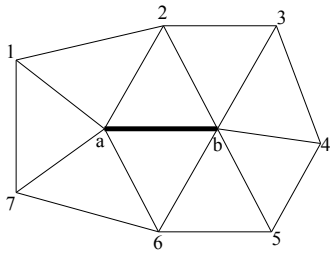
Subdivision Surfaces II

Questions on Homework?

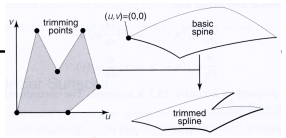
- What's an illegal edge collapse?

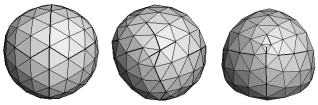


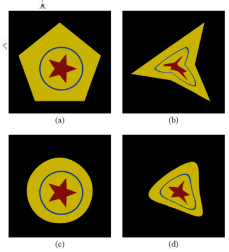
- To be legal, the ring of vertex neighbors *must be unique* (have no duplicates)!

Last Time?

- Spline Surfaces
  - complex topology is challenging, requires trimming curves
- Subdivision Zoo
  - Doo-Sabin
  - Loop
  - Catmull-Clark
- Subdivision w/ Creases





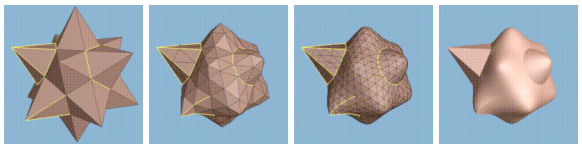


Today

- Piecewise Smooth Surface Reconstruction
- 3D Mesh Operations
- Subdivision Surfaces on the GPU
- Interpolating Subdivision

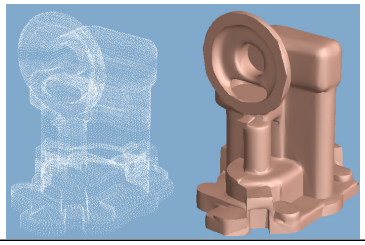
Reading for Today

- Hoppe et al., "Piecewise Smooth Surface Reconstruction" SIGGRAPH 1994



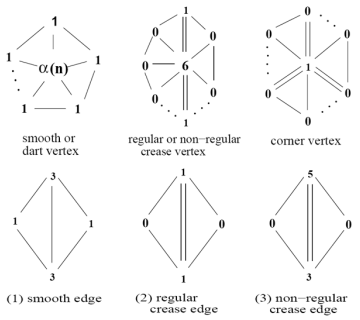
Piecewise Smooth Surface Reconstruction

- From input: scanned mesh points
  - Estimate topological type (genus)
  - Mesh optimization (a.k.a. simplification)
  - Smooth surface optimization



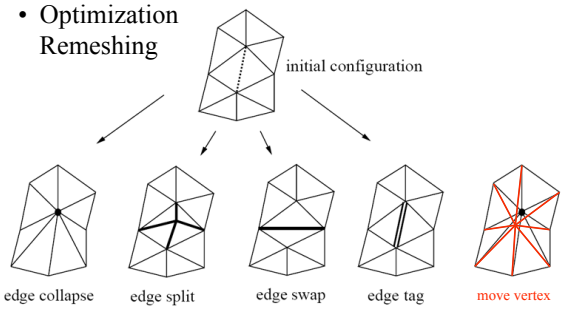
Adding creases to Loop Subdivision

- Vertex & edge masks
- Limit masks
  - Position
  - Tangent



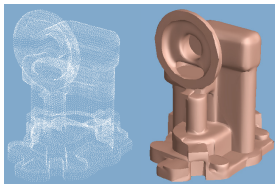
Piecewise Smooth Surface Reconstruction

- Optimization Remeshing



Piecewise Smooth Surface Reconstruction

- Crease subdivision masks *decouple* behavior of surface on either side of crease
- Crease rules cannot model a cone
- Optimization can be done locally
  - subdivision control points have only local influence
- Results
  - Noise?
  - Applicability?
  - Limitations?
  - Running Time



Questions?

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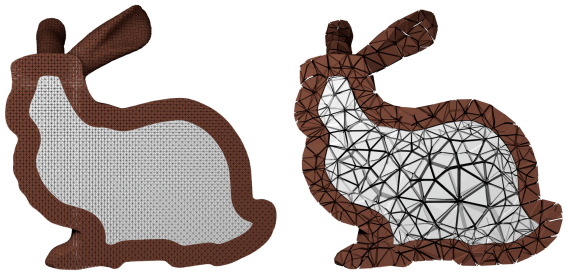
3D Mesh Simplification

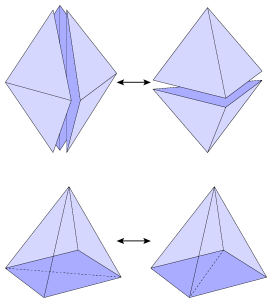


1,050K tetras (133K faces)

10K tetras (3K faces)

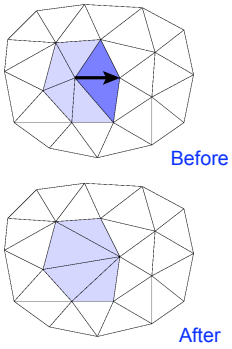
3D Mesh Operations

- Tetrahedral Swaps
  - Choose the configuration with the best local element shape
- Edge Collapse
- Vertex Smoothing
- Vertex Addition



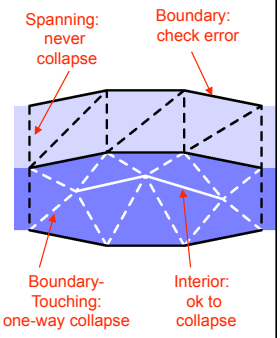
3D Mesh Operations

- Tetrahedral Swaps
- Edge Collapse
  - Delete a vertex & the elements around the edge
- Vertex Smoothing
- Vertex Addition



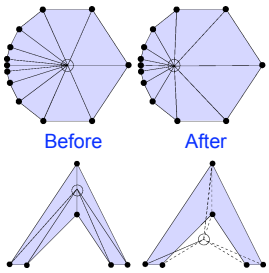
Prioritizing Edge Collapses

- Preserve topology
  - Thin layers should not pinch together
- Collapse weight
  - Edge length + boundary error
- No negative volumes
- Local element quality does not significantly worsen



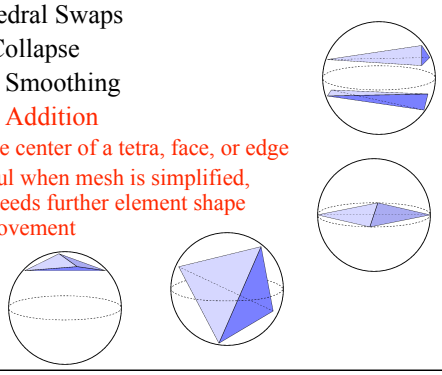
3D Mesh Operations

- Tetrahedral Swaps
- Edge Collapse
- Vertex Smoothing
  - Move a vertex to the centroid of its neighbors
  - Convex or concave, but avoid negative-volume elements
- Vertex Addition



3D Mesh Operations

- Tetrahedral Swaps
- Edge Collapse
- Vertex Smoothing
- Vertex Addition
  - At the center of a tetra, face, or edge
  - Useful when mesh is simplified, but needs further element shape improvement



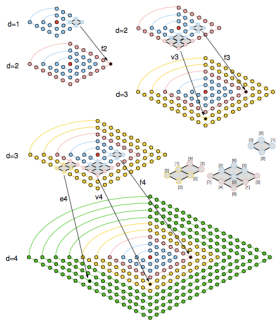
Questions?

Today

- Piecewise Smooth Surface Reconstruction
- 3D Mesh Operations
- Subdivision Surfaces on the GPU
- Interpolating Subdivision

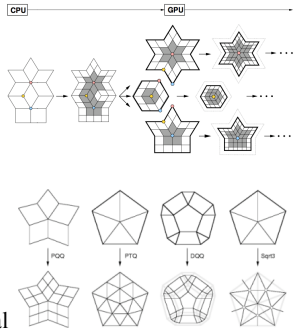
Reading for Today

- Shiue, Jones, and Peters, "A Realtime GPU Subdivision Kernel", SIGGRAPH 2005



A Realtime GPU Subdivision Kernel

- "Real-time" vs. "Interactive" vs. Offline?
- Extraordinary vertices
- Stencil
- PTQ: primal triangle quadrisection
- PQQ: primal quadrilateral quadrisection
- DQQ: Dual quadrilateral quadrisection



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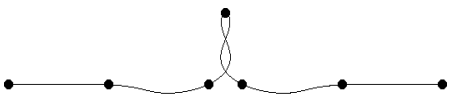
Interpolation vs. Approximation Curves

- Interpolation Curve – over constrained → lots of (undesirable?) oscillations

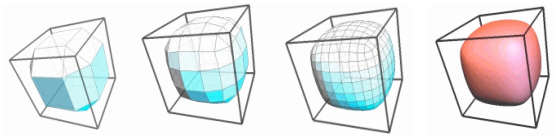


- Approximation Curve – more reasonable?

Interpolating Subdivision

- Chaikin:

- Doo-Sabin:



of the centroids of each edge/face

Interpolating Subdivision

- *Interpolation* vs. *Approximation* of control points
- Handle arbitrary topological type
- Reduce the "extraneous bumps & wiggles"

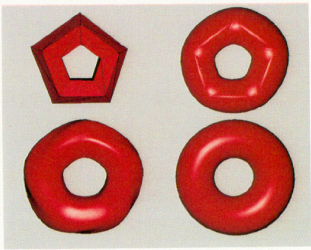
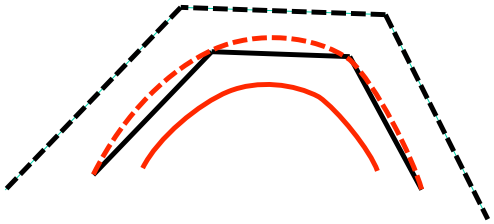


Figure 4: Interpolating a coarsely polygonized torus. Upper left: original mesh. Upper right: Shirman-Séquin interpolation[14]. Lower left: Interpolating Catmull-Clark surface. Lower right: Faired interpolating Catmull-Clark surface.

"Efficient, fair interpolation using Catmull-Clark surfaces", Halstead, Kass & DeRose, SIGGRAPH 1993

Interpolation of Catmull-Clark Surfaces

- Solve for a new control mesh (generally "bigger") such that when Catmull-Clark subdivision is applied it interpolates the original control mesh



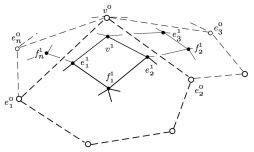
Vertex Position in Limit

- V_n stores the center vertex & surrounding edge & face vertices as a big column vector

$$V_n^{i+1} = \mathbf{S}_n V_n^i$$

- When n = 4: (n = valence)

$$V_n^\infty := \lim_{i \to \infty} \mathbf{S}_n^i V_n^1$$



$$\mathbf{S}_4 = \frac{1}{16} * \begin{pmatrix} 9 & \frac{3}{2} & \frac{3}{2} & \frac{3}{2} & \frac{3}{2} & \frac{1}{4} & \frac{1}{4} & \frac{1}{4} & \frac{1}{4} \\ 6 & 6 & 1 & 0 & 1 & 1 & 0 & 0 & 1 \\ 6 & 1 & 6 & 1 & 0 & 1 & 1 & 0 & 0 \\ 6 & 0 & 1 & 6 & 1 & 0 & 1 & 1 & 0 \\ 6 & 1 & 0 & 1 & 6 & 0 & 0 & 1 & 1 \\ 4 & 4 & 4 & 0 & 0 & 4 & 0 & 0 & 0 \\ 4 & 0 & 4 & 4 & 0 & 0 & 4 & 0 & 0 \\ 4 & 0 & 0 & 4 & 4 & 0 & 0 & 4 & 0 \\ 4 & 4 & 0 & 0 & 4 & 0 & 0 & 0 & 4 \end{pmatrix}$$

Solve for New Positions

- Goal: Find the control mesh vertex positions, *x* (a column vector of 3D points), such that the position of the vertices in the limit match the input vertices, *b* (also a column vector of points)
- Use Least Squares to solve

$$\mathbf{A}x = b$$

where A is a square matrix with the interpolation rules and connectivity of the mesh

- *See paper for extension to match limit normals*

Fairing

- Fairing: an additional part or structure added to an aircraft, tractor-trailer, etc. to smooth the outline and thus reduce drag
- Subdivide initial resolution twice so that all constrained vertex positions are independent

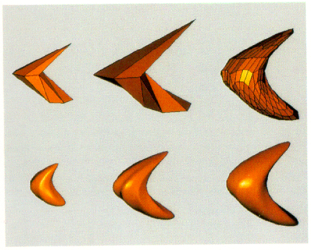
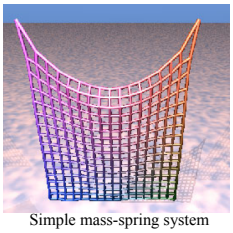


Figure 5: Top row: Original mesh, Interpolating mesh, Faired interpolating mesh. Bottom row: Corresponding Catmull-Clark surfaces. Interpolation introduces wiggles which are removed by fairing.

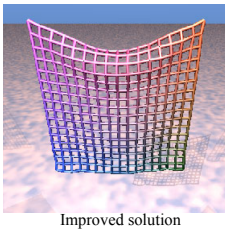
Questions?

Reading for Friday (2/11)

- "Deformation Constraints in a Mass-Spring Model to Describe Rigid Cloth Behavior", Provot, 1995.



Simple mass-spring system



Improved solution

Reading Tuesday (2/15)

- Baraff, Witkin & Kass, *Untangling Cloth,* SIGGRAPH 2003