Structural Optimization 2025

Project #3 Bonus Task

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Bonus Task:

Advantages of meshing-based approaches:

- Realizability: 2D meshing algorithms generate geometries that usually can be manufactured.
- Controlled node placement: Mesh nodes can often be placed at specific coordinates, simplifying the application of boundary conditions and loads.
- Algorithm diversity: A wide variety of meshing algorithms exist, allowing flexibility in choosing one best suited for the problem.
- Low-dimensional design space: Meshing algorithms are typically controlled by a small set of parameters, making them easy to optimise, as in our assignment.
- Integration with commercial FEA: Meshing-based structures can directly be used in fast, commercial FEA software, making the setup of the optimisation process easy.
- Efficient exploration: These methods can quickly generate a broad range of feasible topologies, including non-intuitive ones. (Even the topology of the space that is meshed can be changed parametrically). Unlike ground structure methods based on fully connected graphs, meshing avoids combinatorial explosion. (See the paper by the Lab with the Superformula)

Limitations:

- Mesh-dependency of results: Optimised solutions can be sensitive to the initial mesh or its resolution.
- Local connectivity: Mesh nodes are only connected to nearby nodes, limiting element length variation. This may exclude some efficient structural configurations.
- Limited refinement: While some meshing algorithms allow local refinement, adding this increases problem complexity and introduces new variables to optimise.
- Limited search space: A ground structure with many nodes evenly spaced and fully connected will probably outperform an algorithmically generated mesh (as it contains more elements at all length scales), but will be much more expensive to optimise.

Improving Distmesh (but applies to other algorithms as well):

- Node position optimisation: Incorporating a nested optimisation step to adjust node positions, similar to the LayOpt truss optimiser, could significantly improve results. This allows the mesh to adapt not just in topology but also in geometry, leading to better-performing structures.