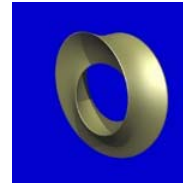
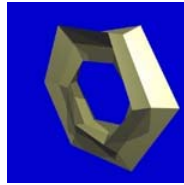


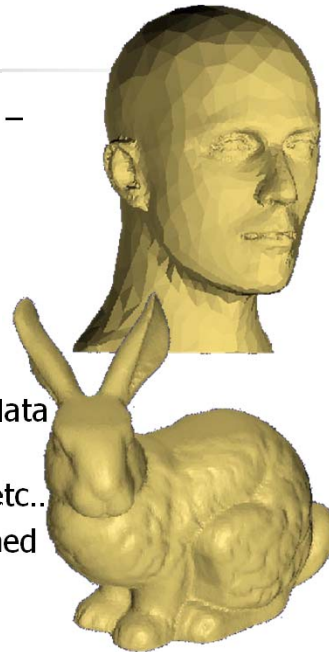
Chapter 13

Geometric Modeling Meshes & Subdivision



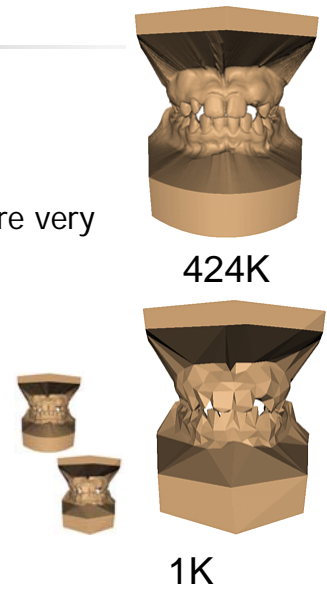
Meshes

- Simplest boundary representation – polygonal mesh
- Properties
 - Triangular/Quad
 - Manifold
- Simplicity of representation & manipulation
- Base representation for scanned data
- Input to hardware rendering algorithms (Z-buffer, polygon fill, etc..)
- Manipulation algorithms well defined (computational geometry)



Processing

- Construction
 - From scans
 - From free-form/volumetric data
- Compression – typical meshes are very large due to
 - Origin (scan)
 - Required LOD
- Manipulation
 - Note: No (u,v) parameterization
- Smoothing
 - Simulate via lighting methods
 - Refine - subdivision



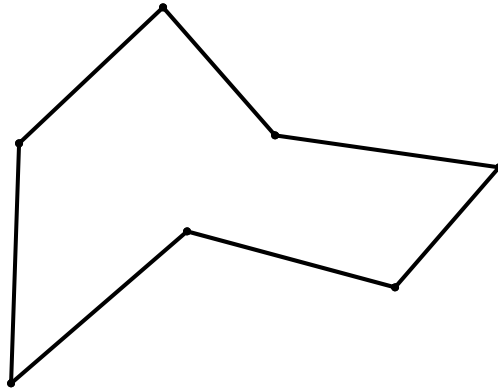
Subdivision Curves and Surfaces

- Subdivision – given polyline/polygon/polyhedron recursively modify its vertices to achieve smooth curve





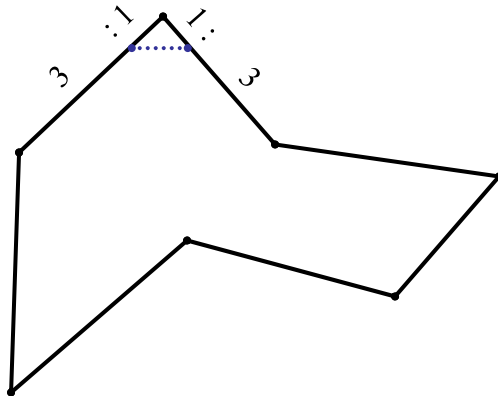
Corner Cutting



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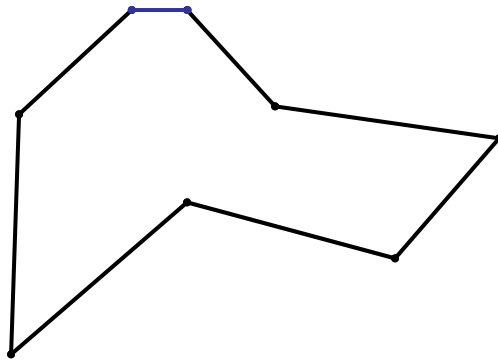
Corner Cutting



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British Columbia



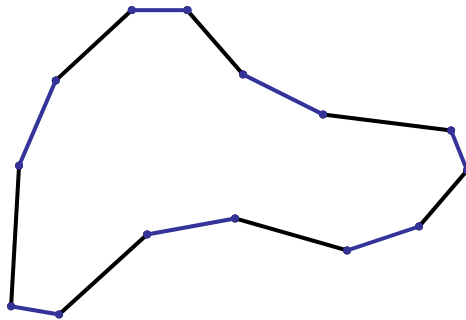
Corner Cutting



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Corner Cutting



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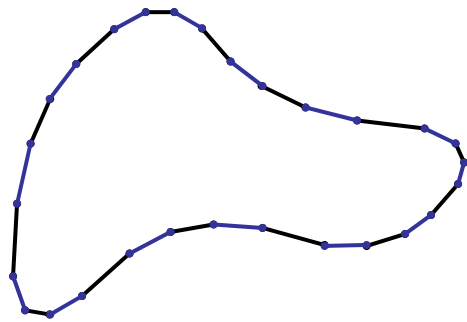
Corner Cutting



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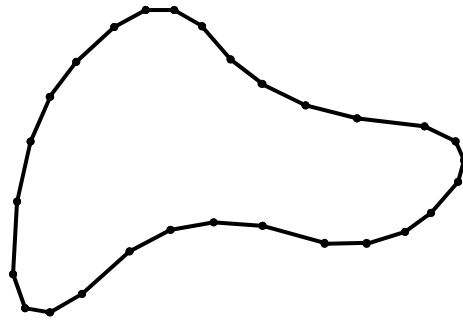
Corner Cutting



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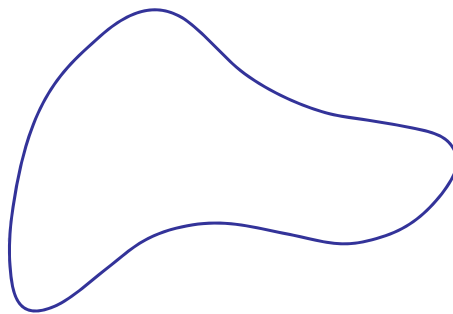
Corner Cutting



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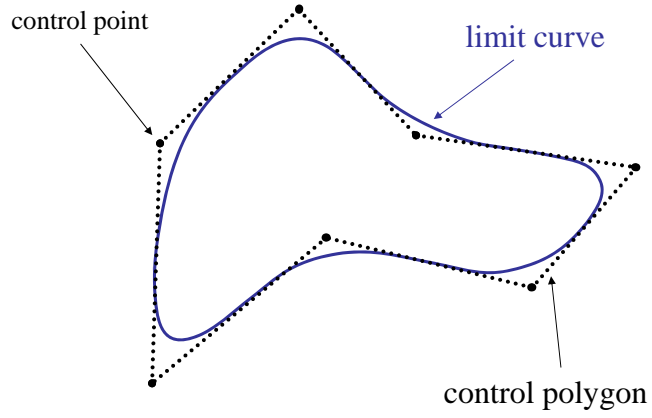
Corner Cutting



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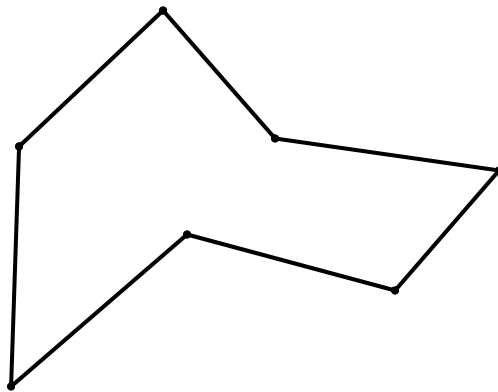
Corner Cutting



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The 4-point scheme



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The 4-point scheme

The diagram shows a polygonal mesh with several vertices. A red line segment connects two vertices on the left side of the mesh. A yellow circle highlights a vertex at the top of the mesh. The rest of the mesh is drawn with black lines.

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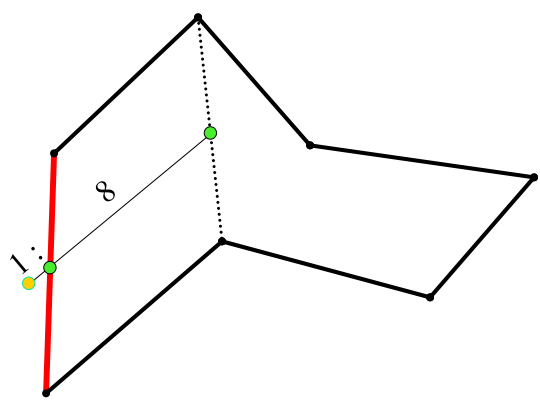
The 4-point scheme

The diagram shows the same polygonal mesh as above. A red line segment connects two vertices on the left side. A yellow circle highlights a vertex at the top. A dotted line connects the top vertex to the vertex below it. Green dots are placed on the edges connecting the top vertex to the left and right vertices, and the left vertex to the bottom-left vertex. Each green dot is accompanied by the label "1:1".

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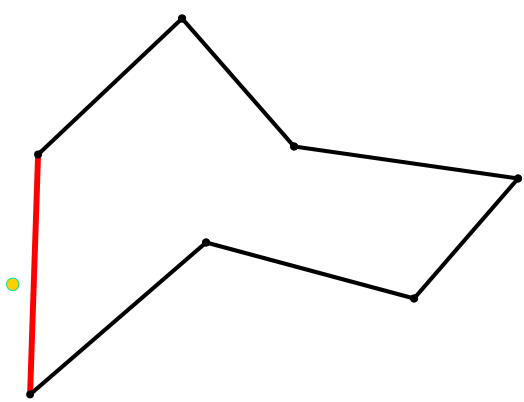
The 4-point scheme



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The 4-point scheme



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The 4-point scheme


A diagram of a closed polygon with 8 vertices. The top-left edge is highlighted in red. A small yellow dot is located on this red edge, approximately one-third of the way from the left vertex.

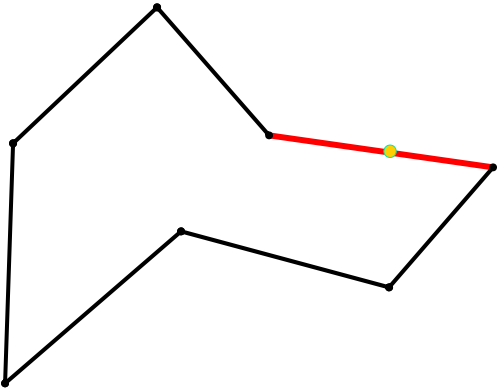
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The 4-point scheme


A diagram of a closed polygon with 8 vertices, identical to the one above. The top-right edge is highlighted in red. A small yellow dot is located on this red edge, approximately one-third of the way from the top vertex.

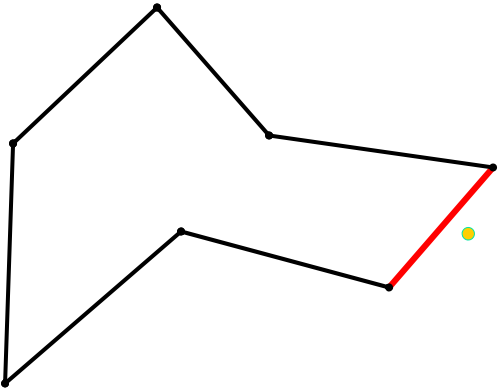
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 The 4-point scheme




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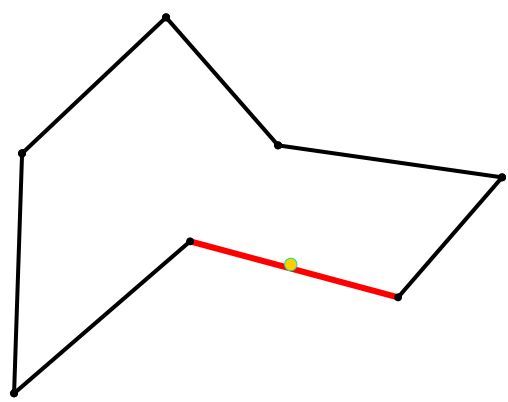
 The 4-point scheme




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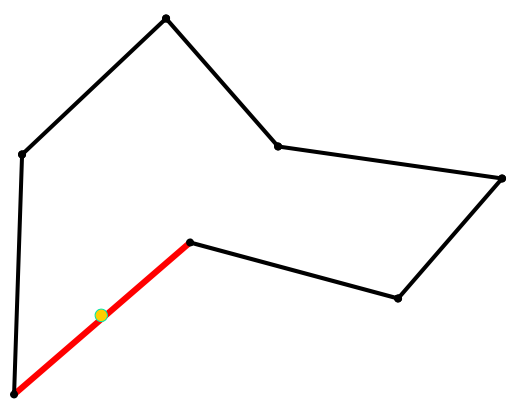
The 4-point scheme



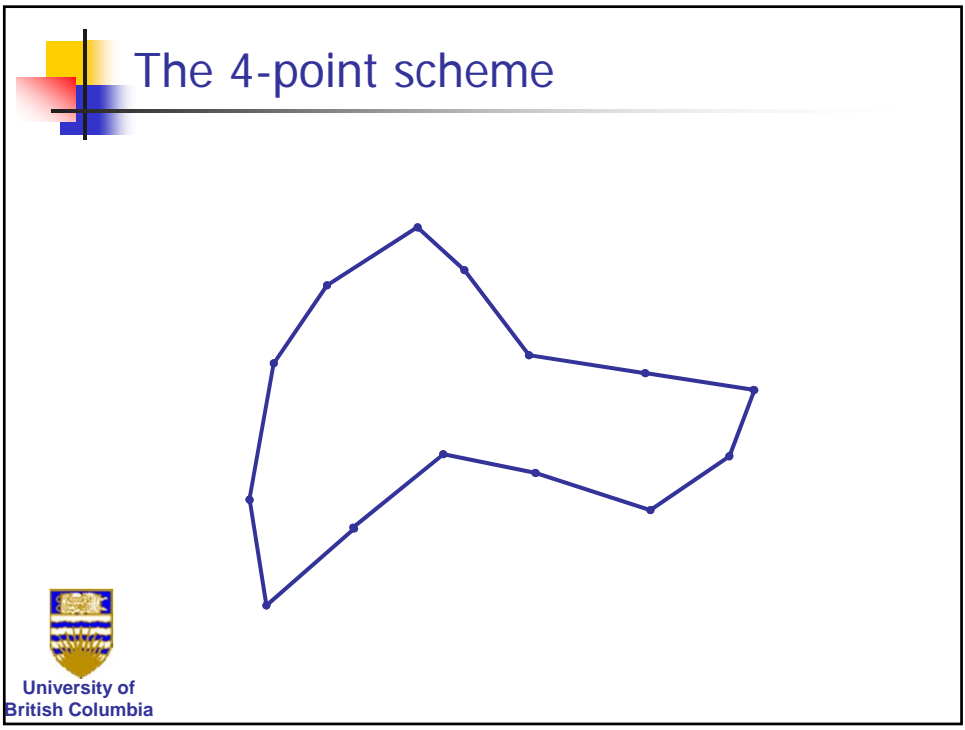
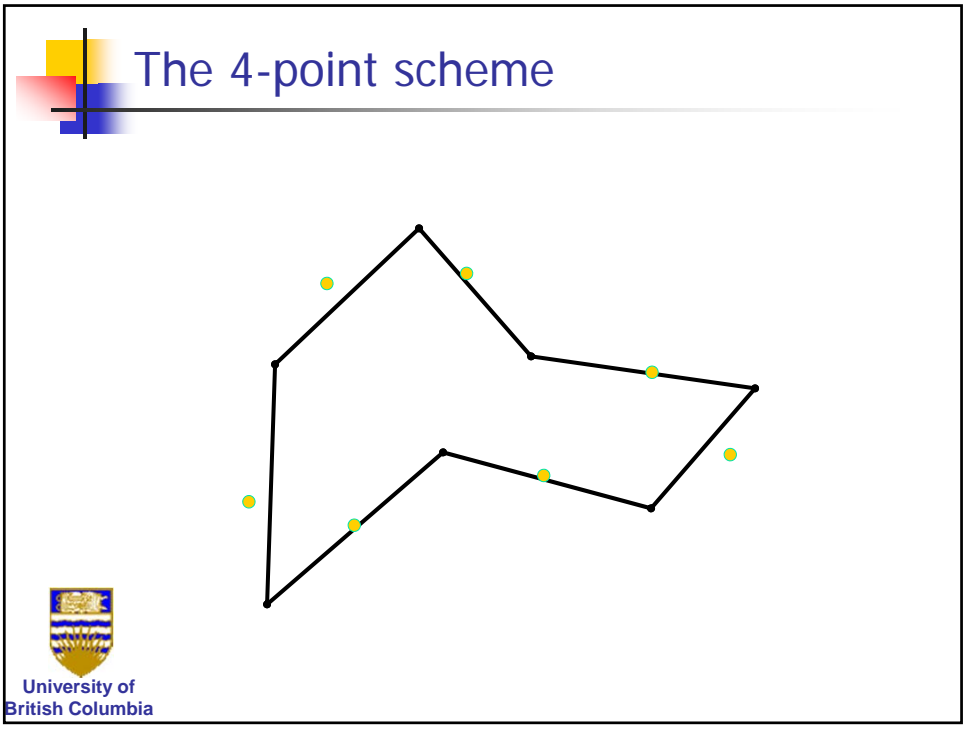
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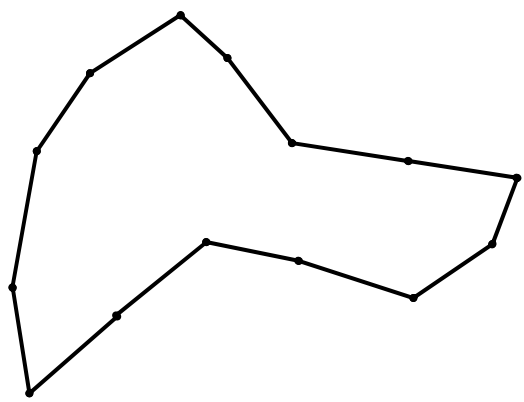
The 4-point scheme





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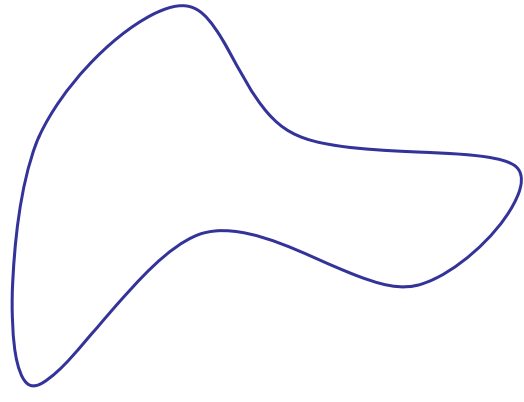



 The 4-point scheme




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 The 4-point scheme



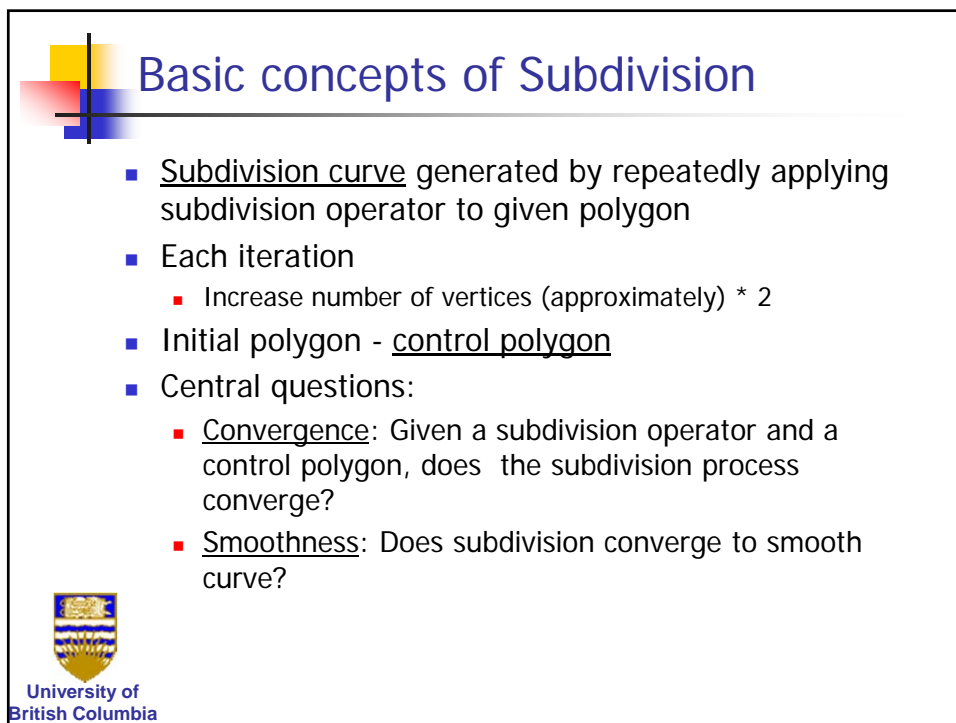
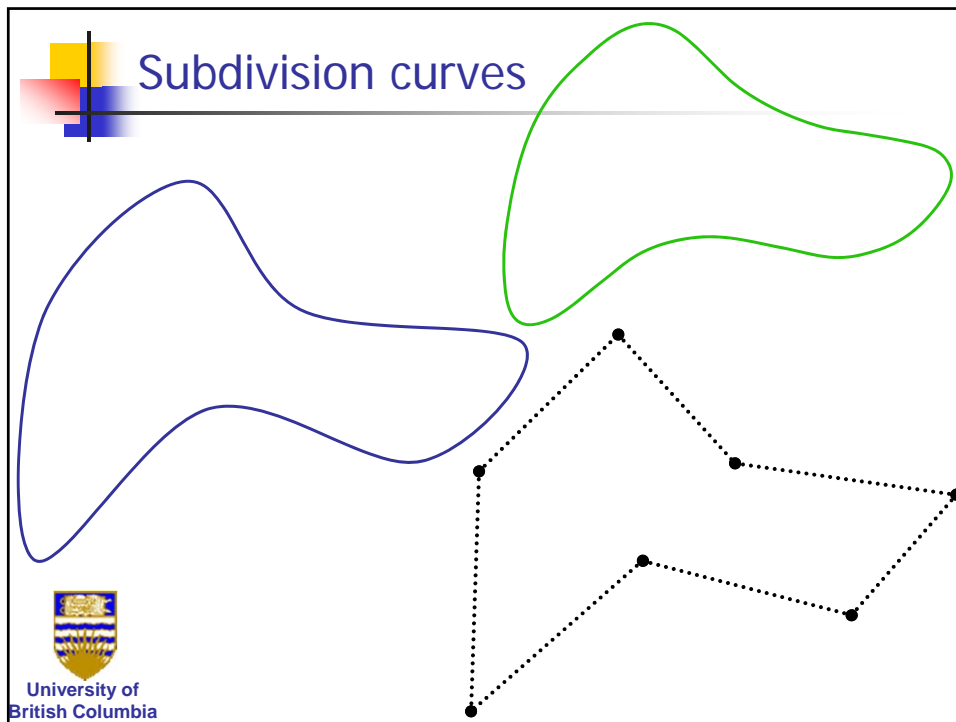

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The 4-point scheme

The diagram illustrates the 4-point scheme for curve generation. It features a control polygon, represented by a dotted line connecting four control points. A solid blue line, labeled as the 'limit curve', is shown passing through the control points. One of the control points is specifically labeled as a 'control point' with an arrow. The University of British Columbia logo is visible in the bottom left corner.

Subdivision curves

This diagram compares two types of subdivision schemes. The control polygon is shown as a dotted line. A legend in the top right identifies 'Non interpolatory subdivision schemes' with a green square, specifically 'Corner Cutting', which is shown as a green curve. A legend in the bottom right identifies 'Interpolatory subdivision schemes' with a blue square, specifically 'The 4-point scheme', which is shown as a blue curve. The University of British Columbia logo is visible in the bottom left corner.



The diagram contains a list of bullet points explaining the basic concepts of subdivision. It includes the University of British Columbia logo in the bottom left corner.

Basic concepts of Subdivision

- Subdivision curve generated by repeatedly applying subdivision operator to given polygon
- Each iteration
 - Increase number of vertices (approximately) * 2
- Initial polygon - control polygon
- Central questions:
 - Convergence: Given a subdivision operator and a control polygon, does the subdivision process converge?
 - Smoothness: Does subdivision converge to smooth curve?

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Subdivision schemes for surfaces

- Each iteration
 - Subdivision refines *control net* (mesh)
 - Increase number of vertices (approximately) * 4
- Mesh vertices converge to limit surface
- Every subdivision method has:
 - Method to generate net topology
 - rules to calculate location of new vertices

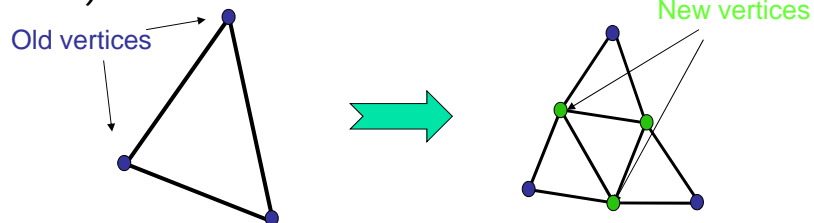


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Triangular subdivision

- Works only for triangular meshes (control nets)



- Every face replaced by 4 new triangular faces
- Two kinds of new vertices:



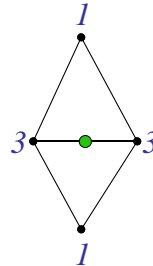
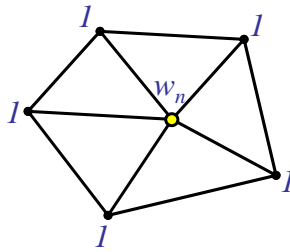
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- Green vertices are associated with old **edges**
- Blue vertices are associated with old **vertices**



Loop's scheme

- New vertex = weighted average of old vertices
- List of weights - subdivision mask or stencil
 - Rule for new **blue** vertices (n - vertex valence)
 - Rule for new **green** vertices

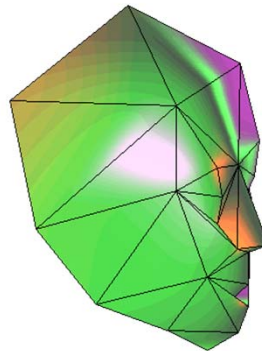


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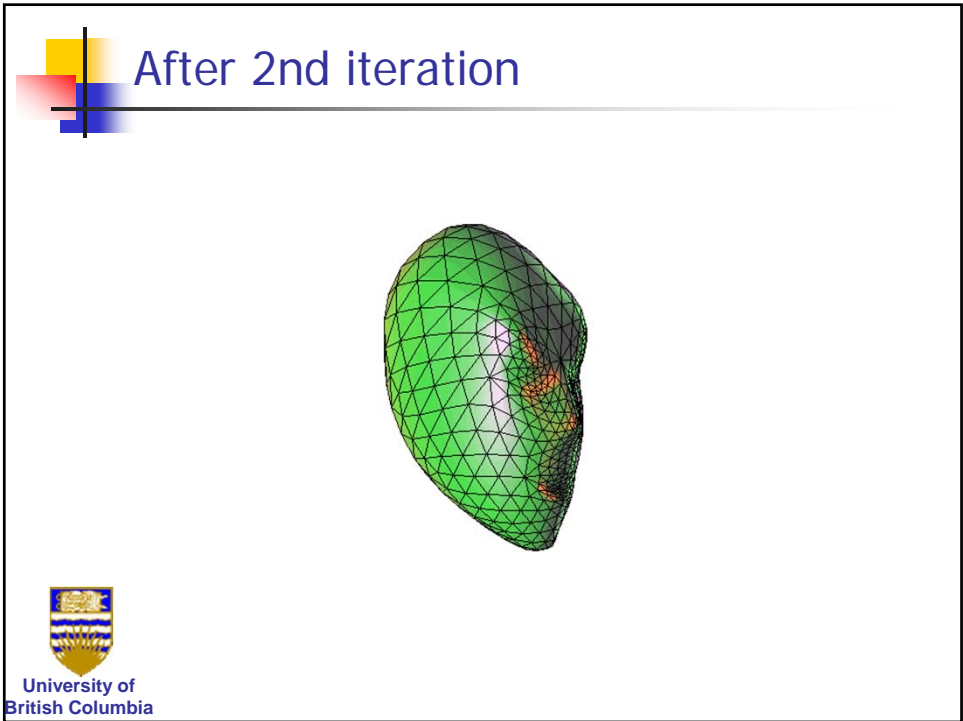
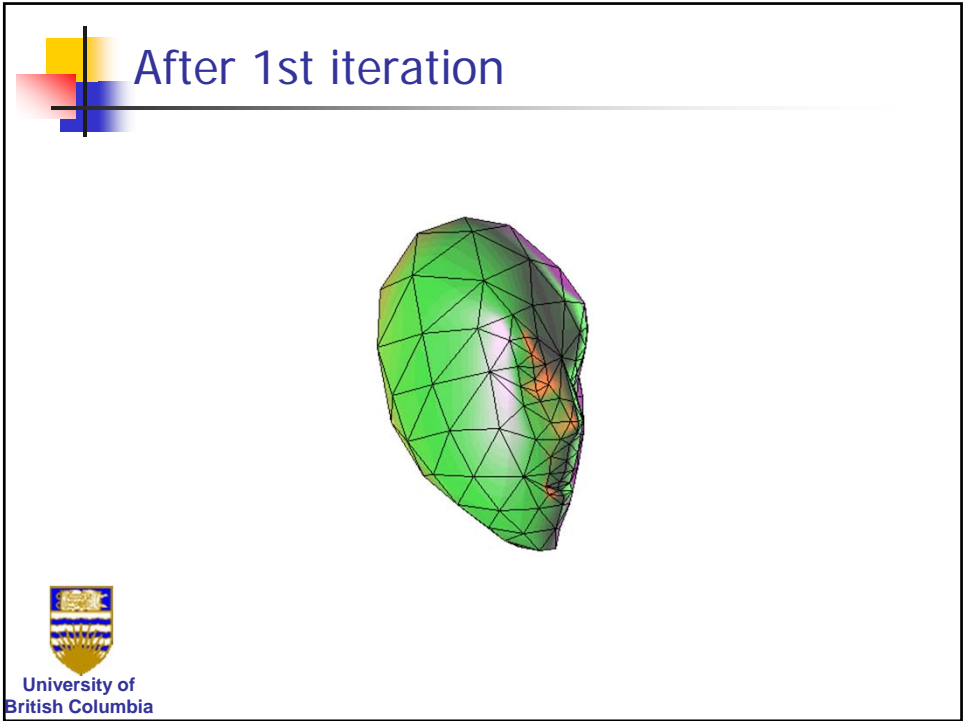
$$w_n = \frac{64n}{40 - (3 + 2\cos(2\pi/n))^2} - n$$




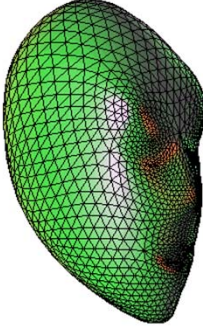
The original control net





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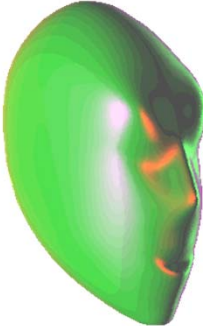



 After 3rd iteration




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 The limit surface



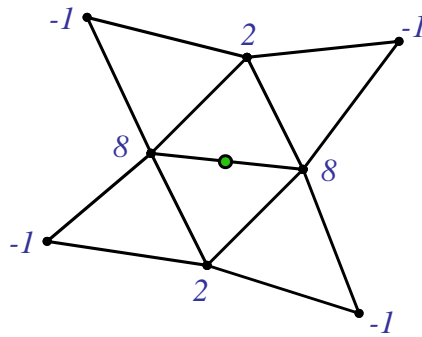

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- Limit surfaces of Loop's subdivision is C^2 almost everywhere



Butterfly scheme

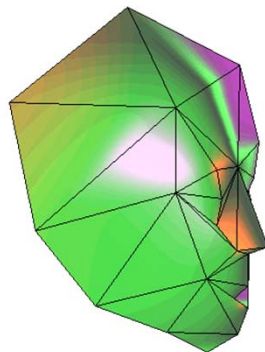
- Interpolatory scheme
- New blue vertices inherit location of old vertices
- New green vertices calculated by following stencil:



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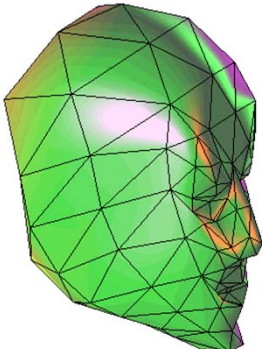


The original control net




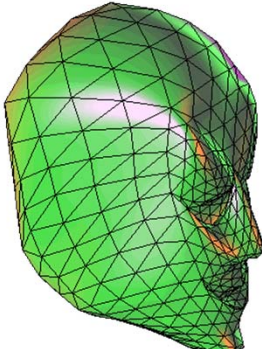
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After 1st iteration




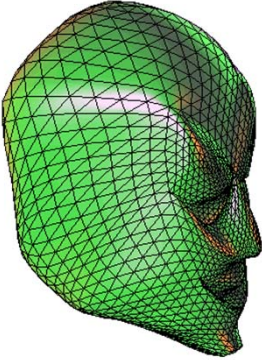
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After 2nd iteration




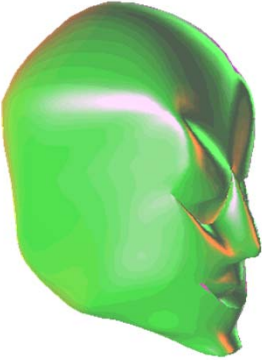
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 After 3rd iteration



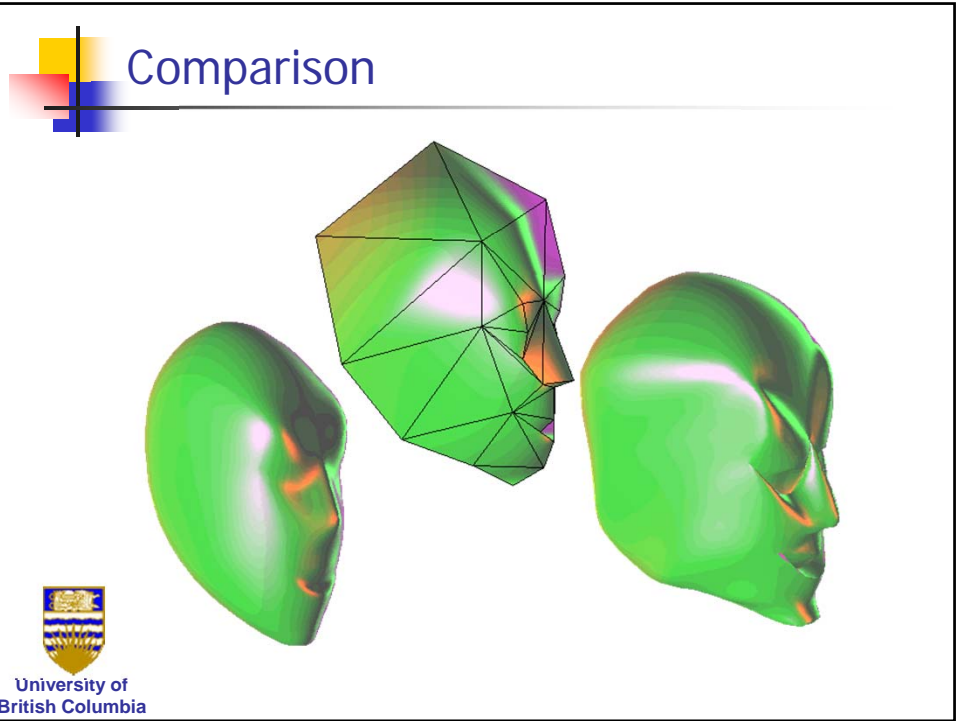

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 The limit surface





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- Limit surfaces of Butterfly subdivision are C^1 , but do not have second derivative



Properties

- Require regular connectivity (valence 6) to work well
- Easy to implement (efficiency...)
- Local support
- Allow LOD
- Continuous

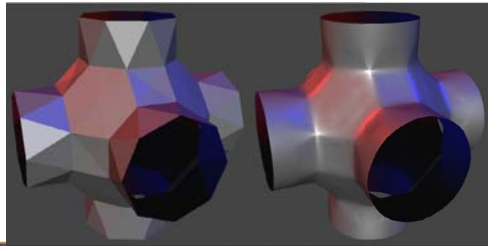


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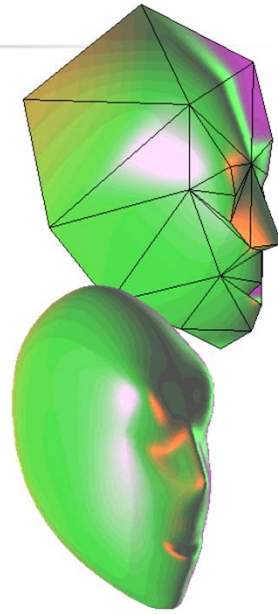
Drawbacks

- Not always intuitive
- Can have artifacts
- Hard to control



Initial mesh

Butterfly scheme interpolation



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