SAND2023-05160C

Sandia National Laboratories

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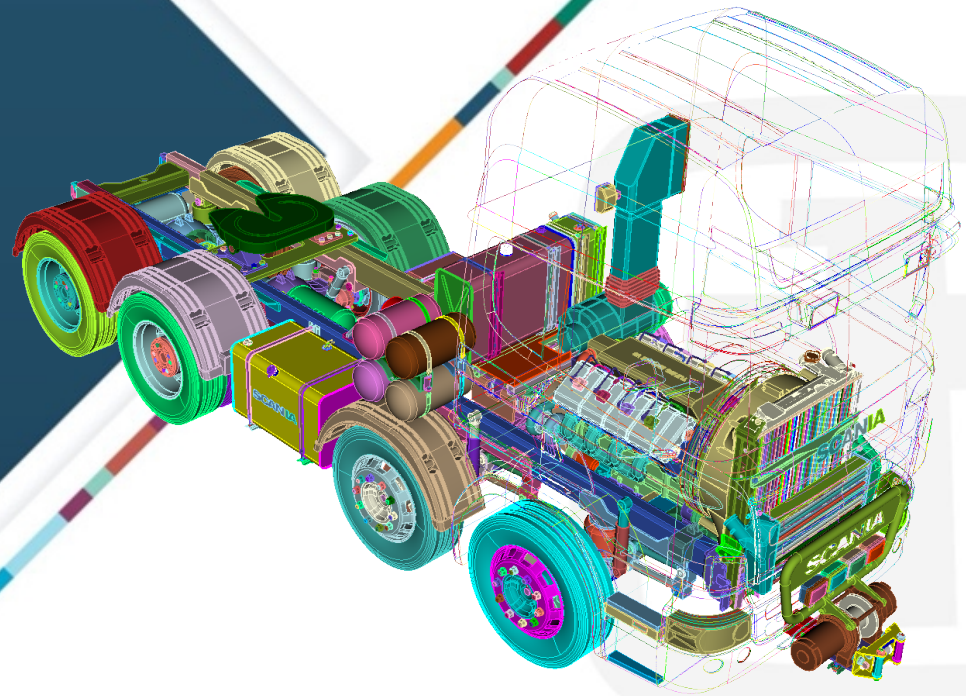
ADVANCEMENTS IN MACHINE LEARNING TECHNOLOGIES

For CAD-to-Simulation



Steven Owen

CEA/NNSA Workshop

June 20th 2023

Ashville, North Carolina

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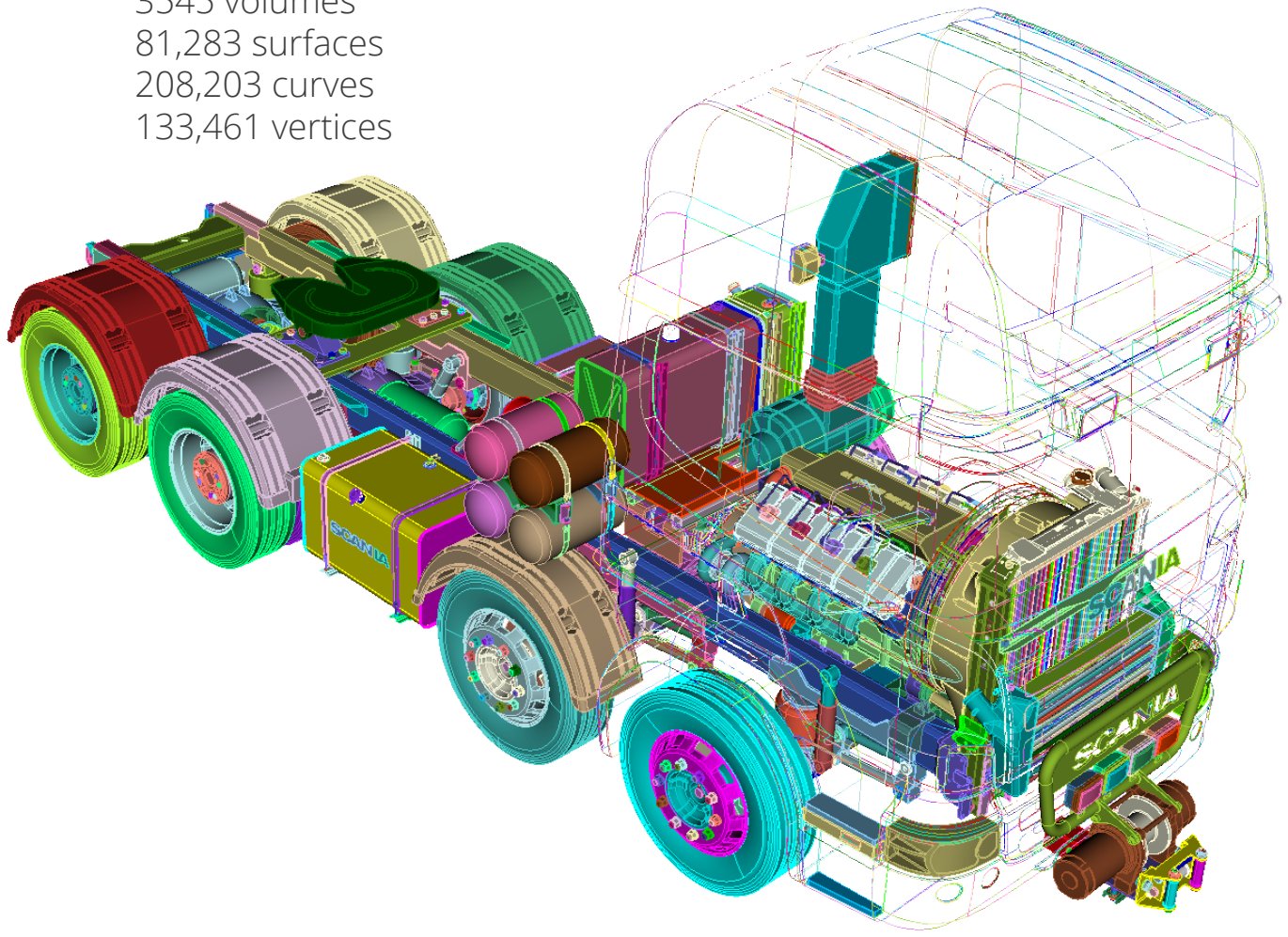
RAPID CAD TO SIMULATION WITH MACHINE LEARNING

Commercial Truck CAD Model
3545 volumes
81,283 surfaces
208,203 curves
133,461 vertices



Example workflow

- Break into subsystems for teaming and/or avoid large model size
- Remove parts that are irrelevant and not normally modeled for a specific physics
- Fix bad geometry
- Remove small features
- Remove gaps, overlaps, misalignments
- Decompose for Hex Meshing
- Tet mesh/Hex Mesh
- Identify and prepare specific categories of mechanisms (Bolts, Springs, Bearings, etc.)
- Reduce Dimension: Model Thin Volumes with Shells and Beams
- Compute preloads on bolts, springs, etc.
- Prepare input deck

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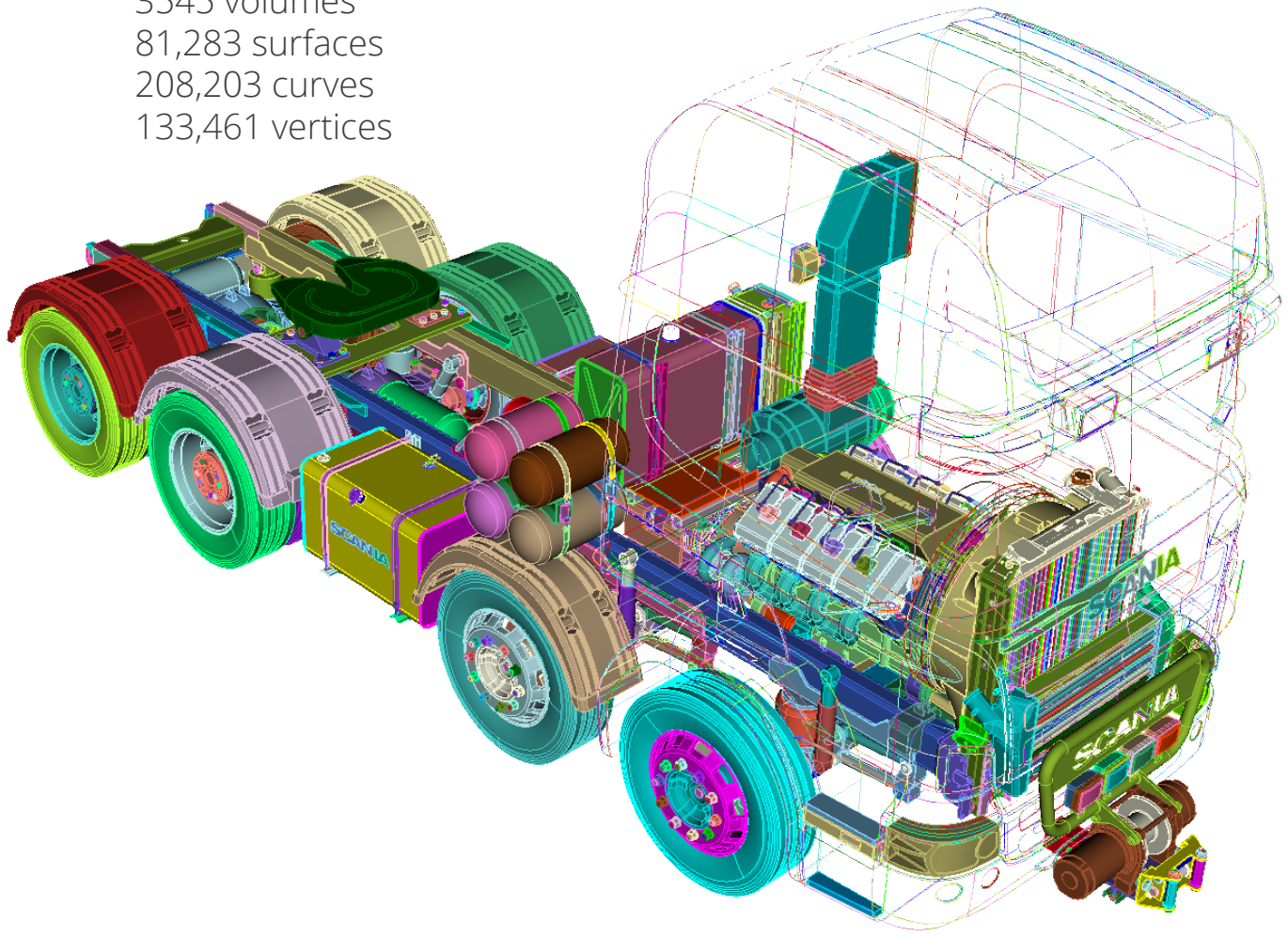

Machine Learning for Analysis Preparation:

- Reduce/Eliminate most tedious tasks
- Guide user to next step
- Present user with smart options
- User validates ML-solutions
- Standardization between analysts

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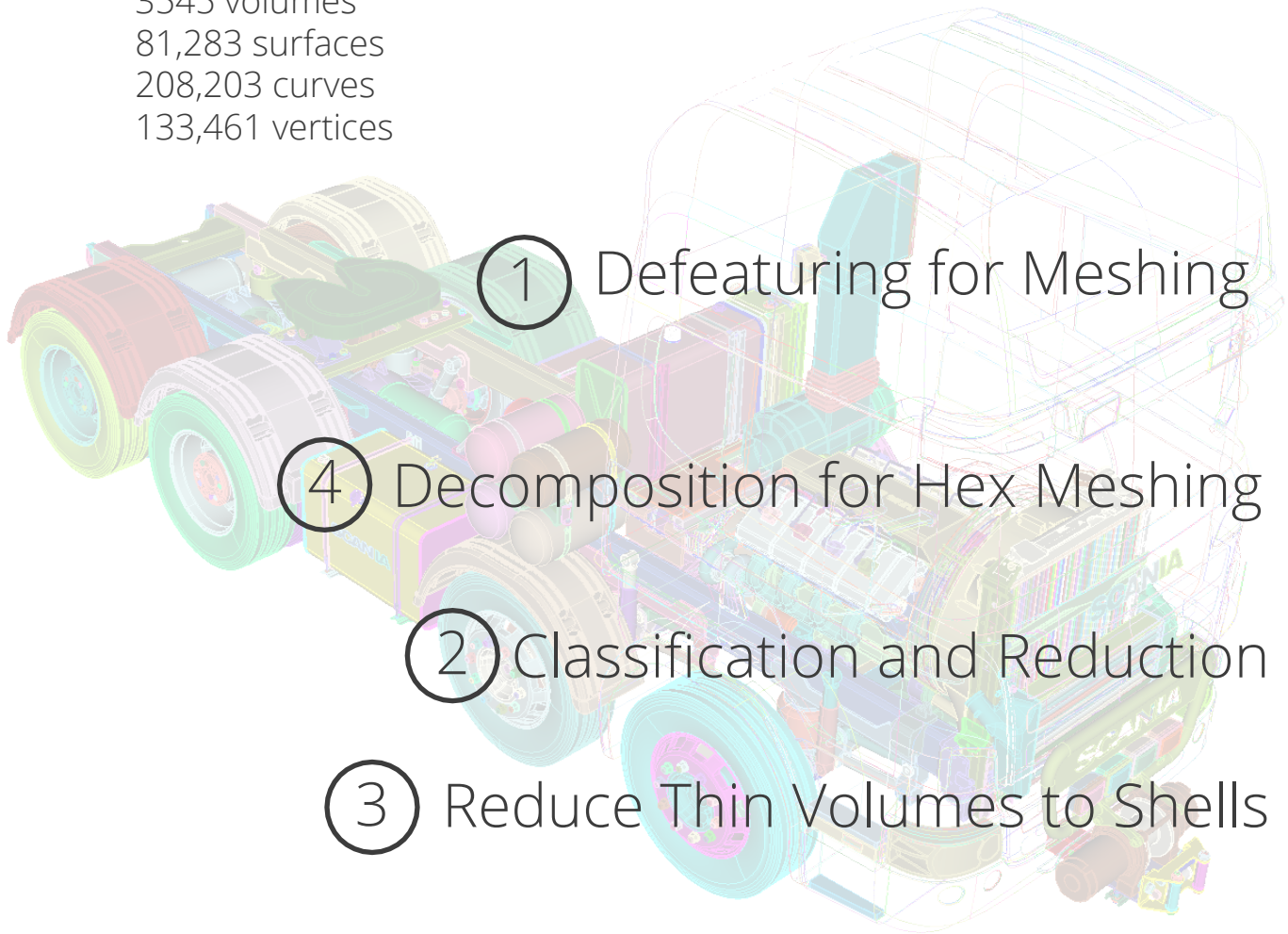

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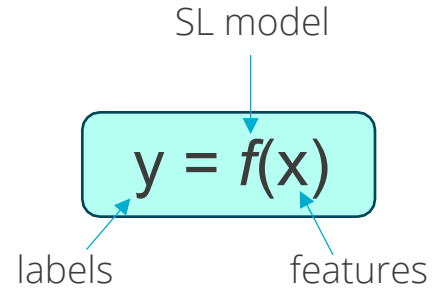
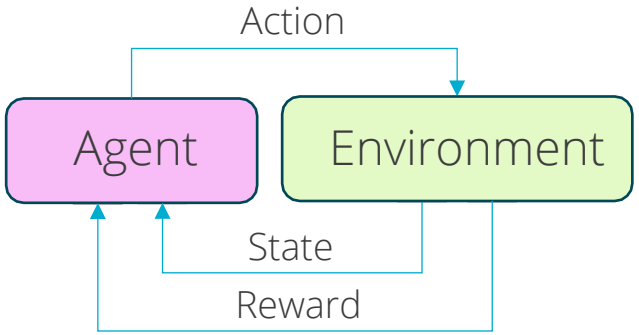
MACHINE LEARNING APPROACHES

1. Supervised Learning
   - Operates using predefined labels during training
   - Processes known input-output pairs (features, labels) for learning
   - Encounters limitations when addressing new, unseen data scenarios
   - Provides a single prediction based on established input-output correlations

2. Reinforcement Learning
   - Operates under a reward system instead of explicit correct answers
   - Employs a trial-and-error methodology, aiming to maximize long-term rewards
   - Balances exploration and exploitation for optimal learning
   - Produces a procedure or series of steps to execute a task, guided by the reward system

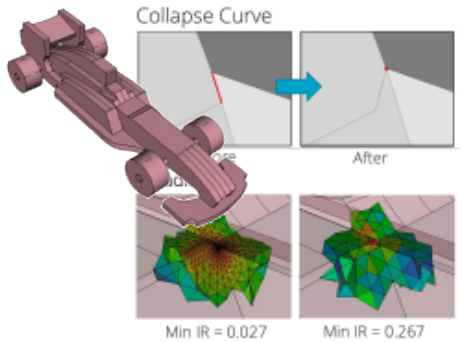


Supervised Learning

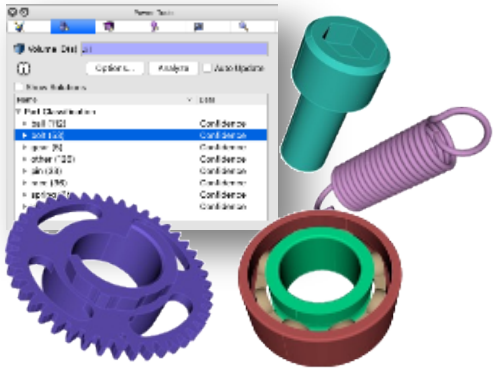


Reinforcement Learning

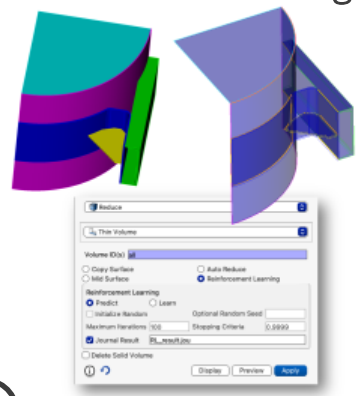
Supervised Learning

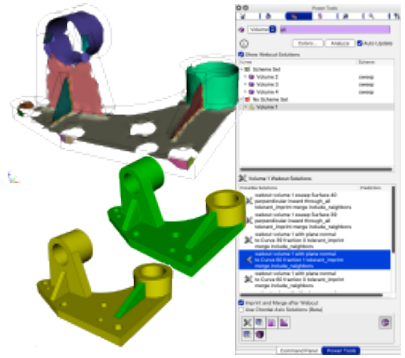


1 Defeaturing for Meshing

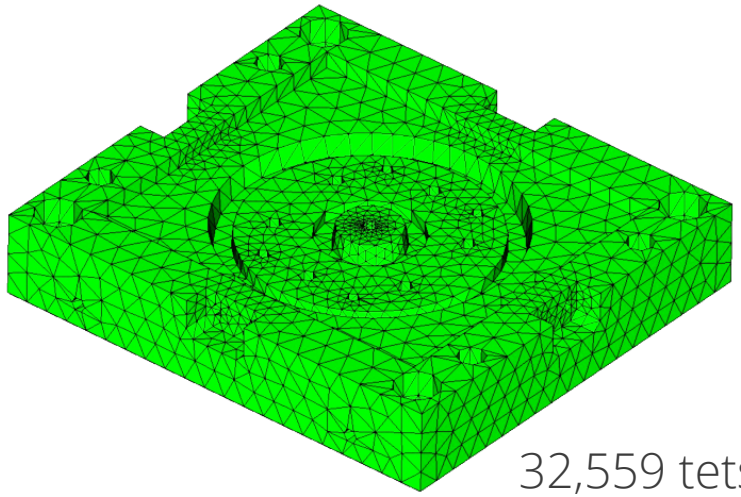

2 Part Classification

Reinforcement Learning


3 Dimension Reduction


4 Geometry Decomposition

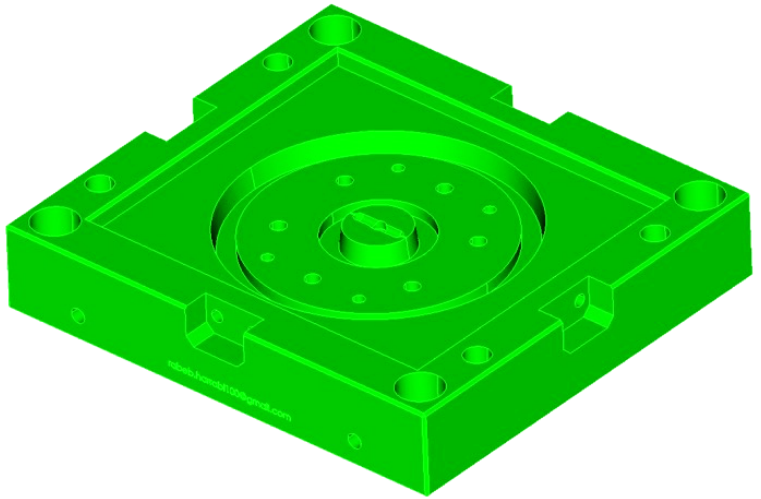
MACHINE LEARNING FOR DEFEATURING



32,559 tets

Machine Learning

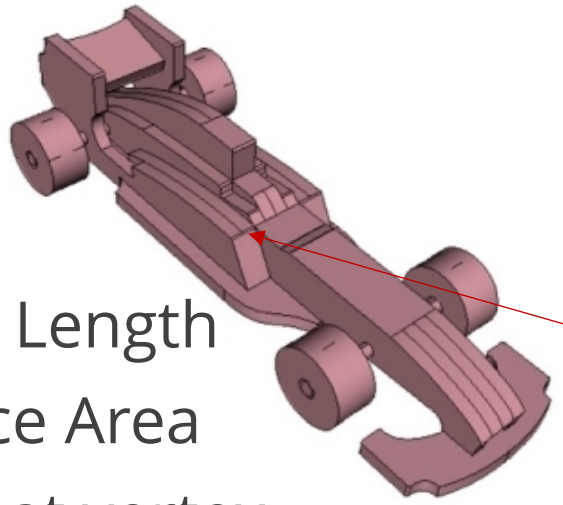
$$y = f(x)$$



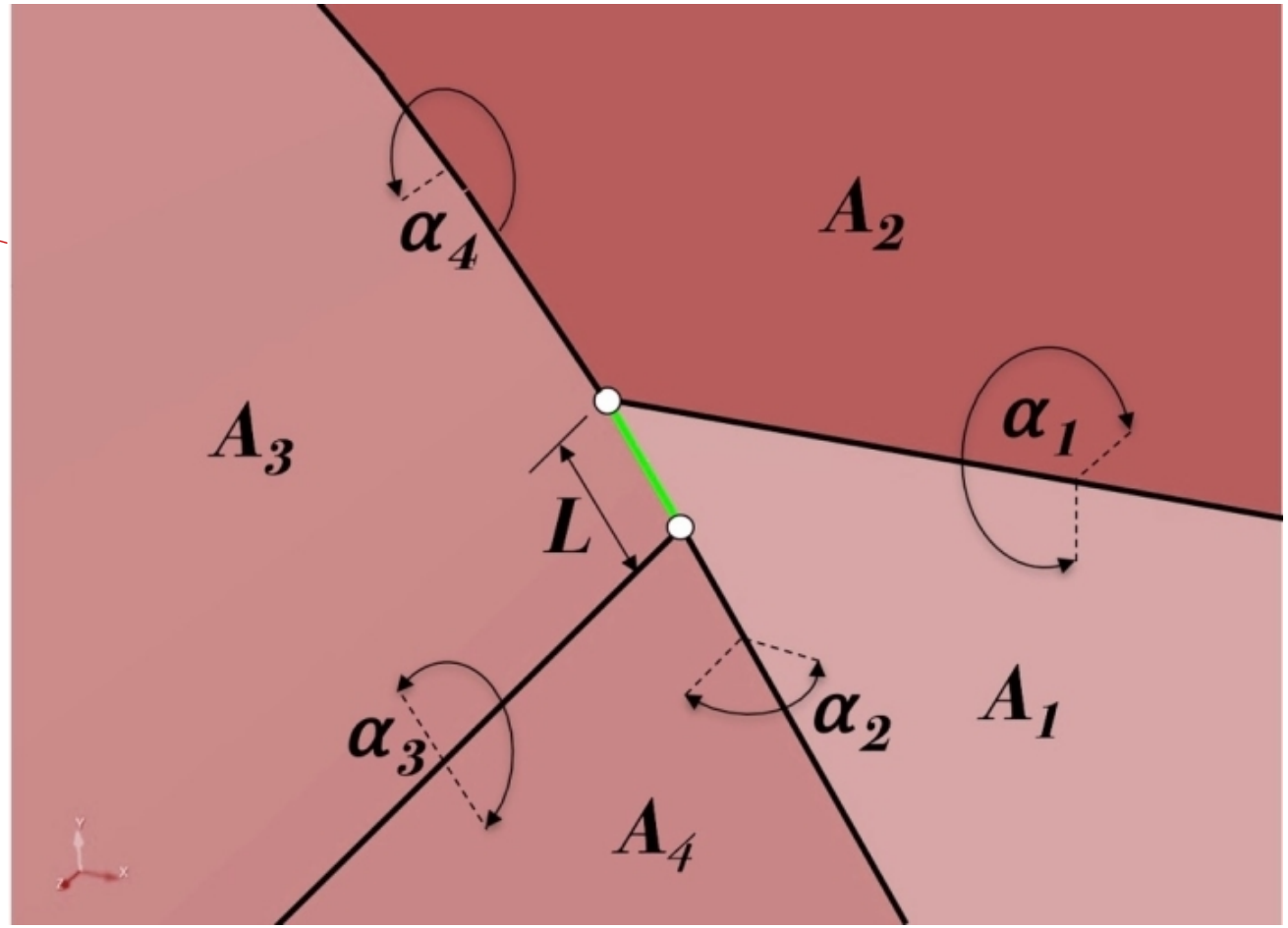
Output: Mesh quality metrics "labels"

Input: CAD Model Local geometry/topology "features"

TRAINING DATA FEATURES



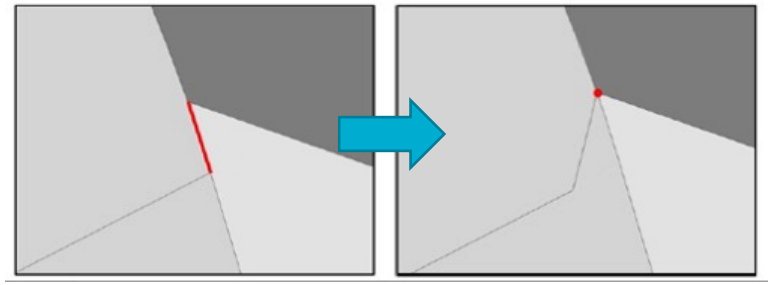
Curve Length
Surface Area
Angle at vertex
Angle at curves
Valence at vertex
Number of loops
Hydraulic Radius
Etc…



Topology-Based Features

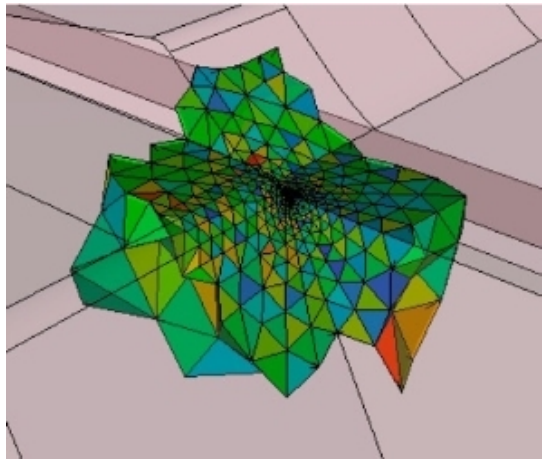
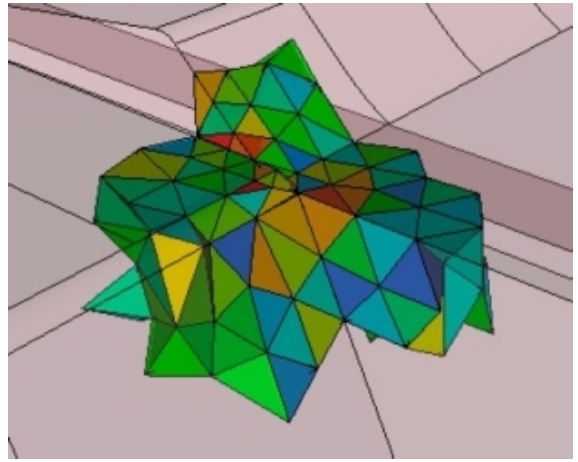
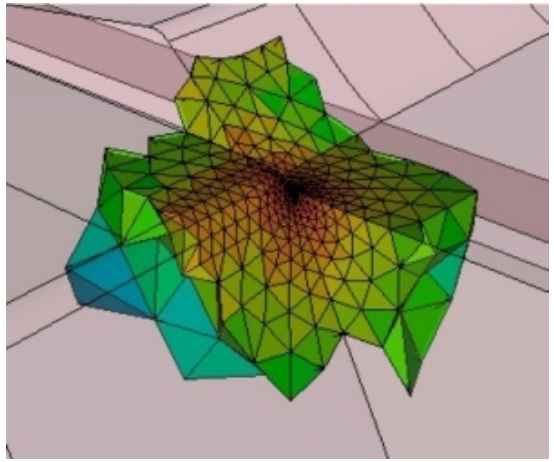
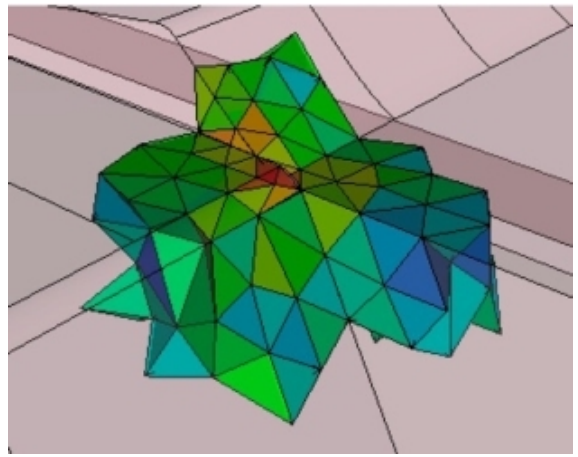
TRAINING DATA LABELS

Collapse Curve

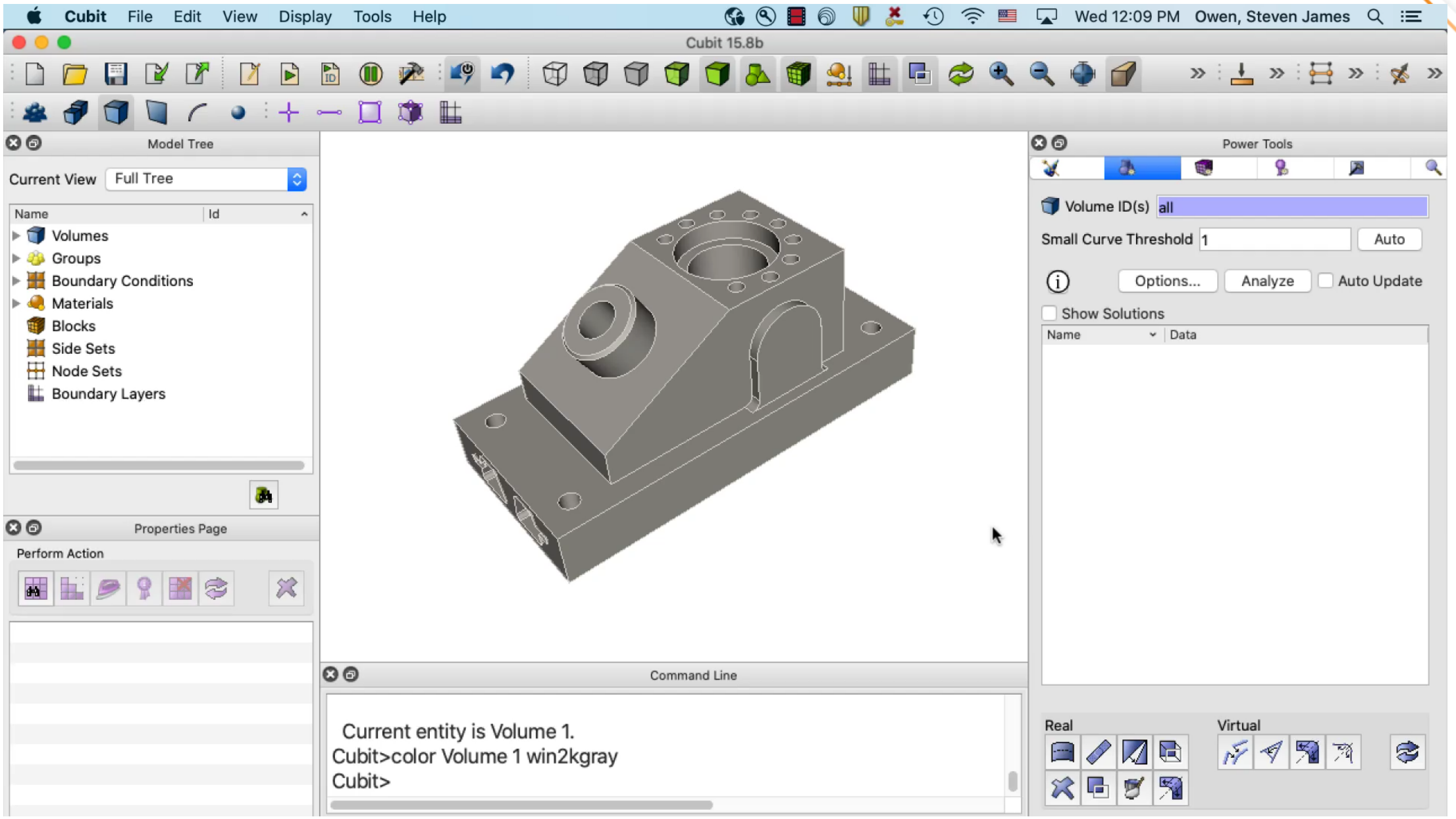


Before After

Collapse Curve

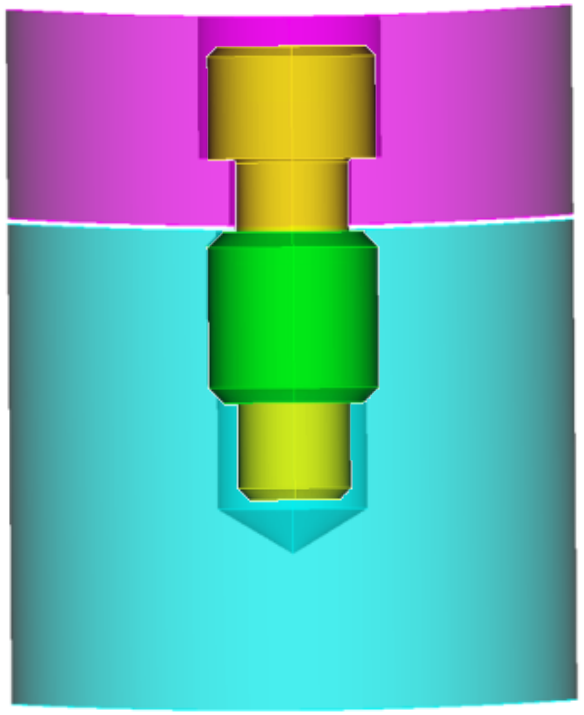
	Before	After
Scaled Jacobian	 Min SJ = 0.250	 Min SJ = 0.227
In-radius	 Min IR = 0.027	 Min IR = 0.267

DEFEATURING FOR MESHING EXAMPLE

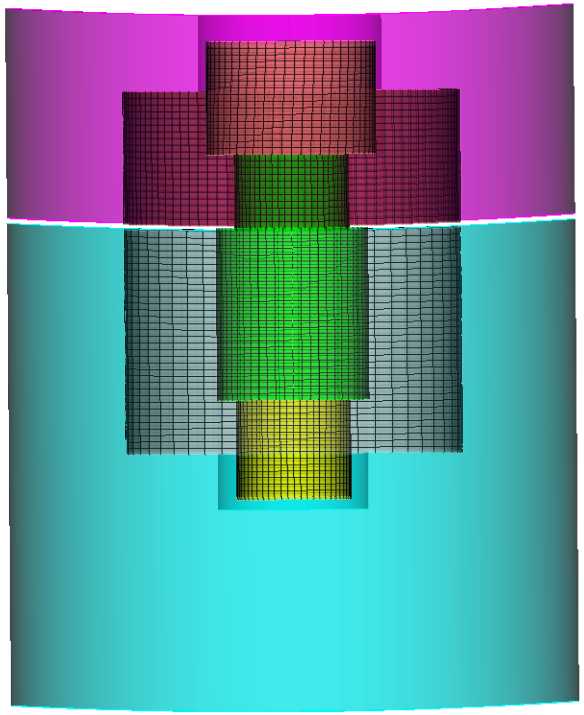


MACHINE LEARNING CLASSIFICATION FOR RAPID CAD-TO-SIMULATION

Classify Common Mechanisms → Rapidly Prepare for Analysis

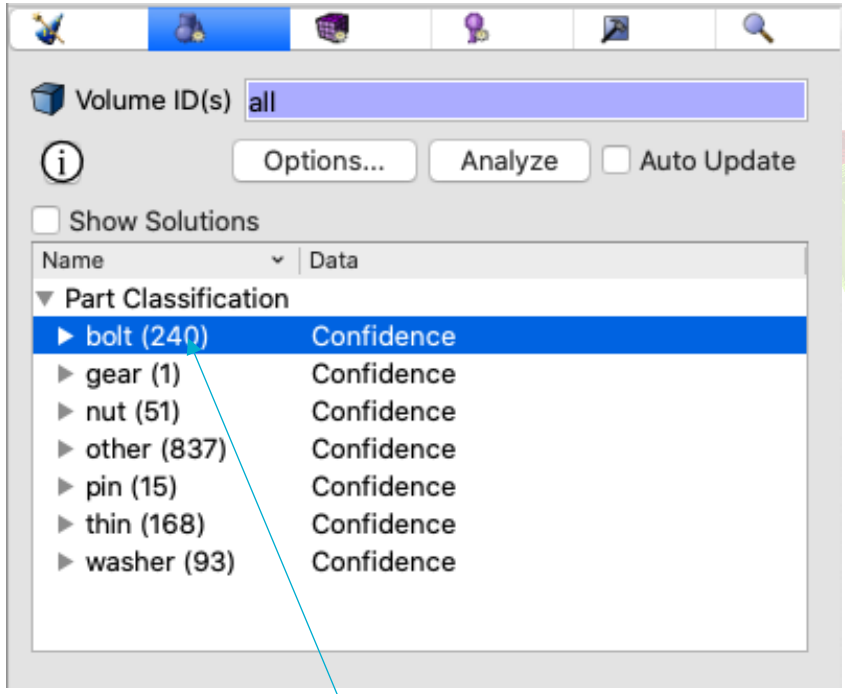


Bolt in CAD assembly before preparation

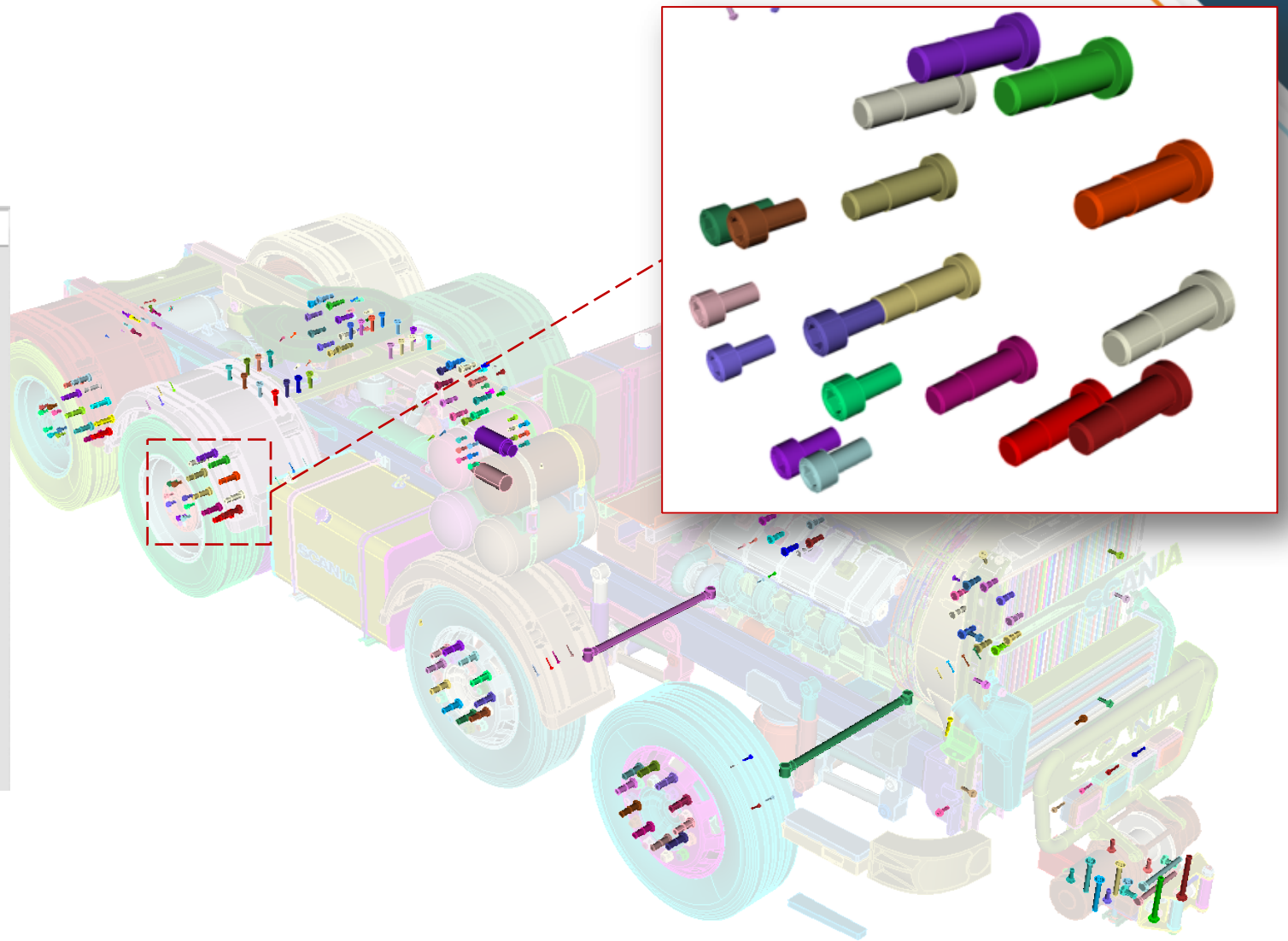


Bolt ready for analysis

MACHINE LEARNING CLASSIFICATION FOR RAPID CAD-TO-SIMULATION



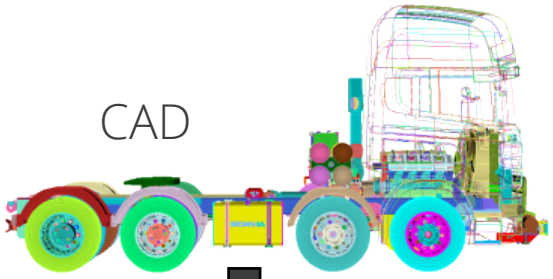
Existing "**bolt**" category
Classified 240 bolts



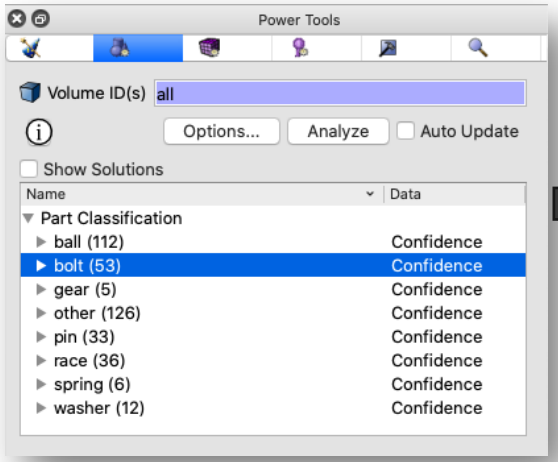
3D Solid Model: "Bolt" Volumes Only
(240 Volumes)

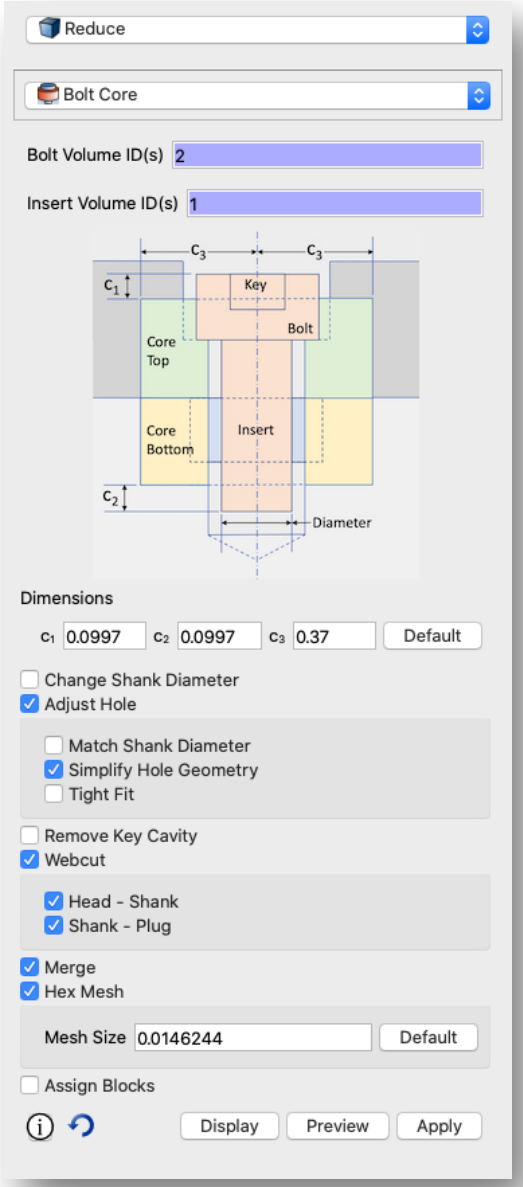
REDUCE FOR SIMULATION (FASTENERS)

CAD



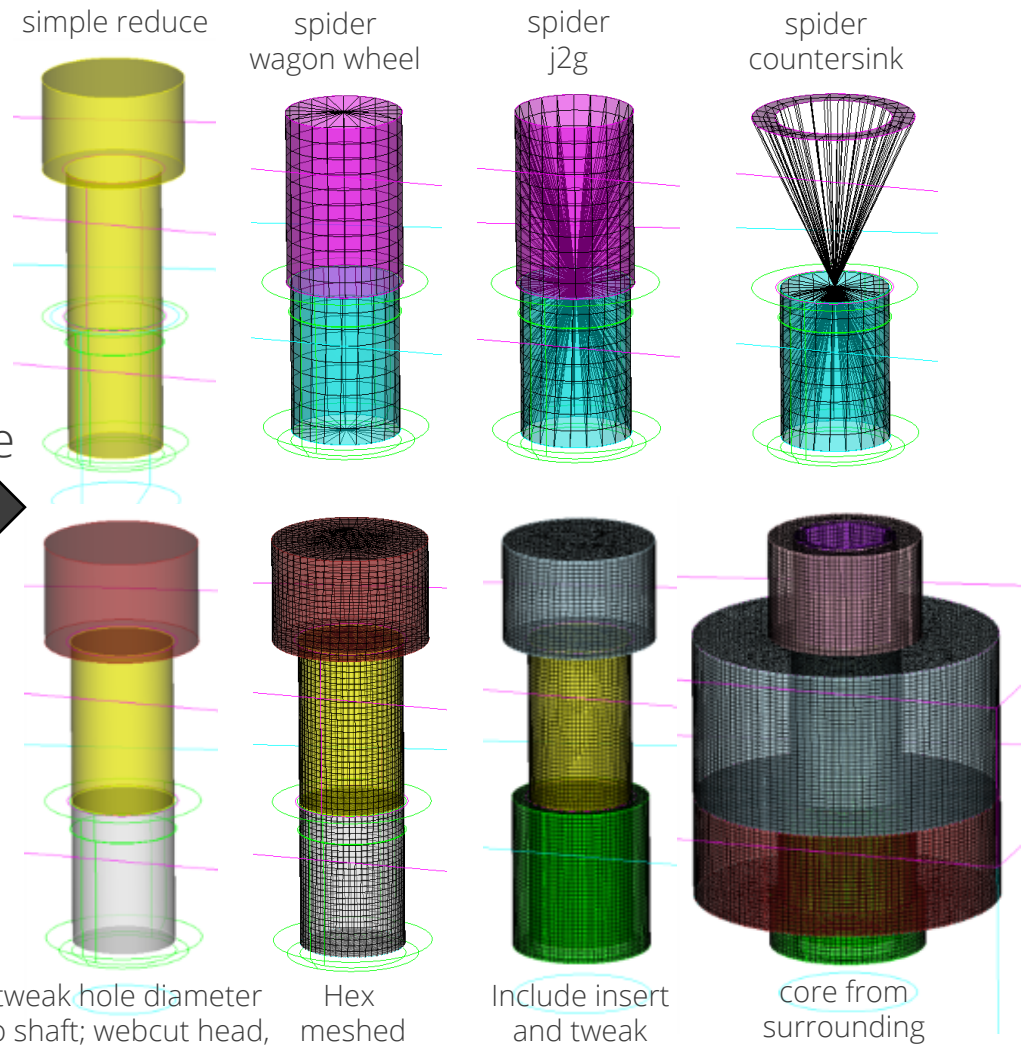
classify



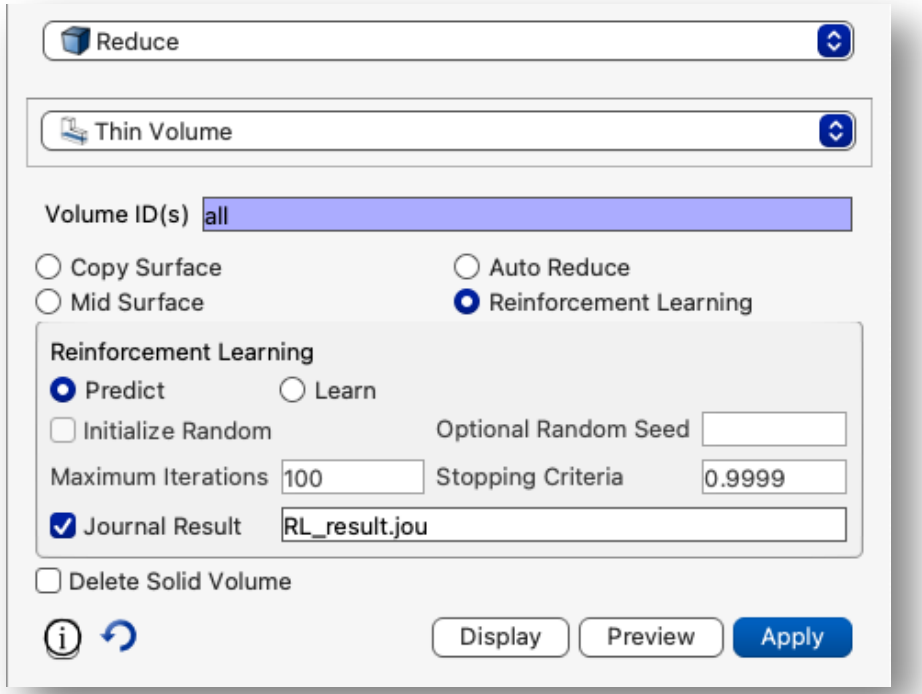


reduce

simulation-ready

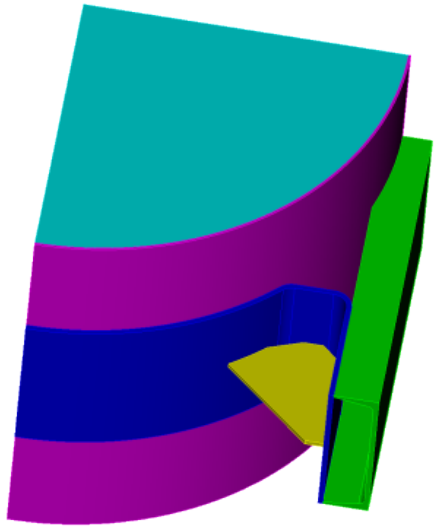


THIN VOLUME REDUCTION WITH REINFORCEMENT LEARNING

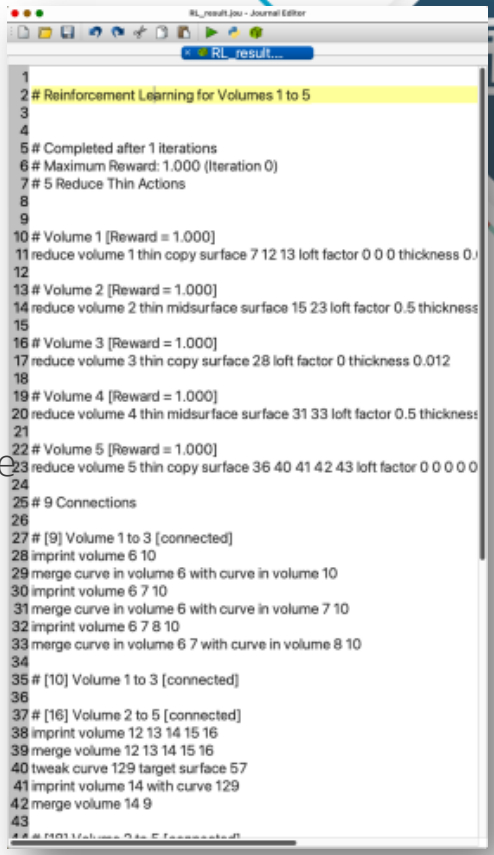


Reinforcement Learning Command Panel

Initial 3D Solid Model

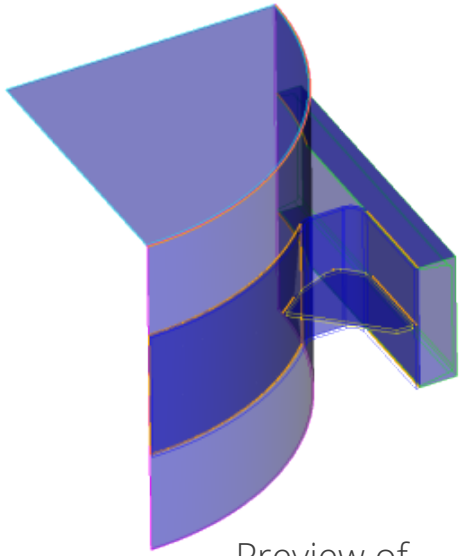


Journal File of Best RL iteration



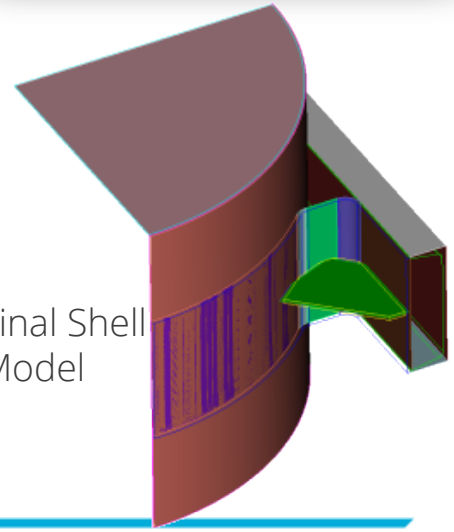

```
reduce {volume <ids>} thin RL
[number iterations <value>] [initialize random [<value>]]
[stopping criteria <value>] [journal result <string>]
[delete] [preview]
```

RL Command Syntax



Preview of Reduction

Final Shell Model



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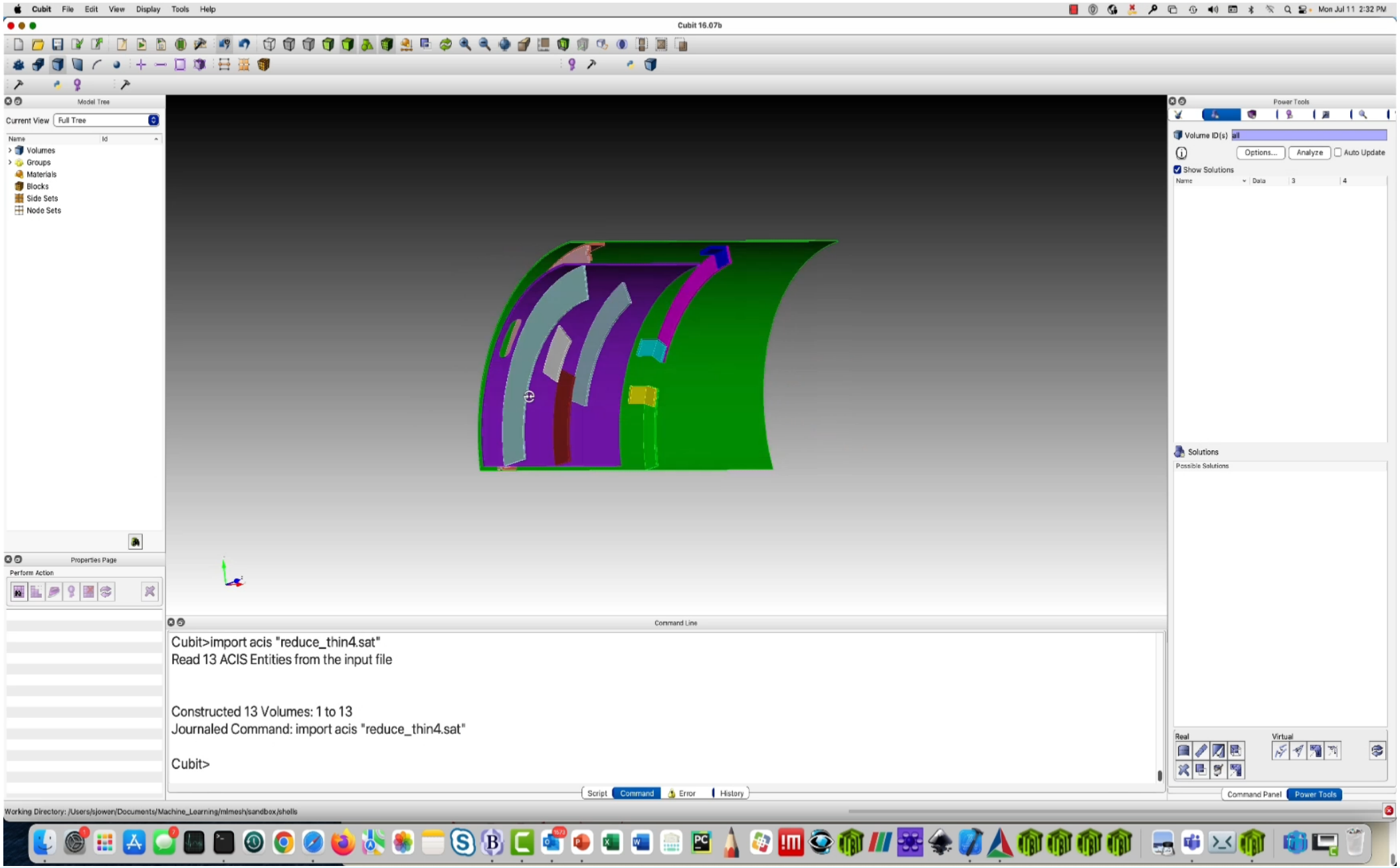
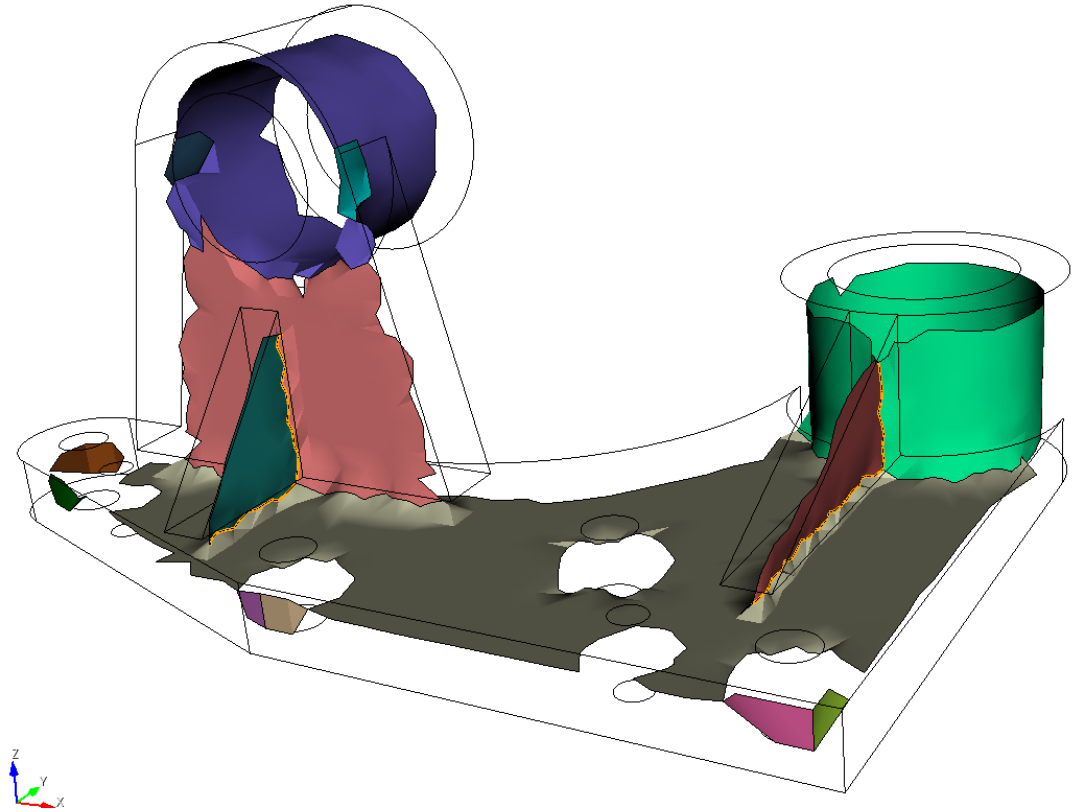
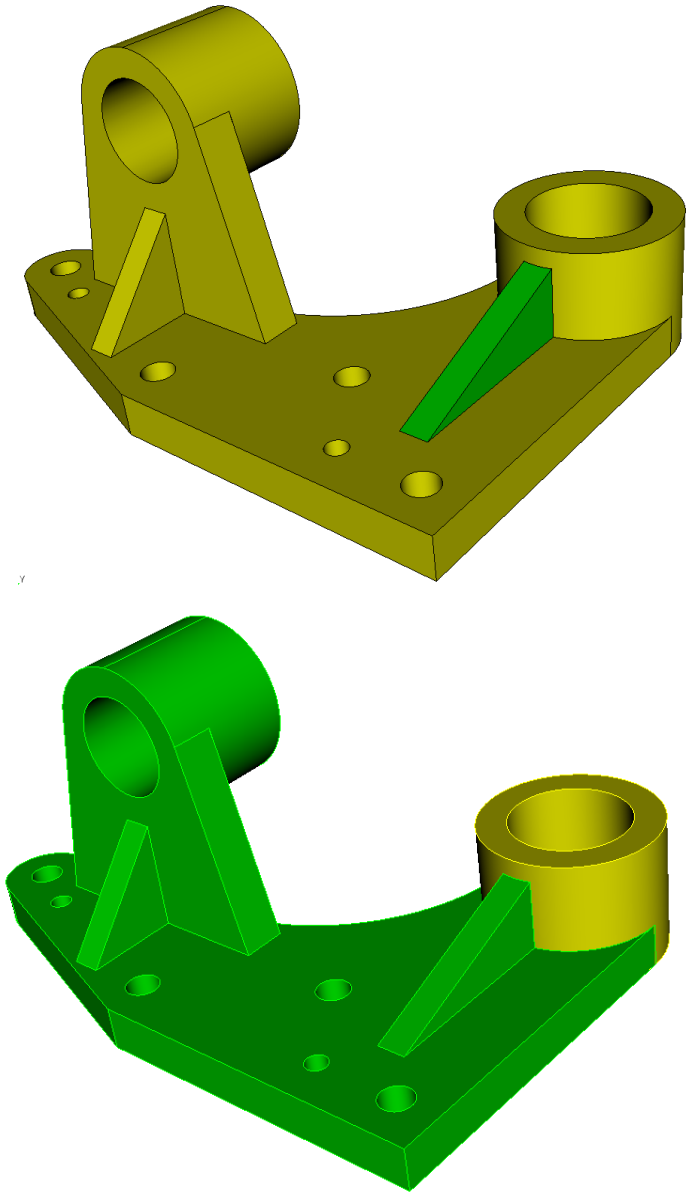


AUTO DECOMPOSITION FOR ALL-HEX OR HYBRID MESHES

Chordal Axis Extraction

(mid-surfaces created from tetmesh)





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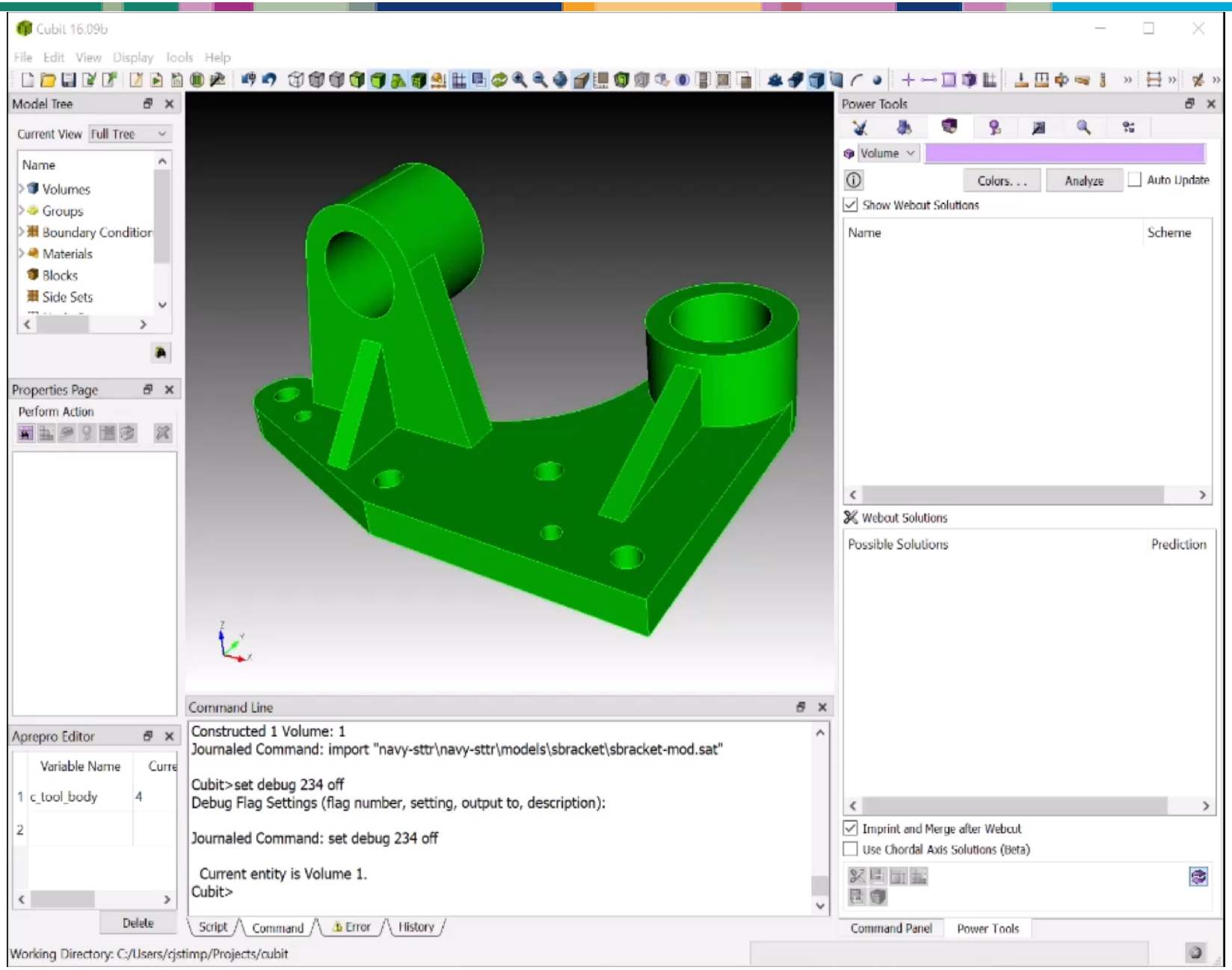

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