CS-C3100 Computer Graphics

4.2 Subdivision Surfaces

Representing Surfaces

- Triangle meshes ✔
  - Surface analogue of polylines, this is what GPUs draw
- Tensor Product Splines (previous video)
  - Surface analogue of spline curves
- **Subdivision surfaces (this video)**
- Implicit surfaces
  - f(x,y,z)=0
- Procedural
  - e.g. surfaces of revolution, generalized cylinder
- From volume data (medical images, etc.)

In This Video

- Subdivision for curves and surfaces
- Loop subdivision for triangle meshes

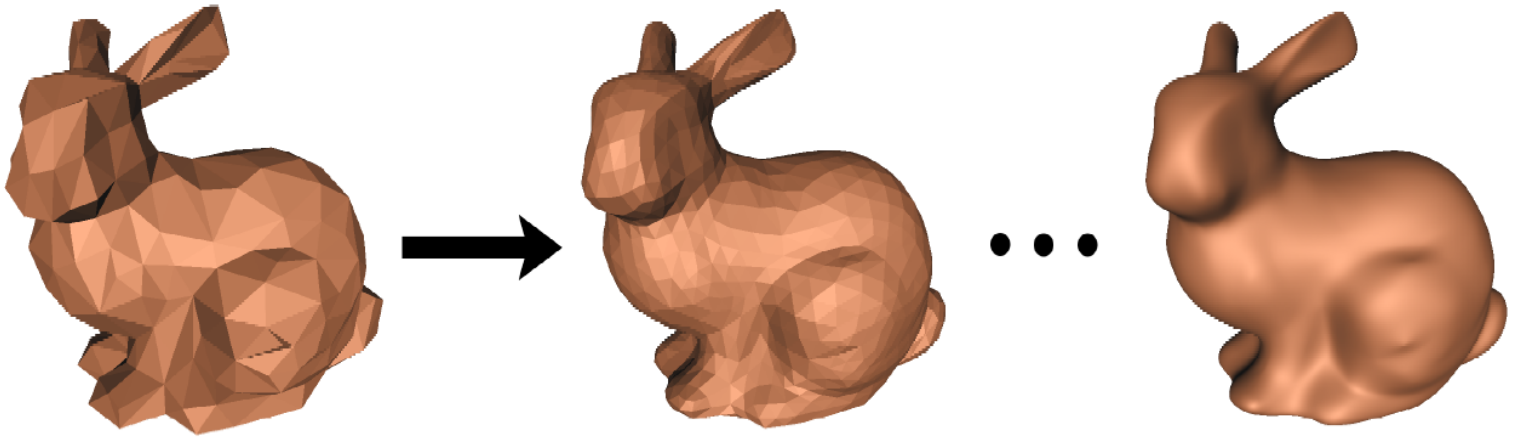
Issues with Spline Patches

- Regular connectivity only (square patches)
- Hard to ensure smoothness across boundaries

- Subdivision surfaces turn meshes into smooth surfaces through a recursive subdivision rule
  - Can use regular mesh modelling tools
  - Intuitive control
  - Smoothness built in (with some caveats)

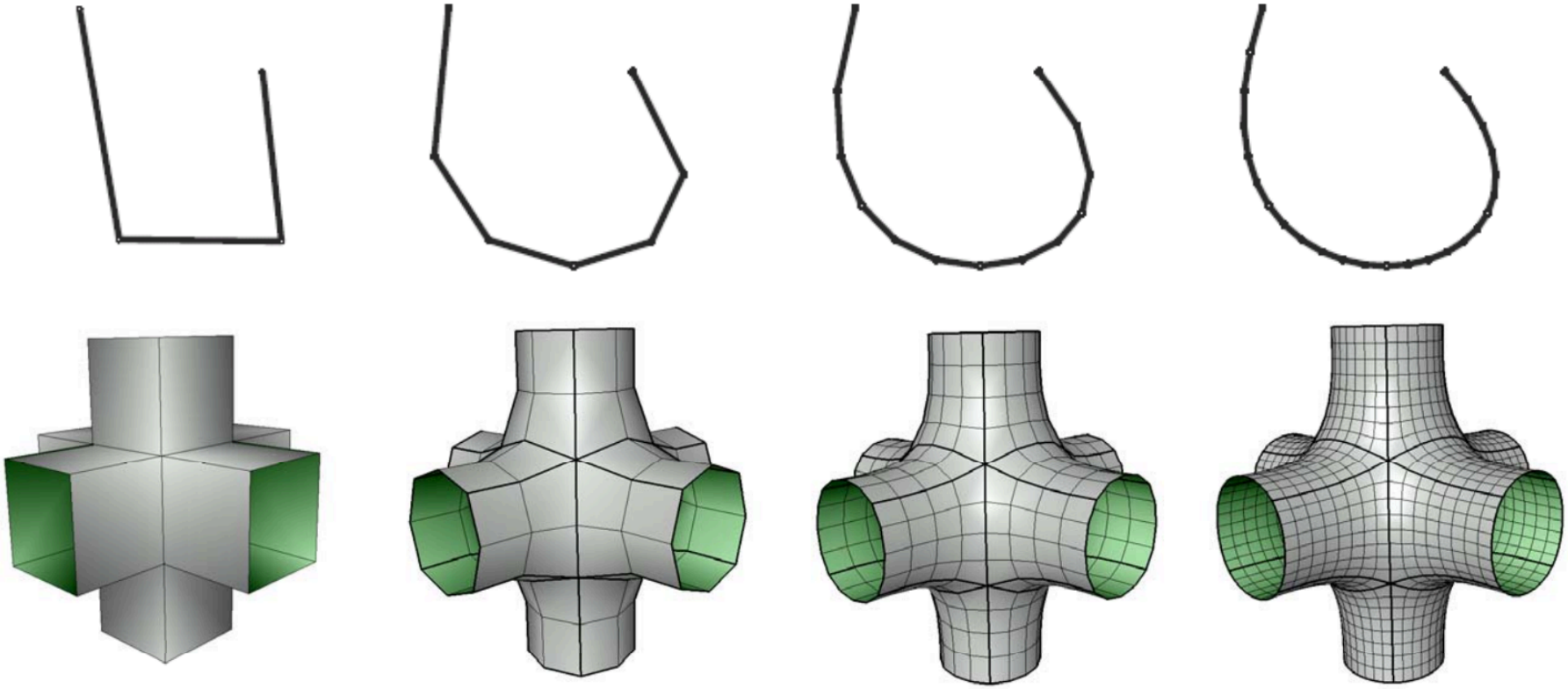
Subdivision Surfaces

- Start with polygonal mesh
- Subdivide into larger number of polygons, smooth result after each subdivision
  - Lots of ways to do this.
- The limit surface is smooth!

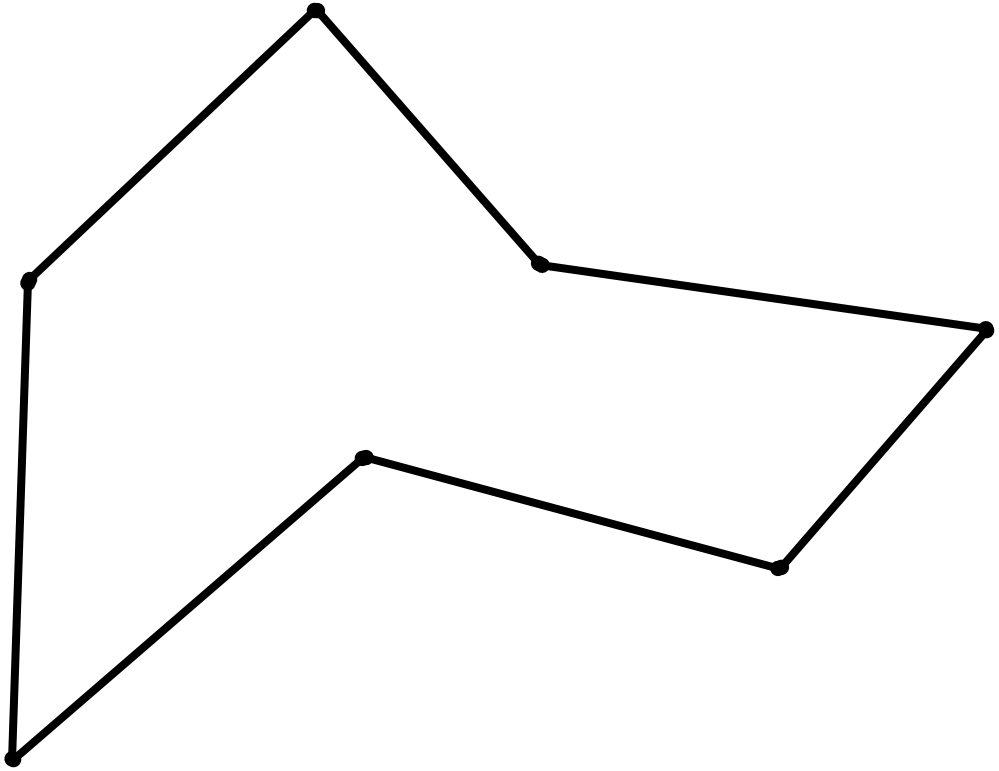


Subdividing curves vs. Surfaces

Image from Mirela Ben-Chen's Geometry Processing Algorithms class (Stanford)

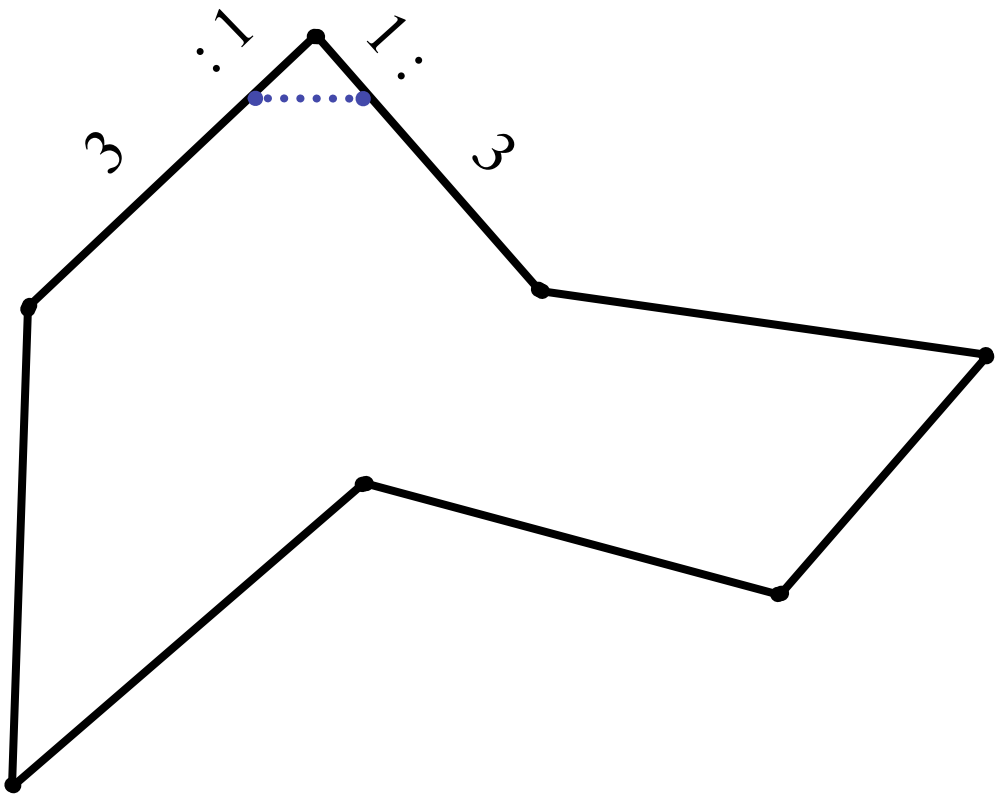


Corner Cutting



Slide by Adi Levin

Corner Cutting



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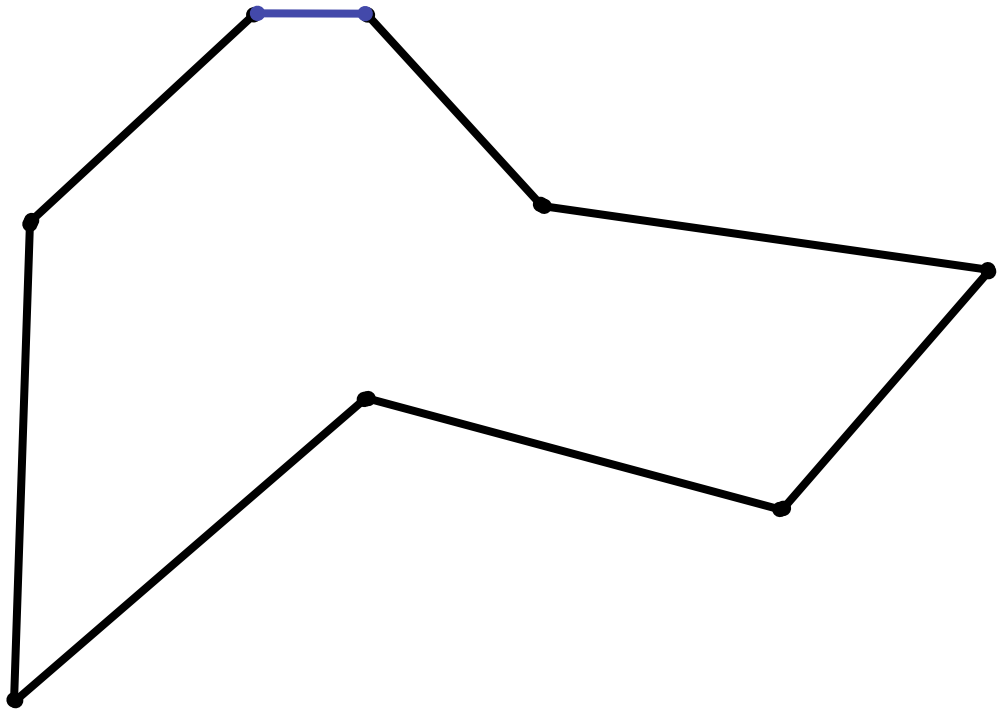

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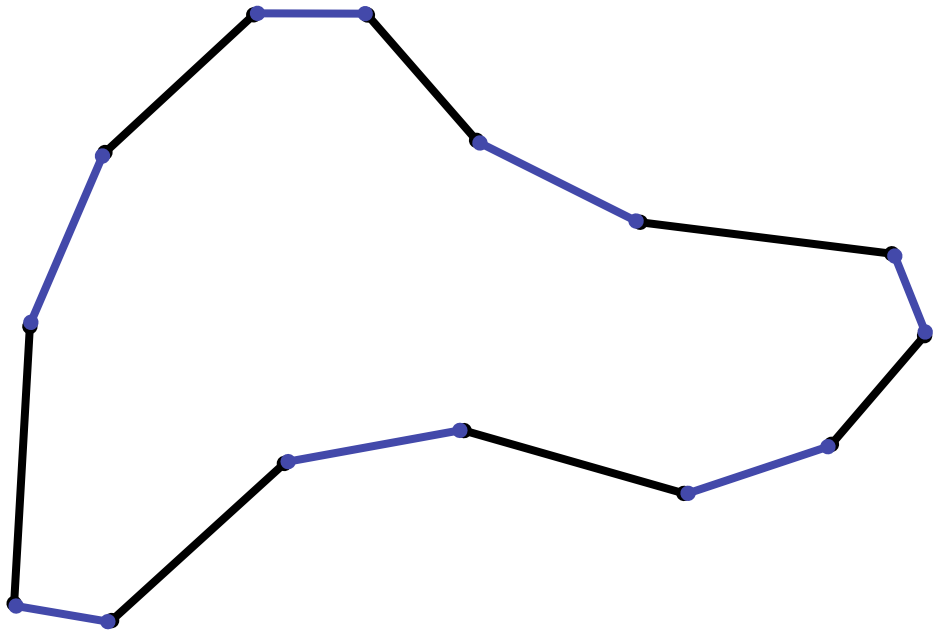

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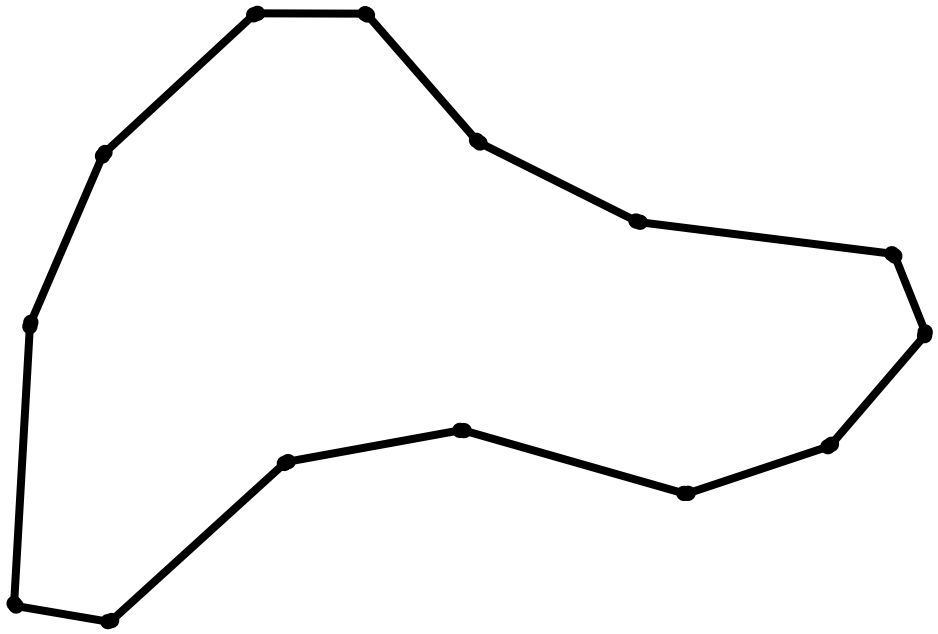
Corner Cutting



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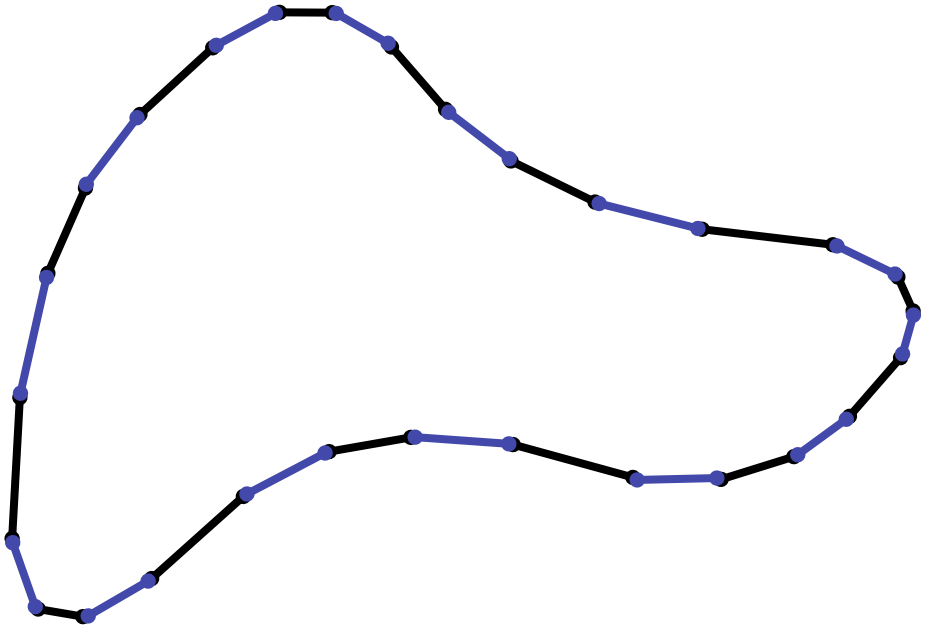

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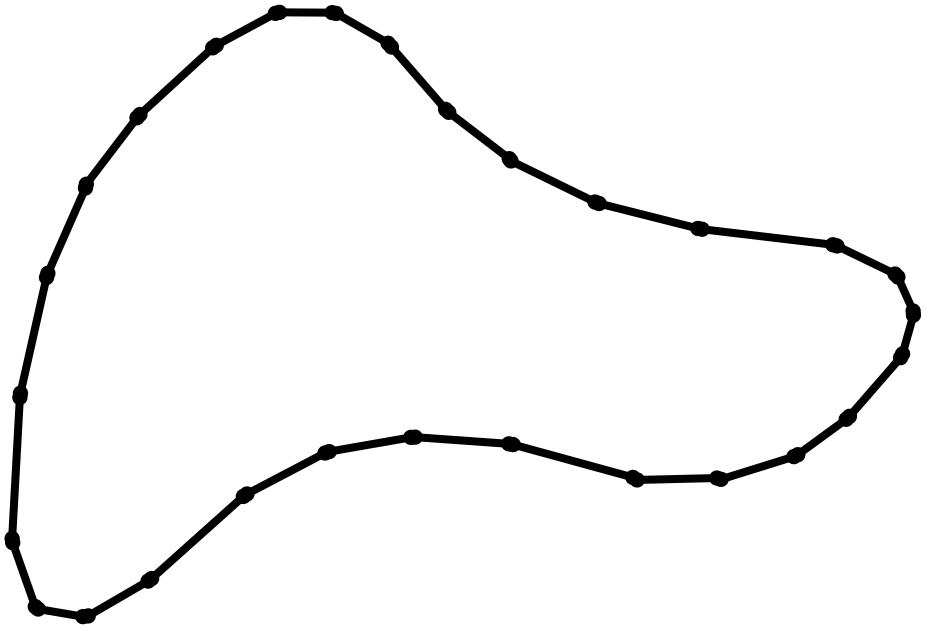

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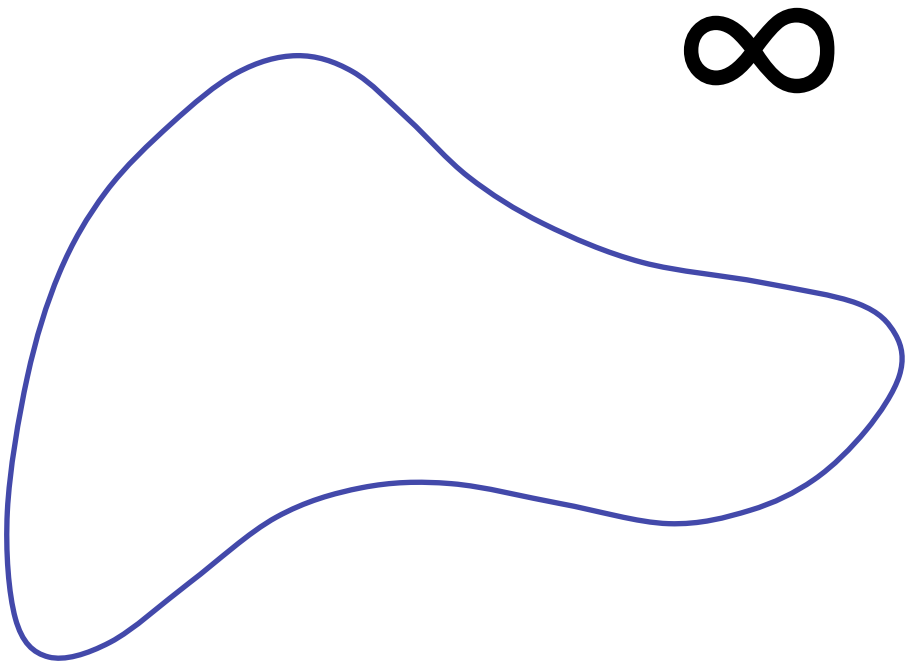
Corner Cutting



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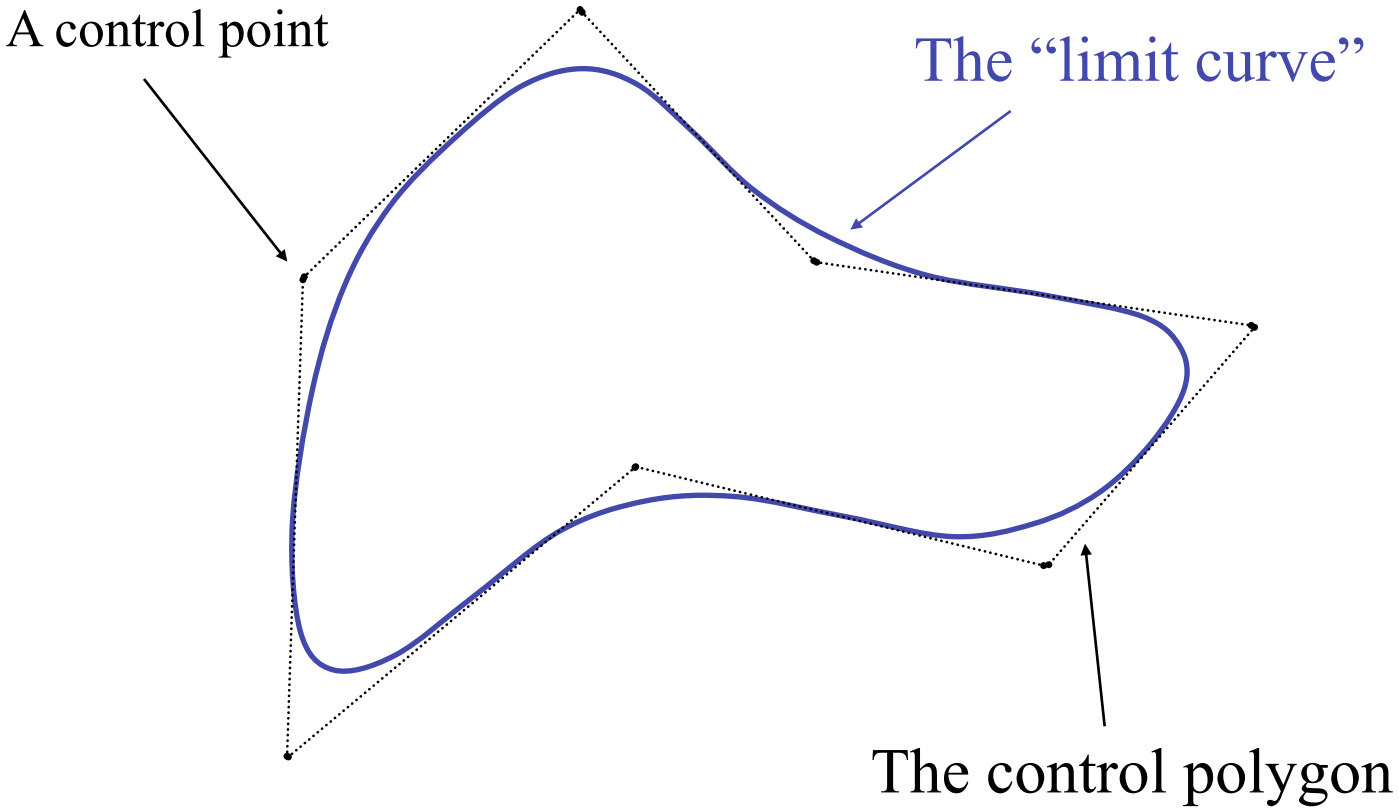
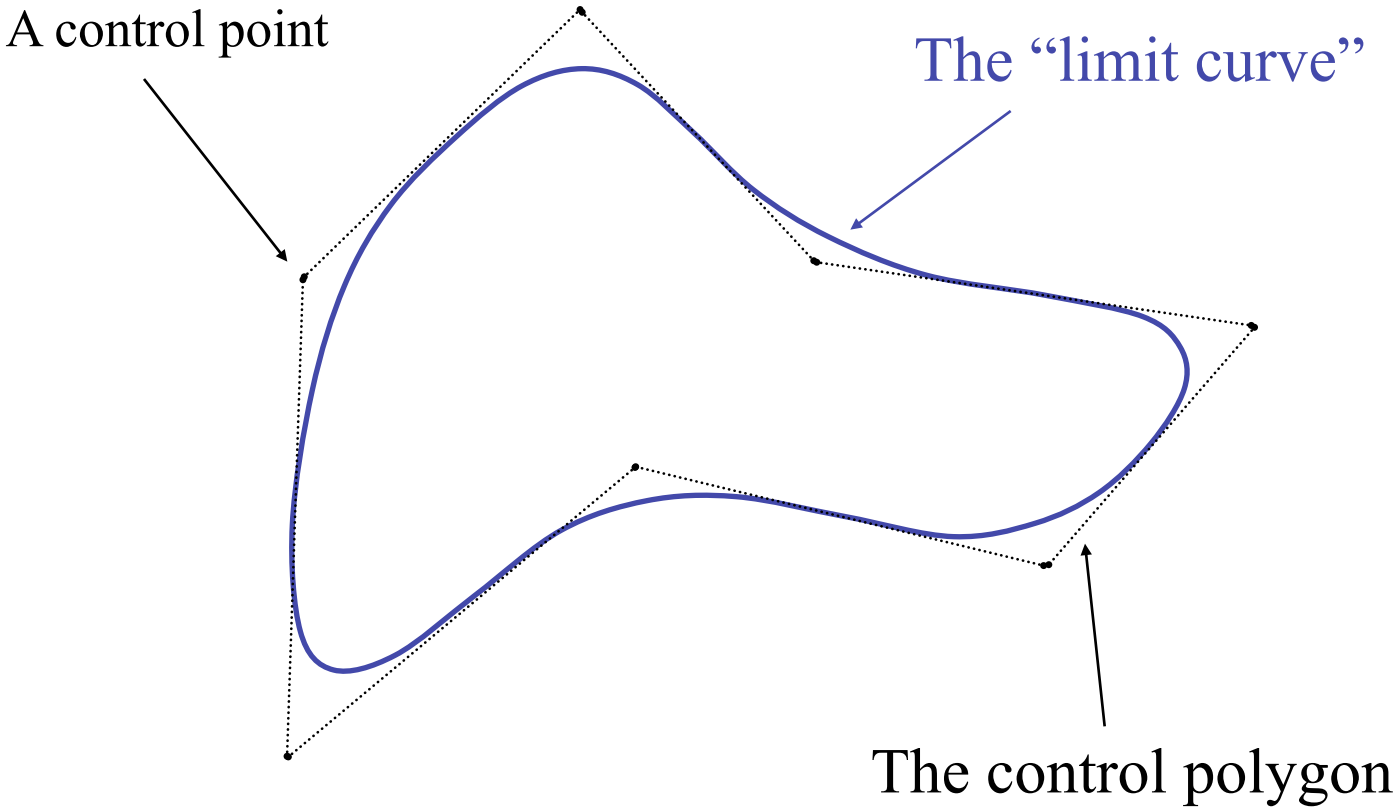


Slide by Adi Levin

Corner Cutting

It turns out corner cutting (Chaikin's Algorithm) produces a quadratic B-Spline curve! (Magic!)



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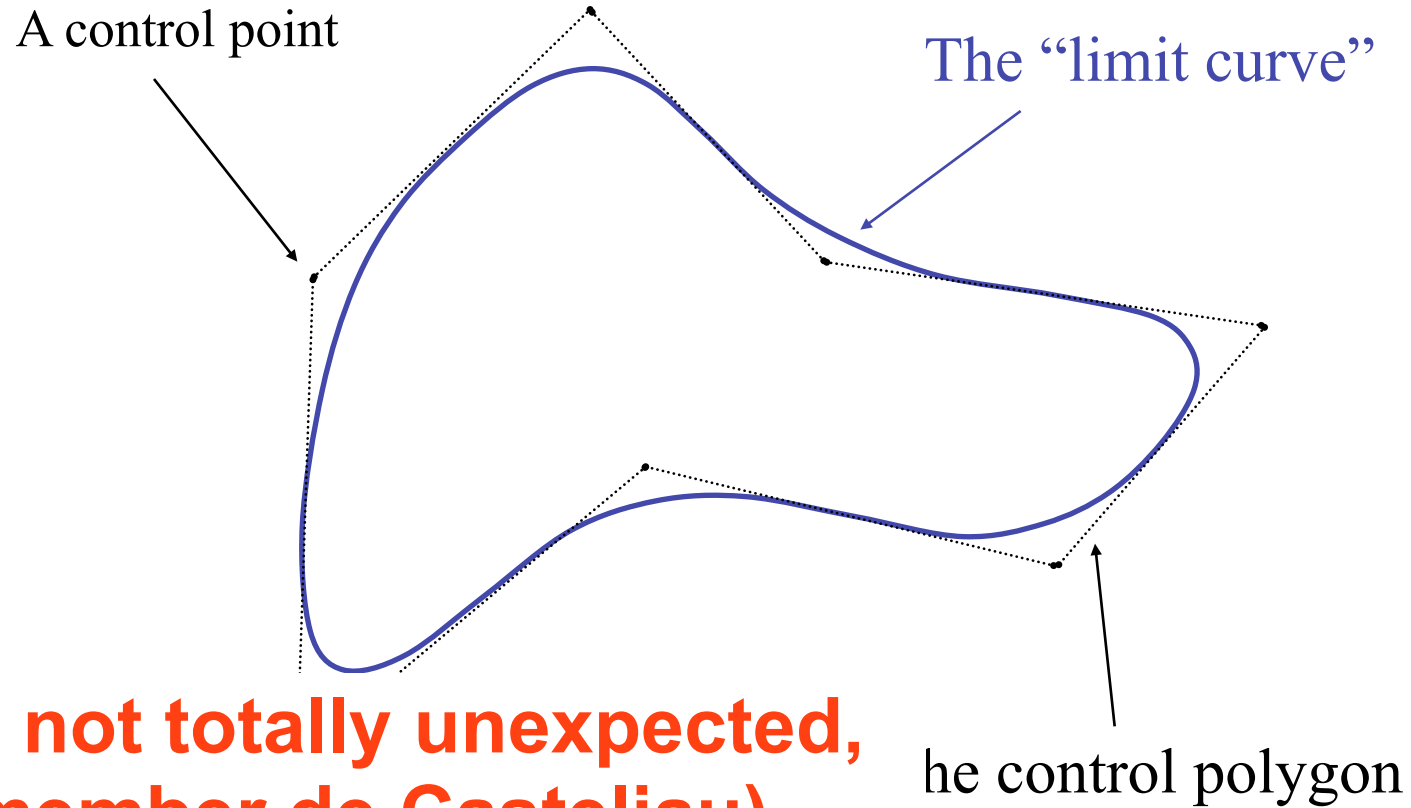
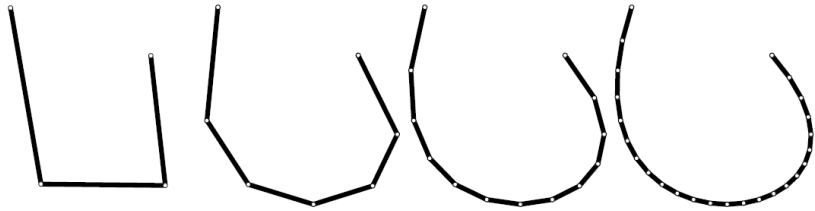


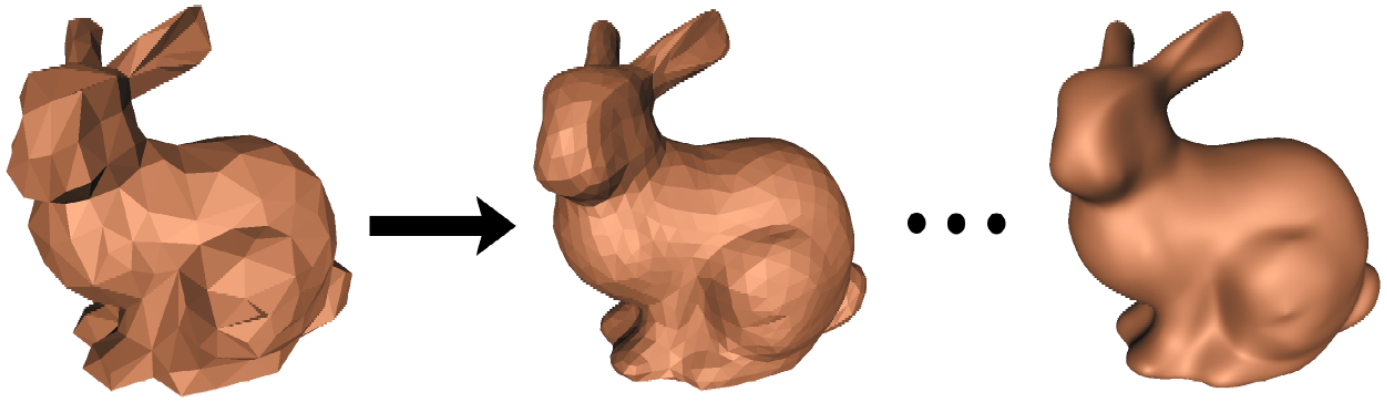
(Well, not totally unexpected, remember de Casteljau)

Slide by Adi Levin

Subdivision Curves and Surfaces

- Idea: cut corners to smooth
- Add points and compute weighted average of neighbors
- Same for surfaces
  - Special case for irregular vertices
    - vertex with more or less than 6 neighbors in a triangle mesh

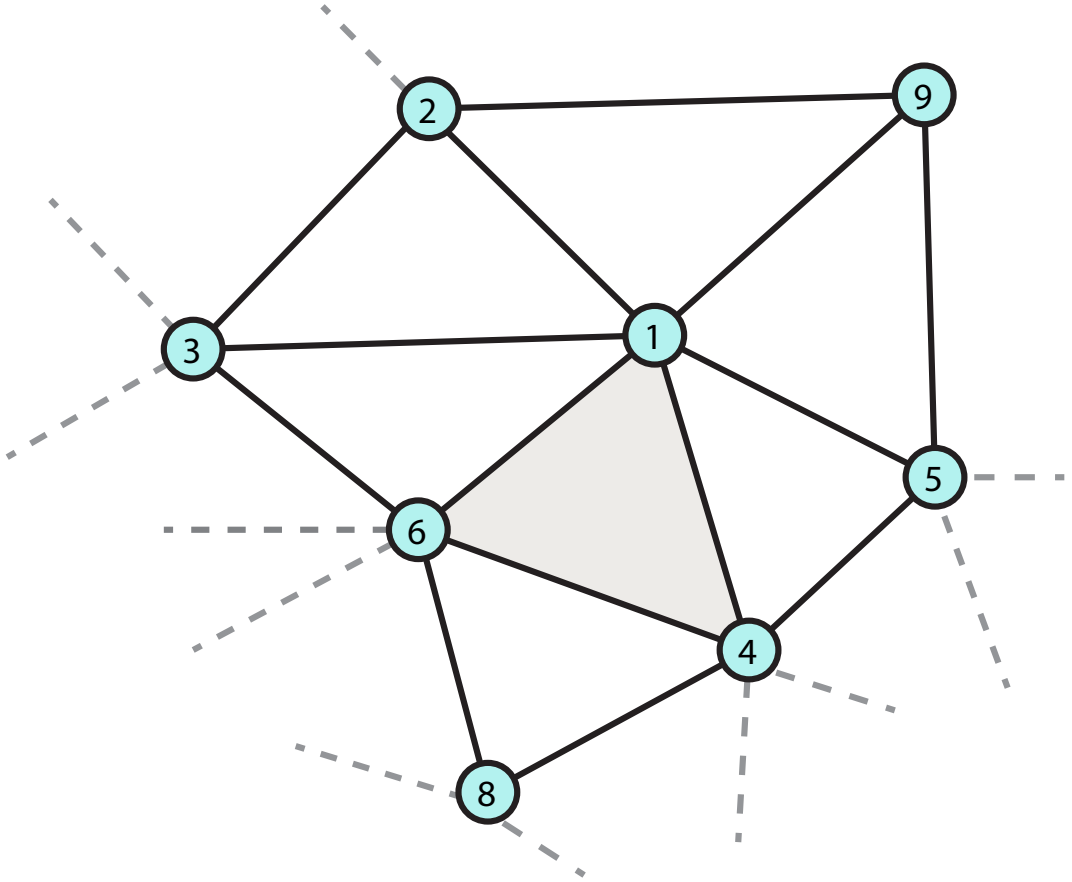




Warren et al.

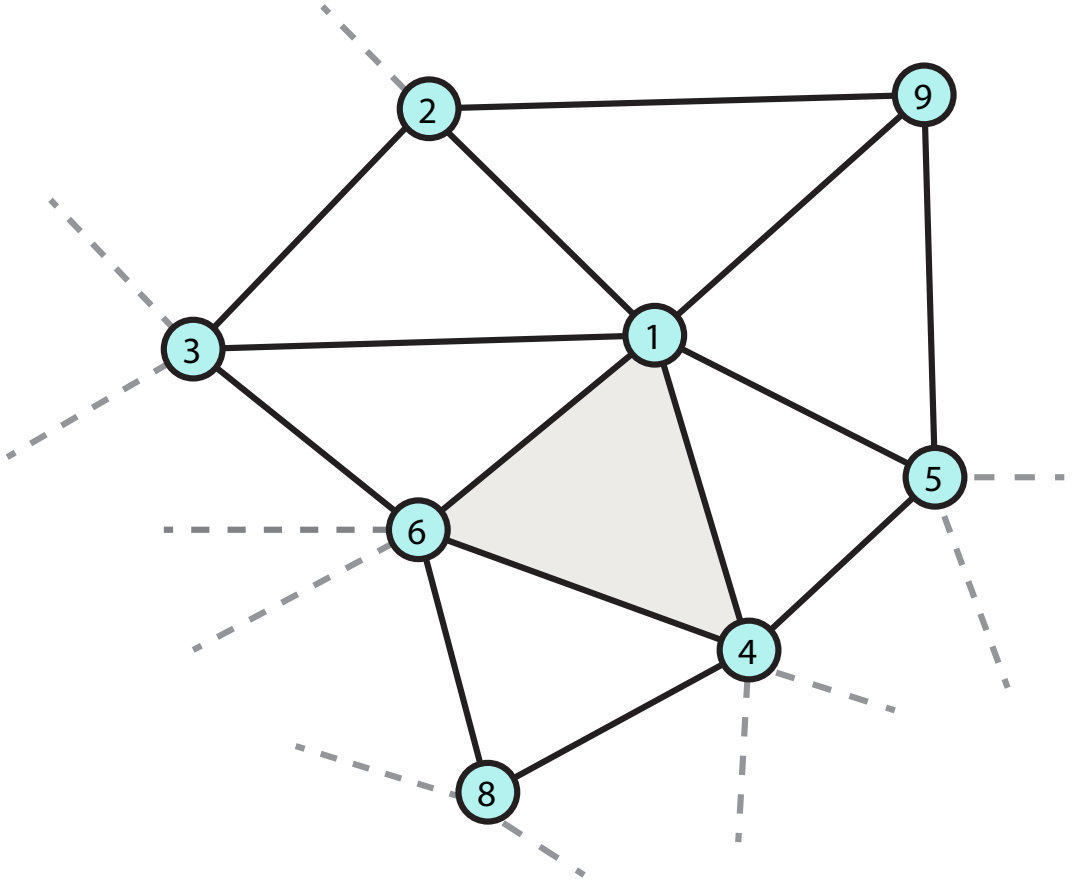
Assignment 2: Loop Subdivision

- (After Charles Loop, now with NVIDIA Research)



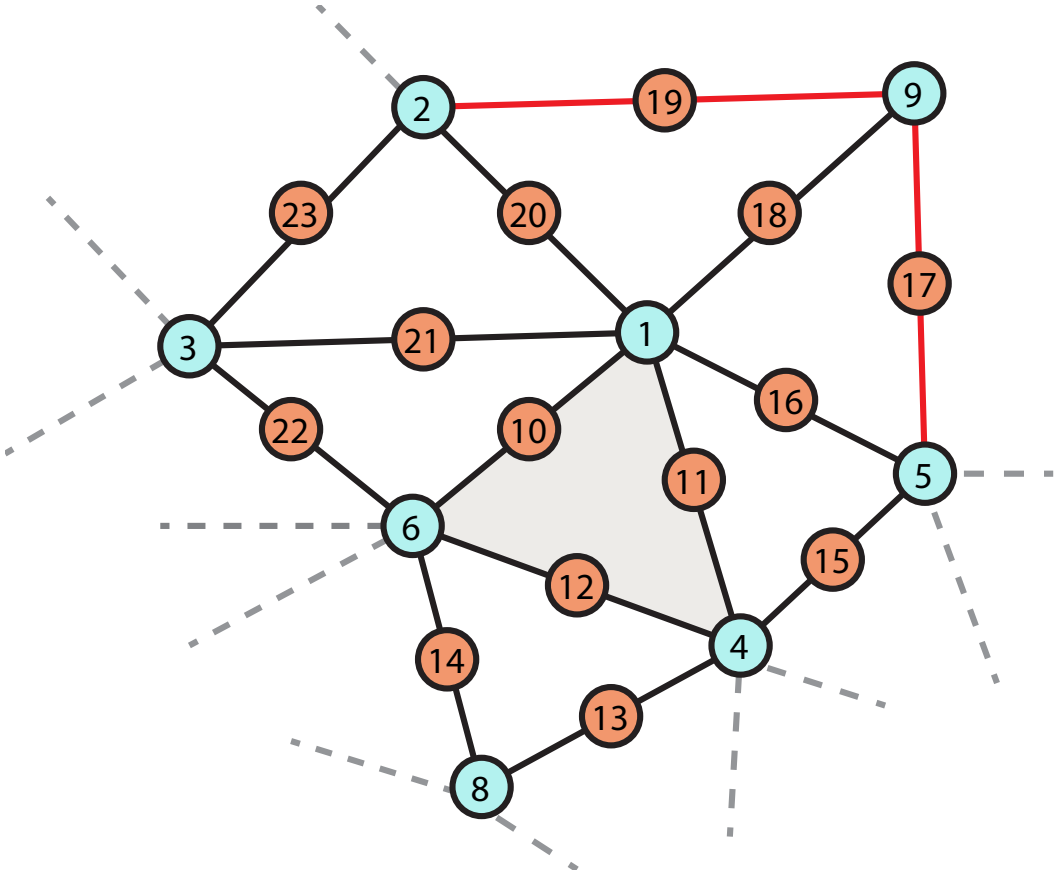
Assignment 2: Loop Subdivision

- The input mesh



Assignment 2: Loop Subdivision

- First step: each input edge gets a new vertex



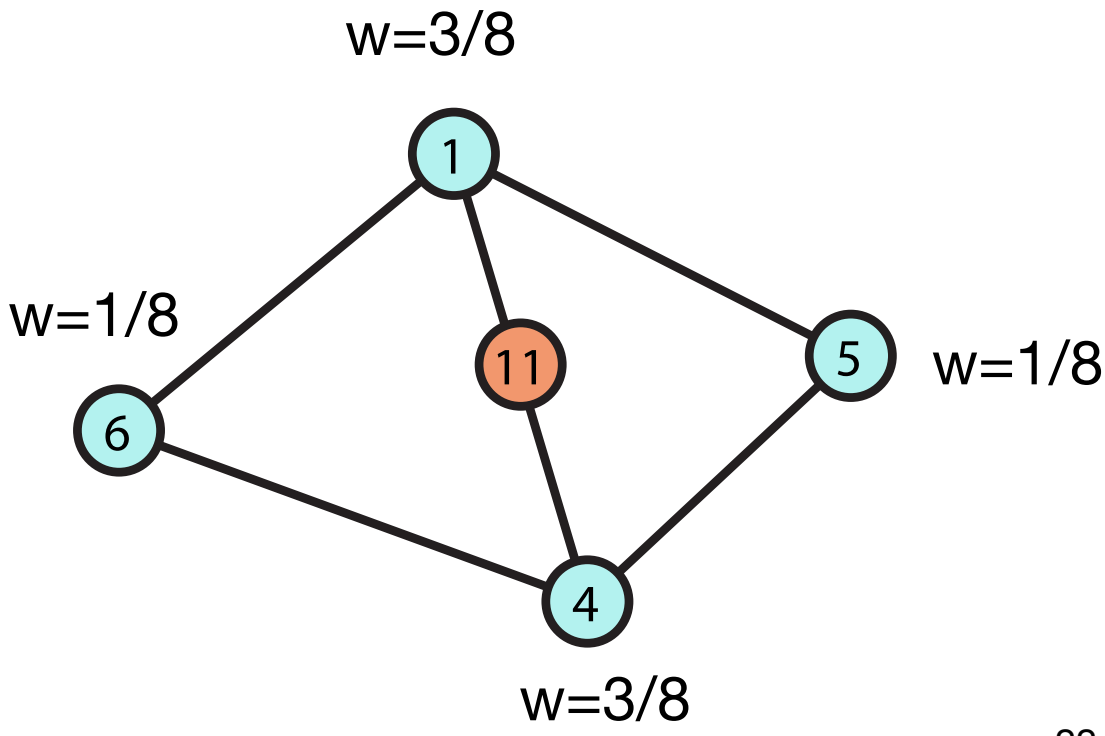
Vertex from input mesh

Newly-introduced vertex

Assignment 2: Loop Subdivision

- Then compute positions for new vertices
  - Weighted combinations of the connected *old* vertices
  - Need adjacency information (details in handout)

$$p_{11} = \frac{1}{8}\, p_5 + \frac{1}{8}\, p_6 + \frac{3}{8}\, p_1 + \frac{3}{8}\, p_4$$



Vertex from input mesh

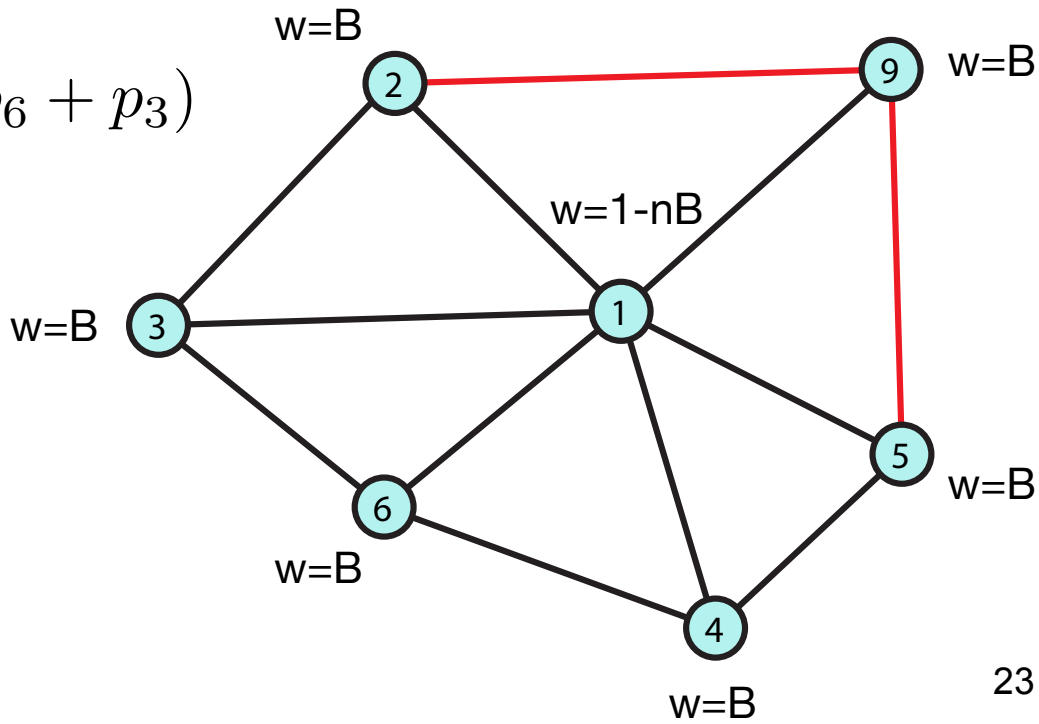
Newly-introduced vertex

Assignment 2: Loop Subdivision

- Then compute new positions for all *old* vertices!
  - Again weighted combinations of nearby *old* vertices
  - Need to find all n connected vertices

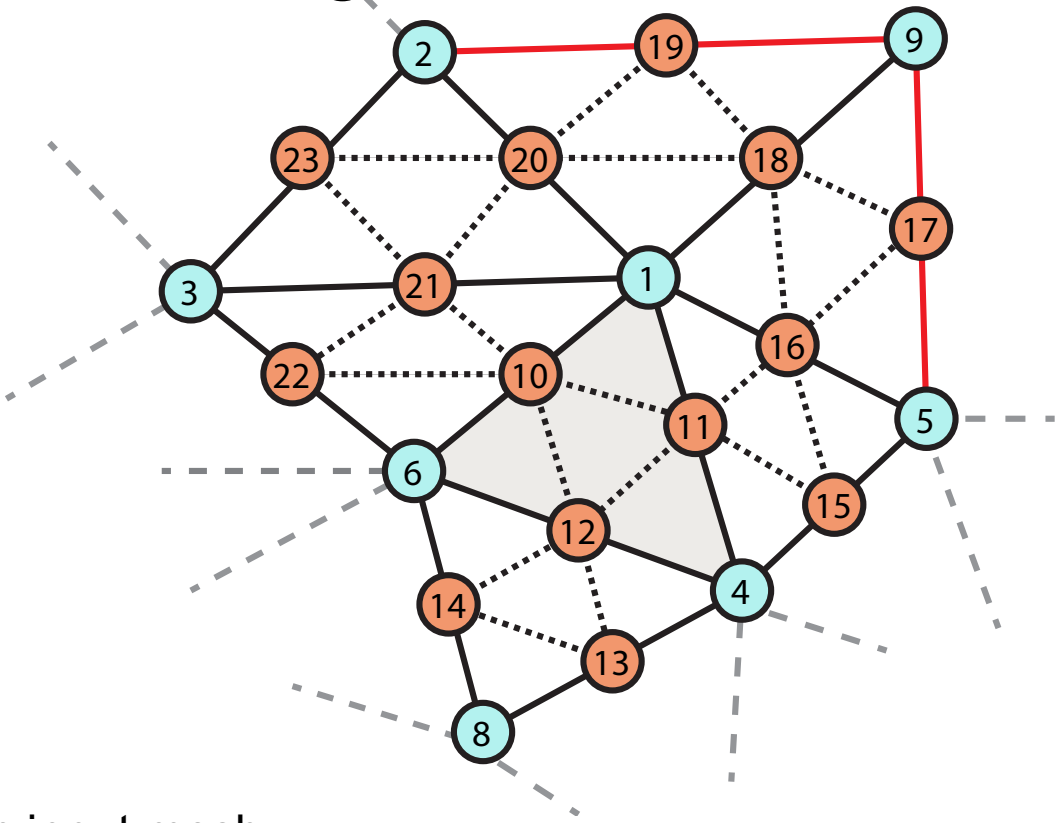
$$p_1' = (1 - nB)\, p_1 + B(p_2 + p_9 + p_5 + p_4 + p_6 + p_3)$$

$$B = \begin{cases} \frac{3}{8n}, & n > 3 \\ \frac{3}{16}, & n = 3 \end{cases}$$



Assignment 2: Loop Subdivision

- Finally, split all input triangles into four: remove old triangle, insert 4 new triangles

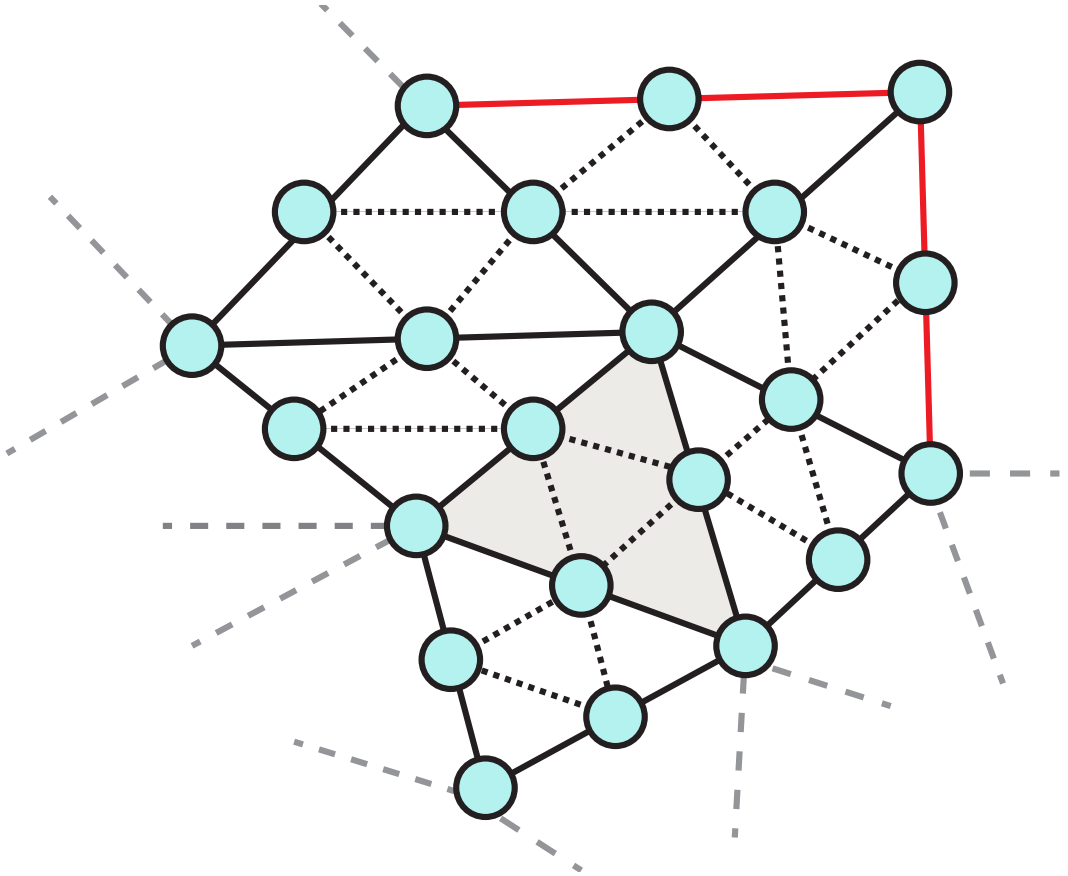


Vertex from input mesh

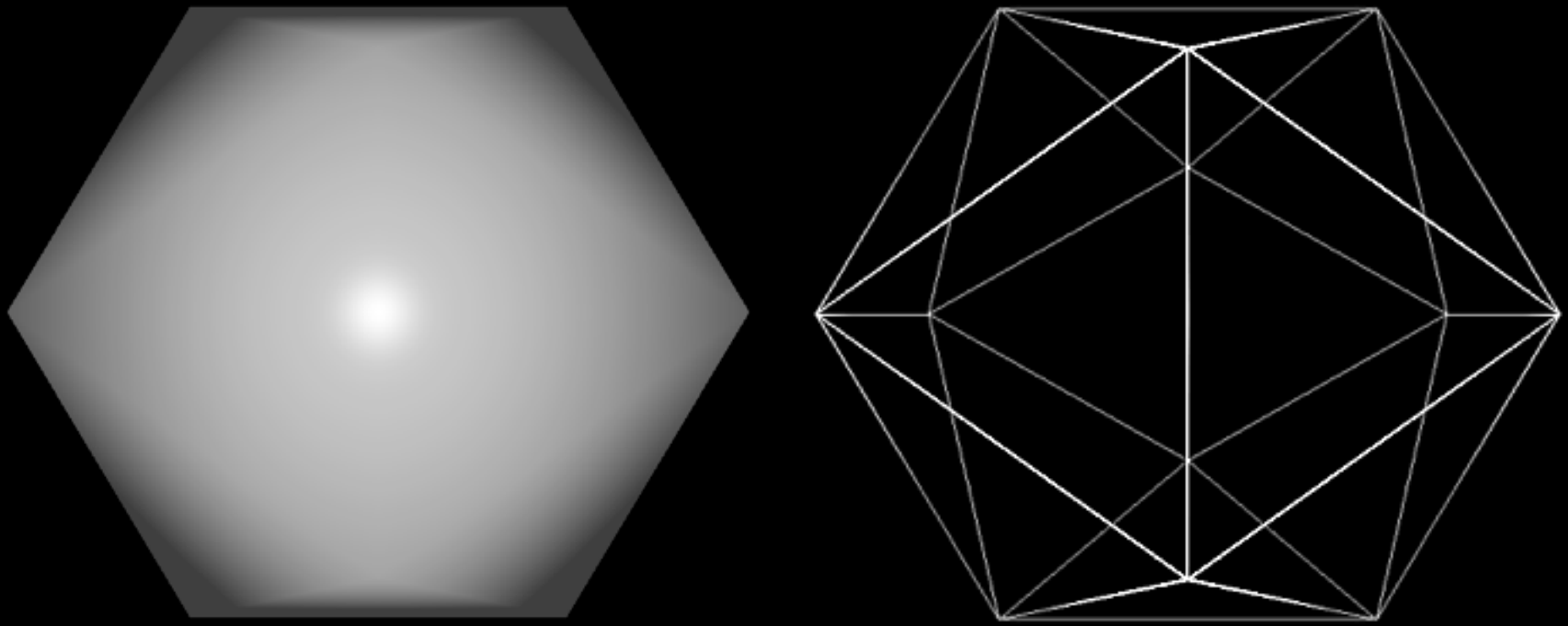
Newly-introduced vertex

Assignment 2: Loop Subdivision

- This becomes the new base mesh for next round

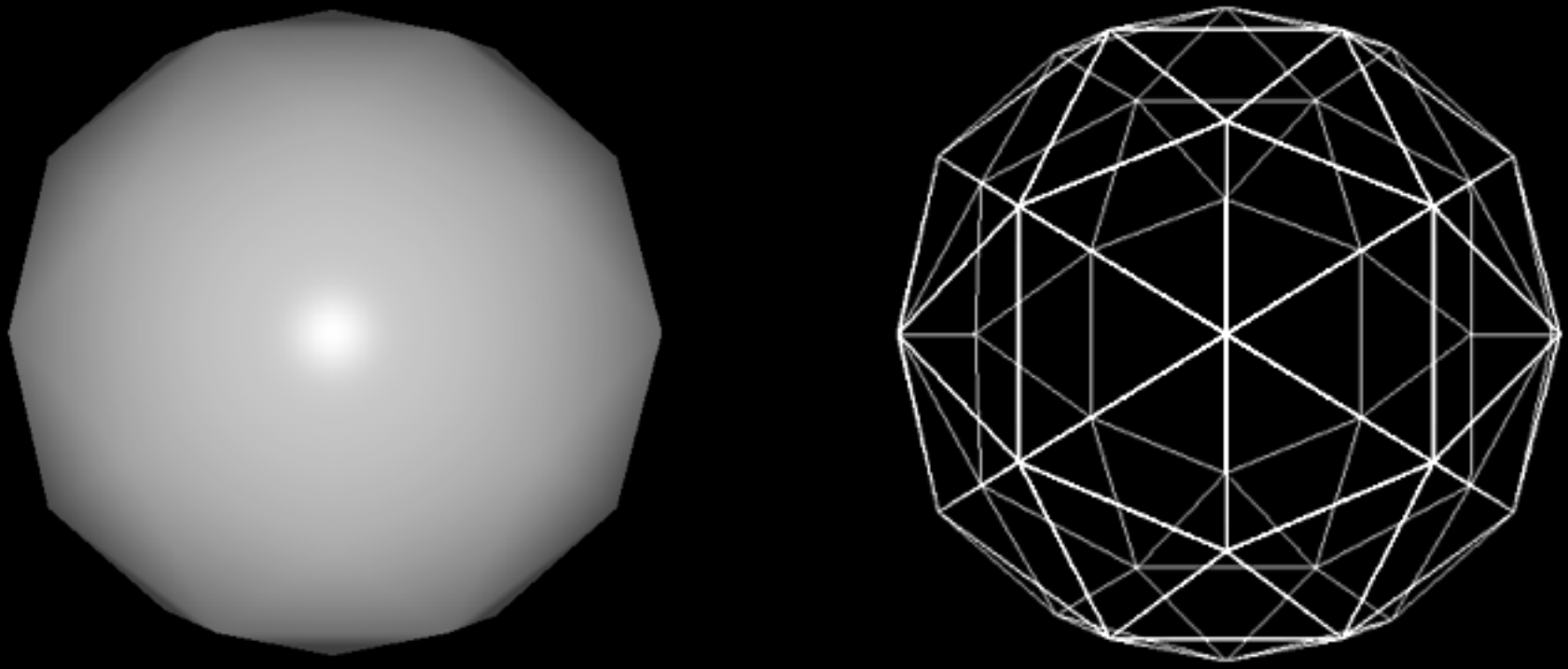


Assignment 2: Loop Subdivision



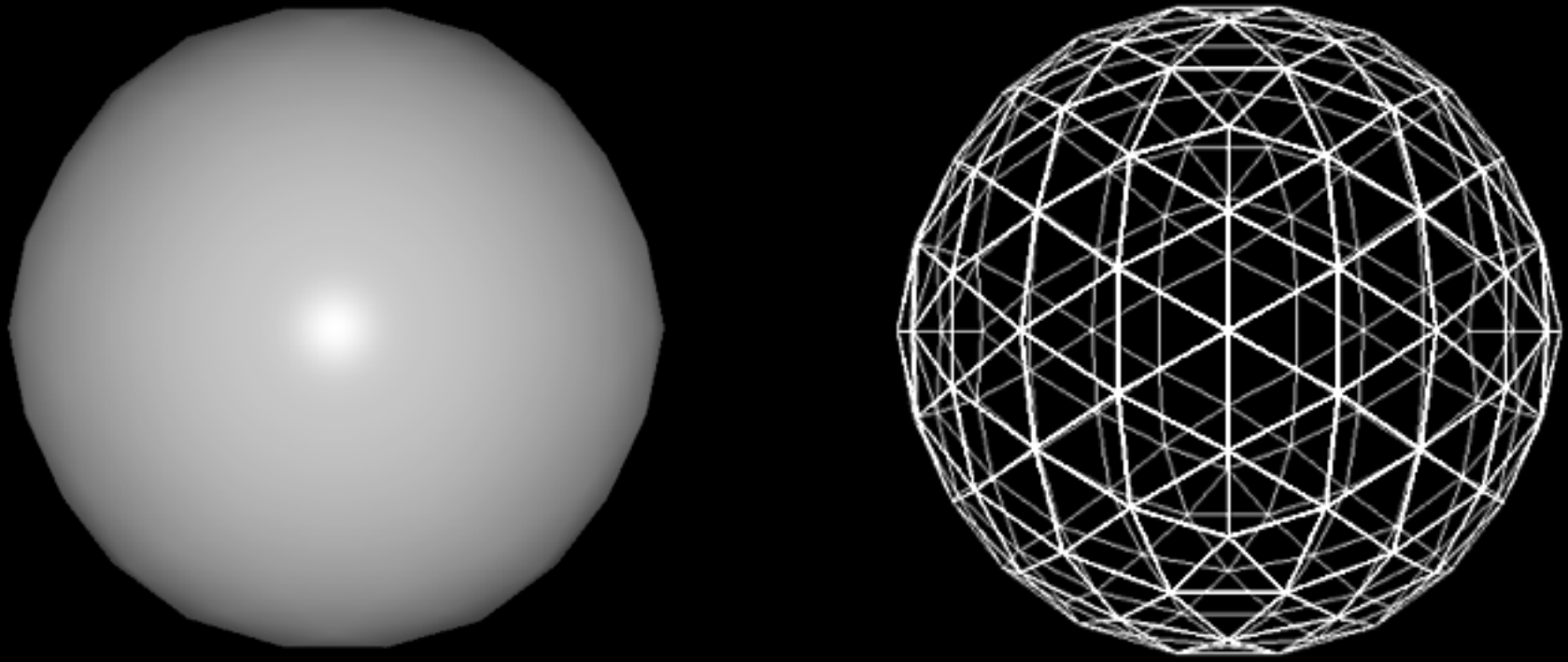
Input mesh

Assignment 2: Loop Subdivision



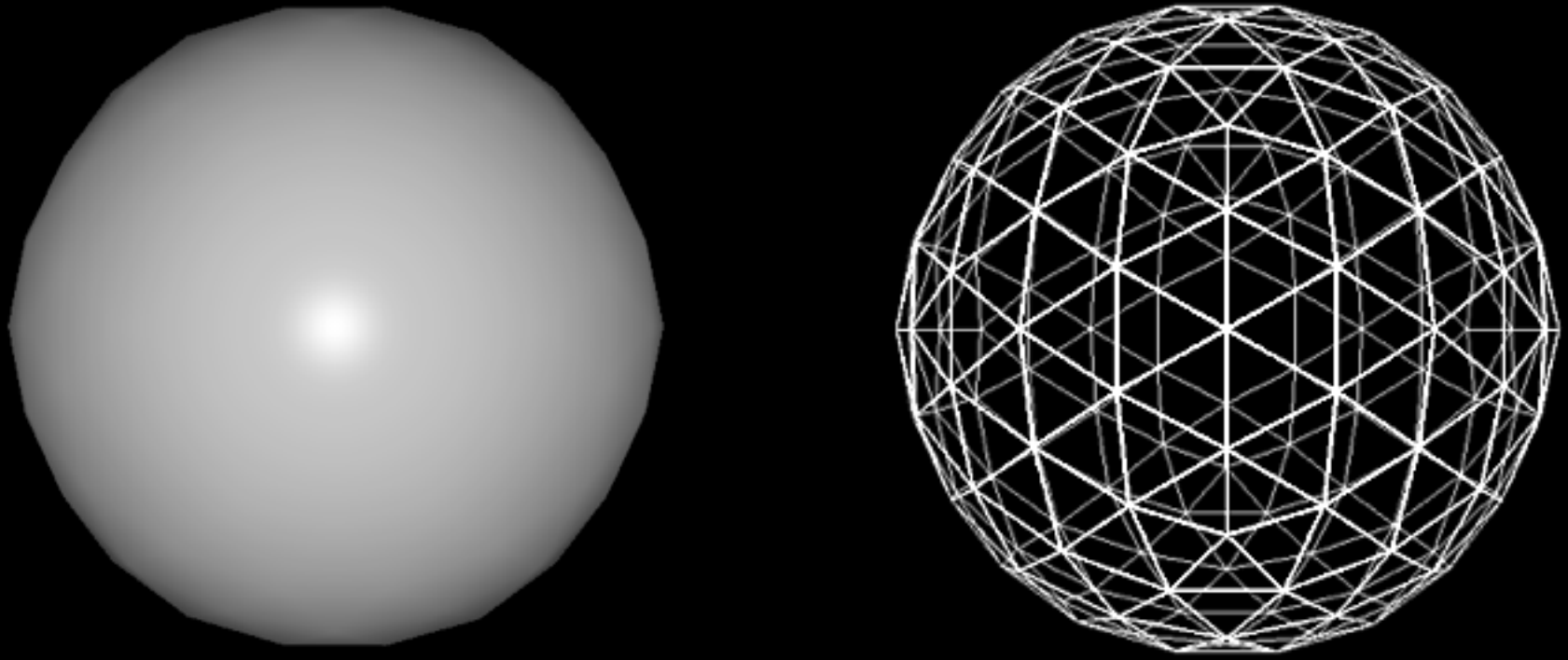
1st level of subdivision

Assignment 2: Loop Subdivision



2nd level of subdivision

Assignment 2: Loop Subdivision

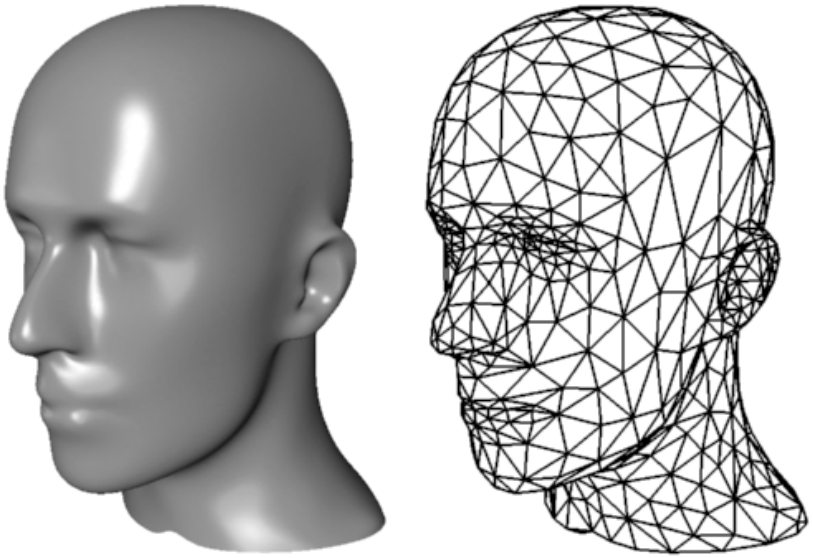


2nd level of subdivision

etc.

Flavors of Subdivision Surfaces

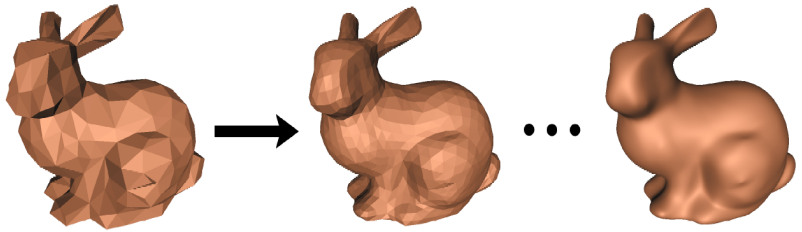
- Catmull-Clark
  - Quads and triangles
  - Generalizes bicubics to arbitrary topology!
- **Loop**, Butterfly
  - Triangles
- Doo-Sabin, sqrt(3), biquartic...
  - and a whole host of others
- Used **everywhere** in movie and game modeling!
- See http://www.cs.nyu.edu/~dzorin/sig00course/



Leif Kobbelt

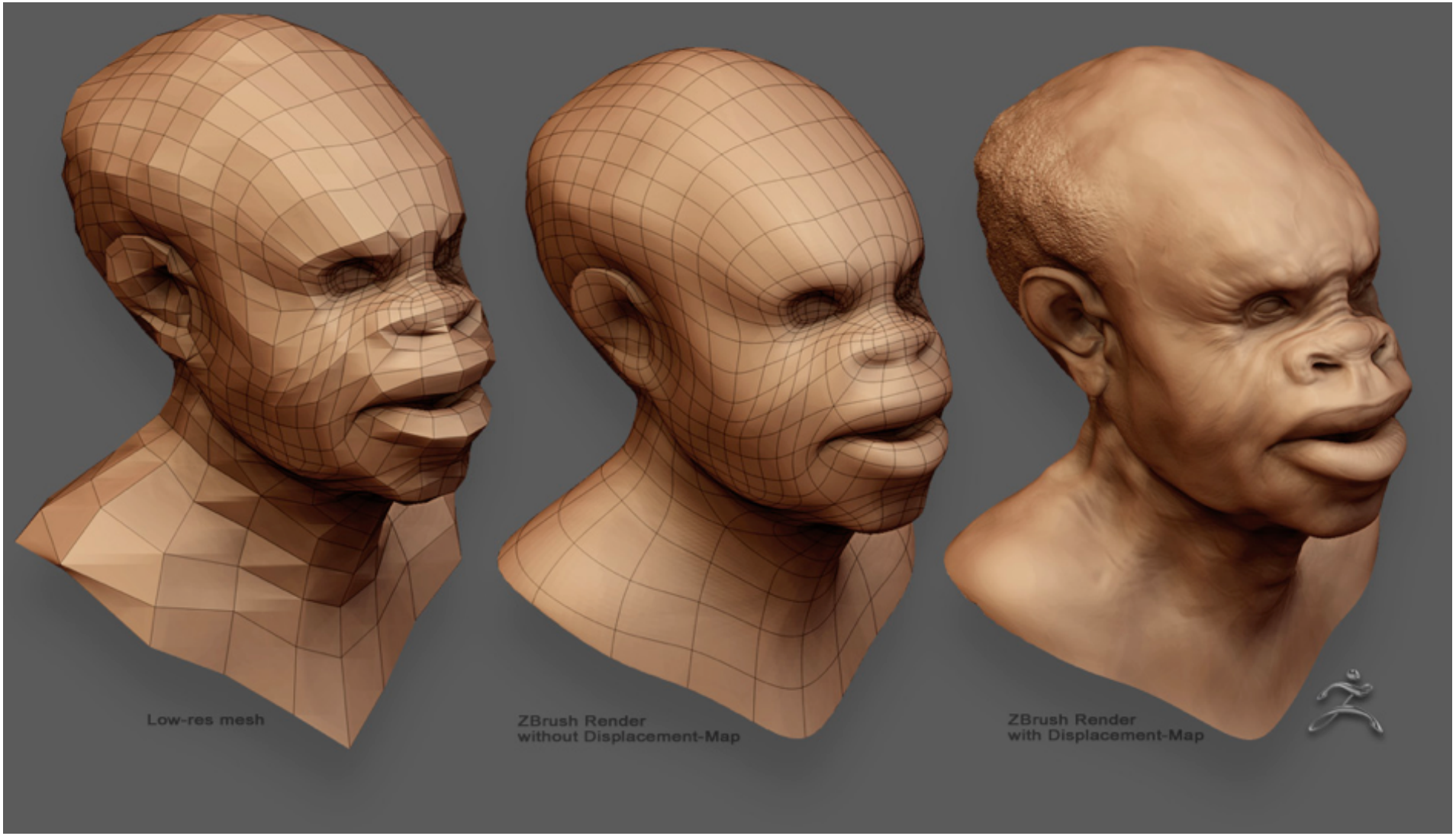
Subdivision Curves and Surfaces

- Advantages
  - Arbitrary topology
  - Smooth at boundaries
  - Level of detail, scalable
  - Simple representation
  - Numerical stability, well-behaved meshes
  - Code simplicity
- Little disadvantage:
  - Procedural definition
  - Not parametric, not implicit
  - Tricky at special vertices



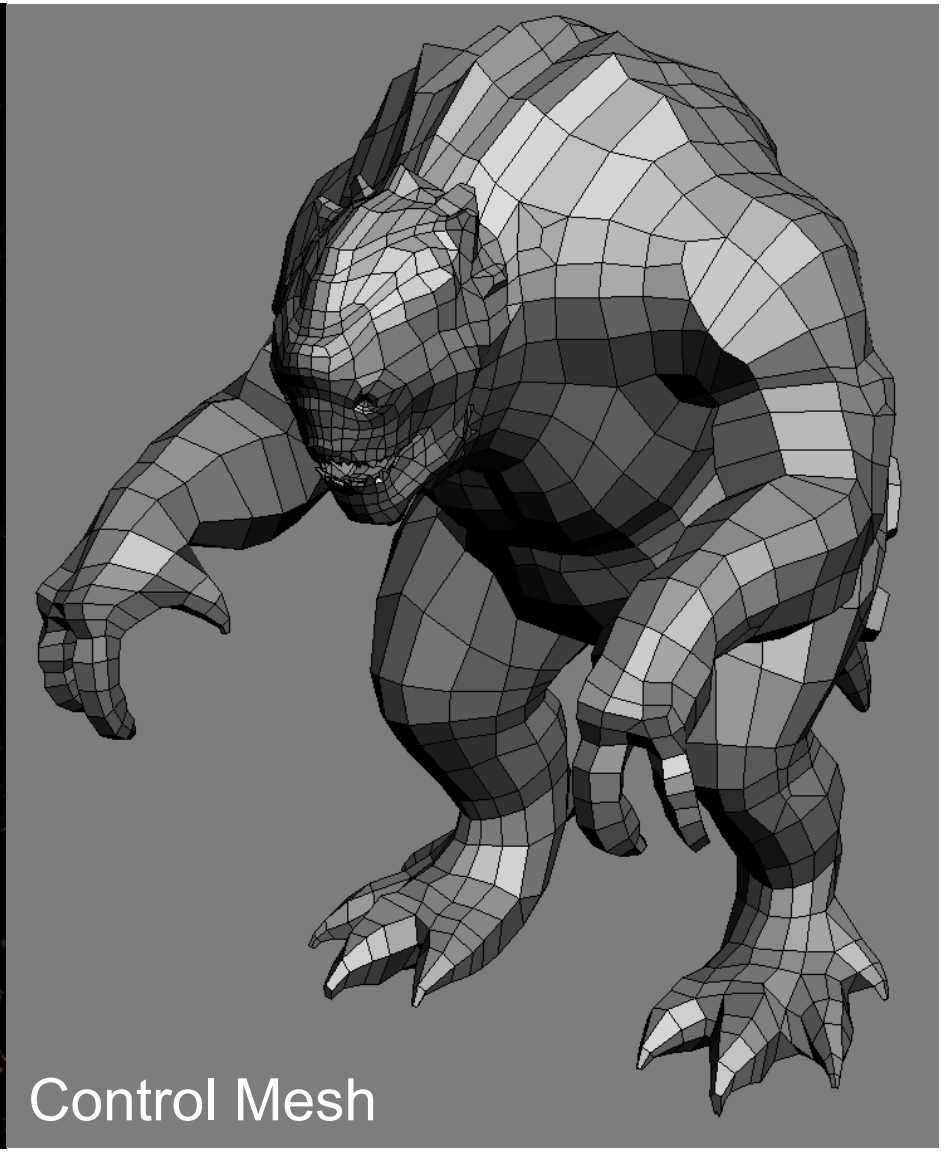
Warren et al.

Subdivision + Displacement



Subdivision + Displacement

Epic Games



ZBrush Modeling Session

- http://www.youtube.com/watch?v=i8lIvWN8ZmQ