Using a Faceted Geometry Representation to Improve the Performance of Overlay Grid Meshing

David Noble* Matt Staten* Riley Wilson*

Abstract
A facet-based geometry engine is presented that significantly improves the performance of an overlay grid tetrahedral mesher as compared to a CAD-based geometry engine.

1 Introduction

Traditional tetrahedral meshing utilizes a bottoms-up approach in which nodes are put on CAD vertices, then edges are meshed along CAD curves, triangle faces are meshed on CAD surfaces, and finally tetrahedral elements are created to fill the CAD volume. When each of these CAD entities are well defined and have reasonable size, this approach can be highly successful in generating high quality meshes. However, when the CAD entities are infinitesimal or ill-posed, this bottoms-up strategy can fail or produce unusable meshes. Overlay grid meshing techniques have been proposed to circumvent these difficulties. Different variations of overlay grid meshing are used in several recent tetrahedral meshers including CISAMR [1], TetWild [3], Morph, and Krino [2].

The Morph mesher, developed at Sandia National Laboratories, uses an abstract geometry interface to define the geometry queries needed by the overlay grid meshing algorithms. Some of the workhorse methods include:

1. Find the intersections between the surfaces of the body and the edges of the overlay grid.
2. Find intersections between the curves of the body and the faces of the overlay grid
3. Determine the body (or void) that contains a given point.
4. Find the closest point projection from a given point to the surfaces of the body and the surface normal at the closest point.

These operations are somewhat unique to an overlay grid mesher. By comparison, a bottoms-up mesher may not require any intersections, or much fewer of them, to generate a boundary conforming mesh. As a result, a CAD engine may not be optimized for these queries. An alternate approach is to create an intermediate facet-based representation of the geometry. This facet representation is then used for the geometry queries, rather than the underlying CAD. An additional benefit of having a robust, performance facet-based geometry engine is that it can be used to mesh an intrinsically facet-based geometry, like the IMR crab in fig. 1.

In this presentation, we describe a facet-based geometry engine implementation for use in the overlay grid mesher, Morph. The engine is based on the open-source toolkit, Krino, within the Trilinos library. The design of Krino is presented. The performance of Morph using the facet-based geometry is compared to that using a CAD engine directly. For the geometry shown in fig. 2, which involves several spline surfaces on the nuts and bolts, a 50x speedup is obtained using the facet-based geometry representation.

*Sandia National Laboratories, a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC (NTESS), a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energys National Nuclear Security Administration (DOE/NNSA) under contract DE-NA0003525. This written work is authored by an employee of NTESS. The employee, not NTESS, owns the right, title and interest in and to the written work and is responsible for its contents. Any subjective views or opinions that might be expressed in the written work do not necessarily represent the views of the U.S. Government. The publisher acknowledges that the U.S. Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this written work or allow others to do so, for U.S. Government purposes. The DOE will provide public access to results of federally sponsored research in accordance with the DOE Public Access Plan.

References

[1] A. Nagarajan and S. Soghrati, *Conforming to interface structured adaptive mesh refinement: 3D algorithm and implementation*, Computational Mechanics, 62 (2018), pp. 1213-1238, https://doi.org/10.1007/s00466-018-1560-2.

[2] S. A. Roberts, H. Mendoza, V. E. Brunini and D. R. Noble, *A verified conformal decomposition finite element method for implicit, many-material geometries*, Journal of Computational Physics, 375 (2018), pp. 352-367, https://doi.org/10.1016/j.jcp.2018.08.022.

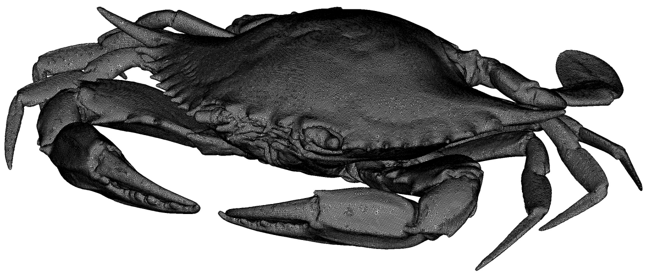

Figure 1: The IMR crab, 7.6M tetrahedral elements, 14 MPI procs, 531 seconds generation time, min scaled Jacobian: 0.126

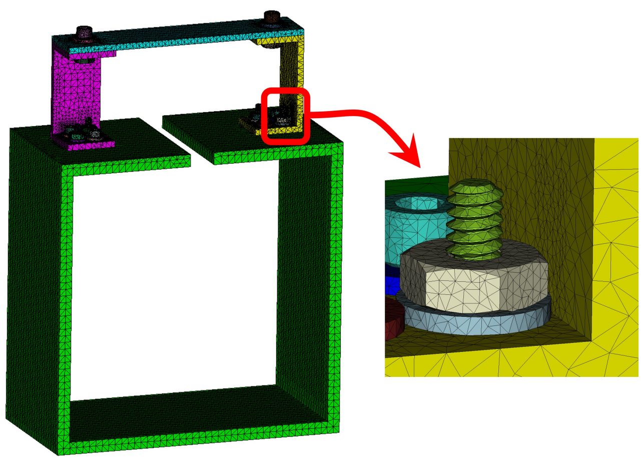

Figure 2: Mesh of Geometry With Many Spline Surfaces

[3] Y. Hu, T. Schneider, B. Wang, D. Zorin and D. Panozzo, *Fast tetrahedral meshing in the wild*, ACM Trans. Graph., 39:4, Article 117 (2020), https://doi.org/10.1145/3386569.3392385.