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Bead Extrusion Path Planning

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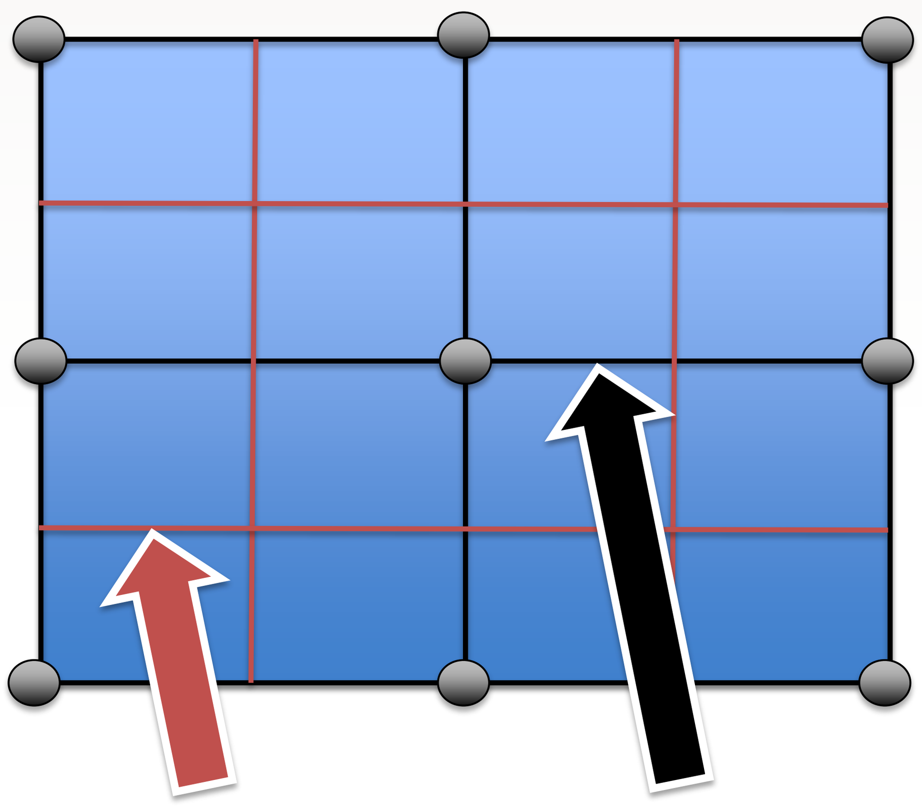
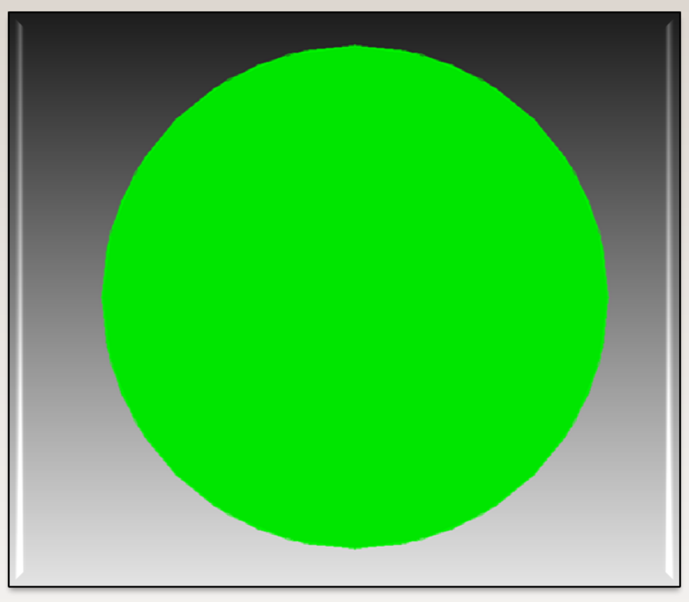
Introduction: Current lattice based paths for additive bead extrusion are problematic when transferred to three dimensions.

Objective: Develop a tool capable of producing paths that possess the following qualities for three dimensional geometries:

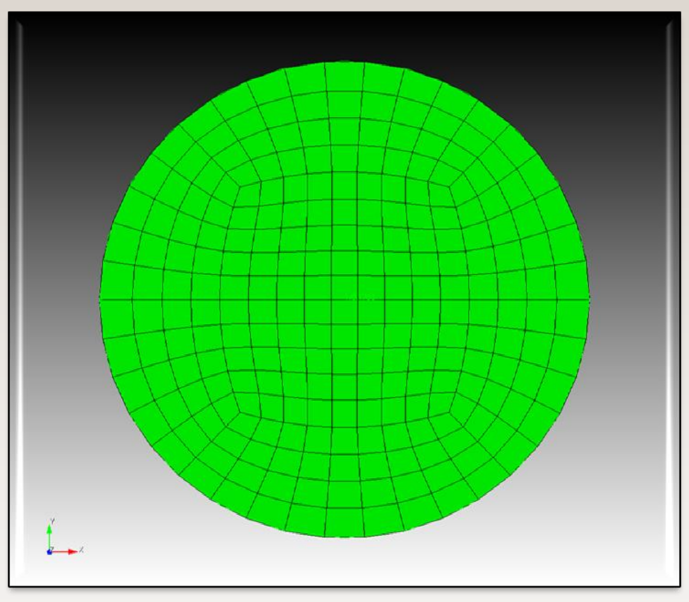
1. *Uniform edge length*
2. *Offset between each layer*
3. *Minimal starts and stops*



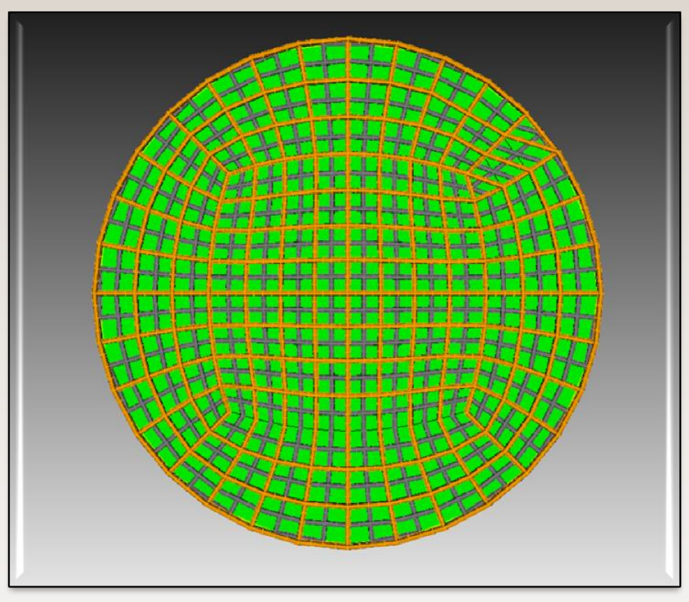
Original Surface



Smoothed Mesh



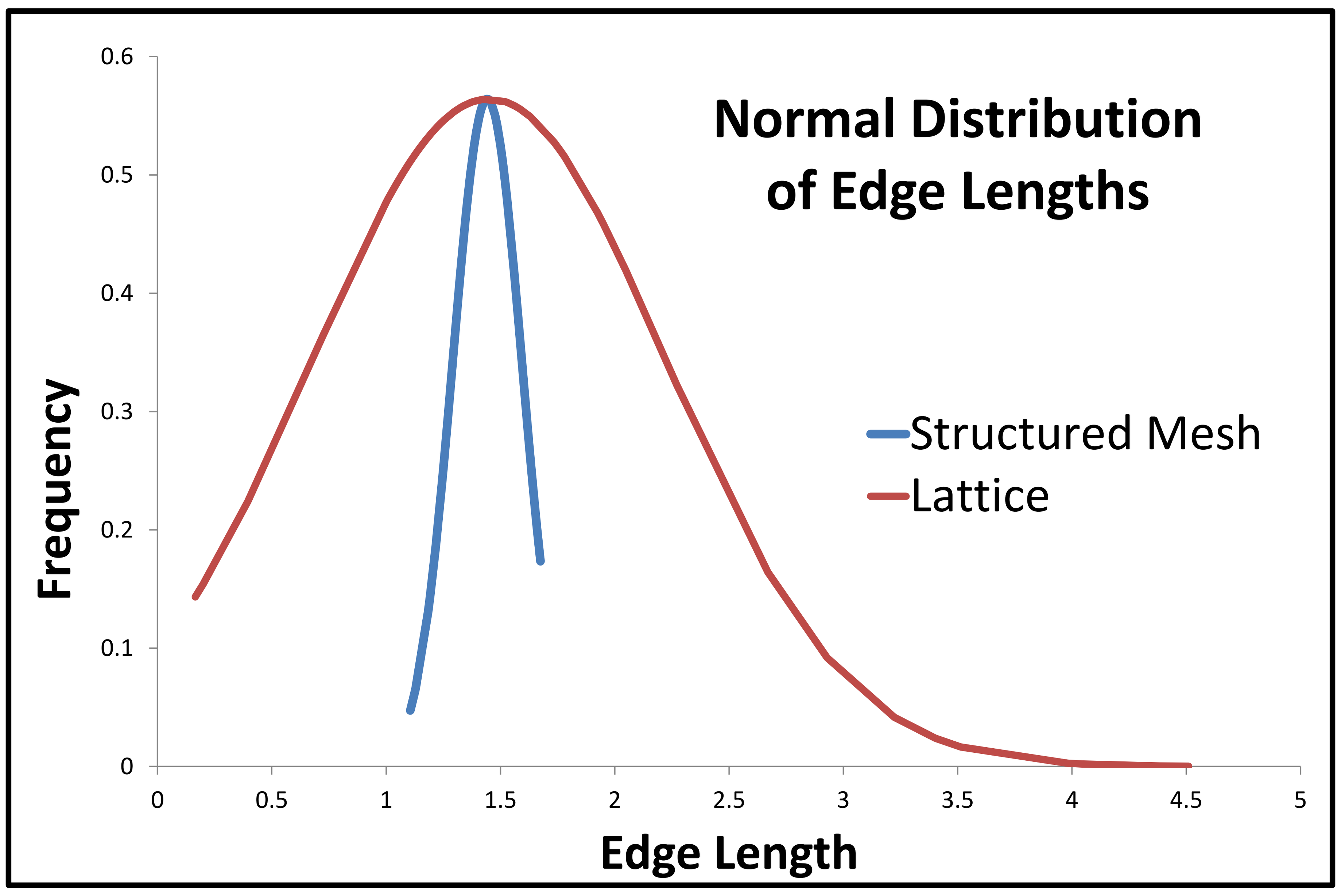
Printed Path

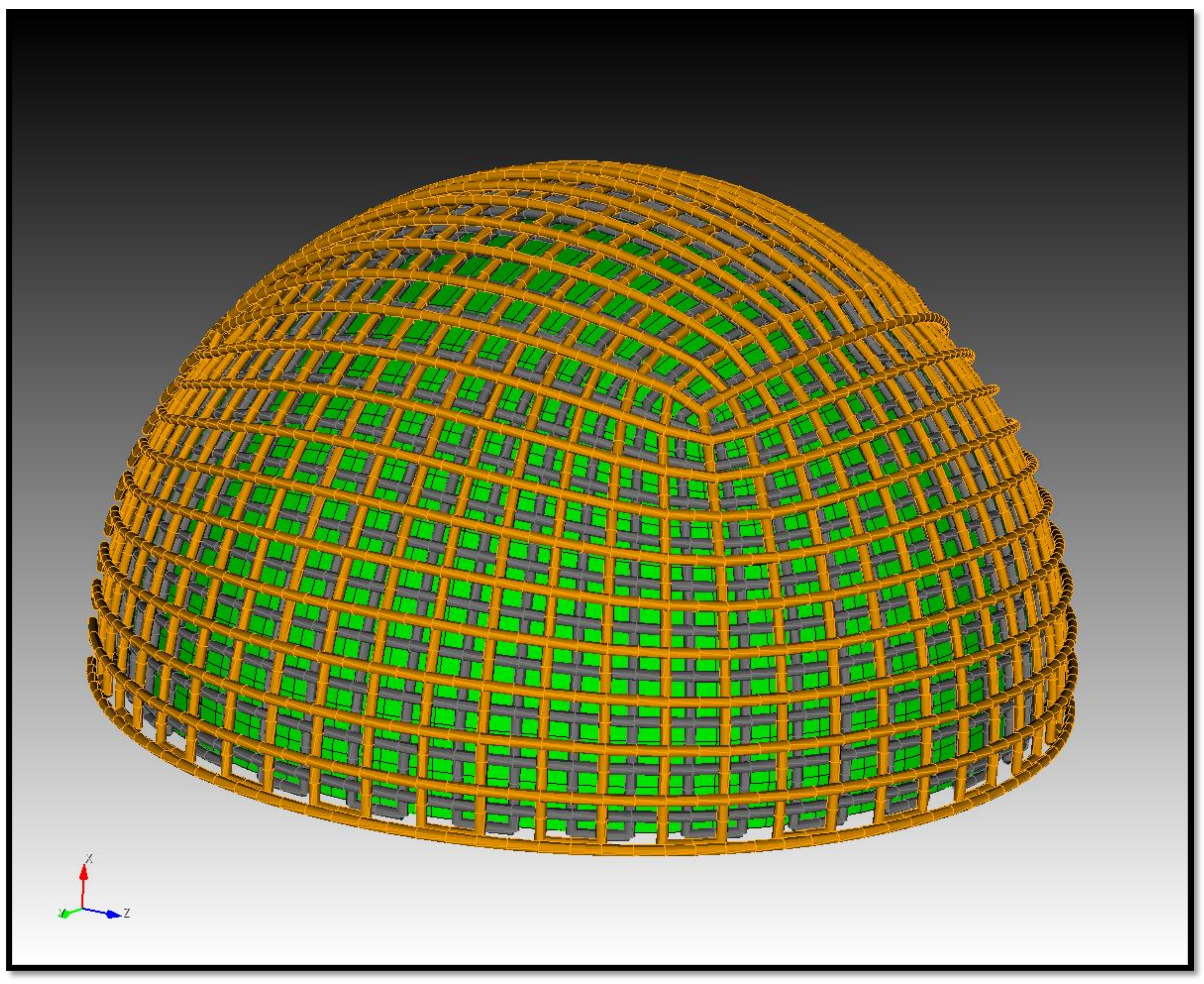


Method: Our approach was to leverage structured meshes normally generated for finite element analysis. By tracing the various elements of these meshes in a calculated progression, we were able to create a path that met the requirements set forth in the objective statement.

To produce uniform edge lengths, smoothing algorithms were applied to the meshes. The offset between each layer was achieved by alternating between the primal and dual of the mesh (see figure on left). We minimized the number of starts and stops by selecting paths that maximized the number of Eulerian paths.

The final step of the process was to convert the list of elements we produced into machine code. This was done by utilizing the coordinates of these elements and normals of the faces with which they were associated.





Results: As the plot above demonstrates, the path derived from structured mesh creates a much more uniform edge length. In fact, the standard deviation for our method was more than 5 times smaller than that of the grid approach. The picture up and to the right also shows that that the offset between layers was successfully achieved with a minimum number of starts and stops.

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Application of Topology Optimization

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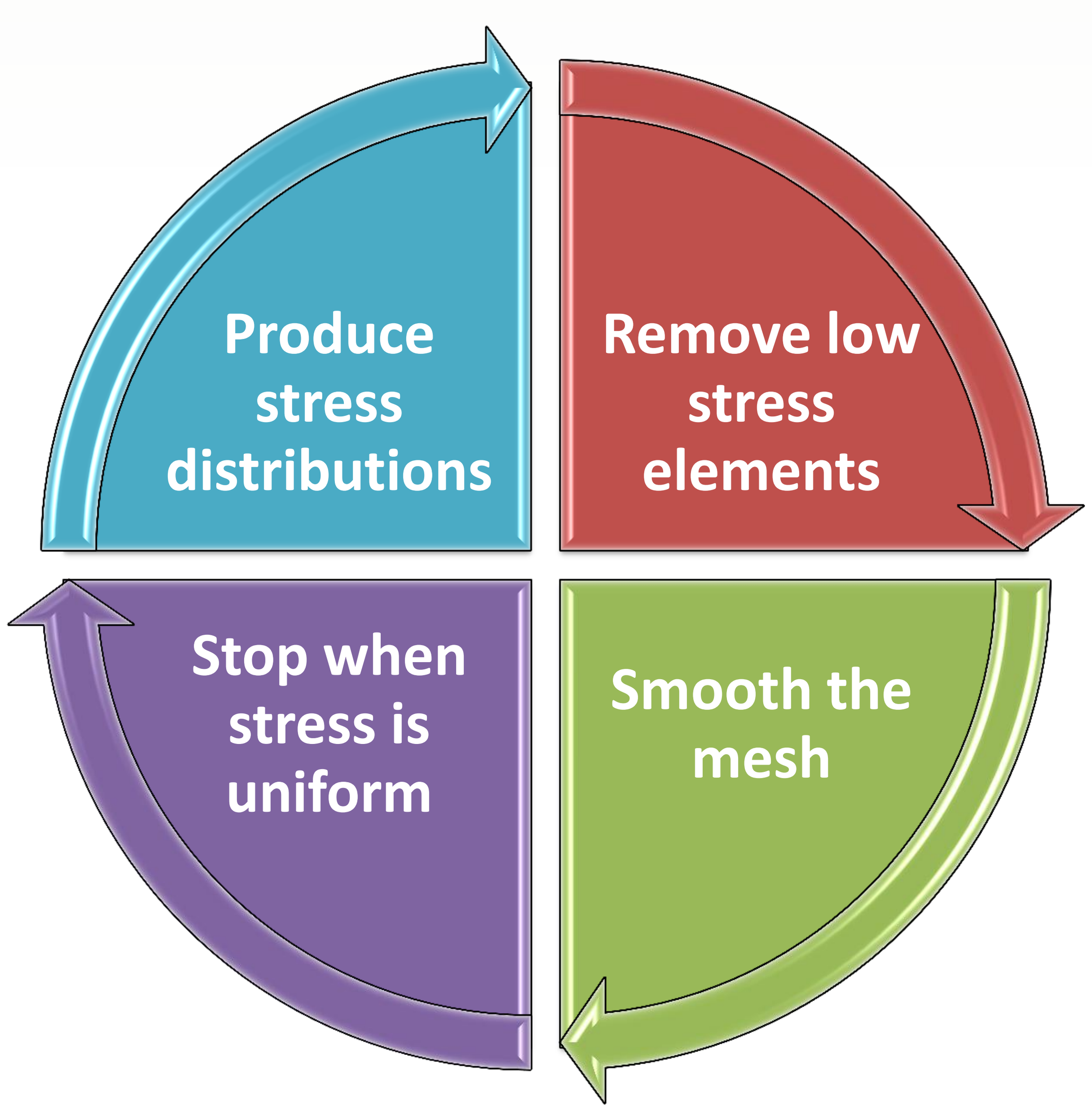
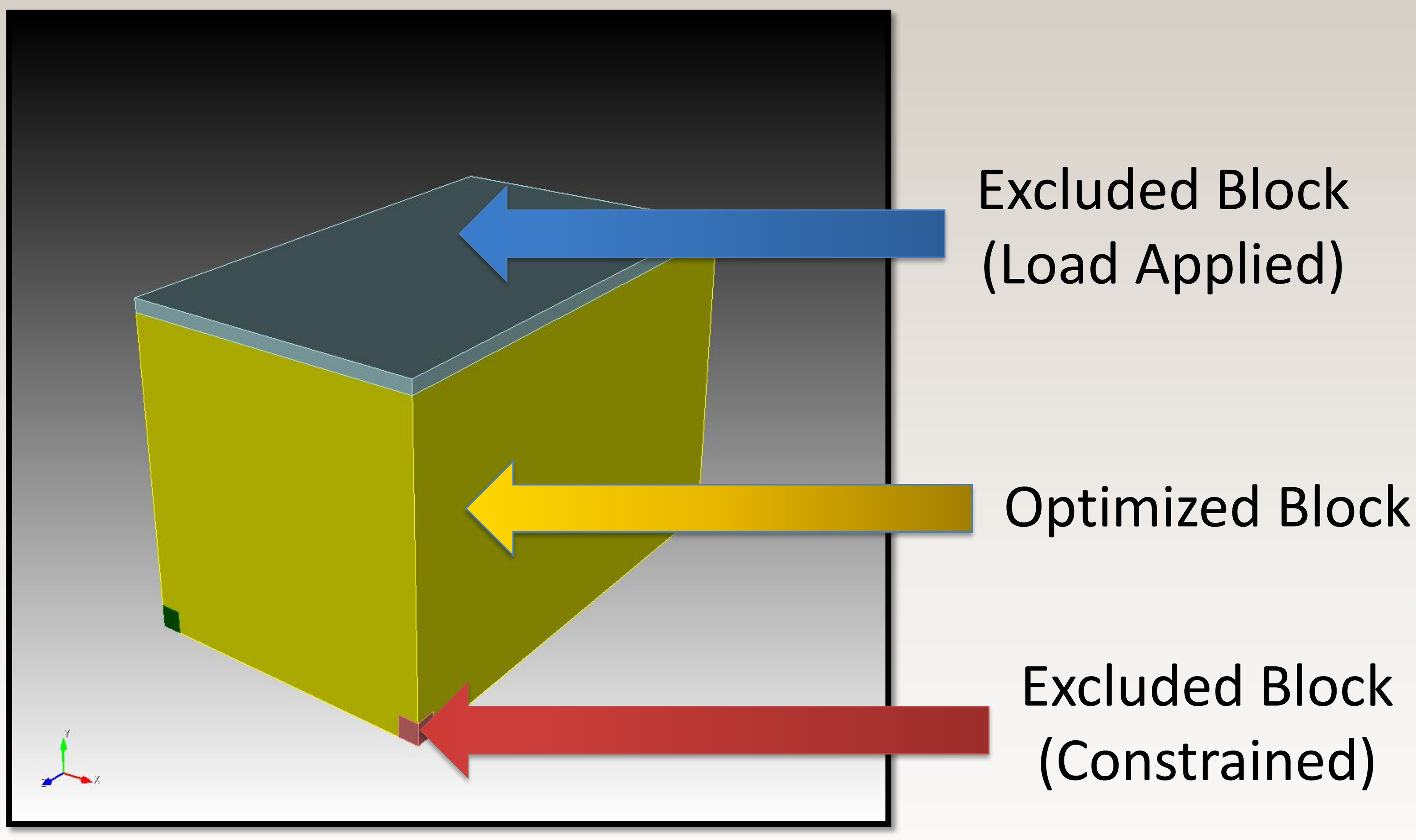
Introduction: Topology optimization is not a novel concept, but the latest advances in parallel computing and additive manufacturing have now made this method of design extremely desirable.

Objective: maximize global stiffness with the minimum material.

Method: The process begins by developing a CAD model to outline the design envelope. The project requirements are then used to produce the input variables (seen on the right) for the analysis. Once the setup is complete, a mesh of the model is sliced into numerous pieces so that the calculations can be carried out in parallel. The steps shown below are then taken.



Post-Processing: Once the analysis is completed, the pieces are reunited and exported to Cubit, a finite element mesh generation toolkit, where the model is refined. The resulting model (seen on the right) can then be used to generate path profiles for additive manufacturing.

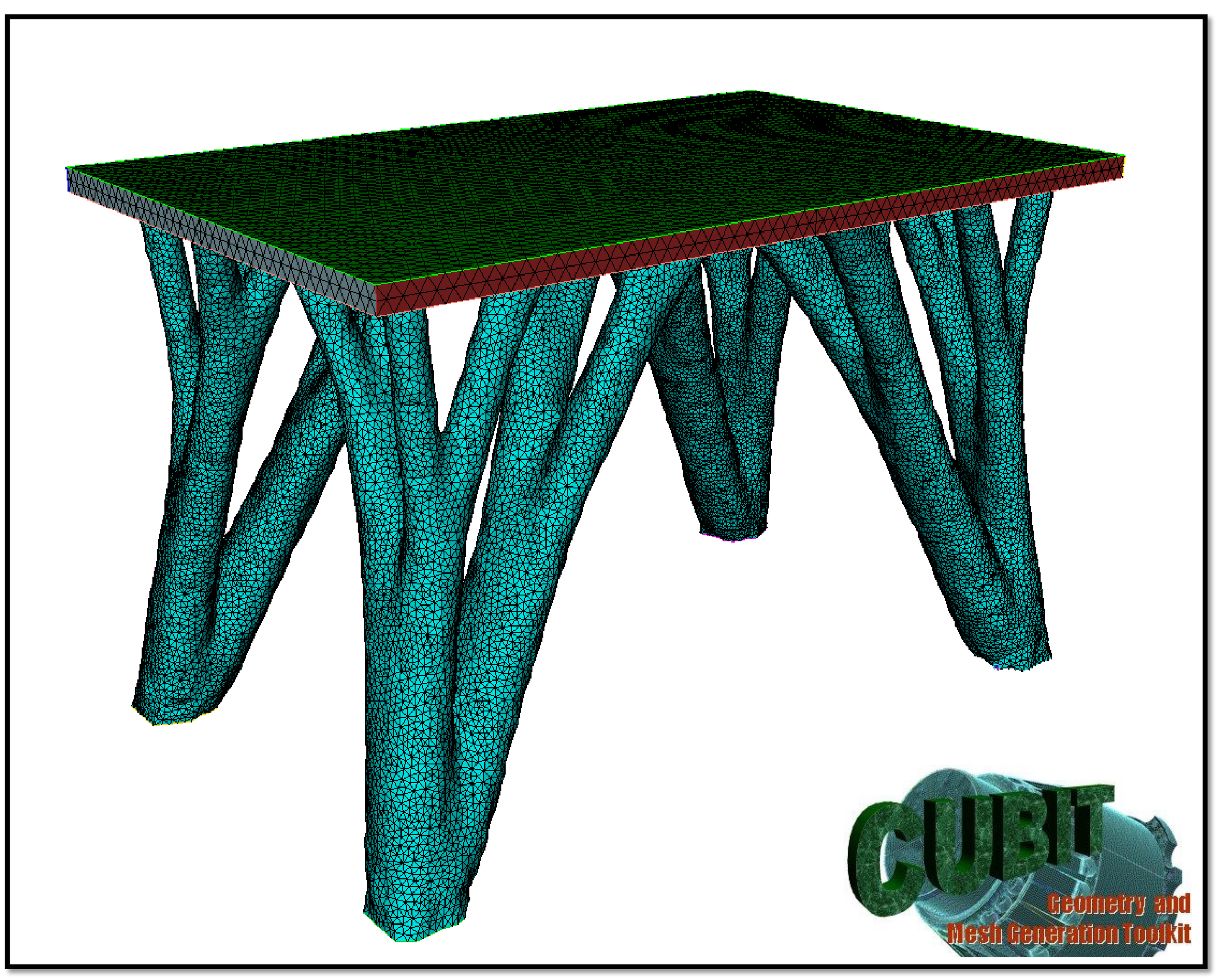


Design Components

- Excluded Blocks
- Boundary Conditions
- Mesh Density

Input Variables:

- Target Volume
- Number of Iterations
- Smoother Quality



Discussion: As can be seen by the table design on the right, this approach produces dramatically different "organic" designs where material is optimally placed to provide maximum benefit. The code being used is a preliminary version and only supports static loadings, but will be updated to provide increased design options. We are working to understand and eliminate barriers to general adoption for design use, including the computational costs, as well as issues with complexity and ease of use.

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