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Parallelized Additive Manufacturing of Variably Partitioned Volumes for Large Scale 3D Printing with Localized Quality

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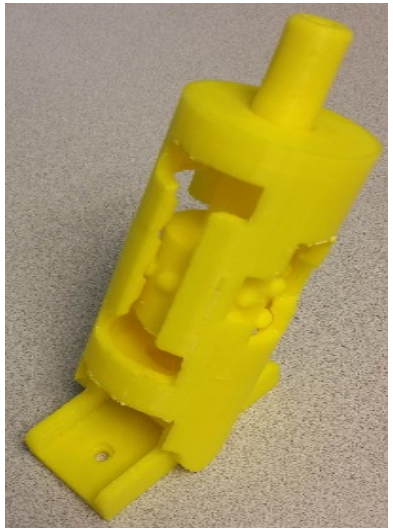
Discussion, Discovery, and Dissemination 2021

Redefine the Possib

Motivation

- Benefits of AM => growing applications
  - Improving design performance
    - Achieving geometric complexity
    - Weight reduction
    - Functionally graded materials
  - Savings in production (in small batches)
    - Min. tooling
    - Min. assembly
- What is hindering this growth?
  - Expensive machines
  - Small build volumes

Partitioning and Printing in Parallel



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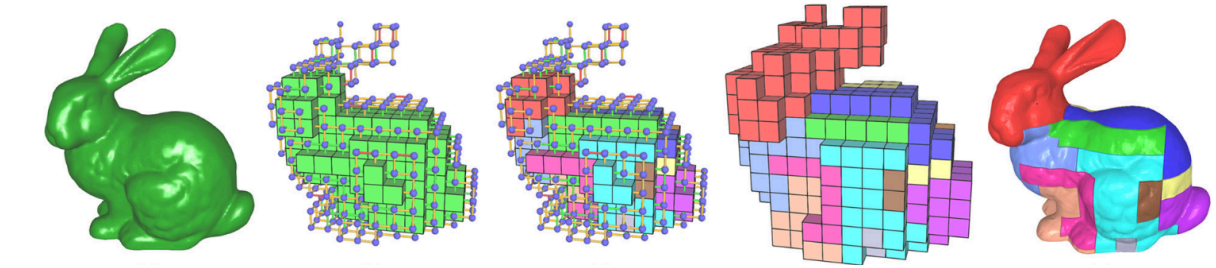
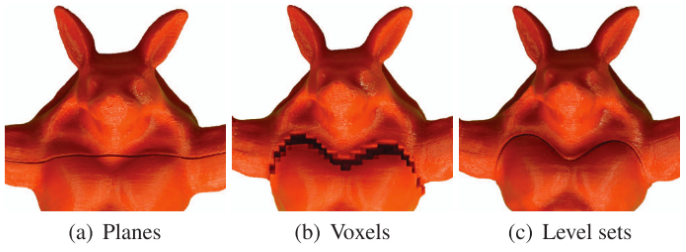
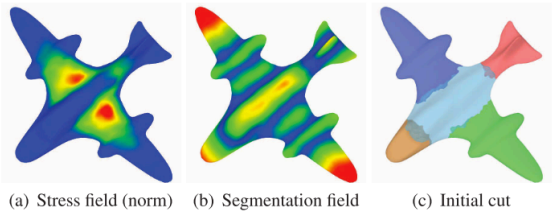
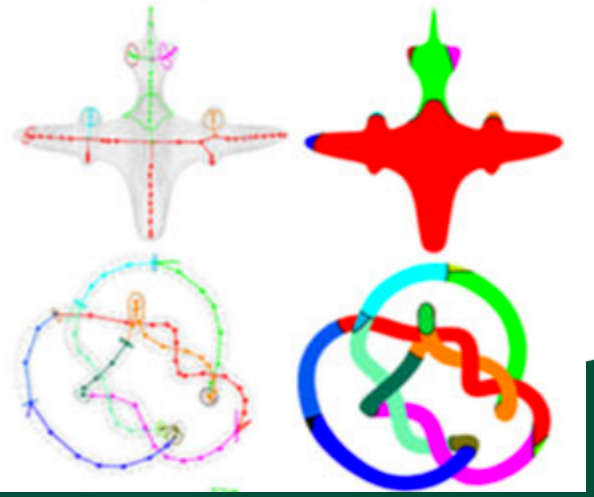
Existing Approaches Focus on Geometry

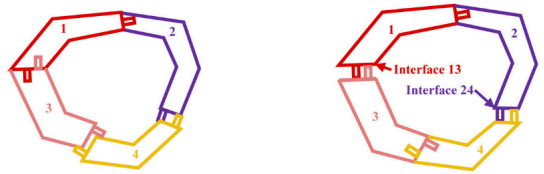
- Voxel-based (Song et al. 2015) => interlocking
- Level-set Partitioning (Yao et al. 2015) => smooth cuts along key features (curvature changes)
- Skeletonization (Jiang et al 2017; Wei et al 2018) => hollowing & support-free printing

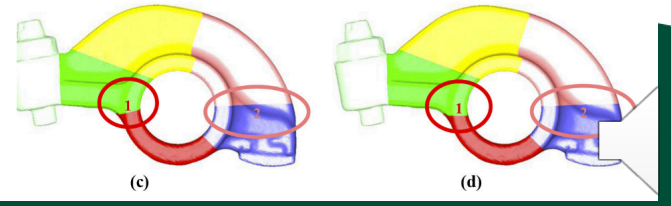






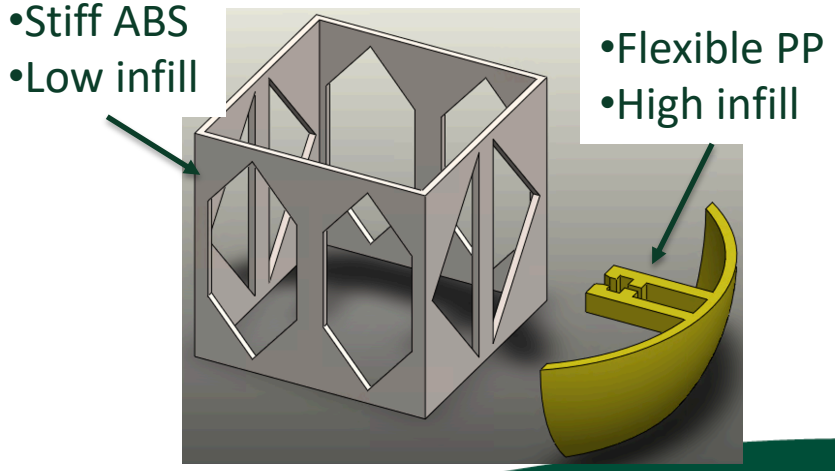




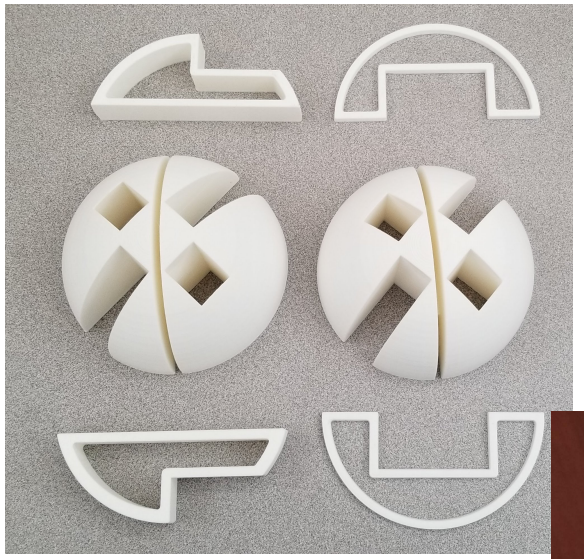


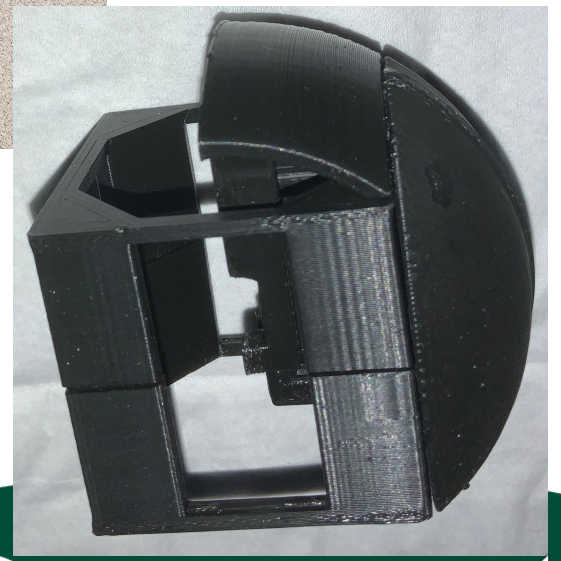
Reasons to Partition besides Size Constraint

- **Weight reduction** by optimizing the topology w.r.t. load conditions
- Having **different materials** with different parameters, e.g., stiffness
- Faster production with **multiple printers in parallel**
- Local control with **independent process parameters** within each sub-volume rather than the entire part
  - **printing resolution**
    - surface finish due to the staircase effect
    - speed
  - **printing orientation**
    - anisotropy (weak cross-layer bonding)
    - support structure



Printing Orientation vs. Joining Orientation





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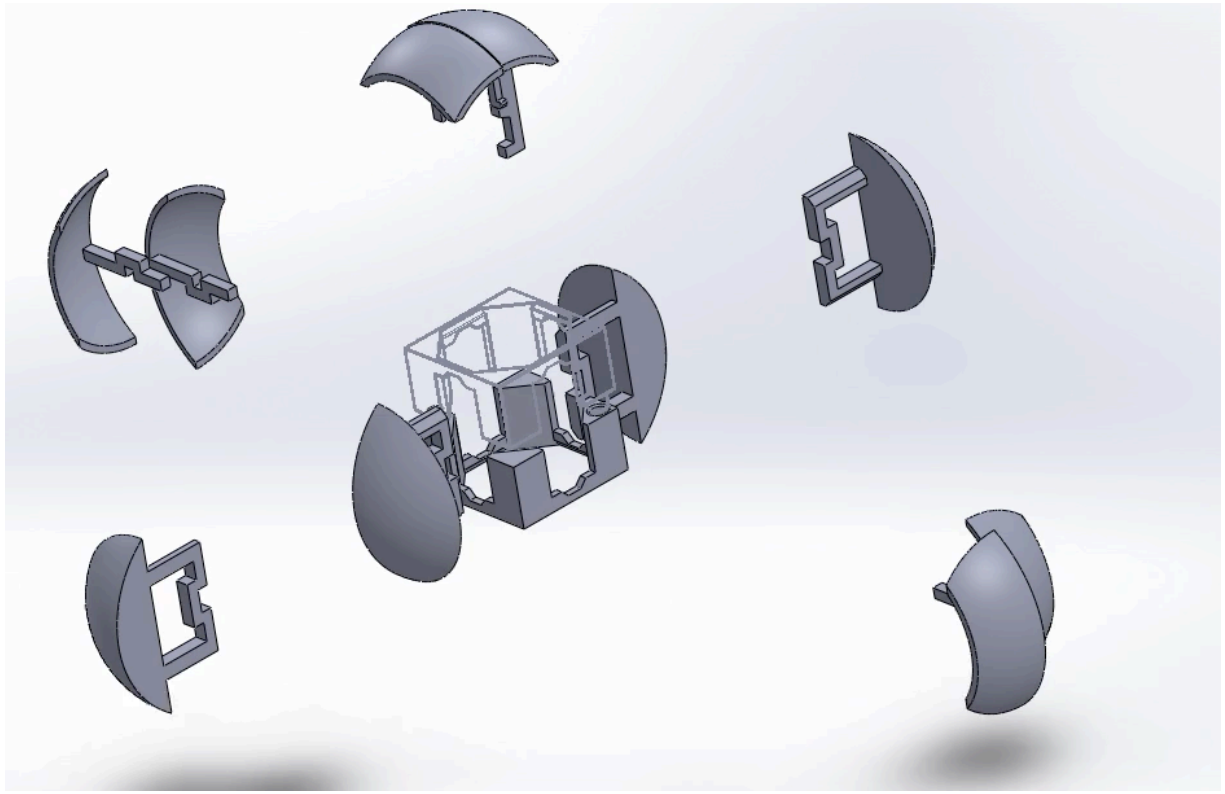
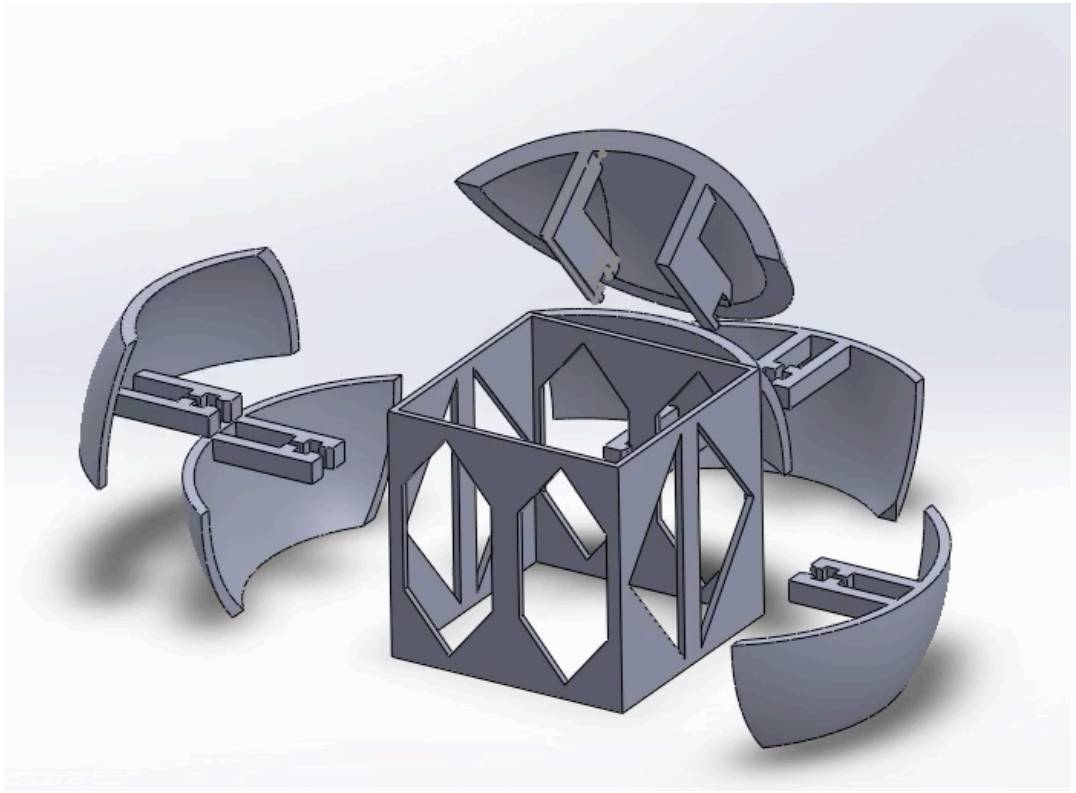
Interlocking Keys vs. Snap Fits





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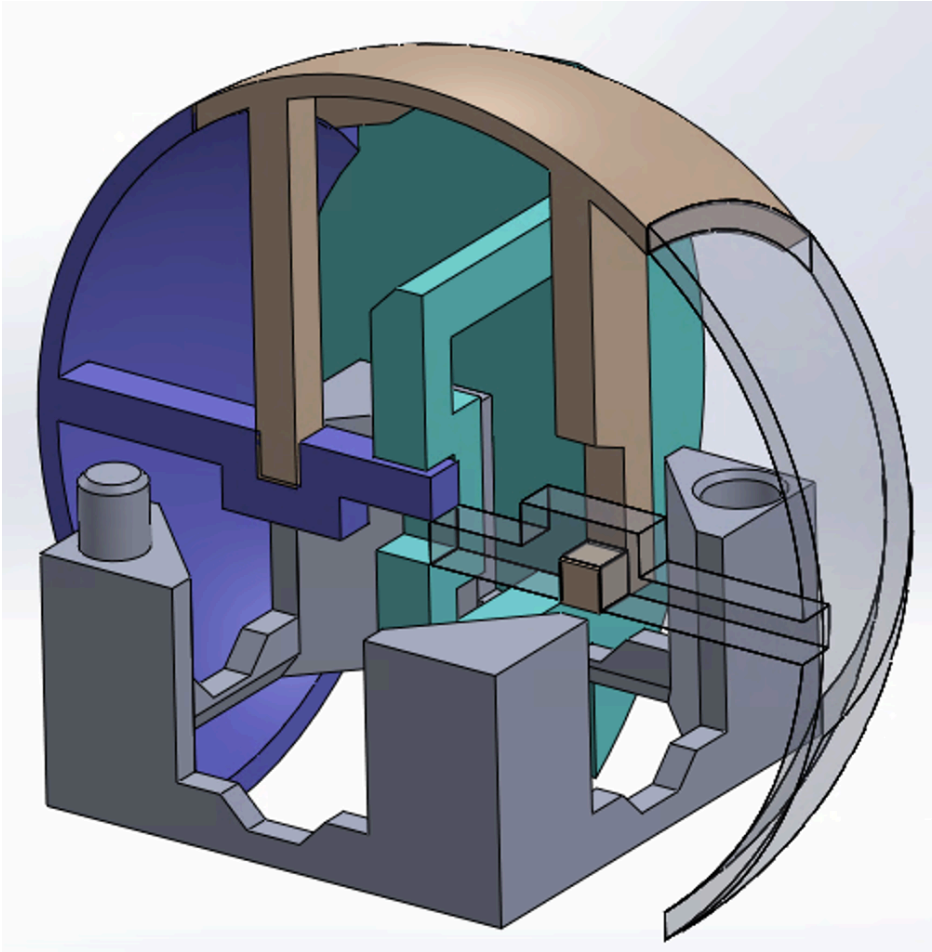
Heuristics Learned from Case

- Lay partitions in different directions w.r.t. printing direction
- Minimize the need for joining operations by self-locking
  - Cutting planes perpendicular to loads
  - Orthogonal keys



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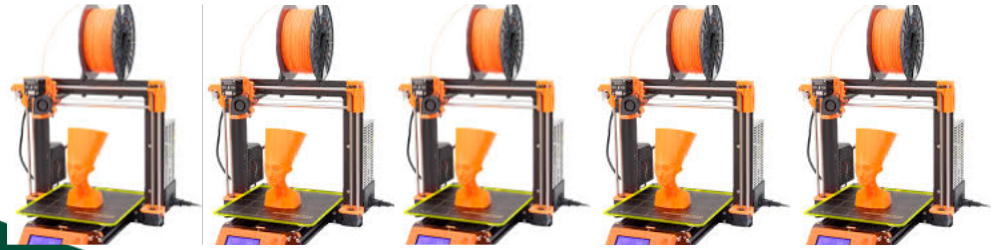
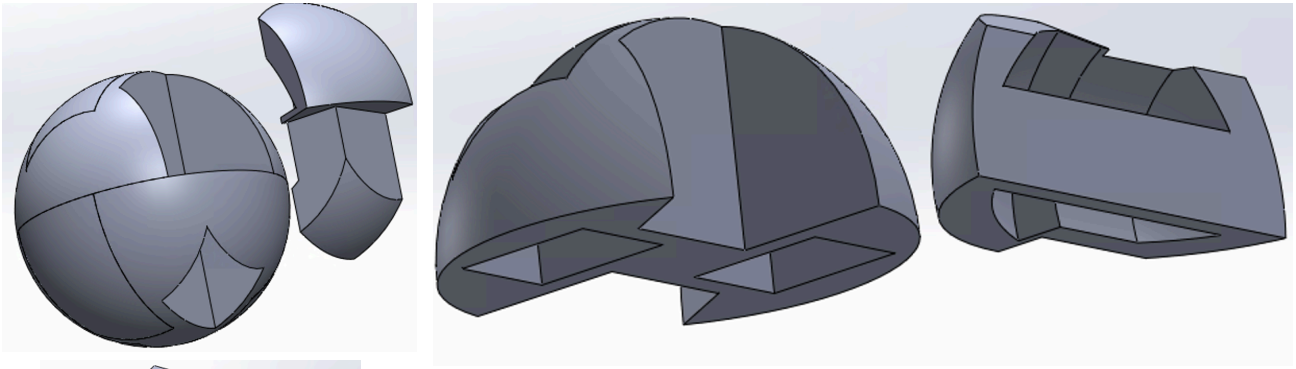
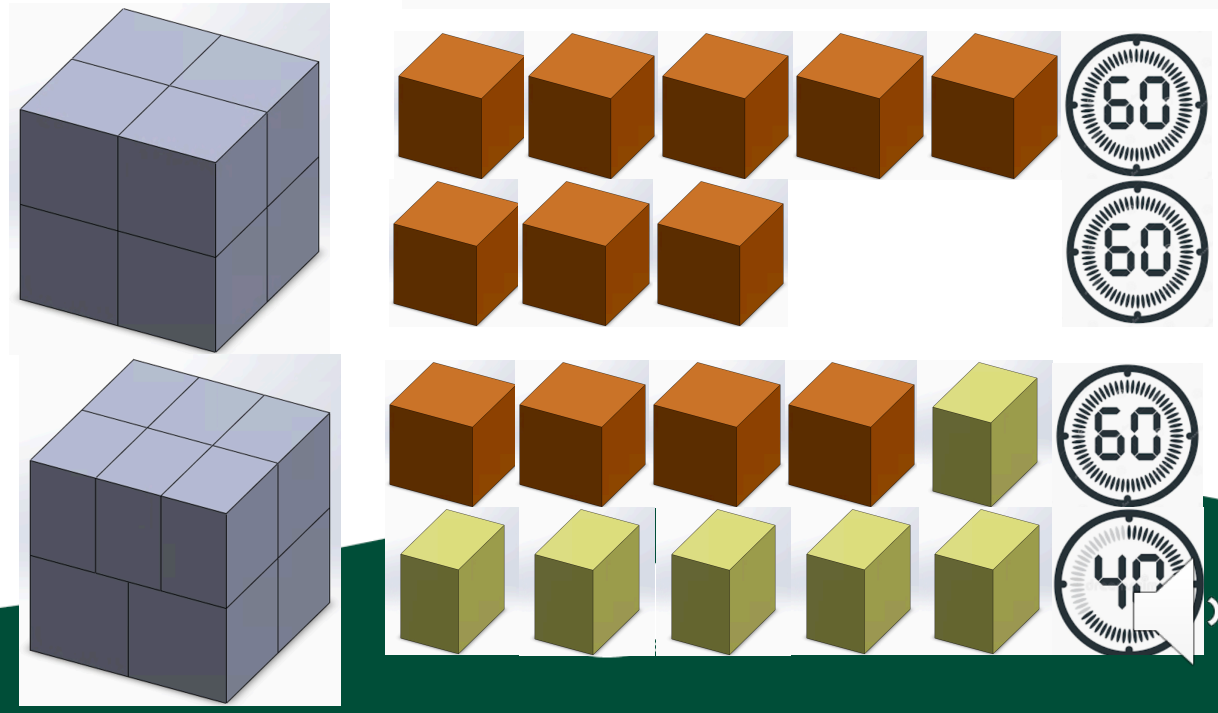
Heuristics Learned from Case

- Place plane reaching the outer surface on baseplate and hollow out perpendicular to the partitioning plane
- Minimize fabrication time by minimizing differences among volumes of partitions

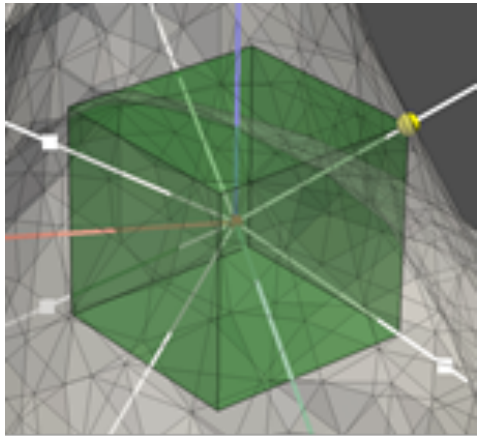


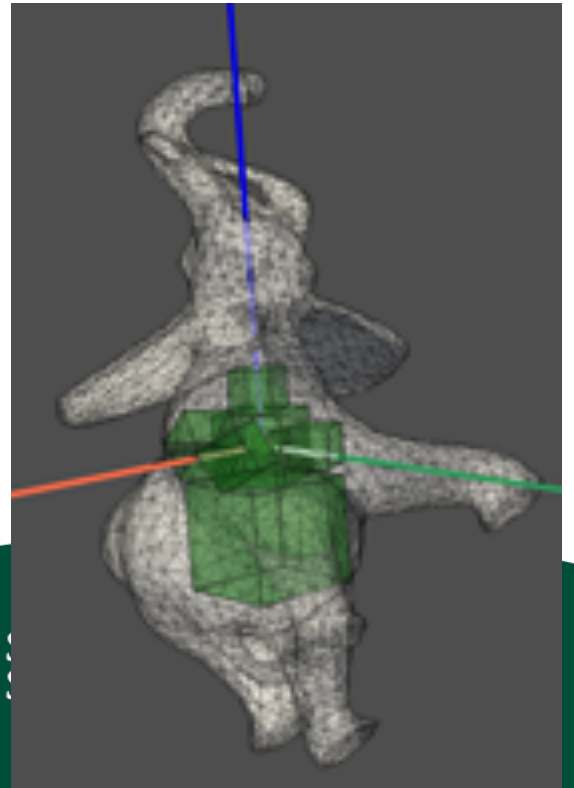




New Algorithm: Skeletonization with Cube Packing and Surface Shell Segmentation

1. Aligning the body along principal axes
2. Constructing the **maximally inscribed base cube** with rays passing through the origin intersecting with the closest facet of the mesh
3. Finding maximally inscribed surrounding cubes in remaining regions
4. *Surface segmentation along planes of skeleton cubes (incomplete)*
5. *Attaching surface shells to skeletons (incomplete)*

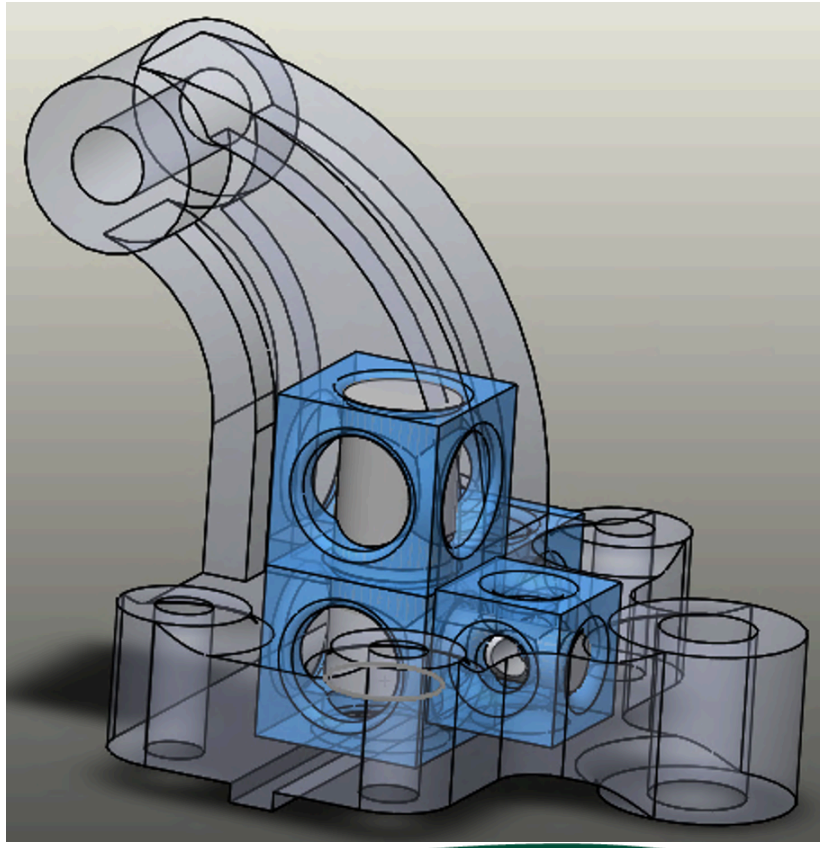




Limitations and Future Work

- Simple case of cubes has low packing efficiency compared to cuboids
- Accuracy of joining seams on surfaces not considered

- Order of heuristics/rules
- Effect of partitioning on deviations for process (shrinkage)
- Partitioning based on machine availability
- Discrete prefab cuboid skeleton base



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