Robust Hex-Dominant Mesh Generation using Field-Guided Polyhedral Agglomeration

Daniele Panozzo*

* New York University, USA

ABSTRACT

While hexahedral meshes are generally preferred for solving nonlinear partial differential equations, automatic techniques capable of producing them robustly are still out of reach despite three decades of extensive research dedicated to this topic. Hexahedral-dominant meshes strike a good balance: they are easier to generate, since they can contain a small number of irregular elements, while offering good numerical properties. Building upon the 2D instant meshing (IM) approach, we introduce a novel algorithm to efficiently, robustly, and automatically create field-aligned hex-dominant meshes.

The first part of the talk will cover a quaternionic representation for a volumetric cross-field, which will guide the edge alignment of the hex-dominant mesh. When paired with a hierarchical accelerations structure, this representation enables us to interpolate user-defined constraints, while naturally aligning to shape features. The volumetric cross-field is used to define a position field encoding the position of the nodes of the hex-dominant mesh.

The second part of the talk will complete the pipeline, providing a robust extraction algorithm guaranteed to extract a compatible manifold mesh from any field-aligned parameterization — it is designed to work with local parameterizations that are characteristic of the output produced by the IM technique, but it can also be applied to any global parameterization generated by other means. The algorithm uses a sequence of local topological operations to collapse and split edges, faces, and polyhedra of the input mesh, eventually converting the input tetrahedral mesh into a hex-dominant output mesh. Topological invariants are checked before each operation, and only those preserving the invariants are executed, which ensures that both genus and manifoldness of the input are preserved throughout this process.

While the two contributions are independently useful in existing meshing pipelines, they have been designed together to extend the IM pipeline to the volumetric cases. Combined, they lead to a simple, robust, automatic, and scalable pipeline that automatically remesh a benchmark composed of 106 meshes, with no user-interaction and no parameter tweaking.