Isosurface Stuffing Improved: Acute Lattices and Feature Matching

Crawford Doran*
University of British Columbia

Athena Chang†
University of British Columbia

Robert Bridson‡
University of British Columbia

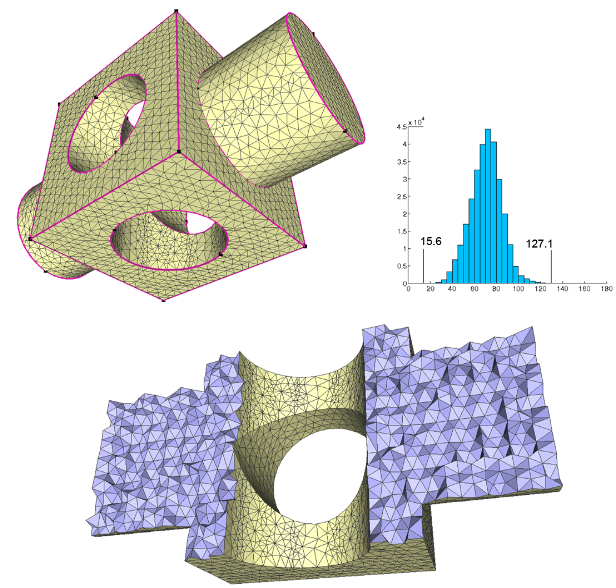

Figure 1: *A model with sharp edges and corners is meshed with our variant of isosurface stuffing, achieving excellent dihedral angles (shown in the histogram) while also precisely matching the input surface (sharp features emphasized).*

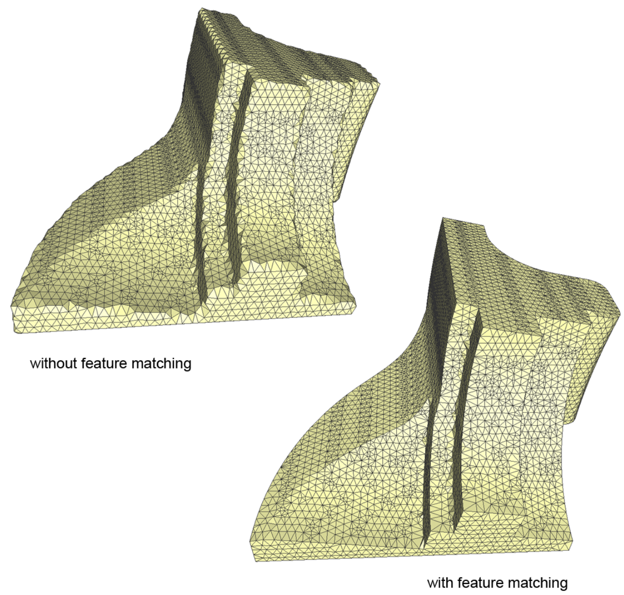

Figure 2: *Without feature-matching, the isosurface stuffing approach rounds off edges and corners when applied to non-smooth inputs. Our variant doesn't yet guarantee every feature is captured, but is effective enough for many models of interest in graphics.*

Tetrahedral mesh generation is an important tool in graphics, both for discretizing dynamics in animation and in providing a domain for geometric algorithms. The search for faster methods which produce higher quality tetrahedra continues. Here we present two modifications of Labelle and Shewchuk's isosurface stuffing [2007], which is exceptionally fast, provides good quality tetrahedra (with strong bounds), and has a simple implementation — with the caveat it only applies to smooth geometry.

We posit that isosurface stuffing's improved element quality over earlier octree methods (e.g. [Shephard and Georges 1991]) is at least in part due to its use of the BCC lattice of tetrahedra as input to the cutting and warping stage, rather than post-tetrahedralizing cut and warped octree cells. We take this a step further, using an even higher quality lattice of strictly *acute* tetrahedra, the "modified A-15 tile" identified by Üngör [2001], and previously used by Williams for isosurface extraction due to its favourable valences [2008]. All dihedral angles begin between 53° and 79°, affording significantly better output elements and/or allowing a greater degree of warping before quality is degraded too far (see figure 1 for example dihedral angle statistics).

This flexibility allows us to recover some of the earlier octree methods' ability to capture sharp features such as edges and corners in the input, even without refinement. We added a feature-matching stage to the mesh generator after the usual stuffing. For each feature point (e.g. corner or endpoint of a curve) we snap the position of the closest boundary vertex to it, breaking ties to the closest feature when conflicted. Then, for each feature curve (whose endpoints now have snapped vertices) we find a path through the boundary mesh that runs as close as possible to the curve using Dijkstra's algorithm, subject to avoiding excessive deformations, and snap the vertices of the path to lie on the feature curve. In difficult situations, such as high valence features and features underresolved w.r.t. the lattice spacing, not all features are matched — but such cases are localized and don't detract from mesh quality. Especially with a standard smoothing postprocess to optimize vertex locations, this produces extremely high quality meshes for inputs of general interest to graphics, yet is still fast and simple to implement.

*e-mail:cdoran@cs.ubc.ca
†e-mail:athena.me@gmail.com
‡e-mail:rbridson@cs.ubc.ca

SIGGRAPH 2013, July 21 – 25, 2013, Anaheim, California.

ACM 978-1-4503-2261-4/13/07

References

LABELLE, F., AND SHEWCHUK, J. 2007. Isosurface stuffing: fast tetrahedral meshes with good dihedral angles. *ACM Transactions on Graphics (TOG) 26*, 3, 57.

SHEPHARD, M. S., AND GEORGES, M. K. 1991. Automatic three-dimensional mesh generation by the Finite Octree technique. *Int'l. J. Num. Meth. Eng. 32*, 709–749.

ÜNGÖR, A. 2001. Tiling 3D Euclidean space with acute tetrahedra. In *Proc. Canadian Conference on COmputational Geometry*, 169–172.

WILLIAMS, B. 2008. Fluid surface reconstruction from particles. *M.Sc Thesis, University Of British Columbia*.