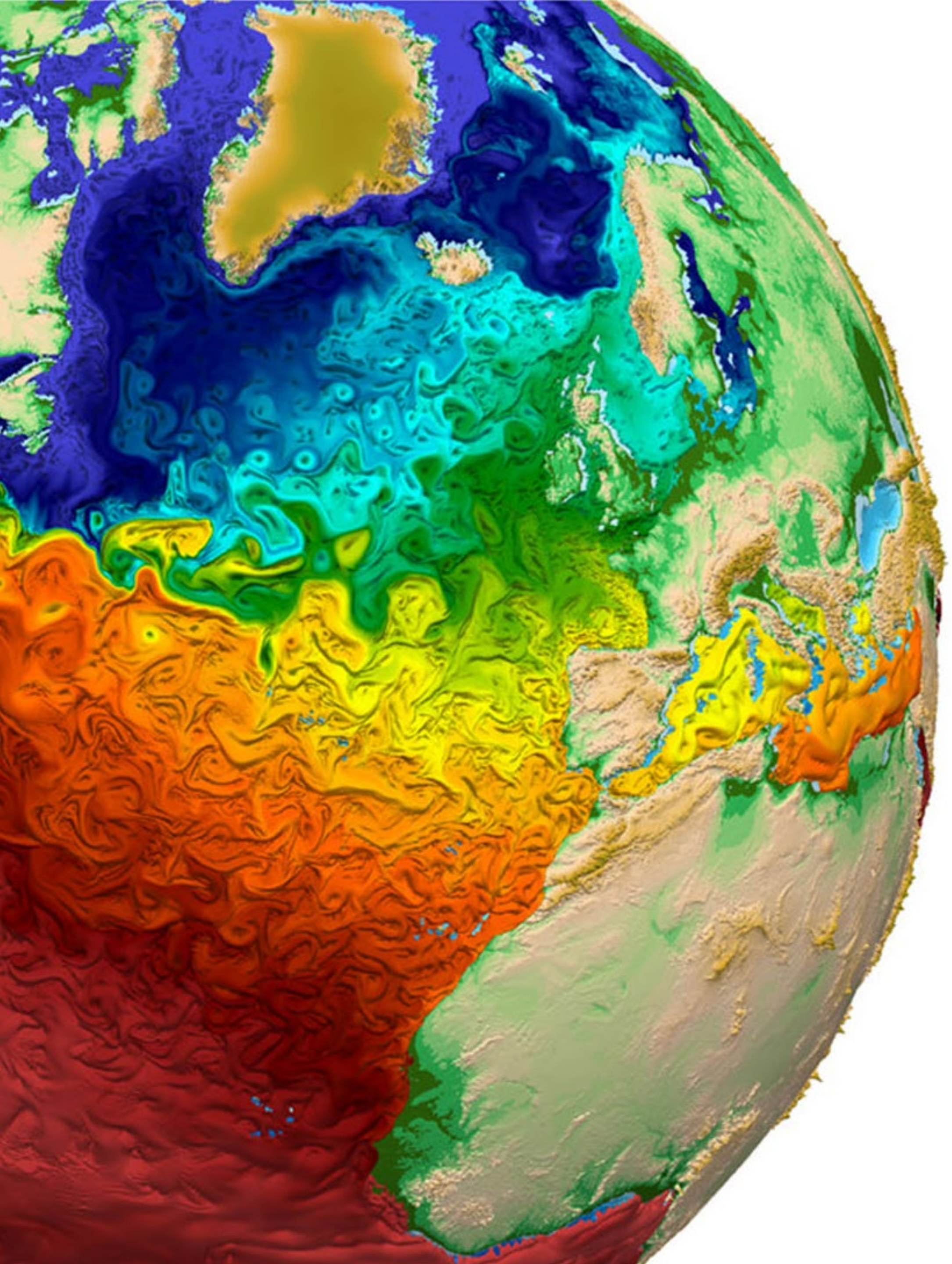


Contouring

Dual Marching Cubes

Scientific Visualization

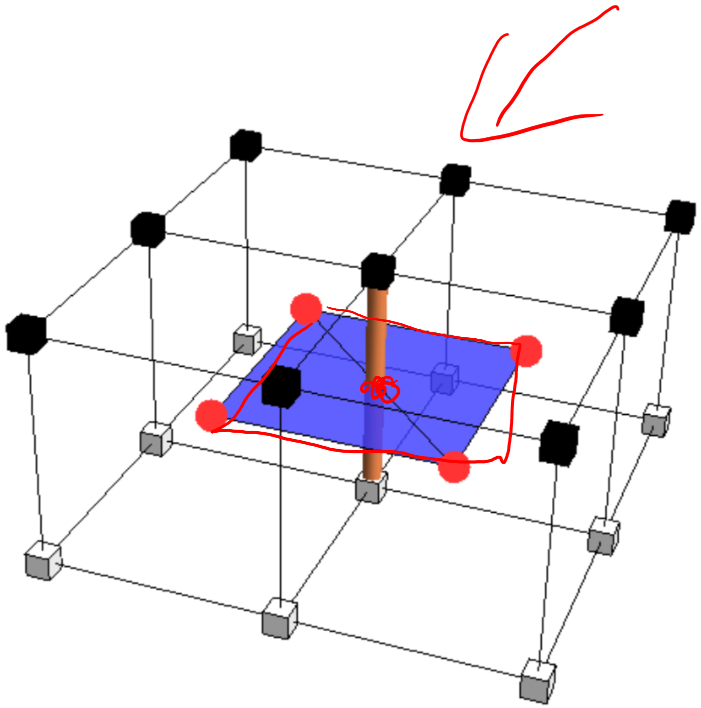
Professor Eric Shaffer

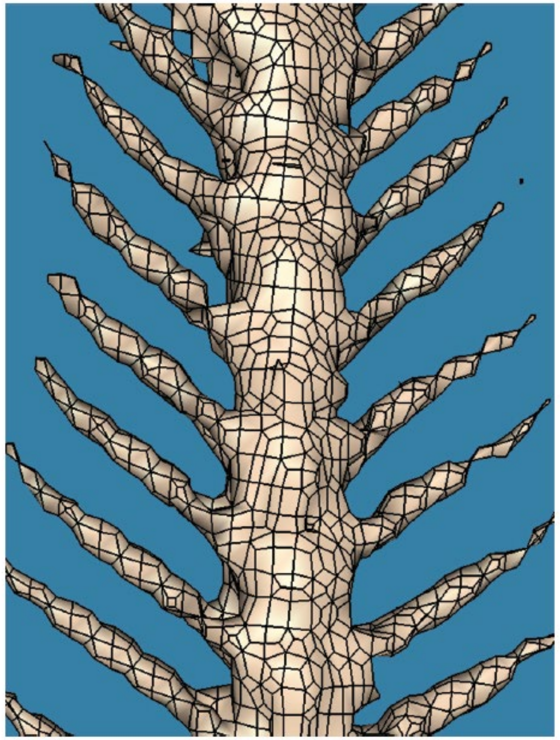
ILLINOIS

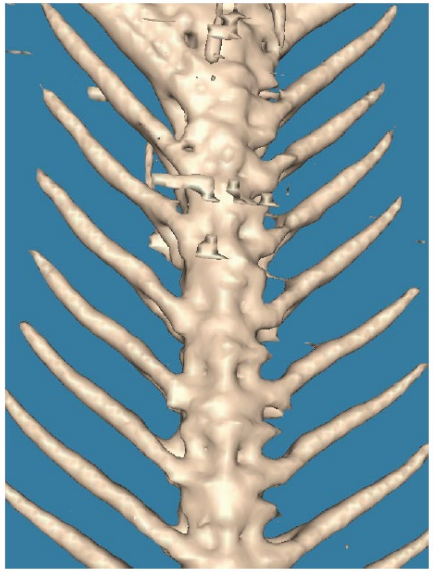
Dual Marching Cubes

Operates on structured grids…like Marching Cubes

Generates quadrilaterals…dual to the vertices generated by Marching Cubes







ILLINOIS

Dual Marching Cubes: Algorithm

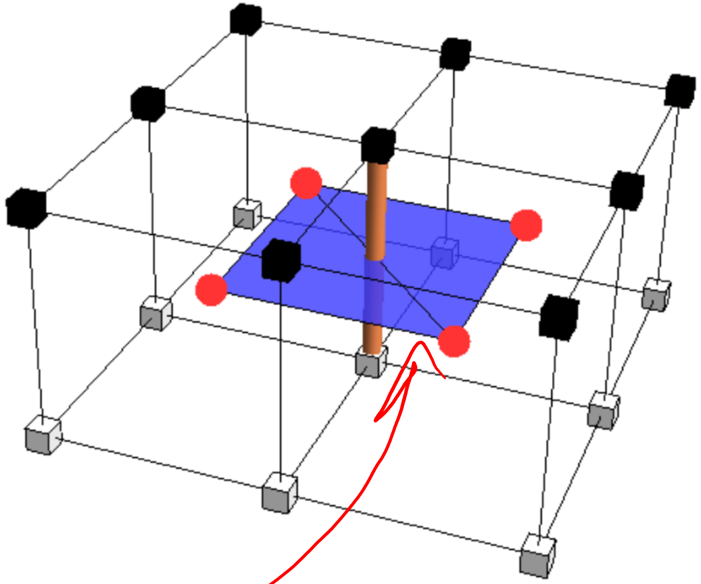
For each interior bipolar grid edge, construct a dual isosurface quadrilateral

↓

Compute isosurface vertex coordinates

↓

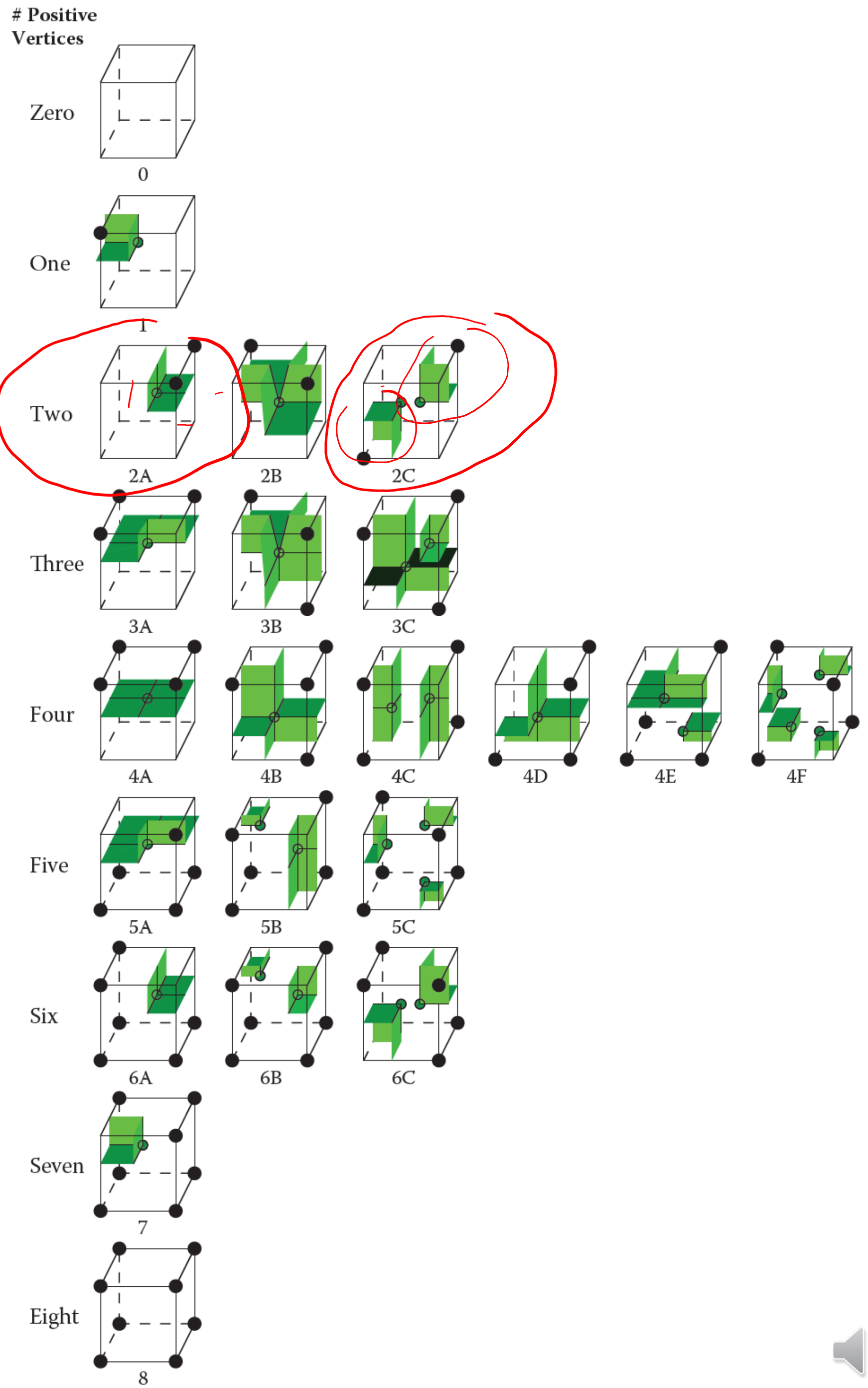
Triangulate the isosurface quadrilaterals



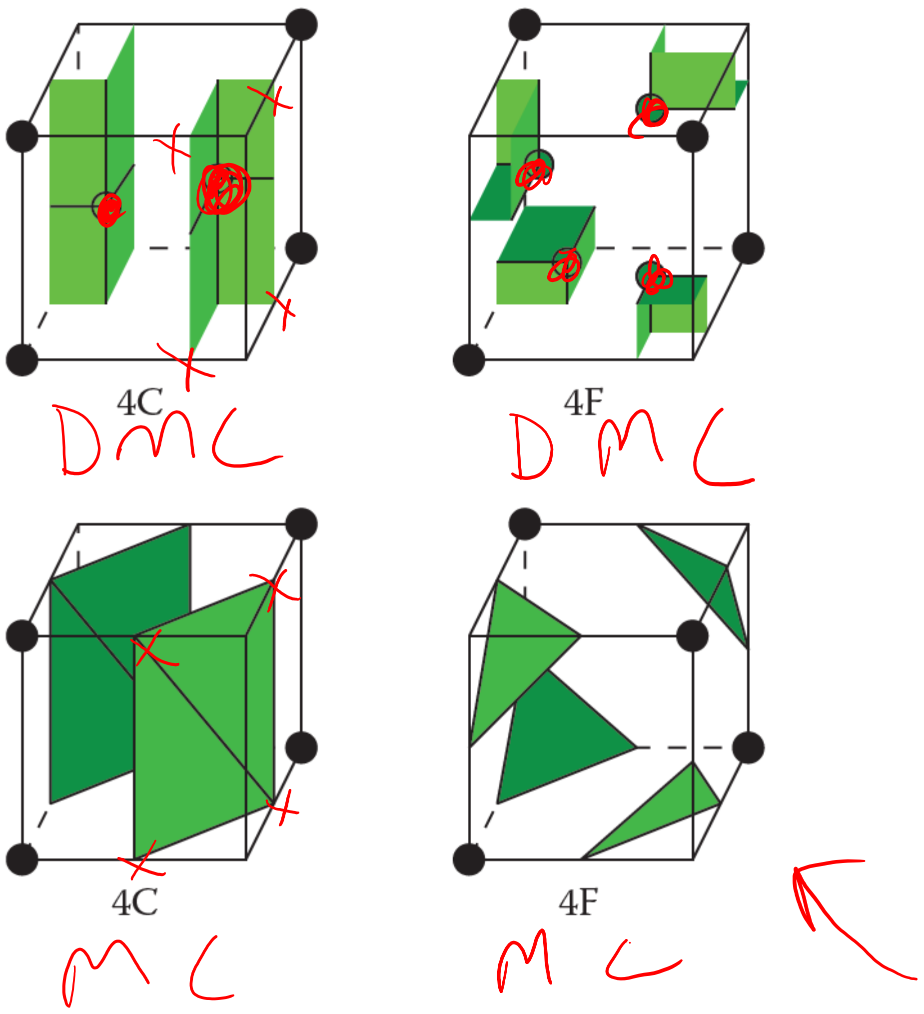
How Many Vertices in a Cell?

- Each bipolar edge generates a vertex in cells around it
  - Corner of a quadrilateral of the isosurface
  - Quad will intersect four cells
- Some vertices are shared….
- Cases are based on MC cases
  - Each polygonal patch in a cell will generate a vertex in DMC
- Can create a table of cases….

Table-based algorithm from:
Nielson, G. M. (2004). Dual Marching Cubes. In *Proceedings of IEEE Visualization 2004*, pages 489–496, Los Alamitos, CA. IEEE Computer Society.



Duality



Each polygonal patch in a MC cell → vertex in the dual

We can associate a set of bipolar edges with the dual vertex

Each bipolar edge creating vertex for a MC patch,
will be in the set for the associated dual vertex

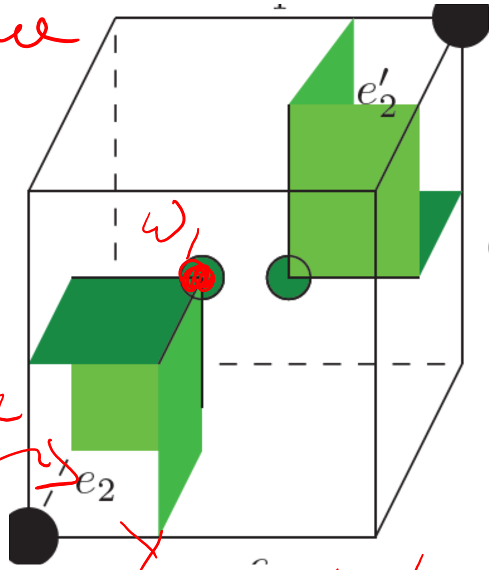
These edges are used to position the dual vertex

Positioning Vertices

For each bipolar grid edge $\mathbf{e} = (v, v')$,
  $w_{\mathbf{e}} \leftarrow \texttt{LinearInterpolation}(v, F(v), v', F(v'), \sigma)$

isovalue

For each grid cube $\mathbf{c}$,
  For each isosurface vertex $w_{\mathbf{c}}^m$ in $\mathbf{c}$,
    coordinates$(w_{\mathbf{c}}^m) \leftarrow$
      centroid of $\{w_{\mathbf{e}} : \text{edge } \mathbf{e} \text{ is associated with } w_{\mathbf{c}}^m\}$



w_1

w_{e_2}

w_{e_m}

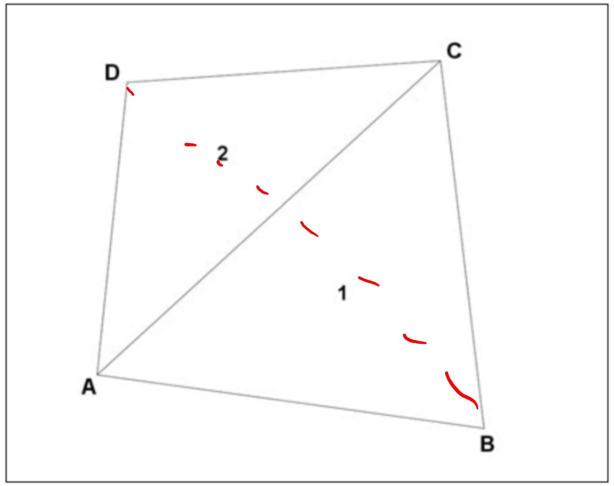
v $\quad w_{e_1}$ $\quad v'$

$$t = \frac{\sigma - F(v)}{F(v') - F(v)}$$

$$w_e = (1-t)v + t v'$$

Triangulation

Can replace each quadrilateral around bipolar edge by two triangles.



To construct the isosurface patch with two triangles, use the diagonal that minimizes the maximum triangle angle.

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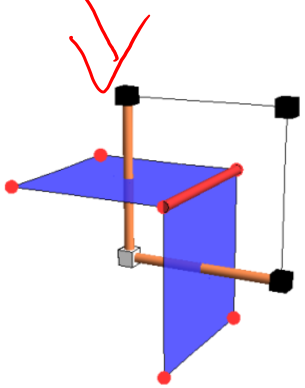
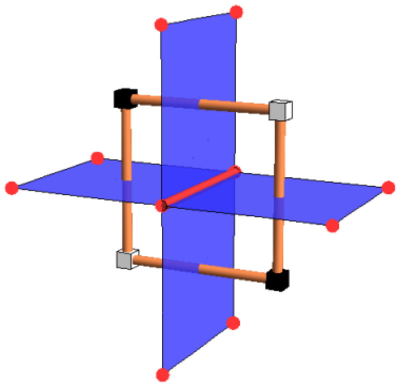
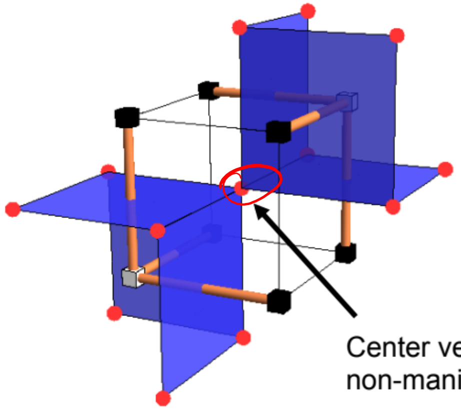
Non-manifold Cases



Red edge is shared by 2 quads



Red edge is shared by 4 quads (non-manifold)



Center vertex is non-manifold

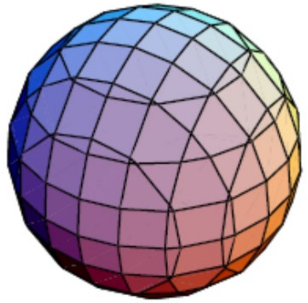
Comparison

Marching Cubes

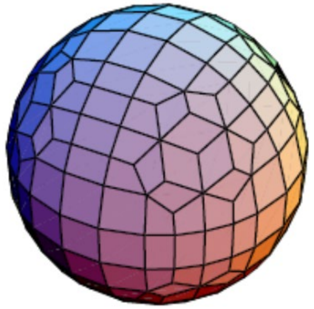
- Closed, manifold, and intersection-free
- Often generates thin and tiny polygons

Dual Contouring

- Closed and intersection-free
- Generates better-shaped polygons
- Can be non-manifold

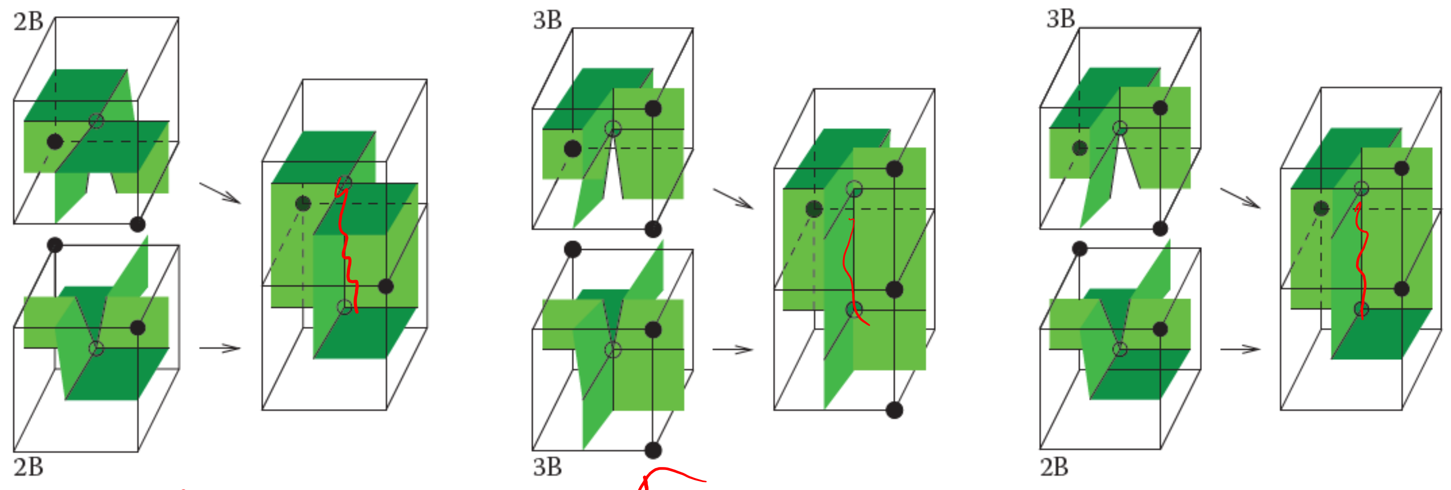


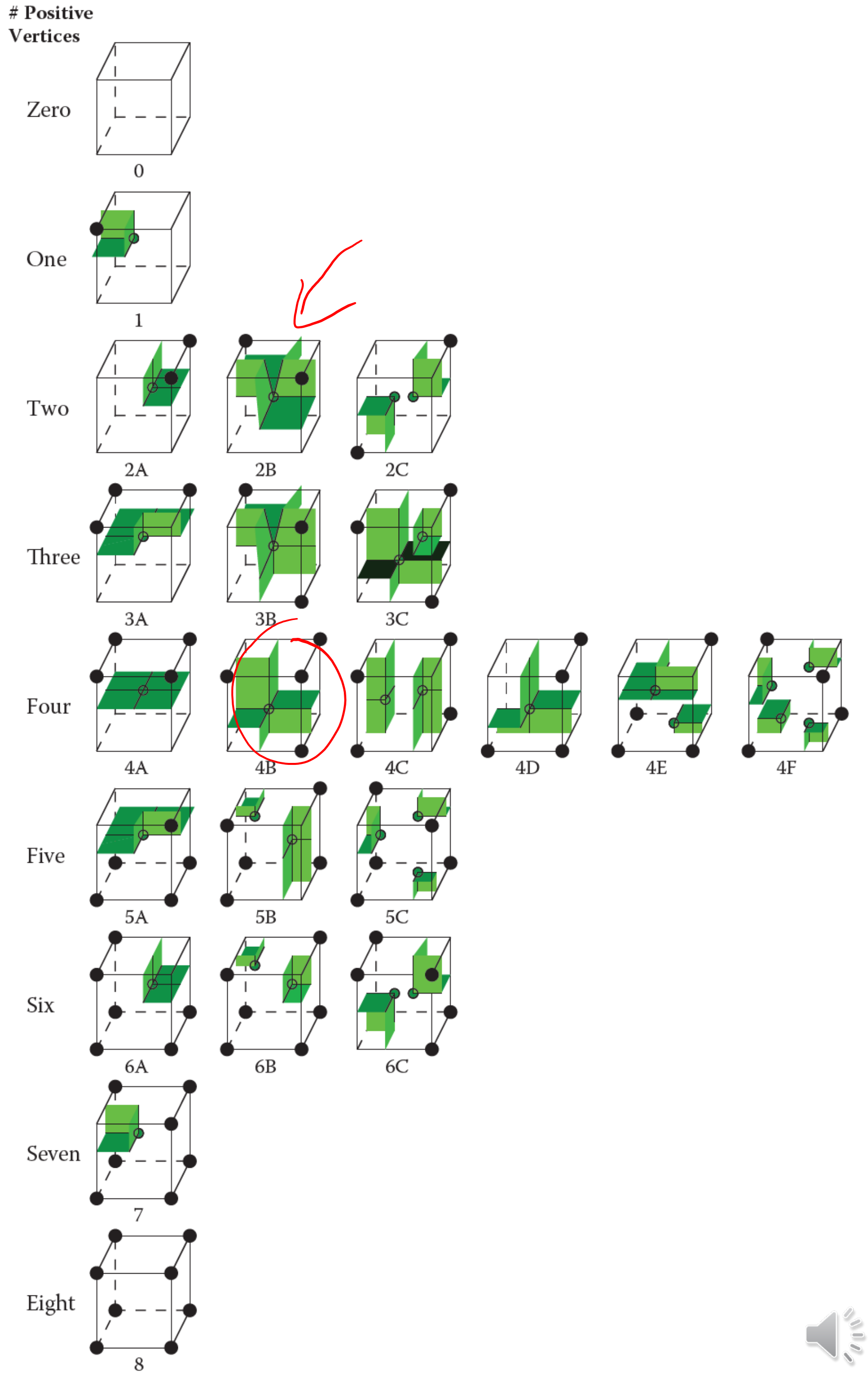
Marching Cubes



Dual Contouring

Manifold Dual Marching Cubes





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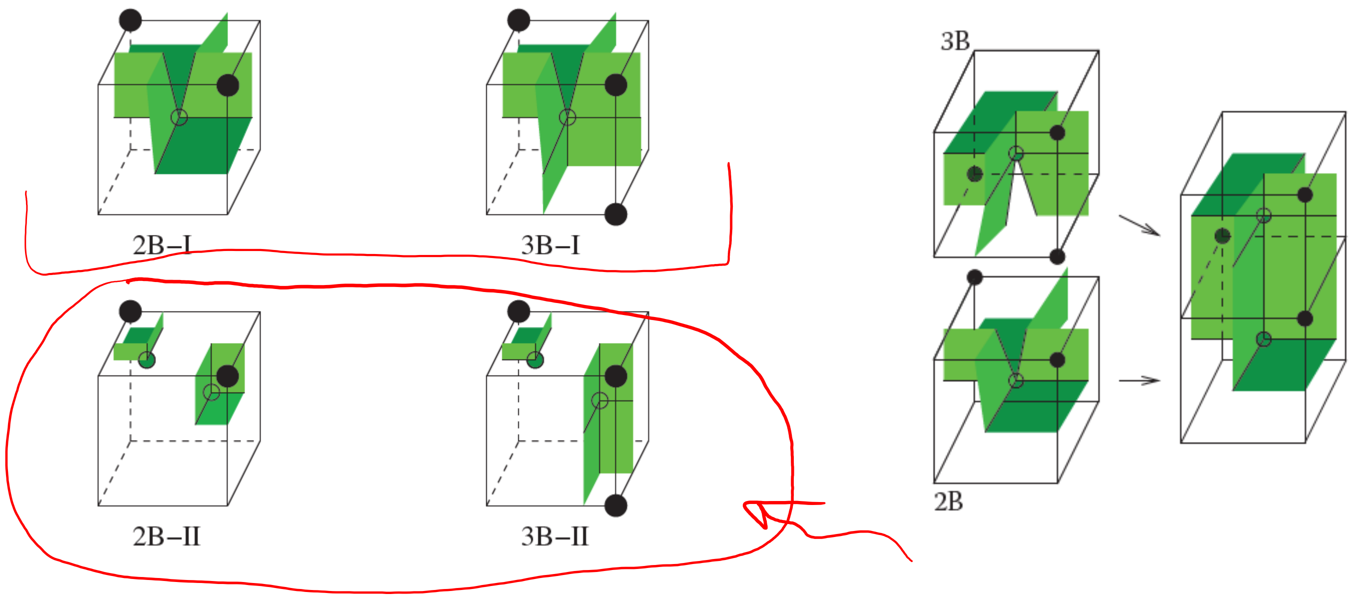
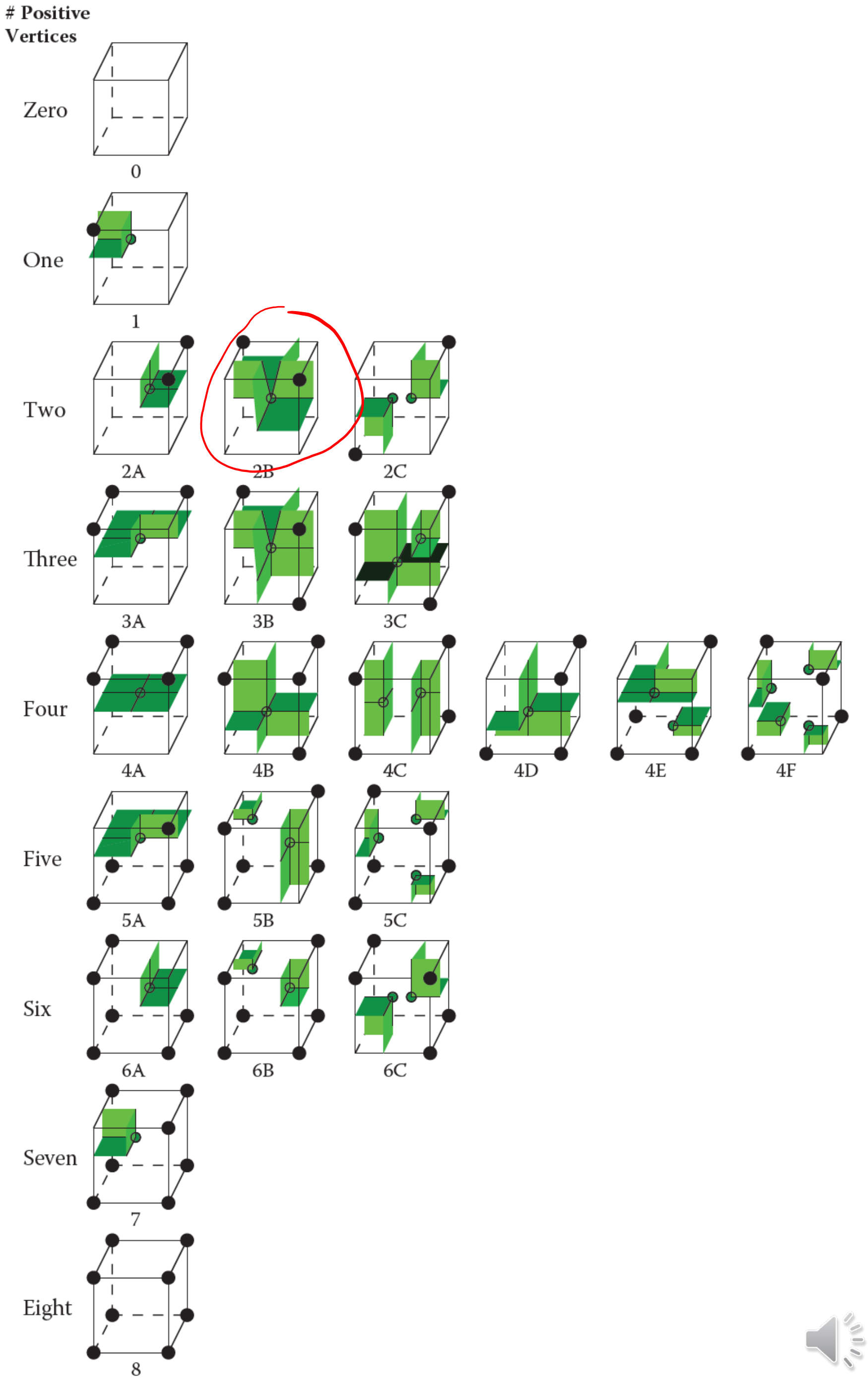
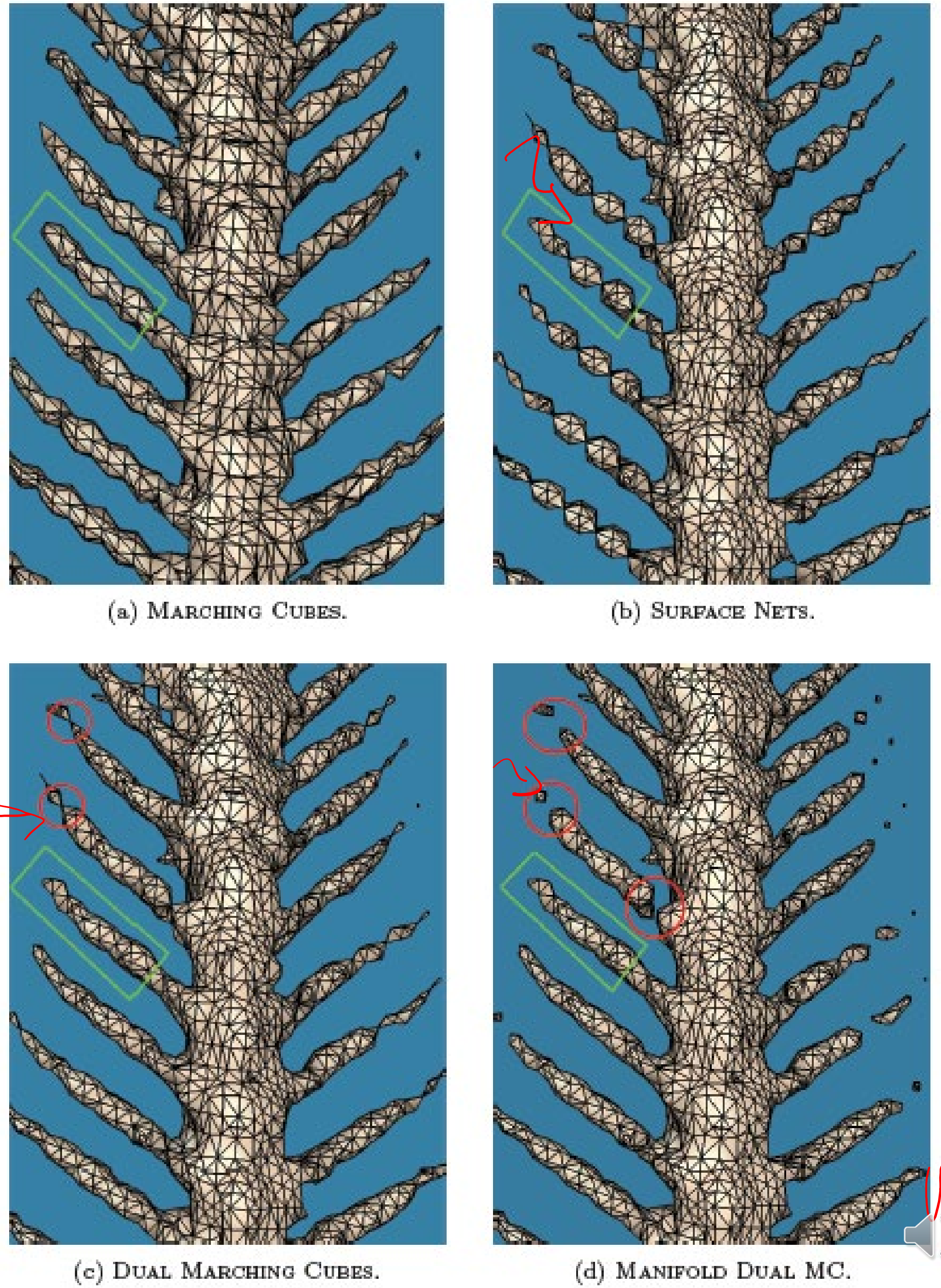
Manifold Dual Marching Cubes



Manifold Dual Marching Cubes avoids creating non-manifold edges by using isosurface patches 2B-II and 3B-II instead of 2B-I and 3B-I whenever two cubes with configurations 2B and 3B share their ambiguous facets.



Manifold Dual Marching Cubes



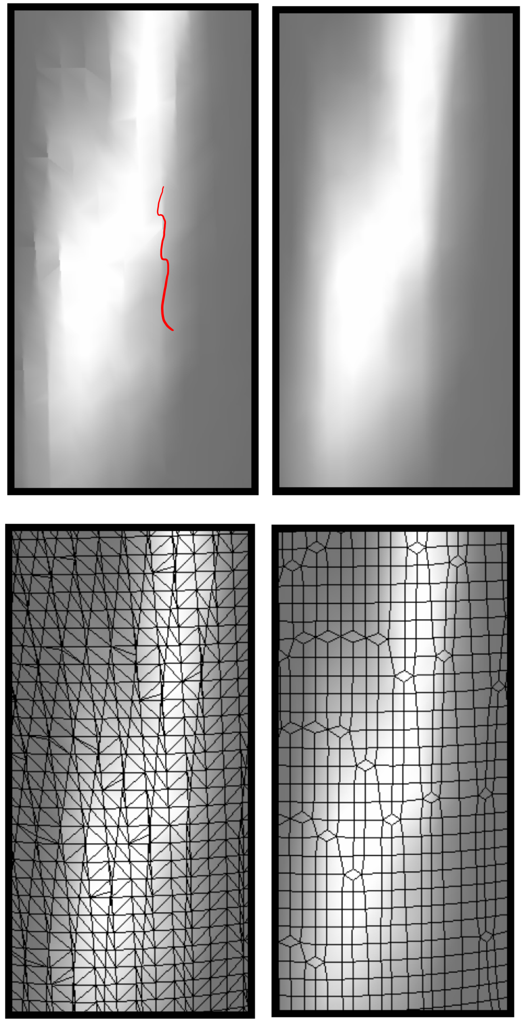
(a) Marching Cubes. (b) Surface Nets. (c) Dual Marching Cubes. (d) Manifold Dual MC.

For other approaches….

S. Schaefer, T. Ju and J. Warren, "Manifold Dual Contouring," in *IEEE Transactions on Visualization and Computer Graphics*, vol. 13, no. 3, pp. 610-619, May-June 2007, doi: 10.1109/TVCG.2007.1012.

Tanweer Rashid, Sharmin Sultana, Michel A. Audette, "Watertight and 2-manifold Surface Meshes Using Dual Contouring with Tetrahedral Decomposition of Grid Cubes"

Comaparison with Marching Cubes



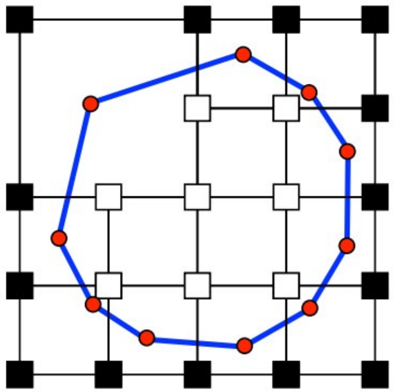
MC DMC

Can see fewer thin polygons in DMC surface

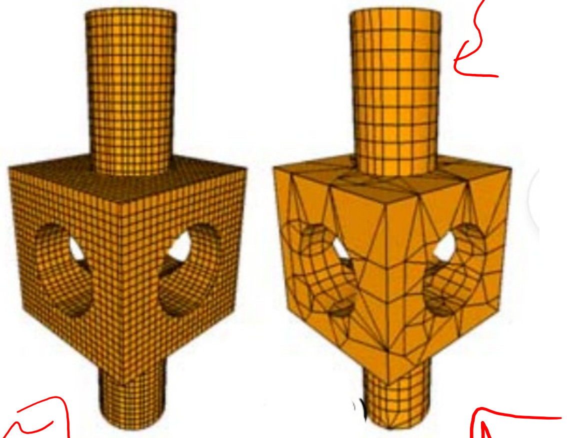
DMC generates smoother surface

- better able to match curvature

Extensions: Contouring on Adaptive Grids



DC on a Quadtree (2D)



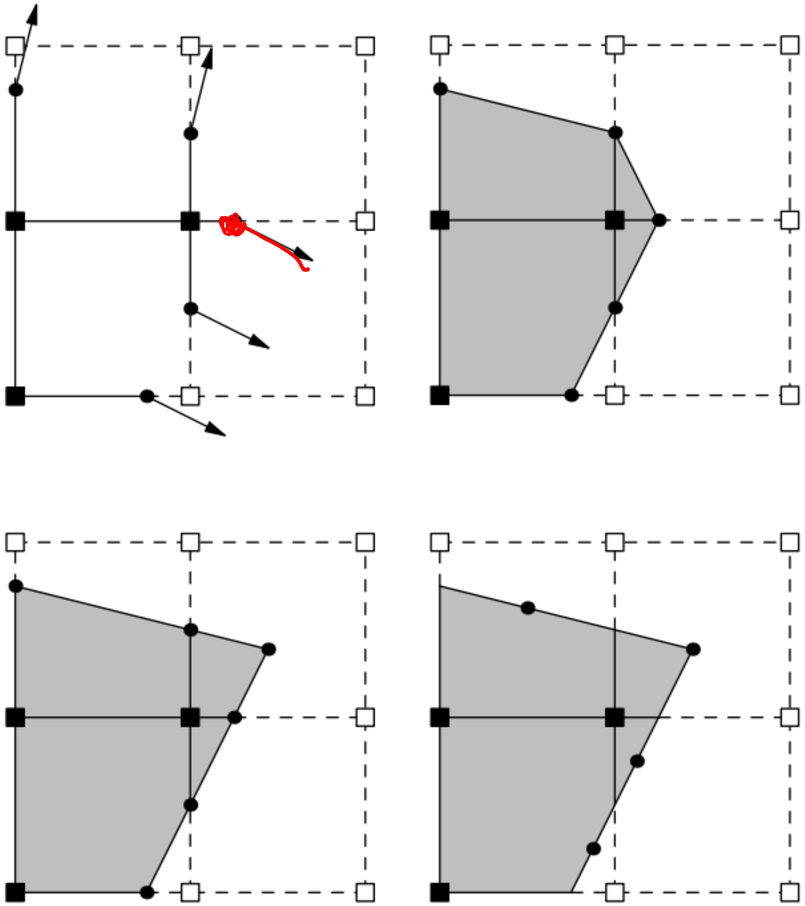
Benefits

Better use of polygon budget…fewer polygons in low curvature areas

Waste less time processing lots of small empty cubes

S. Schaefer and J. Warren, "Dual marching cubes: primal contouring of dual grids," *12th Pacific Conference on Computer Graphics and Applications, 2004. PG 2004. Proceedings.*, Seoul, South Korea, 2004

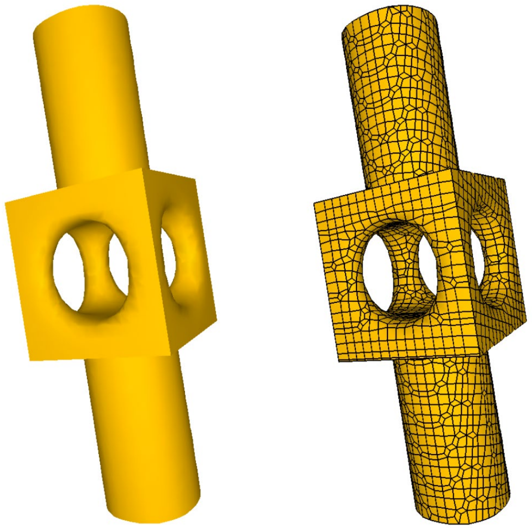
Dual Contouring on Hermite Data



Hermite data → Exact intersections and normal

Used on data from implicit surfaces

Retains sharp features



Ju, T., Losasso, F., Schaefer, S., Warren, J.: Dual contouring on hermite data. In: ACM SIGGRAPH (2002)