Polygonal Meshes

COS 426, Spring 2015

Princeton University

3D Object Representations

Points

- Range image
- Point cloud

Surfaces

- Polygonal mesh
- Subdivision
- Parametric
- Implicit

Solids

- Voxels
- BSP tree
- CSG
- Sweep

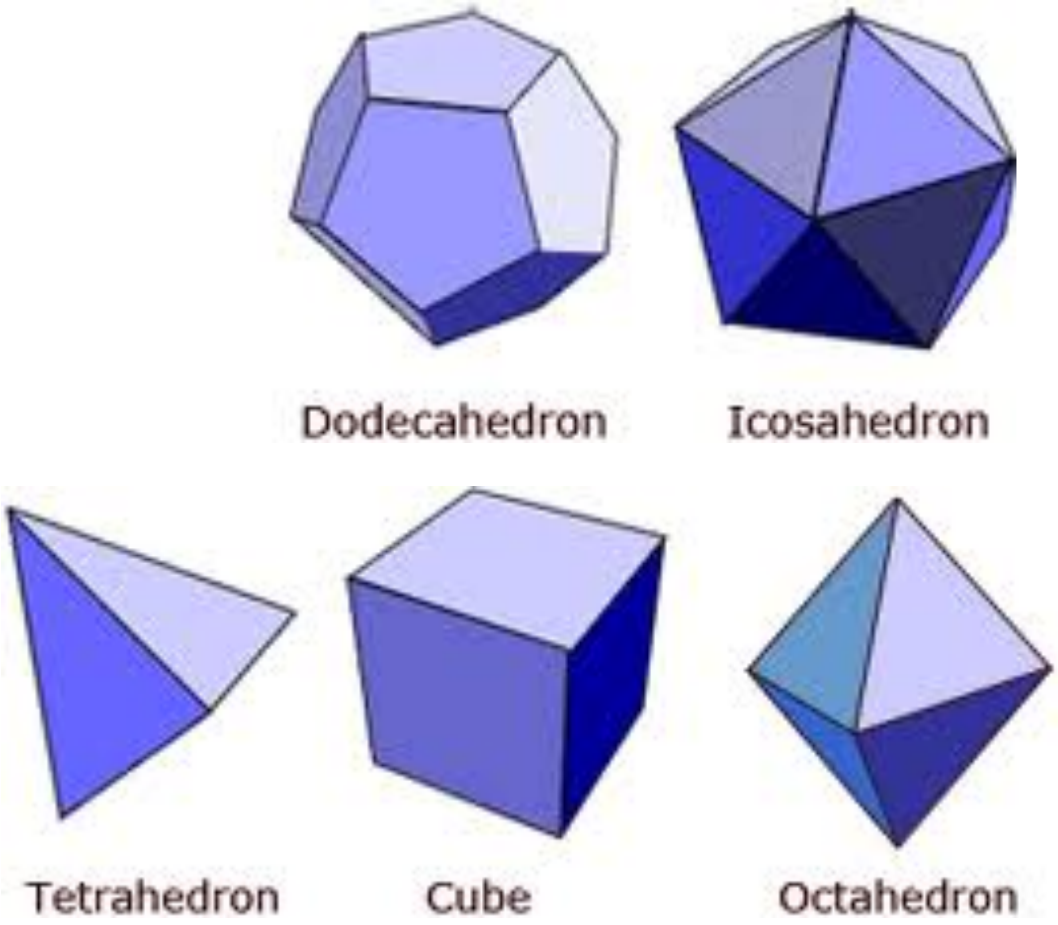
High-level structures

- Scene graph
- Application specific

3D Polygonal Mesh

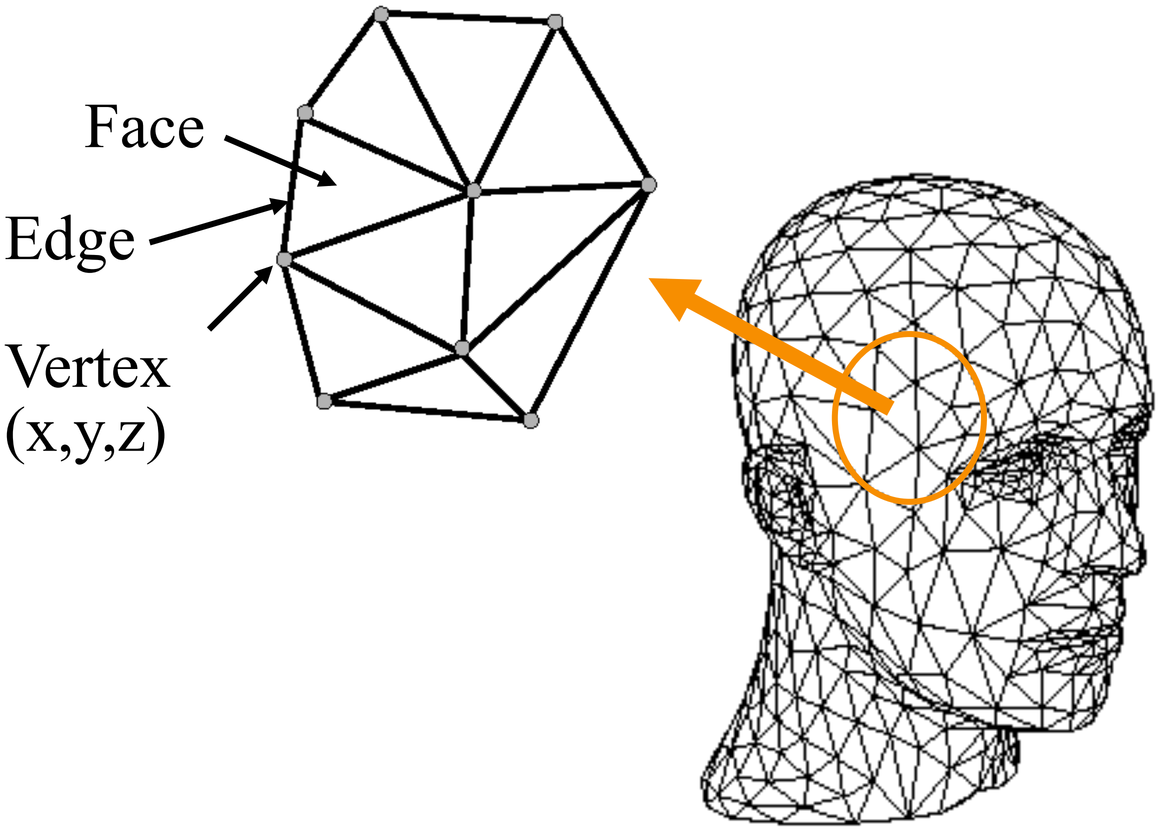
Set of polygons representing a 2D surface embedded in 3D

Platonic Solids



3D Polygonal Mesh

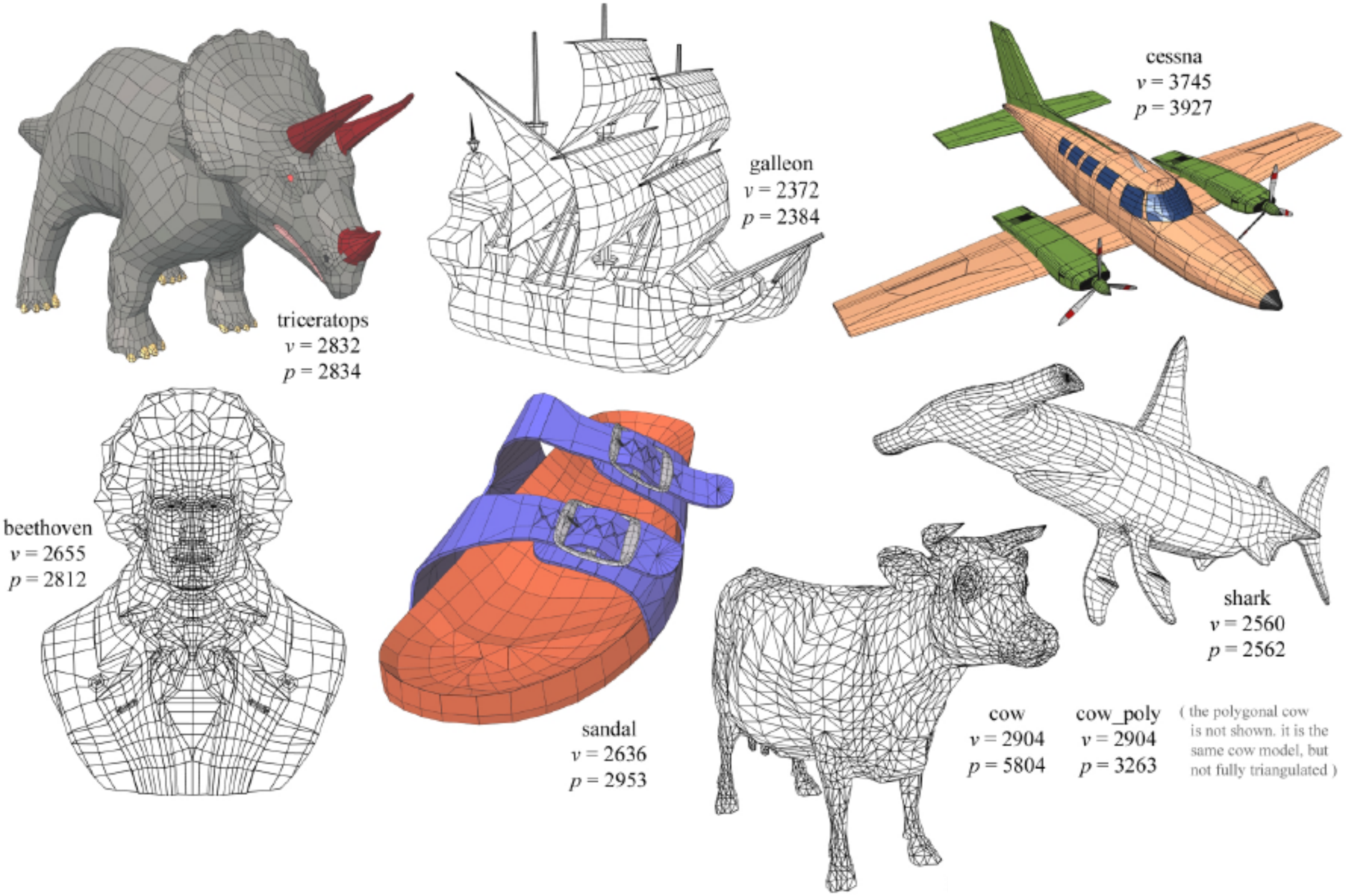
Set of polygons representing a 2D surface embedded in 3D



Zorin & Schroeder

3D Polygonal Mesh

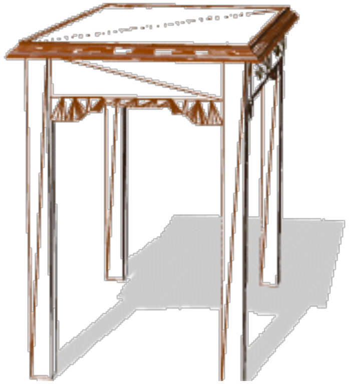
Set of polygons representing a 2D surface embedded in 3D

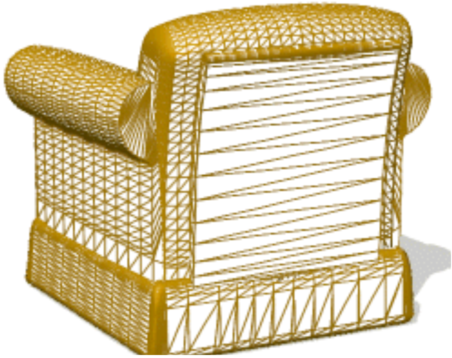


3D Polygonal Meshes

Why are they of interest?

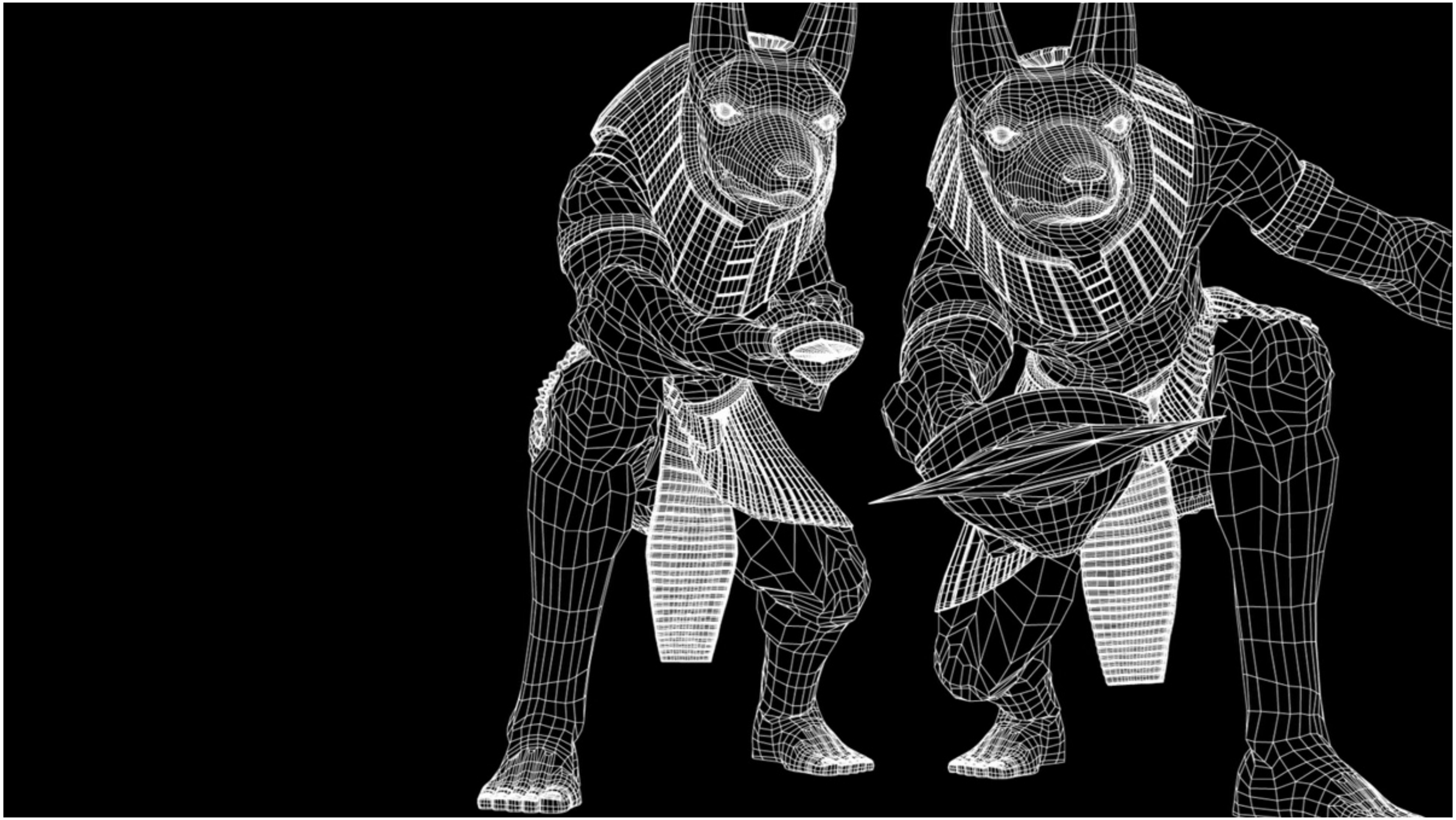
- Simple, common representation
- Rendering with hardware support
- Output of many acquisition tools
- Input to many simulation/analysis tools





Viewpoint

3D Polygonal Meshes



http://www.fxguide.com/featured/Comic_Horrors_Rocks_Statues_and_VanDyke/

3D Polygonal Meshes

Properties

? Efficient display

? Easy acquisition

? Accurate

? Concise

? Intuitive editing

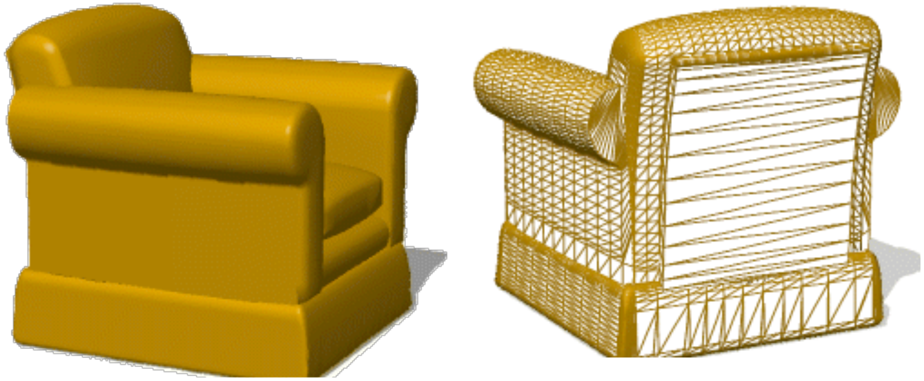
? Efficient editing

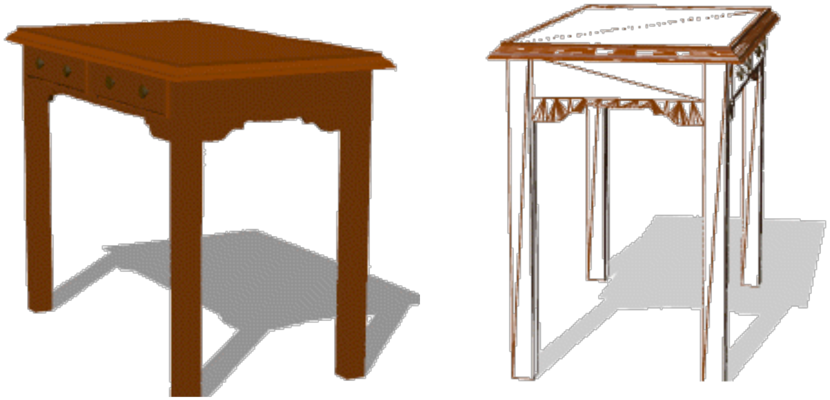
? Efficient intersections

? Guaranteed validity

? Guaranteed smoothness

? etc.





Viewpoint

Outline

Acquisition ←

Processing

Representation

Polygonal Mesh Acquisition

Interactive modeling

- Polygon editors
- Interchange formats

Scanners

- Laser range scanners
- Geological survey

Procedural generation

- Surface of revolution
- Sweep

Simulations

- Physical processes

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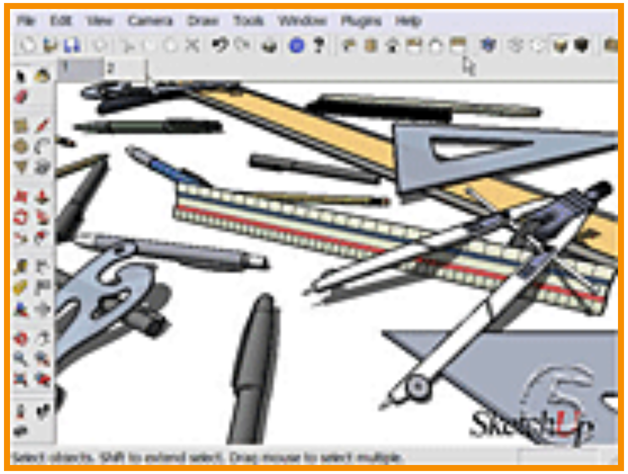
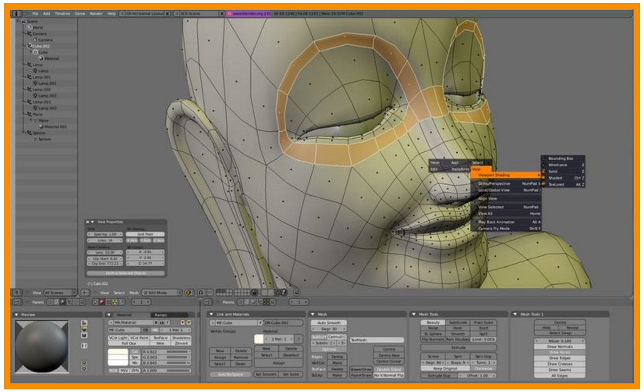


Select objects. Shift to extend select. Drag mouse to select multiple.

Sketchup



Blender

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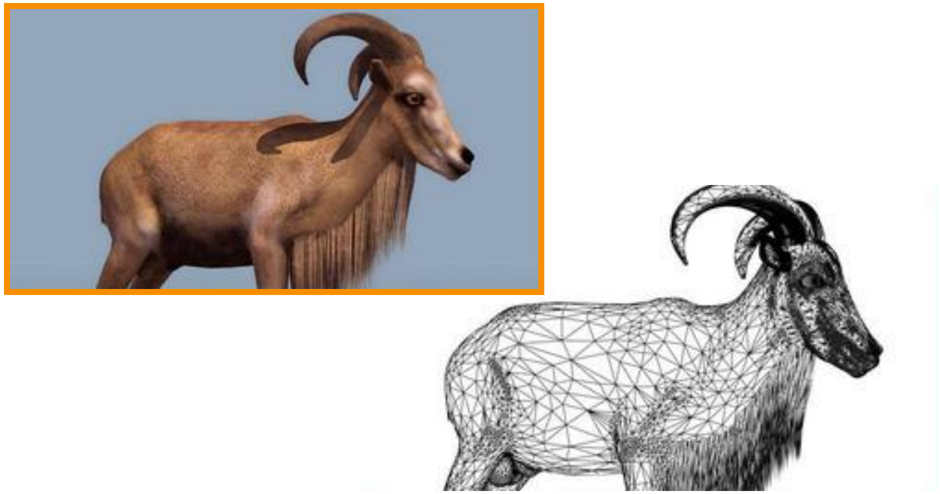

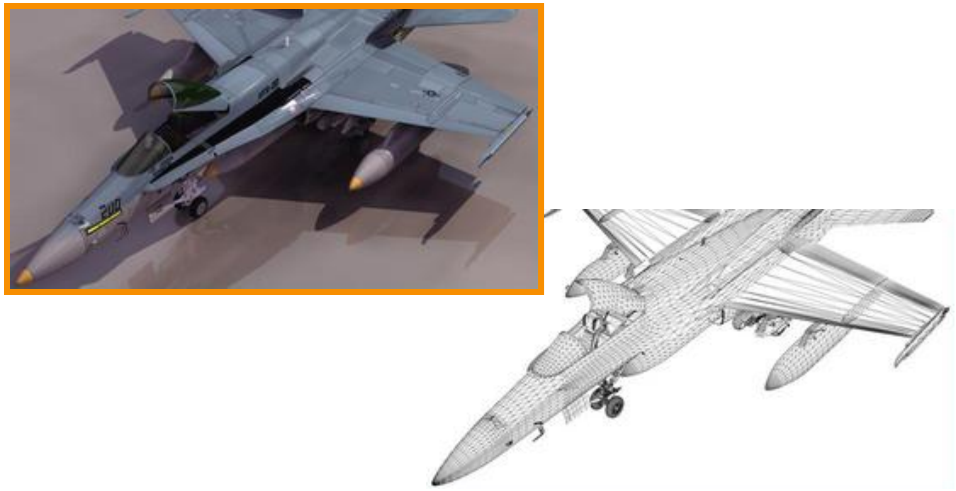

Jose Maria De Espona

Polygonal Mesh Acquisition

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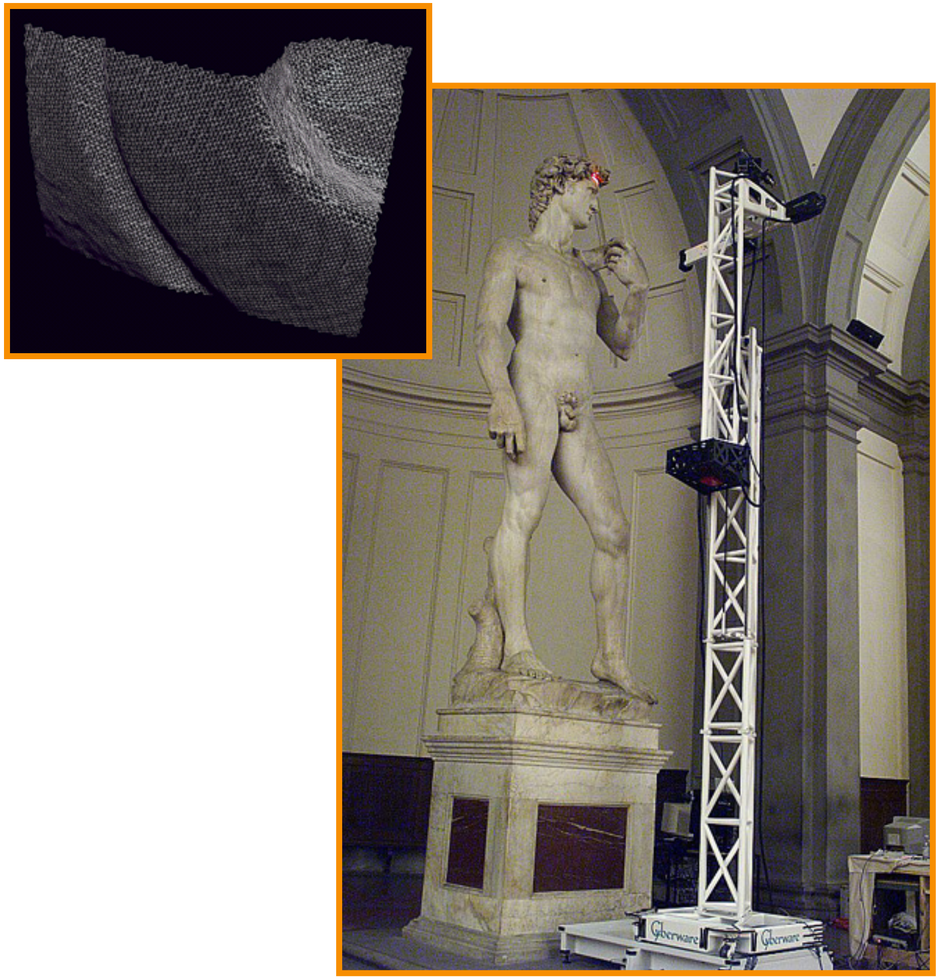

Digital Michelangelo Project
Stanford

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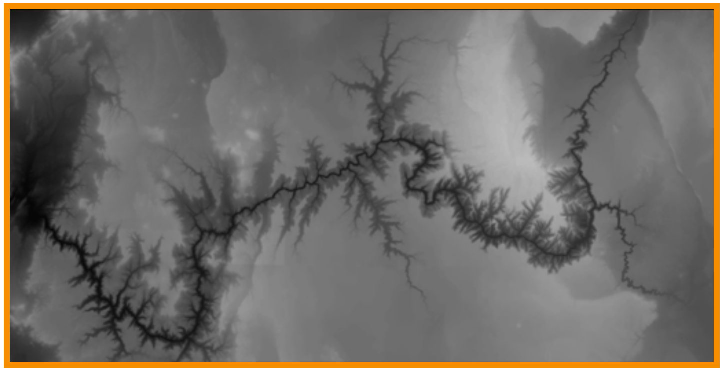

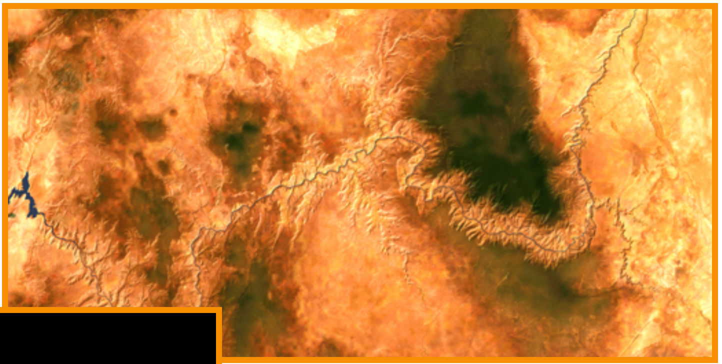

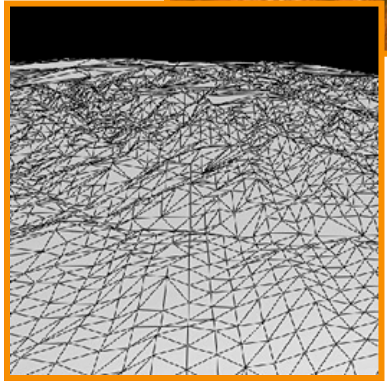

Large Geometric
Model Repository
Georgia Tech

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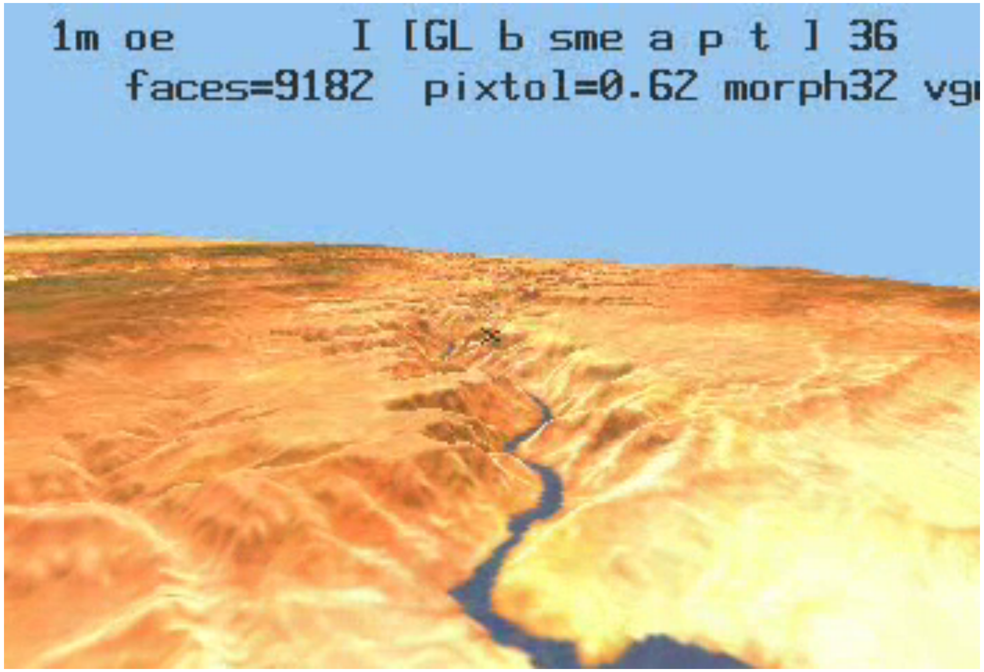

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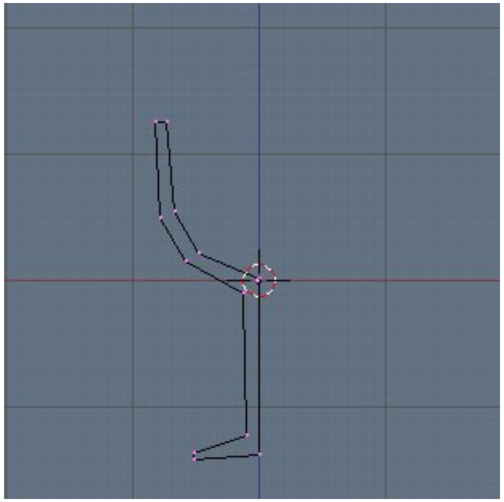

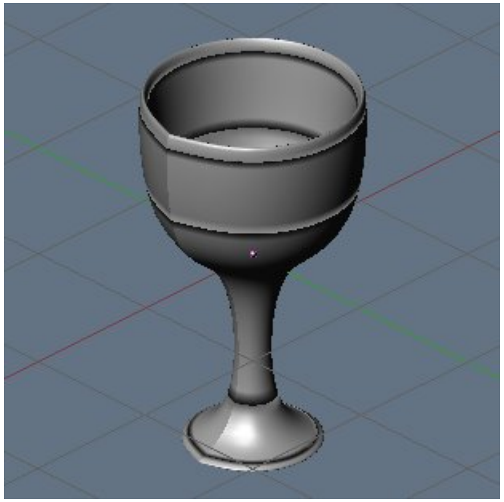

sphynx.co.uk

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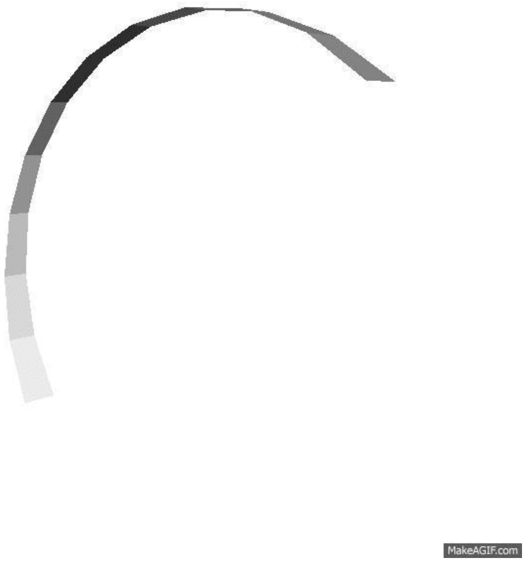

Nicky Robinson, COS 426, 2014

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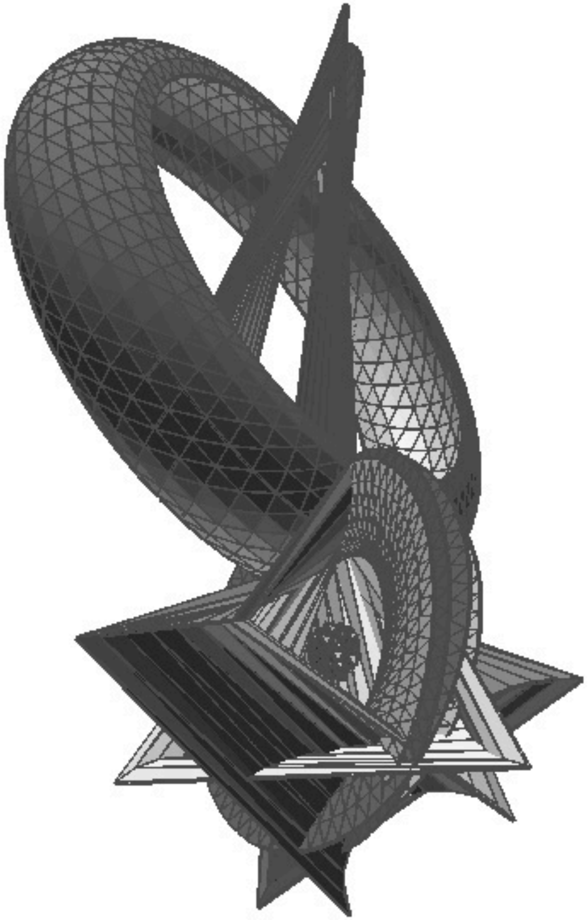

Alejandro Van Zandt-Escobar, COS 426, 2014

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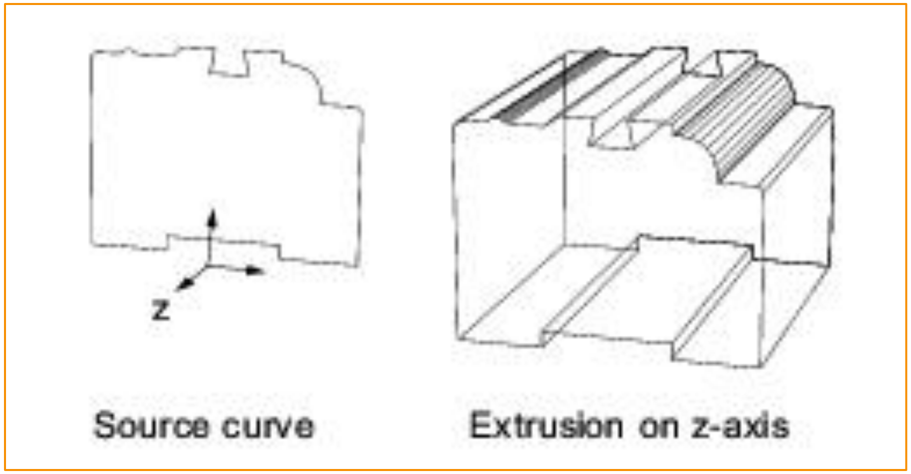

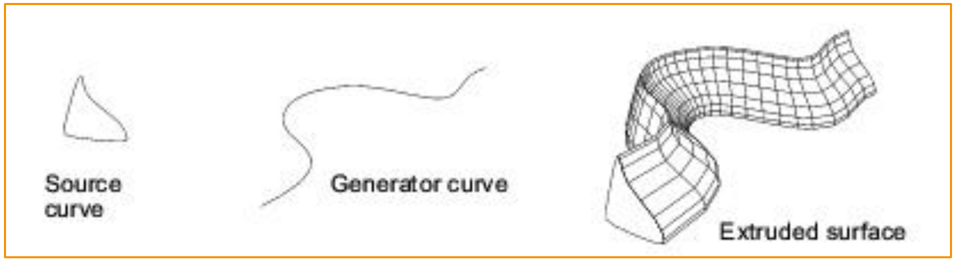

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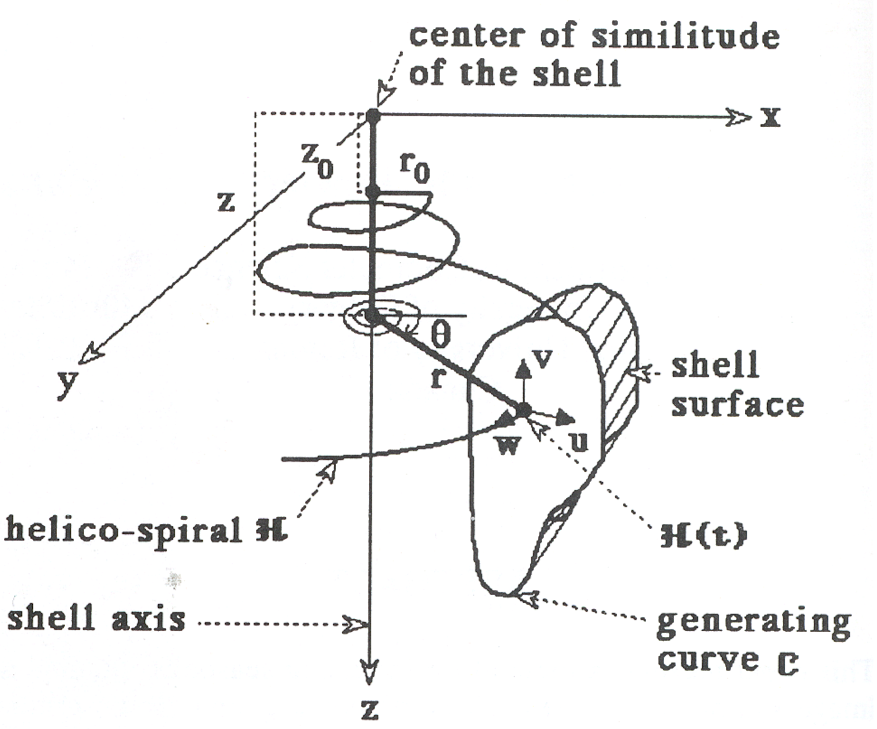

Fowler et al., 1992

Polygonal Mesh Acquisition

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Fowler et al., 1992

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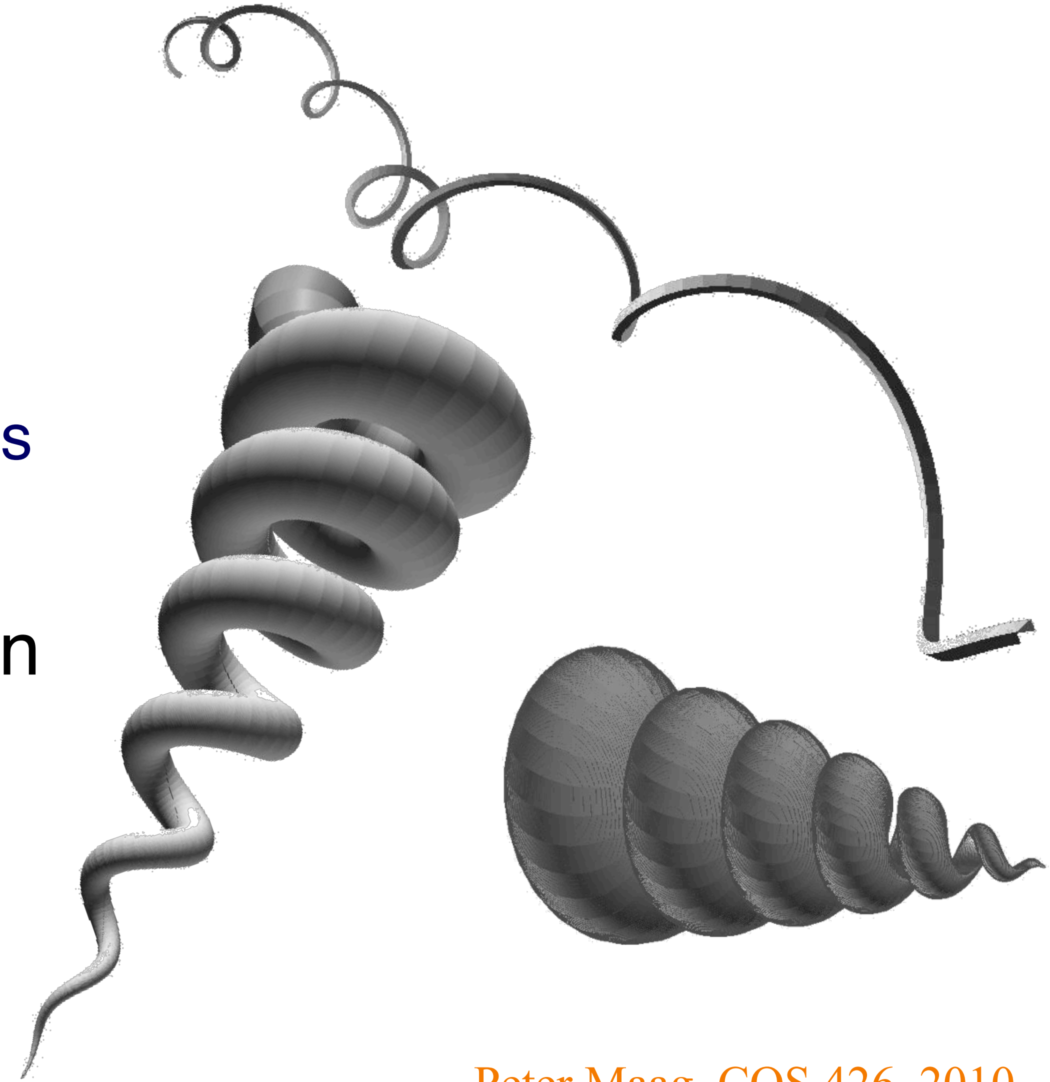

Peter Maag, COS 426, 2010

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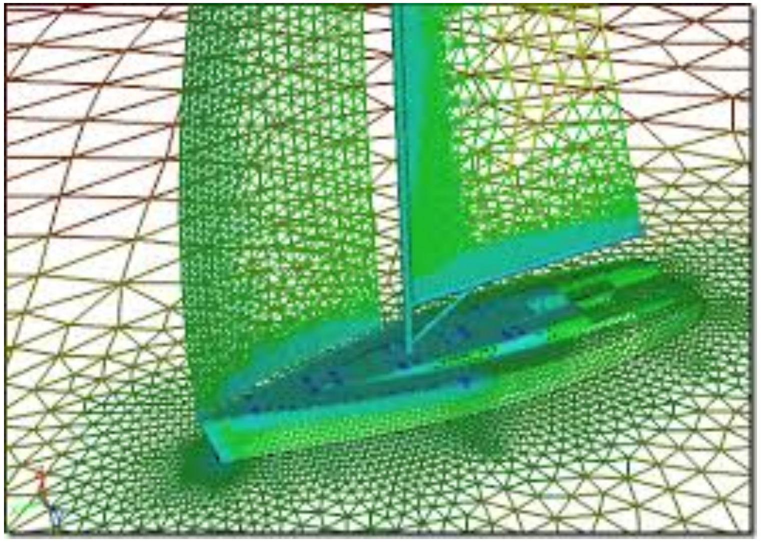
SGI



symscape

Outline

Acquisition

Processing ⟵

Representation

Polygonal Mesh Processing

Analysis

- Normals
- Curvature

Warps

- Rotate
- Deform

Filters

- Smooth
- Sharpen
- Truncate
- Bevel

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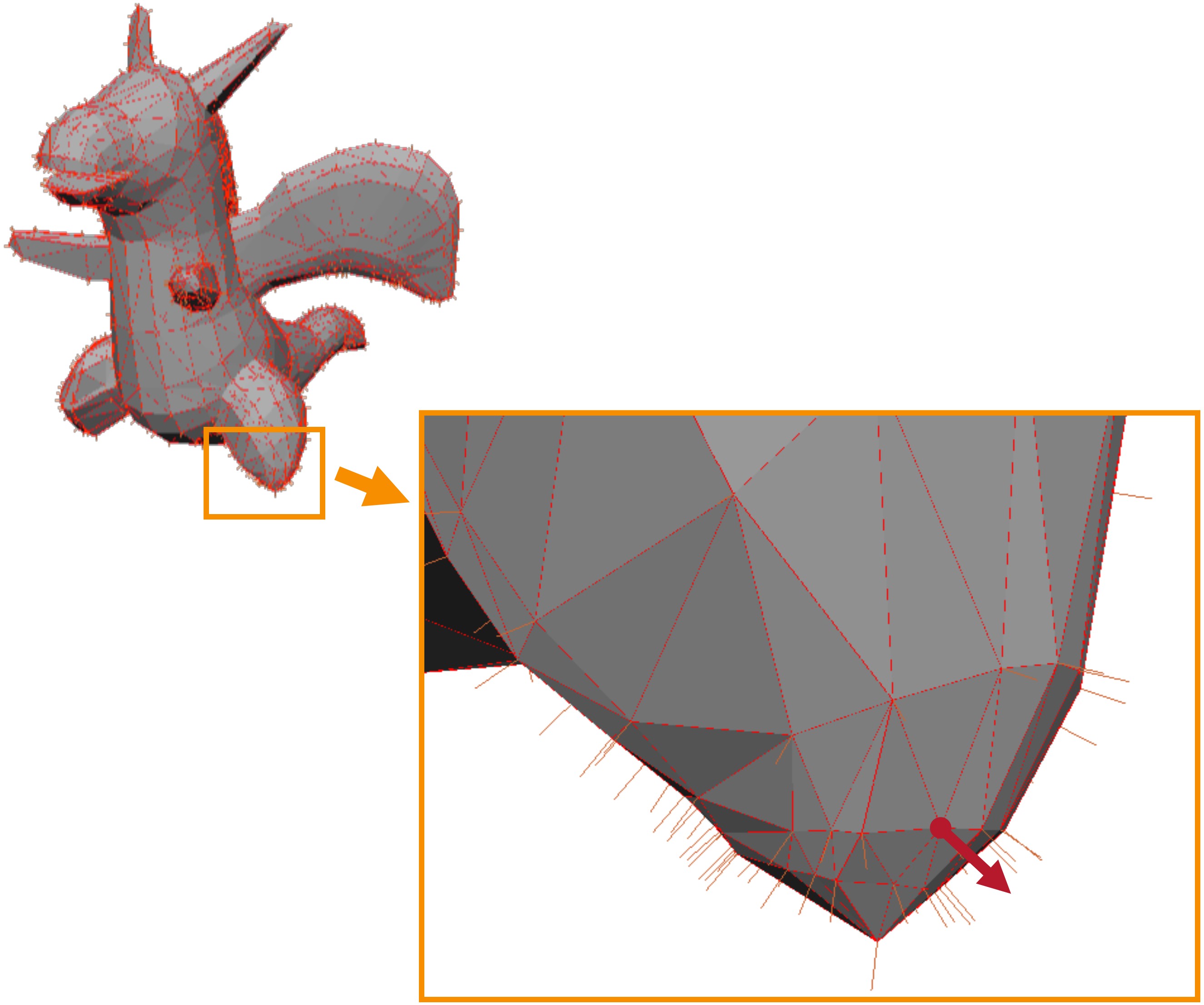

Polygonal Mesh Processing

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NORMAL VERTEX
presents
The Next Dual

"The bunny with normal vertices shown.
Reminded me of an album cover so I made it into one."

Lucas Mayer, COS 426, 2014

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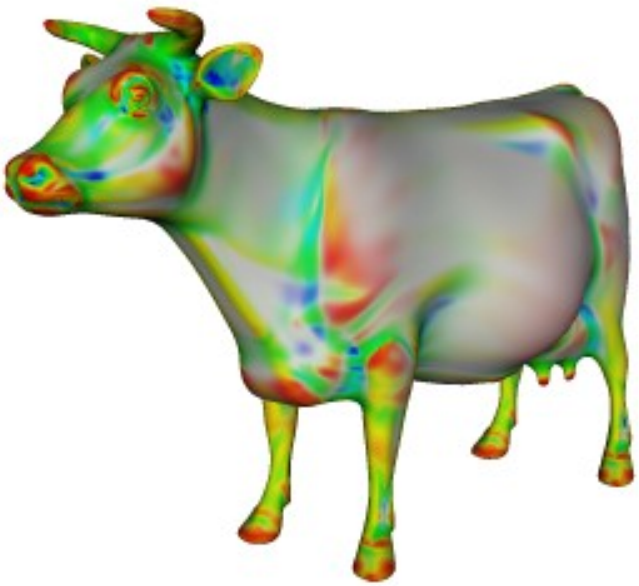

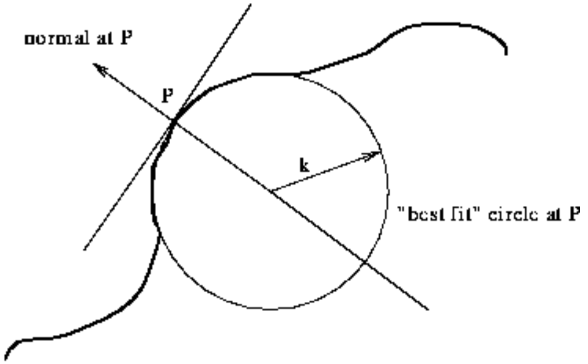

Figure 32: curvature of curve at P is $1/k$

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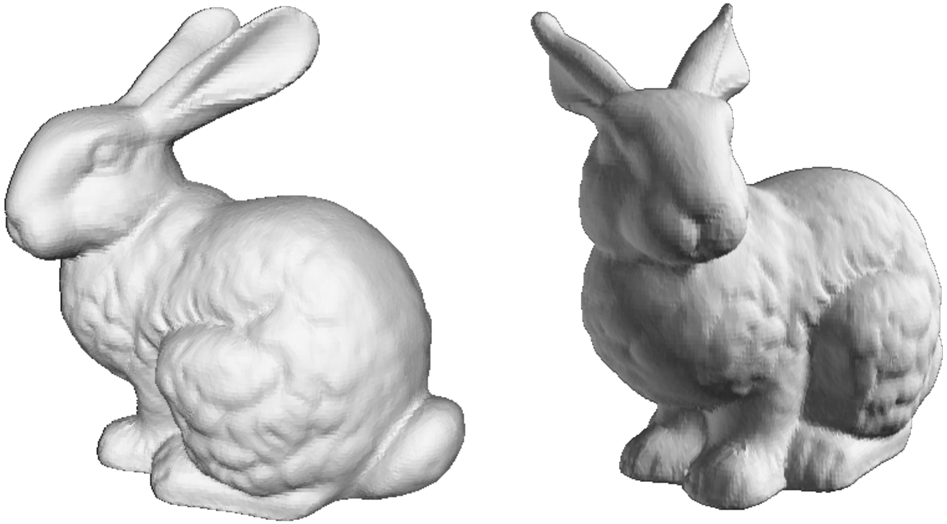

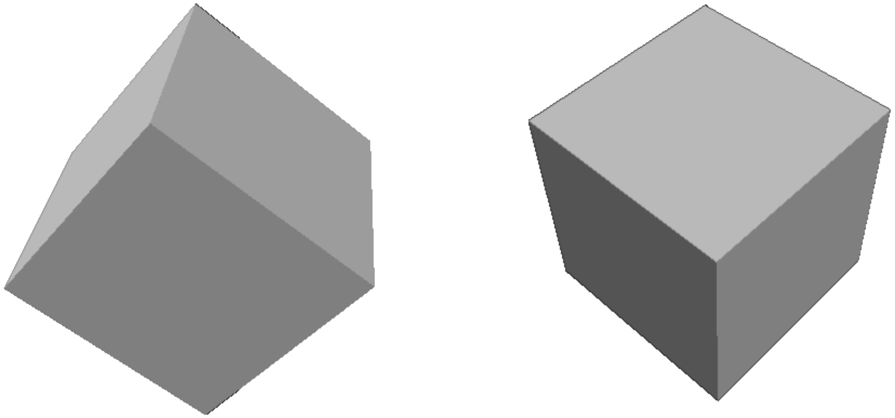

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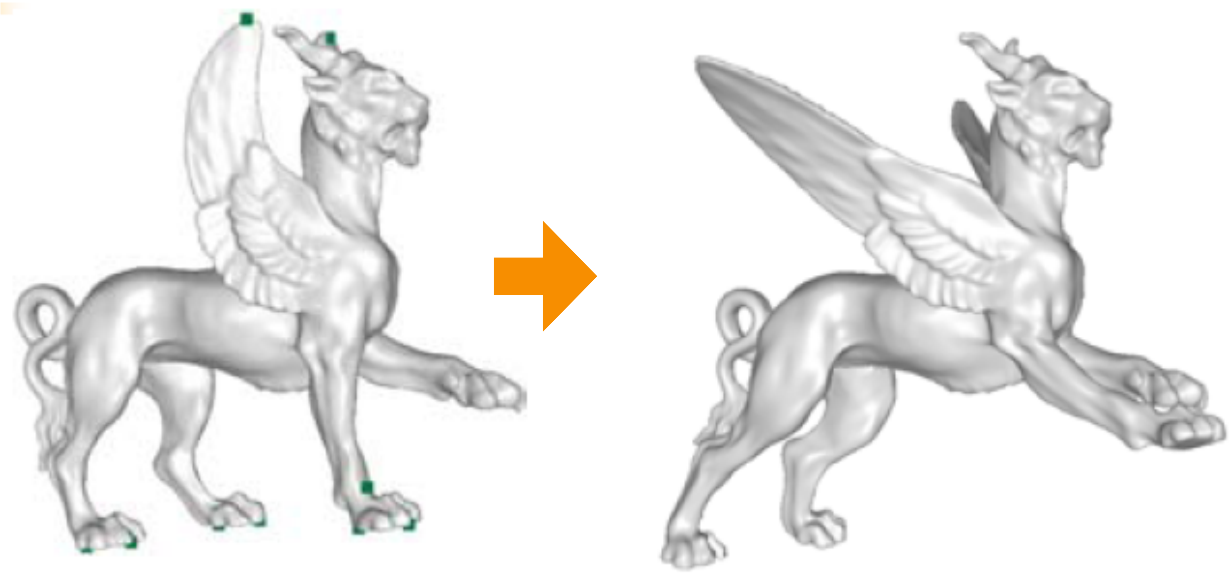

Sheffer

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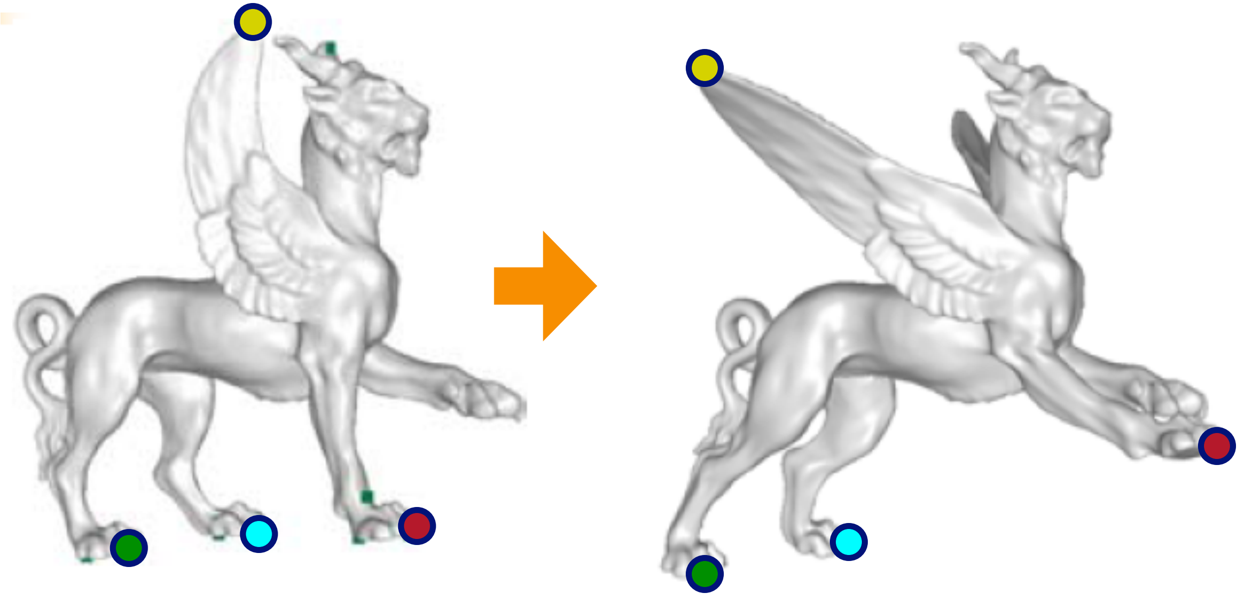

Sheffer

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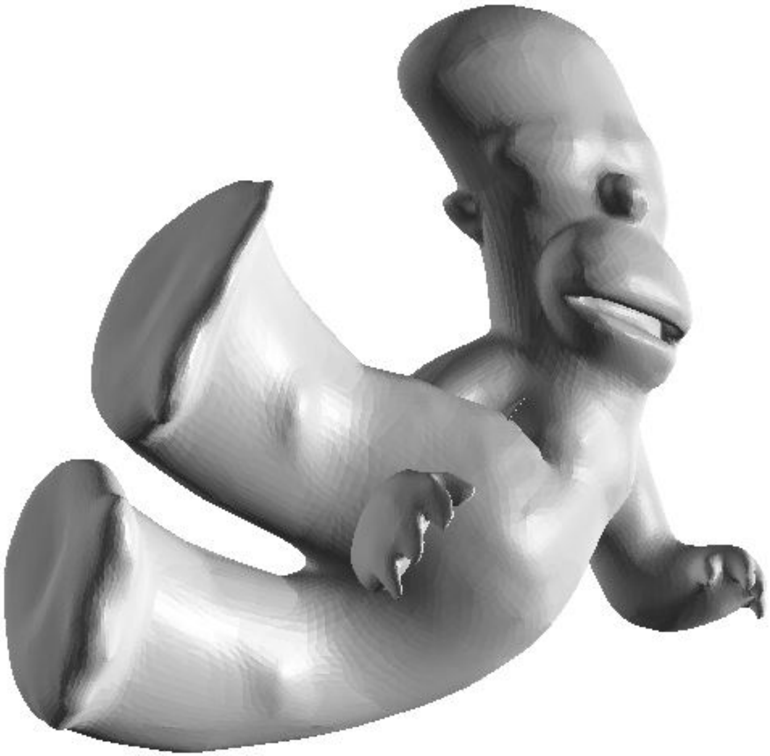

Brendan Chou, COS 426, 2014

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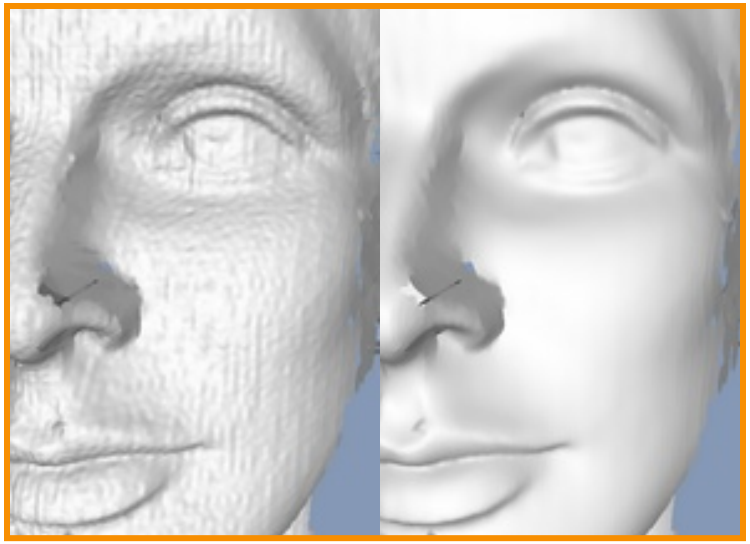
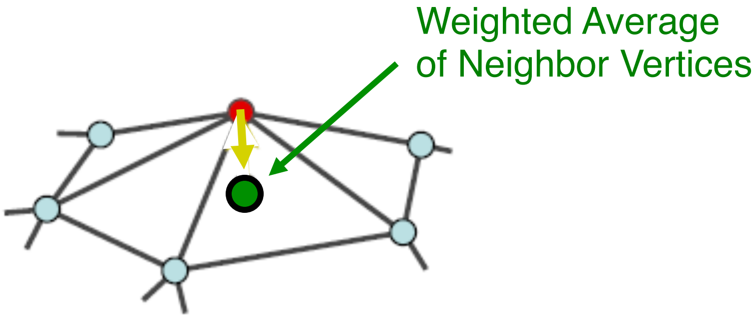


Thouis "Ray" Jones



Olga Sorkine

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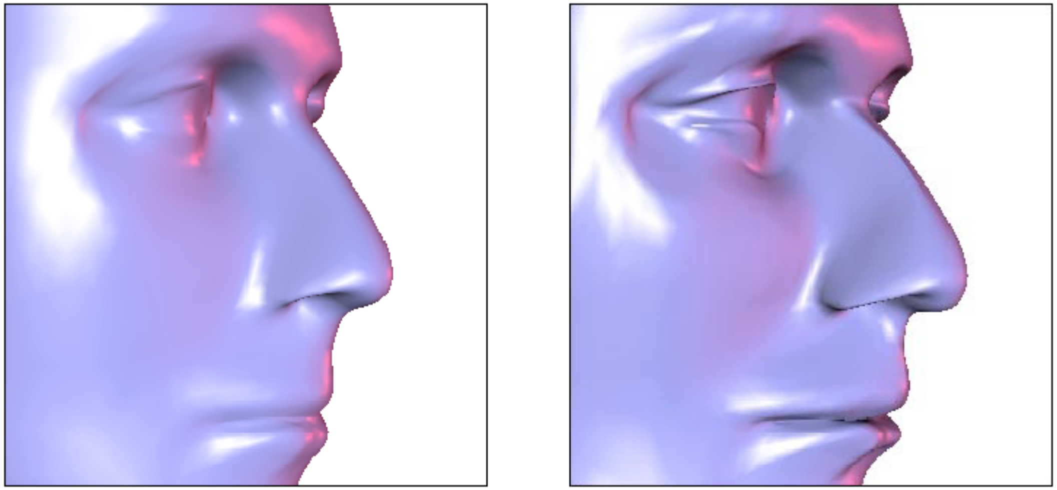

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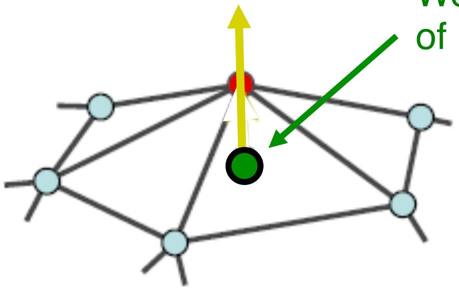

Weighted Average of Neighbor Vertices

Olga Sorkine

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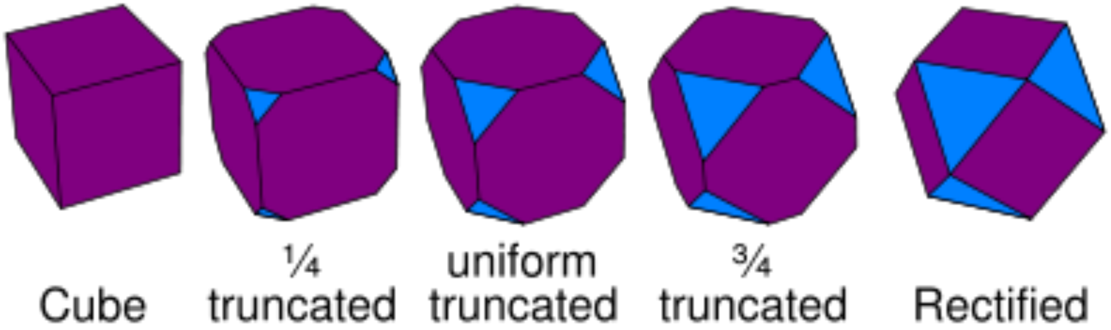

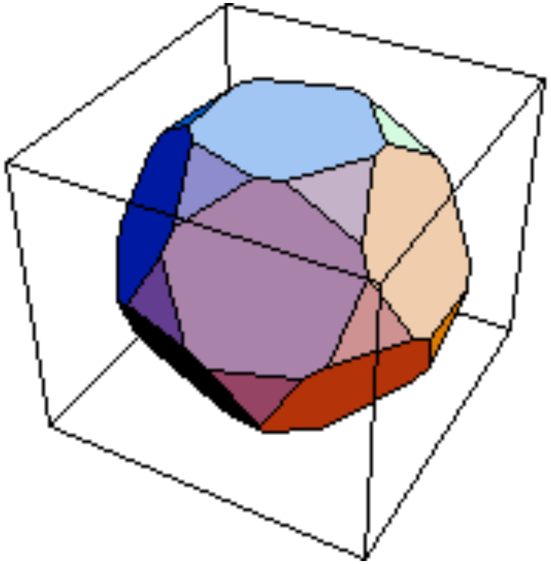

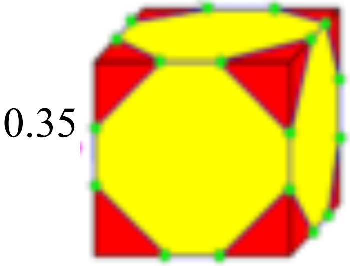

Conway

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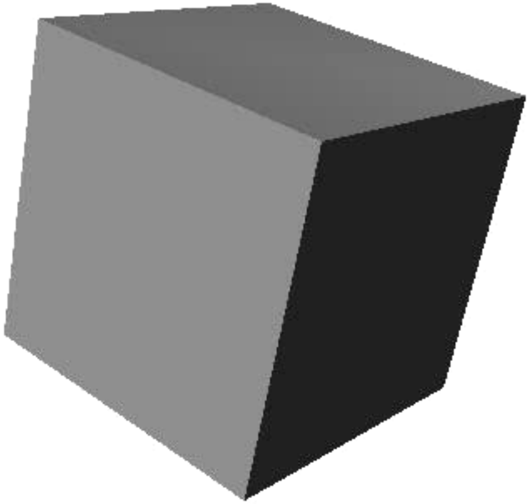

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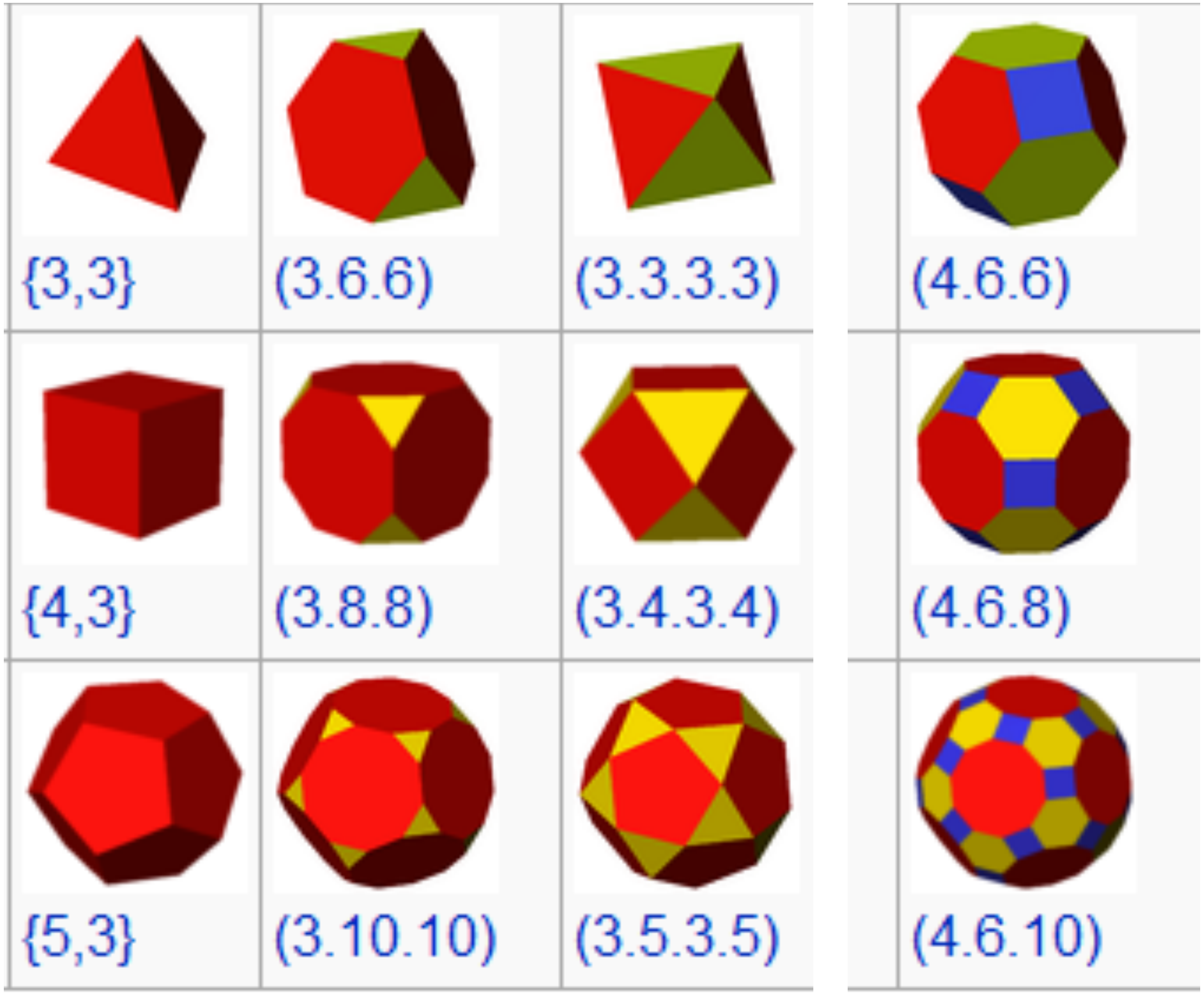

Wikipedia

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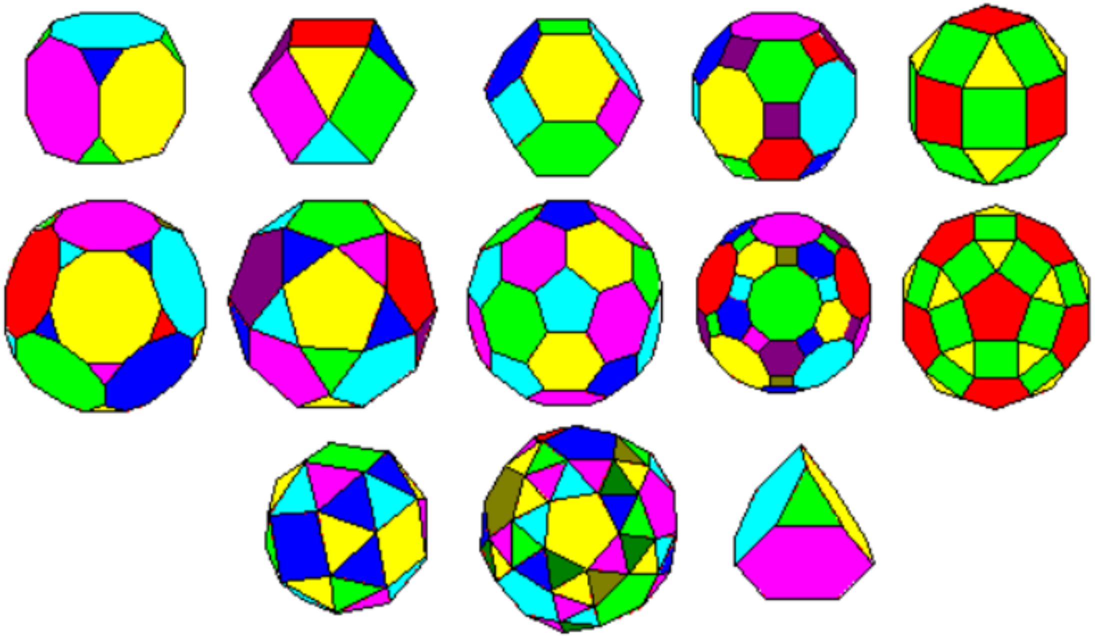

Archimedean Polyhedra
http://www.uwgb.edu/dutchs/symmetry/archpol.htm

Polygonal Mesh Processing

Analysis

- Nc
- Cu

Warp

- Ro
- De

Filter

- Sr
- Sh
- ➢ Tr
- Bevel

Carlo Sèquin

Polygonal Mesh Processing

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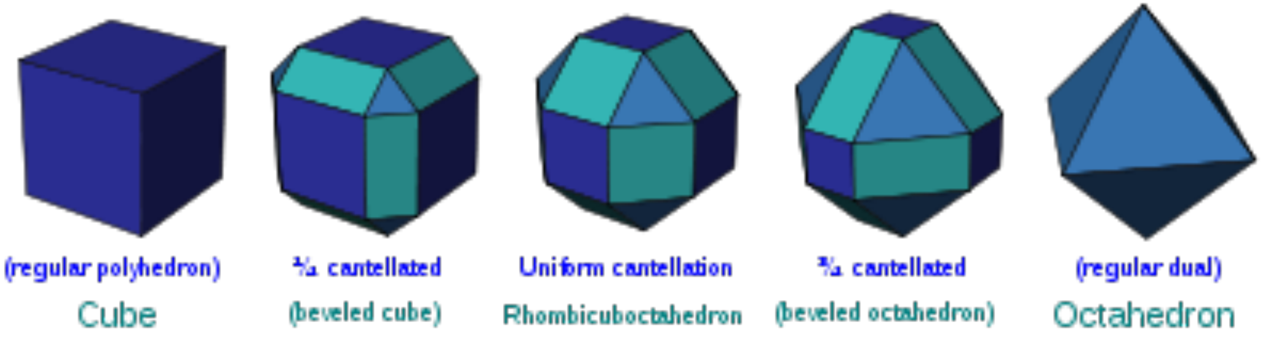
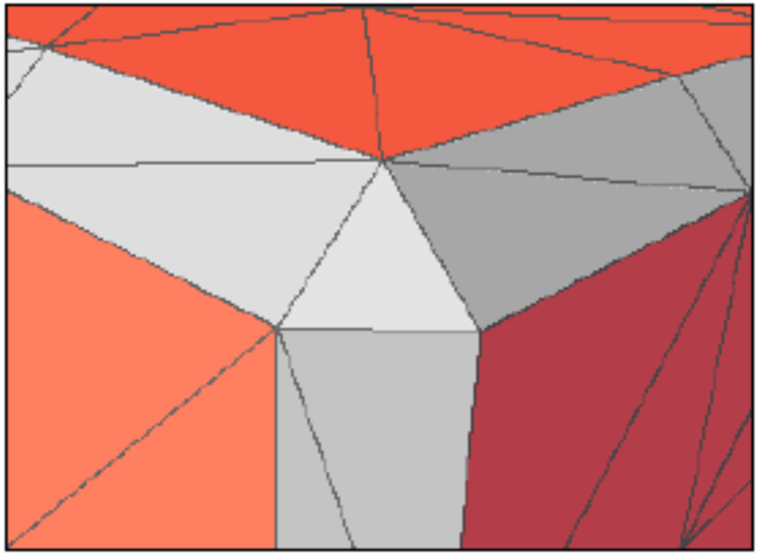
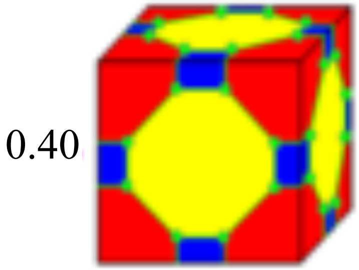




Jarek Rossignac



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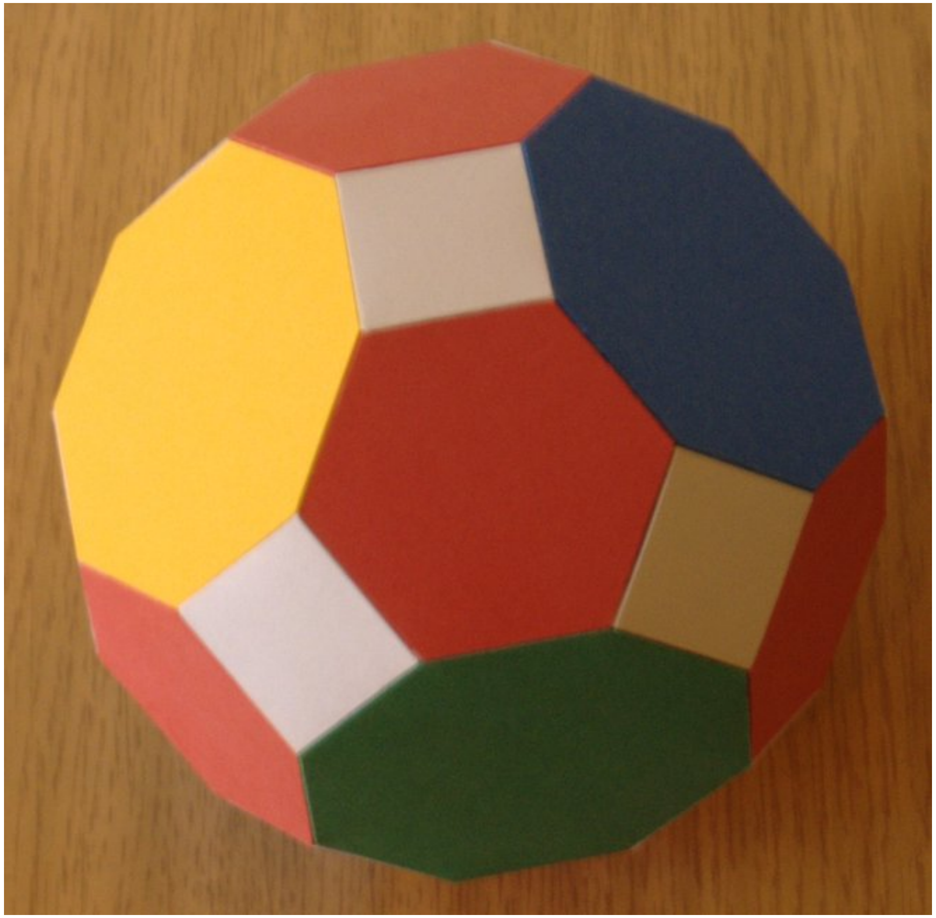

www.srcf.ucam.org

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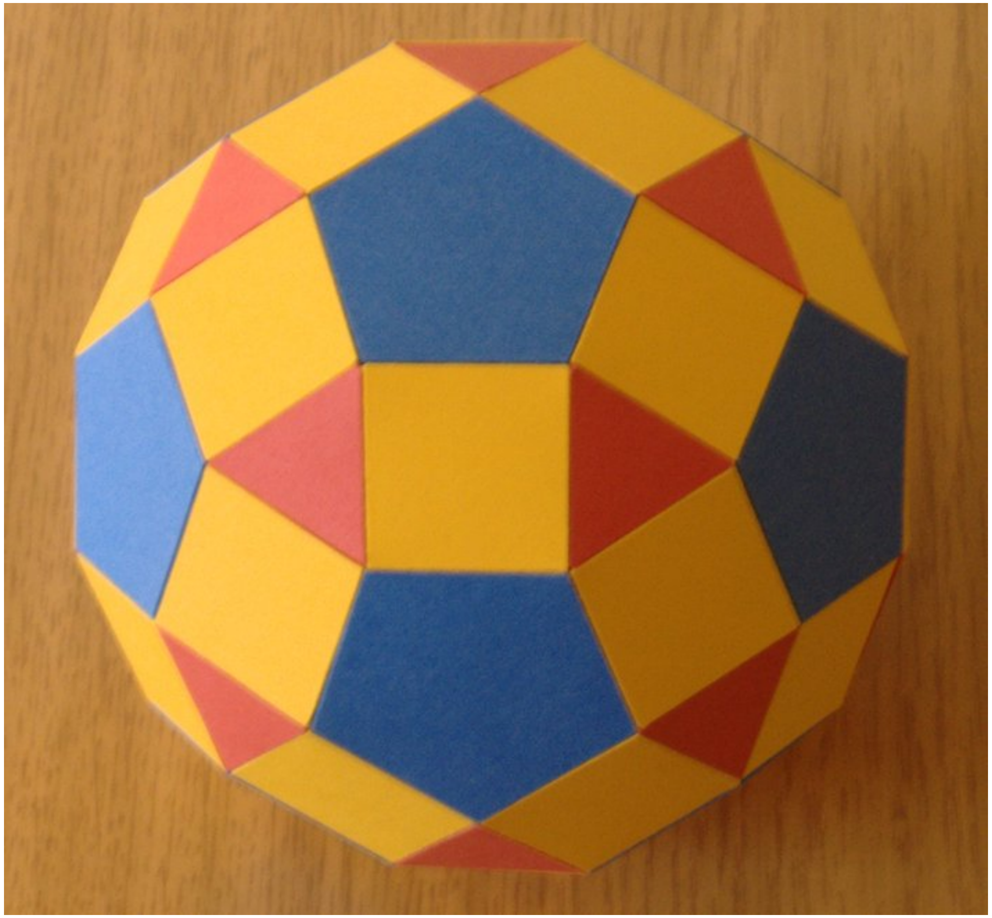
- Curvature

Warps
- Rotate
- Deform

Filters
- Smooth
- Sharpen
- Truncate
- ➢ Bevel



www.srcf.ucam.org

Polygonal Mesh Processing

Remeshing

- Subdivide
- Resample
- Simplify

Topological fixup

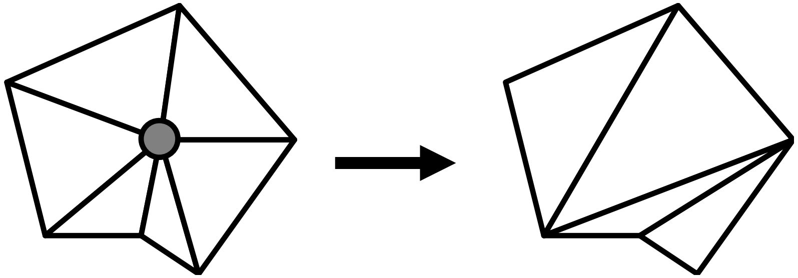
- Fill holes
- Fix self-intersections

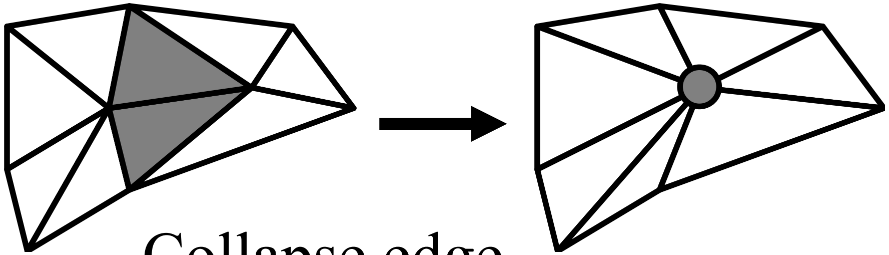
Boolean operations

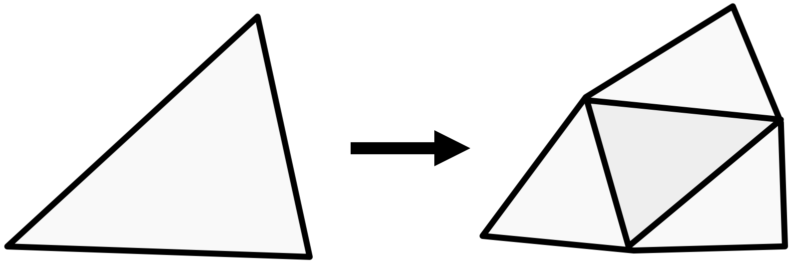
- Crop
- Subtract

Polygonal Mesh Processing

- Remeshing ←
  - Subdivide
  - Resample
  - Simplify
- Topological fixup
  - Fill holes
  - Fix self-intersections
- Boolean operations
  - Crop
  - Subtract


Remove Vertex


Collapse edge


Subdivide face

Polygonal Mesh Processing

Remeshing

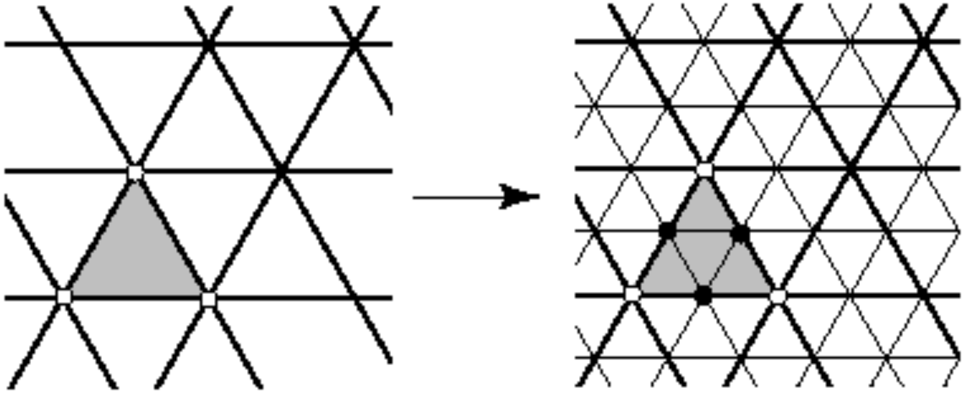
- ➢ Subdivide
- ◦ Resample
- ◦ Simplify

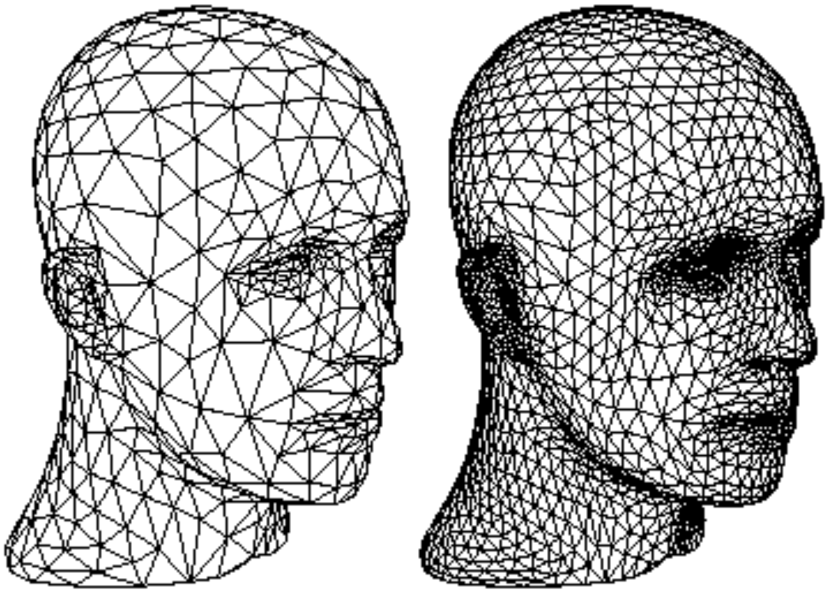
Topological fixup

- ◦ Fill holes
- ◦ Fix self-intersections

Boolean operations

- ◦ Crop
- ◦ Subtract





Zorin & Schroeder

Polygonal Mesh Processing

Remeshing

- ➢ Subdivide
- ○ Resample
- ○ Simplify

Topological fixup

- ○ Fill holes
- ○ Fix self-intersections

Boolean operations

- ○ Crop
- ○ Subtract

Polygonal Mesh Processing

Remeshing

- Subdivide
- Resample
- Simplify

Topological fixup

- Fill holes
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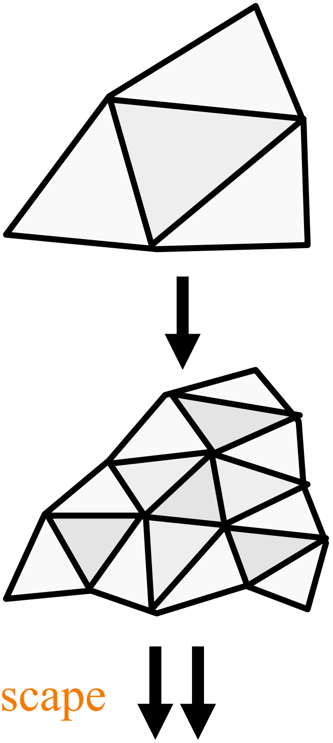
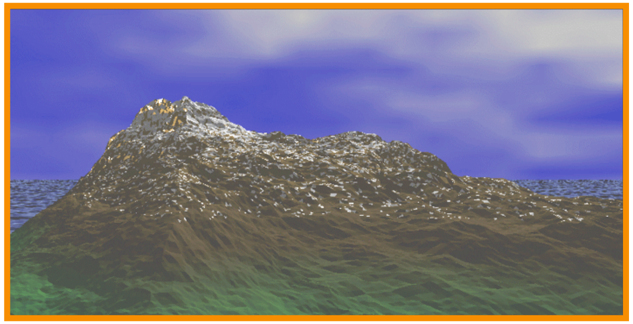


Fractal Landscape



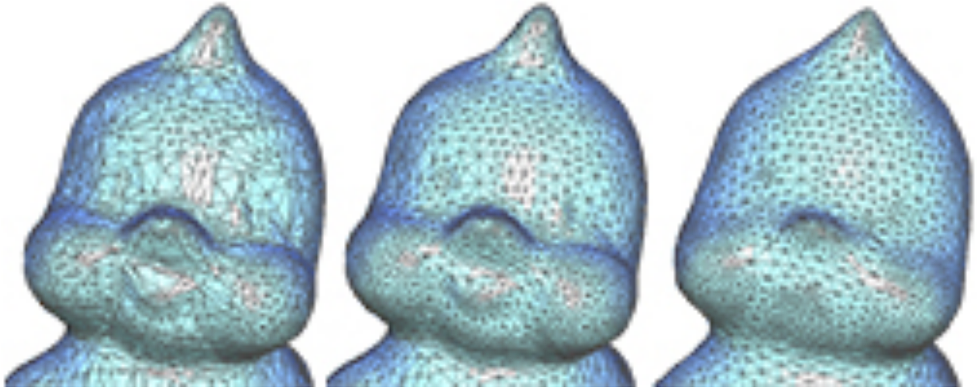
Dirk Balfanz, Igor Guskov, Sanjeev Kumar, & Rudro Samanta,

Polygonal Mesh Processing

Remeshing
- ○ Subdivide
- ➢ Resample
- ○ Simplify

Topological fixup
- ○ Fill holes
- ○ Fix self-intersections

Boolean operations
- ○ Crop
- ○ Subtract



Original

Resampled

- more uniform distribution
- triangles with nicer aspect

Sorkine

Polygonal Mesh Processing

Remeshing
- Subdivide
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- ➢ Simplify

Topological fixup
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Boolean operations
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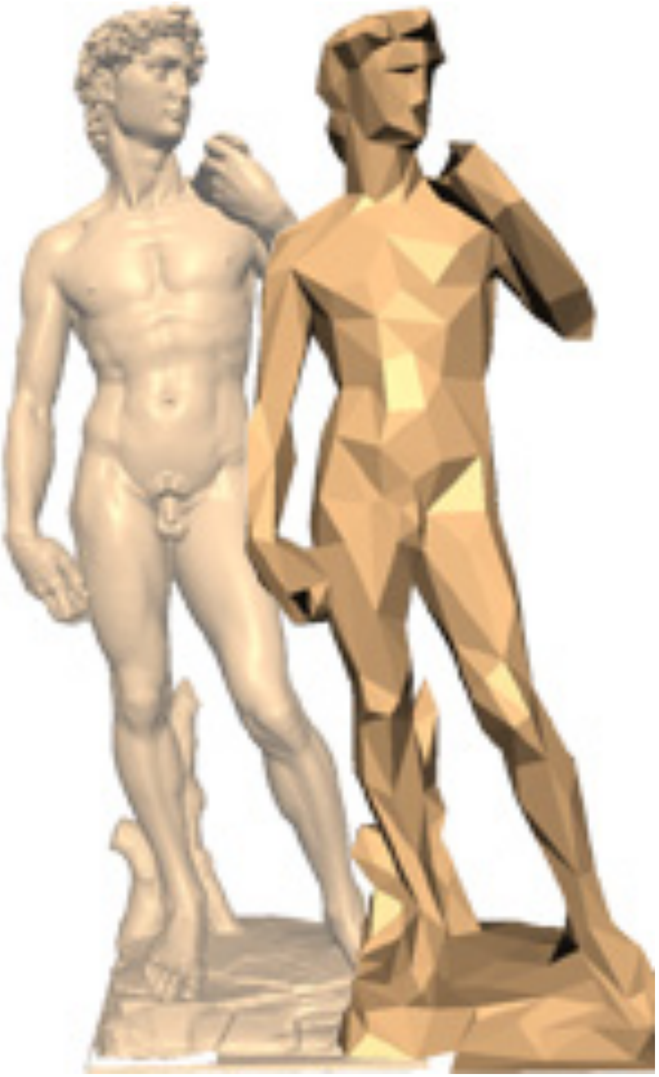

Garland

Polygonal Mesh Processing

Remeshing

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- Resample
- Simplify

Topological fixup ←

- Fill holes
- Fix self-intersections

Boolean operations

- Crop
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Polygonal Mesh Processing

- Remeshing
  - Subdivide
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  - ➢ Fill holes
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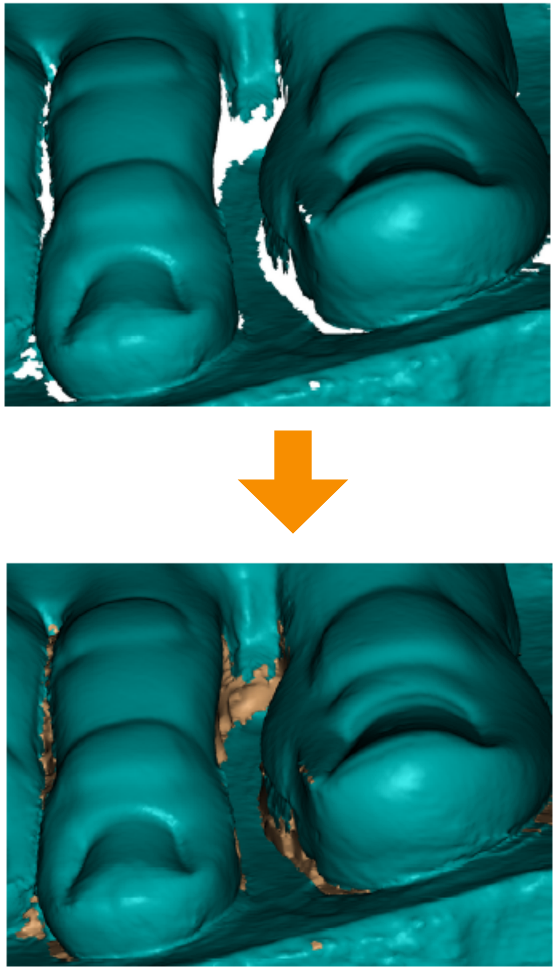

Podolak

Polygonal Mesh Processing

Remeshing

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Topological fixup

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Boolean operations

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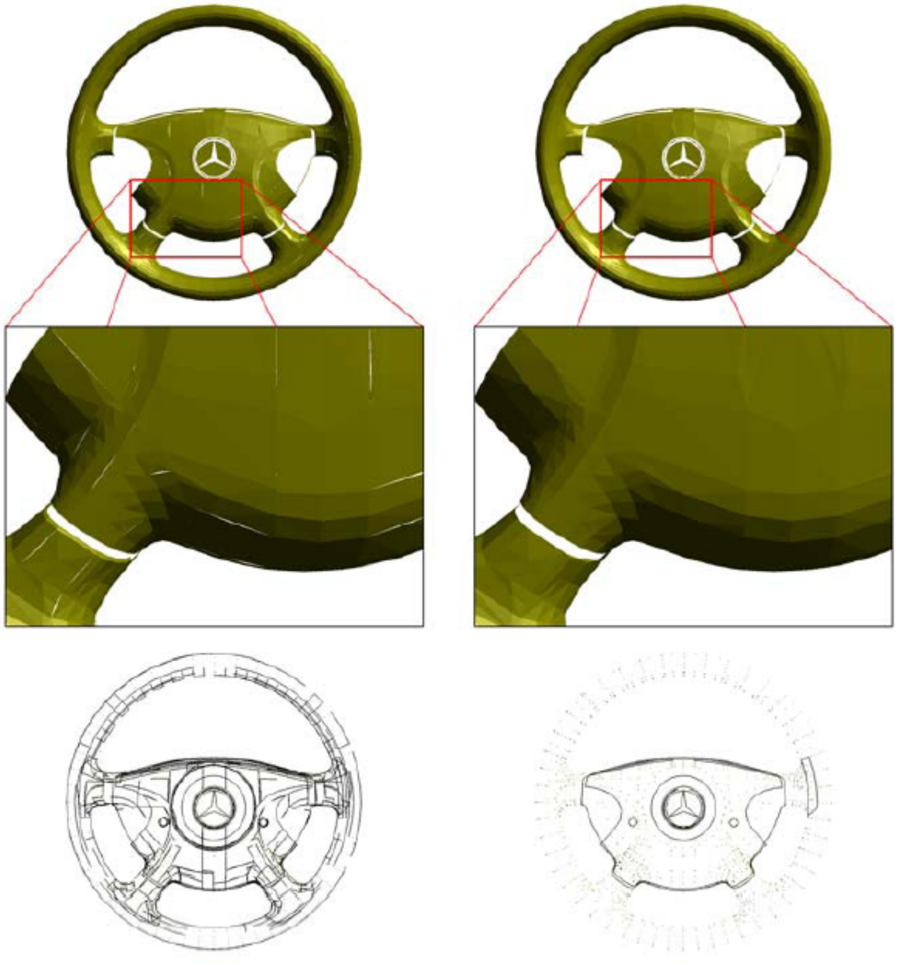

Borodin

Polygonal Mesh Processing

- Remeshing
    - Subdivide
    - Resample
    - Simplify
- Topological fixup
    - Fill holes
    - Fix self-intersections
- Boolean operations ←
    - Crop
    - Subtract

Polygonal Mesh Processing

- Remeshing
  - Subdivide
  - Resample
  - Simplify
- Topological fixup
  - Fill holes
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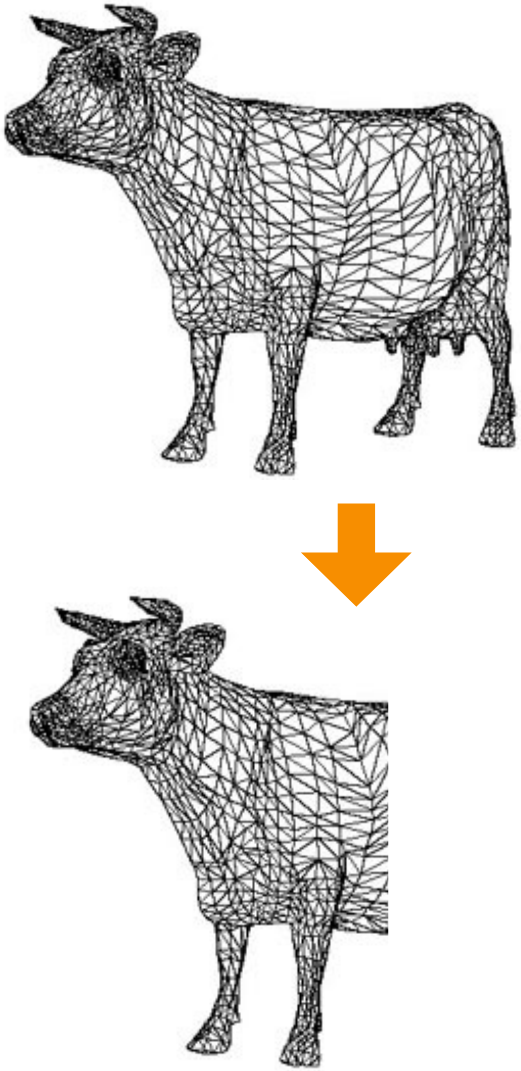
  - Subtract



Polygonal Mesh Processing

Remeshing

- Subdivide
- Resample
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Topological fixup

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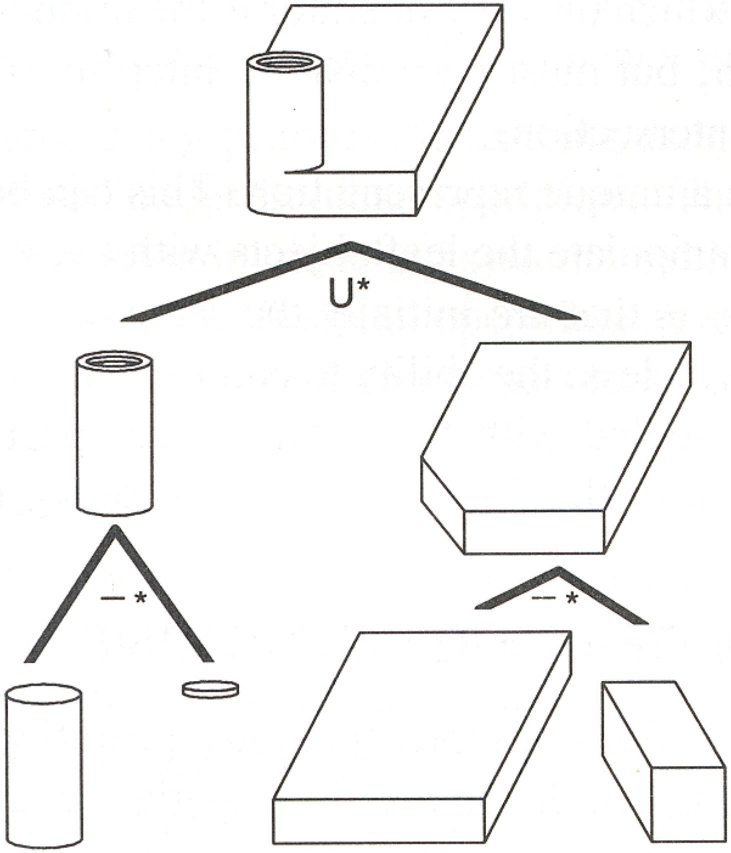
- ➢ Subtract



FvDFH Figure 12.27

Outline

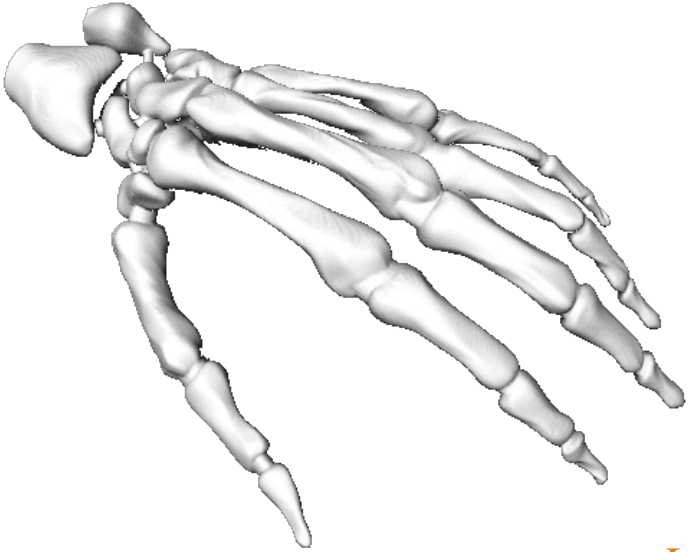
Acquisition

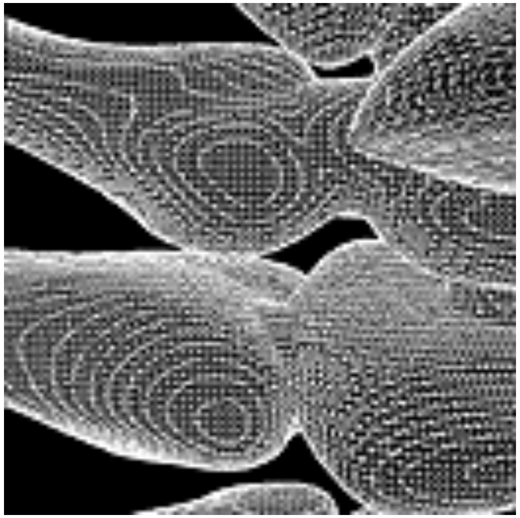
Processing

Representation ←

Polygon Mesh Representation

Important properties of mesh representation?



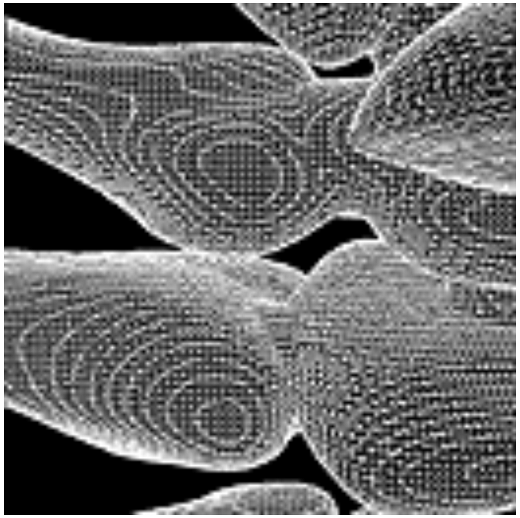


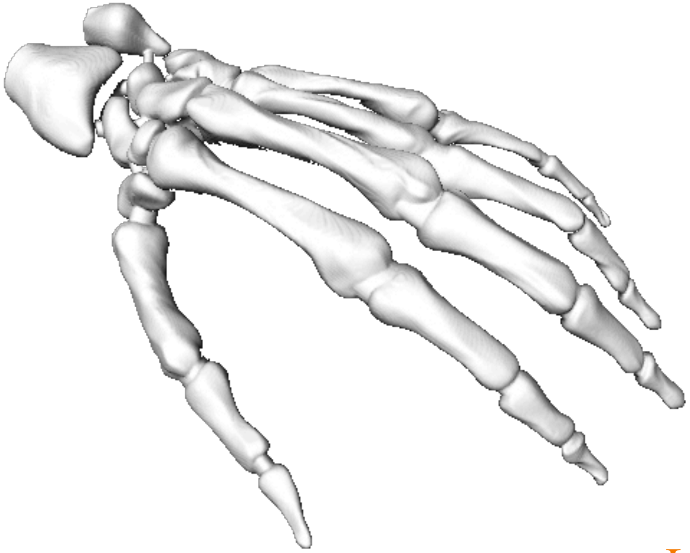
Large Geometric Model Repository
Georgia Tech

Polygon Mesh Representation

Important properties of mesh representation?

- Efficient traversal of topology
- Efficient use of memory
- Efficient updates



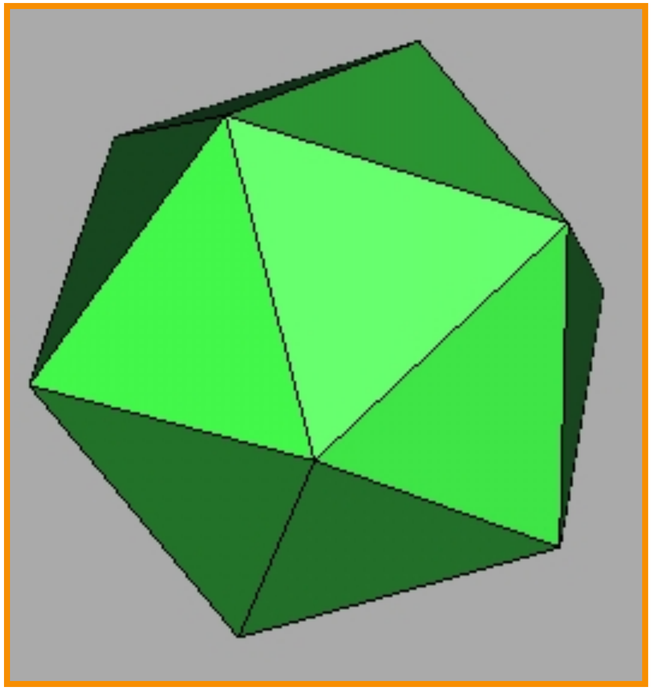


Large Geometric Model Repository
Georgia Tech

Polygon Mesh Representation

Possible data structures

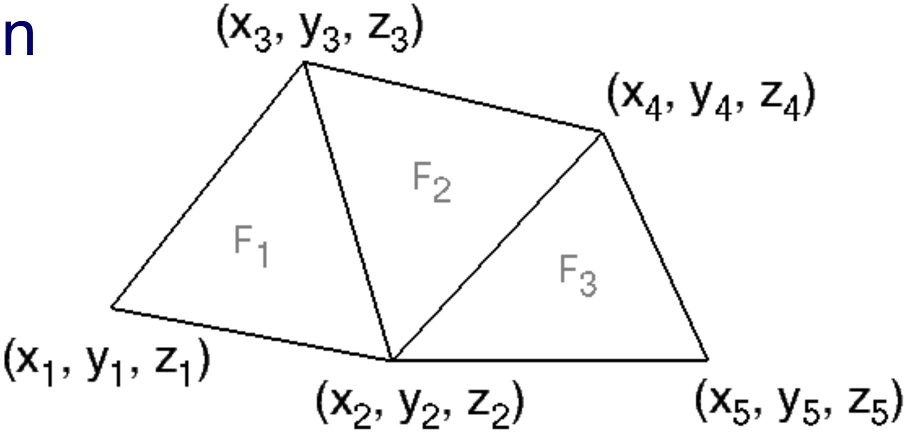
- List of independent faces
- Vertex and face tables
- Adjacency lists
- Winged edge
- Half edge
- etc.

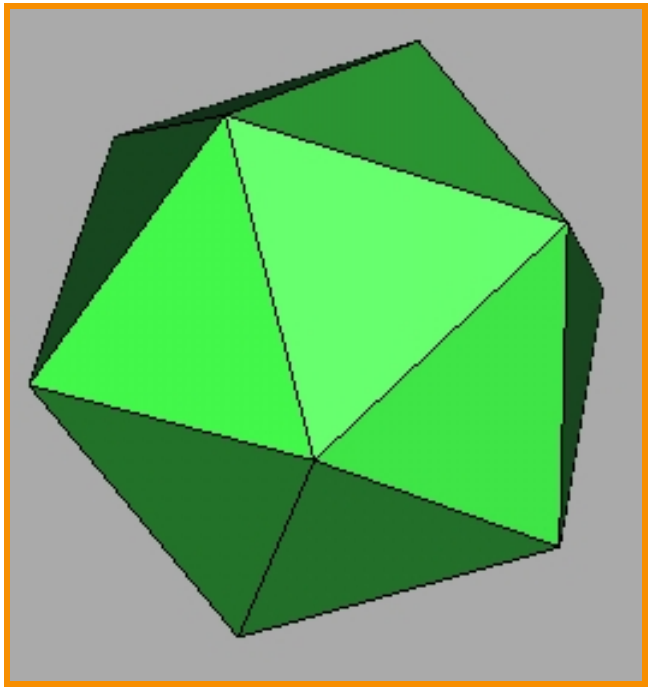


Independent Faces

Each face lists vertex coordinates

- Redundant vertices
- No adjacency information



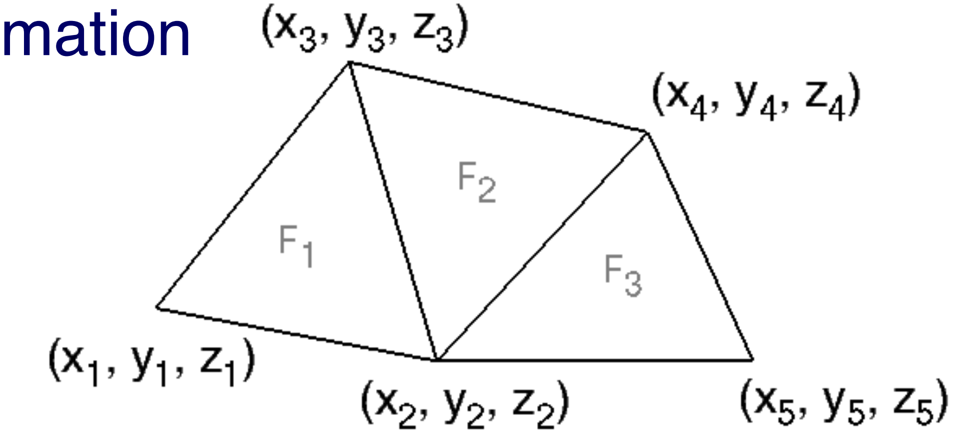


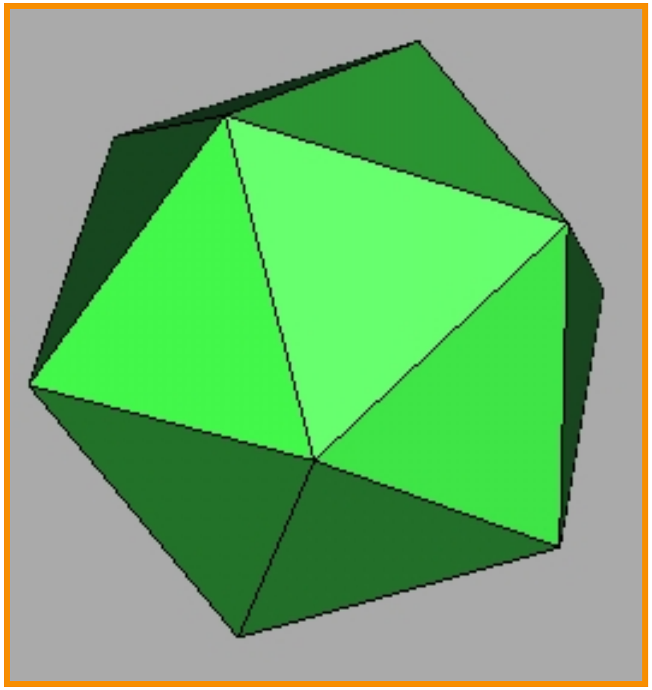
FACE TABLE	
F_1	(x_1, y_1, z_1) (x_2, y_2, z_2) (x_3, y_3, z_3)
F_2	(x_2, y_2, z_2) (x_4, y_4, z_4) (x_3, y_3, z_3)
F_3	(x_2, y_2, z_2) (x_5, y_5, z_5) (x_4, y_4, z_4)

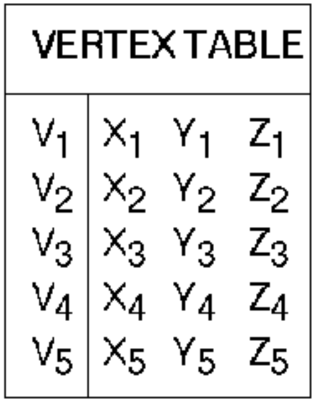
Vertex and Face Tables

Each face lists vertex references

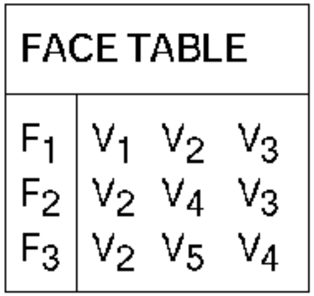
- Shared vertices
- Still no adjacency information







VERTEX TABLE			
V_1	X_1	Y_1	Z_1
V_2	X_2	Y_2	Z_2
V_3	X_3	Y_3	Z_3
V_4	X_4	Y_4	Z_4
V_5	X_5	Y_5	Z_5

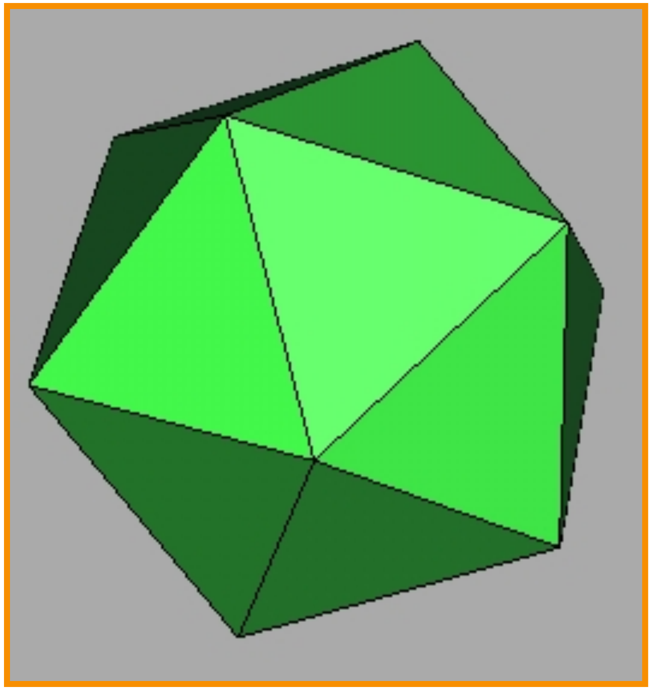


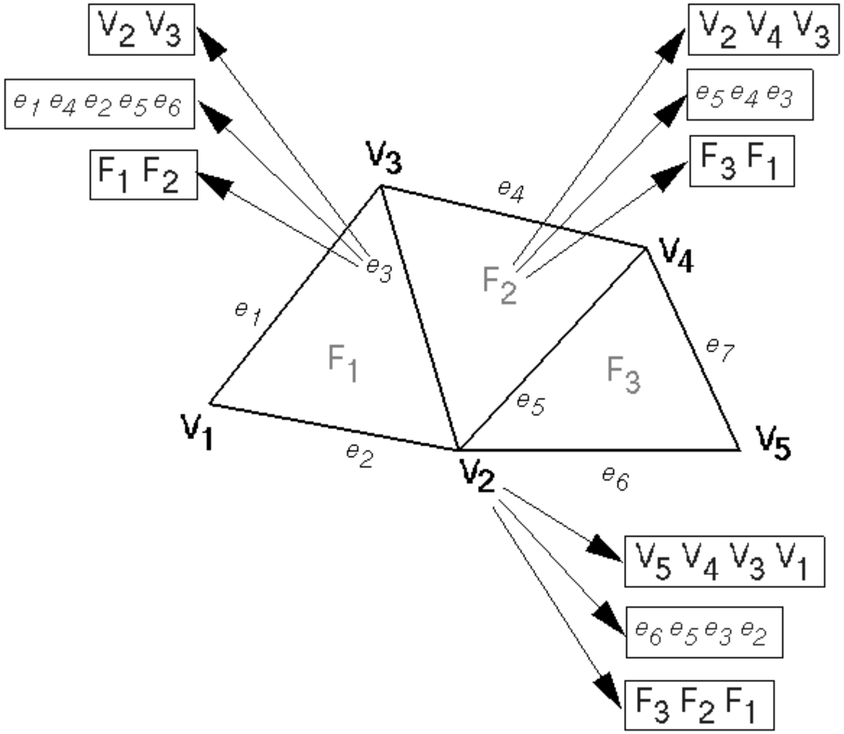
FACE TABLE			
F_1	V_1	V_2	V_3
F_2	V_2	V_4	V_3
F_3	V_2	V_5	V_4

Adjacency Lists

Store all vertex, edge, and face adjacencies

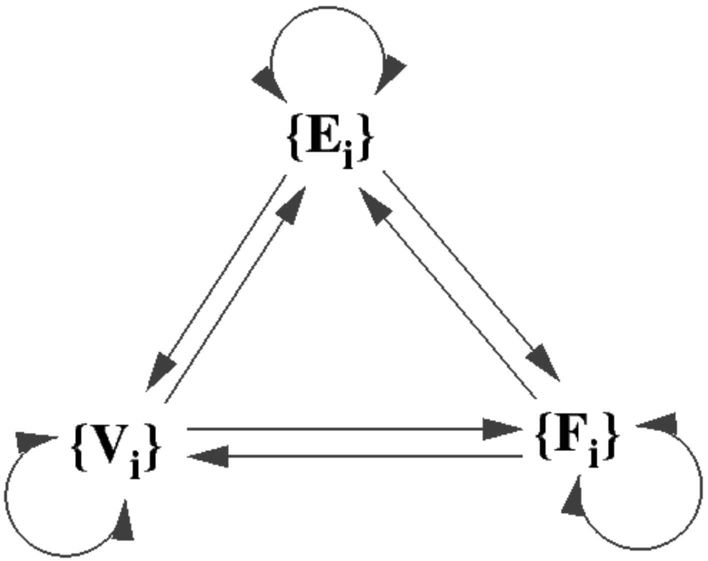
- Efficient adjacency traversal
- Extra storage

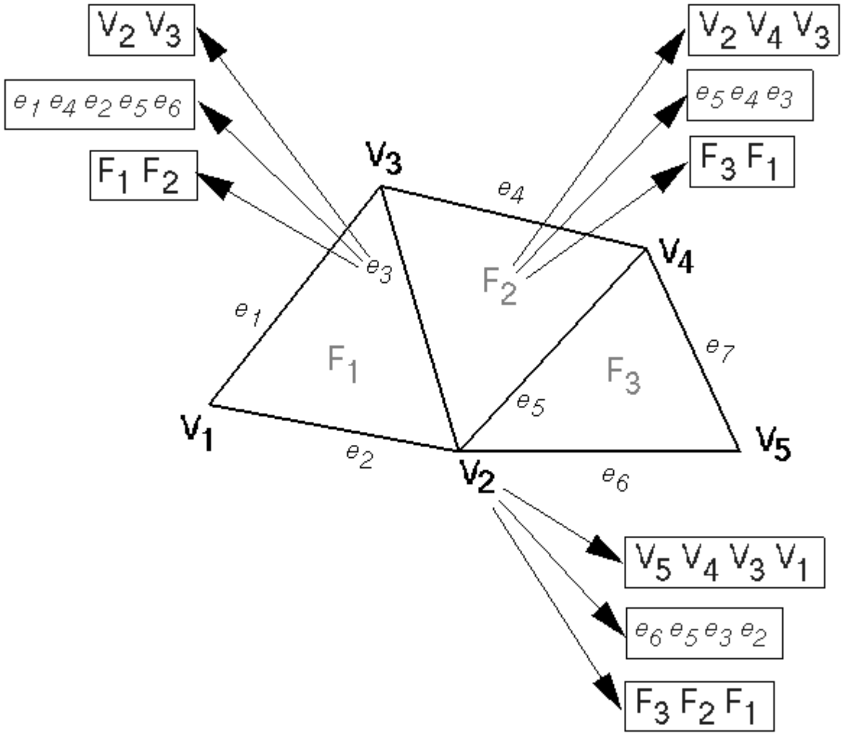




Partial Adjacency Lists

Can we store only some adjacency relationships and derive others?

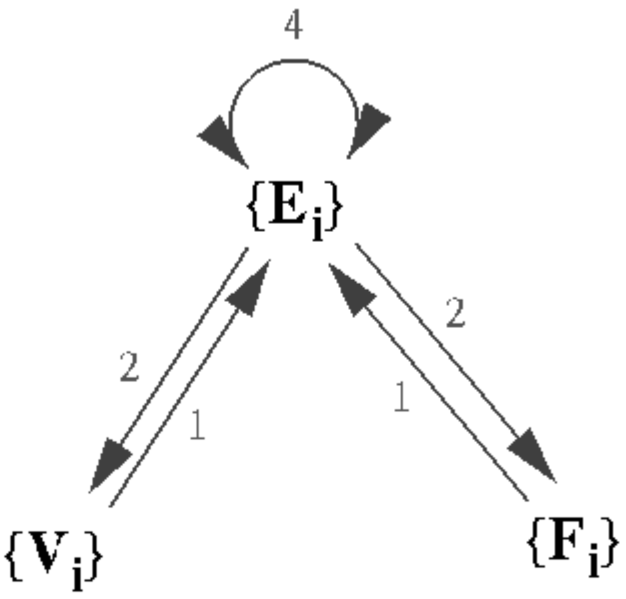


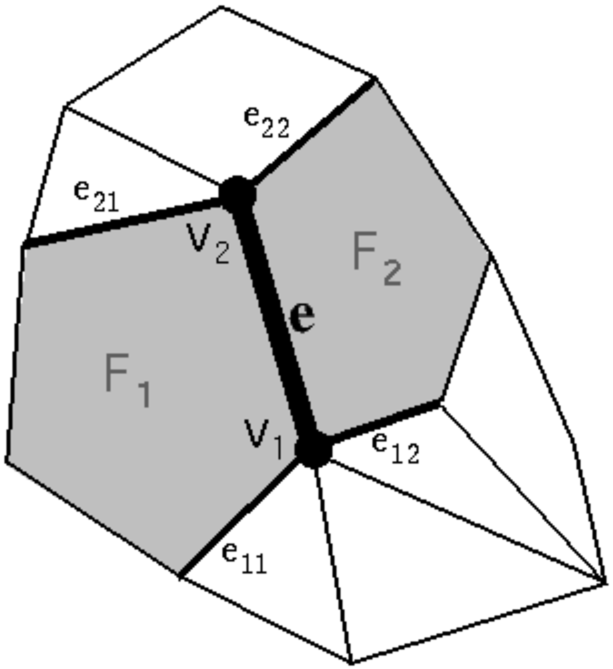


Winged Edge

Adjacency encoded in edges

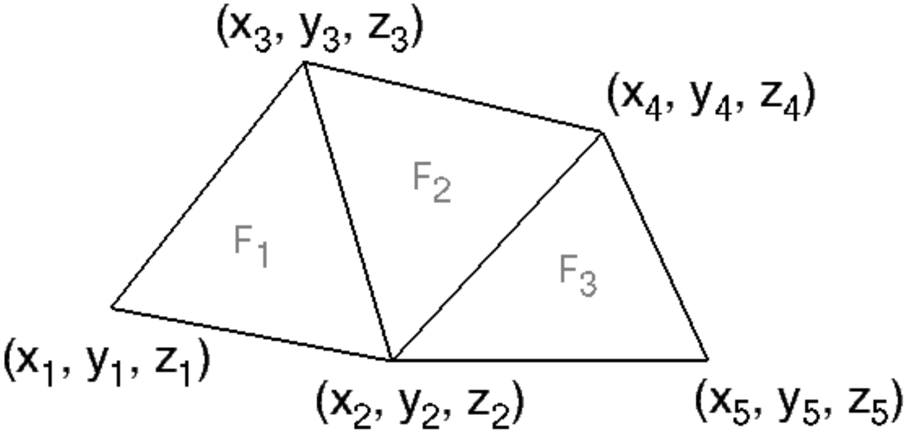
- All adjacencies in O(1) time
- Little extra storage (fixed records)
- Arbitrary polygons

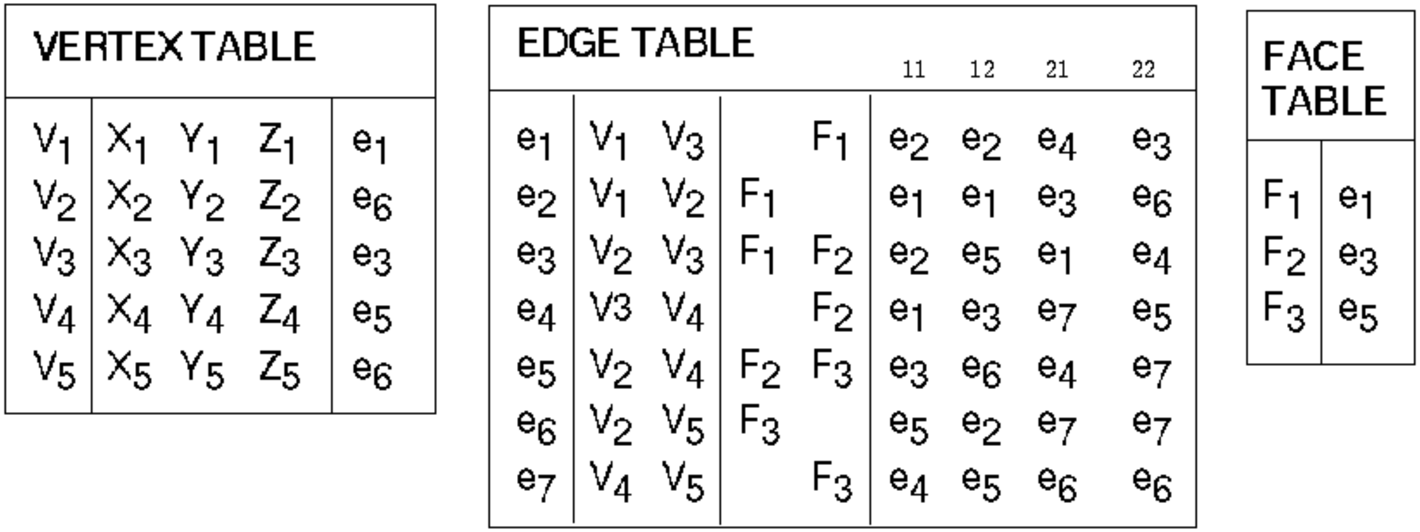




Winged Edge

Example:





VERTEX TABLE				
V_1	X_1	Y_1	Z_1	e_1
V_2	X_2	Y_2	Z_2	e_6
V_3	X_3	Y_3	Z_3	e_3
V_4	X_4	Y_4	Z_4	e_5
V_5	X_5	Y_5	Z_5	e_6

EDGE TABLE					11	12	21	22
e_1	V_1	V_3		F_1	e_2	e_2	e_4	e_3
e_2	V_1	V_2	F_1		e_1	e_1	e_3	e_6
e_3	V_2	V_3	F_1	F_2	e_2	e_5	e_1	e_4
e_4	$V3$	V_4		F_2	e_1	e_3	e_7	e_5
e_5	V_2	V_4	F_2	F_3	e_3	e_6	e_4	e_7
e_6	V_2	V_5	F_3		e_5	e_2	e_7	e_7
e_7	V_4	V_5		F_3	e_4	e_5	e_6	e_6

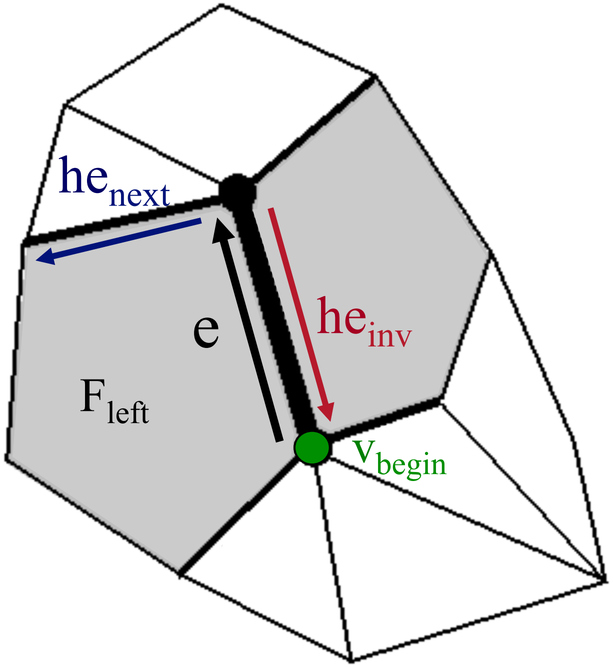
FACE TABLE	
F_1	e_1
F_2	e_3
F_3	e_5

Half Edge

Adjacency encoded in edges

- All adjacencies in O(1) time
- Little extra storage (fixed records)
- Arbitrary polygons

Similar to winged-edge, except adjacency encoded in half-edges



Summary

Polygonal meshes

- Most common surface representation
- Fast rendering

Processing operations

- Must consider irregular vertex sampling
- Must handle/avoid topological degeneracies

Representation

- Which adjacency relationships to store depend on which operations must be efficient

3D Polygonal Meshes

Properties

? Efficient display

? Easy acquisition

? Accurate

? Concise

? Intuitive editing

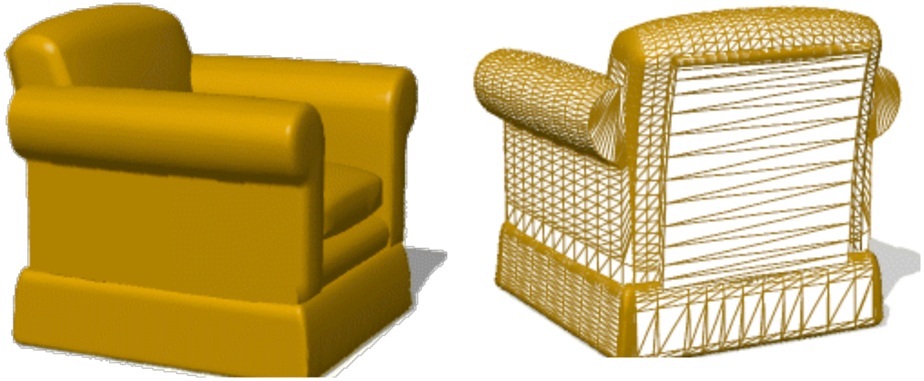
? Efficient editing

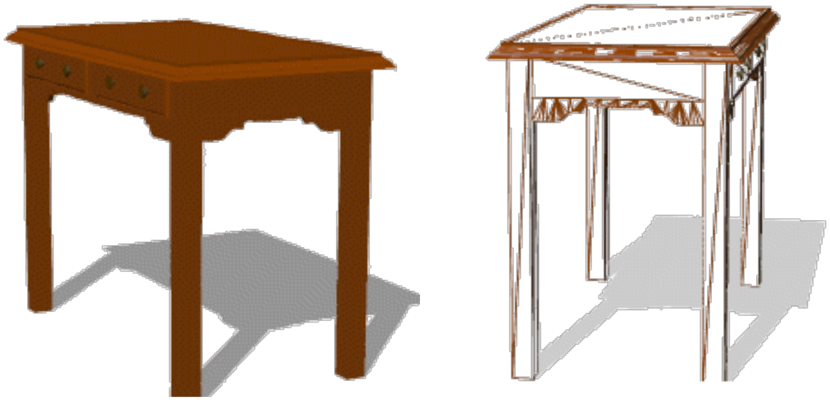
? Efficient intersections

? Guaranteed validity

? Guaranteed smoothness

? etc.



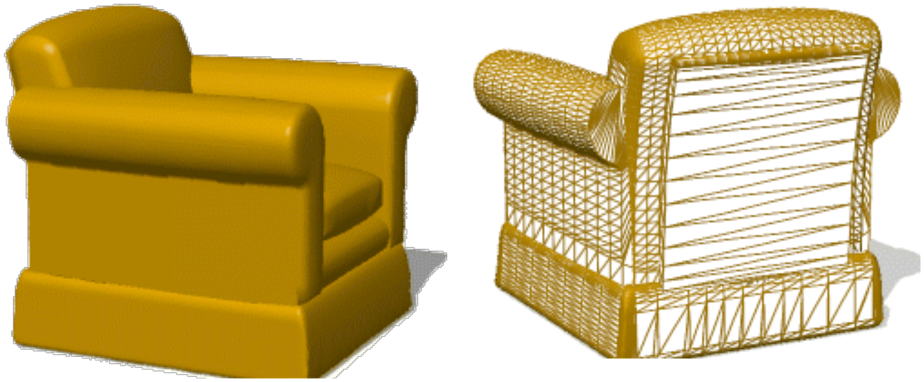


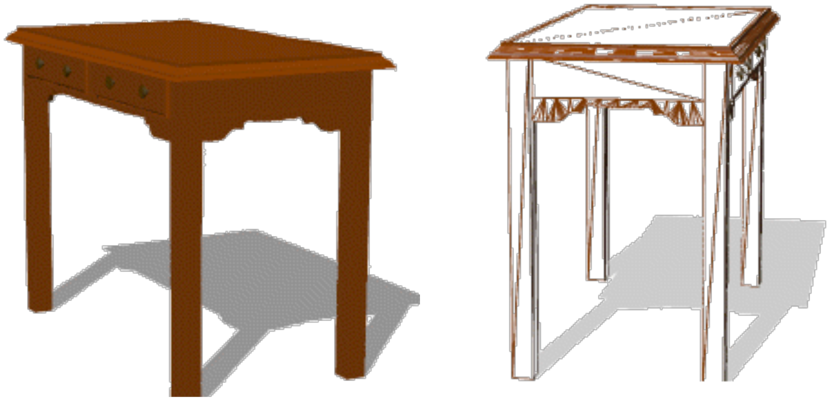
Viewpoint

3D Polygonal Meshes

Properties

- ☺ Efficient display
- ☺ Easy acquisition
- ☹ Accurate
- ☹ Concise
- ☹ Intuitive editing
- ☹ Efficient editing
- ☹ Efficient intersections
- ☹ Guaranteed validity
- ☹ Guaranteed smoothness





Viewpoint