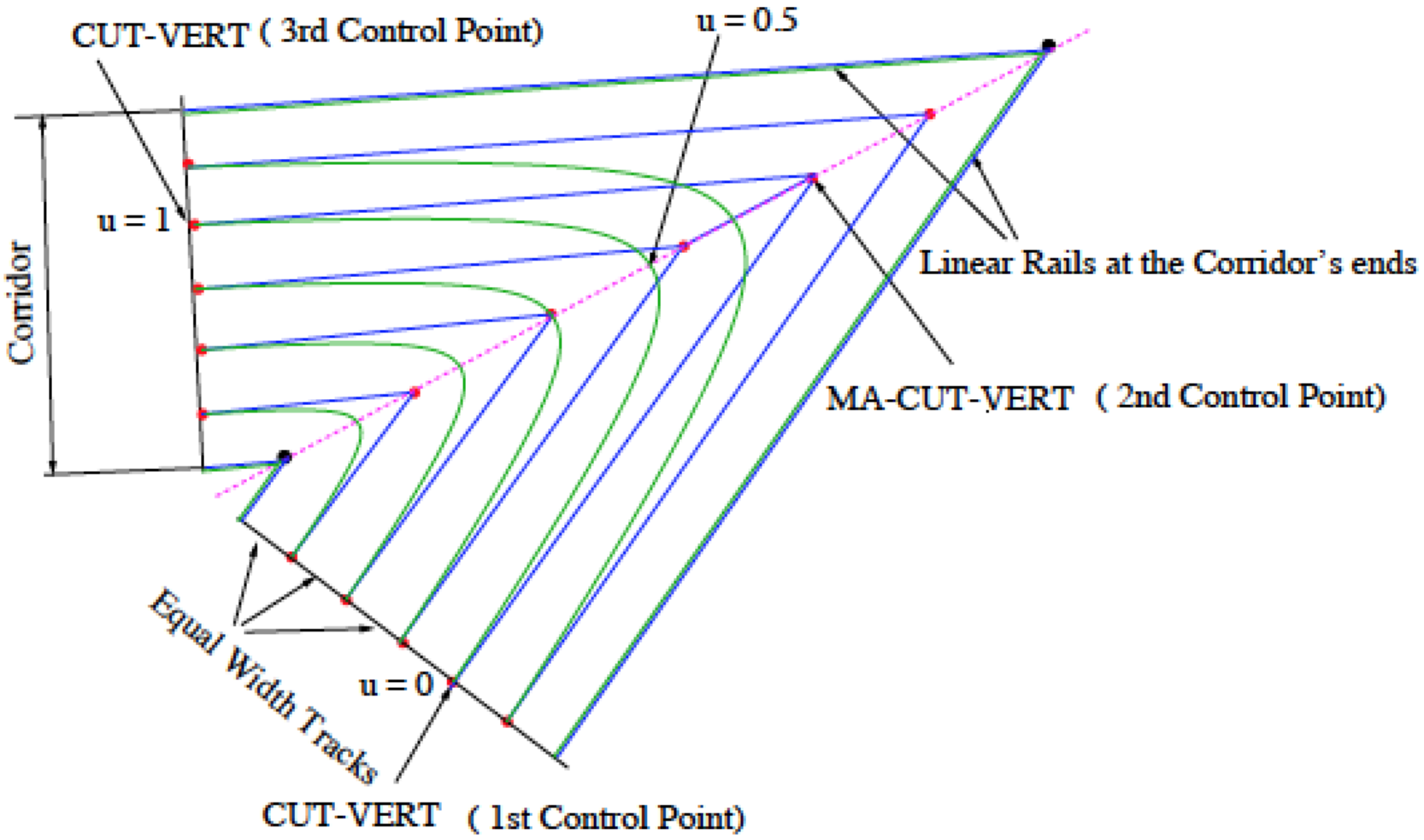
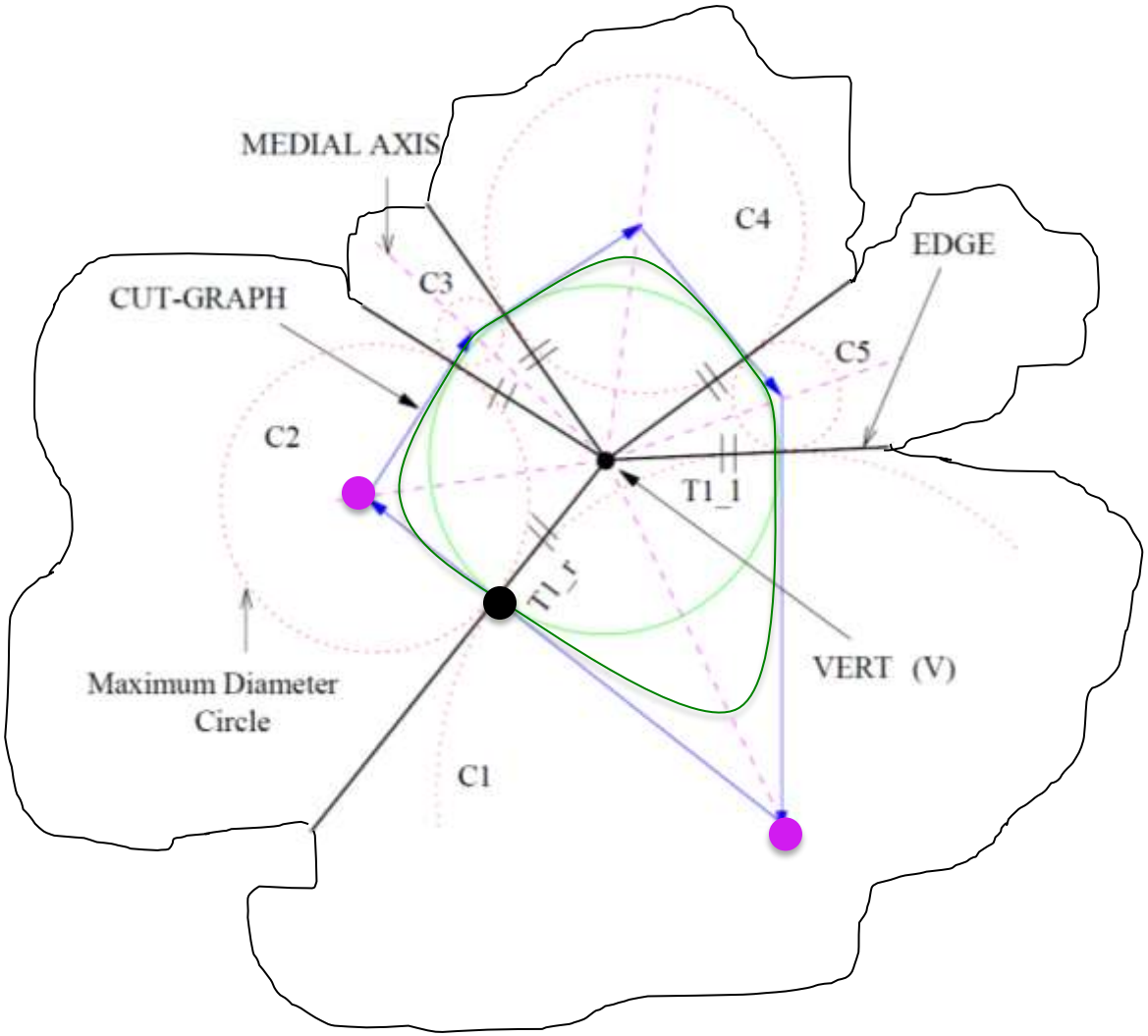


Figure 6.1: Rails Represented by Straight Lines and NURBS

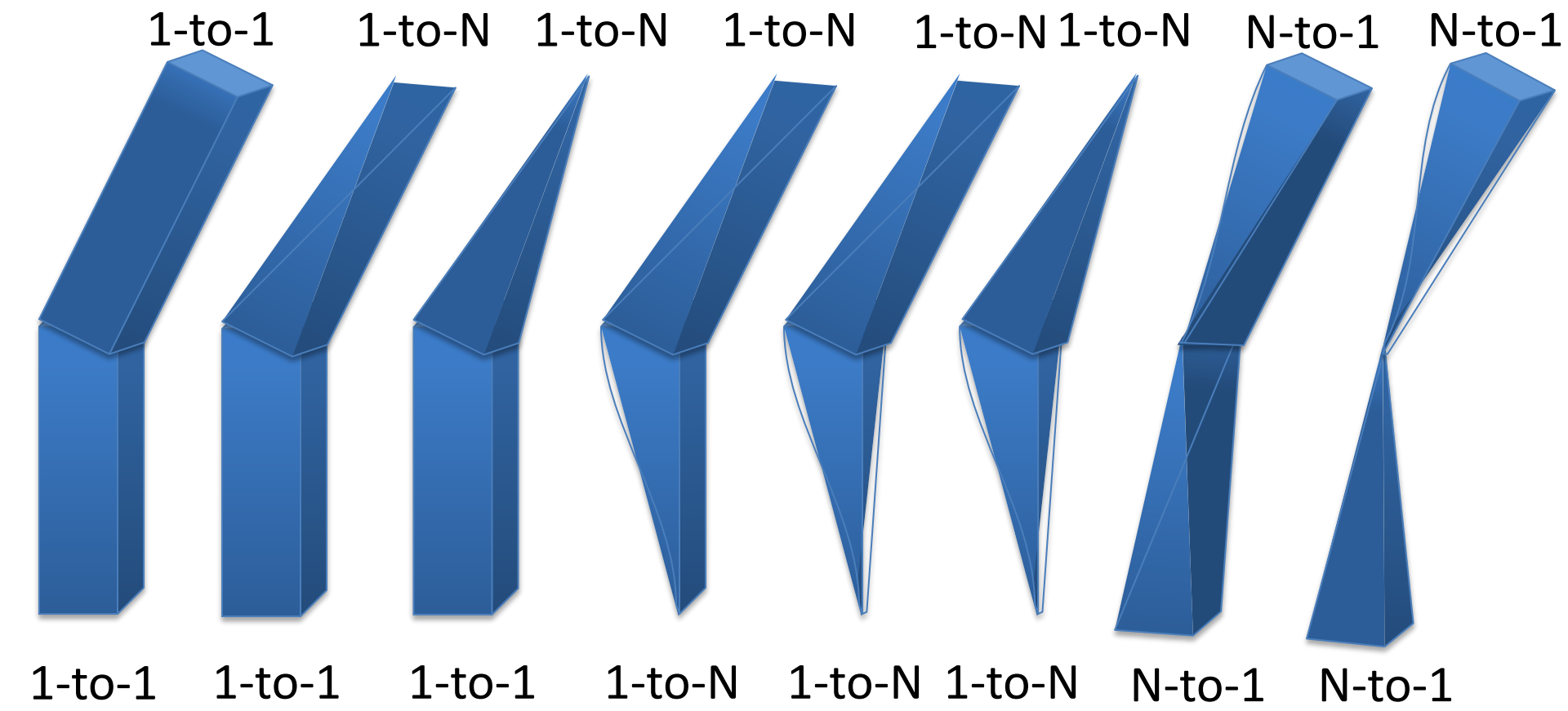
Rail as Control Polygon: Non-intersecting & Orthogonal



Tracks in 3D

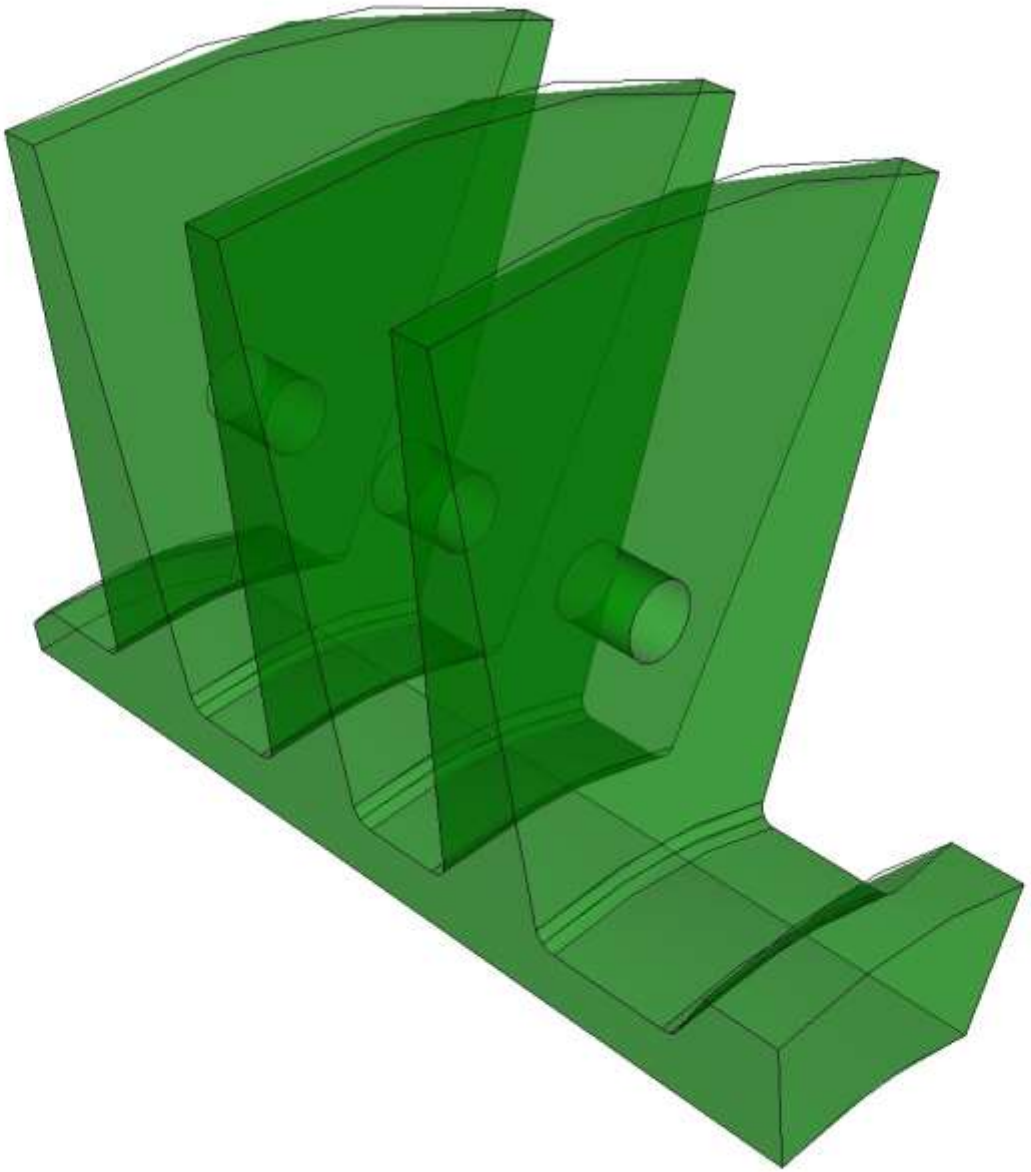
- Region Bounded by Path of Adjacent Rails.
- No Branch: One entry and One exit
- Enters and Exists Boundary Orthogonally
- Symmetric Inside Each Solid
- Shortest Path
- Track with can vary with Medial Radius
- Tracks can be non-linear

Types of Tracks in 3D

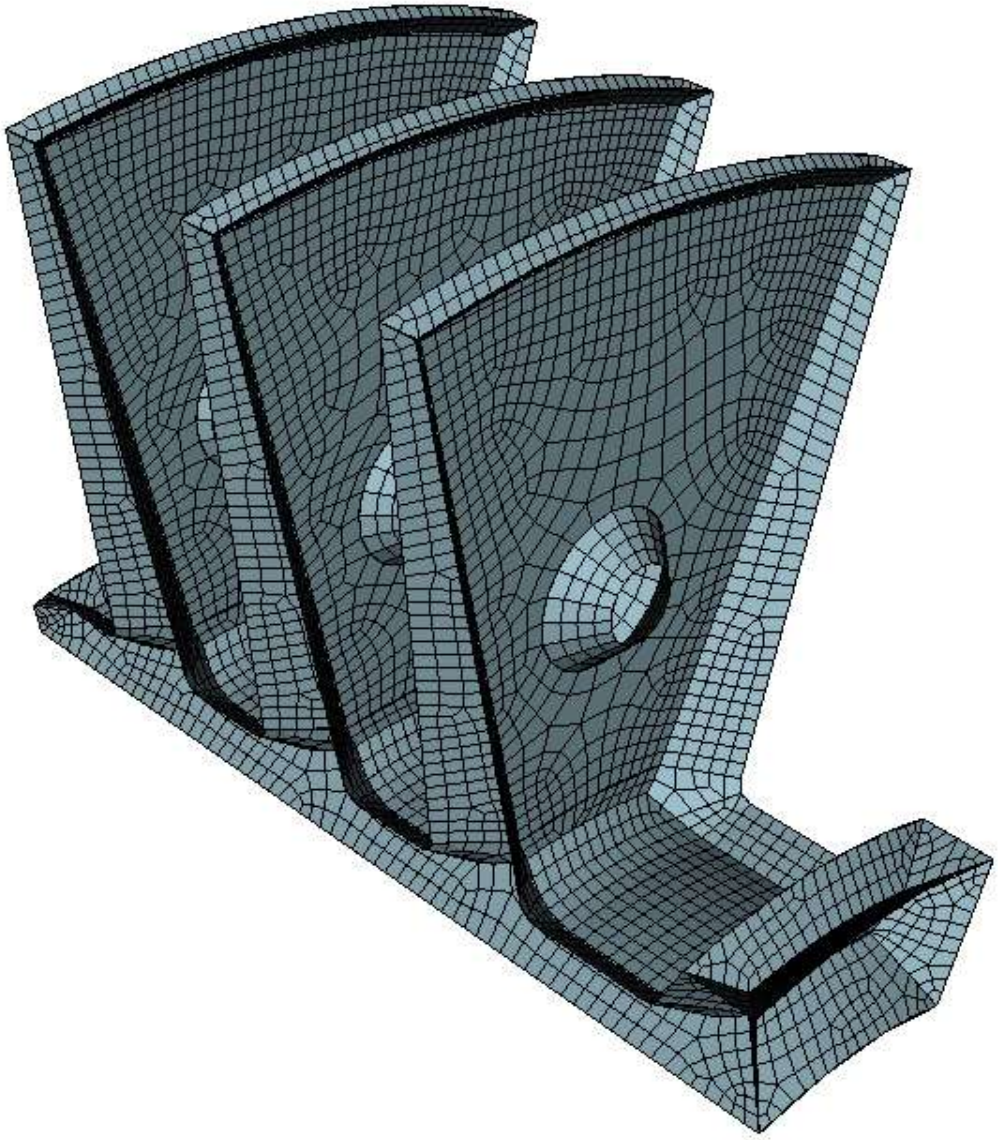


Results

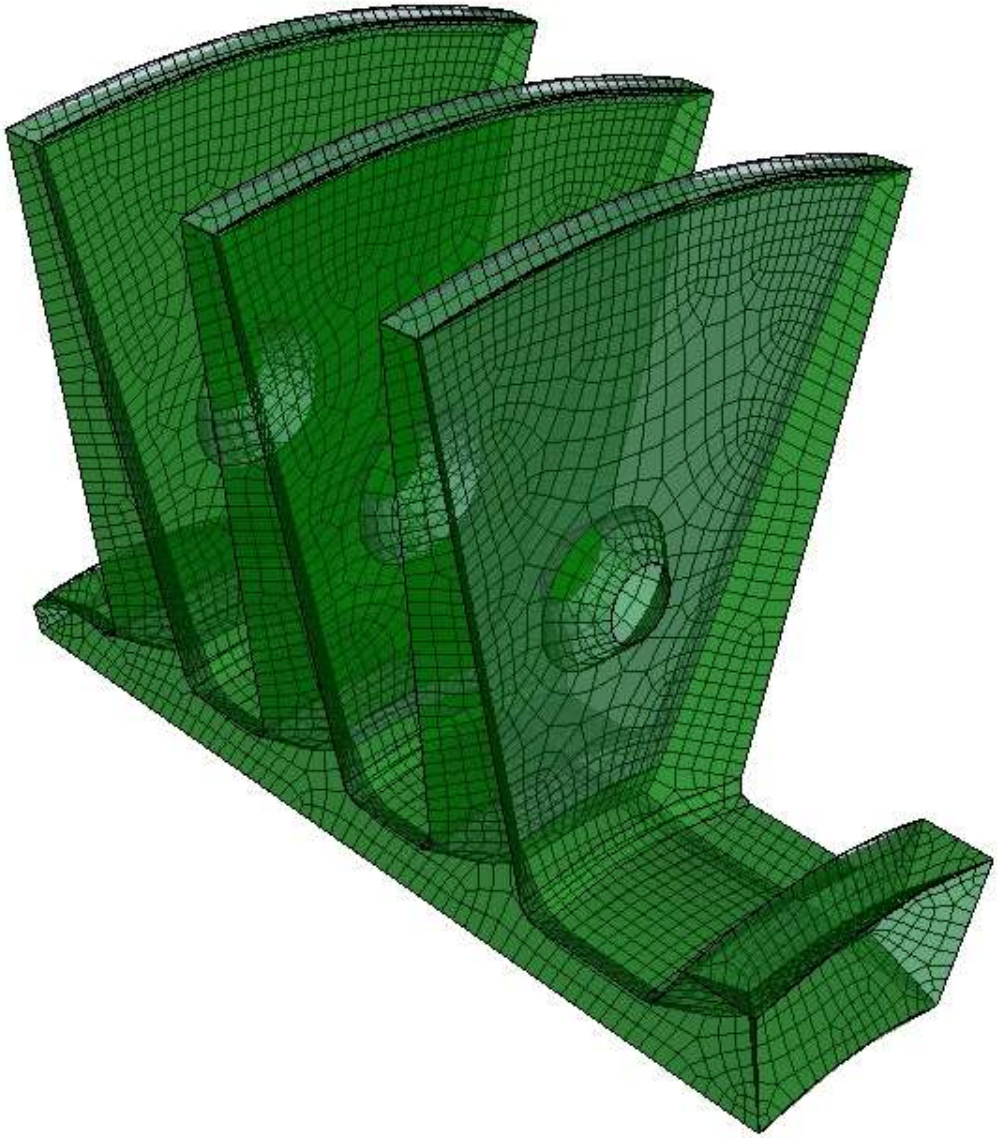
Input Solid



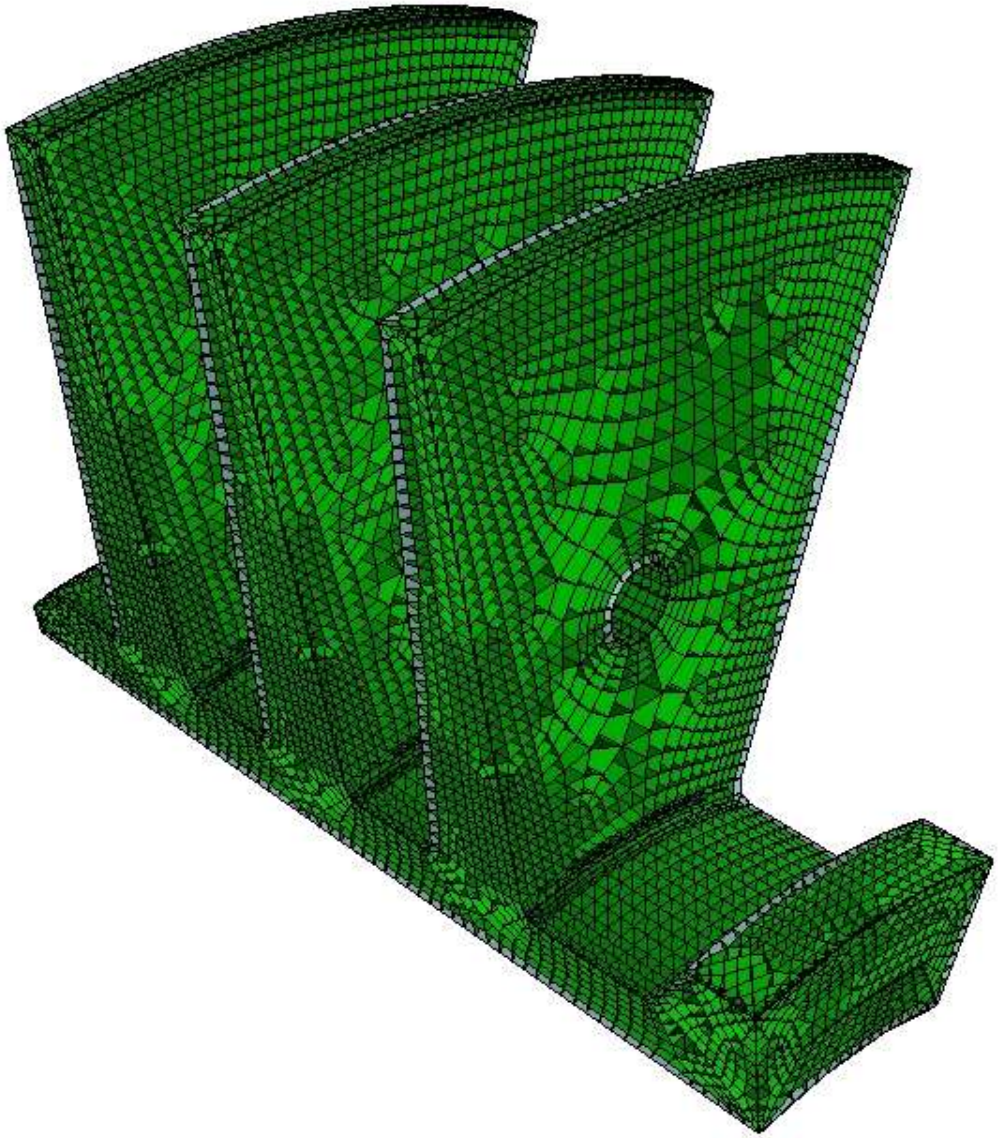
All-Quad Mesh on Medial



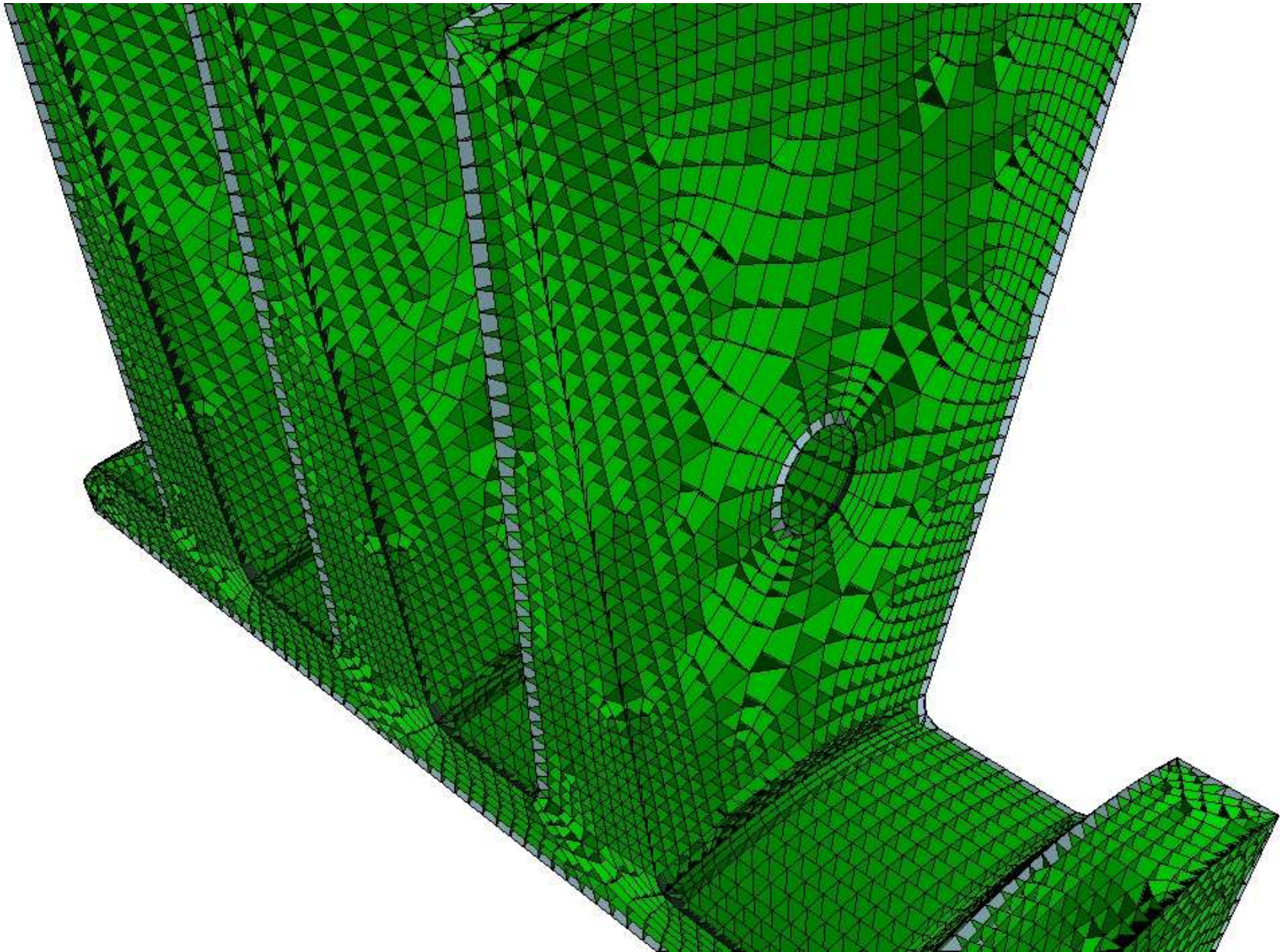
Medial Mesh Inside Solid



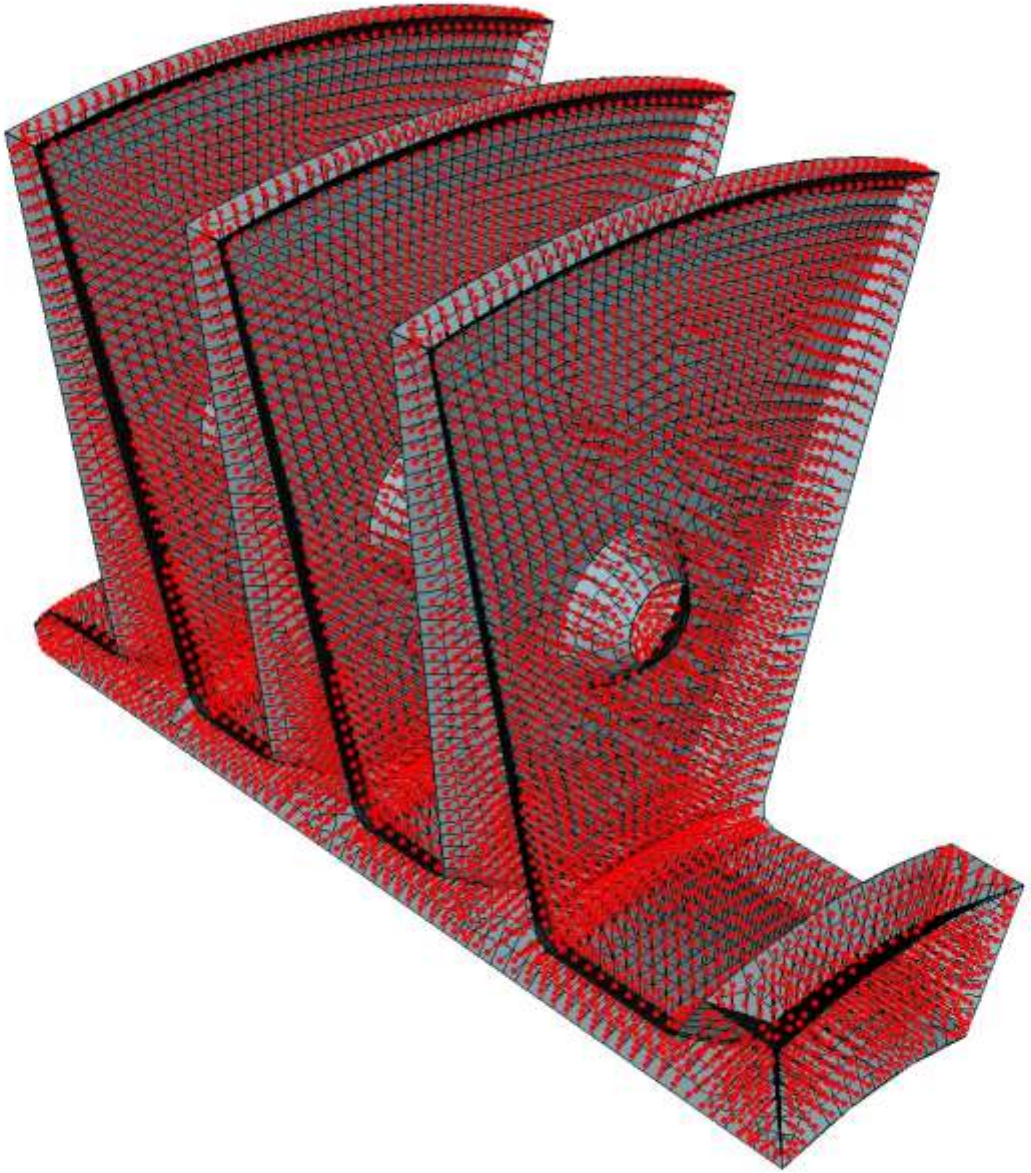
Tracks in 3D



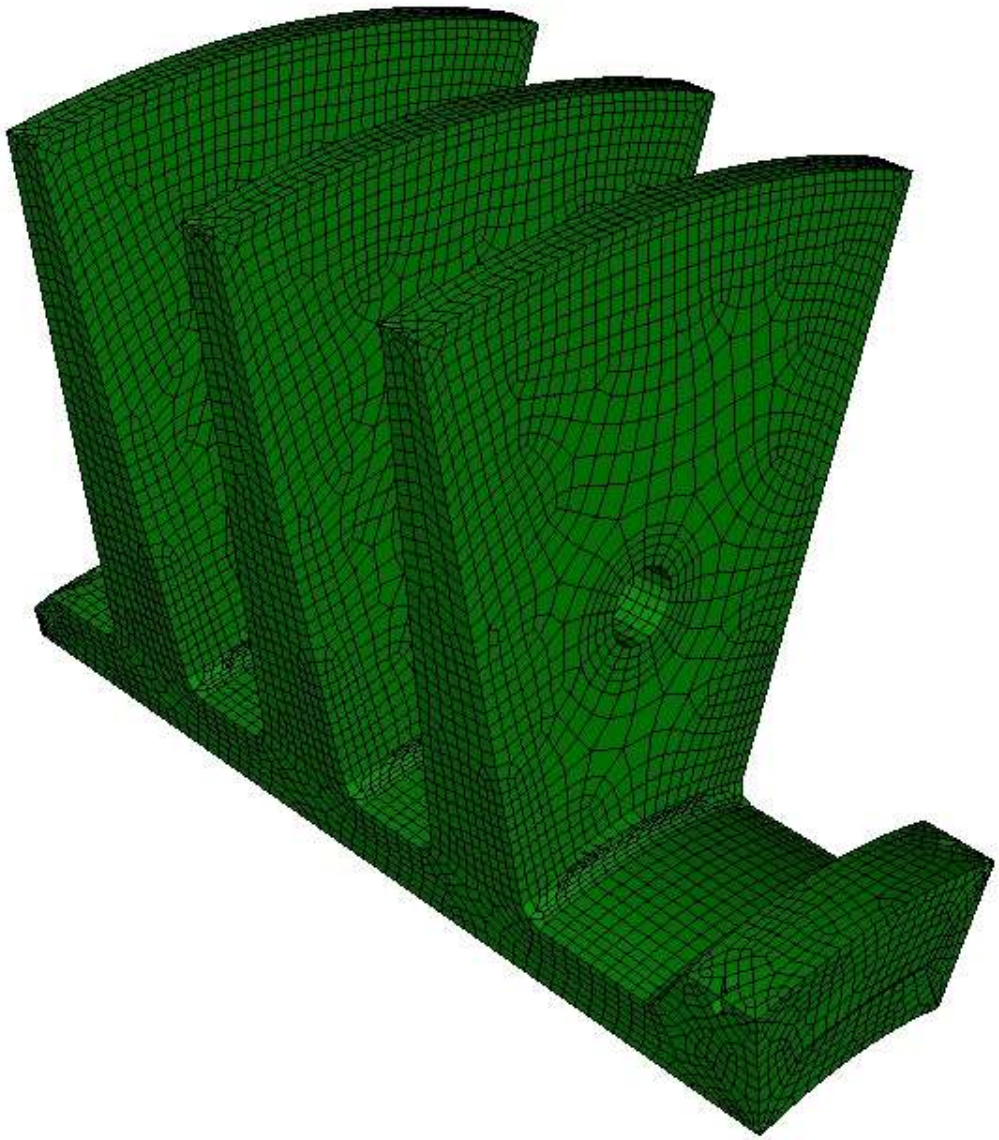
Tracks in 3D



Nodes on Rails

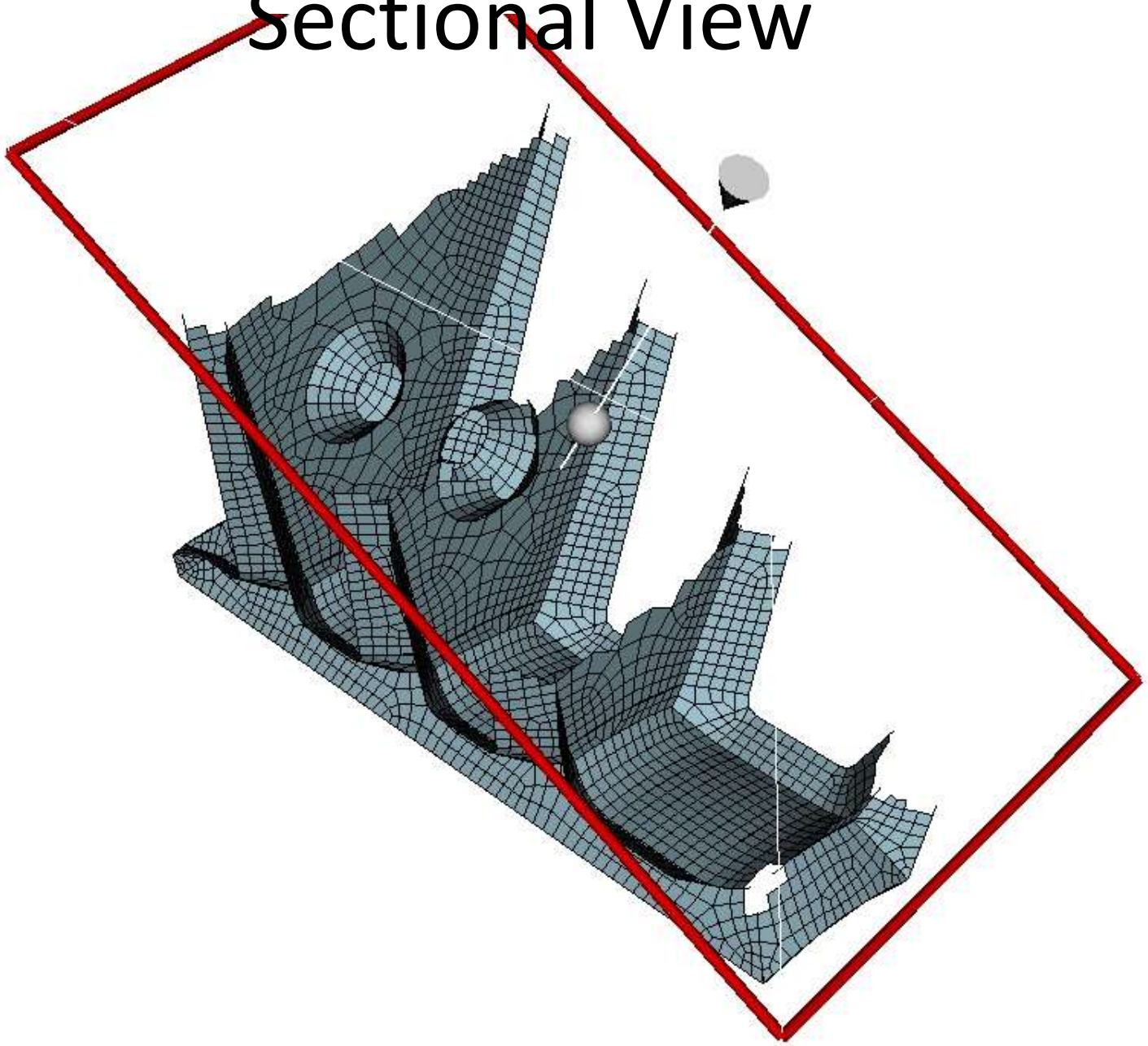


Hex Mesh

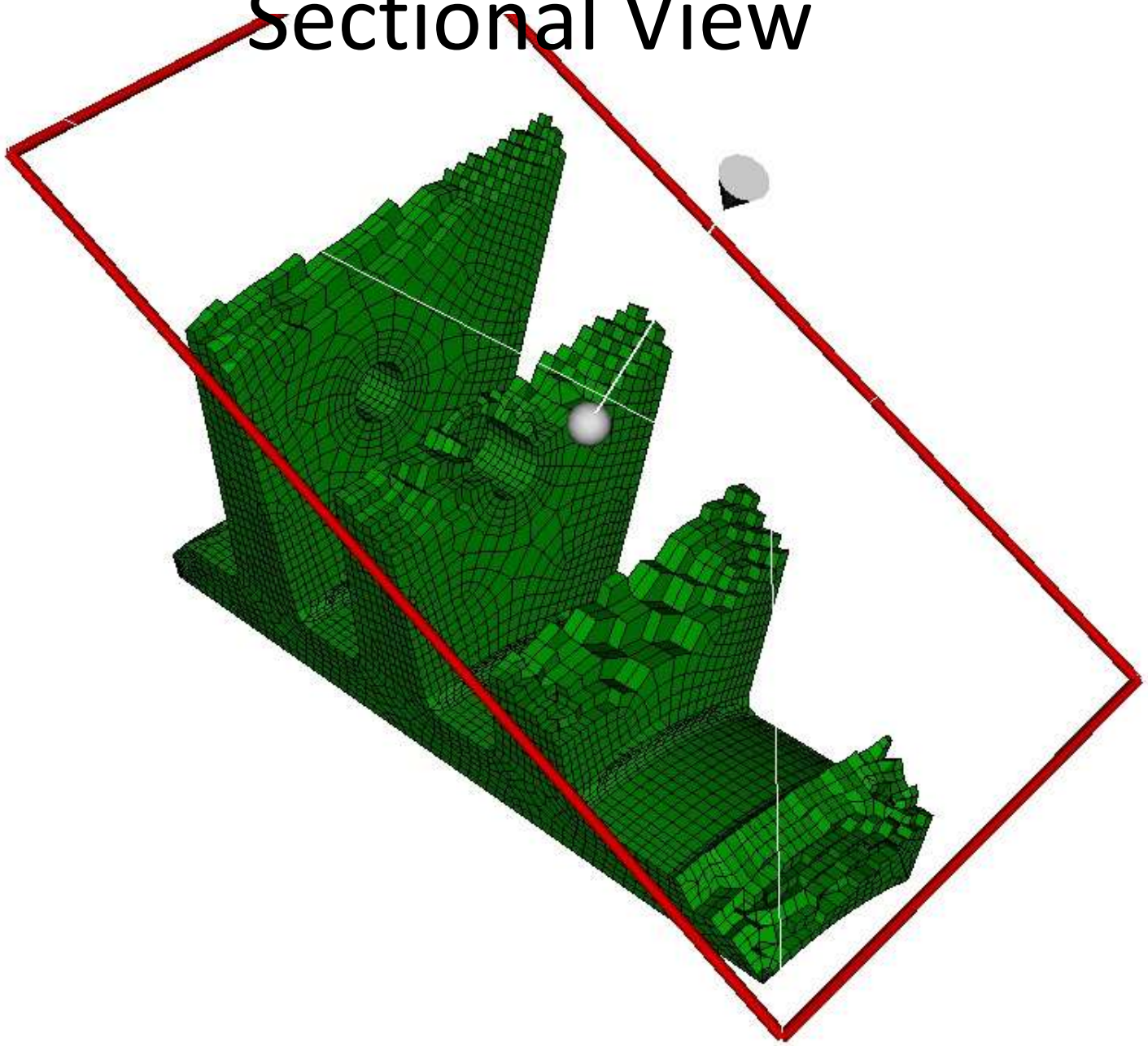


(All-Hex Needs Further Work at Concave Fillets)

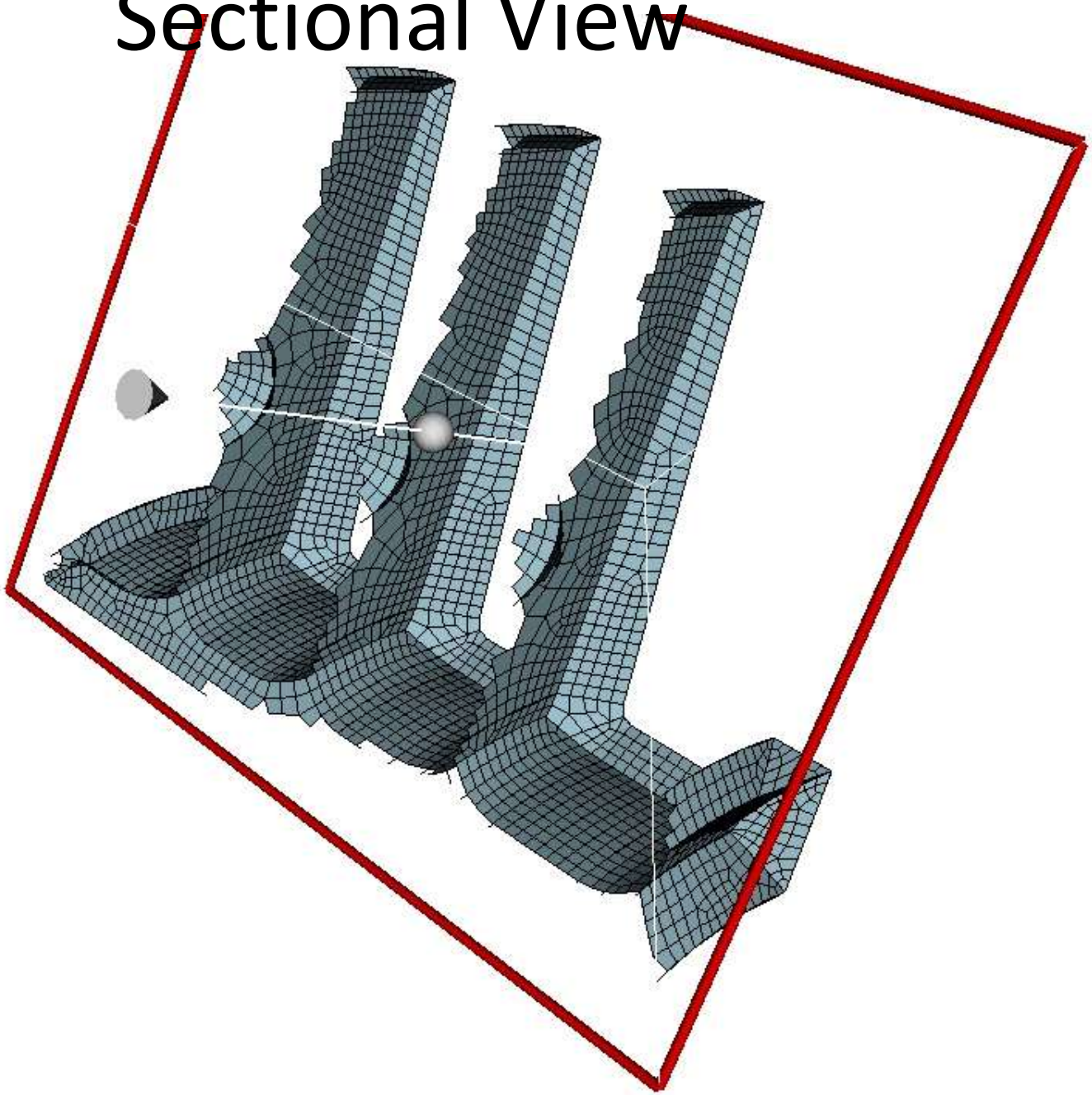
Sectional View



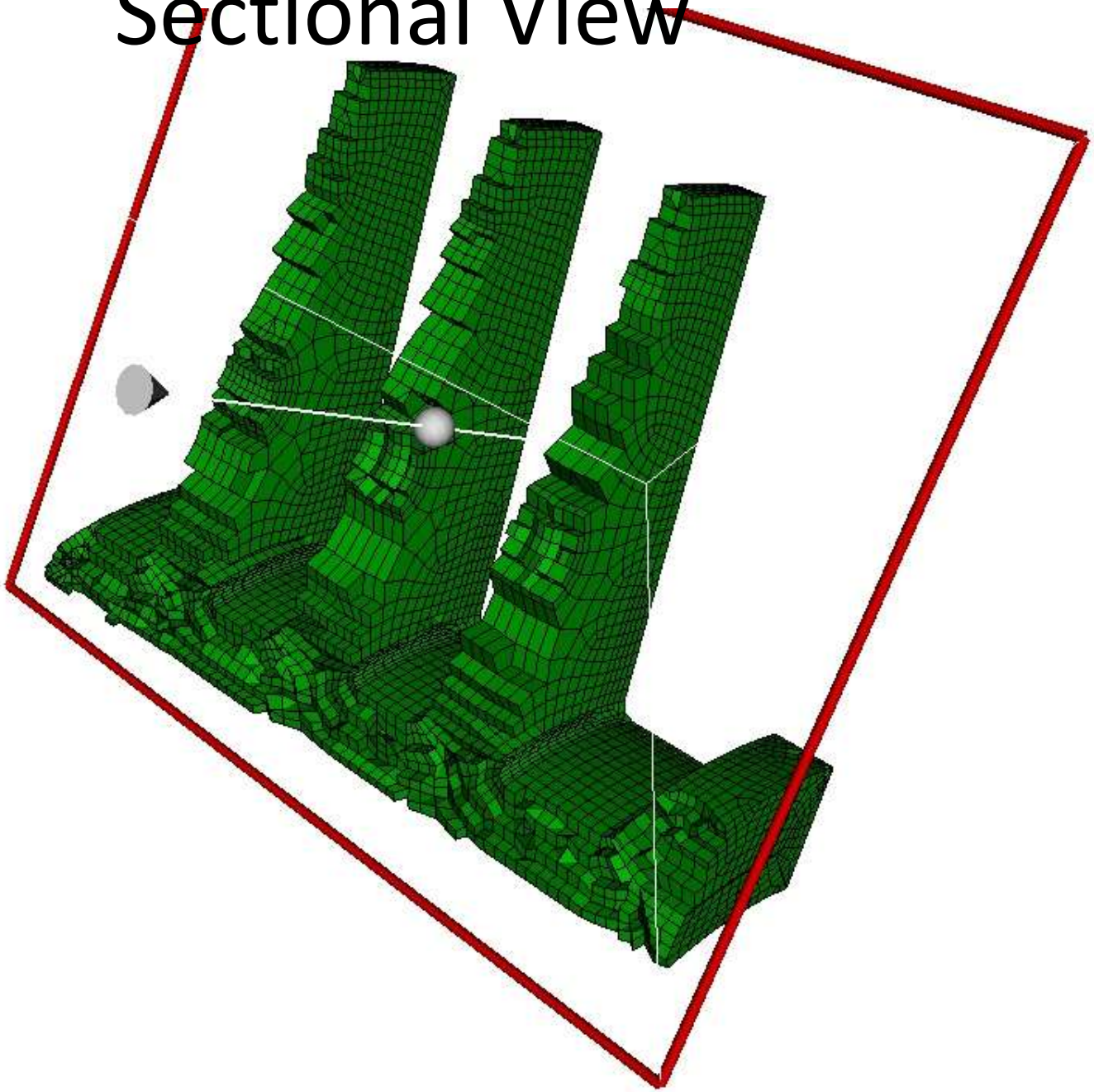
Sectional View



Sectional View

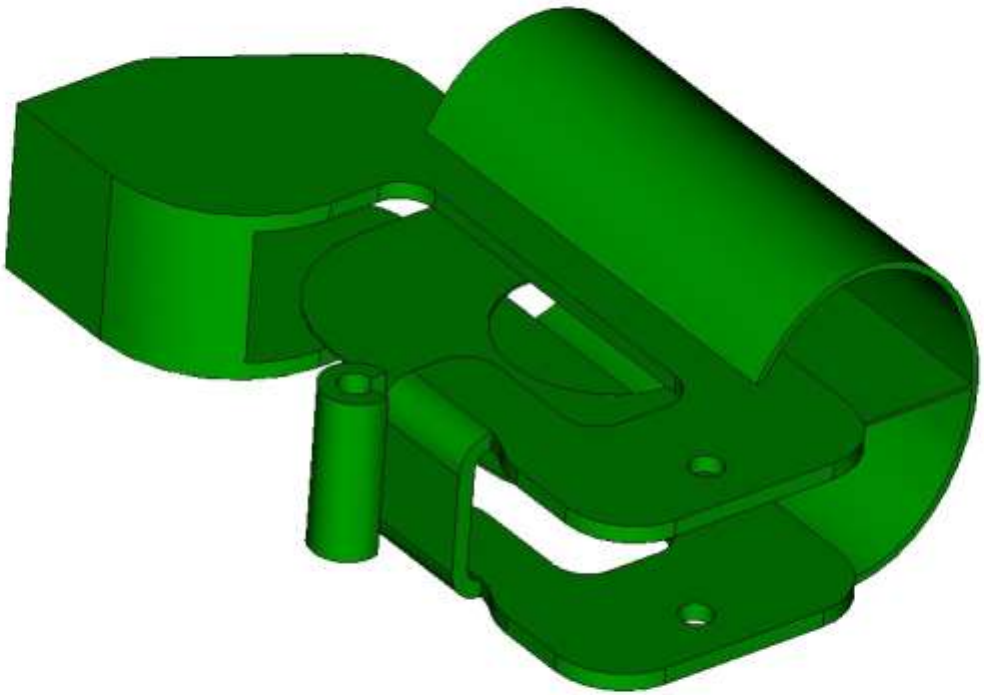


Sectional View

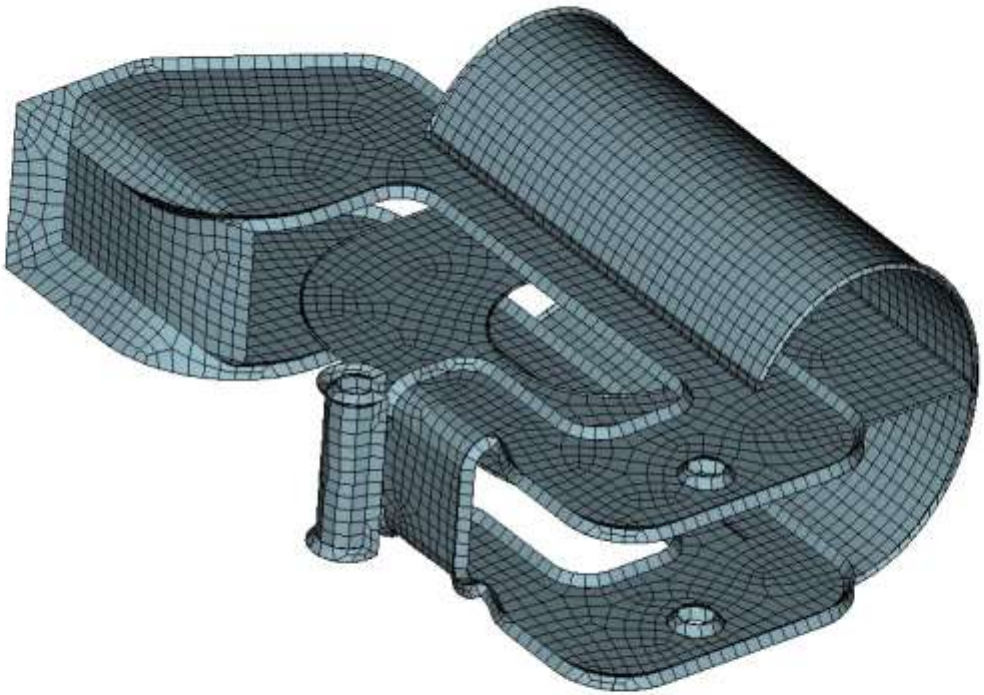


Result

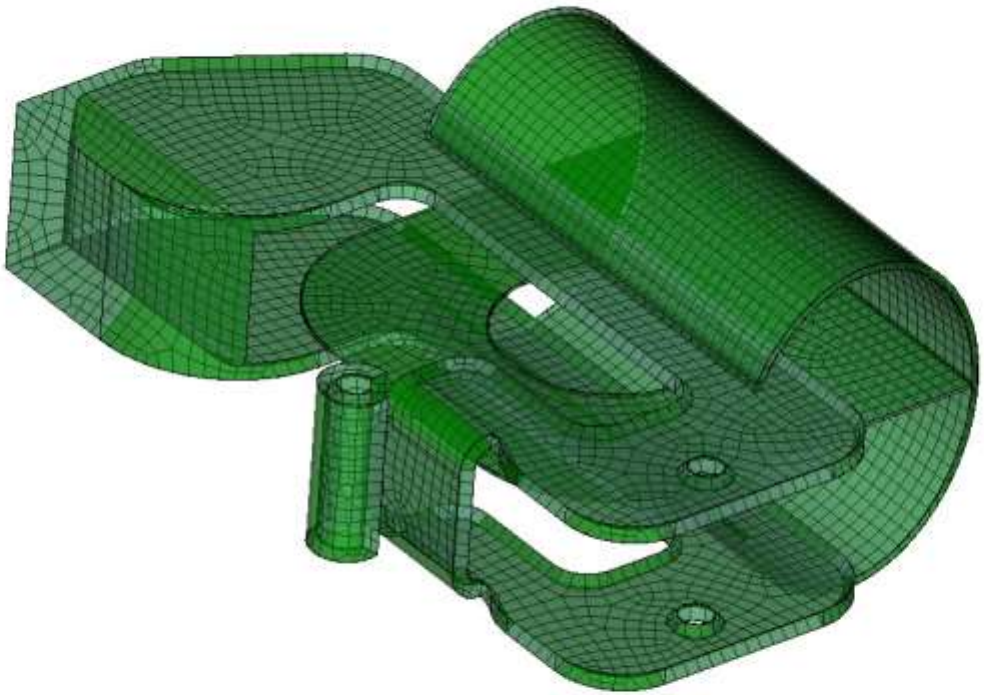
Input Solid



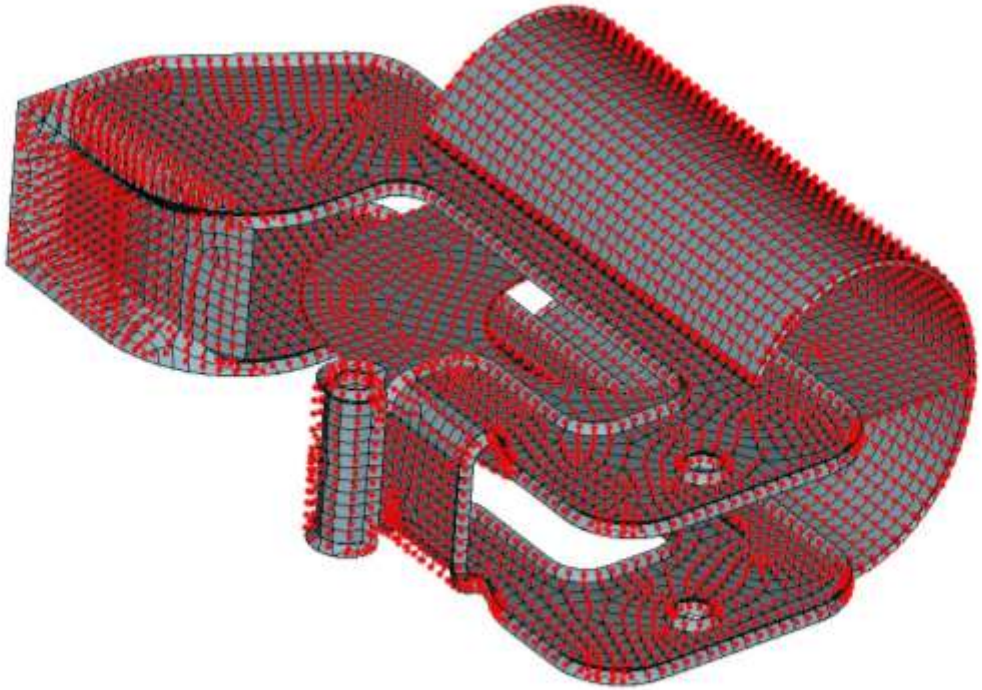
All-Quad Mesh on Medial



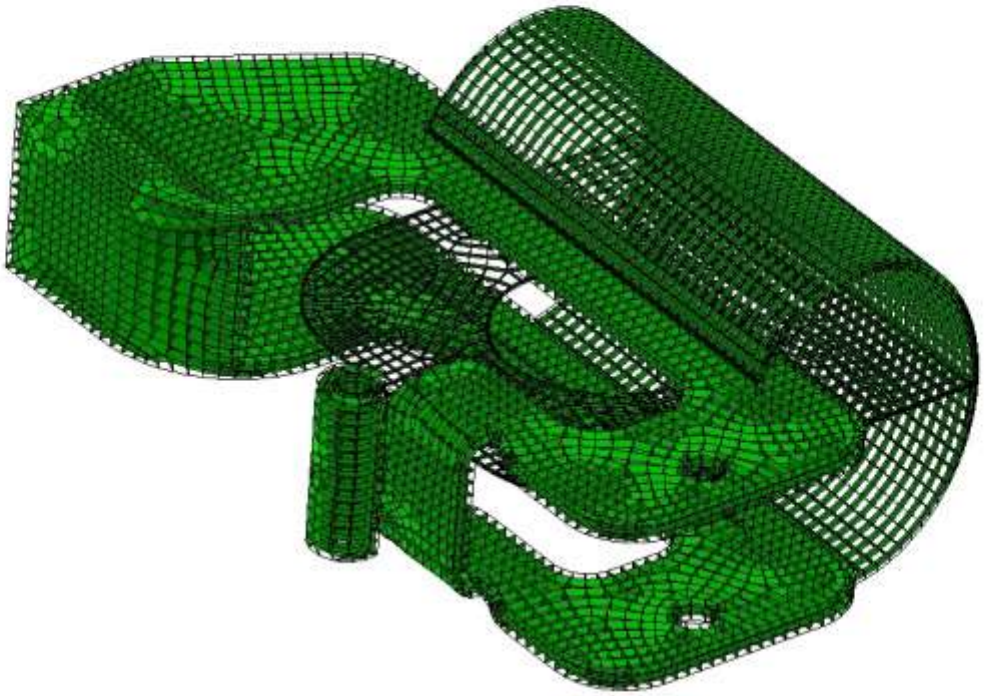
Medial Mesh Inside Solid



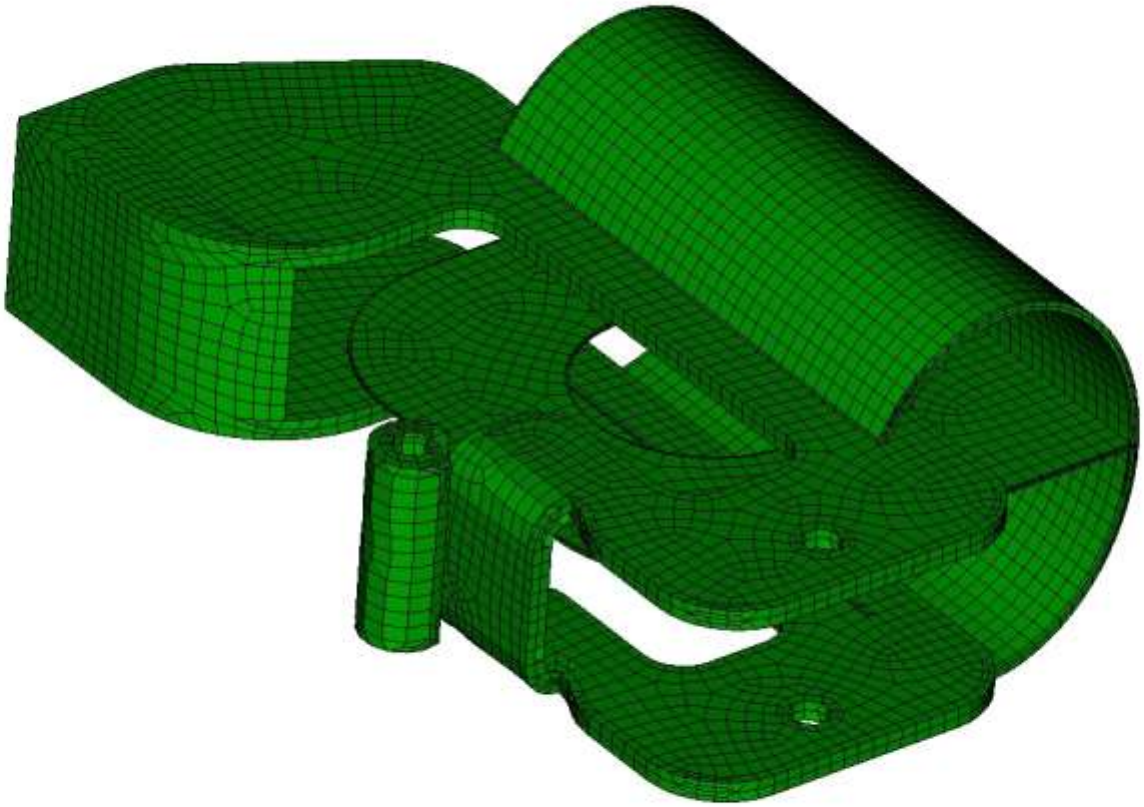
Nodes Along Rails



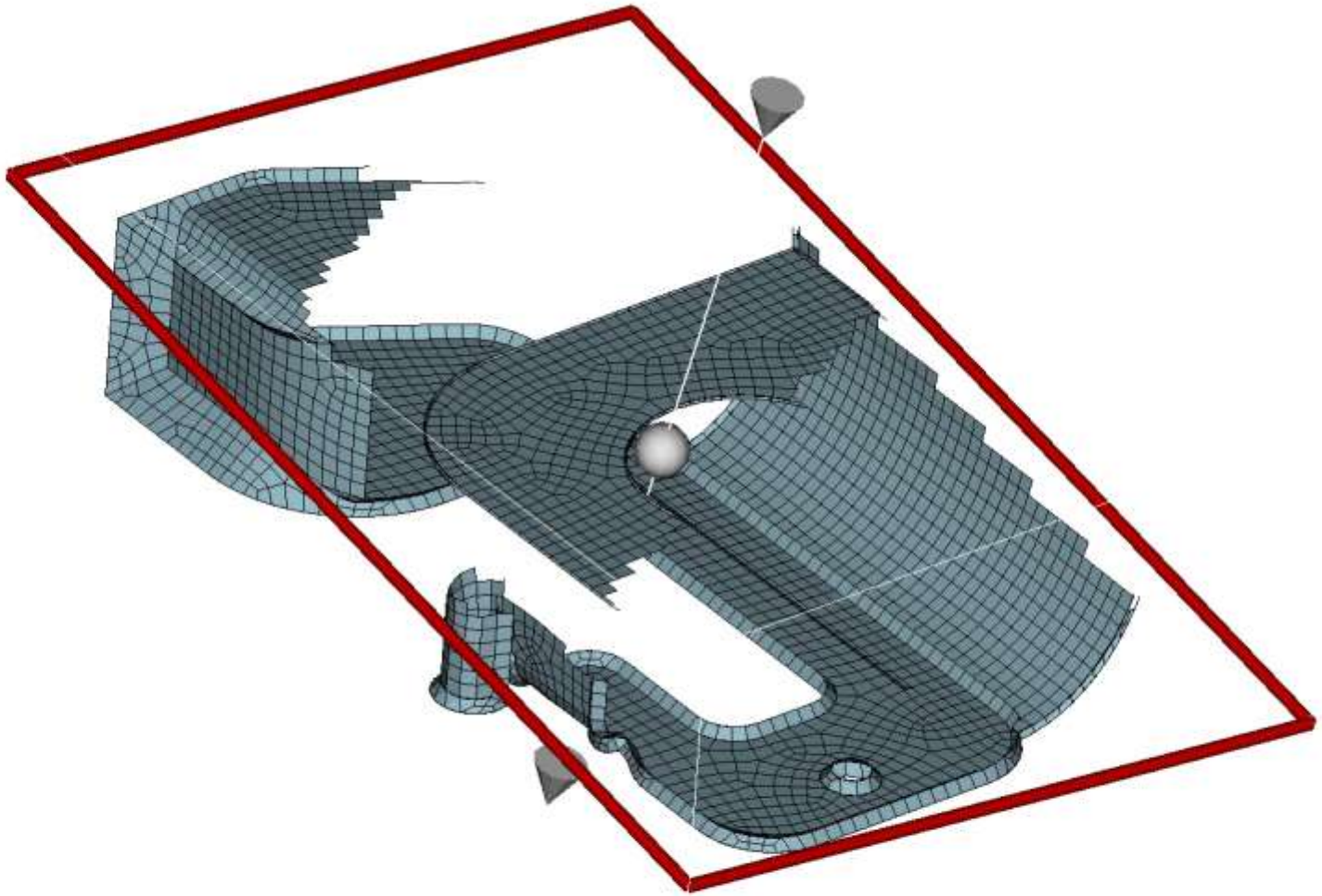
Tracks



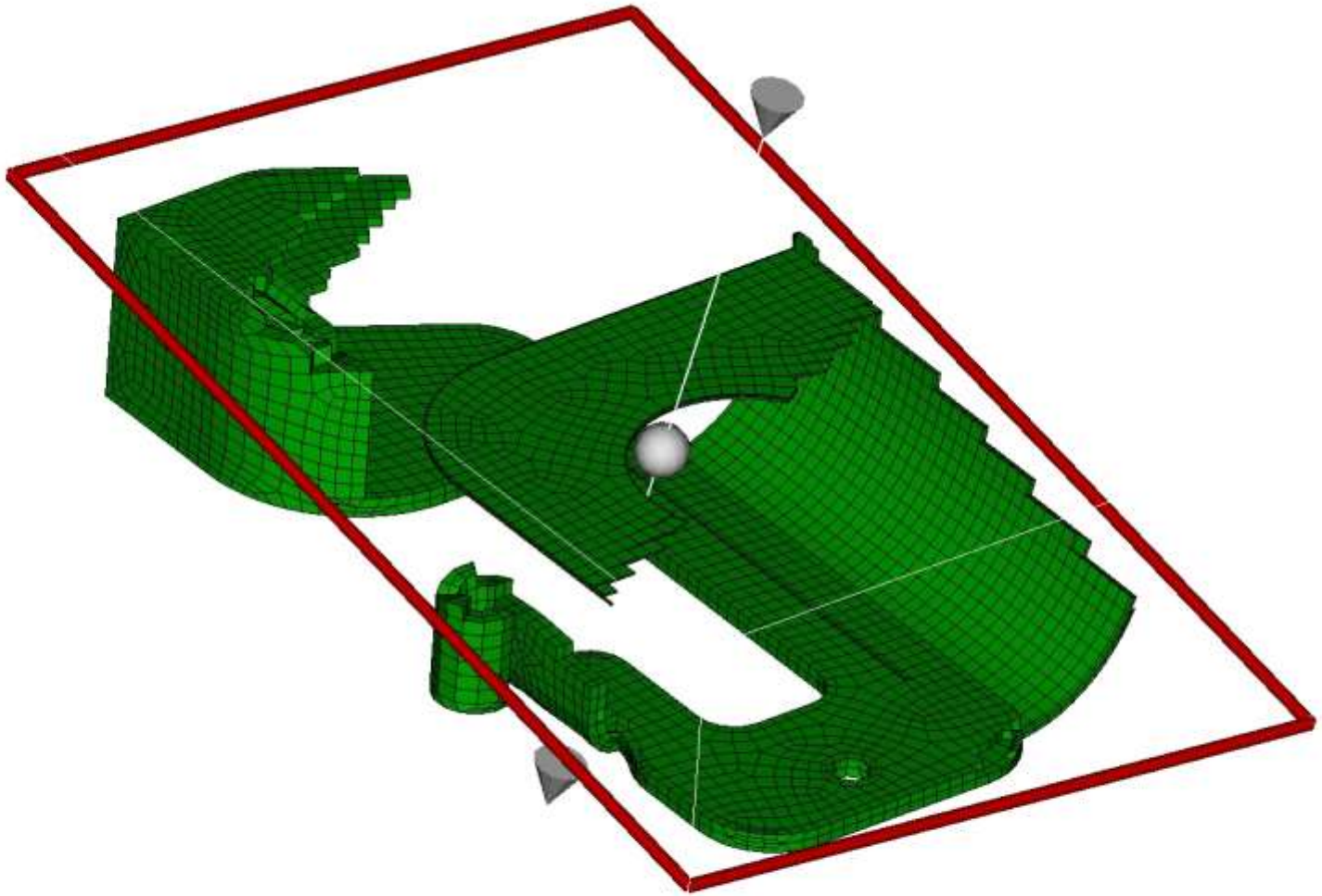
Hex Mesh



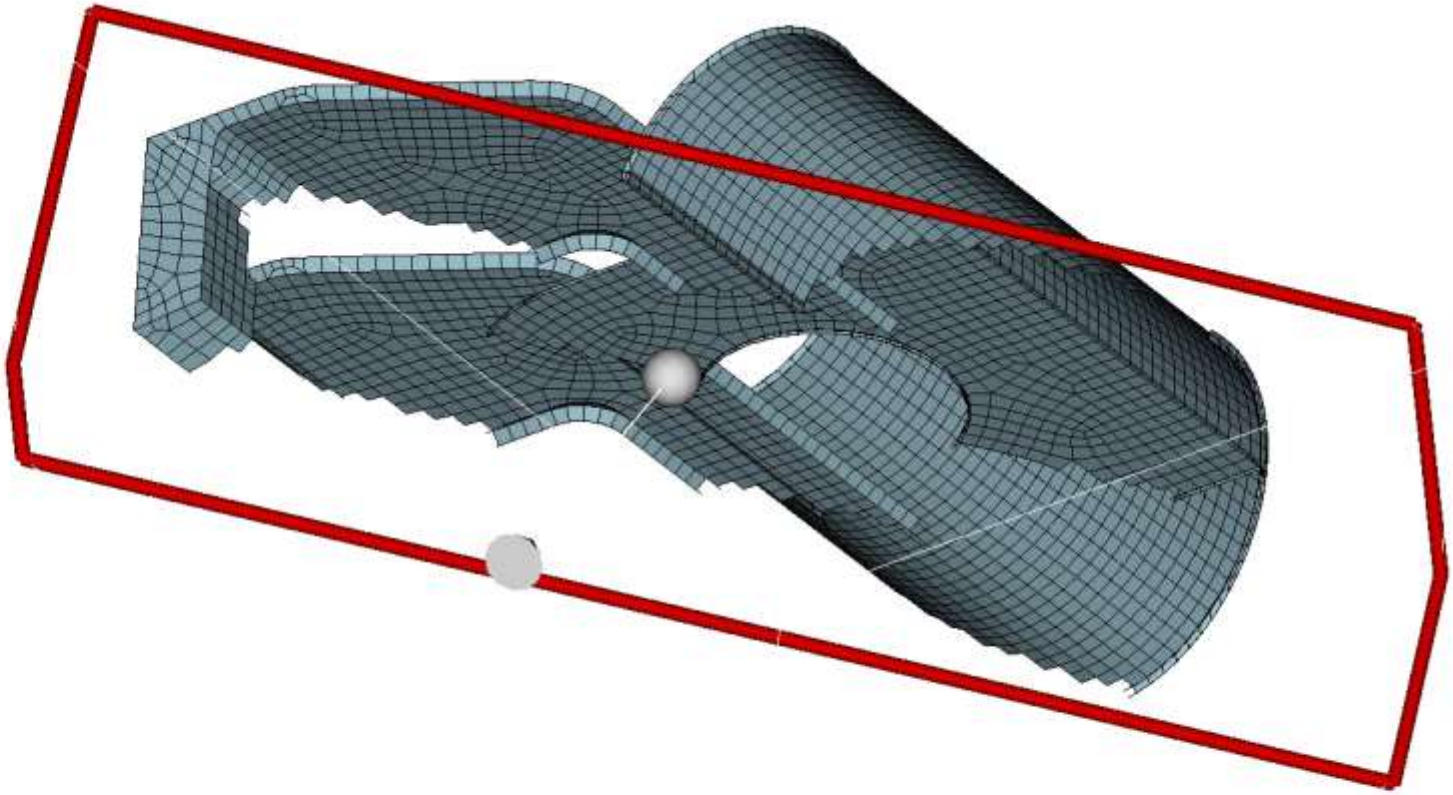
Sectional View



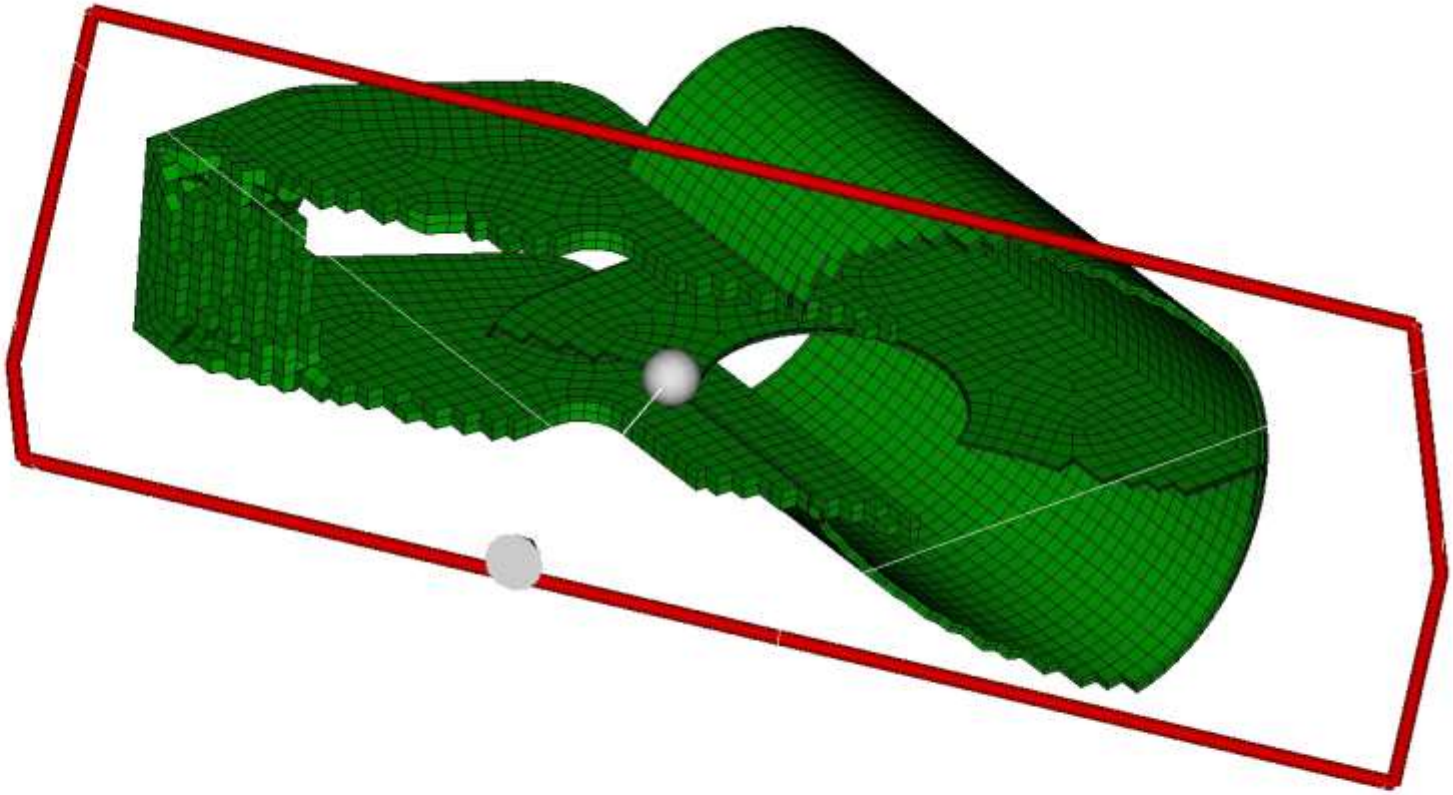
Sectional View



Sectional View

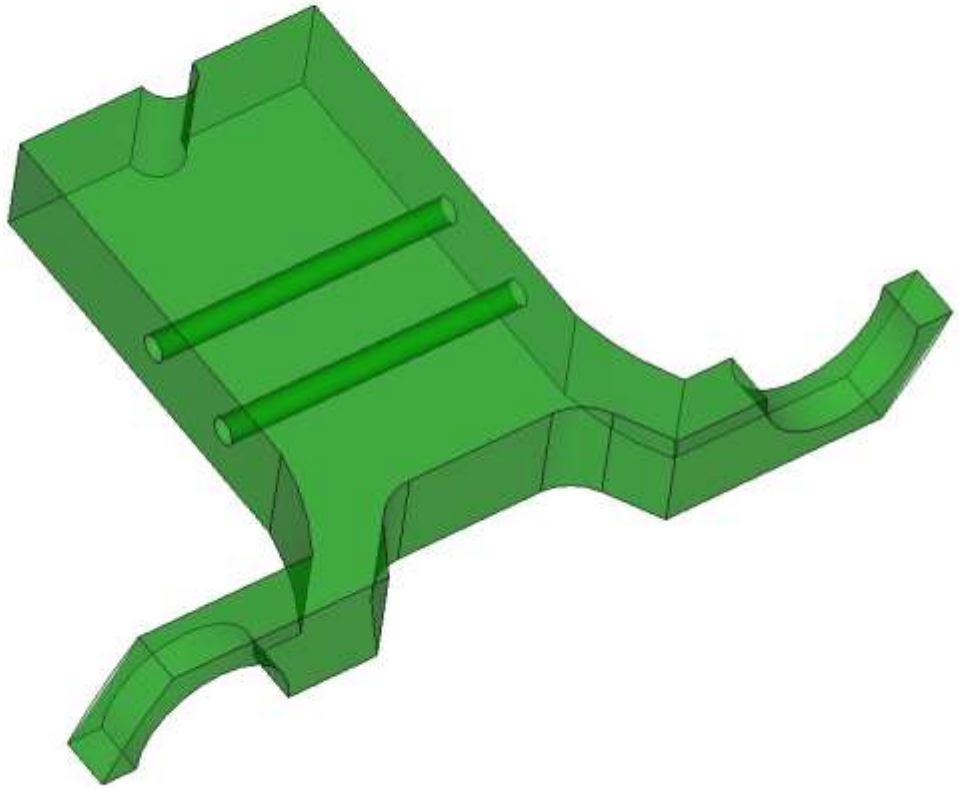


Sectional View

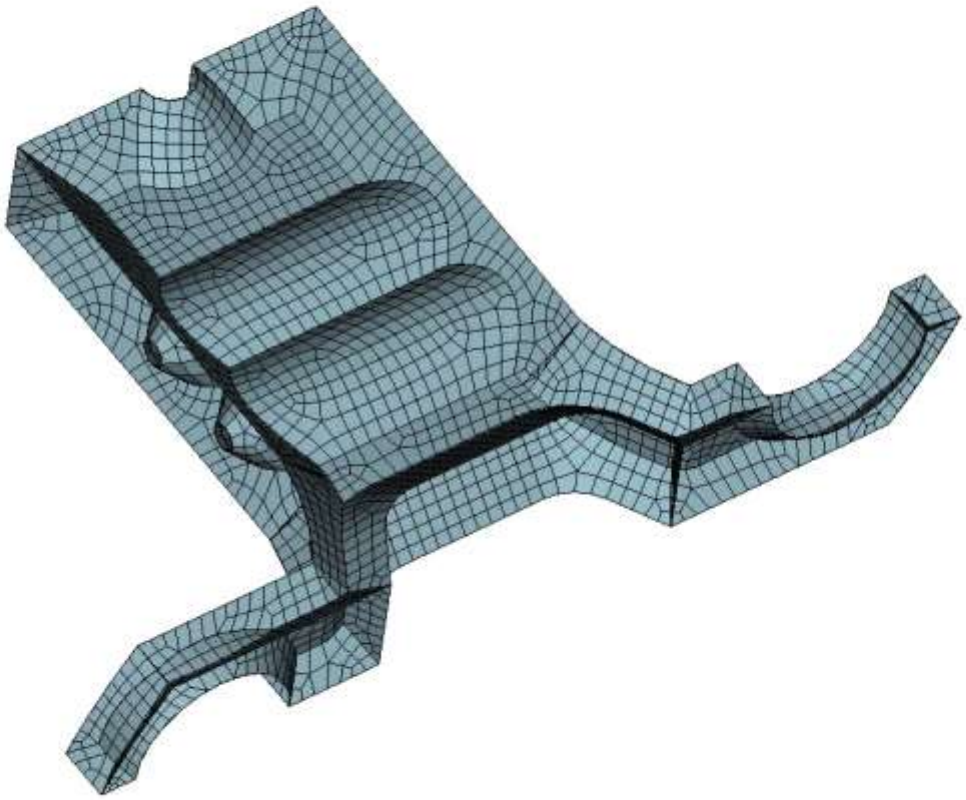


Result

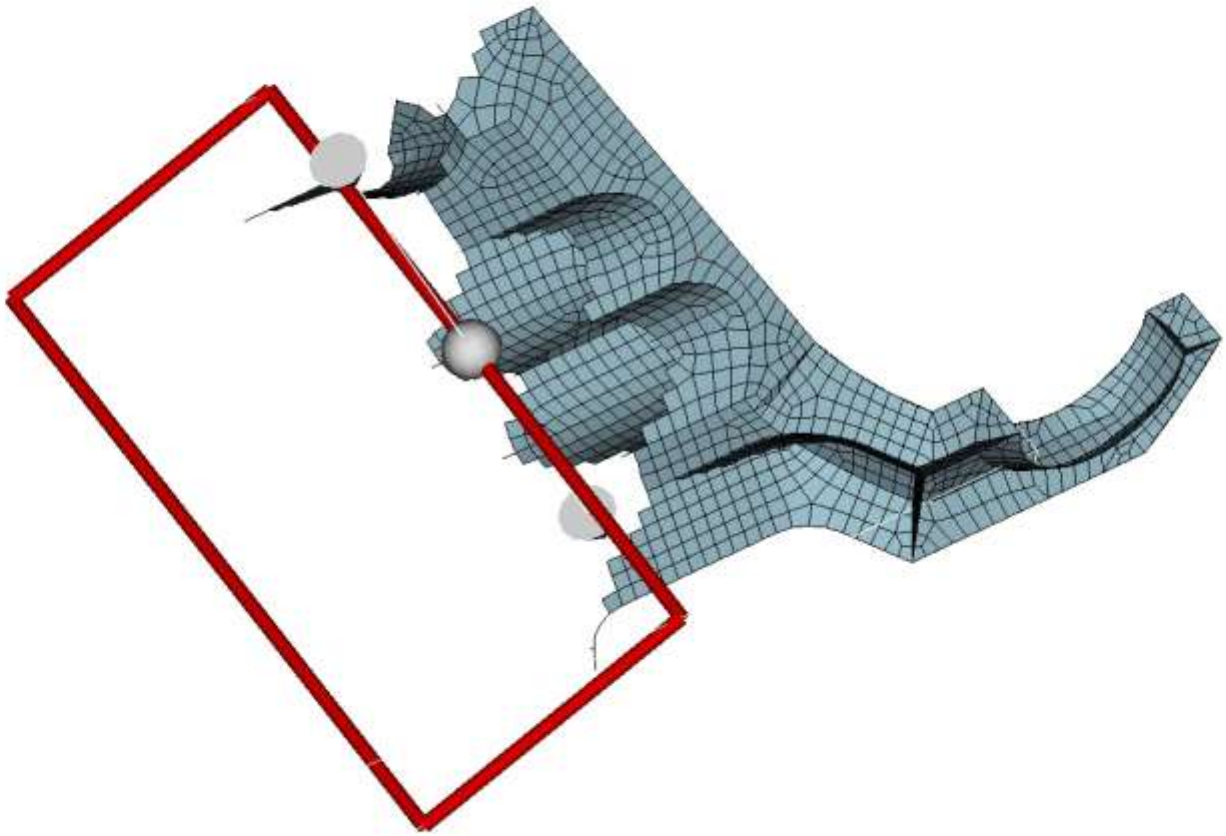
Input Solid



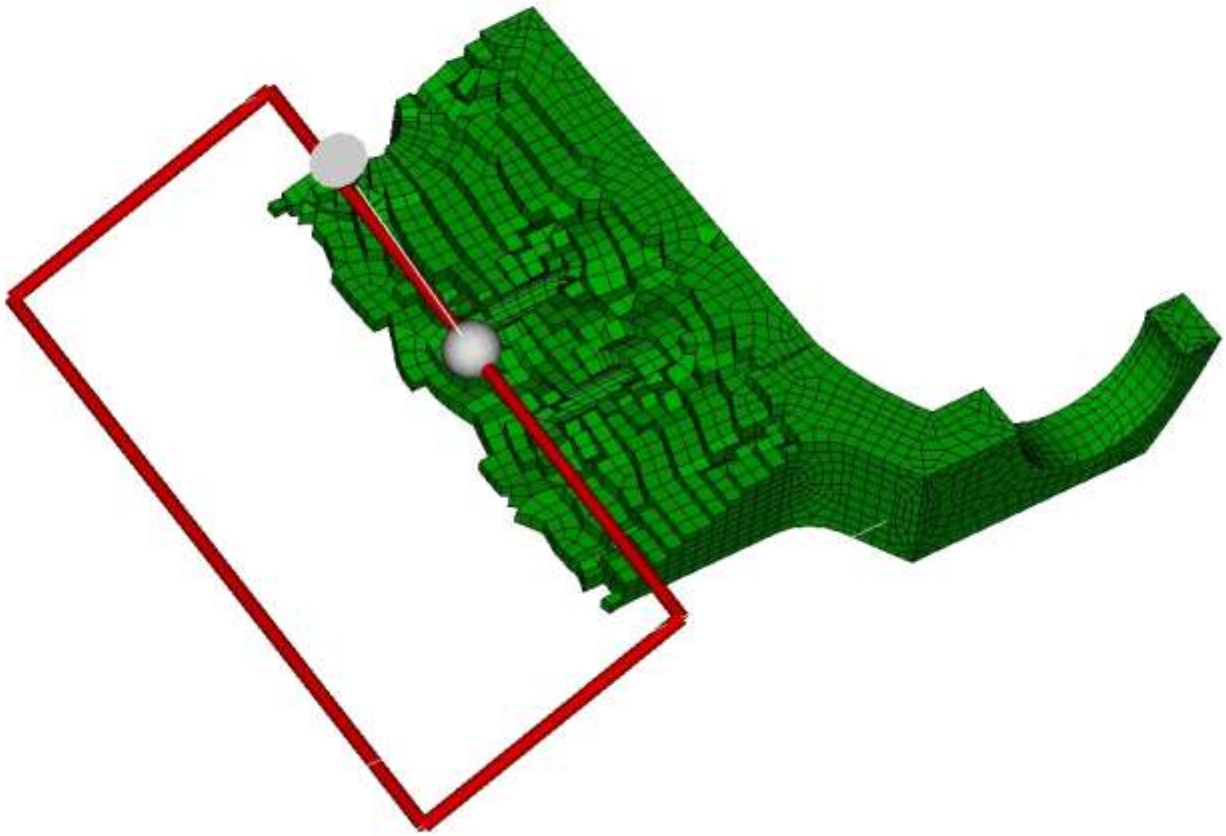
All-Quad Mesh on Medial



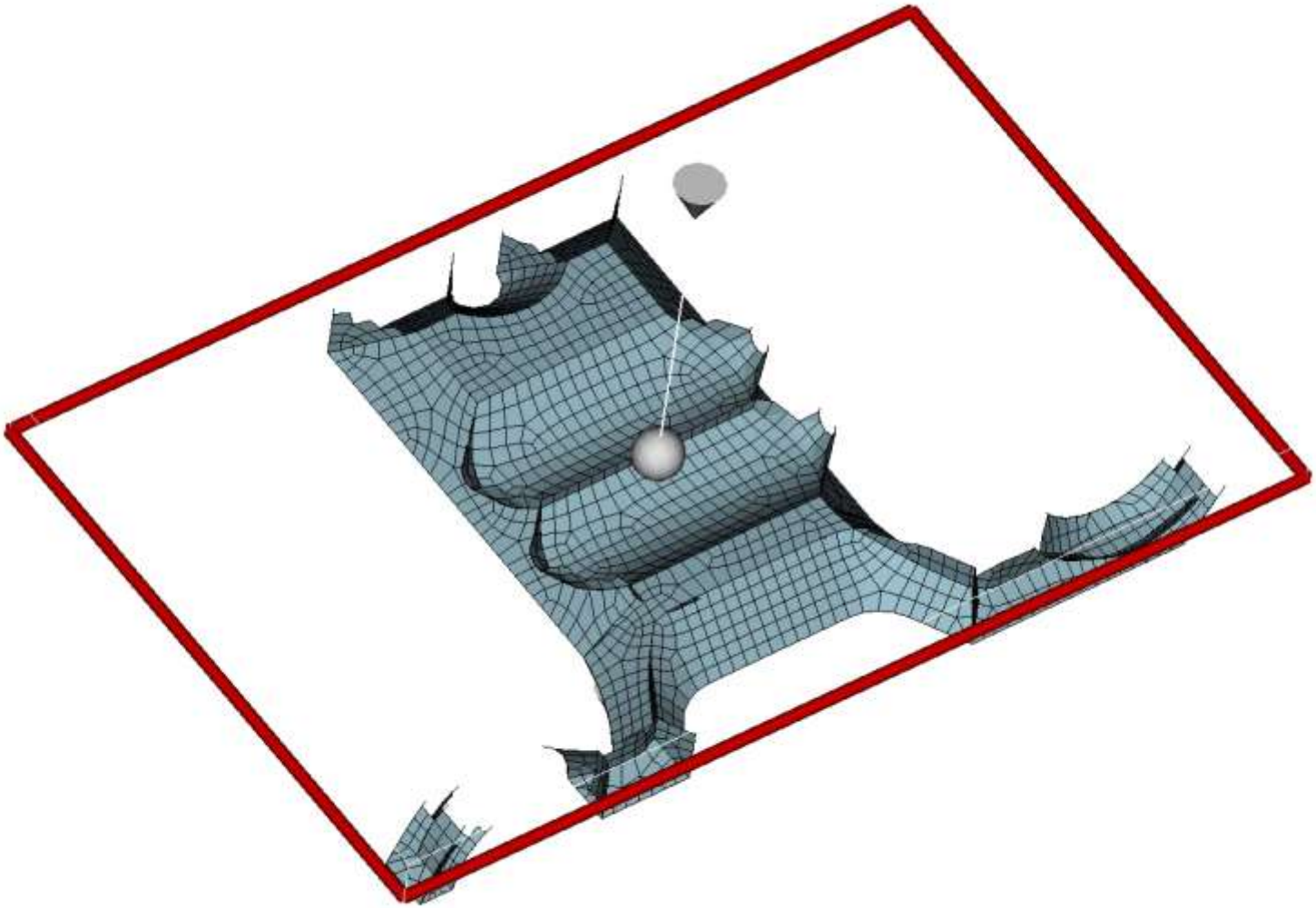
Sectional View



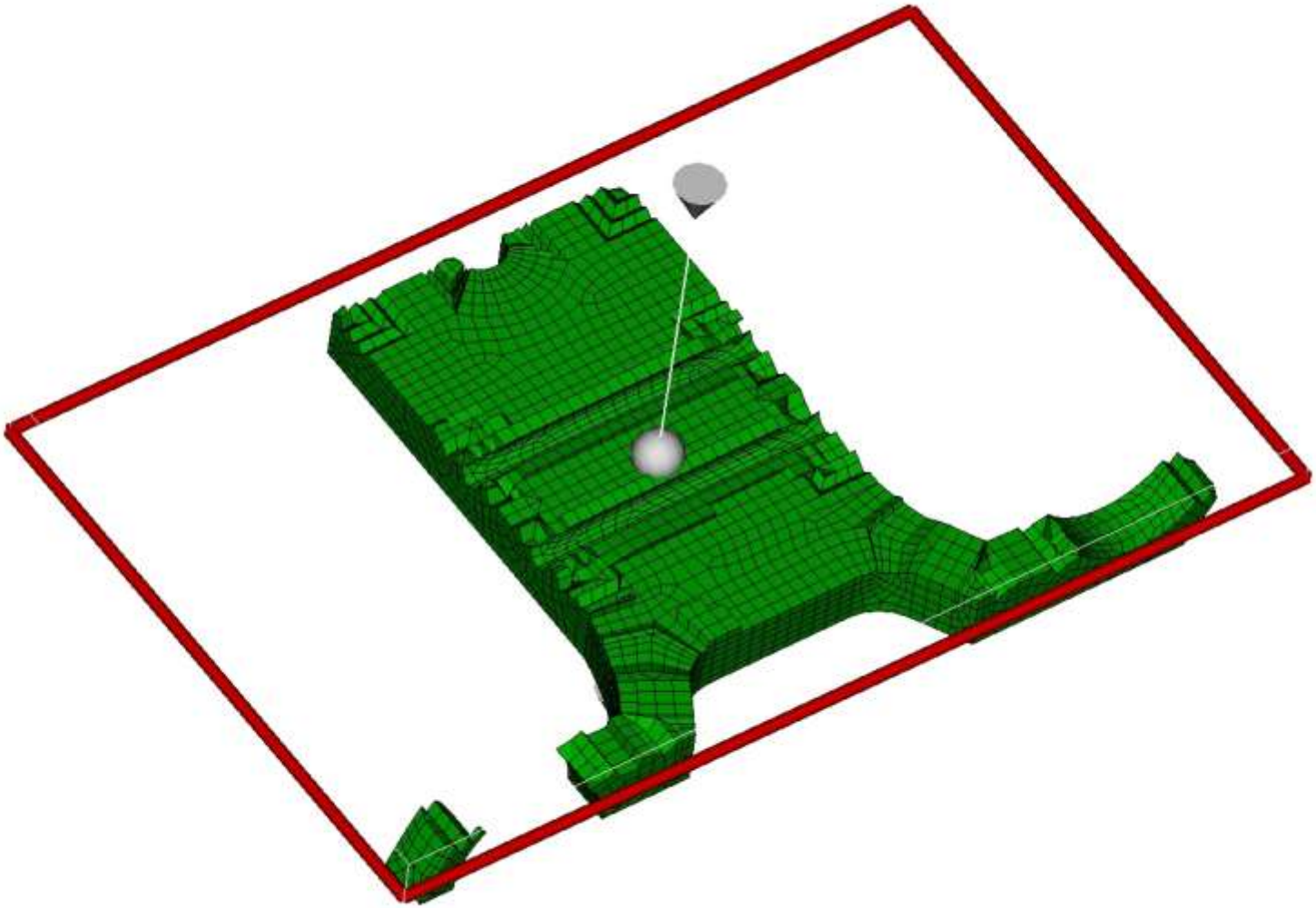
Sectional View



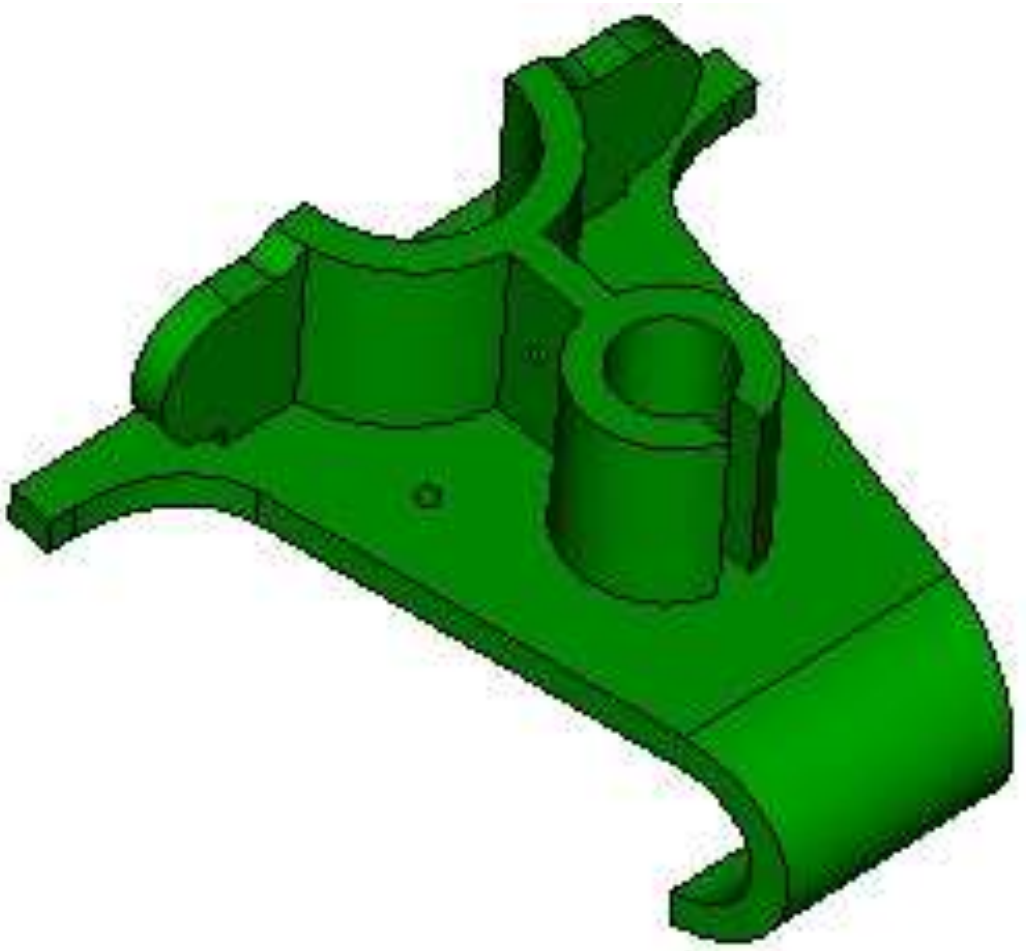
Sectional View



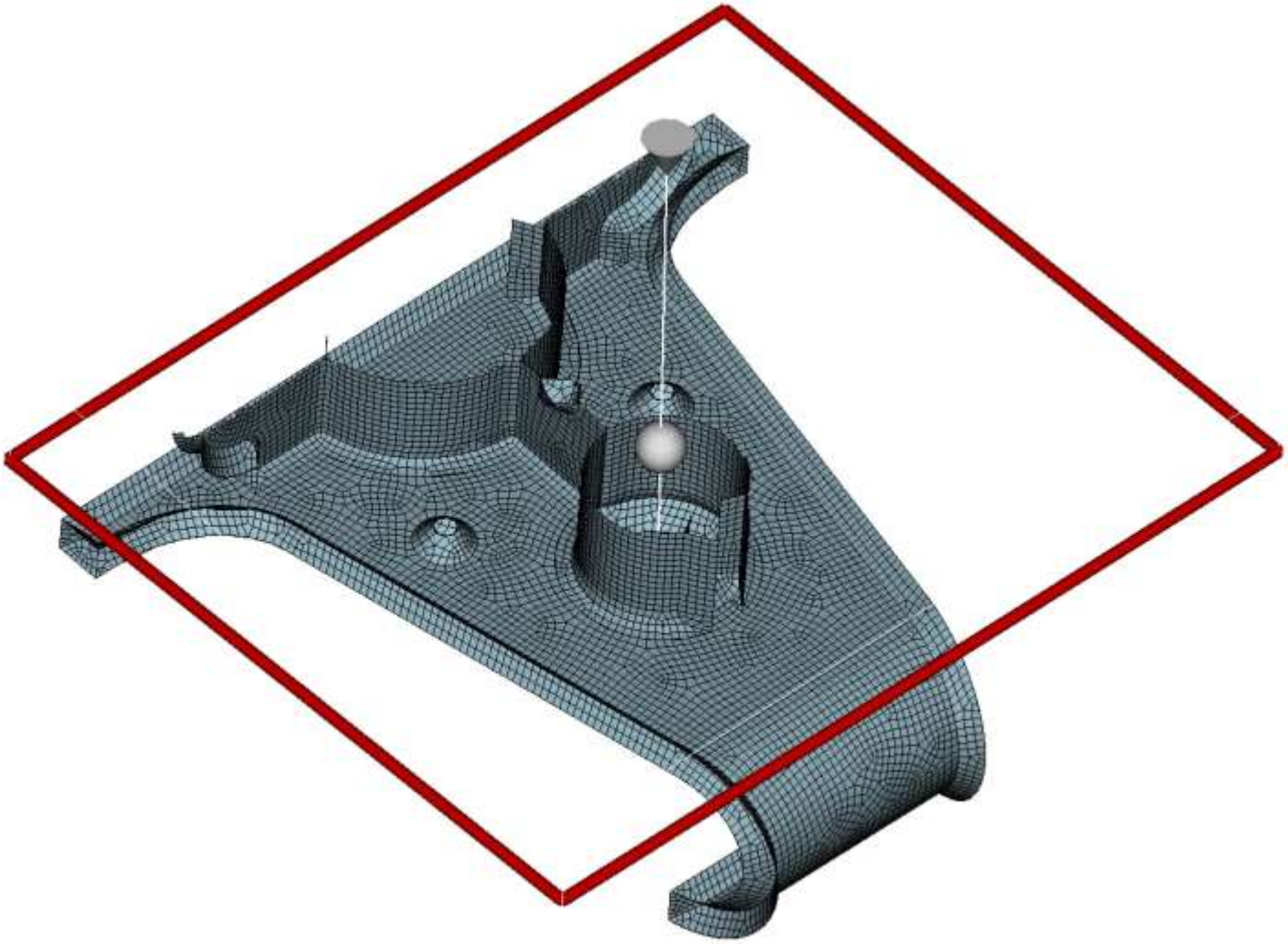
Sectional View

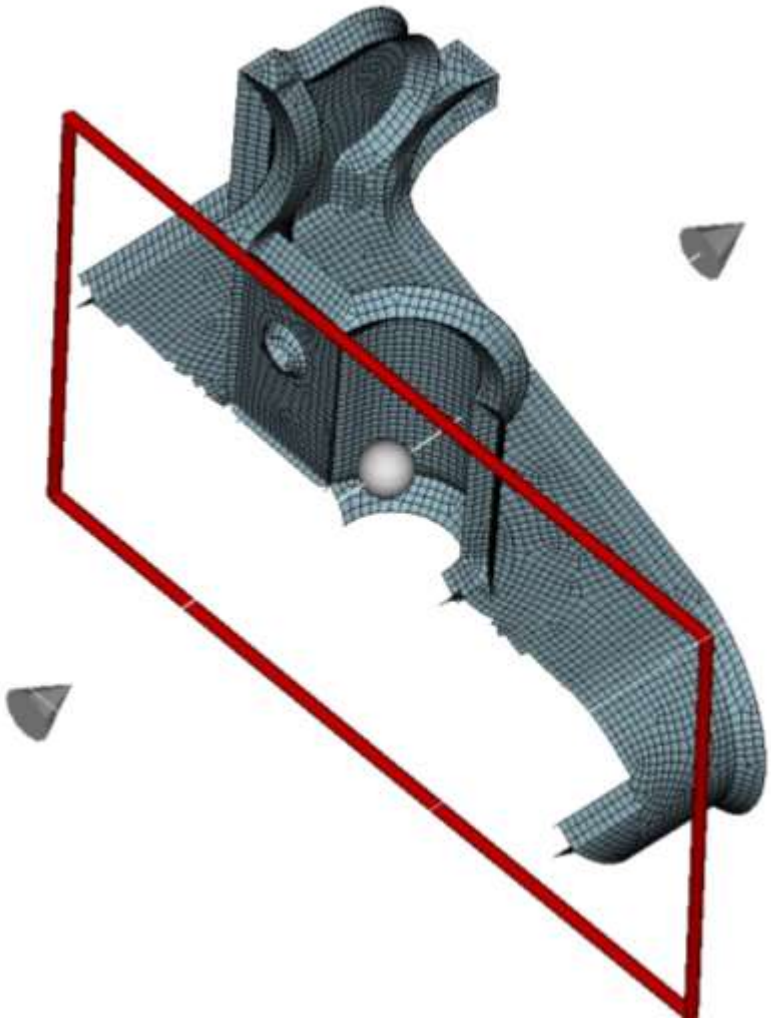


Input Solid

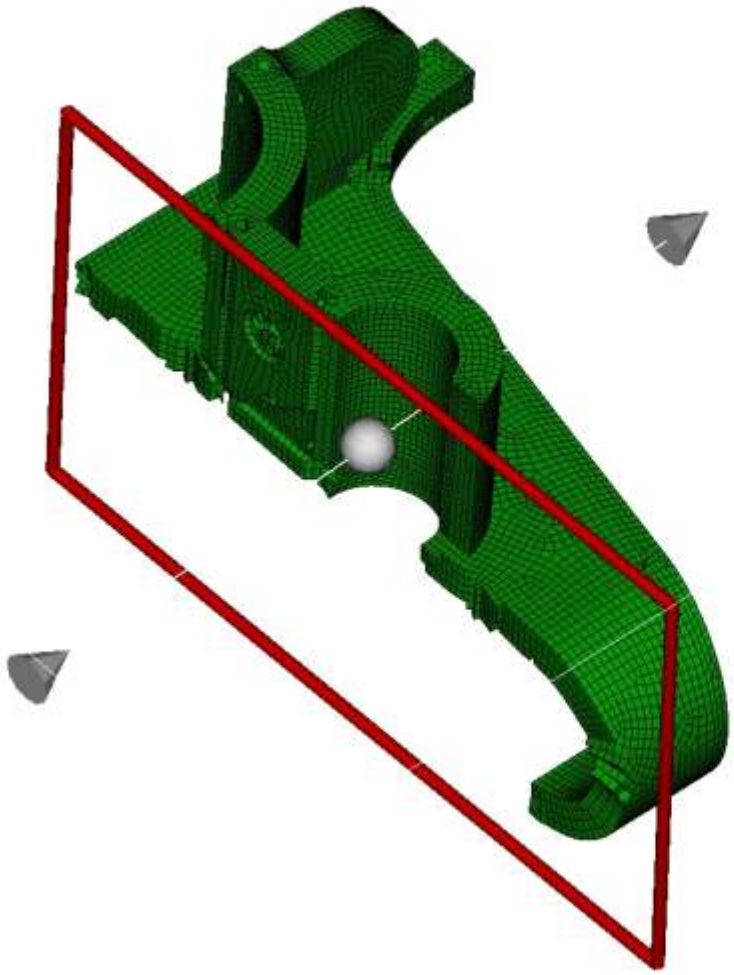


Mesh on MAT





Mesh Cross Section



All-Hex?

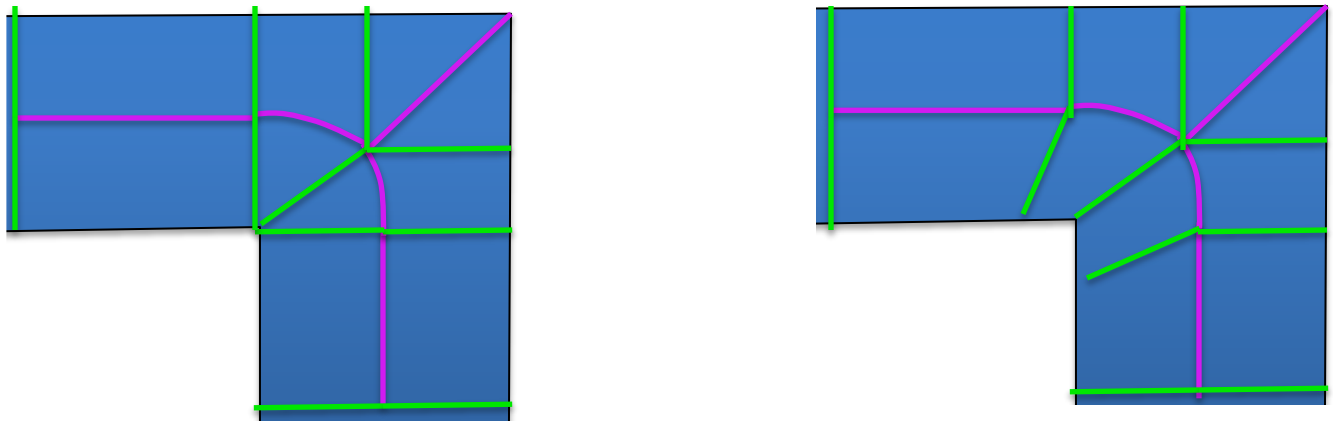
1. LayTracks3D decomposes a general 3D domain into a set of connected 3D Tracks*.
2. LayTracks3D guarantees even number of quads on the boundary of each 3D Track and guarantees all-hex in each 3D Track.

*N-to-1 and 1-to-N regions need to transformed into 1-to-1 map

2-Way Map at Regions of Interest

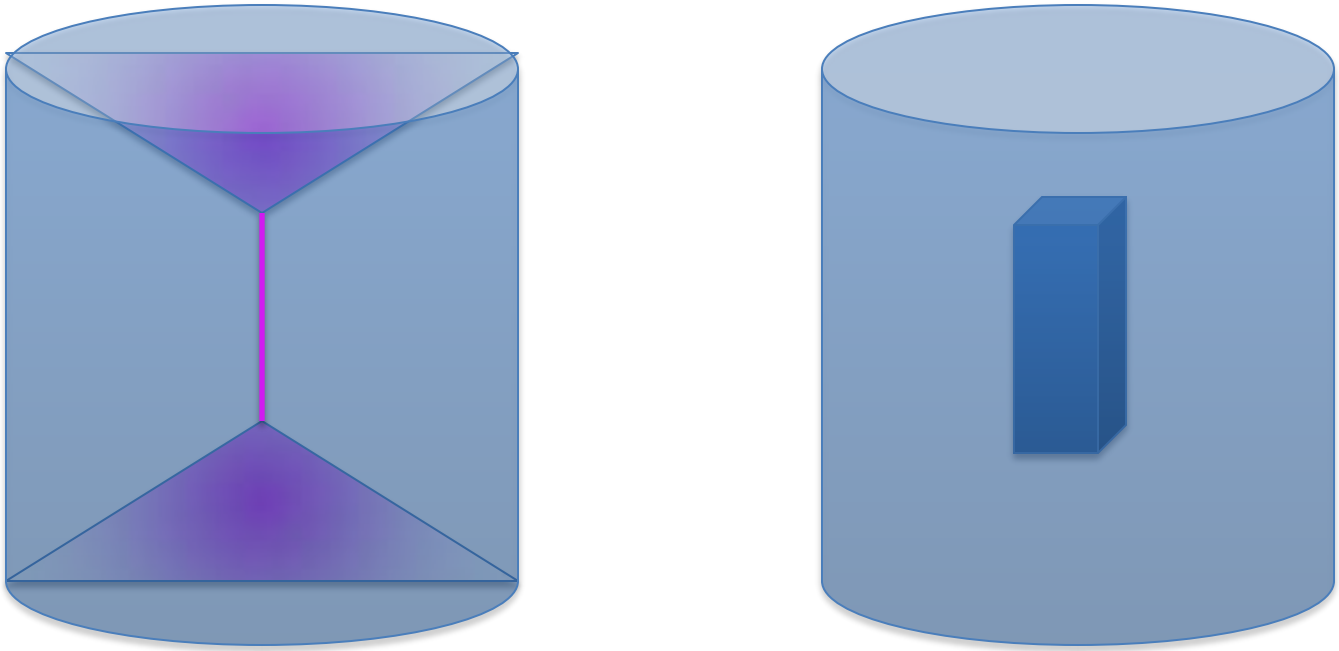
- 1-to-1
  - Convex Edge
  - Convex Vertex
  - Convex Edge with Large Angle
- N-to-1
  - Concave Vertex
  - Concave Edge
- 1-to-N
  - Finite Contact at Cylinder
  - Finite Contact at Sphere

Solution for Concave Edge/Vertex: Transform 1-to-N to 1-to-1

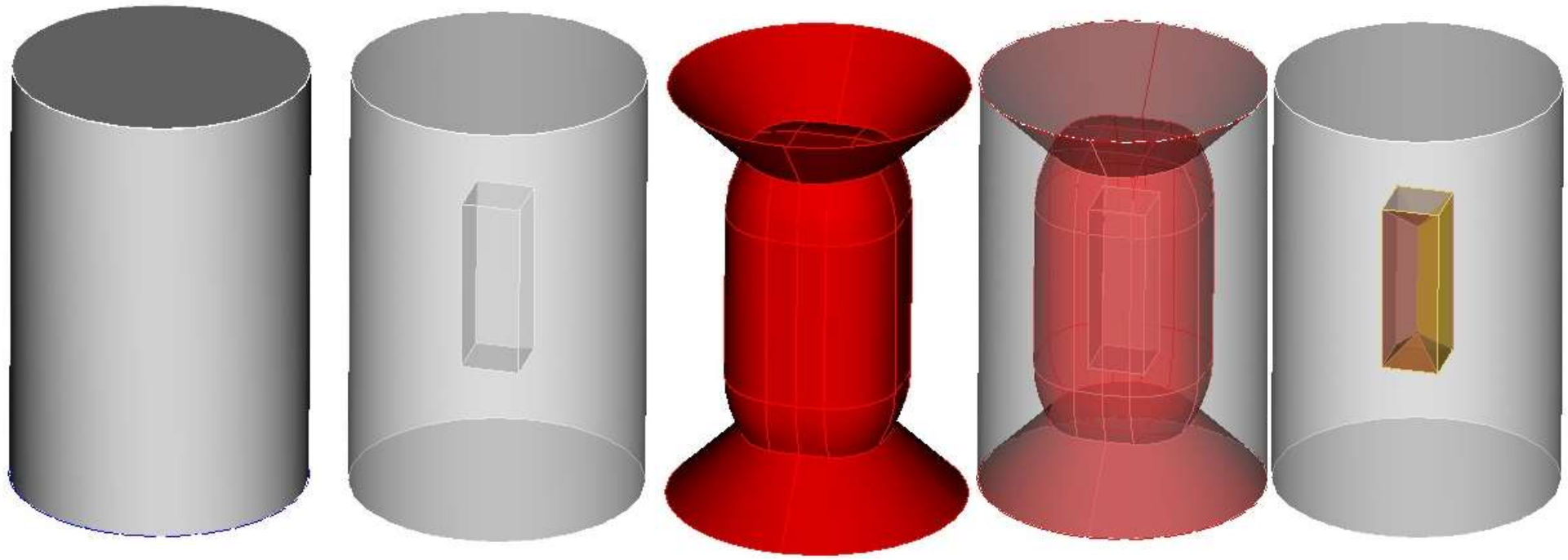


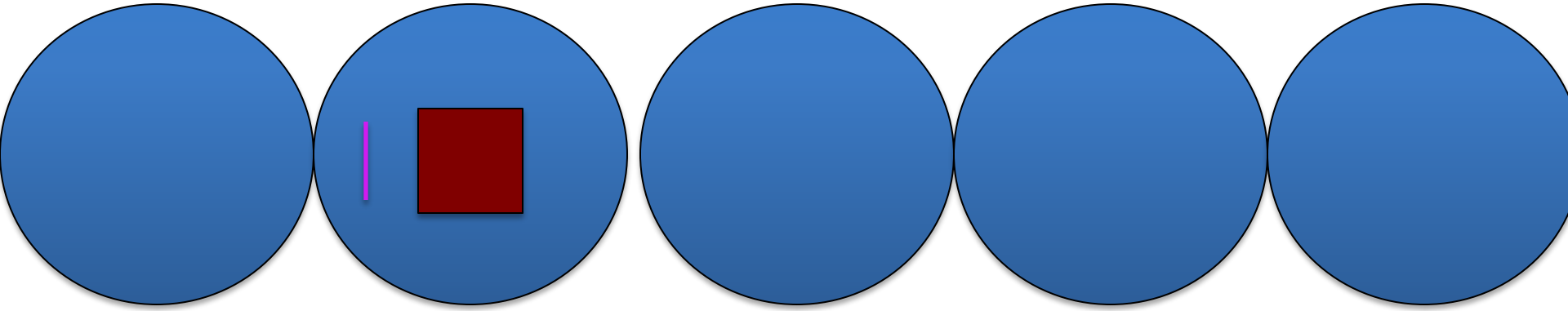
Spread duplicate nodes at concave vertex/edge
by perturbing the 2-way map

Solution for Finite Contacts - Transform N-to-1 to 1-to-1

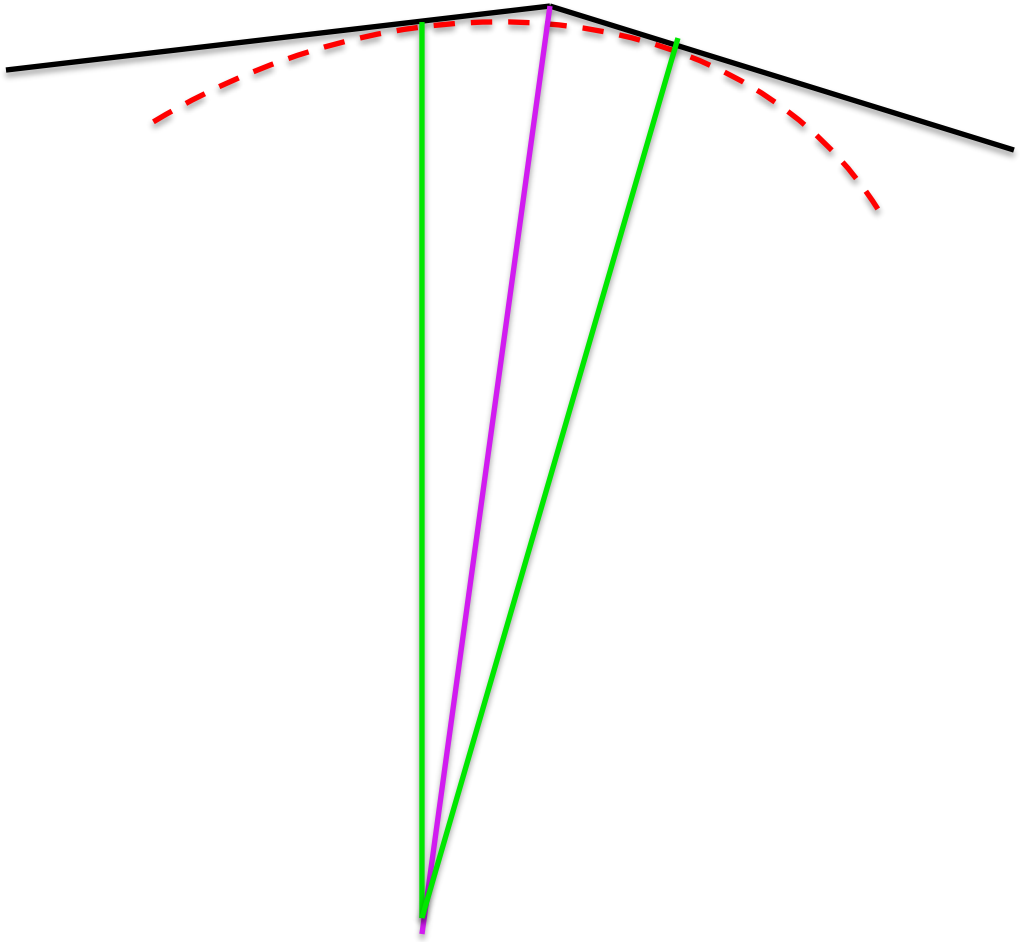


(N-to-1) → (1-to-N) → (1-to-1)





Solution at Large Angle Convex Edge: Collapse Medial Face



Optimizing Interval and Merging Tracks at Medial

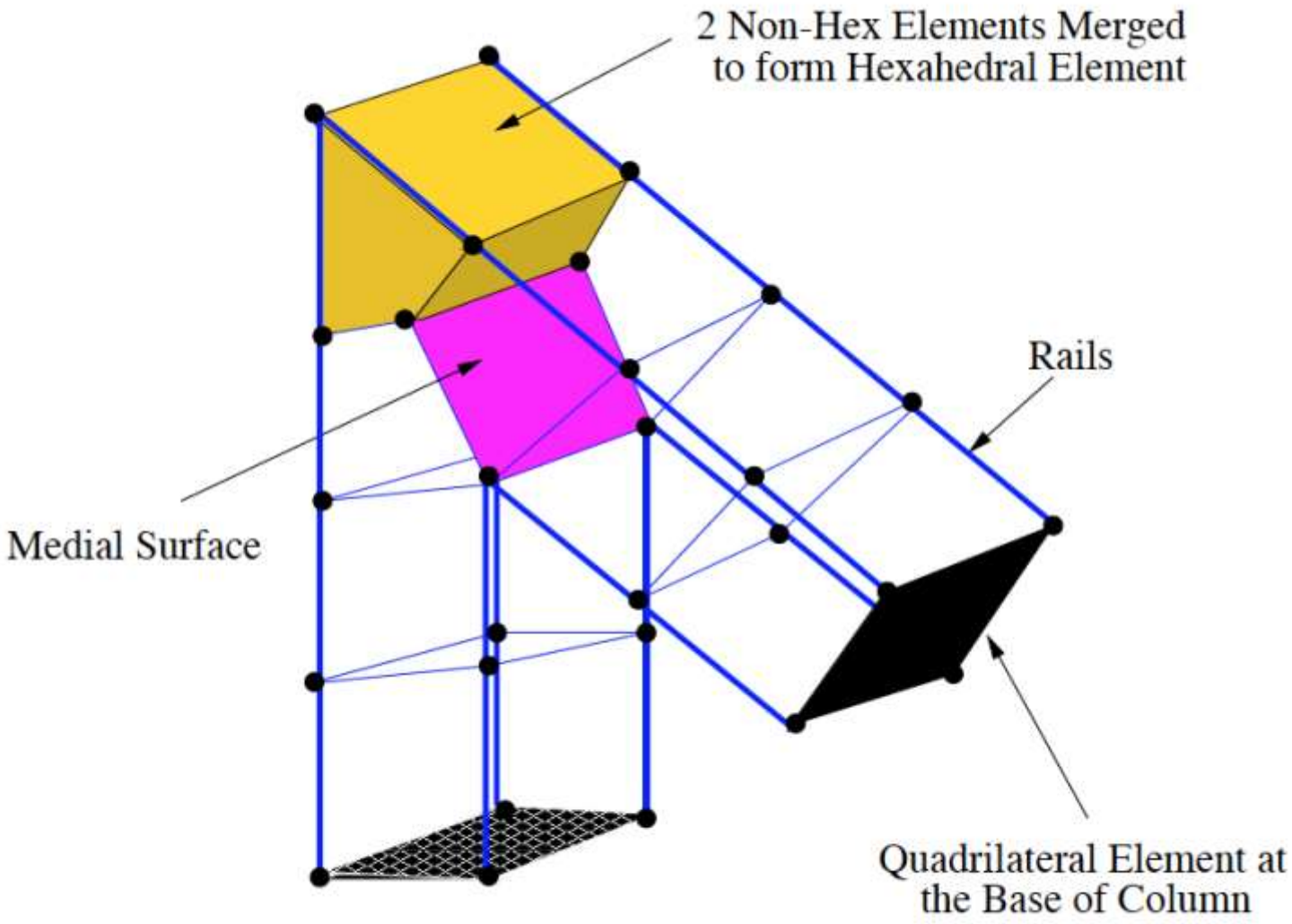
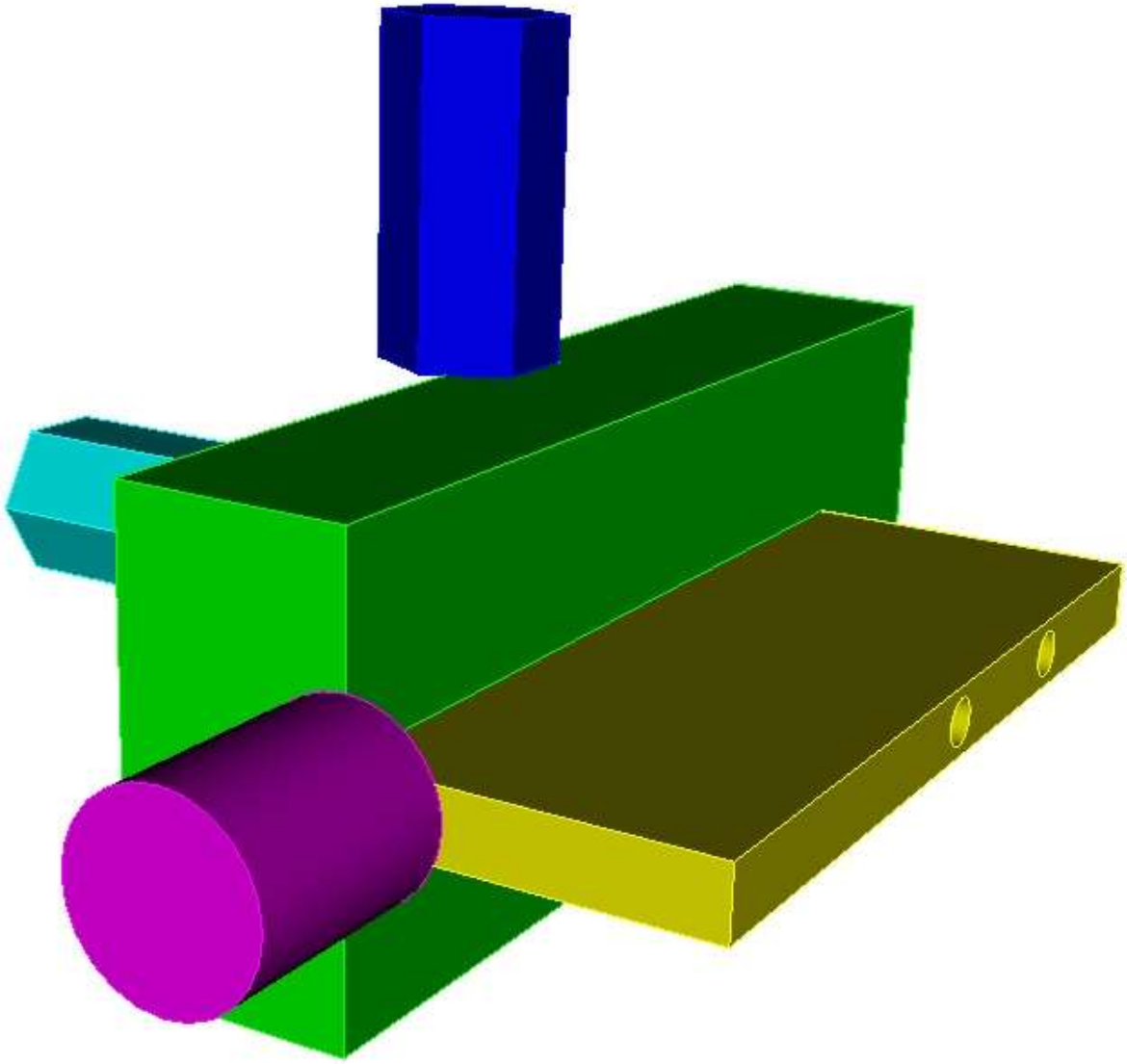


Figure 5.27: Building Hex elements inside column and merging at Medial Surface

LayTracks3D for Assembly

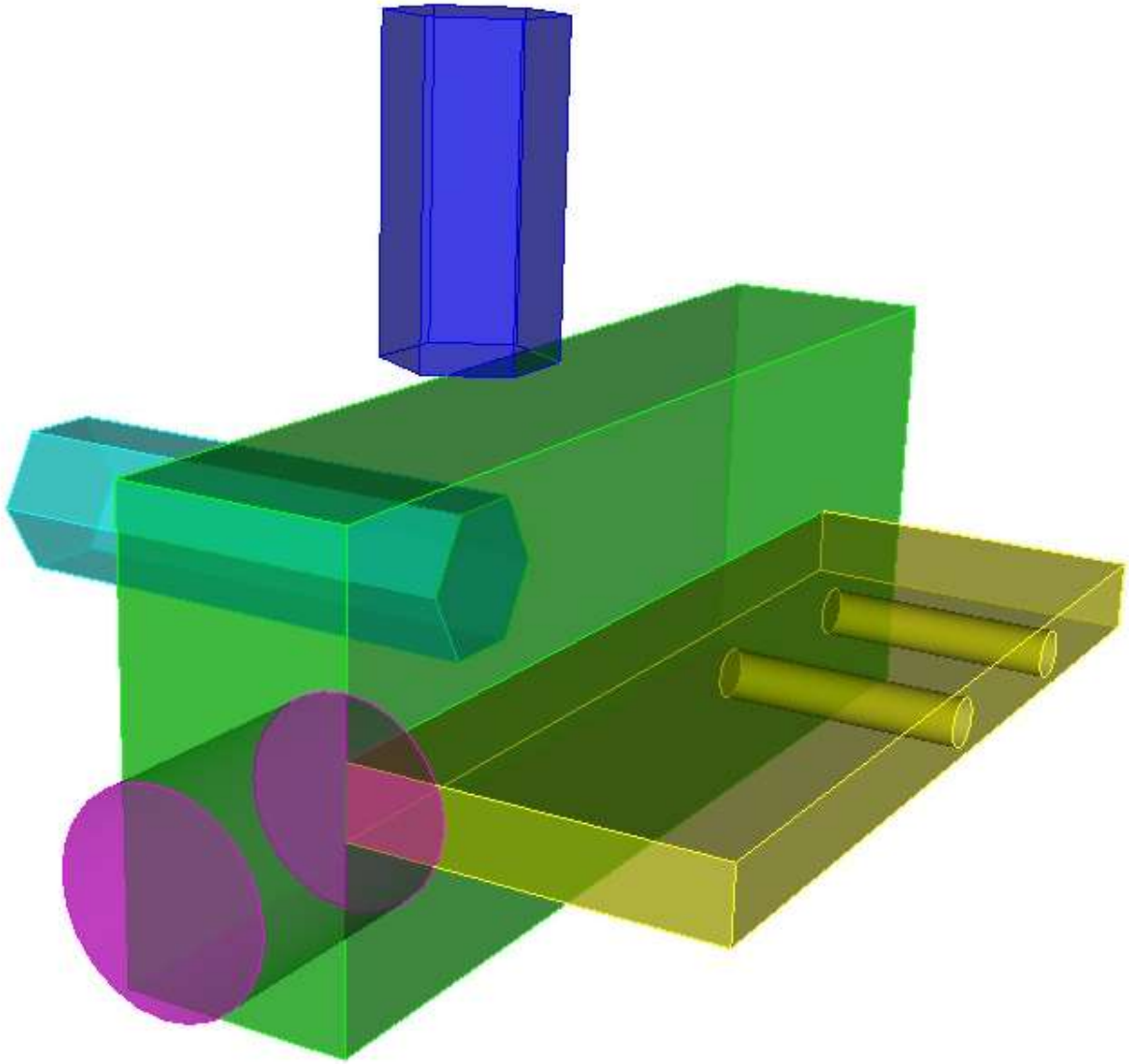
Assembly Model



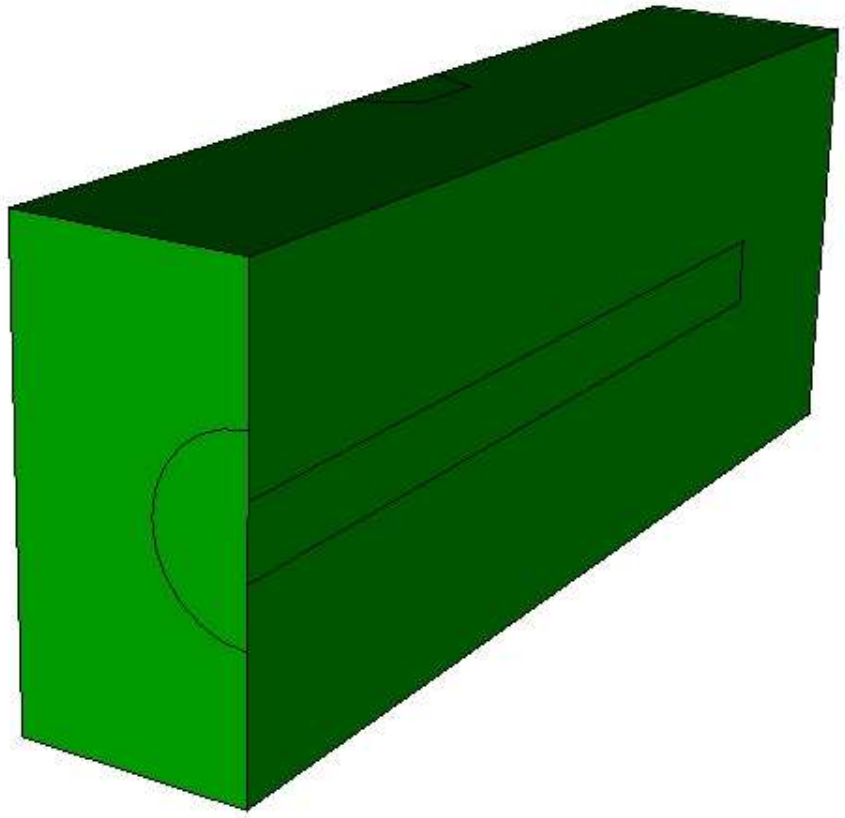
LayTracks3D for Assembly Model

- LayTracks3D resolves all the boundary imprints and medial junctions.
- Tracks cut through the interface and gives automatic conformal orthogonal mesh.

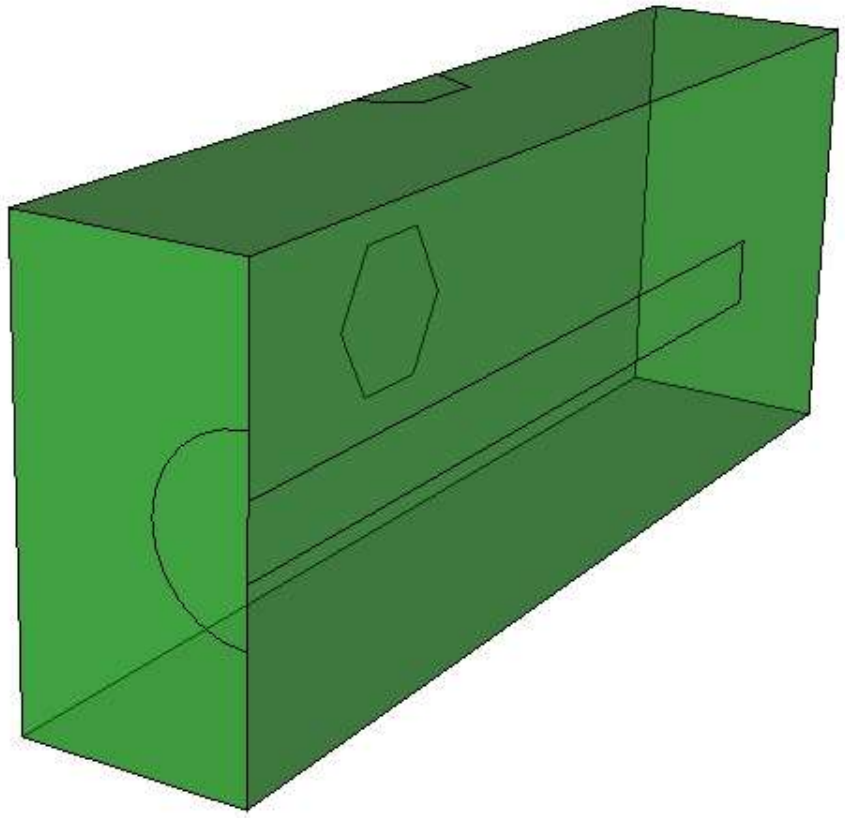
Assembly Model



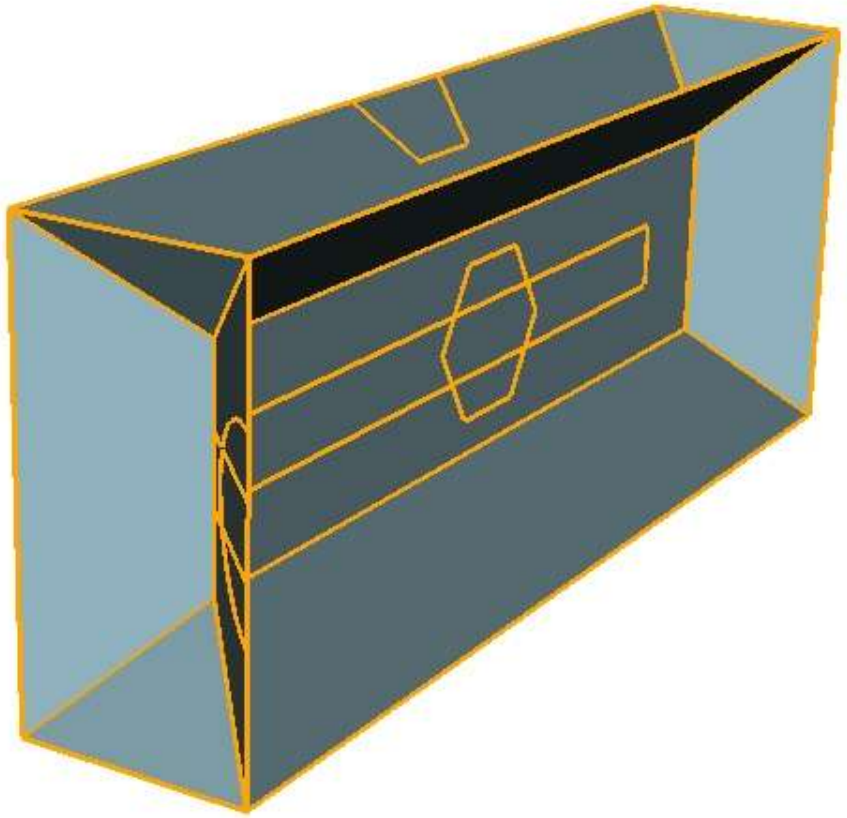
Imprints on Top, Bottom, and Sides



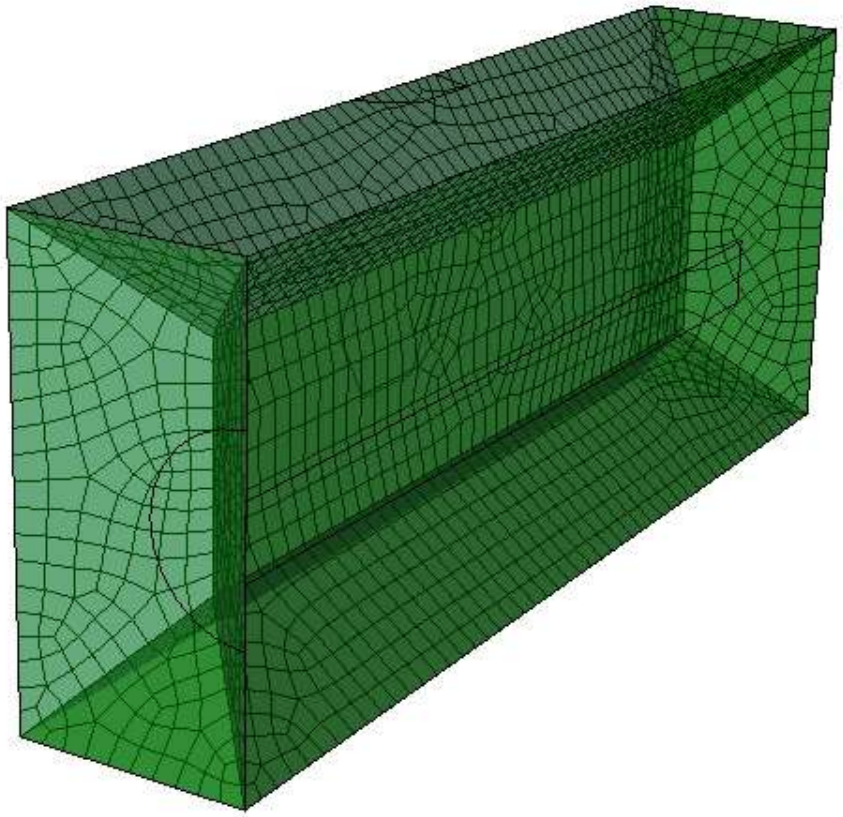
Imprints on Top, Bottom, and Sides



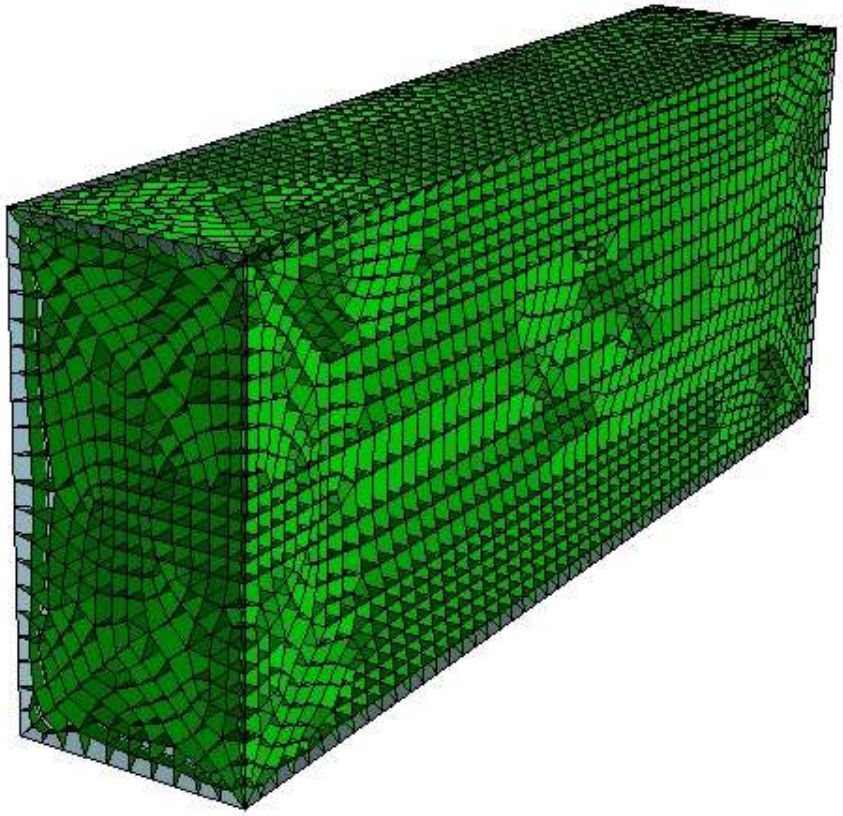
All Imprints Resolved on Medial



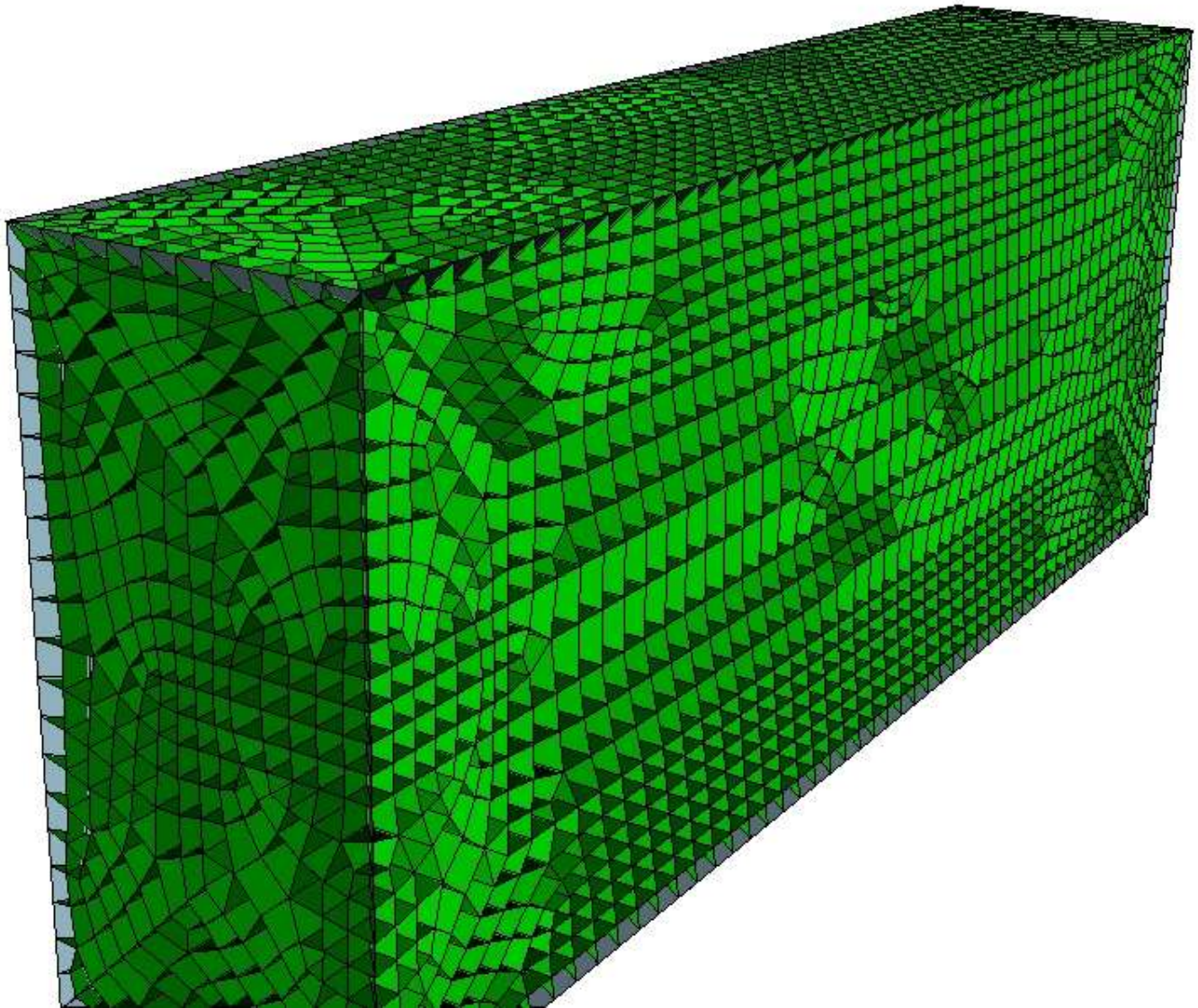
Quad Mesh on Imprinted Medial



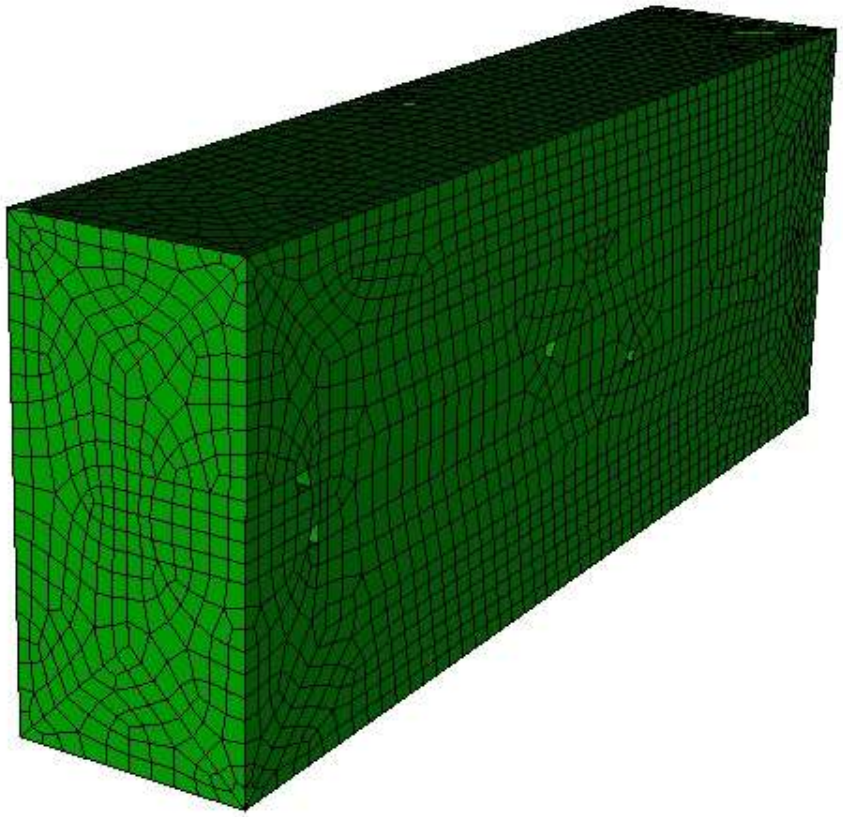
Tracks in 3D



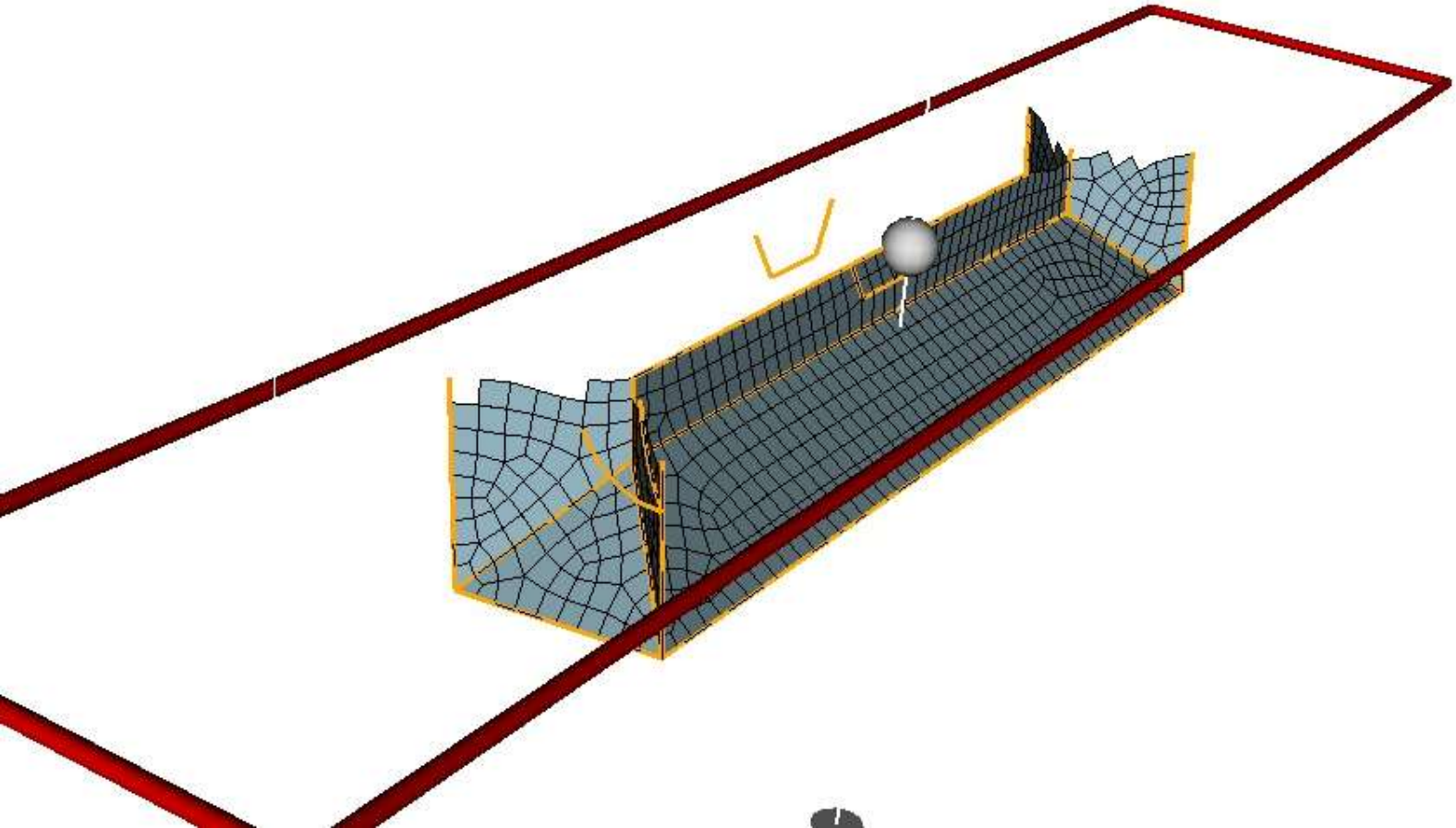
Tracks in 3D



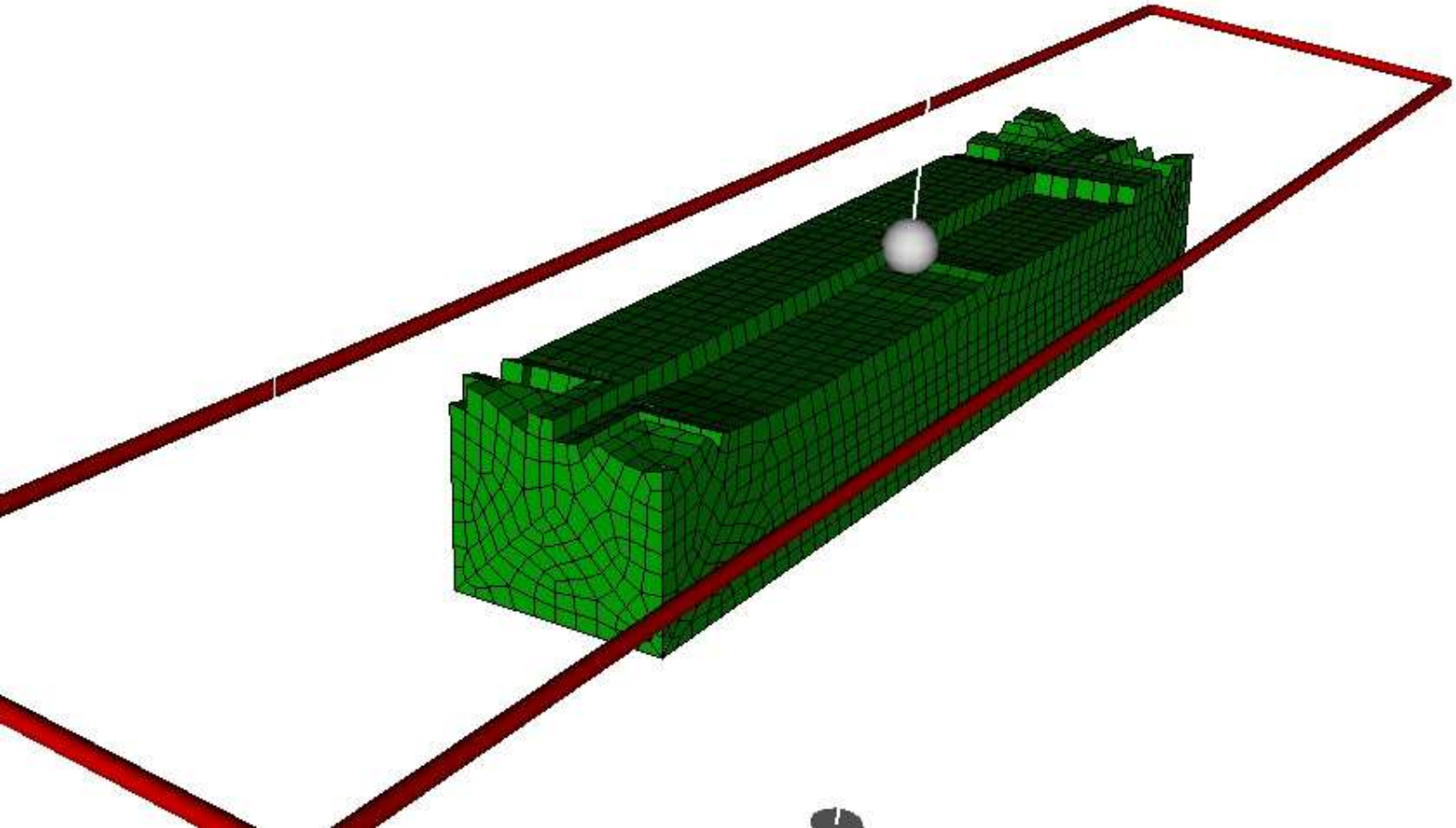
Hex Mesh



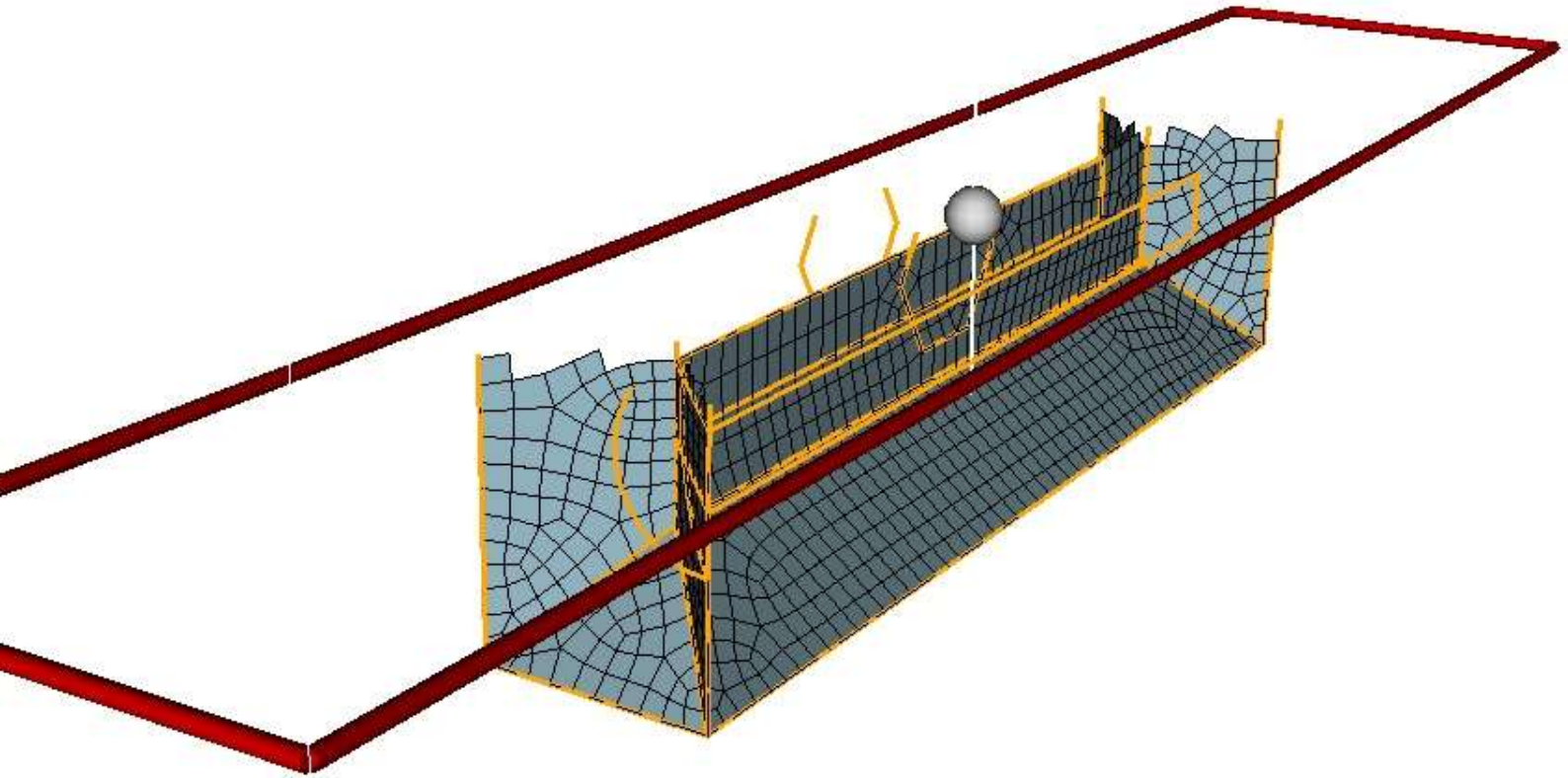
Sectional View



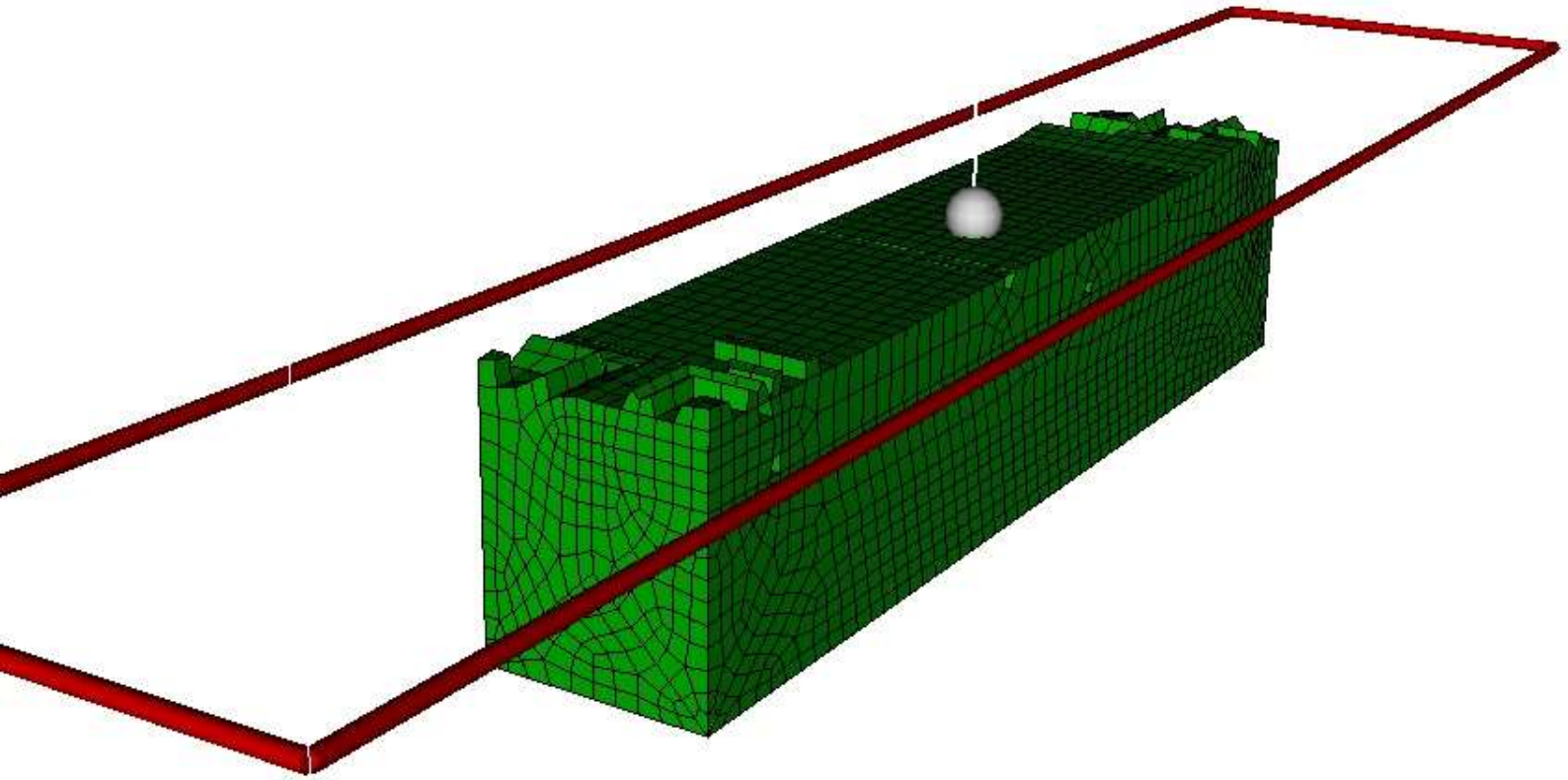
Sectional View



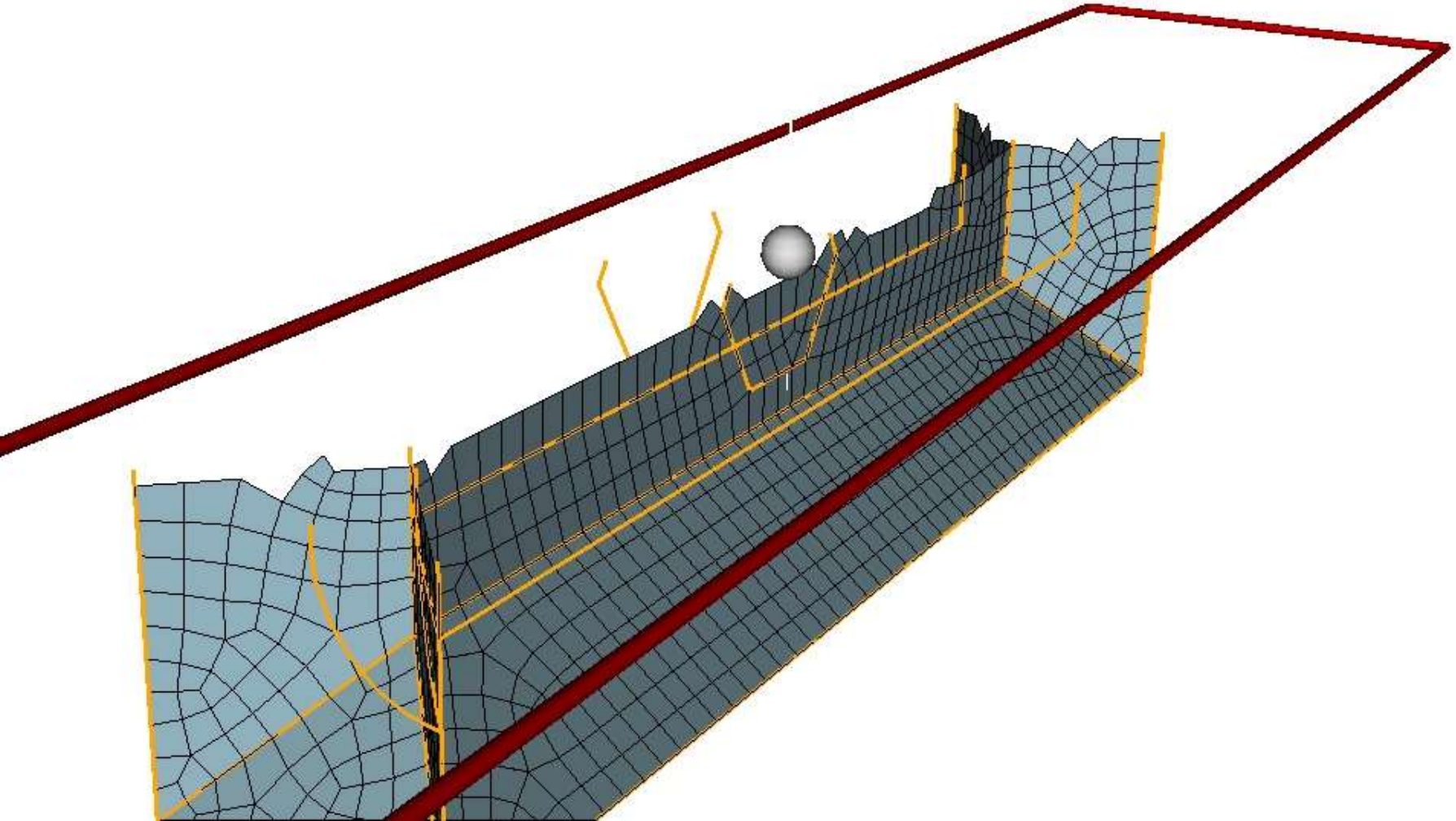
Sectional View



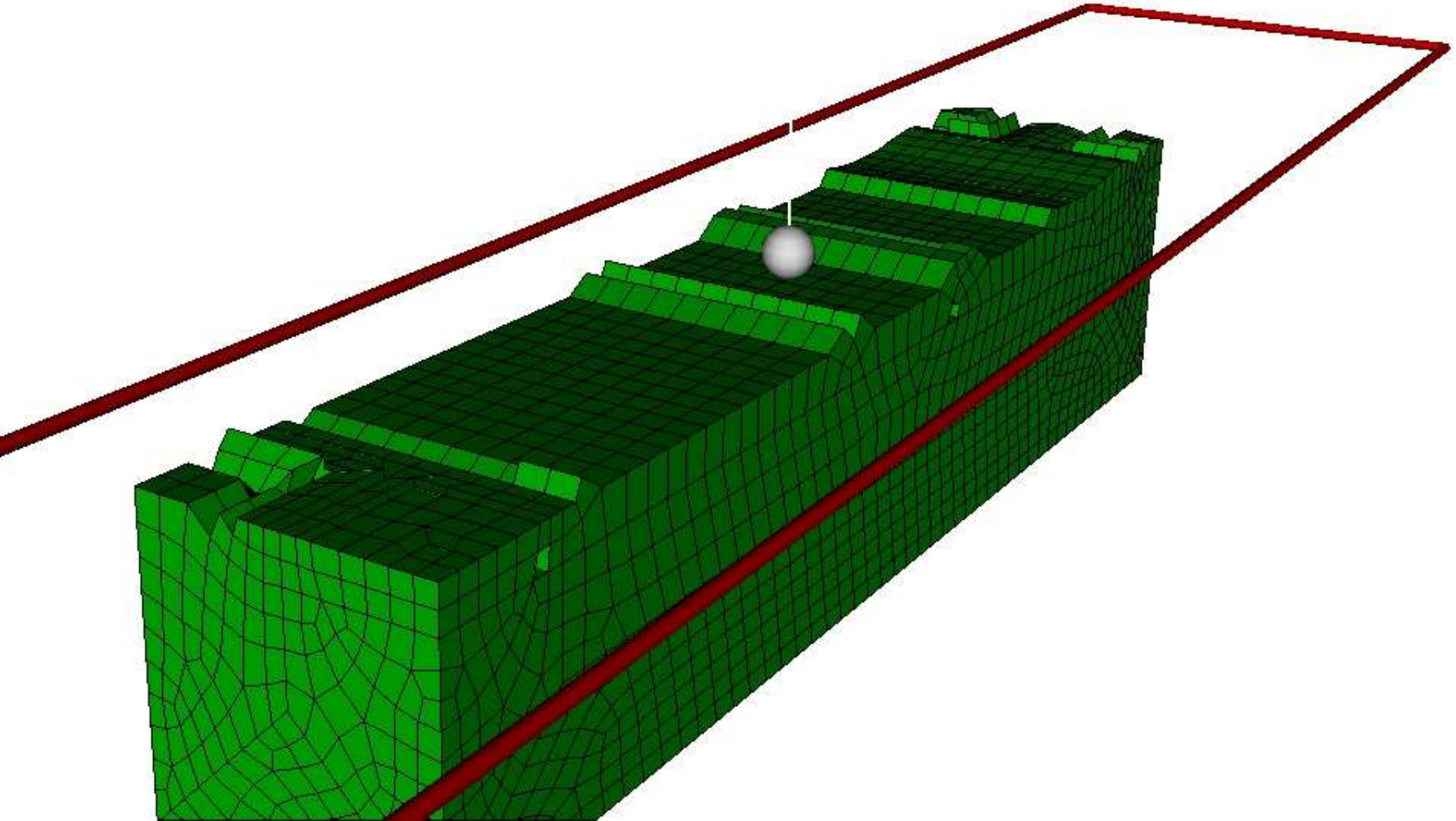
Sectional View



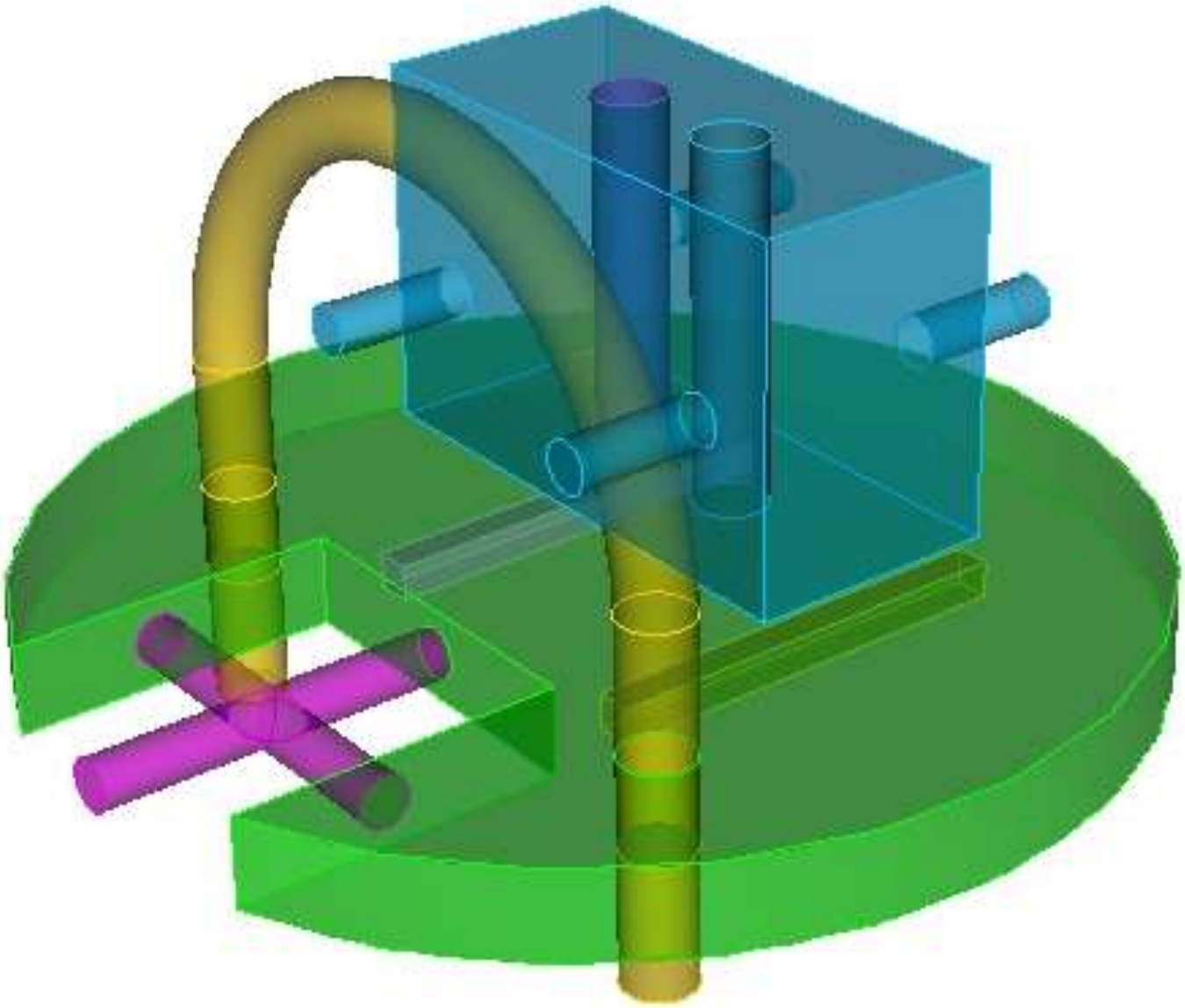
Sectional View



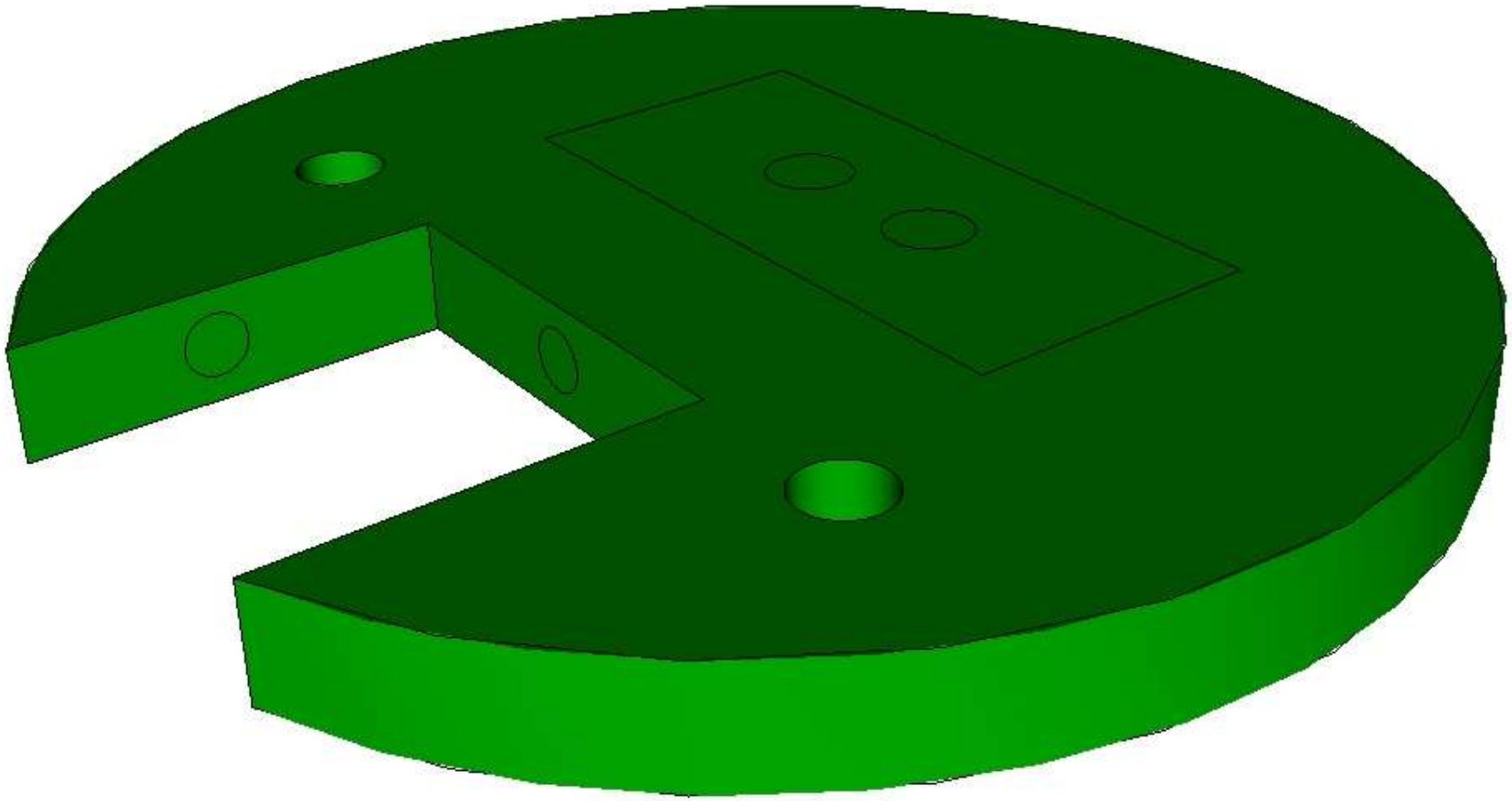
Sectional View



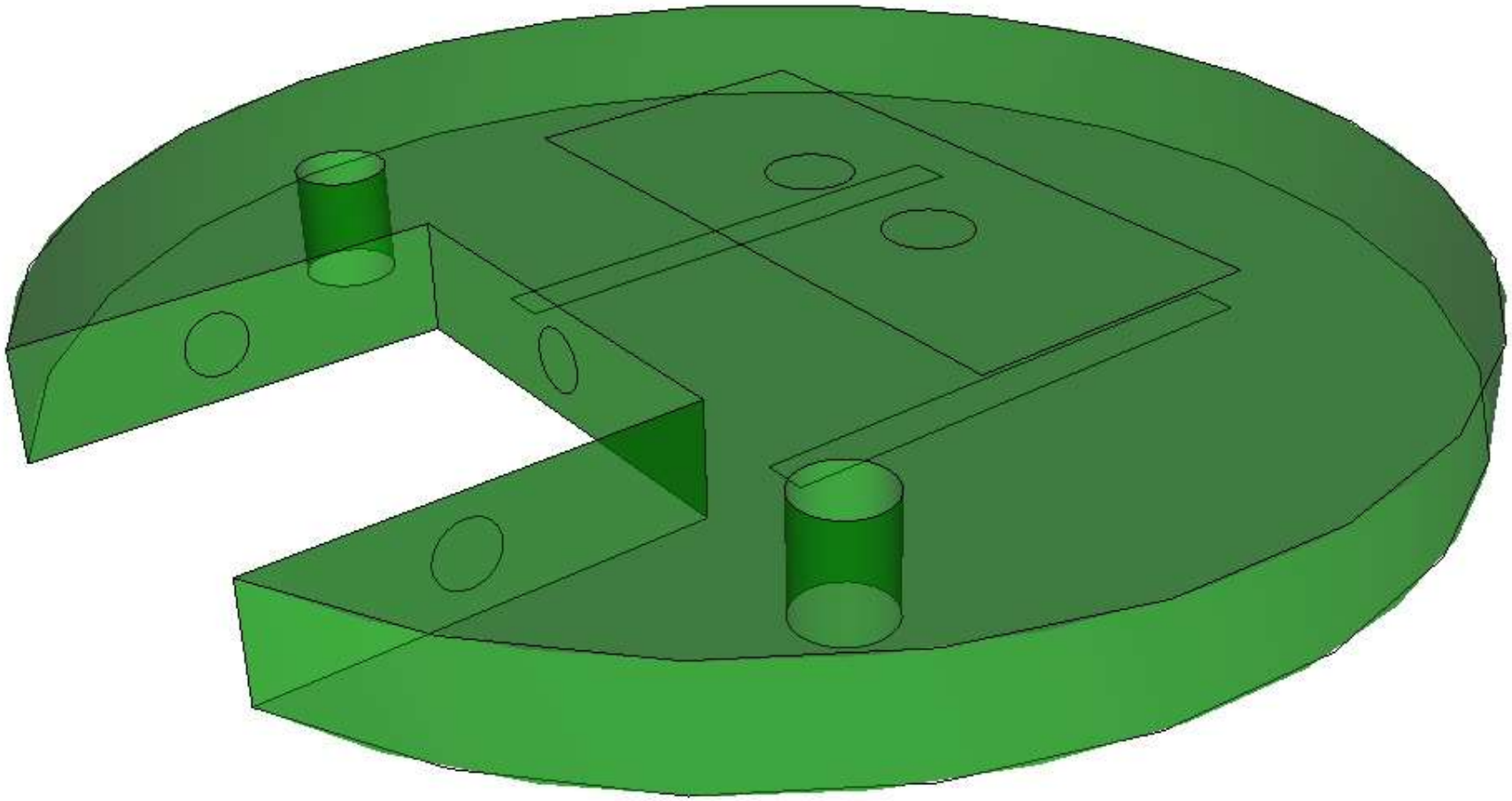
Assembly Model



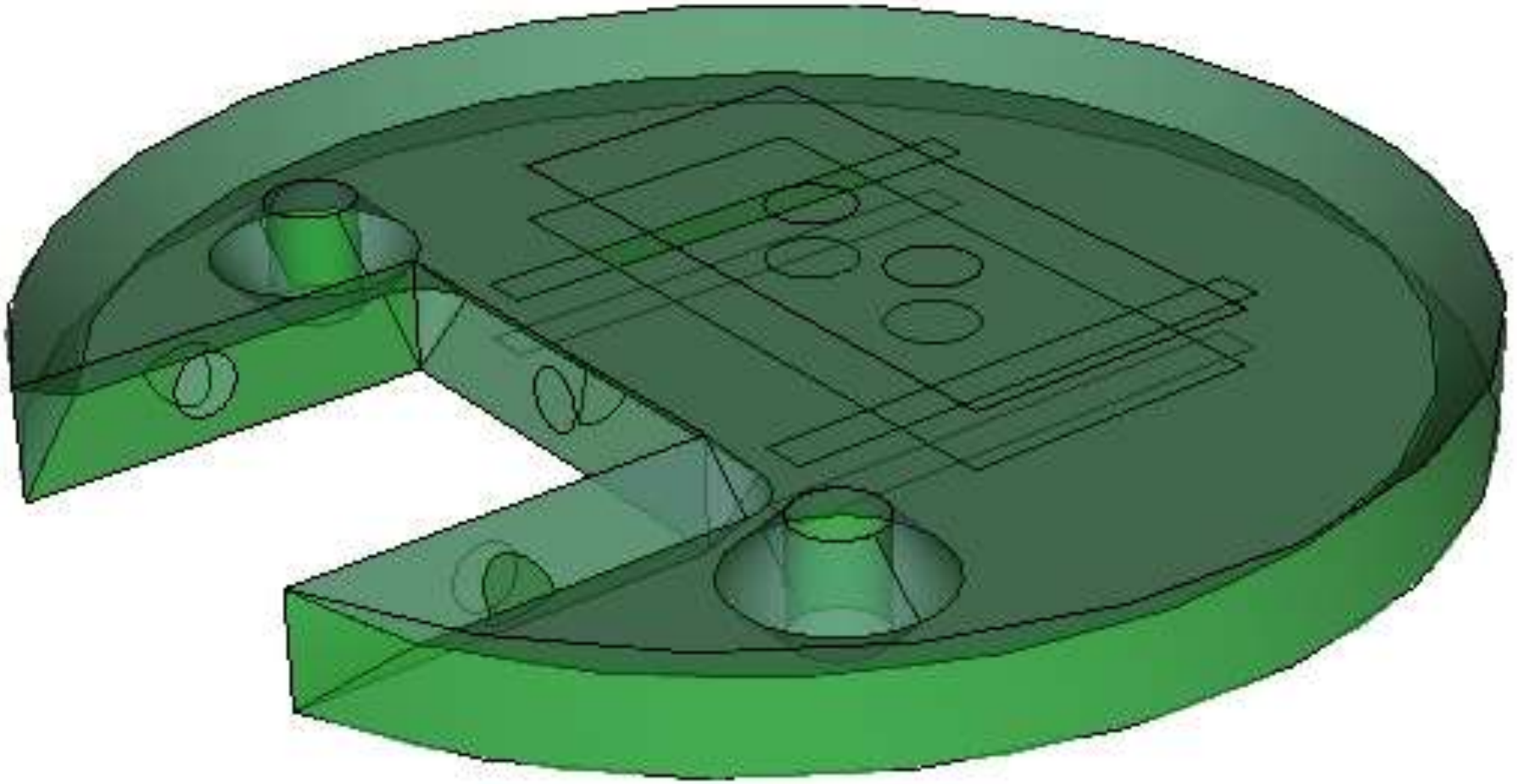
Imprints on Top, Bottom, and Sides



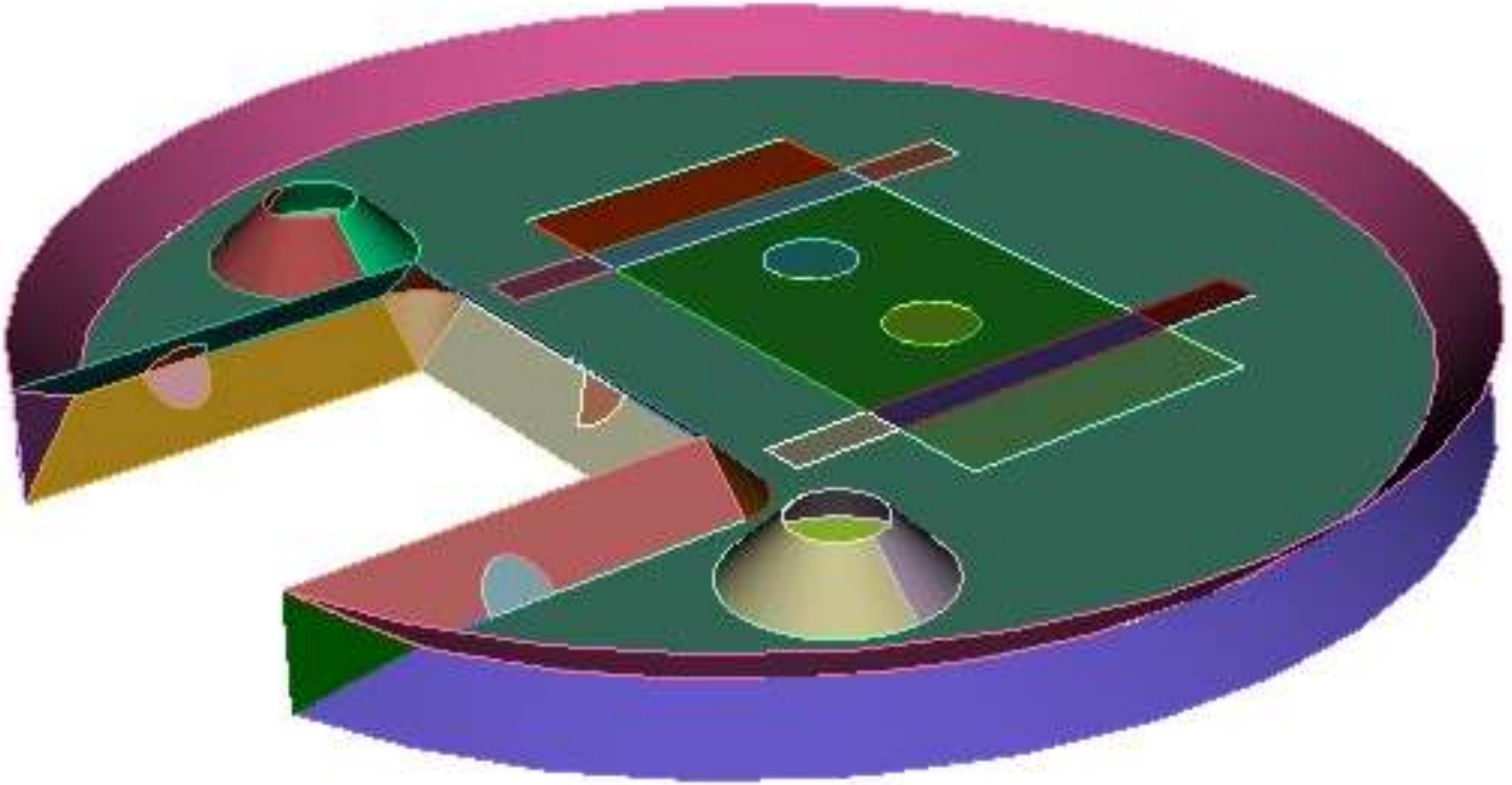
Imprints on Top, Bottom, and Sides



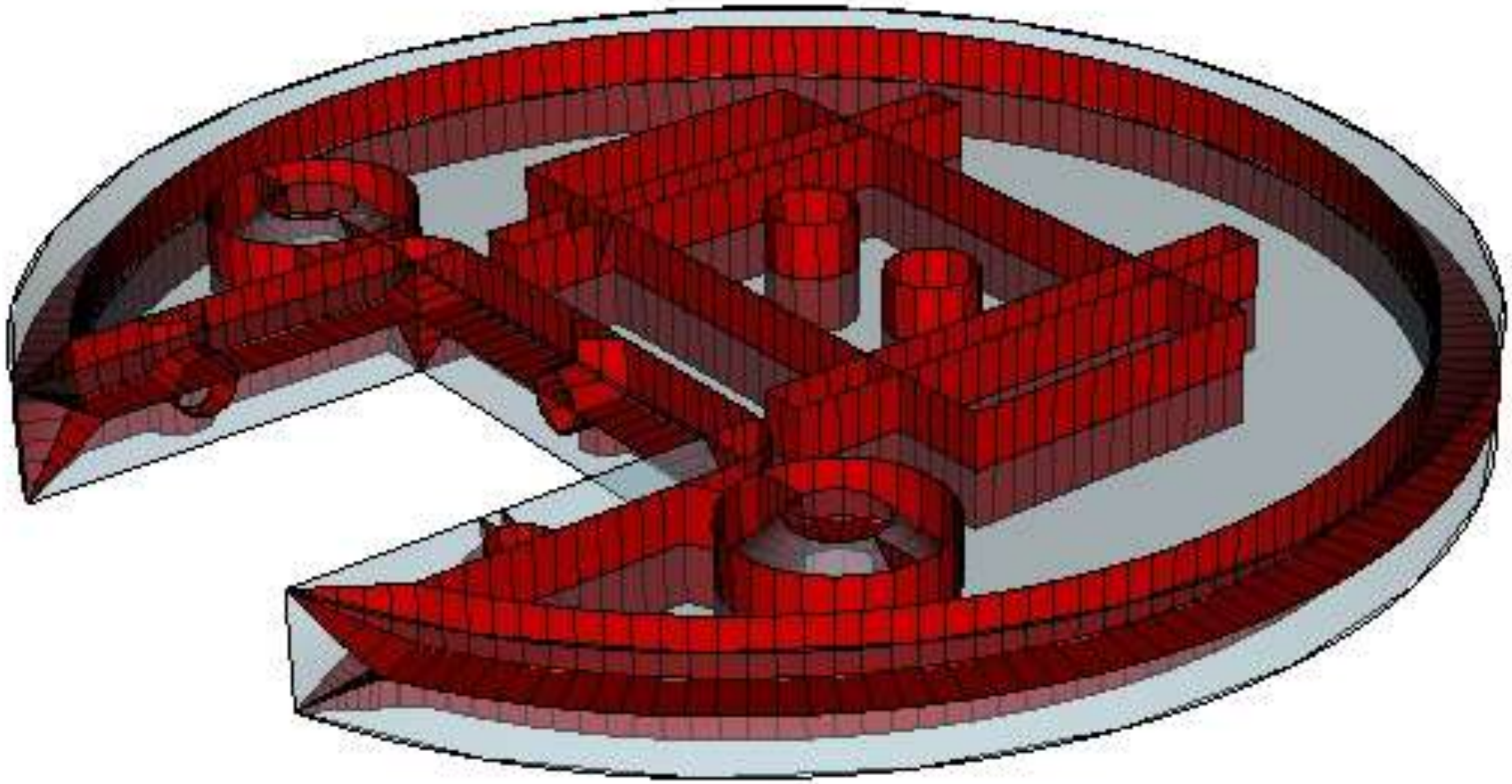
Projection of All Boundary Imprints on Medial using Map



Medial Resolves Imprints From All Directions

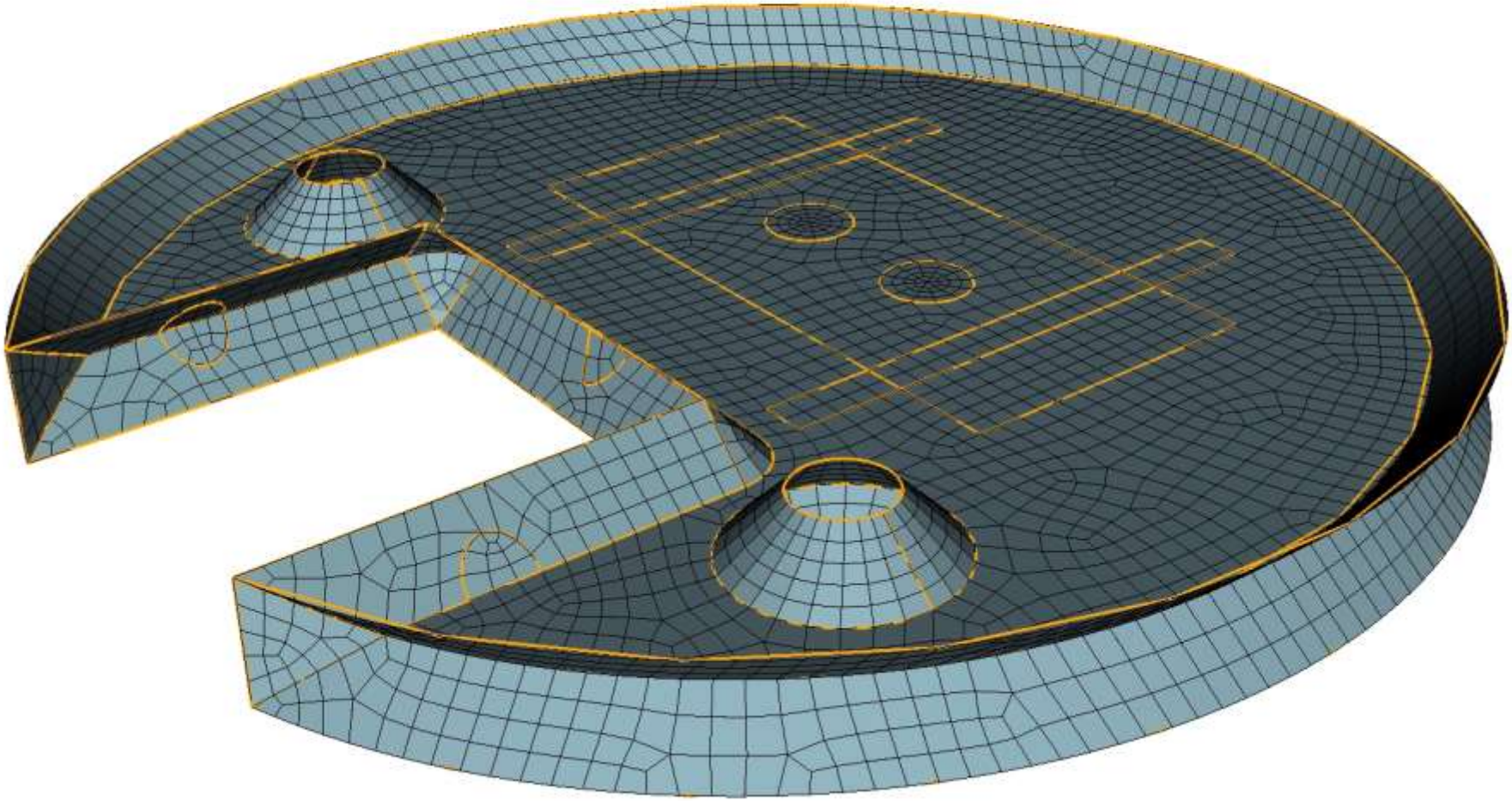


Automatic Geometry Decomposition via Imprints and Medial Junctions

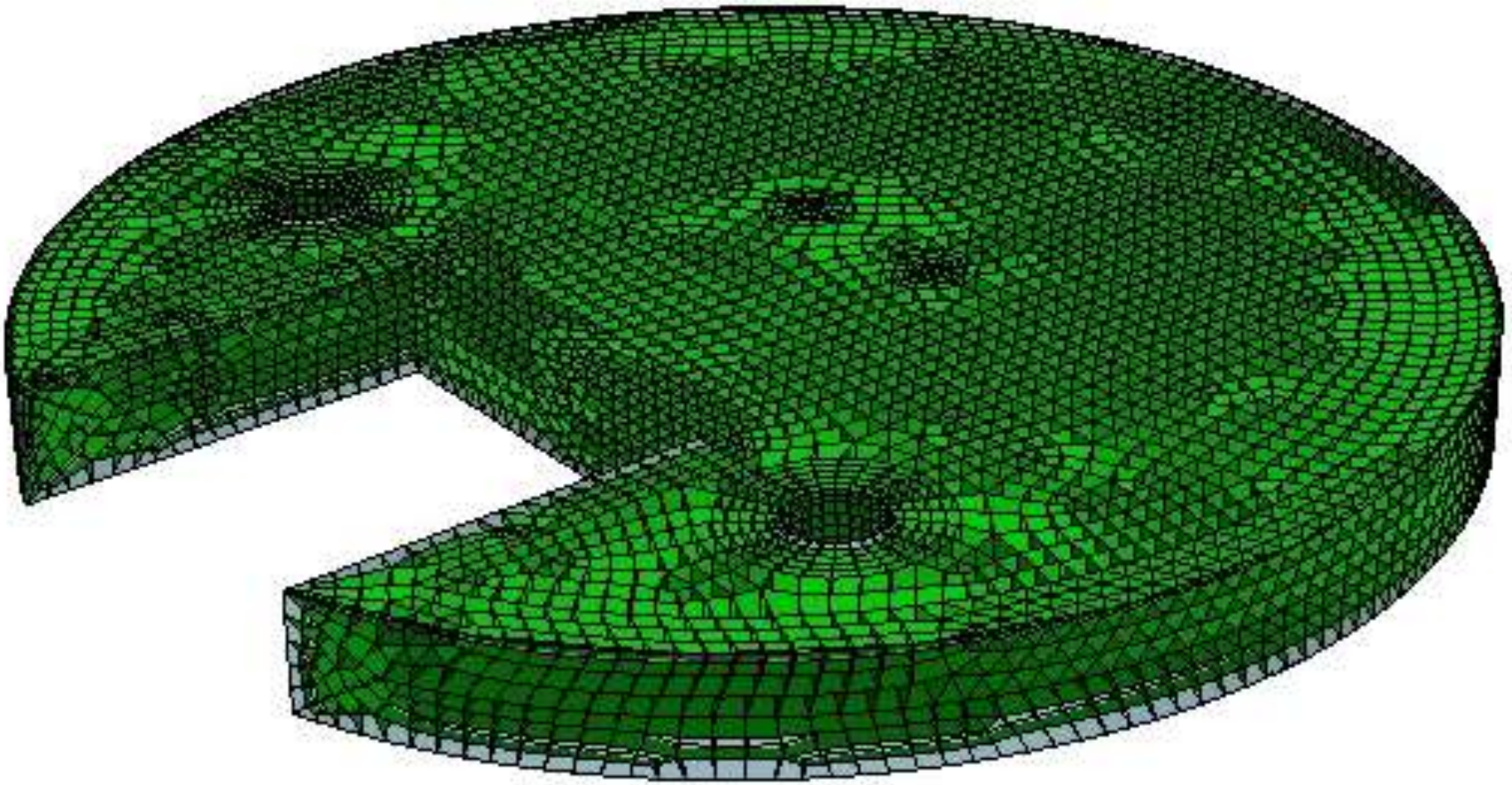


CORRIDORS

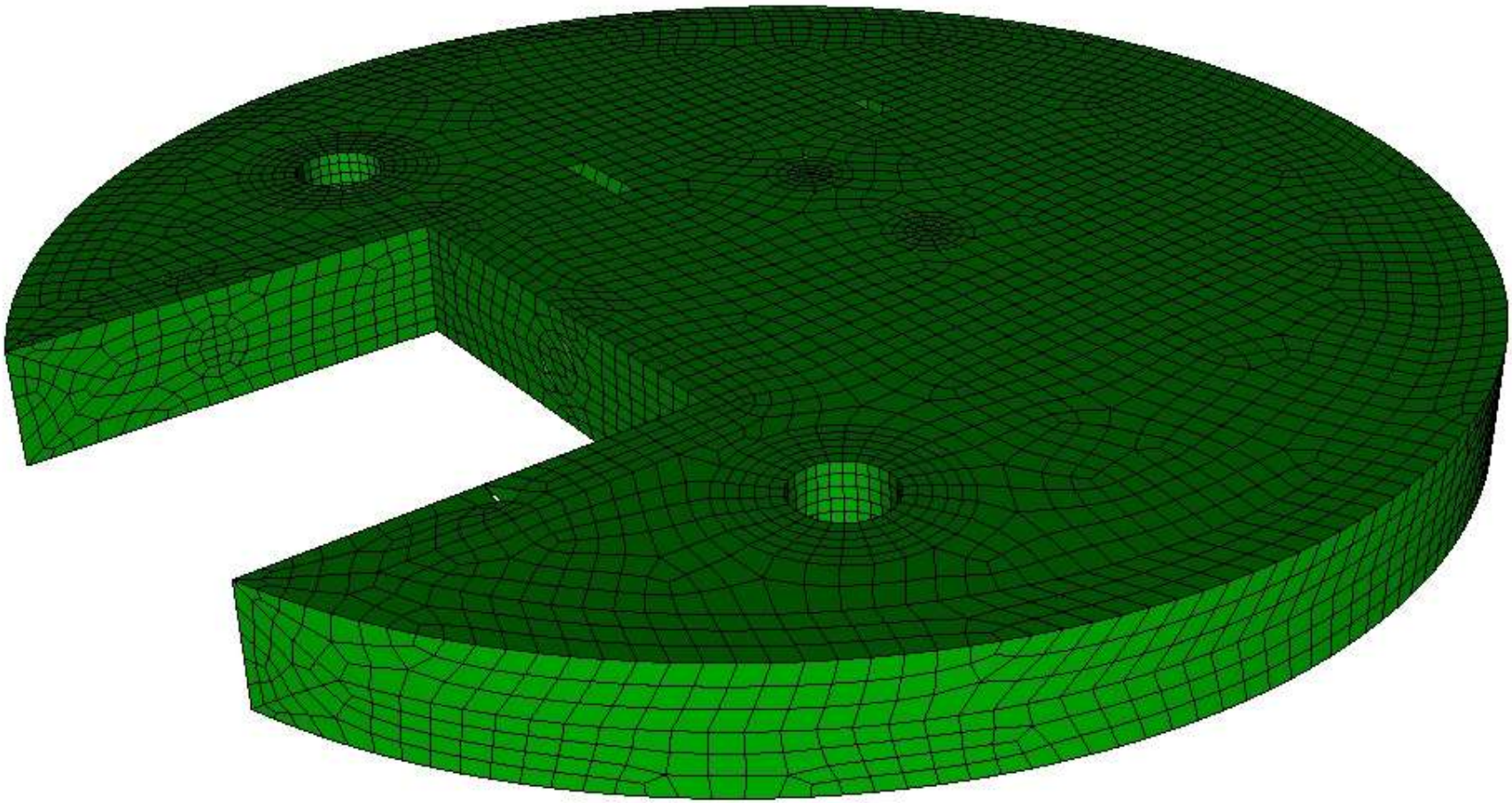
Quad Mesh on Imprinted Medial



Tracks in 3D



Hex Mesh



Future Work

- LayTracks3D
  - All-Hex
  - Size & Anisotropy Control
  - Geometry Adaptive
    - Track width based on radius function
  - Non-Linear Tracks
    - Rails as Control Polygon in 3D with repeated knots
  - Mesh Morphing
  - Parallel Meshing

Geometry Adaptive Meshes via Radius Function

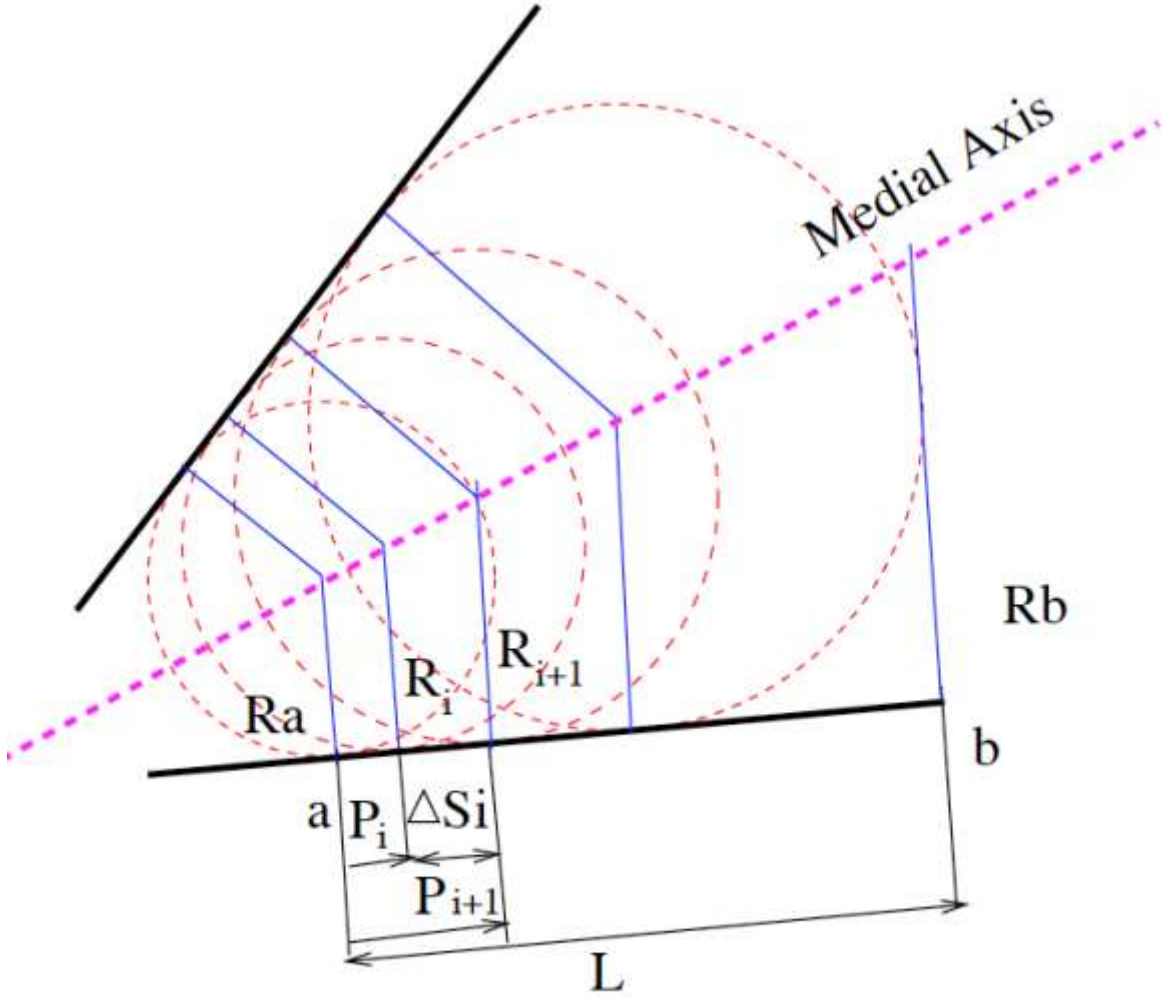
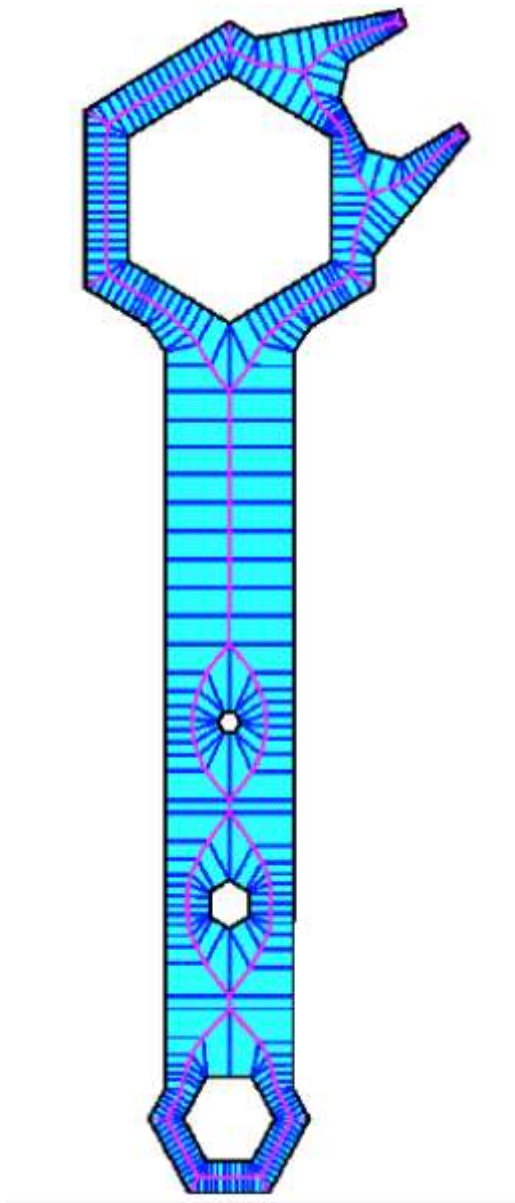


Figure 5.1: Paving for adaptive mesh.

Geometry-Adaptive Tracks



Non-linear Tracks: Rails as Control Polygons

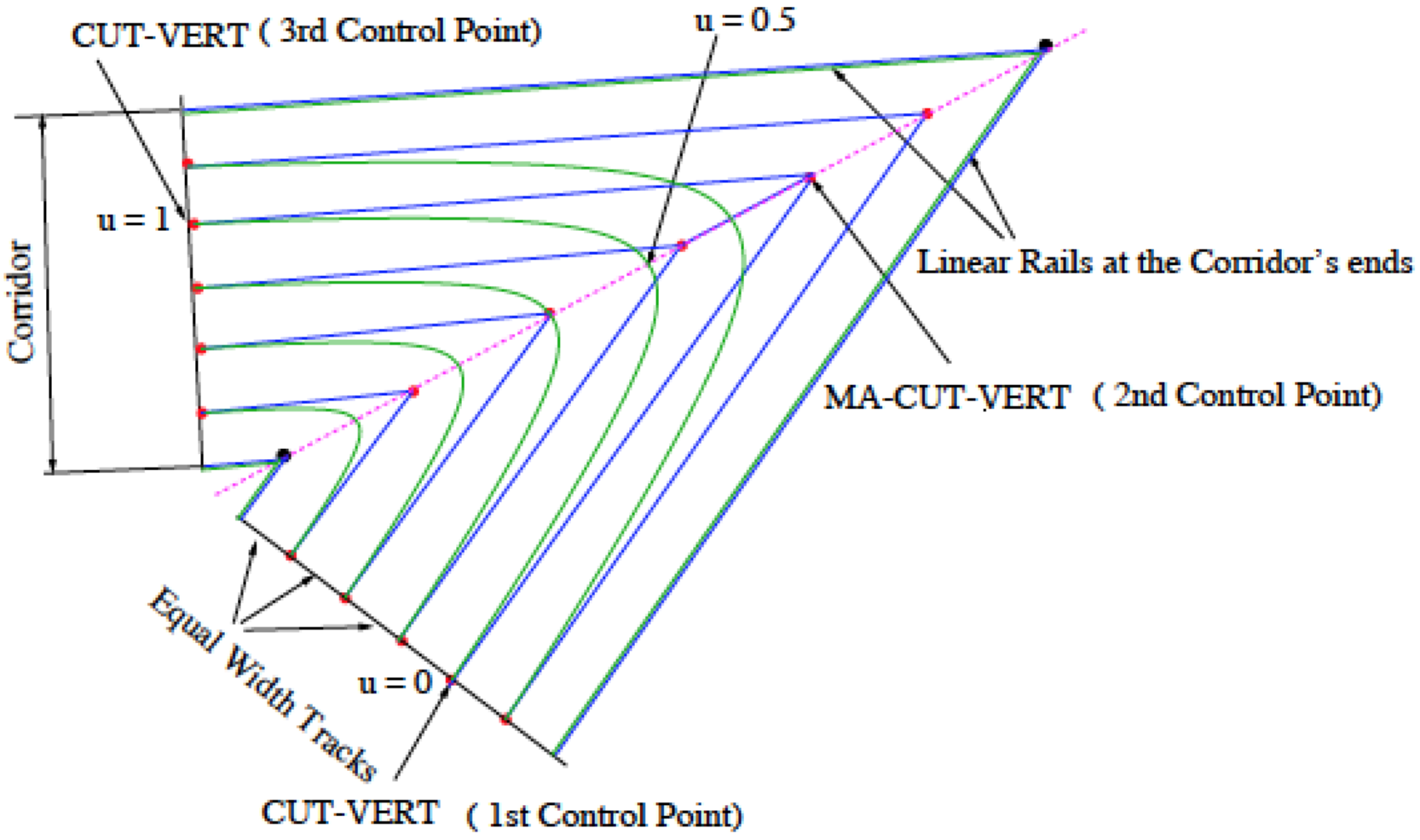


Figure 6.1: Rails Represented by Straight Lines and NURBS

Non-Linear Tracks and Mesh

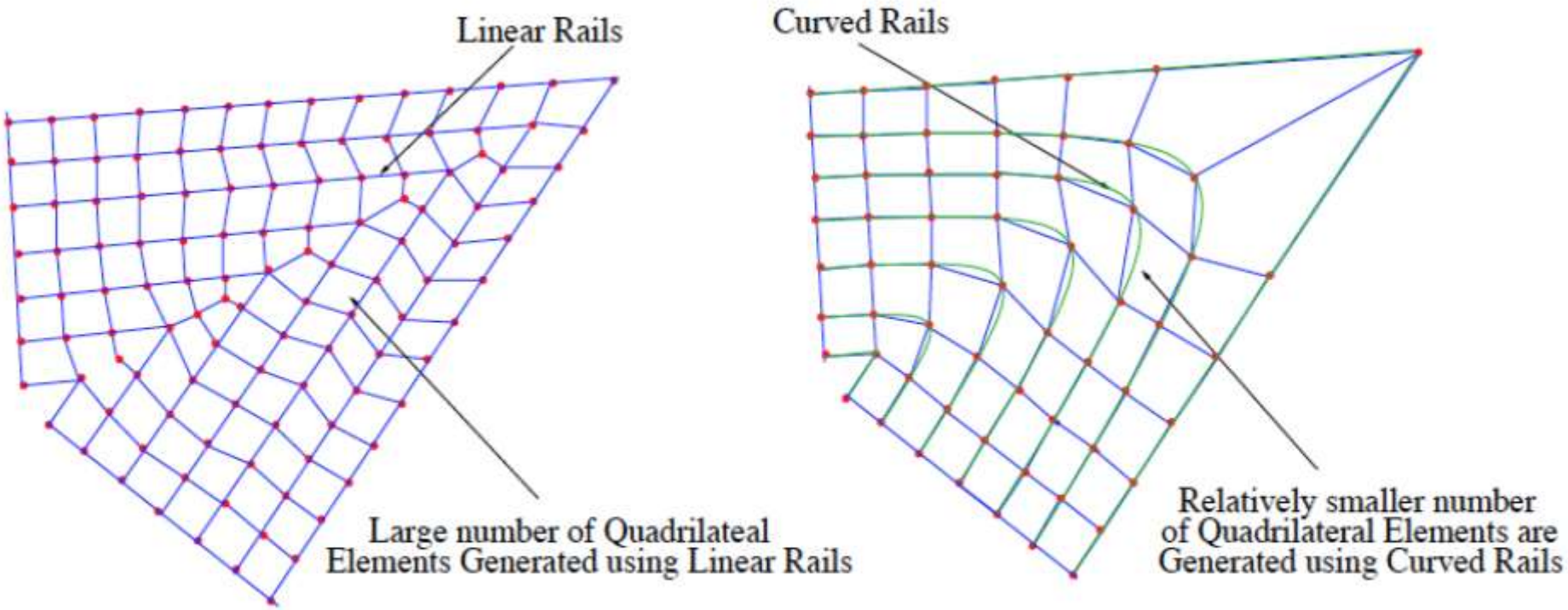
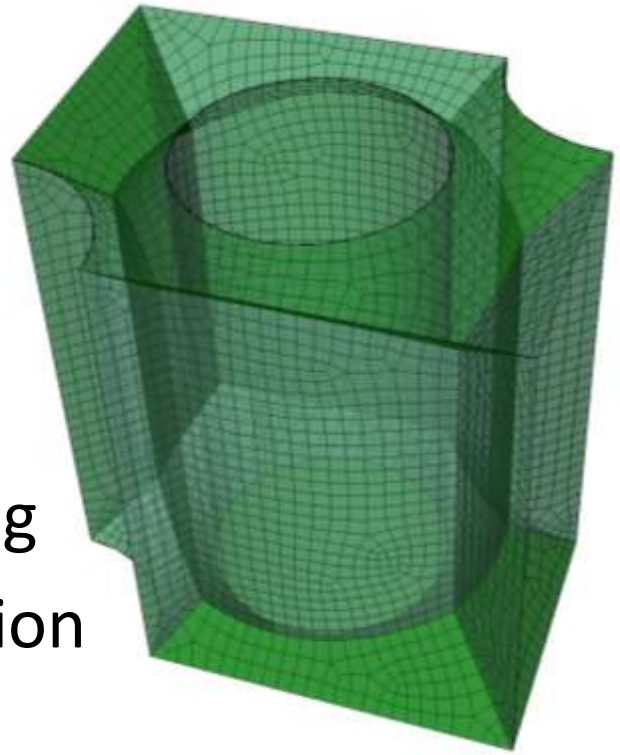


Figure 6.2: Quadrilateral Mesh using Linear Rails and Curved Rails

Sizing & Anisotropy Control

- Normal Direction (p1)
  - Intervals/Layers Along Rails
  - Non-linear Rails
- Tangential Direction (p2 & p3)
  - Quad mesh using Skeleton Sizing
  - Track Width using Radius Function
- Local Control via Map



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Thank You

Questions?

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