



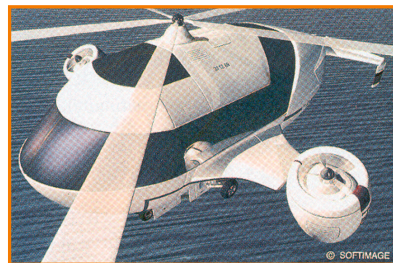
Subdivision Surfaces

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COS 526, Fall 2002



Surfaces

- What makes a good surface representation?
 - Accurate
 - Concise
 - Intuitive specification
 - Local support
 - Affine invariant
 - Arbitrary topology
 - Guaranteed continuity
 - Natural parameterization
 - Efficient display
 - Efficient intersections



H&B Figure 10.46

Problems with Splines



- Difficult to stitch together
 - Maintaining continuity is hard
 - Trimming boundaries is hard
- Difficult to model objects with complex topology
 - OK for disk, cylinder, torus



Subdivision



- How do you make a smooth curve?



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Subdivision Surfaces



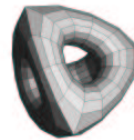
- Coarse mesh & subdivision rule
 - Define smooth surface as limit of sequence of refinements



(a)



(b)



(c)



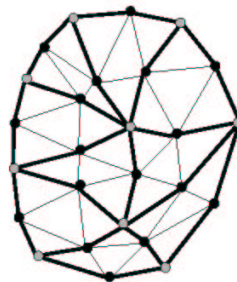
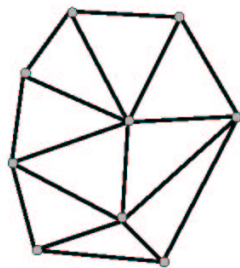
(d)

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Key Questions



- How refine mesh?
 - Topology changes
- Where to place new vertices
 - Provable properties about limit surface

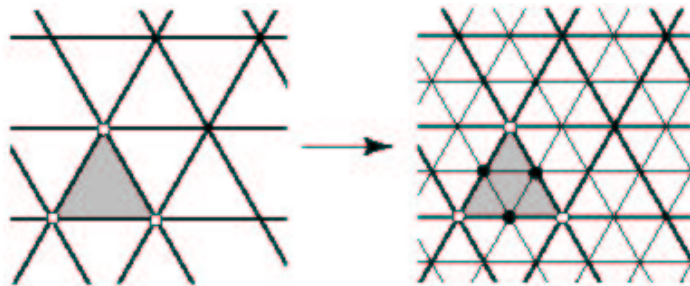


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Loop Subdivision Scheme



- How refine mesh?
 - Refine each triangle into 4 triangles by splitting each edge and connecting new vertices

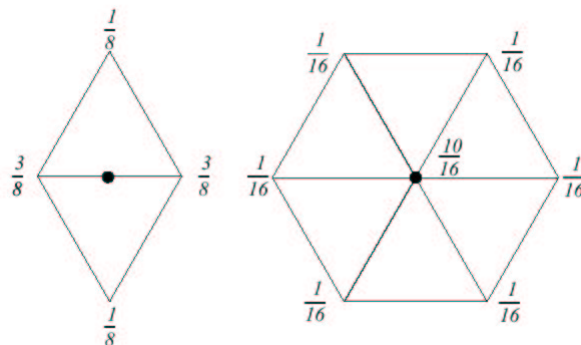


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Loop Subdivision Scheme



- How position new vertices?
 - Choose locations for new vertices as weighted average of original vertices in local neighborhood



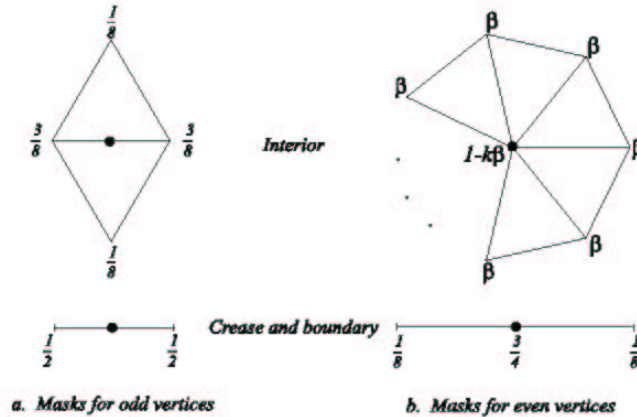
What if vertex does not have degree 6?

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Loop Subdivision Scheme



- Rules for *extraordinary vertices* and *boundaries*:



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Loop Subdivision Scheme



- How to choose β ?
 - Analyze properties of limit surface
 - Interested in continuity of surface and smoothness
 - Involves calculating eigenvalues of matrices

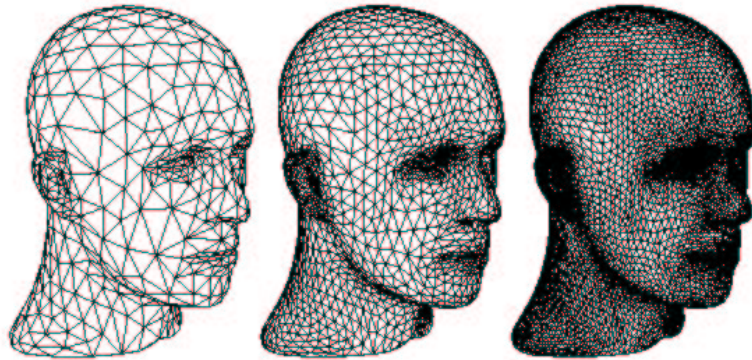
» Original Loop

$$\beta = \frac{1}{n} \left(\frac{5}{8} - \left(\frac{3}{8} + \frac{1}{4} \cos \frac{2\pi}{n} \right)^2 \right)$$

» Warren

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

Loop Subdivision Scheme



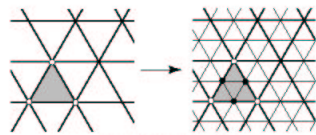
Limit surface has provable smoothness properties!

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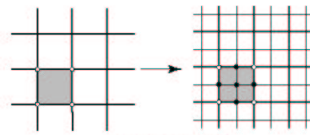
Subdivision Schemes



- There are different subdivision schemes
 - Different methods for refining topology
 - Different rules for positioning vertices
 - » Interpolating versus approximating



Face split for triangles



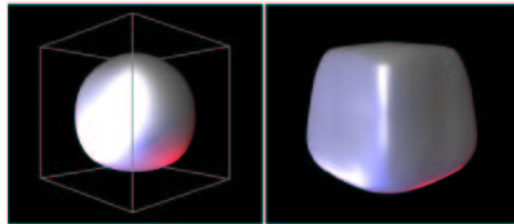
Face split for quads

Face split		
	Triangular meshes	Quad. meshes
Approximating	Loop (C^2)	Catmull-Clark (C^2)
Interpolating	Mod. Butterfly (C^1)	Kobbelt (C^1)

Vertex split
Doo-Sabin, Midedge (C^1)
Biquartic (C^2)

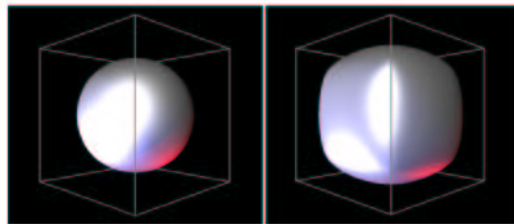
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Subdivision Schemes



Loop

Butterfly

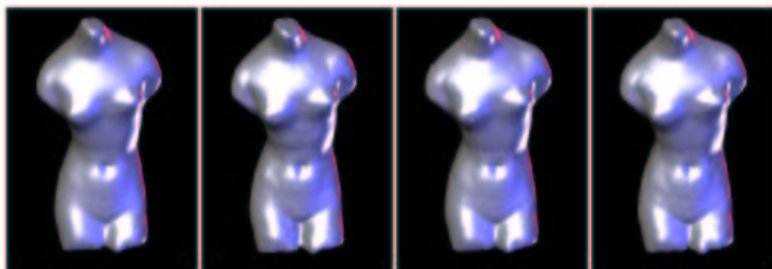


Catmull-Clark

Doo-Sabin

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Subdivision Schemes



Loop

Butterfly

Catmull-Clark

Doo-Sabin

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Subdivision Surfaces



- Properties:
 - Accurate
 - Concise
 - Intuitive specification
 - Local support
 - Affine invariant
 - Arbitrary topology
 - Guaranteed continuity
 - Natural parameterization
 - Efficient display
 - Efficient intersections



Pixar

Summary



- Advantages:
 - Simple method for describing complex surfaces
 - Relatively easy to implement
 - Arbitrary topology
 - Local support
 - Guaranteed continuity
 - Multiresolution
- Difficulties:
 - Intuitive specification
 - Parameterization
 - Intersections

