


THE PREMIER CONFERENCE & EXHIBITION ON
COMPUTER GRAPHICS & INTERACTIVE TECHNIQUES

LOCALLY MESHABLE FRAME FIELDS

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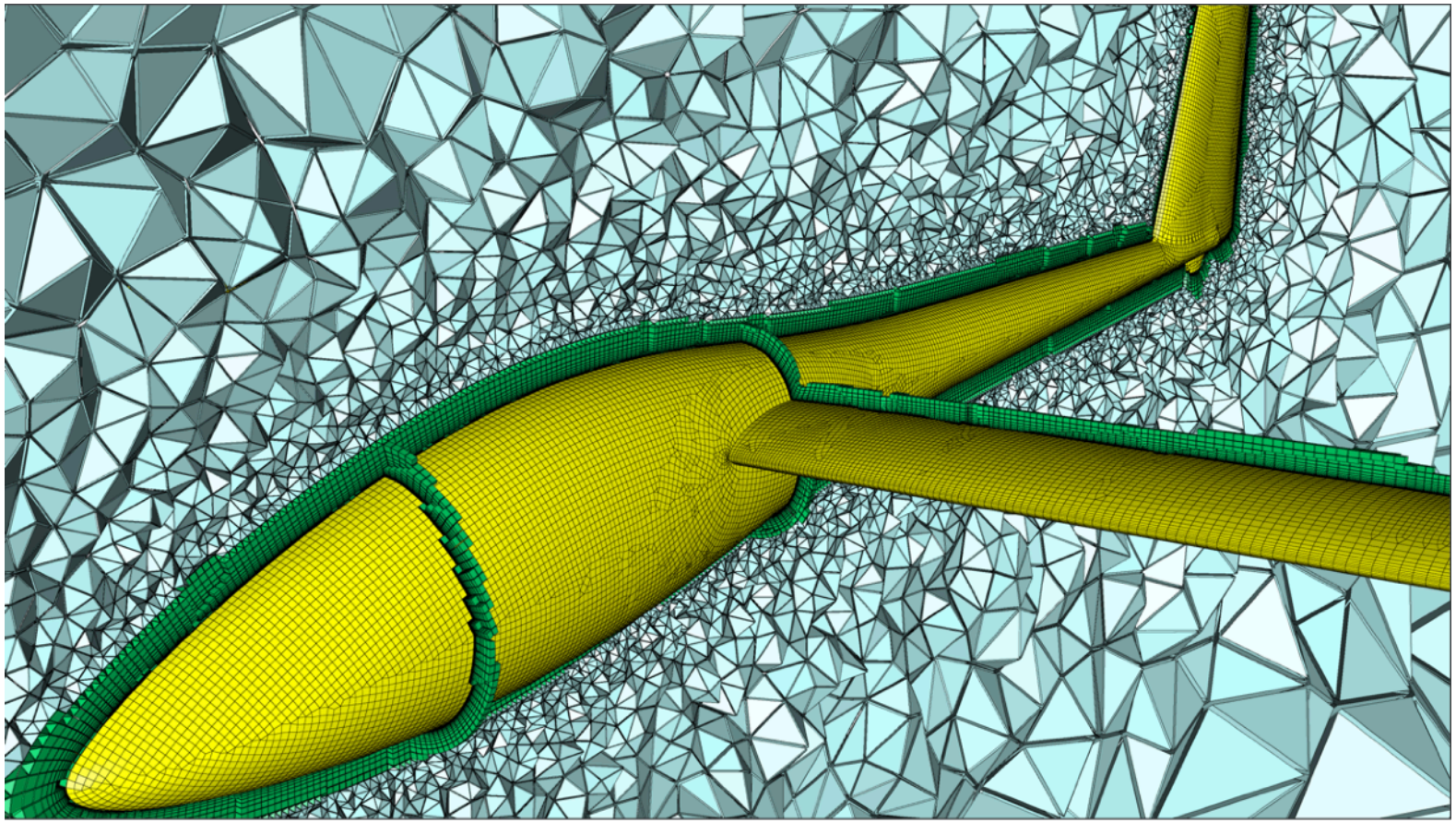
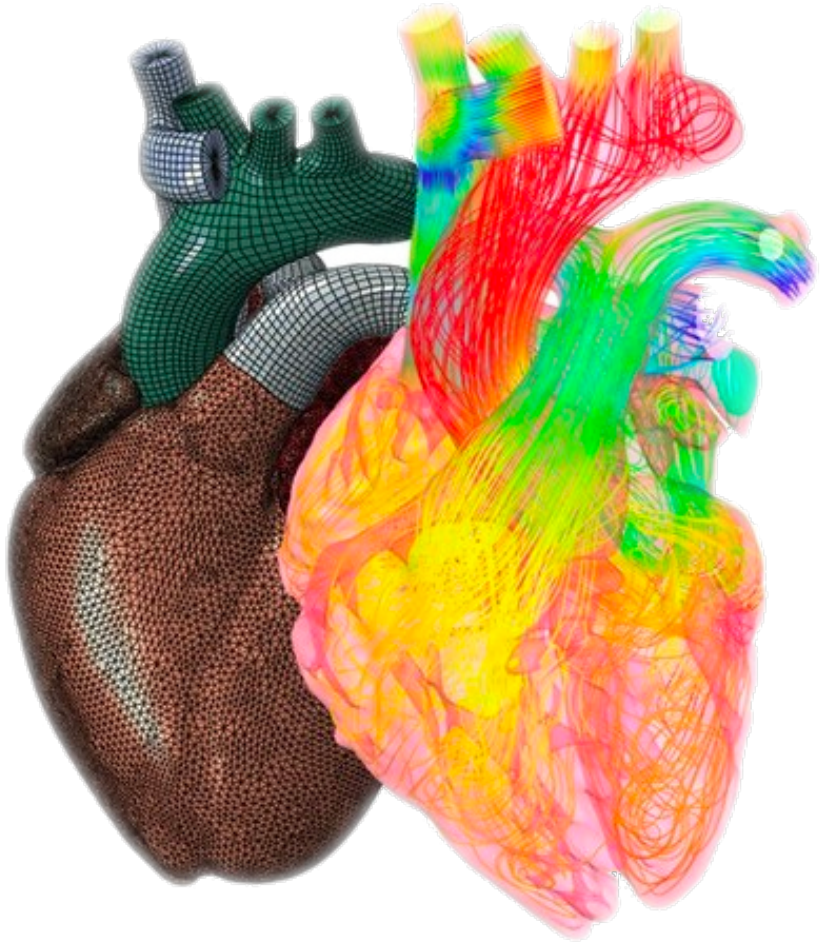
CONTEXT



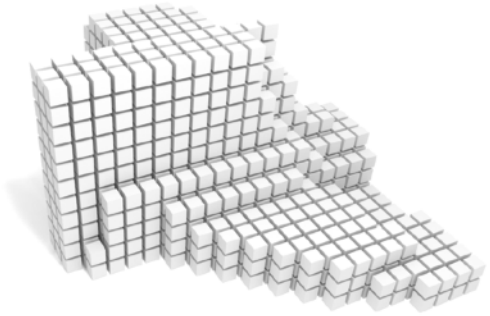
[© Cadence]

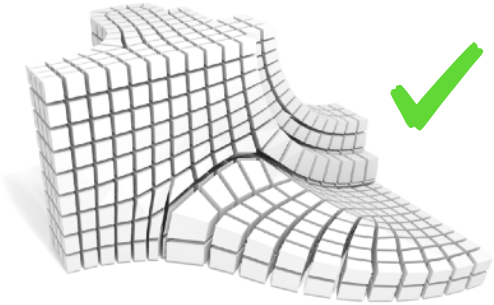


[© FlowVision]

HEX MESH QUALITY

- Geometric Fidelity





HEX MESH QUALITY

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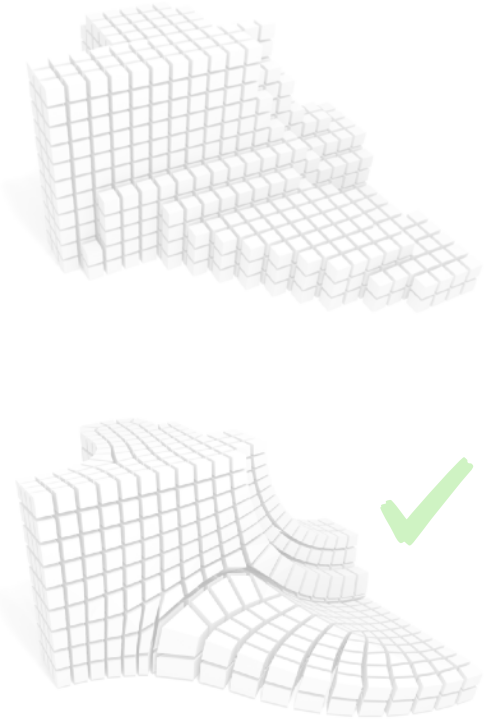
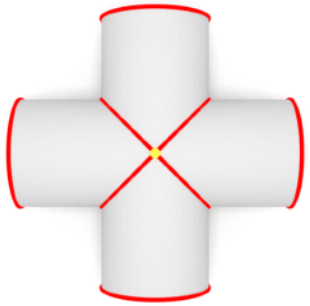
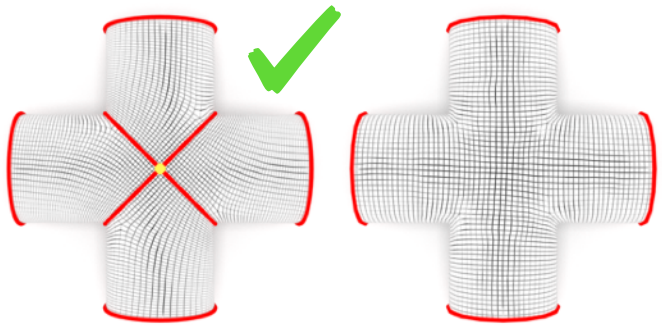


- Feature preservation



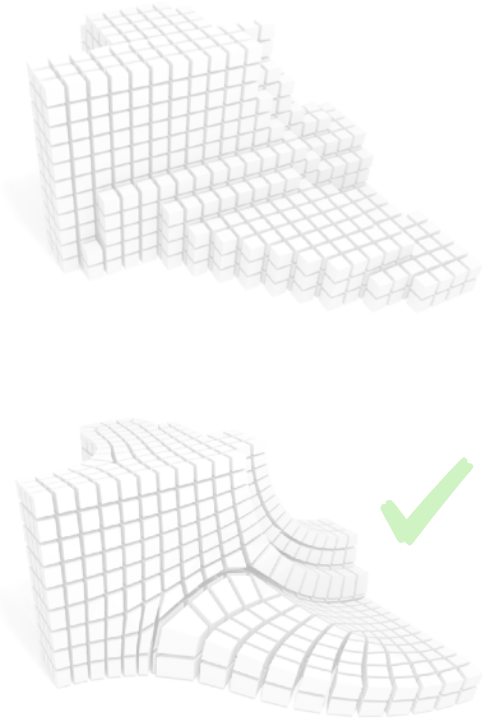
Input shape



Output hex mesh 1 Output hex mesh 2

HEX MESH QUALITY

- Geometric Fidelity

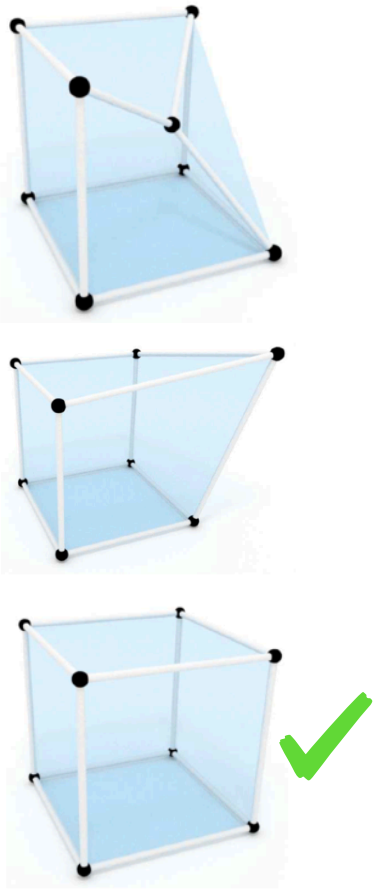


- Feature preservation

Input shape

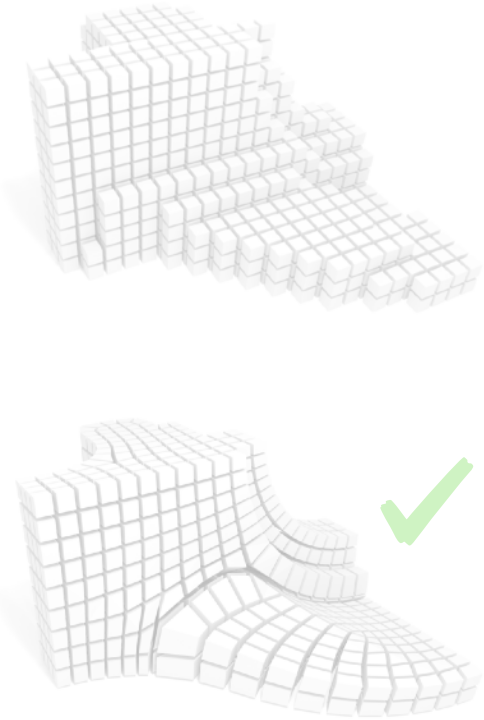
Output hex mesh 1 Output hex mesh 2

- Element quality



HEX MESH QUALITY

- Geometric Fidelity

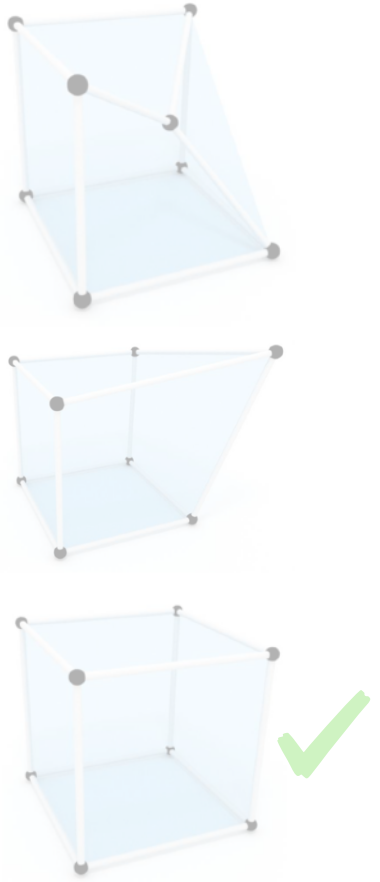


- Feature preservation

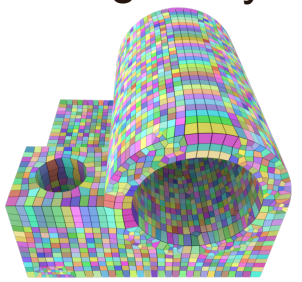
Input shape

Output hex mesh 1 Output hex mesh 2

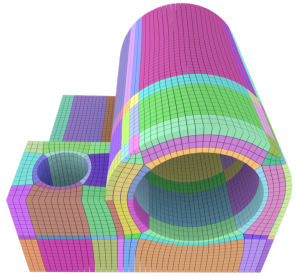
- Element quality



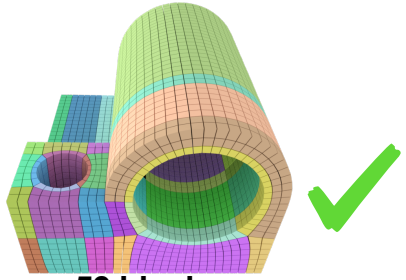
- Regularity



16945 blocks

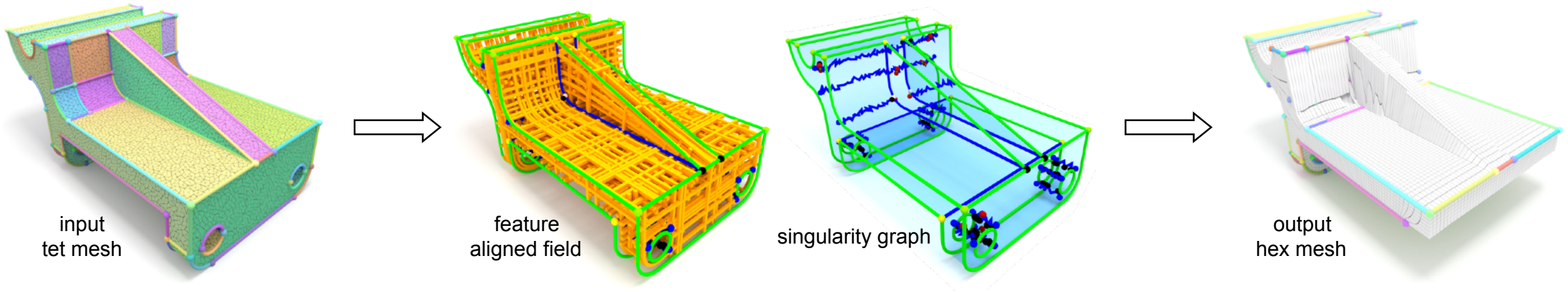


155 blocks

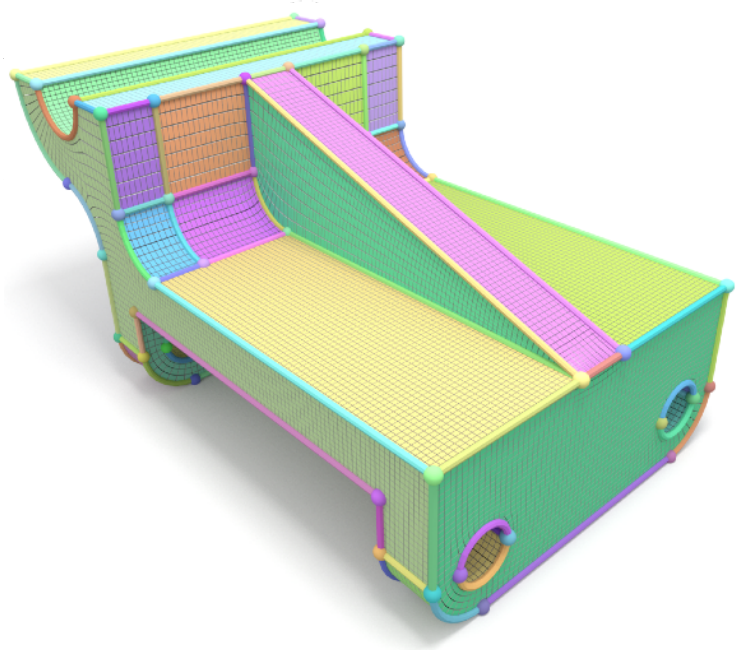


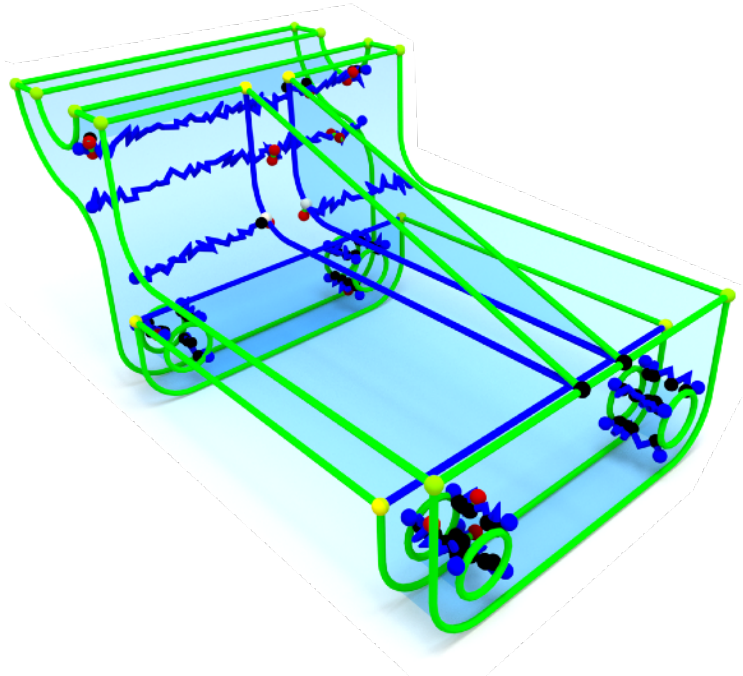
59 blocks

FRAME FIELD BASED HEX MESHING



PROBLEM

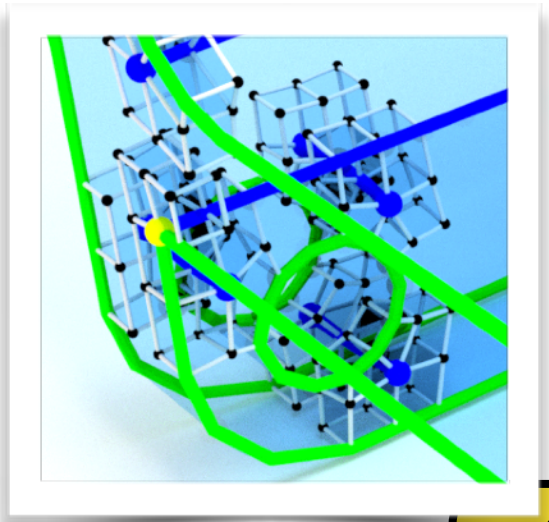


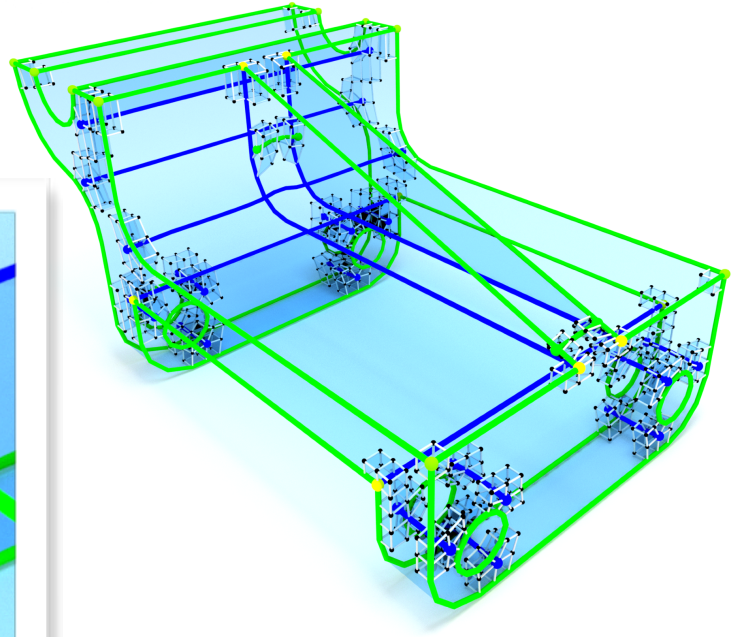


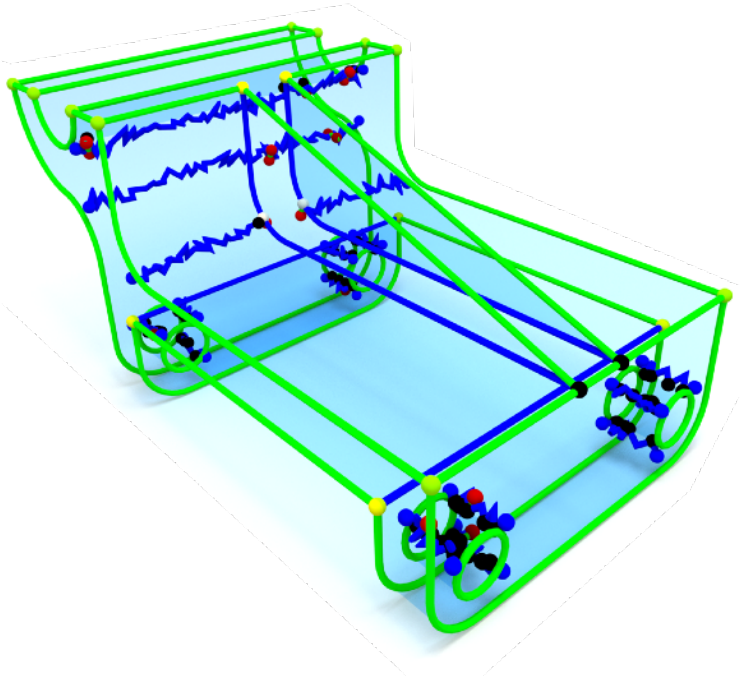
Locally Meshable Frame Fields

Frame Fields

GOAL



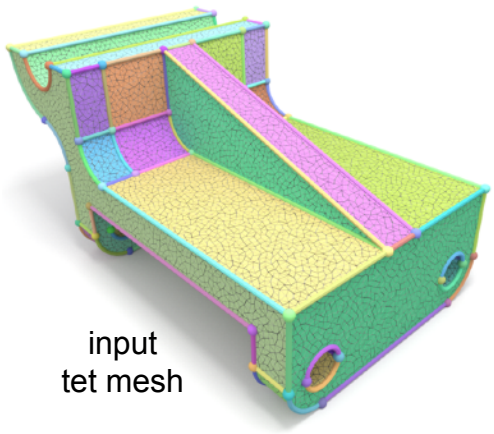


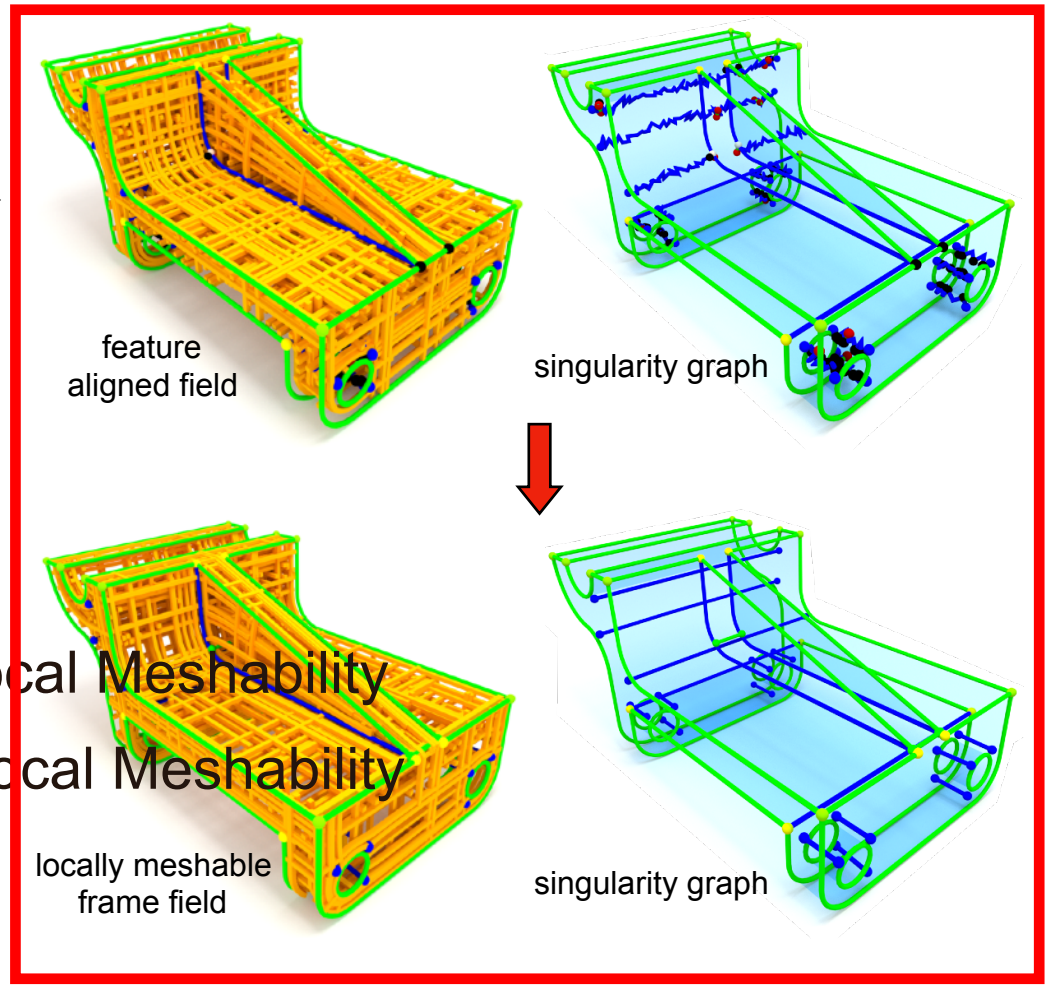


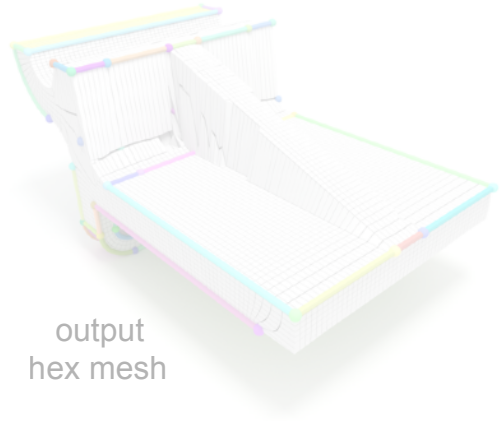
Locally Meshable Frame Fields

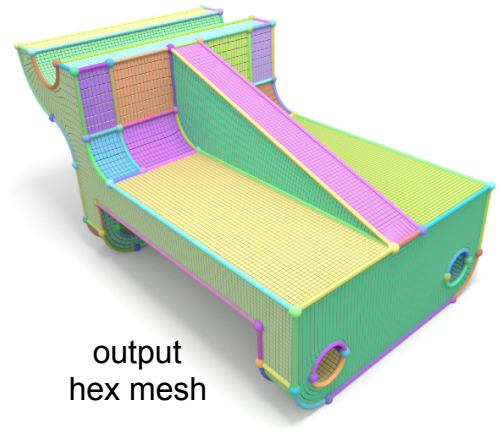
Frame Fields

CONTRIBUTIONS





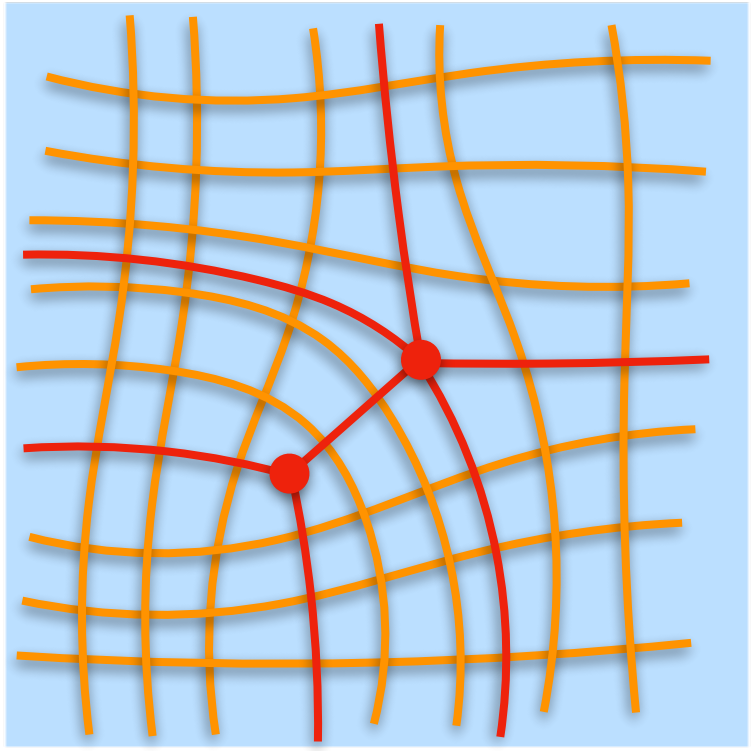




- Characterization of Local Meshability
- Algorithm to ensure Local Meshability

Frame Field Meshability 2D

QUAD MESH VS. FRAME FIELD TOPOLOGY

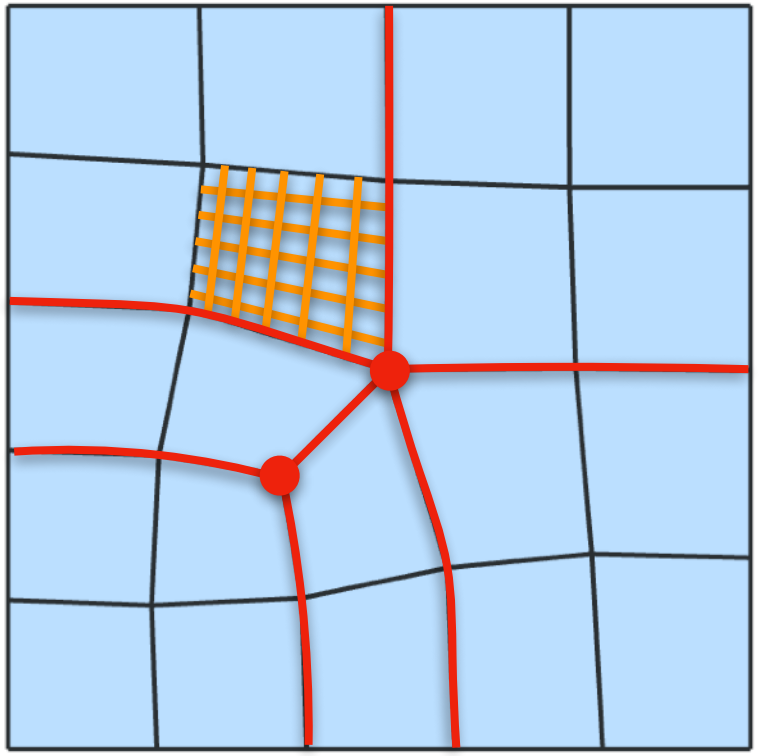


Induced Field

always

sometimes

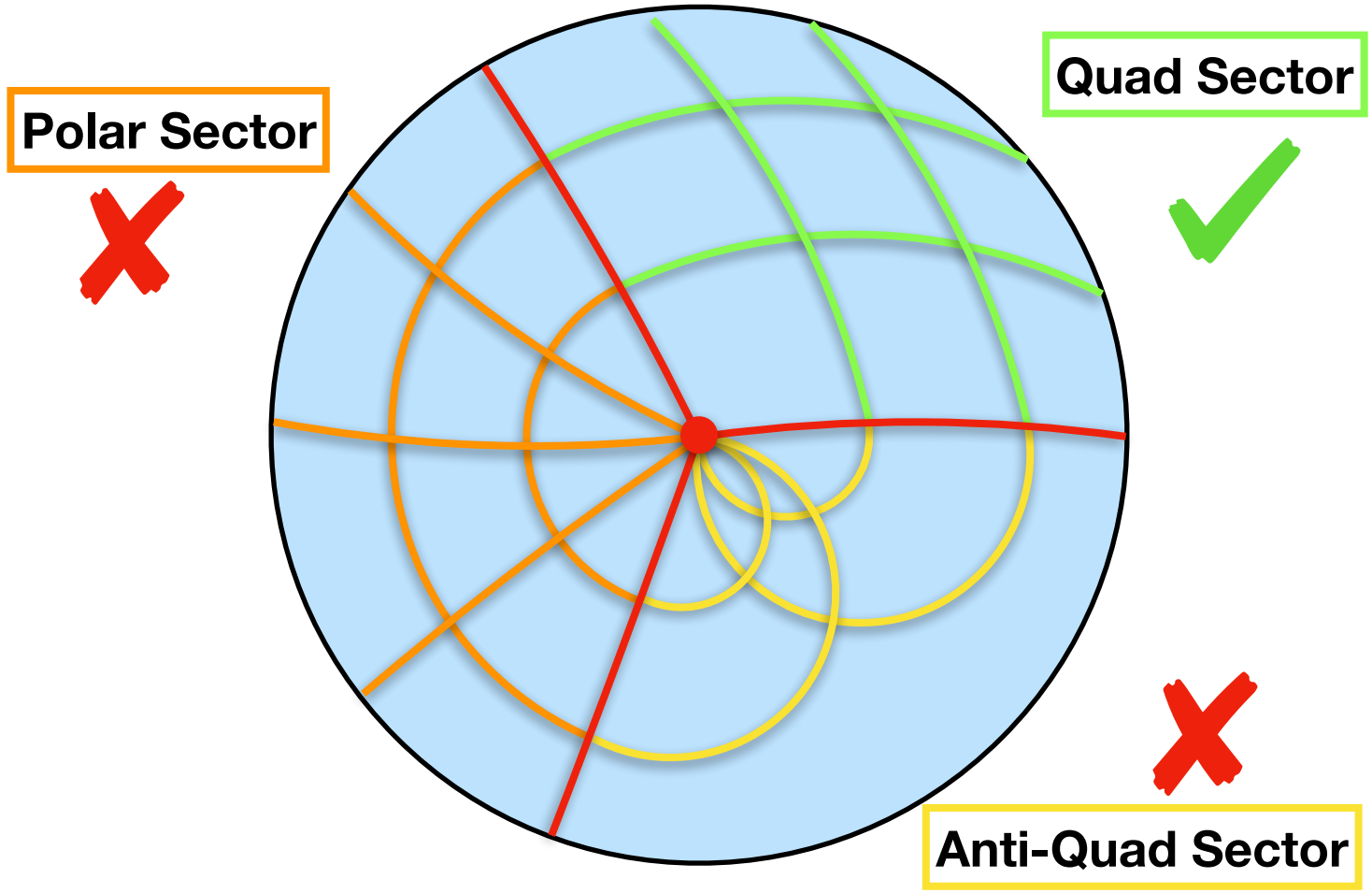
Meshability



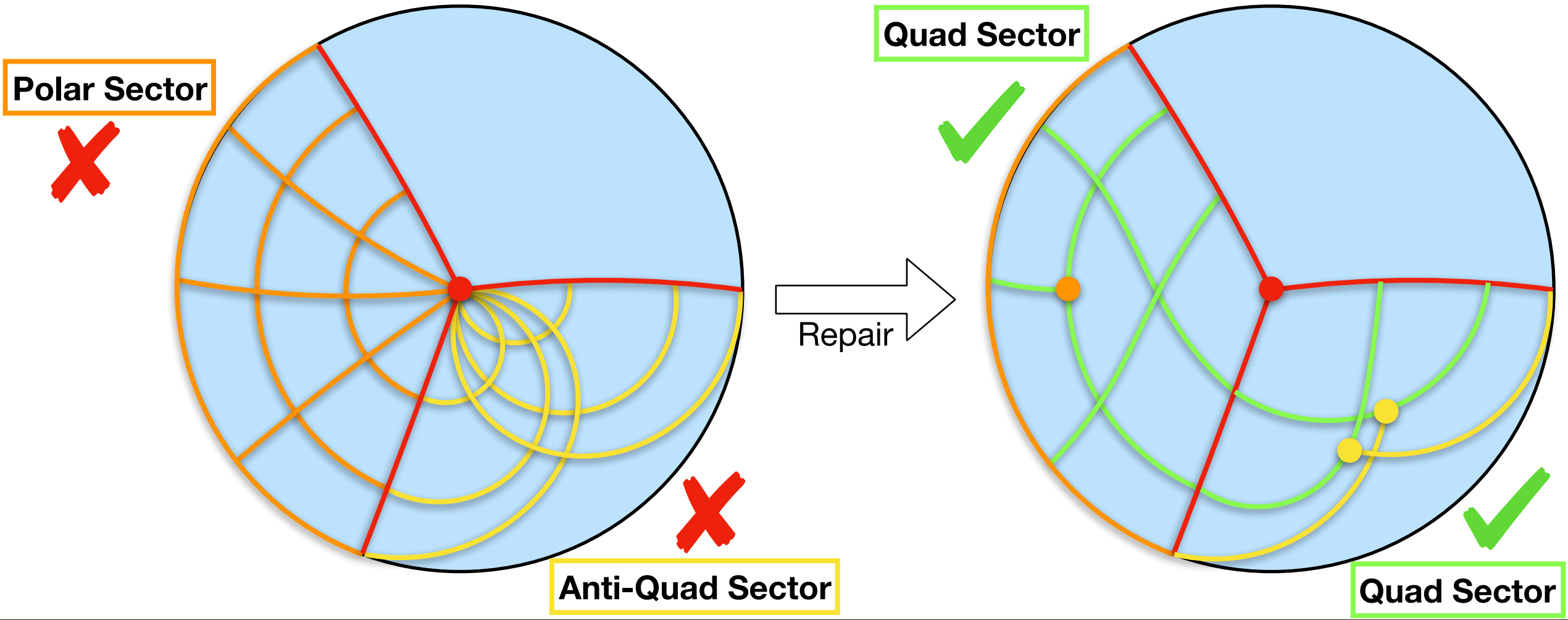
Frame Field

Quad Mesh

LOCAL MESHABILITY CONDITION

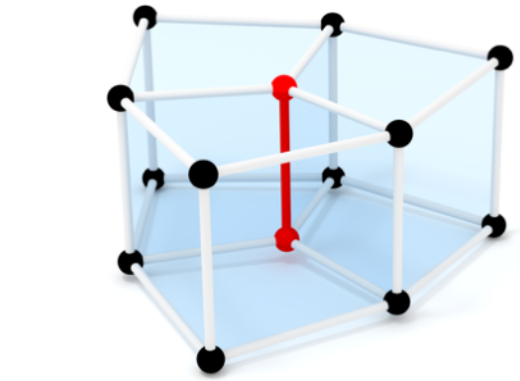


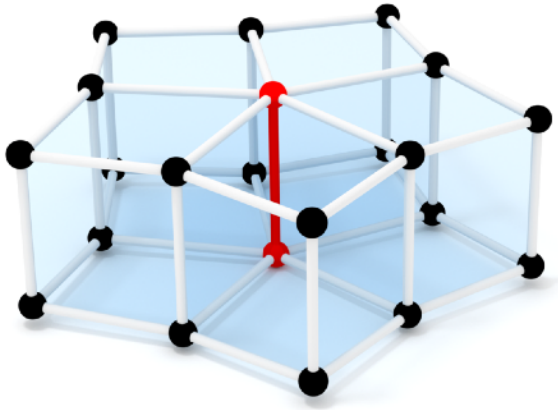
LOCAL MESHABILITY REPAIR

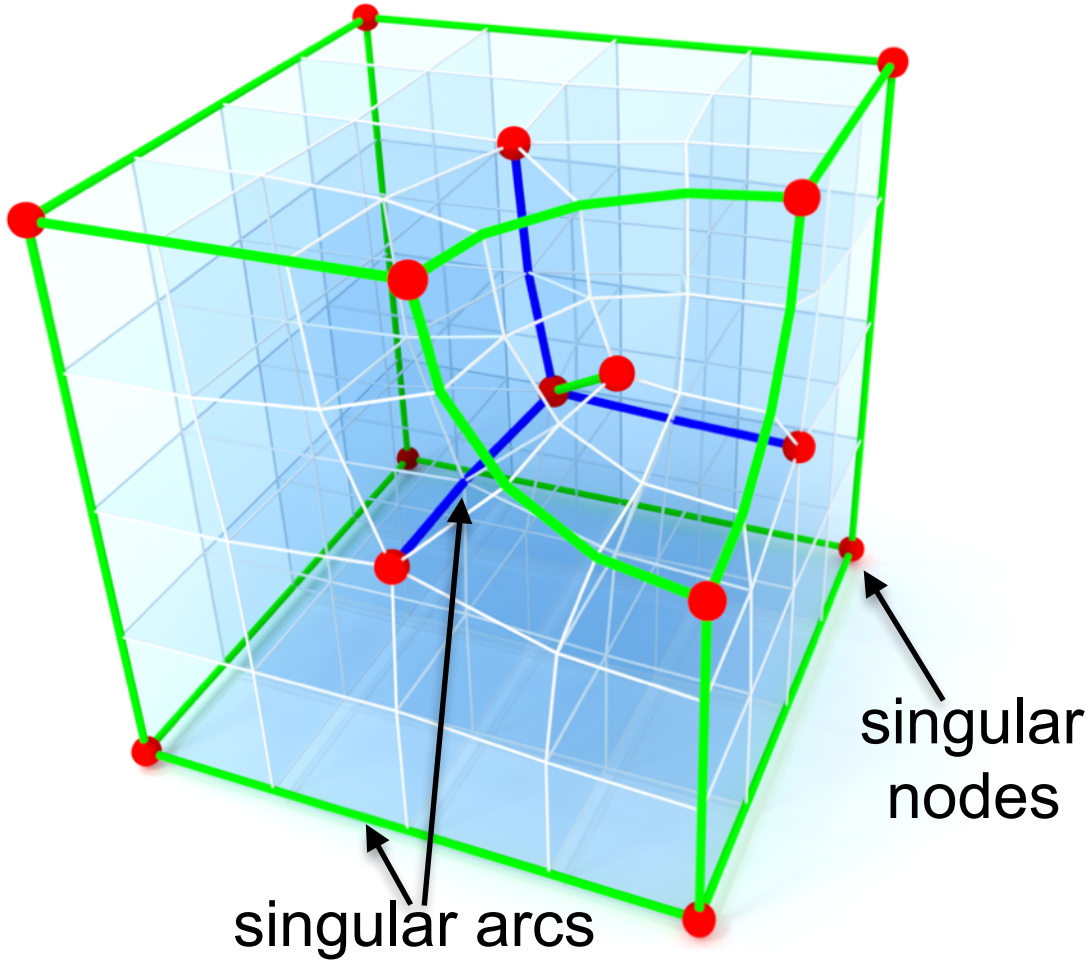


Frame Field Meshability 3D

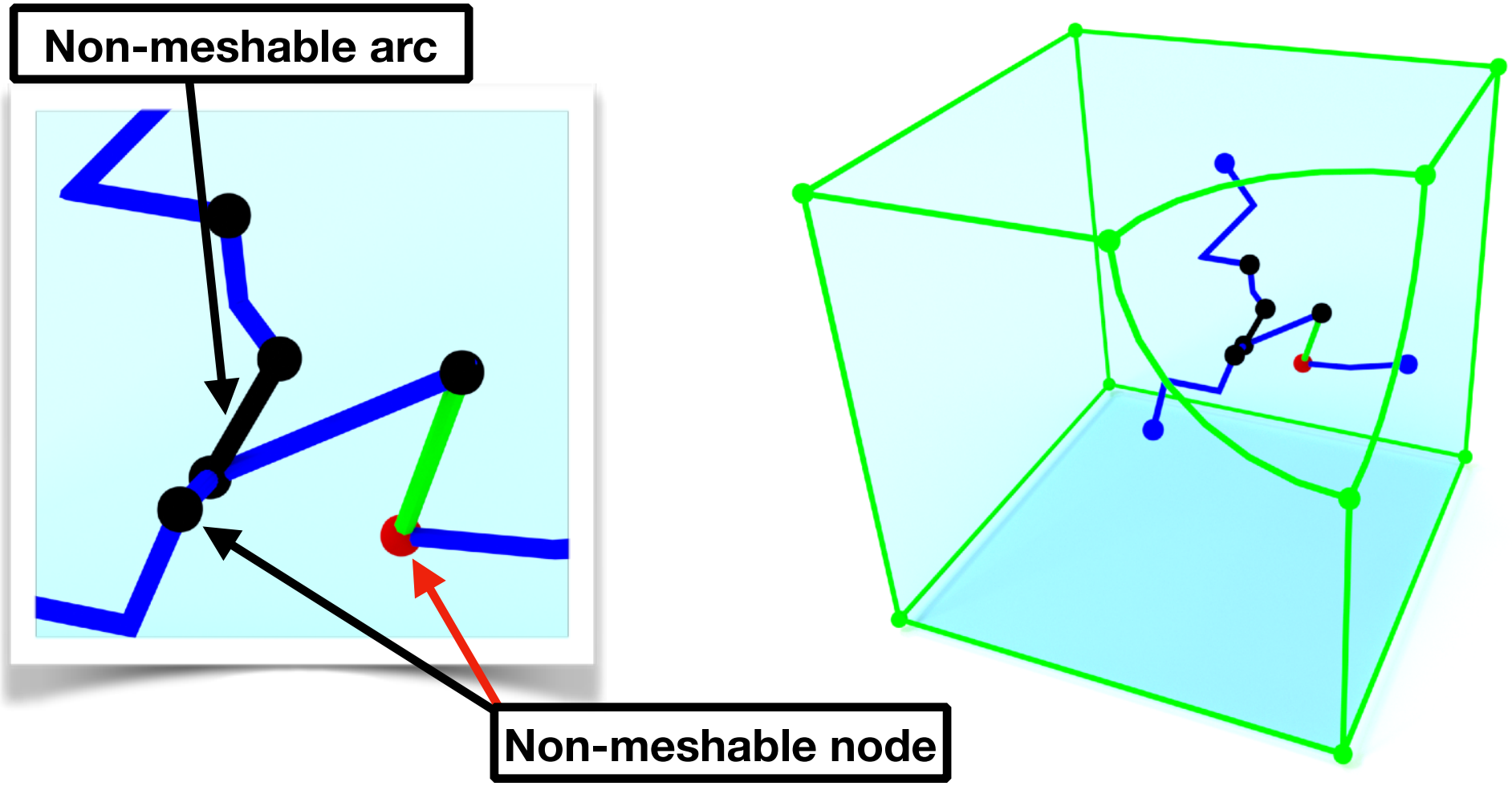
HEX MESH SINGULAR GRAPH







FRAME FIELD SINGULARITIES



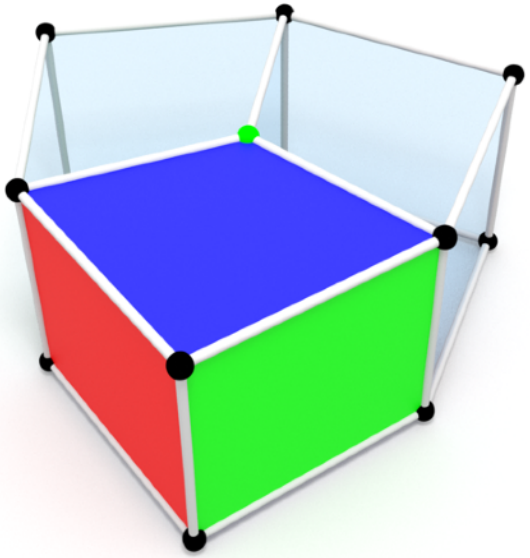
Algorithm

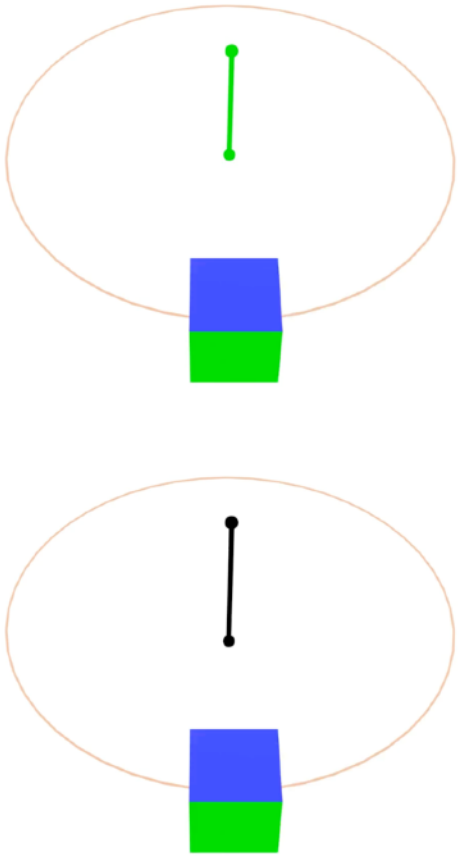
1. Repair non-meshable **arcs**
2. Repair non-meshable **nodes**

Arc Meshablity

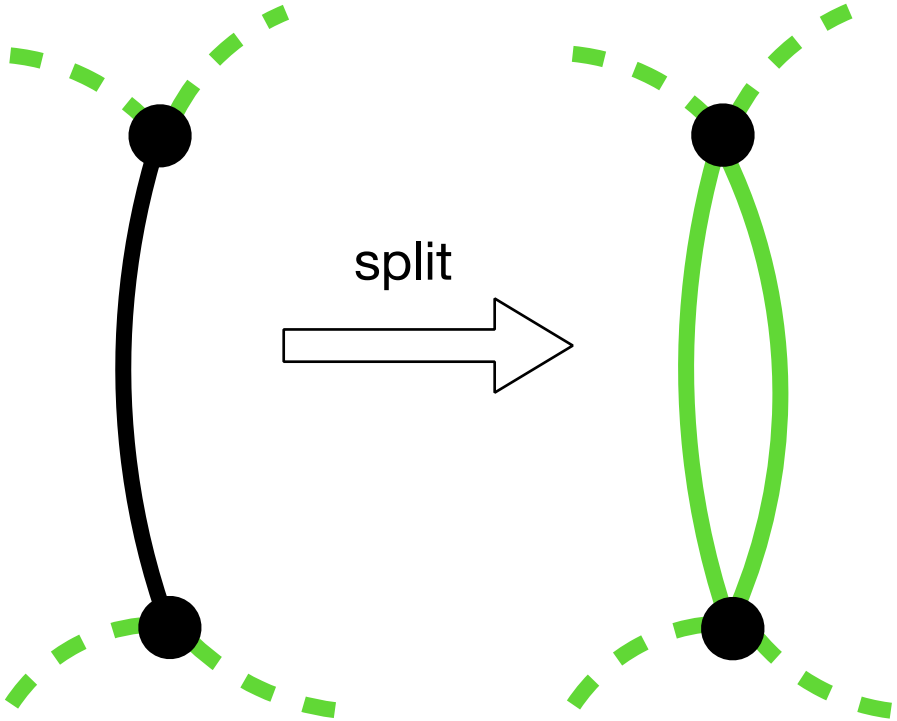
ARC MESHABILITY

- Non-meshable Monodromy



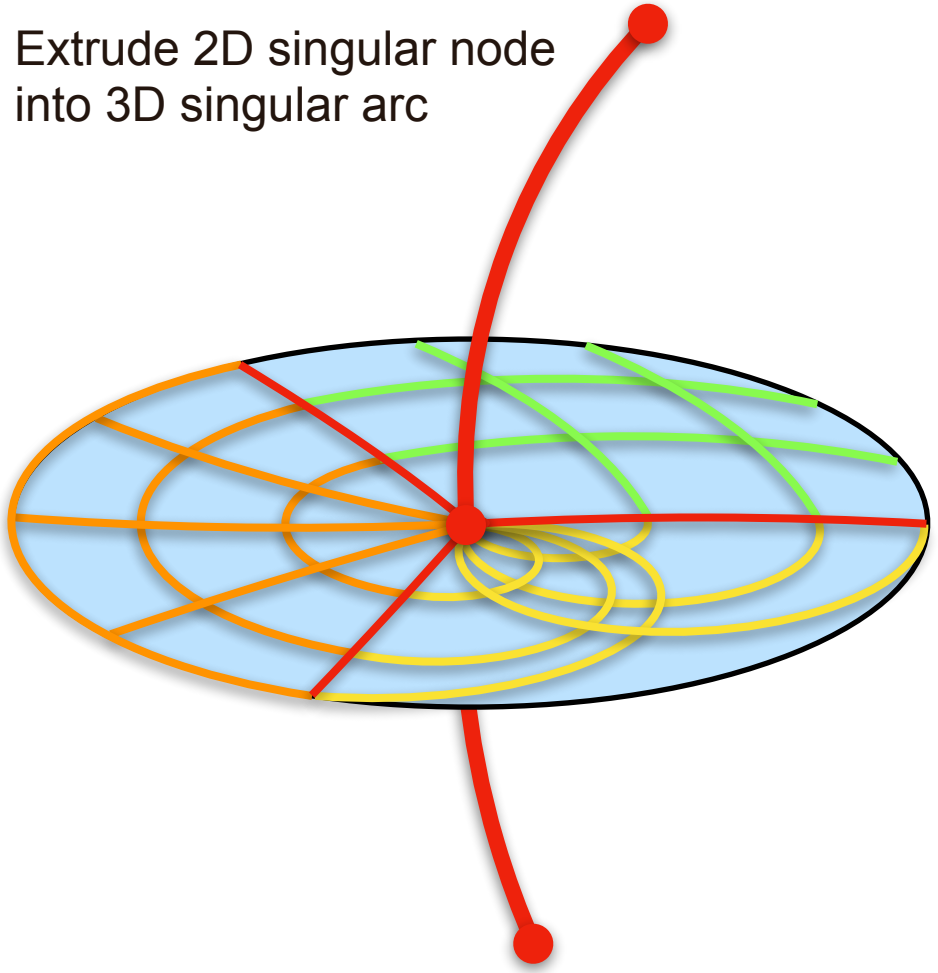


- Repair
  - always splittable into two flow-aligned arcs [Jiang et al. 2014]



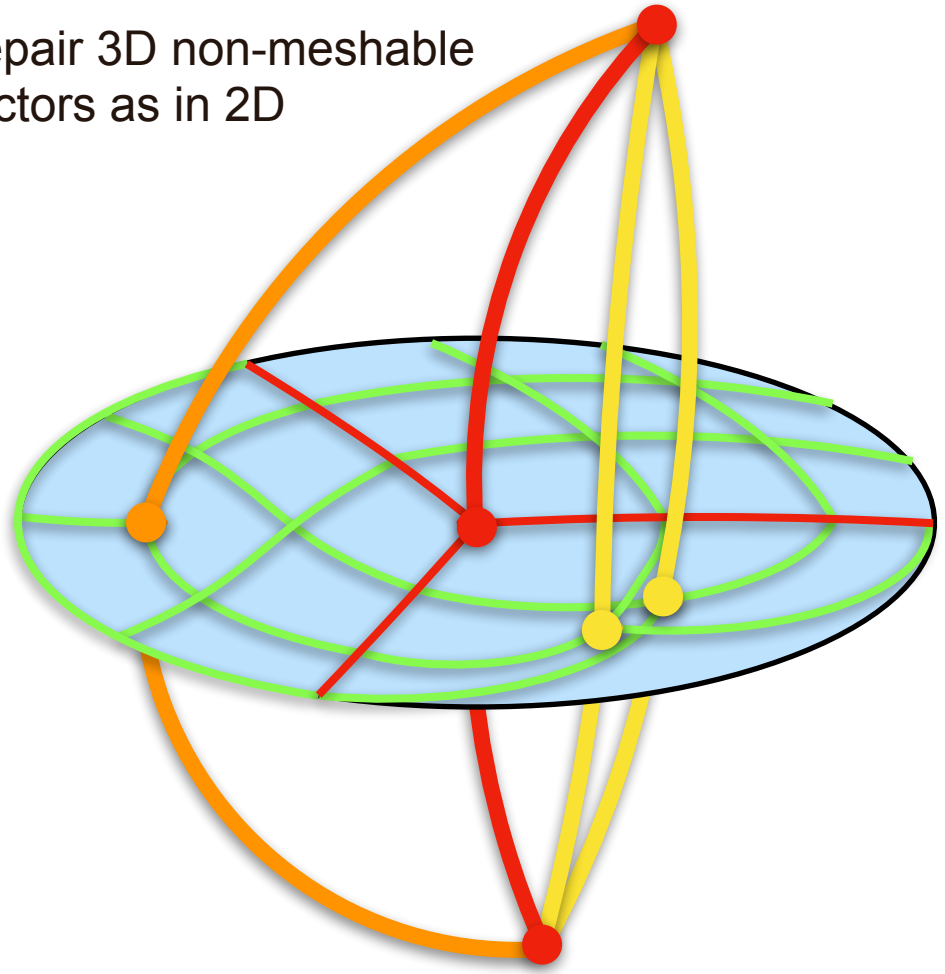
FLOW-ALIGNED SINGULAR ARCS

- Extrude 2D singular node into 3D singular arc



Repair

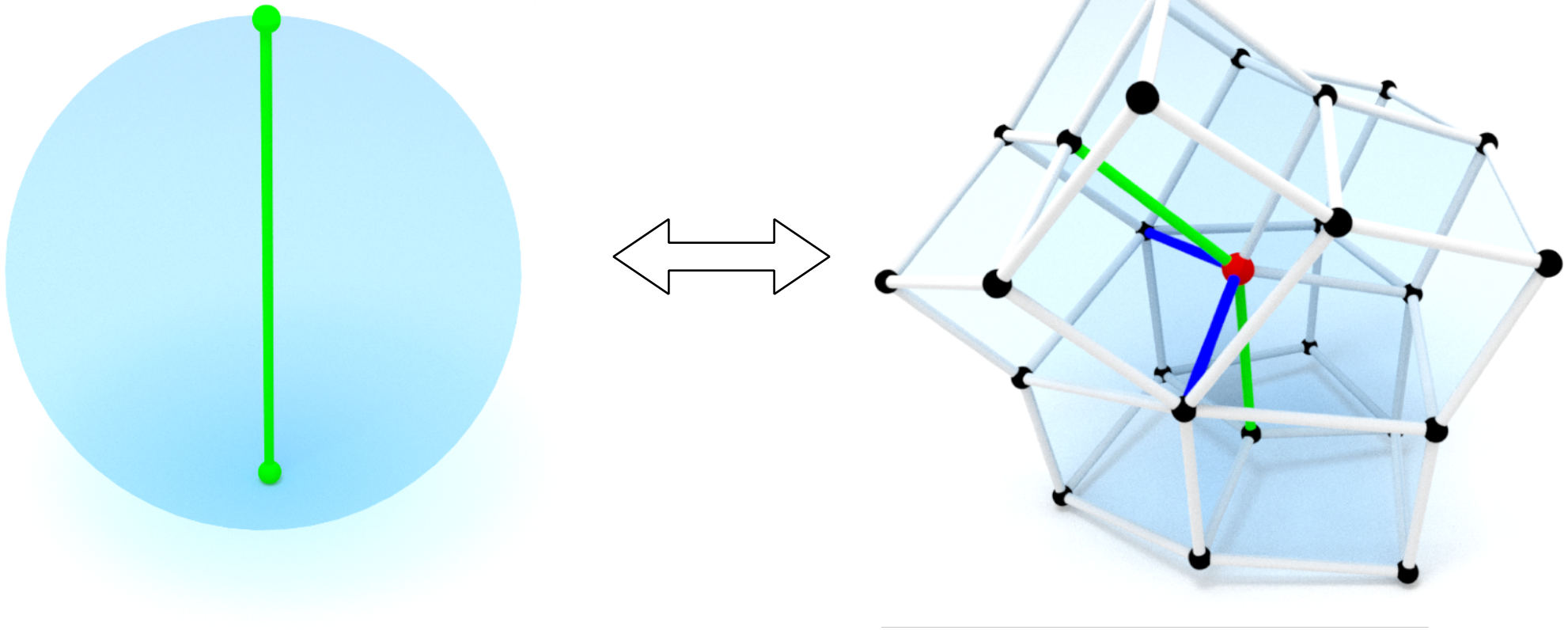
- Repair 3D non-meshable sectors as in 2D



Node Meshability

SINGULAR NODES

- Singular nodes result from the interaction between multiple singular arcs



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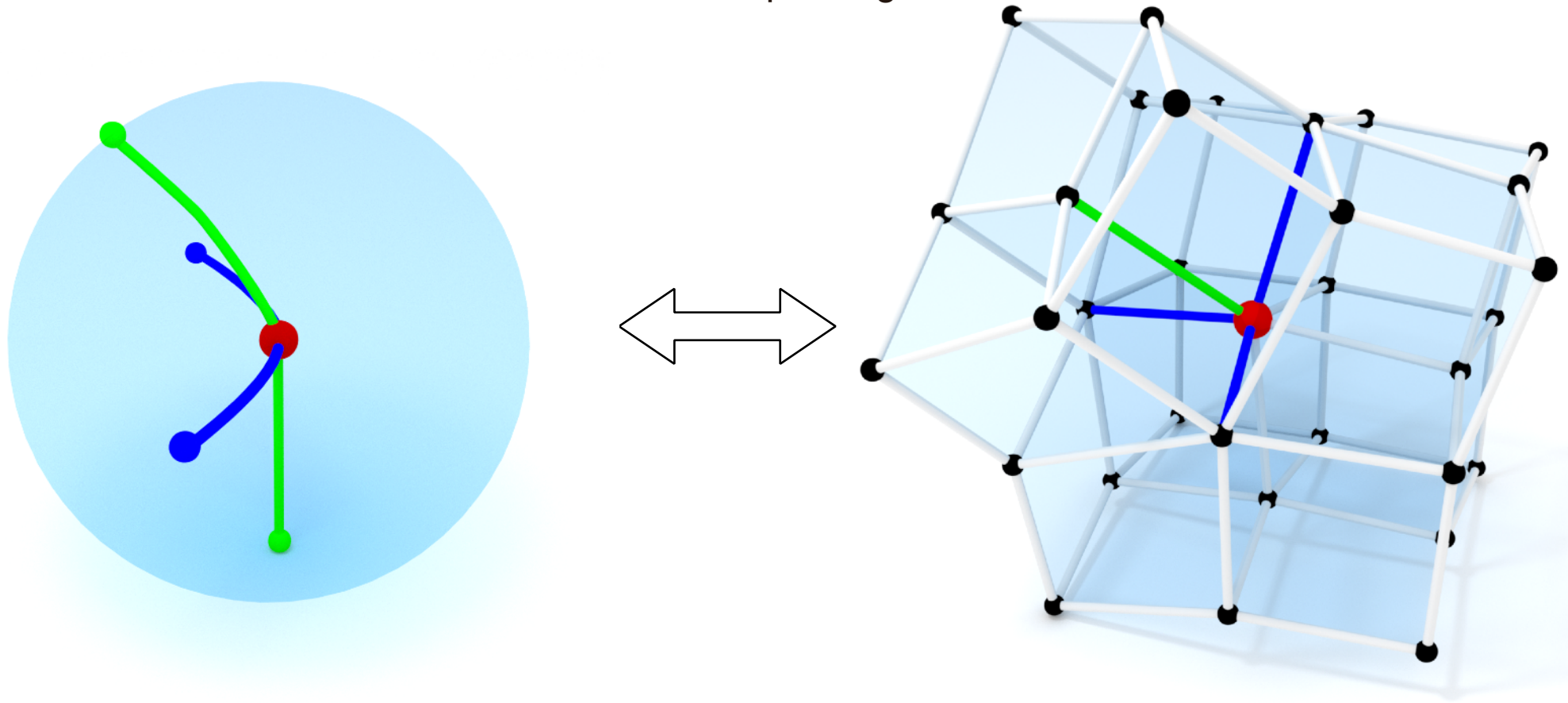
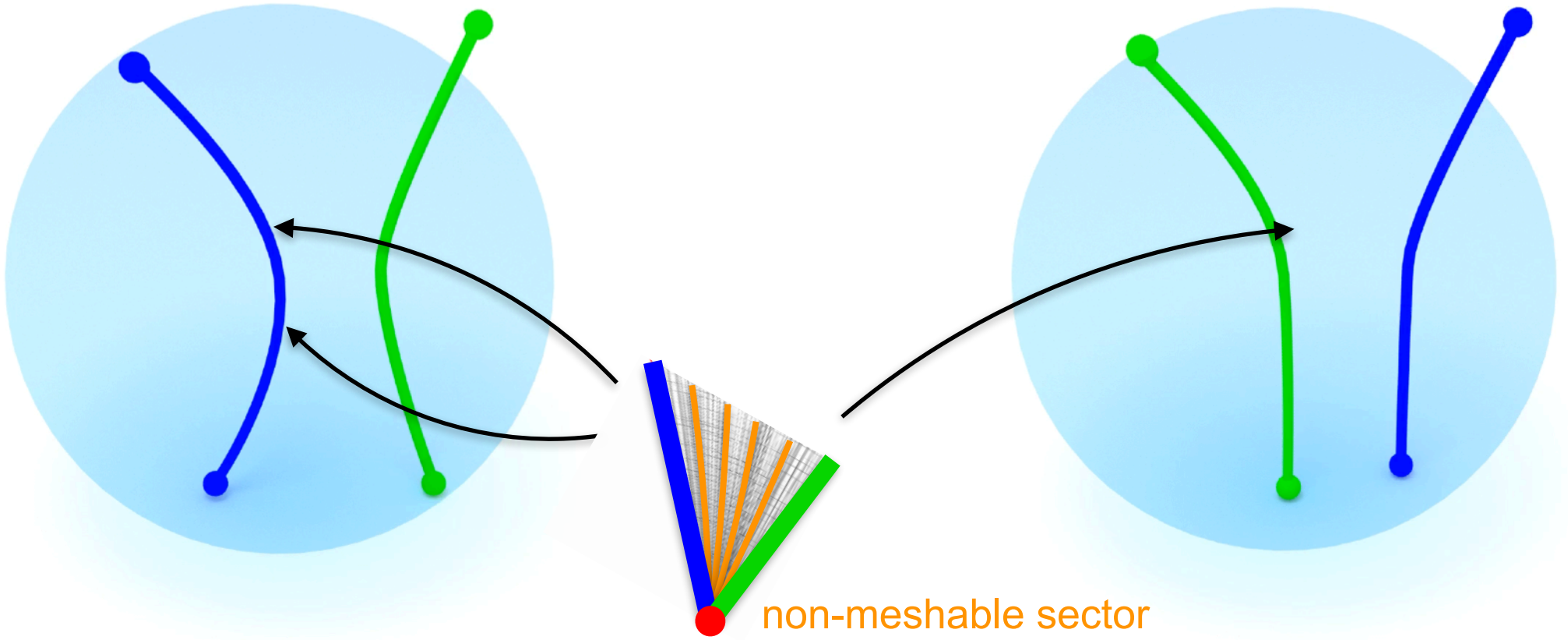


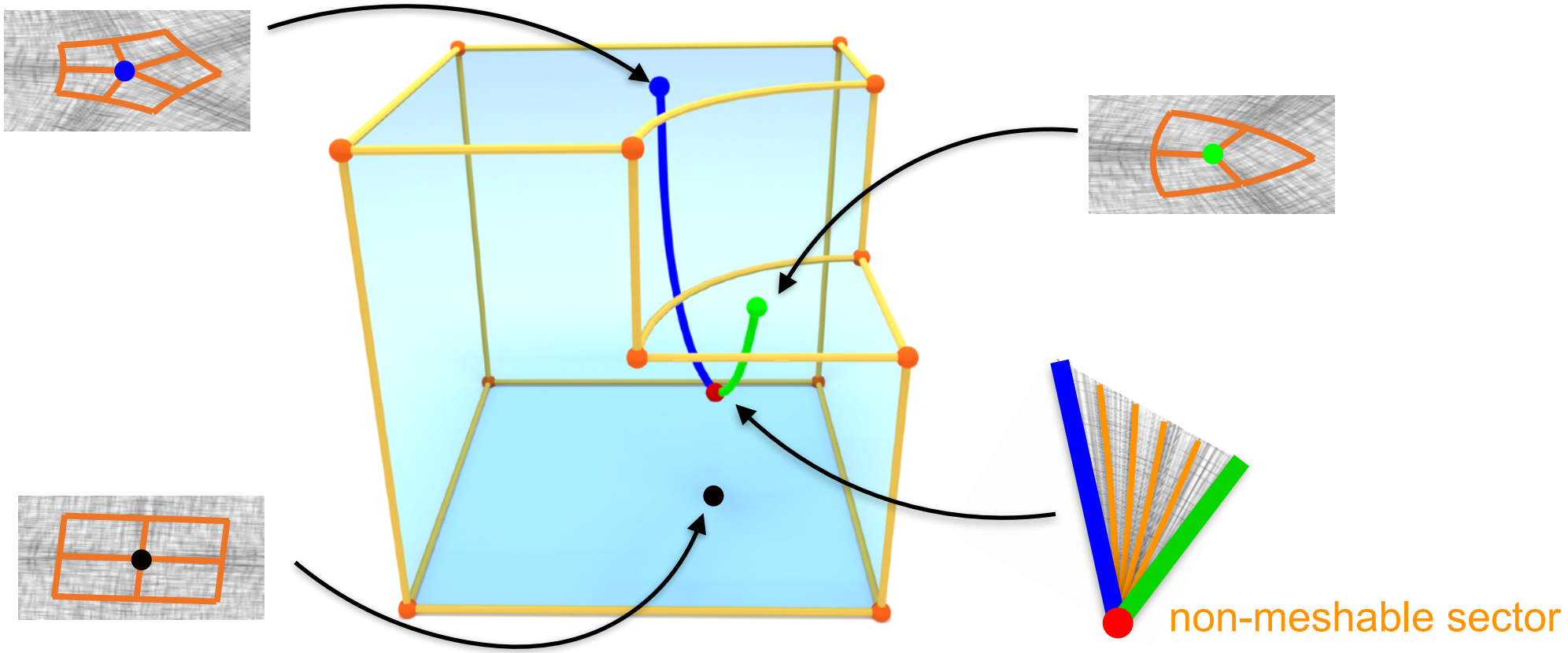
NON-MESHABLE INTERACTIONS

- Partial overlap of parallel arcs



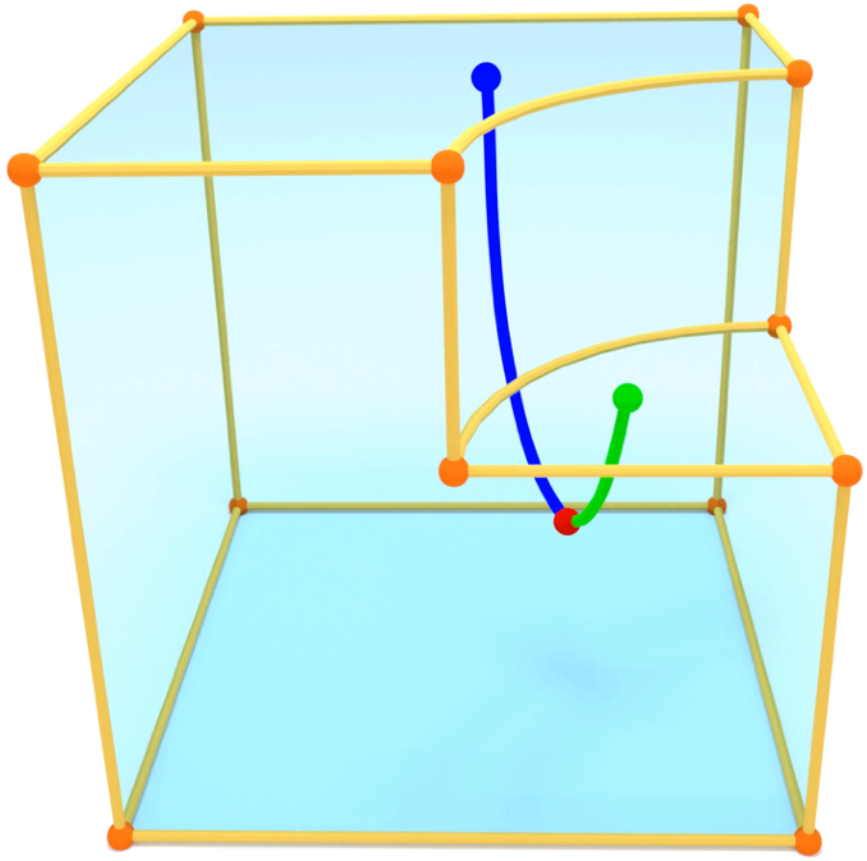
REPAIRING ZIPPER NODES

- Smoothest Fields contain non-meshable **Zipper Nodes**



REPAIRING ZIPPER NODES

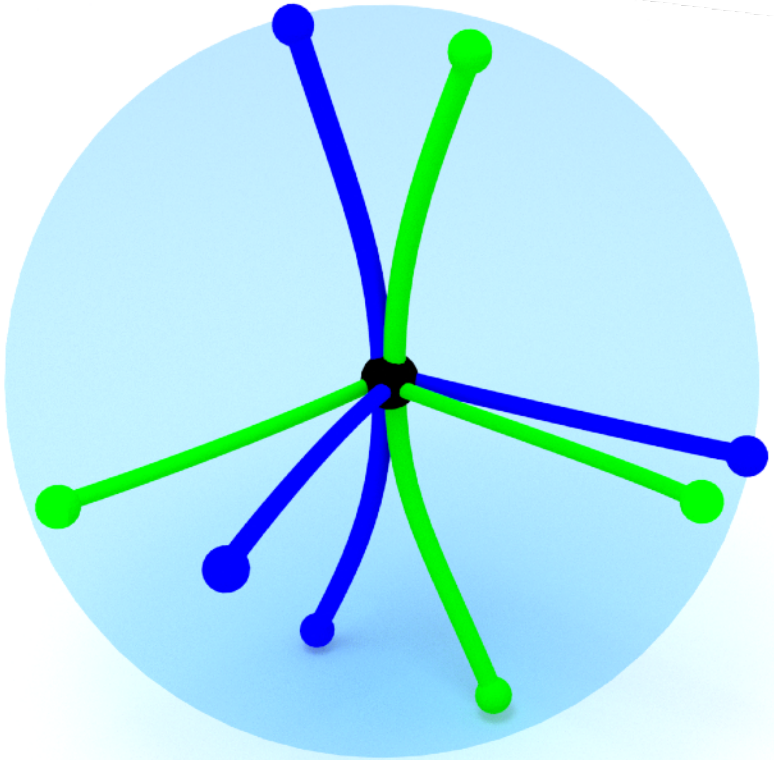
- Resolve partial overlap by **unzipping** along common streamline



REPAIRING GENERAL NODES

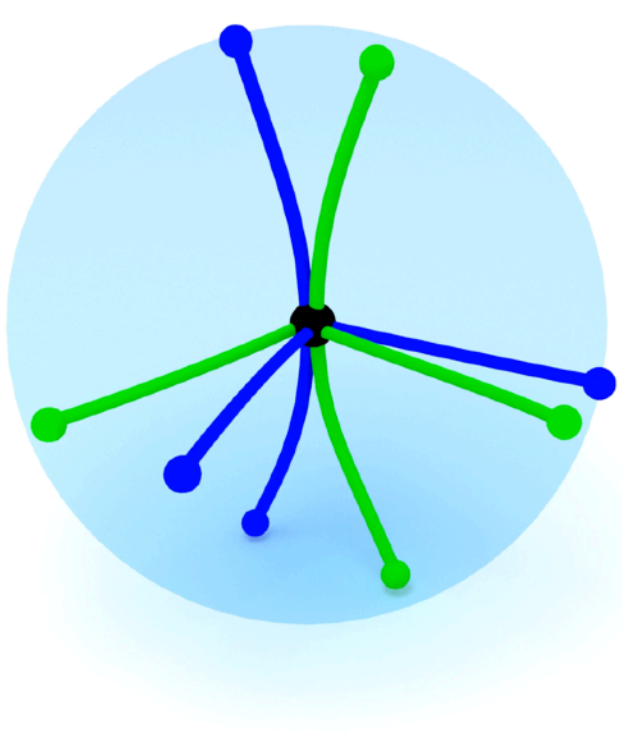
- **Decomposition Theorem**

  Every singular node can locally be decomposed into isolated singular arcs and zipper nodes.

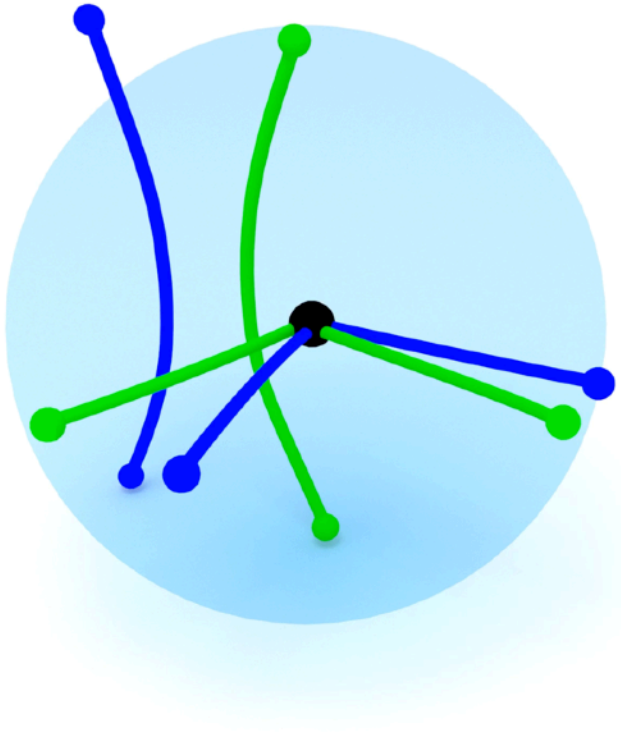


REPAIRING GENERAL NODES

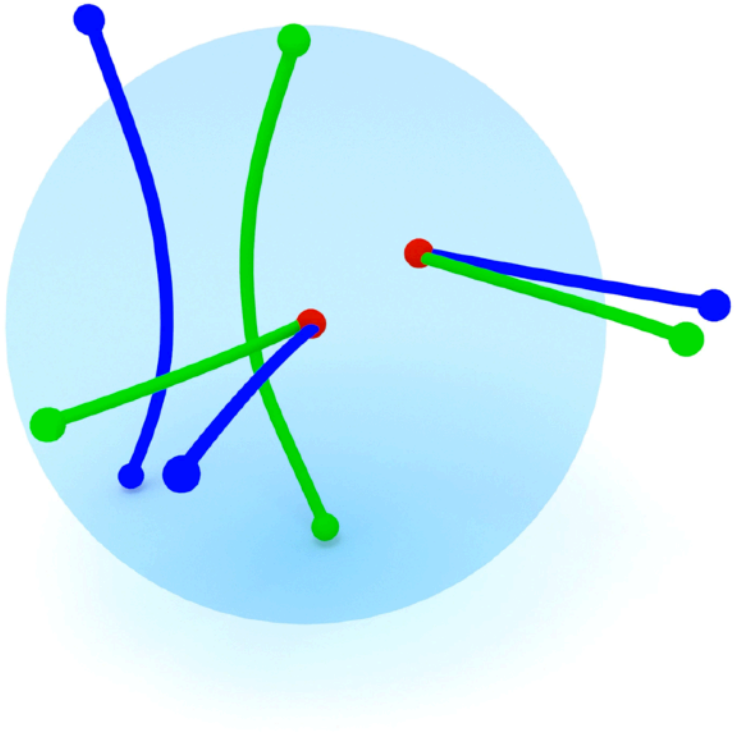
- Detaching arcs



- Detaching zipper nodes



- Repairing zipper nodes

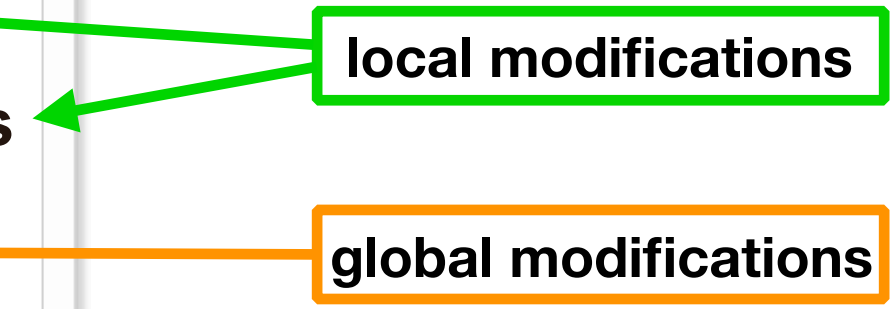


Algorithm

ACHIEVING LOCAL MESHABILITY

Algorithm

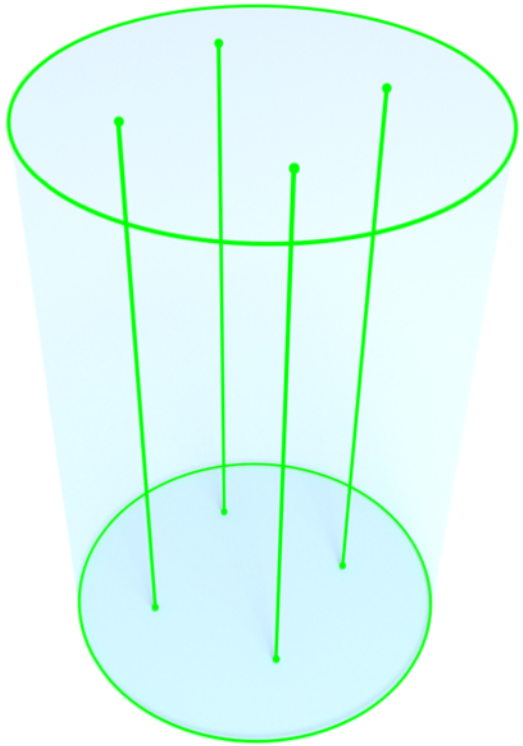
1. Repair non-meshable **arcs**
2. Decompose non-meshable **nodes**
3. Repair **zipper nodes**

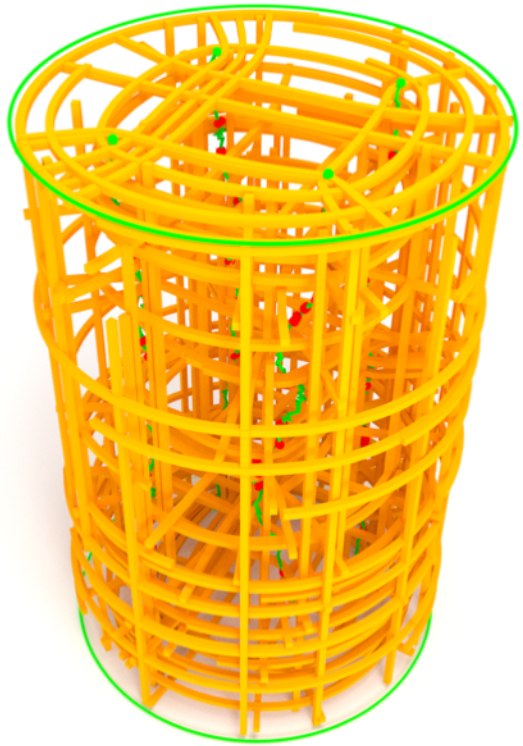


Handling Noisy Singularities

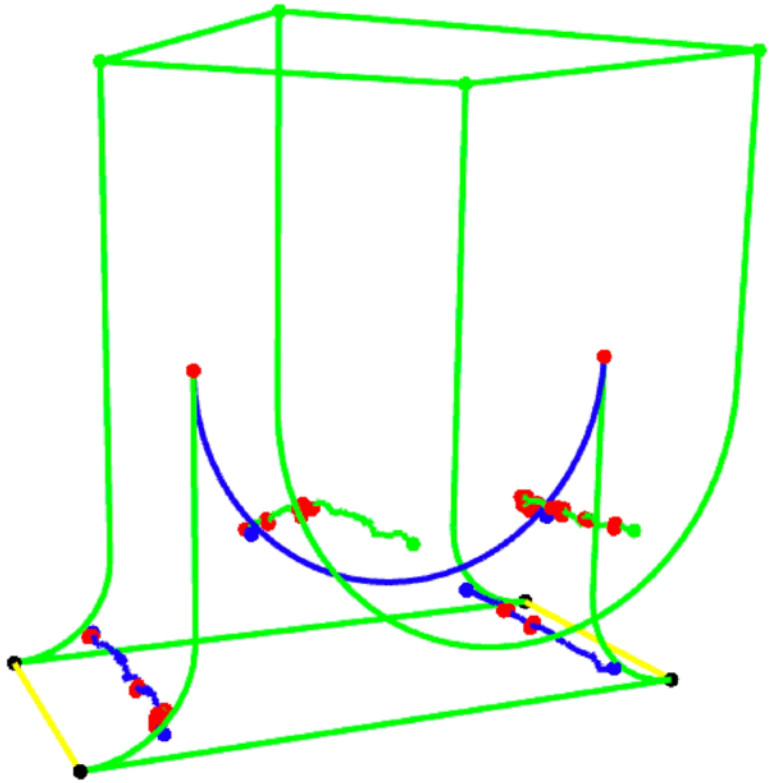
SINGULARITY GRAPH OPTIMIZATION

- **Discrete Singular Arcs**
  - are edges of input tetrahedral mesh
  - not necessarily align to frame field
  - ➡ often contain many zipper nodes
- **Strategy**
  - delay zipper node repair
  - geometrically optimize singular arcs
  - ➡ co-optimize frame field and tet mesh

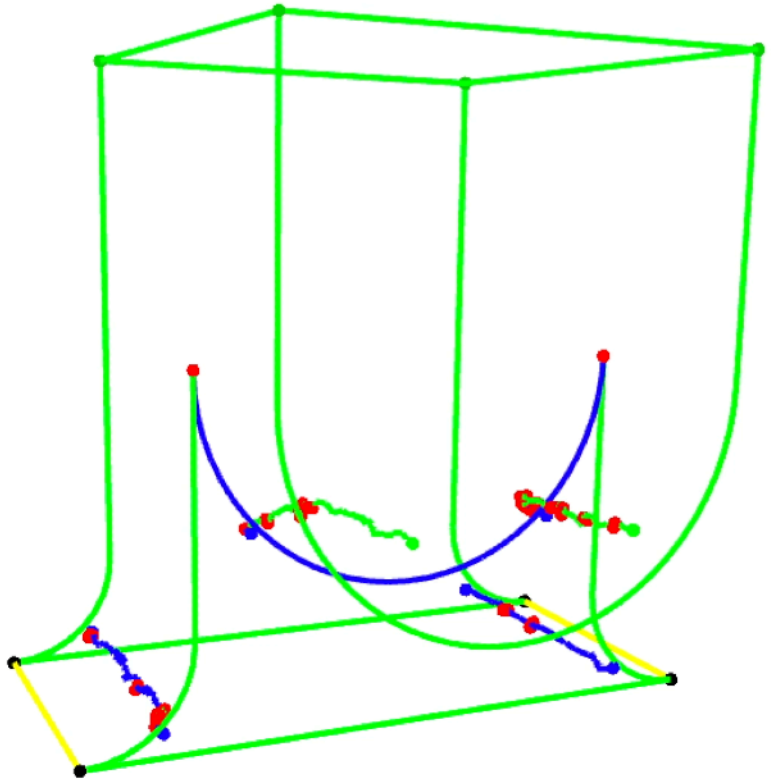




TWO-STAGE ALGORITHM

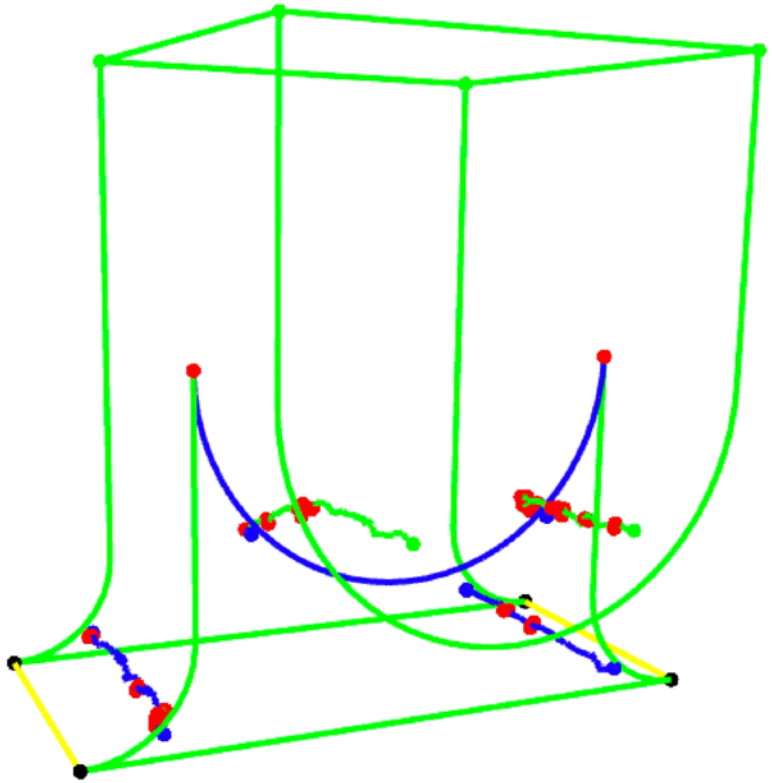


Input

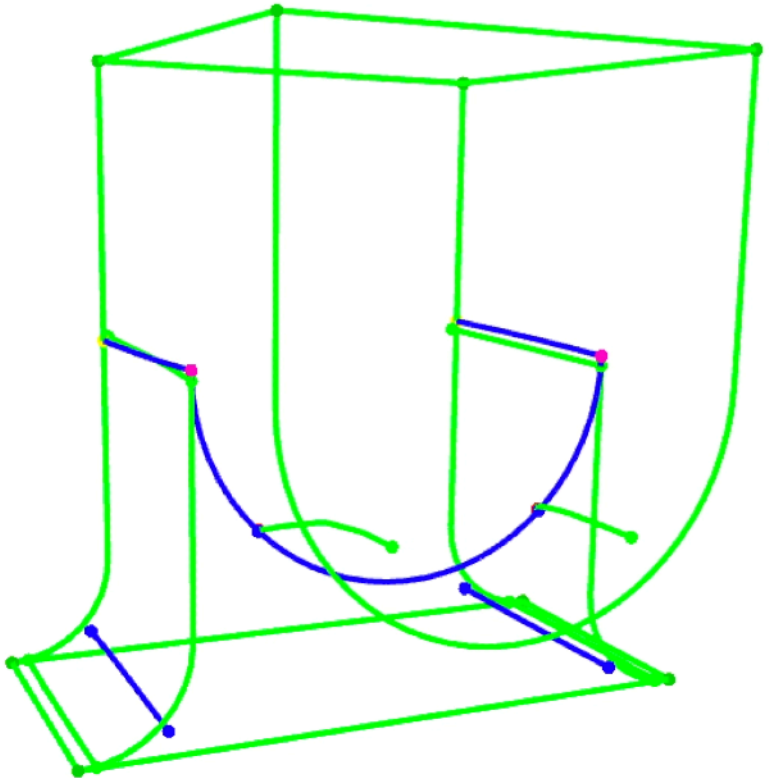


First Stage

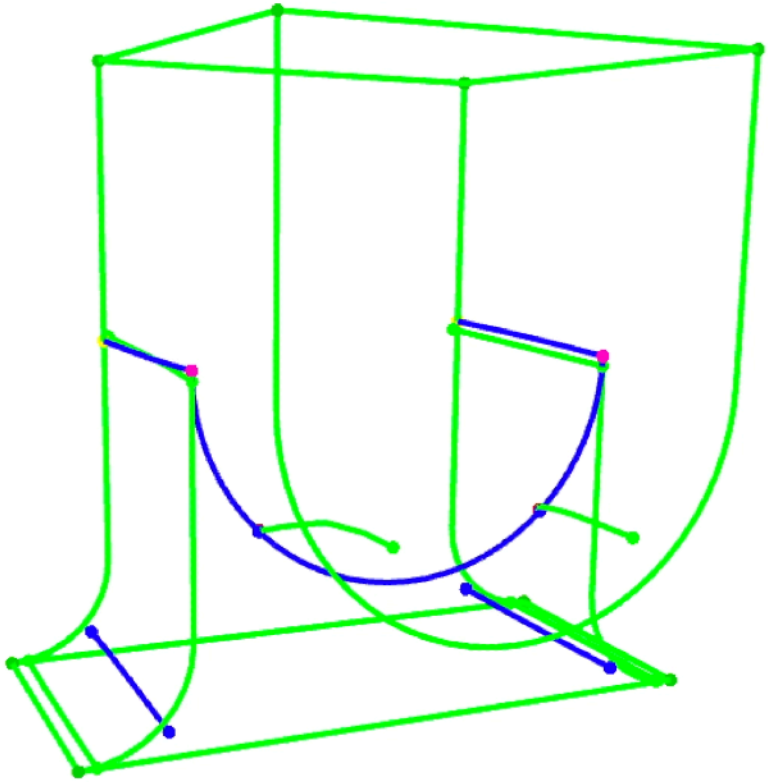
TWO-STAGE ALGORITHM



Input



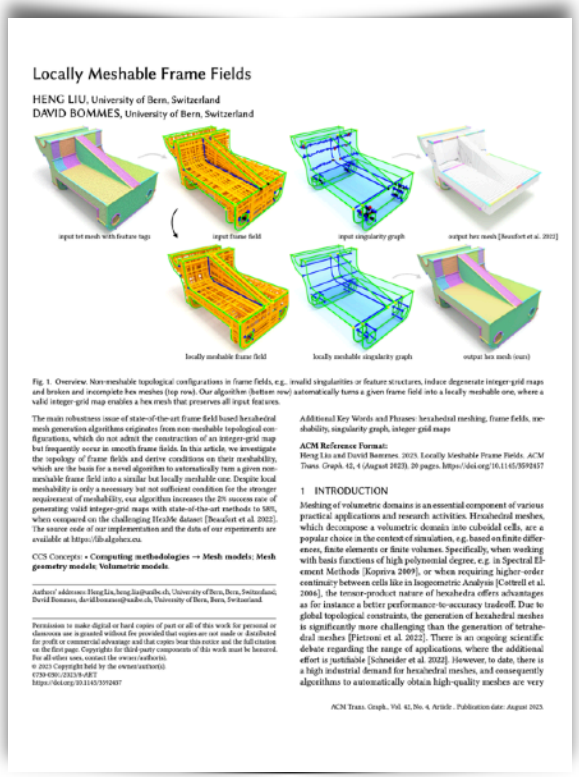
First Stage



Second Stage

ADDITIONAL ASPECTS

- Feature Constraints
  - Curves & Surfaces
- Zipper Node Repair
- Discretization on Tetrahedral Mesh
- Singularity Graph Optimization
- …

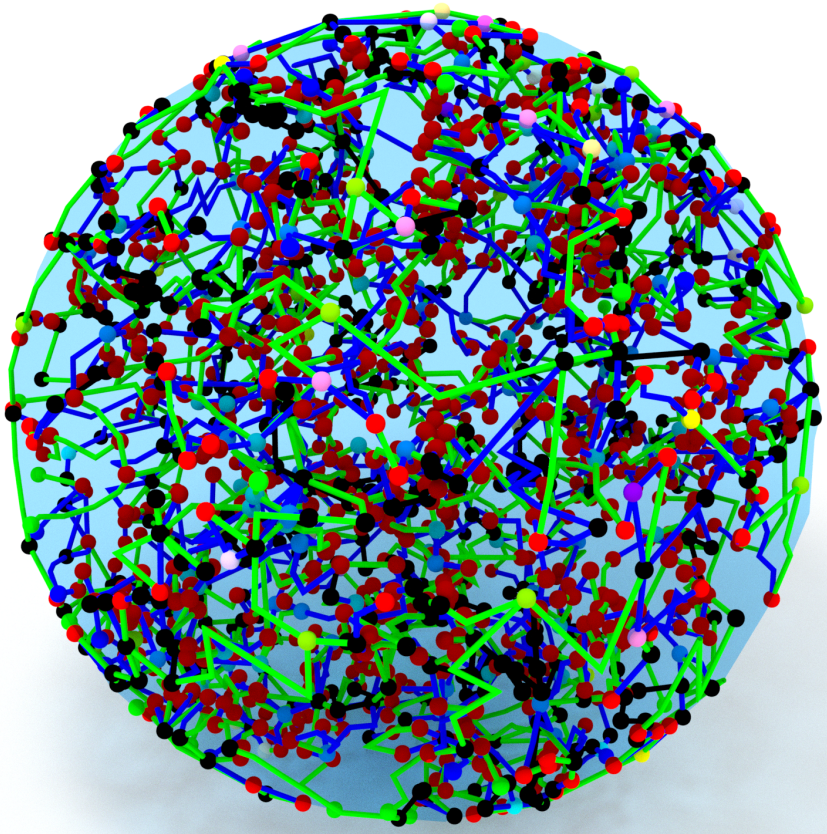


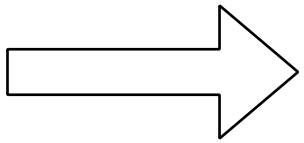
Locally Meshable Frame Fields

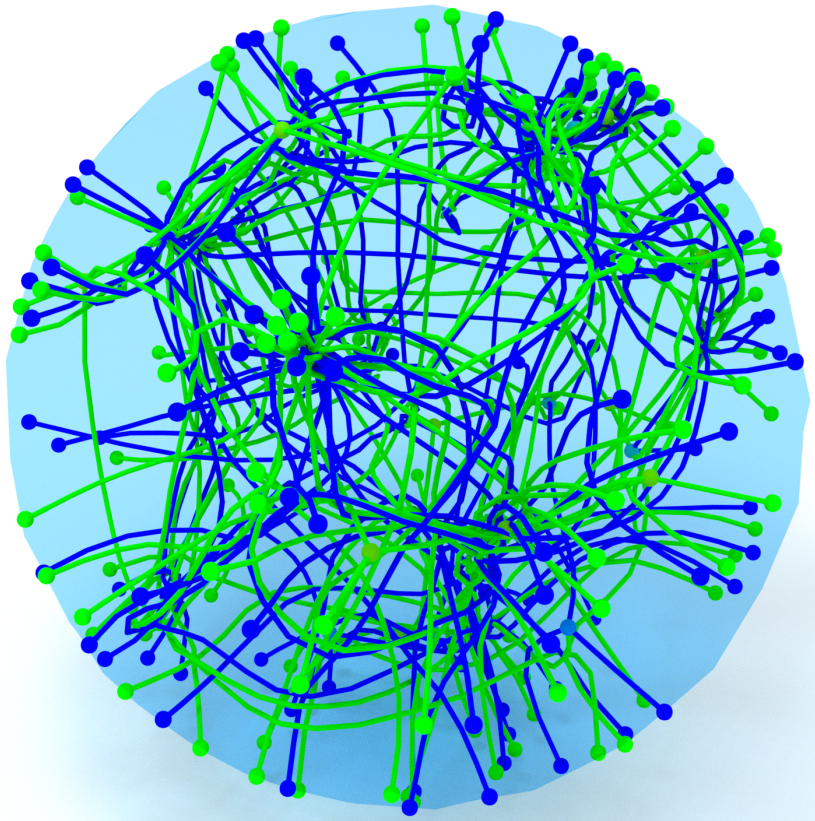
HENG LIU, University of Bern, Switzerland
DAVID BOMMES, University of Bern, Switzerland

Results

STRESS TEST - RANDOM FRAME FIELD





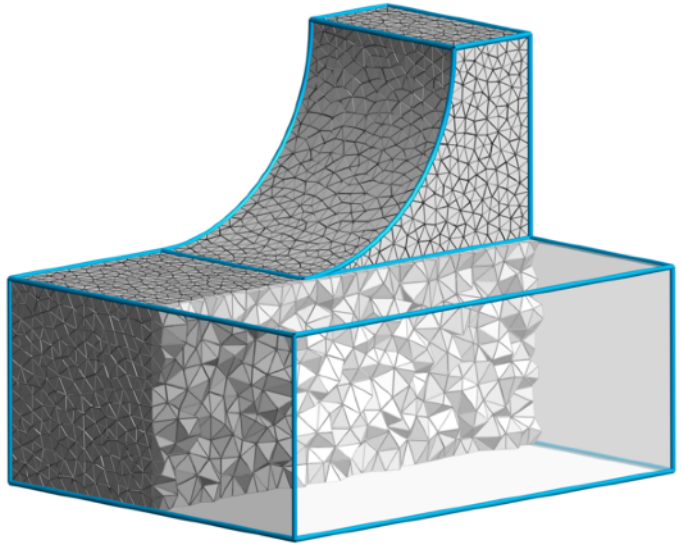


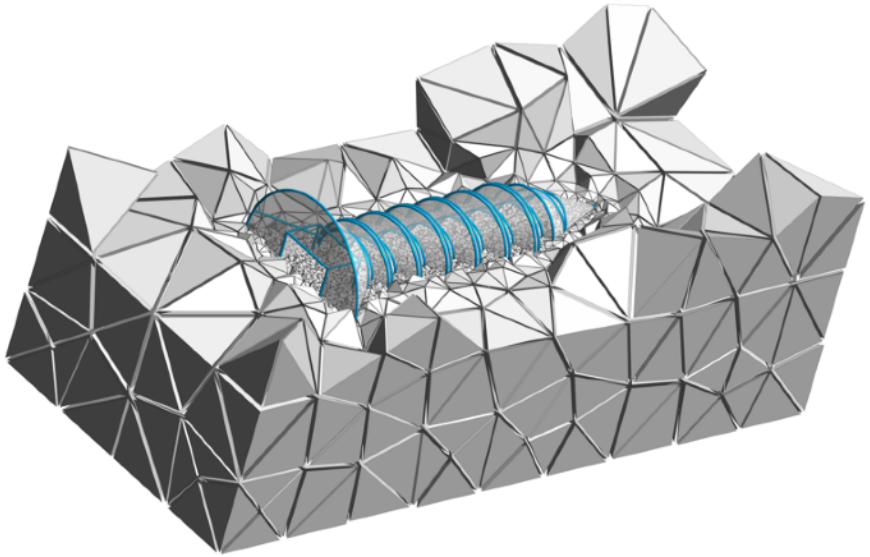
input

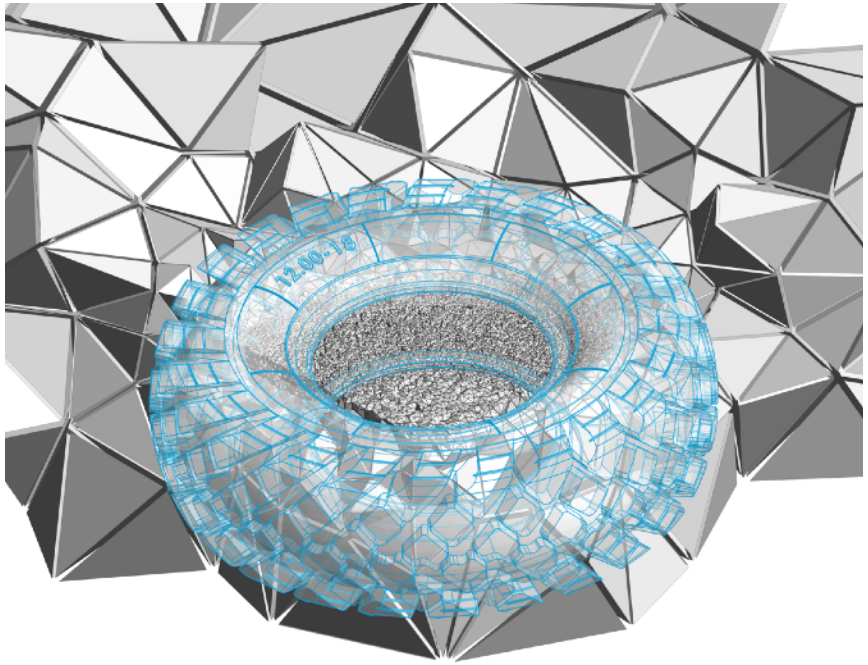
locally meshable

EVALUATION

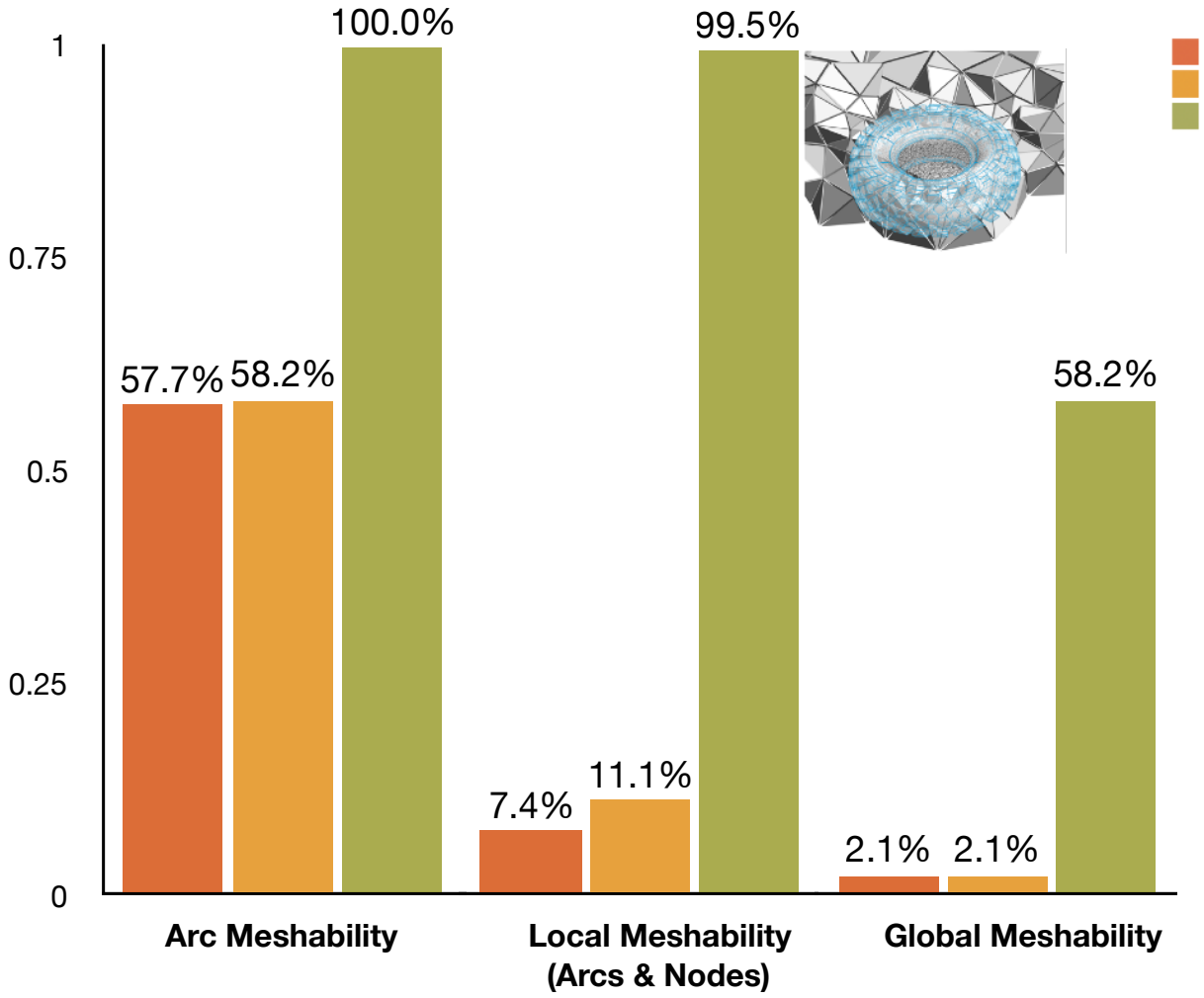
- **HEXME - Dataset** [Beaufort et al. 2022]
  - collection of 189 domains to evaluate and challenge hexmeshers
    - categories: simple, nasty, industrial, including multi-material
  - **goal:** facilitate comparison & guide future research



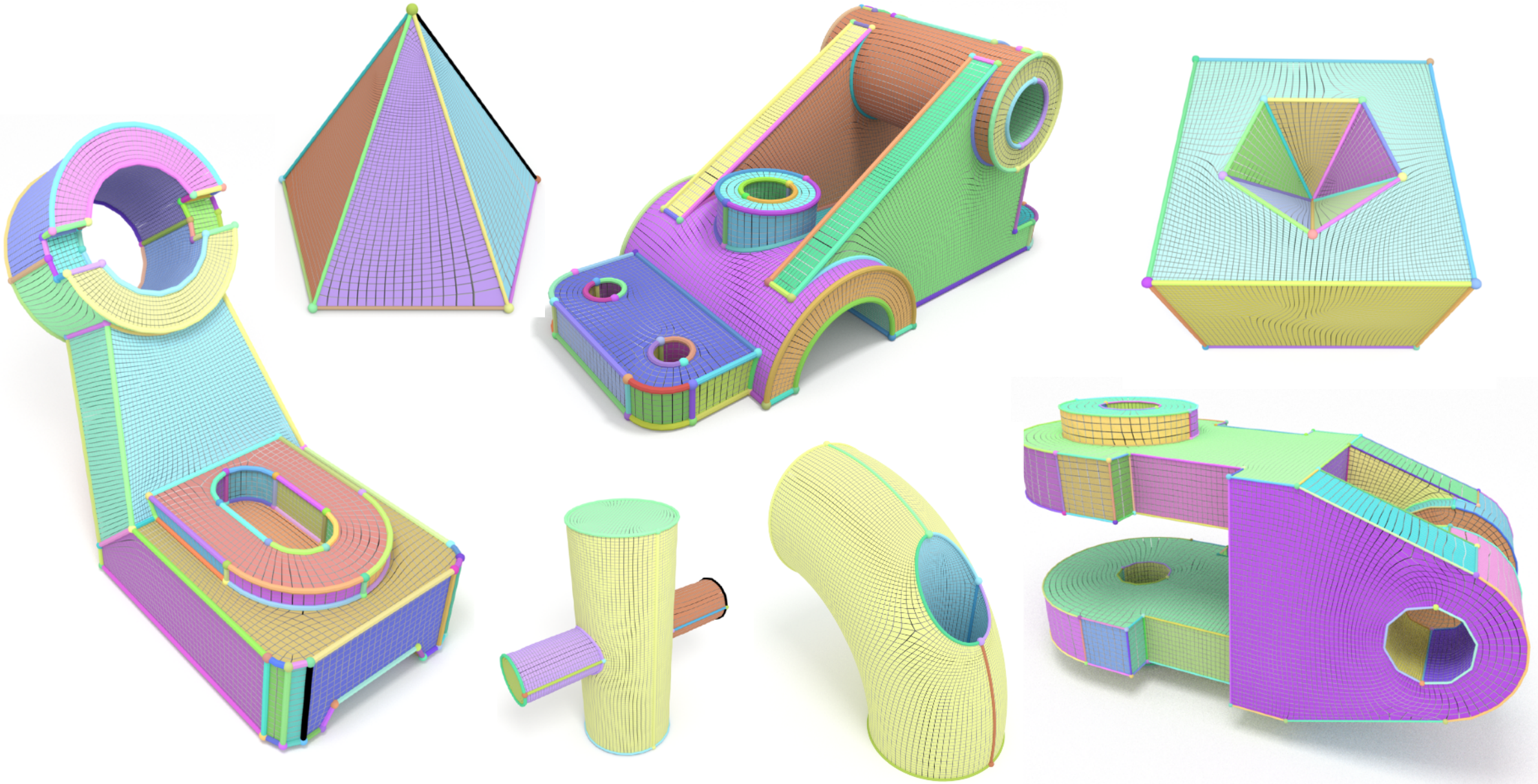




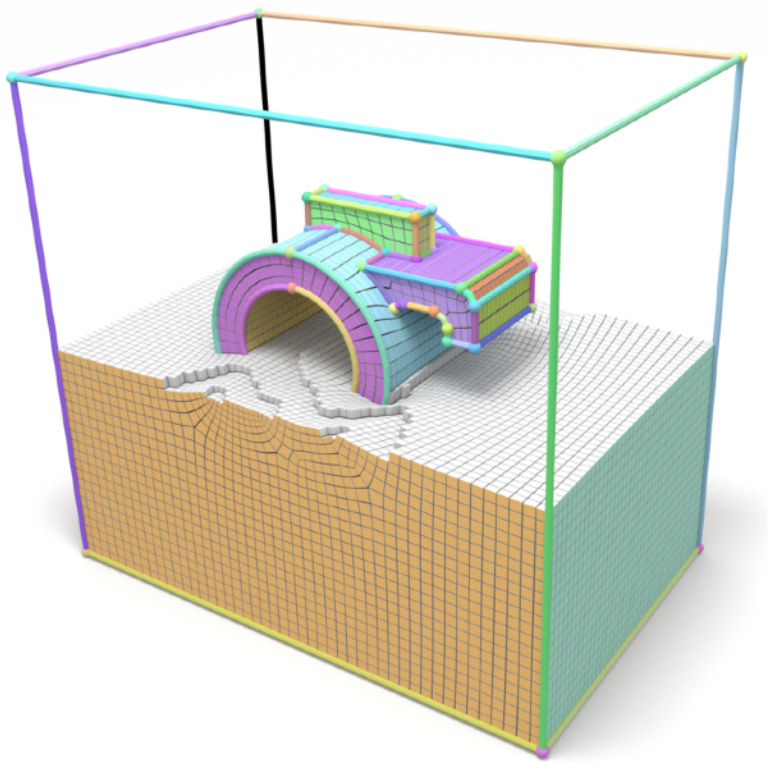
EVALUATION - COMPARISON

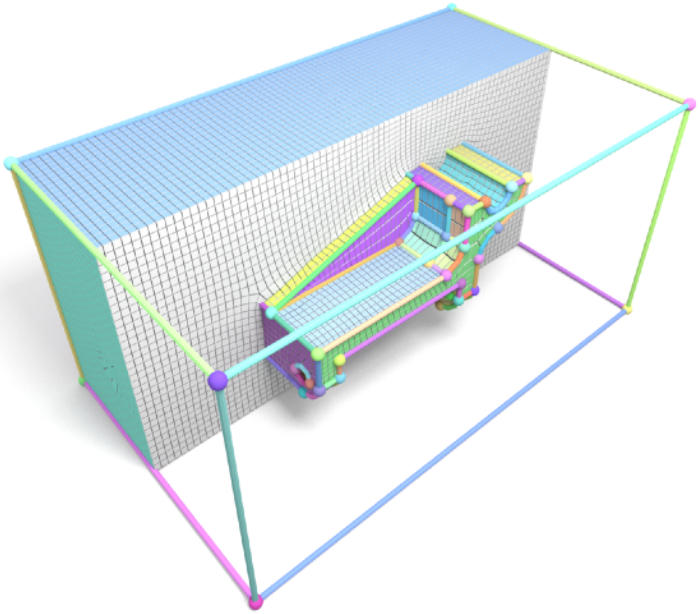


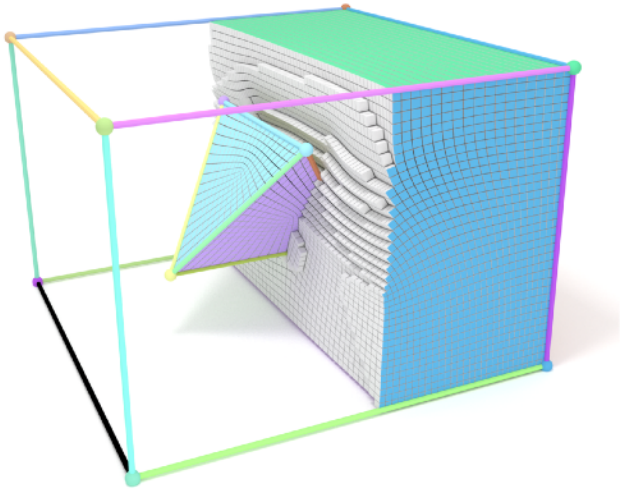
EVALUATION - HEX MESHES

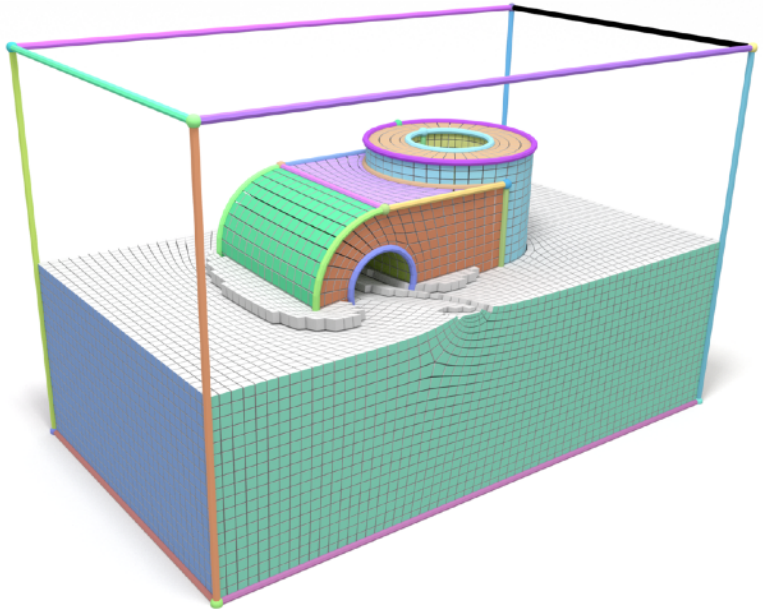


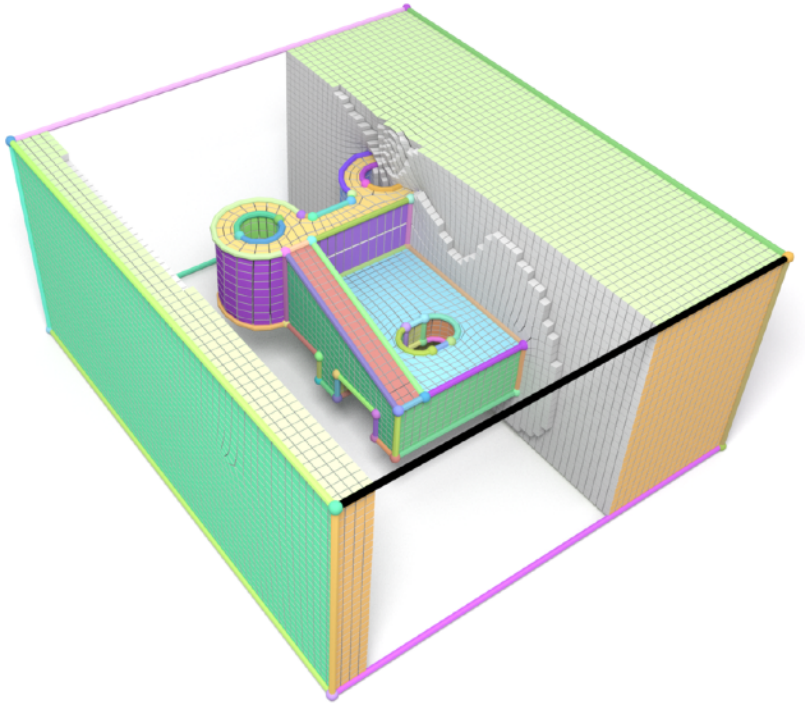
EVALUATION - HEX MESHES



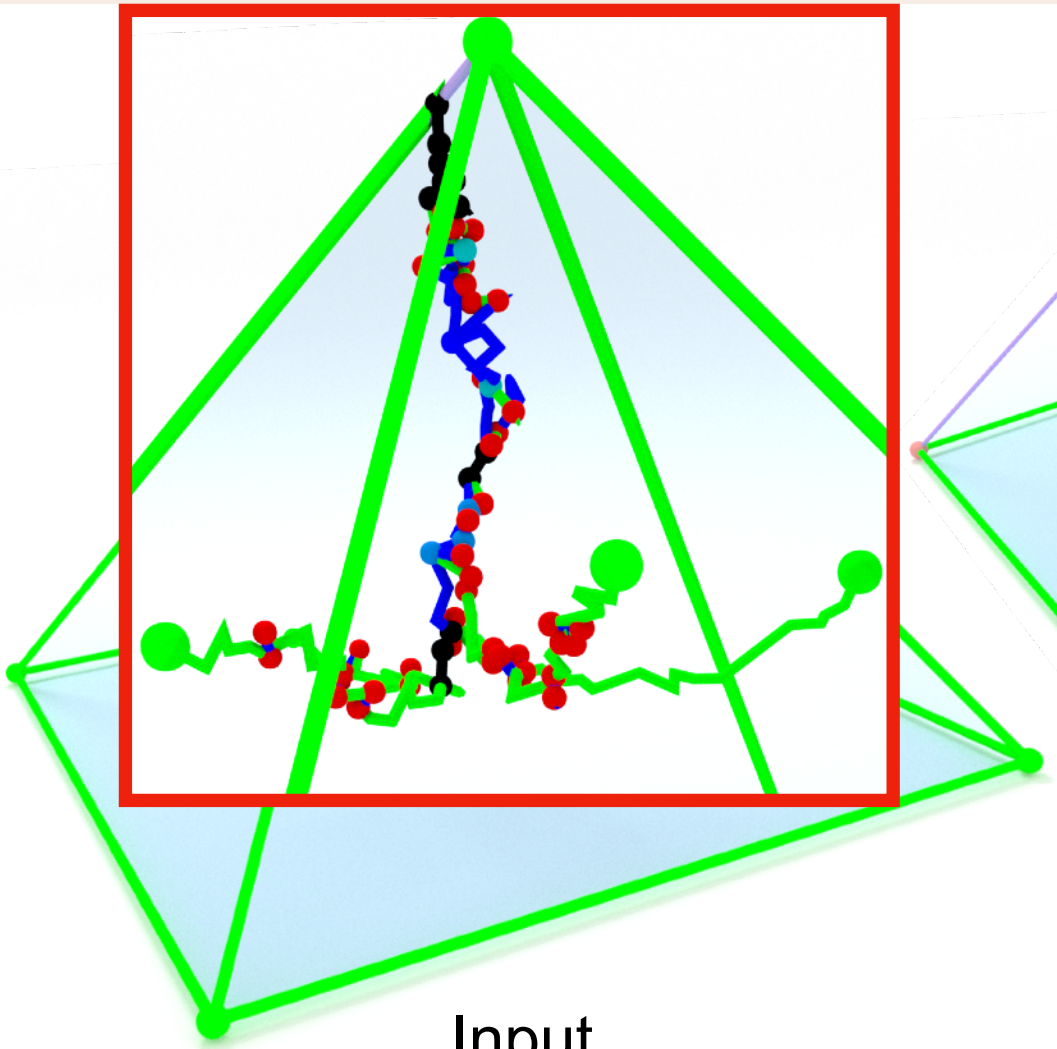




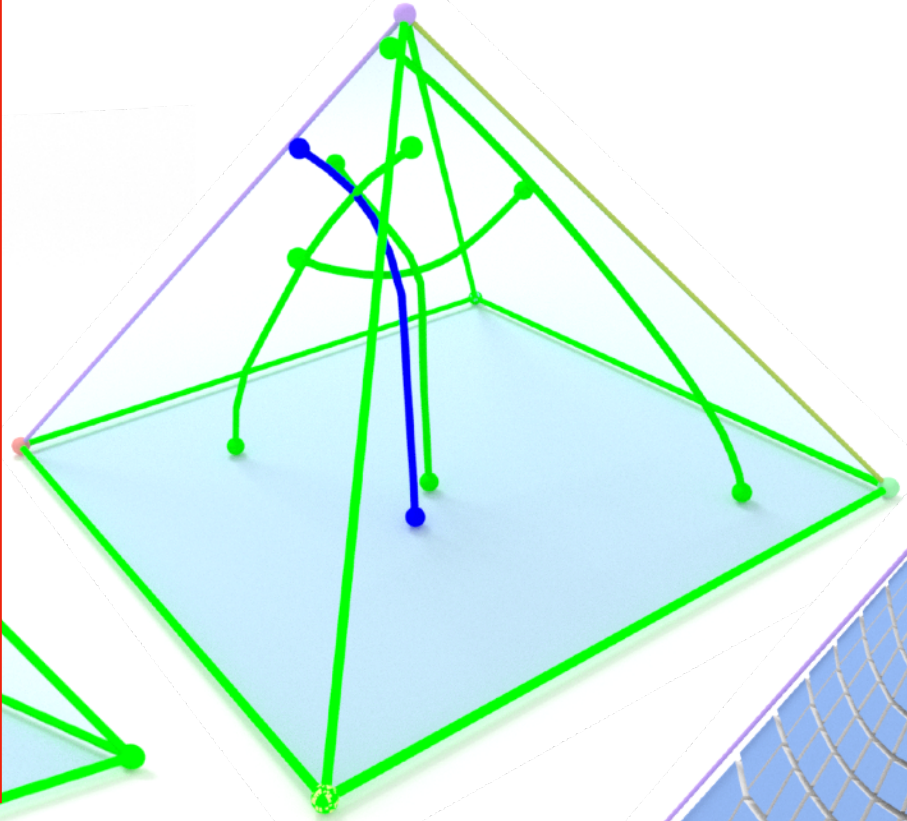




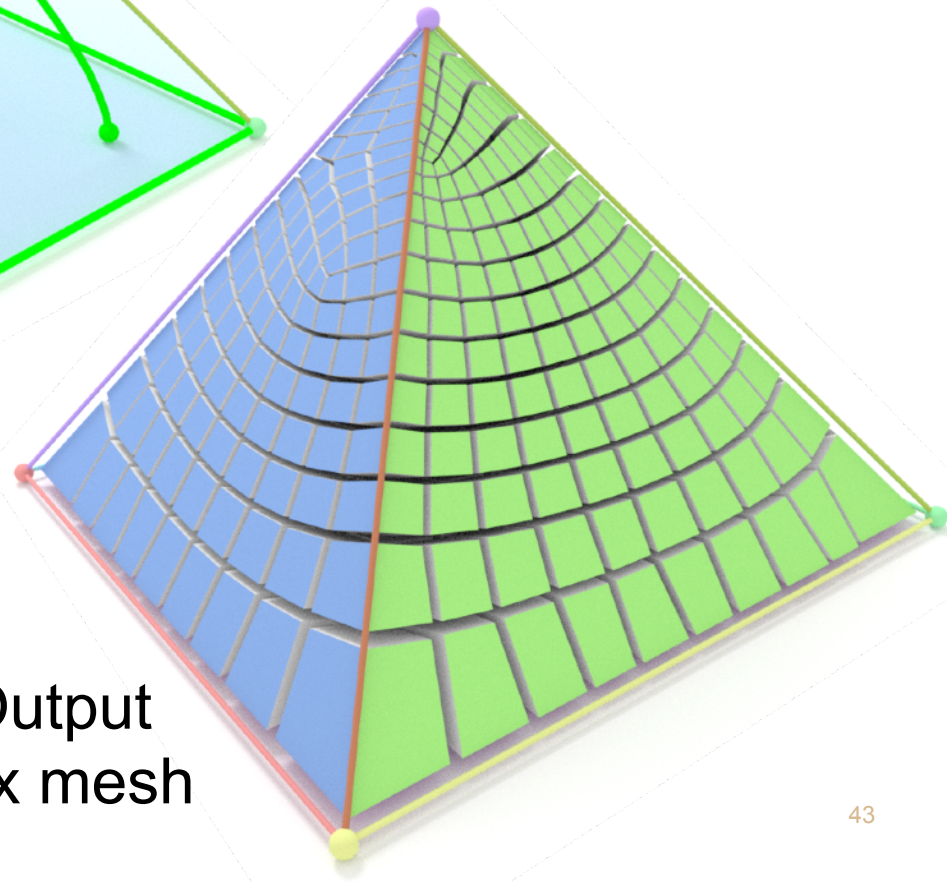
PYRAMID



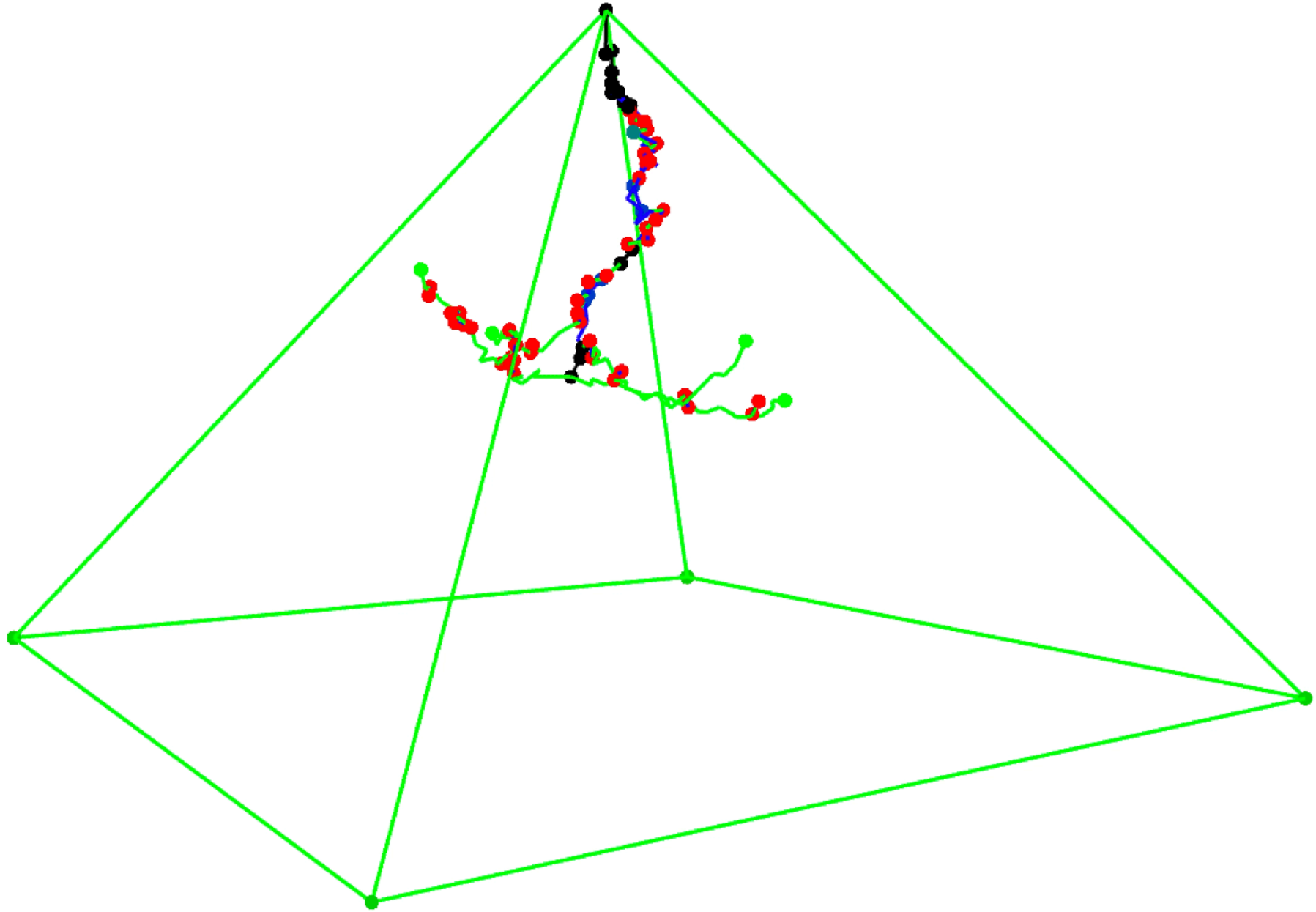
Input



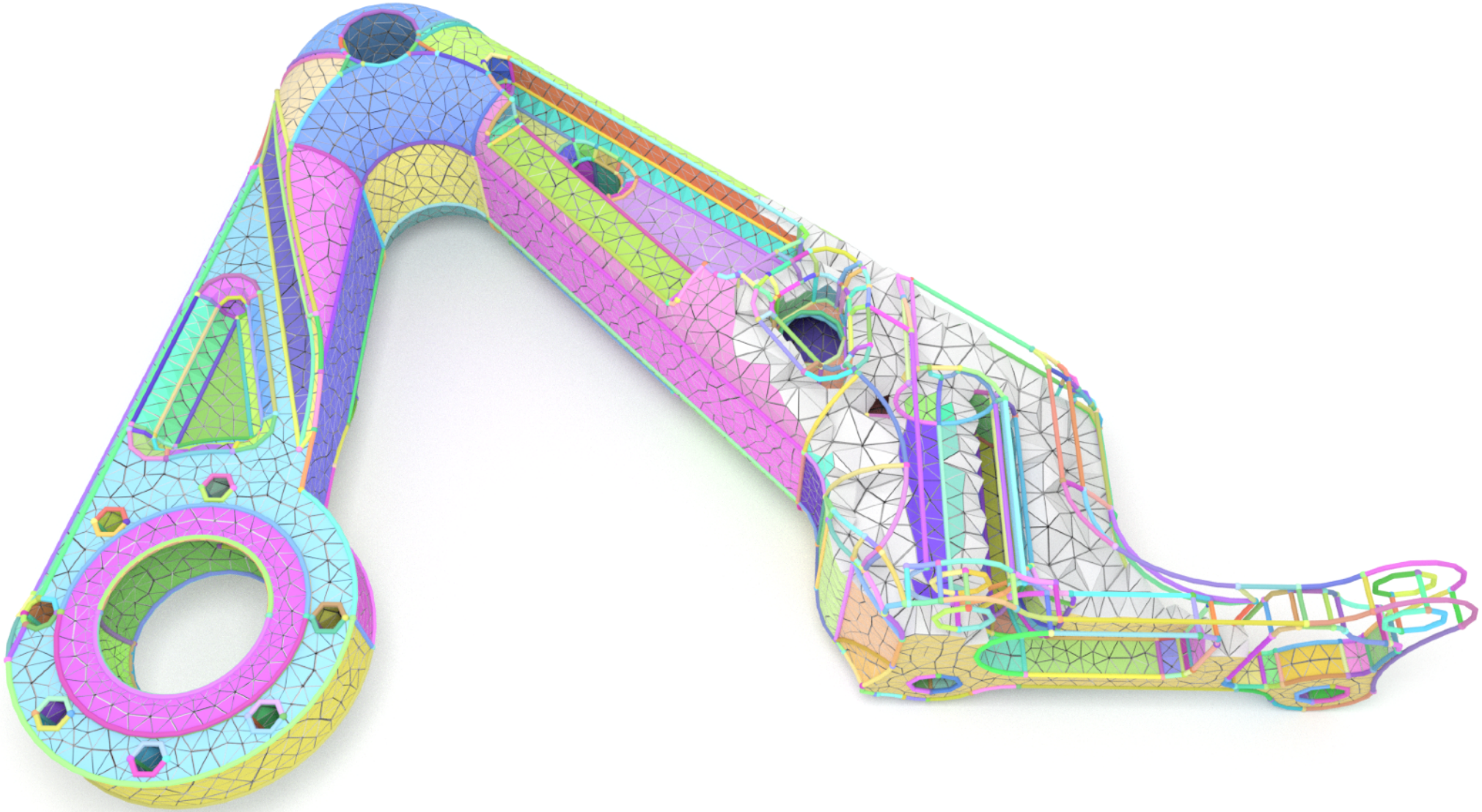
Locally meshable



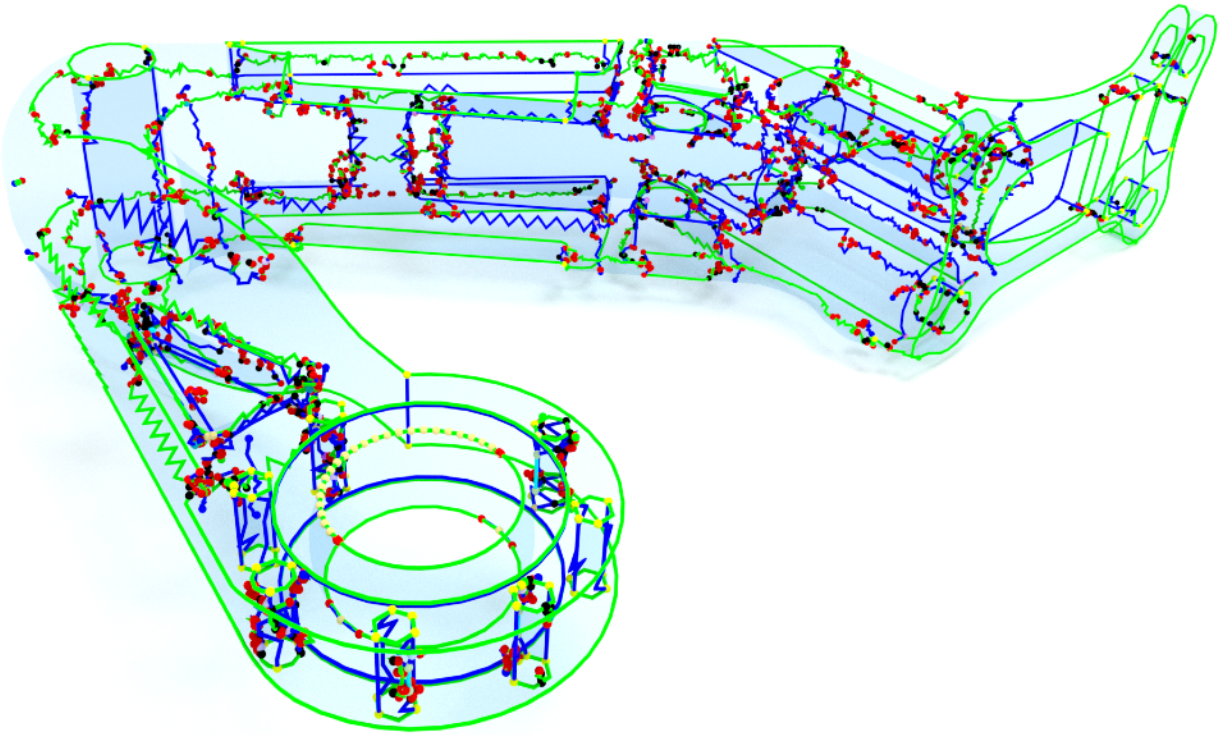
Output hex mesh



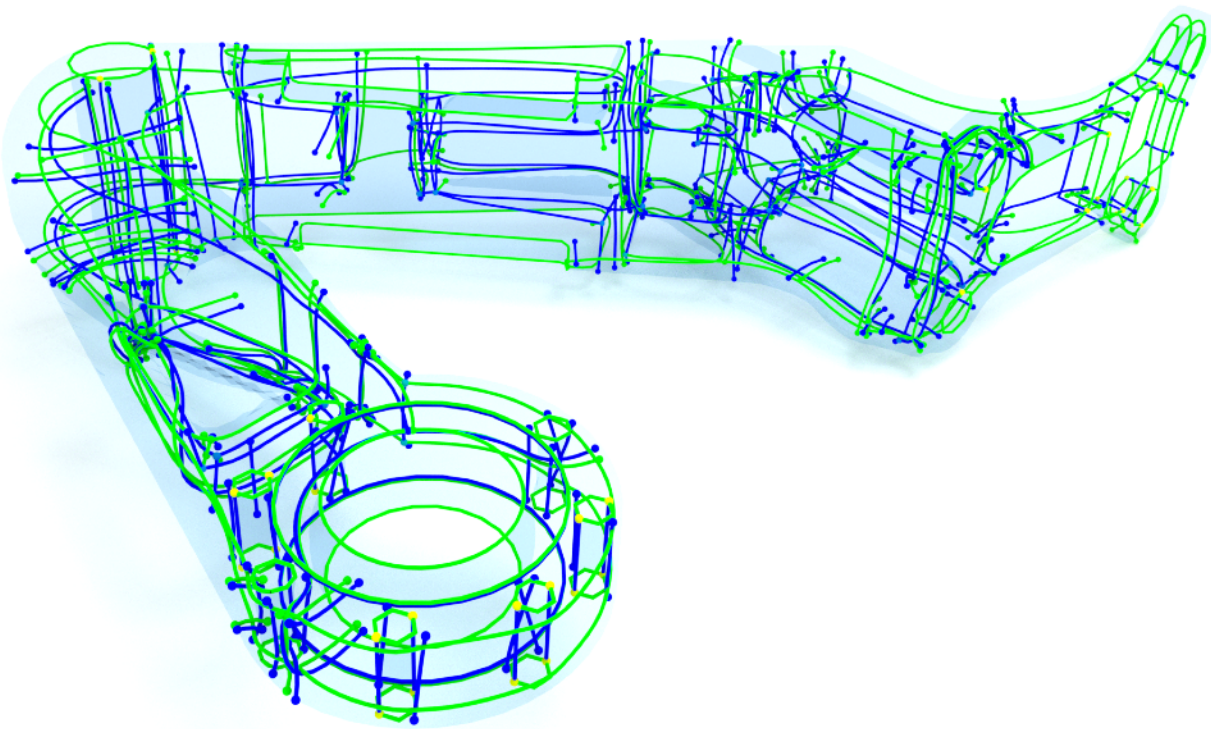
MECHANICAL BRACKET - HEXME I29



MECHANICAL BRACKET - HEXME I29



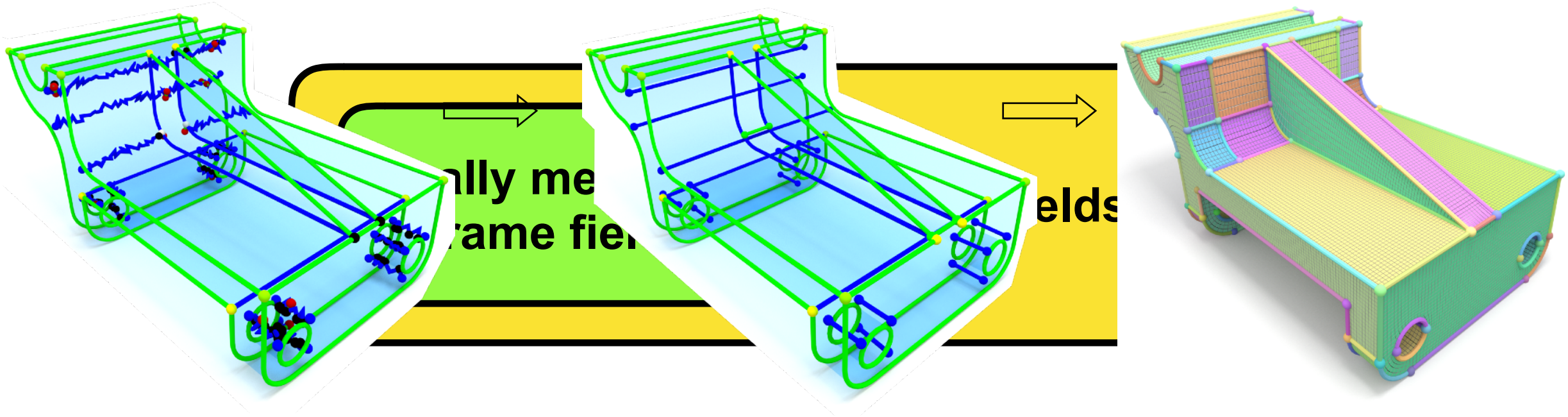
input



locally meshable

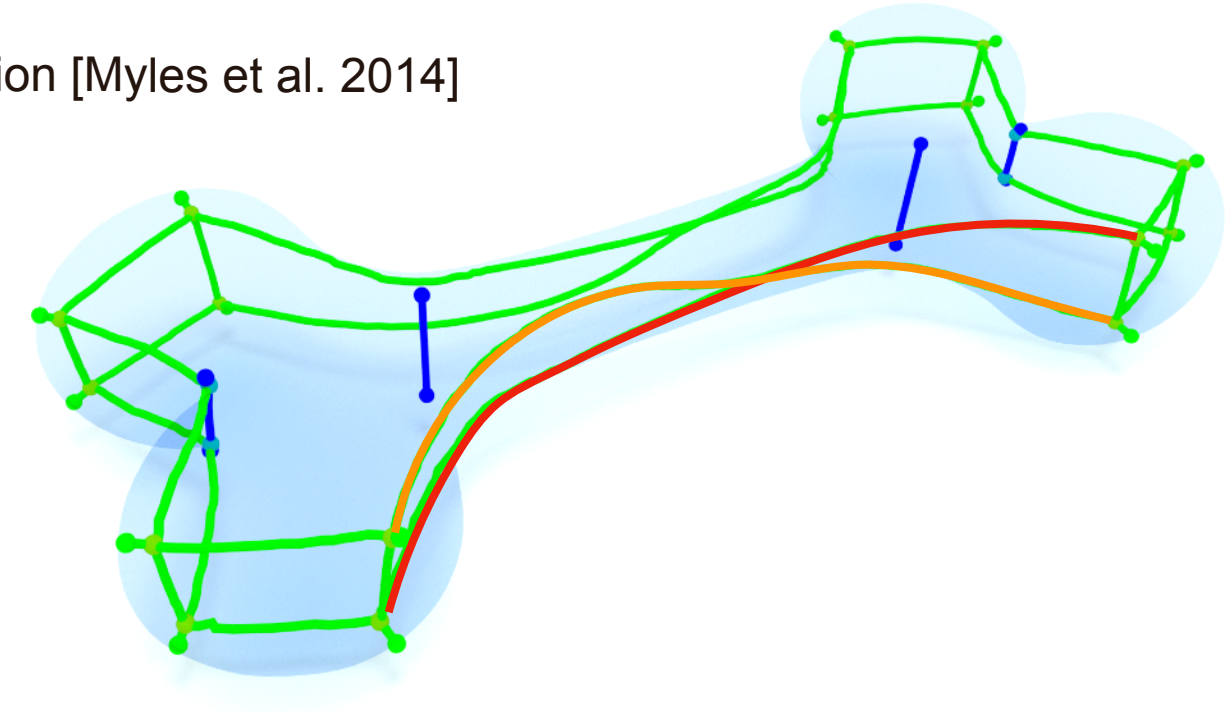
SUMMARY & OUTLOOK

- **Contributions**
  - Characterization of Local Meshability
  - Algorithm to ensure Local Meshability



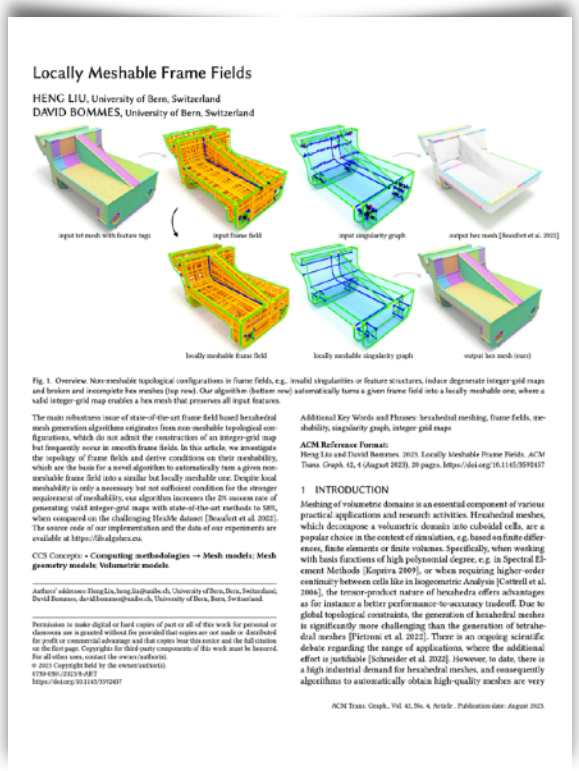
SUMMARY & OUTLOOK

- **Future Work**
  - Global Meshability
    - Solved in 2D: Robust Field-Aligned Parametrization [Myles et al. 2014]
    - Open Problem in 3D



THANK YOU!

SIGGRAPH 2023
LOS ANGELES+ 6-10 AUG



Locally Meshable Frame Fields

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http://www.algohex.eu

European Research Council

Code available!