

Topologically Aware Construction of Minimal Spanning Trees in Meshes

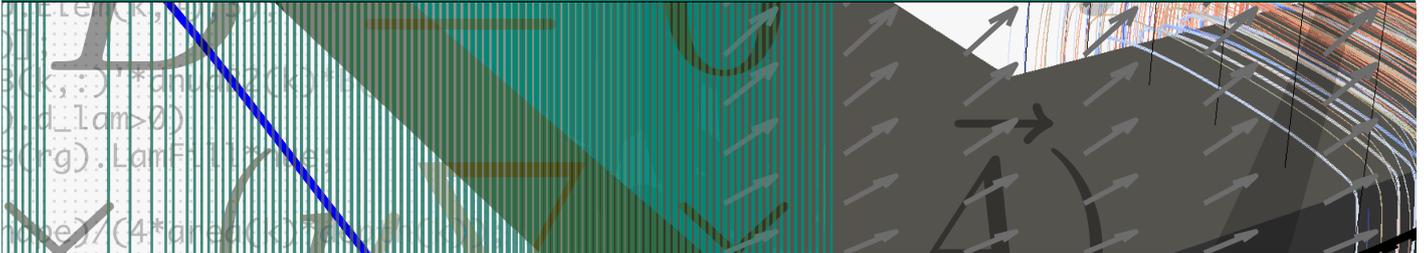


TECHNISCHE
UNIVERSITÄT
DARMSTADT

Proposal for a bachelor's or master's thesis

Study field: Computational Engineering | Computer Science | Electrical Engineering | Mathematics

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Description

Most finite element methods can be related to some kind of mesh \mathcal{M} . In computational electromagnetism, the gradient can be associated with vertices and edges of \mathcal{M} . We can exploit this knowledge in simulations by identifying and using a spanning tree, i.e., a selection of $\#\text{vertices} - 1$ edges that connect all vertices. The vertices and edges are implicitly linked to the topology of the mesh. This can be, for example, observed in the Euler characteristic

$$\#\text{vertices} - \#\text{edges} + \#\text{faces} - \#\text{cells} = b_0(\mathcal{M}) - b_1(\mathcal{M}) + b_2(\mathcal{M}),$$

where $b_i(\mathcal{M})$ is the i -th Betti number (0: $\#\text{conn. comp.}$, 1: $\#\text{holes}$, 2: $\#\text{voids}$). This can impact simulation as well because a tree might not provide enough information, which necessitates adding additional edges to obtain a belted tree.

For the tree construction, the well-known Kruskal's algorithm is a flexible and simple choice. It requires weights that are assigned to each edge and builds a minimal spanning tree, i.e., it tries to minimize the weights of the edges in the tree. This allows us to control the structure of the tree via specifying appropriate weights. To enable this flexibility for general \mathcal{M} , we propose the project:

- Set up a mesh format that allows you to enrich edges with weights and contains data on vertices, faces, and cells as well. One focus should also be on the easy conversion between different available formats that are already in use within the institute.
- Implement Kruskal's algorithm for the constructed mesh format
- Exploit the trees within simulation workflows (up for discussion)
- (Master: Detection of non-trivial topologies and belted tree construction)
- (Master: Exploit the enriched trees within simulation workflows)

Prerequisites

Programming skills and motivation for a topic with an algorithmic focus.

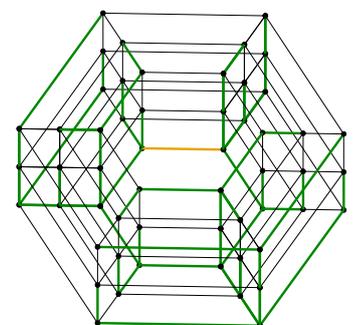
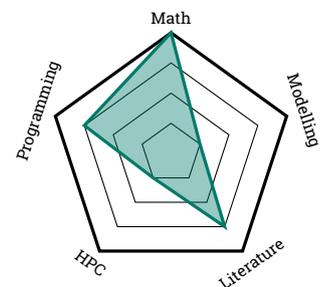
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Weighted Core Areas:



Tree Edges
Harmonic Edges — Belted Tree

