Polygonal Meshes

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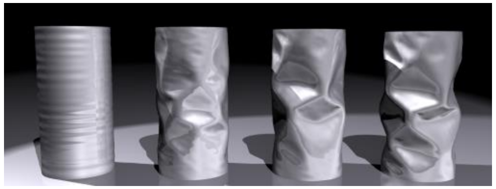
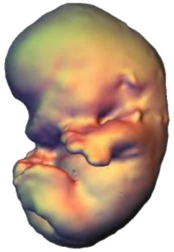
COS 526, Fall 2014

Digital Geometry Processing

Processing of 3D surfaces

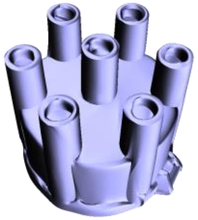
- Creation, acquisition
- Storage, transmission
- Editing, animation, simulation
- Manufacture





Applications

- Movies, games
- Computer-aided design
- Medicine, biology
- Art, history

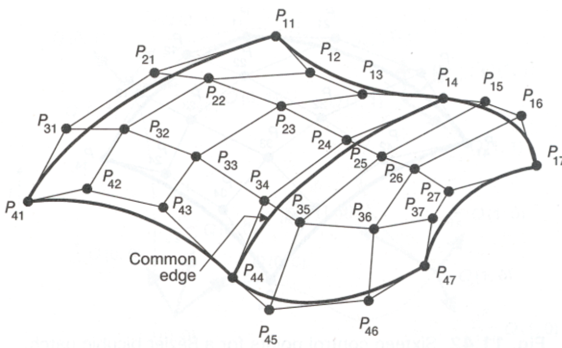


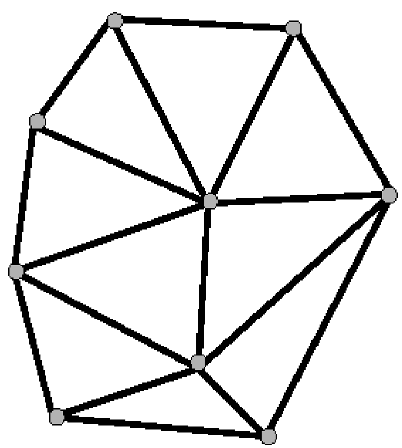
Sweldens

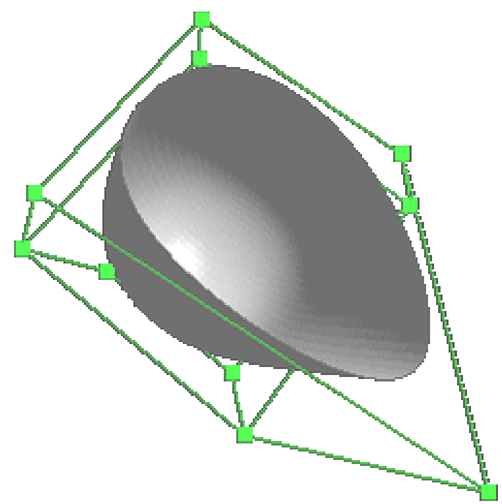
Digital Geometry Processing

Many possible surface representations

- Polygonal meshes
- Parametric surfaces
- Subdivision surfaces
- Implicit surfaces
- etc.



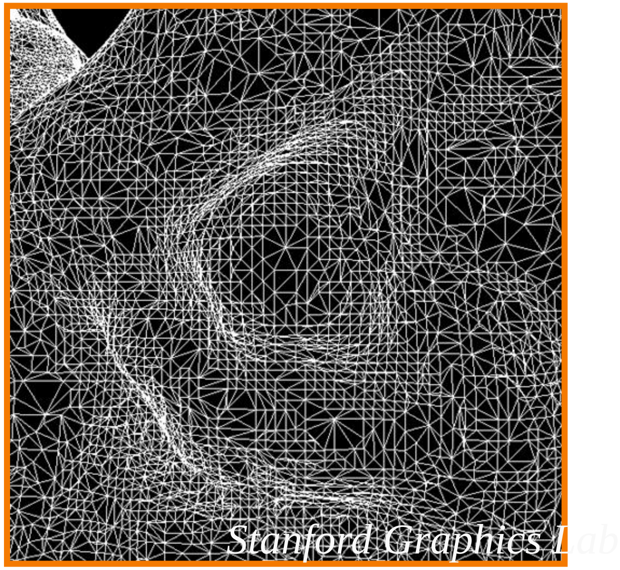




Digital Geometry Processing

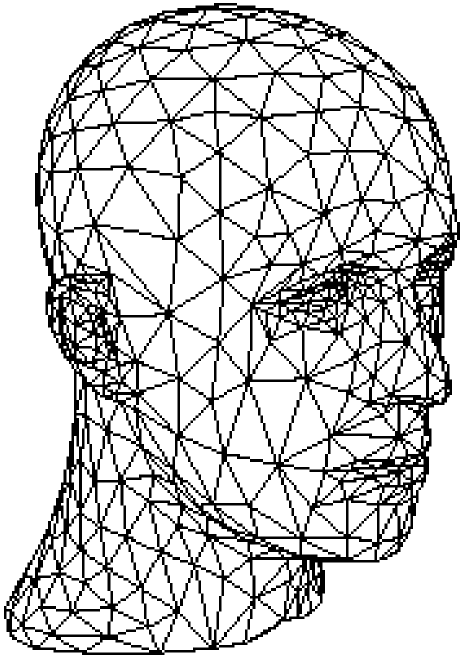
Let’s focus on 3D polygonal meshes

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



3D Polygonal Meshes

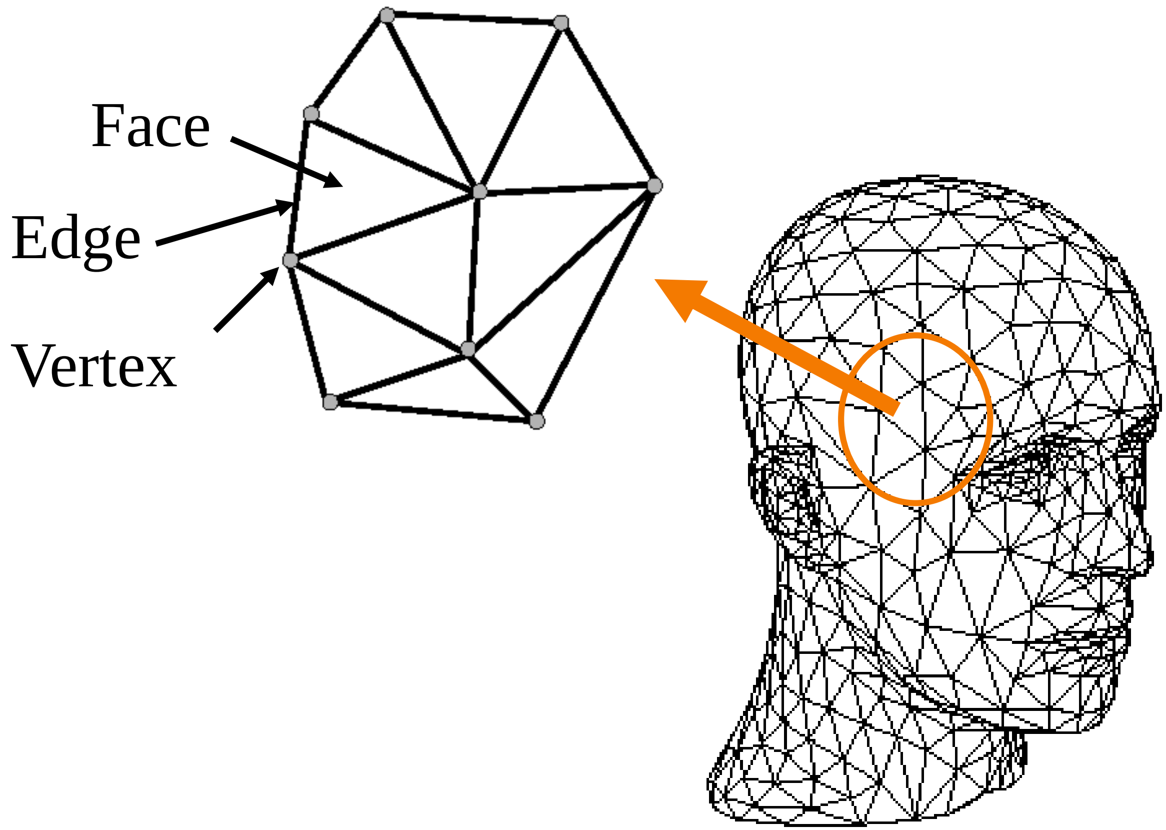
Set of polygonal faces representing a 2D surface embedded in 3D



Zorin & Schroeder, SIGGRAPH 99, Course Notes

3D Polygonal Meshes

Set of polygonal faces representing a 2D surface embedded in 3D



Zorin & Schroeder, SIGGRAPH 99, Course Notes

Outline

Acquisition

Processing

Representation

Outline

Acquisition ←

Processing

Representation

Polygonal Mesh Acquisition

- Interactive modeling
  - Polygon editors
  - Interchange formats
- Scanners
  - Laser range scanners
  - CAT, MRI, etc. (isosurfaces)
- Simulations
  - Physical processes

Polygonal Mesh Acquisition

Interactive modeling
- ➢ Polygon editors
- Interchange formats

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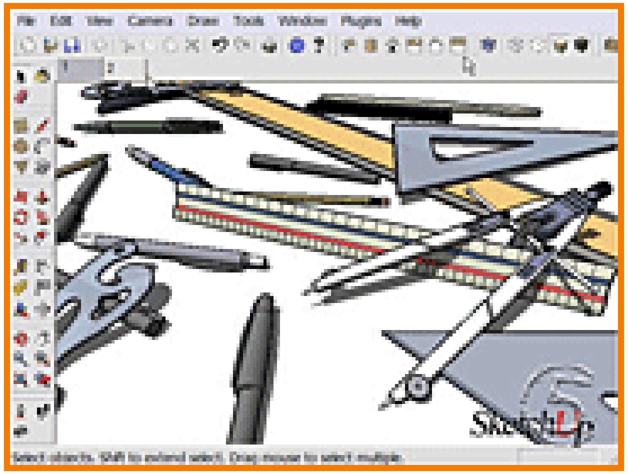
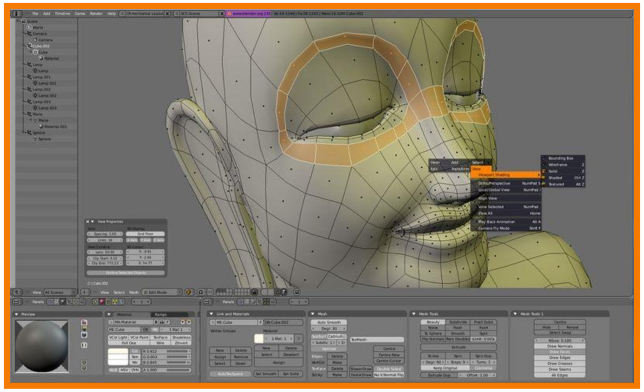
- CAT, MRI, etc. (isosurfaces)

Simulations
- Physical processes



Sketchup



Blender

Polygonal Mesh Acquisition

Interactive modeling
- Polygon editors
- Interchange formats

Scanners
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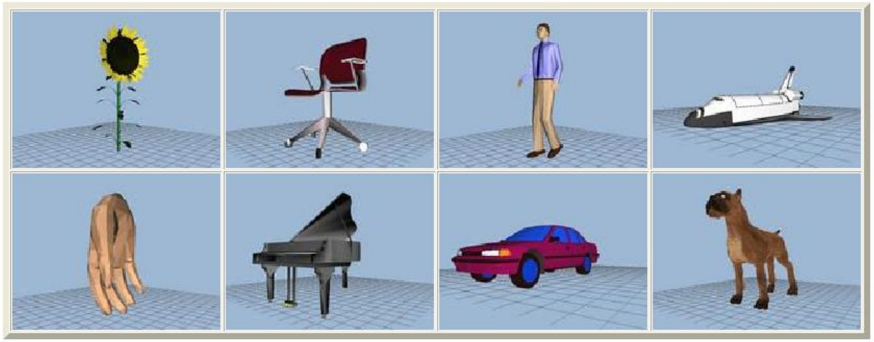
Simulations
- Physical processes



Princeton Shape Benchmark

Polygonal Mesh Acquisition

Interactive modeling
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Scanners
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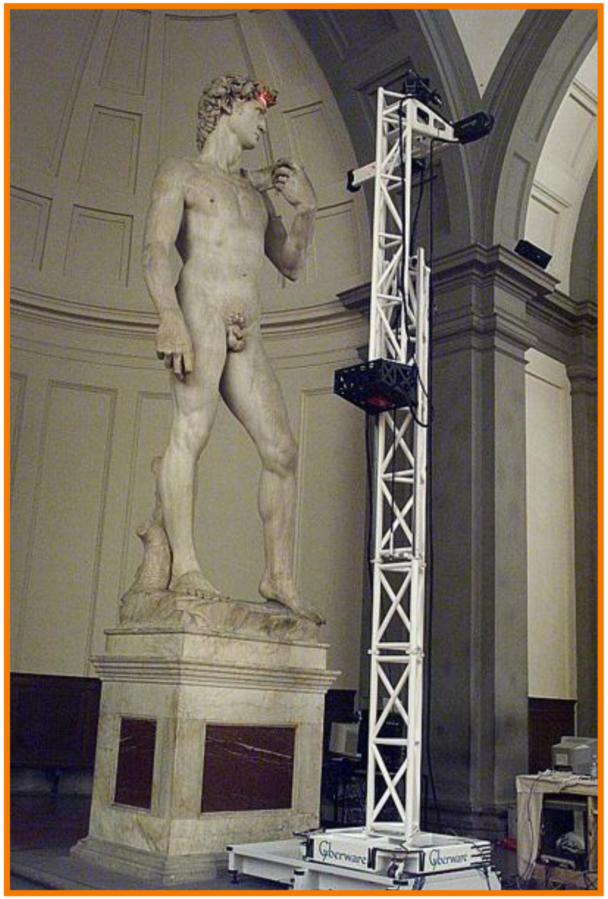
Simulations
- Physical processes



Digital Michelangelo Project
Stanford

Polygonal Mesh Acquisition

Interactive modeling

- Polygon editors
- Interchange formats

Scanners

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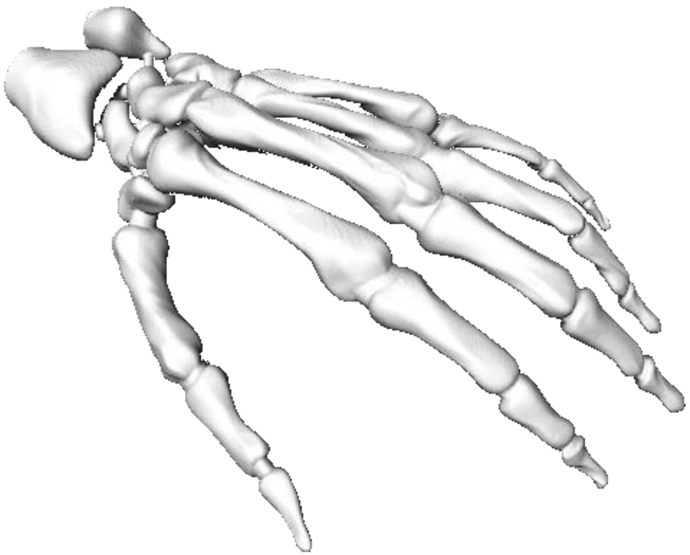
Simulations

- Physical processes



Large Geometric Model Repository
Georgia Tech

Polygonal Mesh Acquisition

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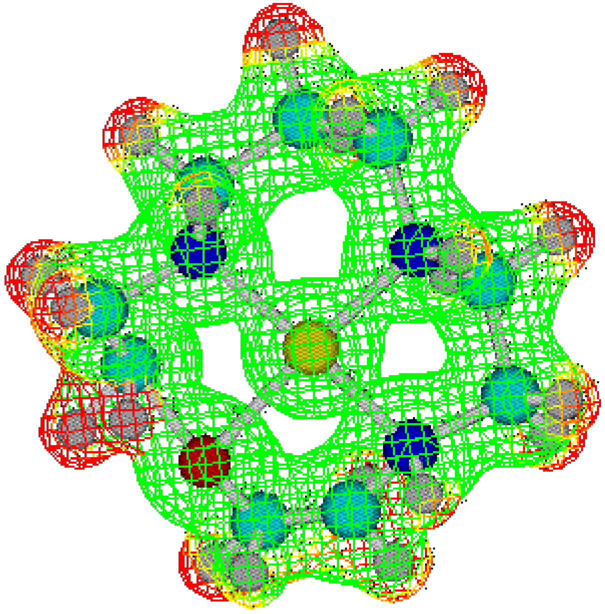

MIT

Outline

Acquisition

Processing ←

Representation

Polygonal Mesh Processing

Storage
- Compression
- Transmission

Analysis
- Parameterization
- Differential geometry
- Feature detection
- Segmentation

Editing
- Smoothing, sharpening, etc.
- Deformation
- Completion

Polygonal Mesh Processing

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Lossy Compression (Simplification)

Garland

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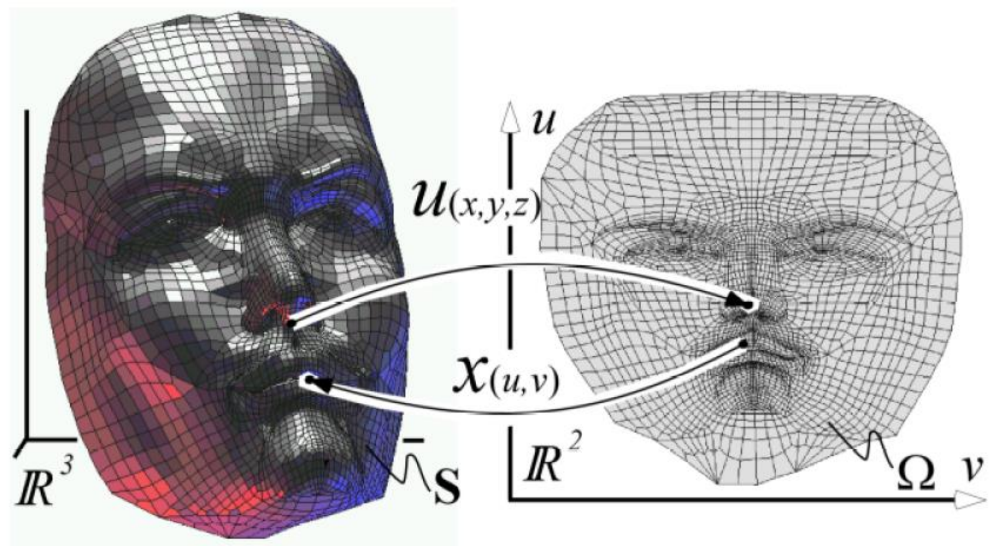

Editing
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Sheffer

Polygonal Mesh Processing

- Storage
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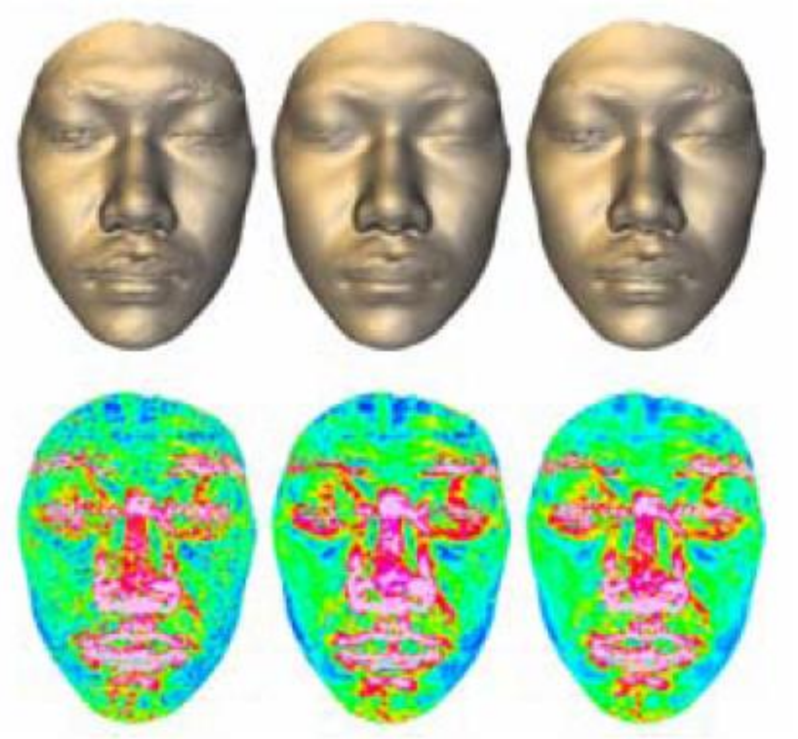

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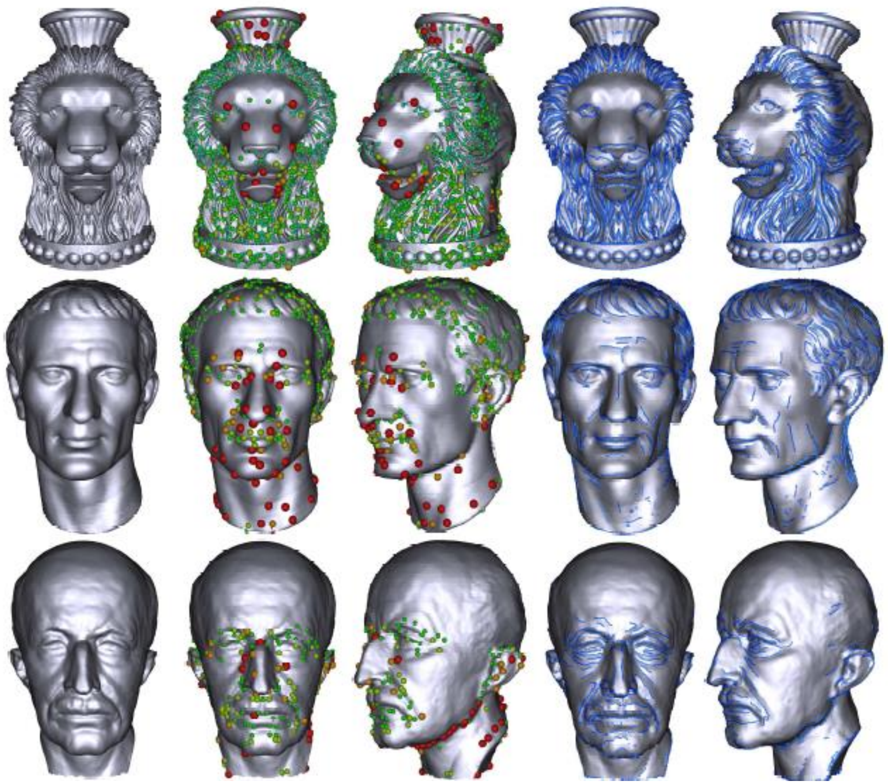

Novatnek et al.

Polygonal Mesh Processing

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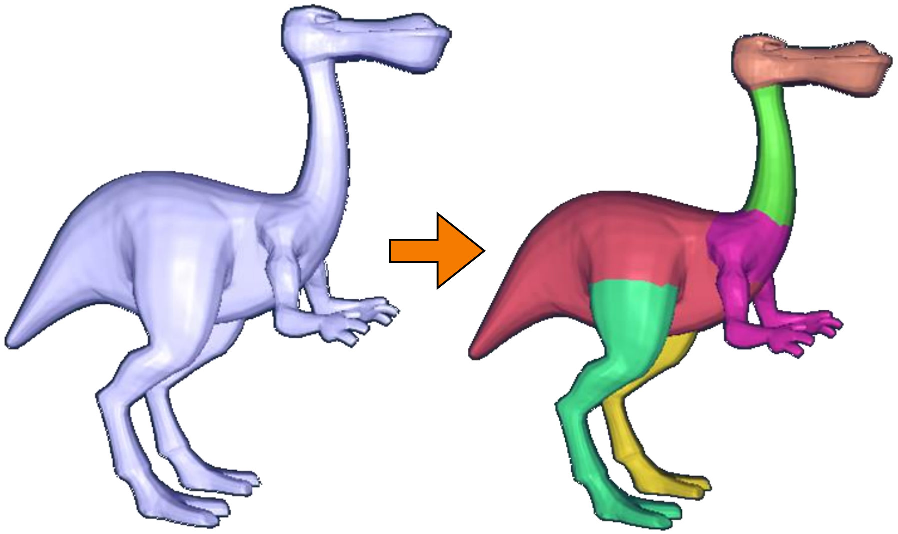

Katz & Tal

Polygonal Mesh Processing

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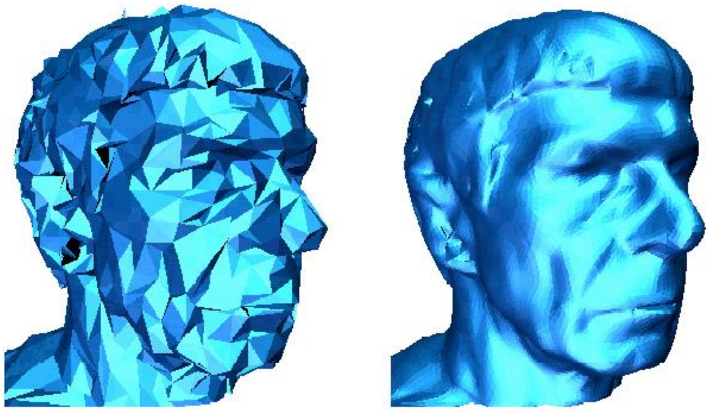
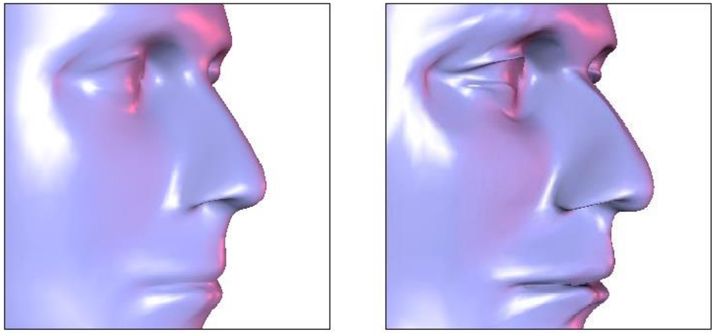


Smoothing



Sharpening

Desbrun

Polygonal Mesh Processing

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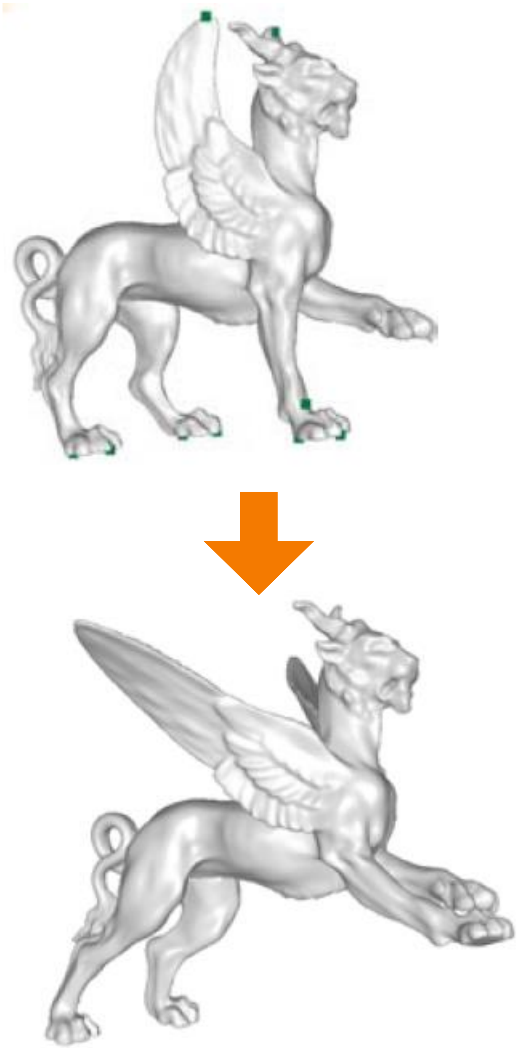

Sheffer

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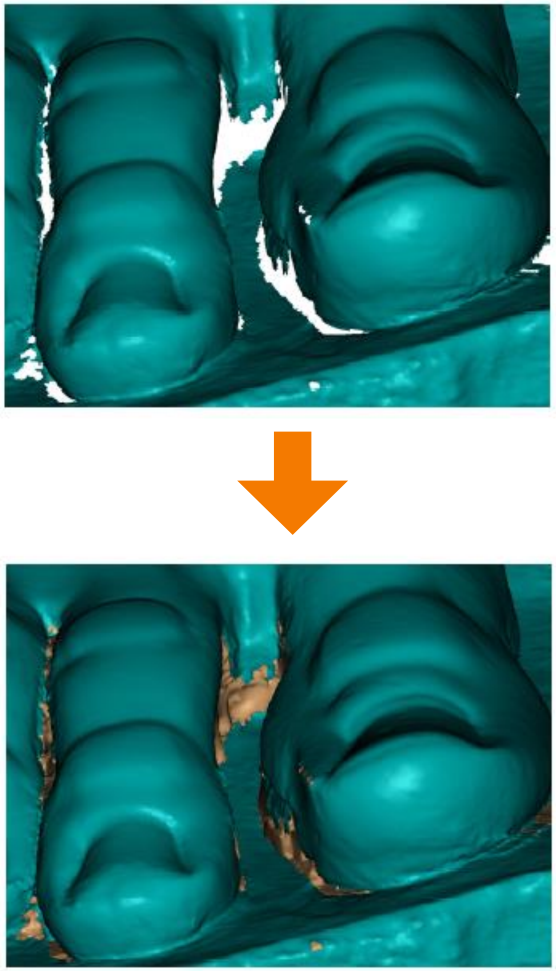

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Outline

Acquisition

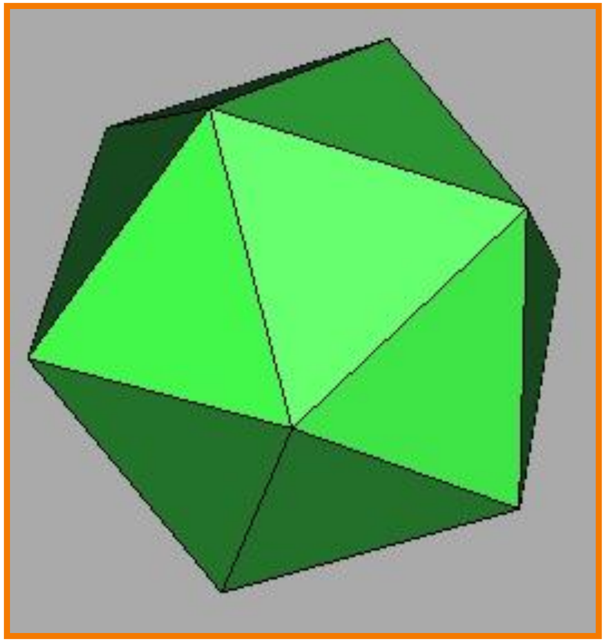
Processing

Representation ←

Polygon Mesh Representation

Data structures determine algorithms

- Data structure must support key operations of algorithm efficiently



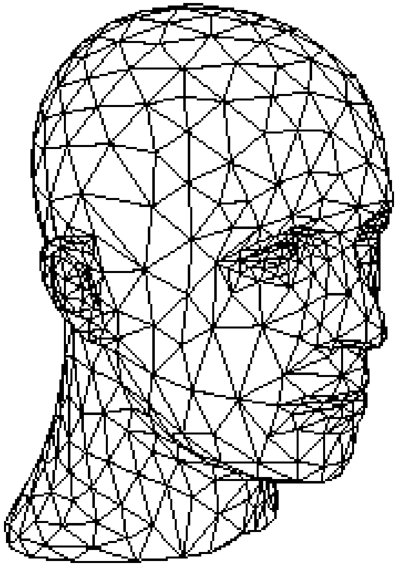
Examples:

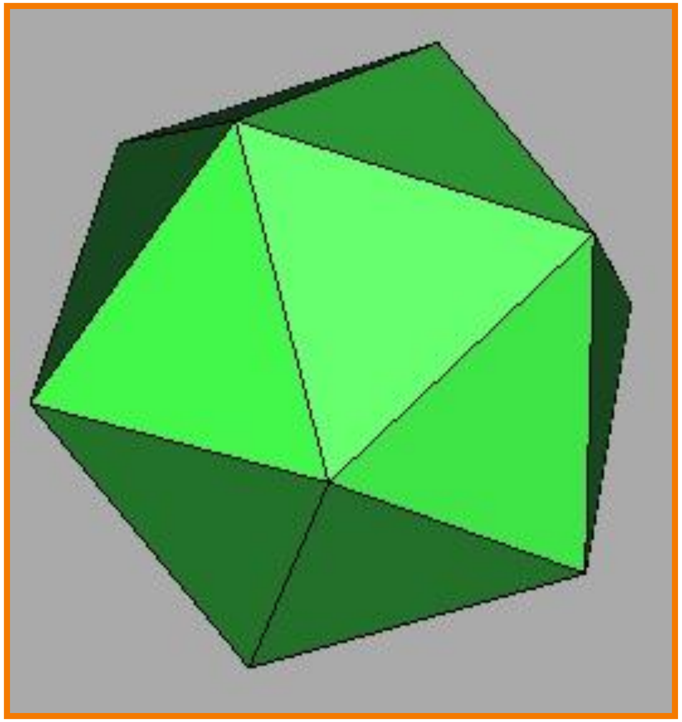
- Drawing a mesh
- Removing a vertex
- Computing per-vertex normals

Different data structures for different algorithms

Polygon Mesh Representation

Important properties of mesh representation?

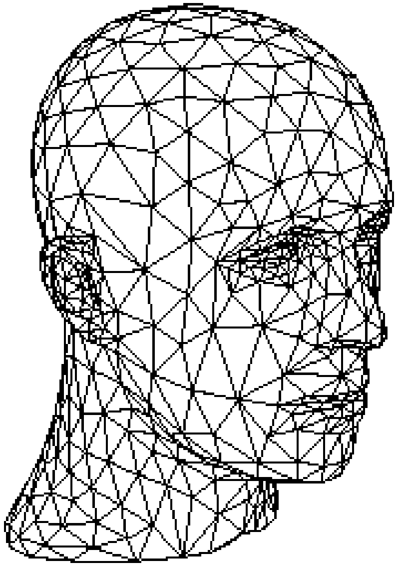


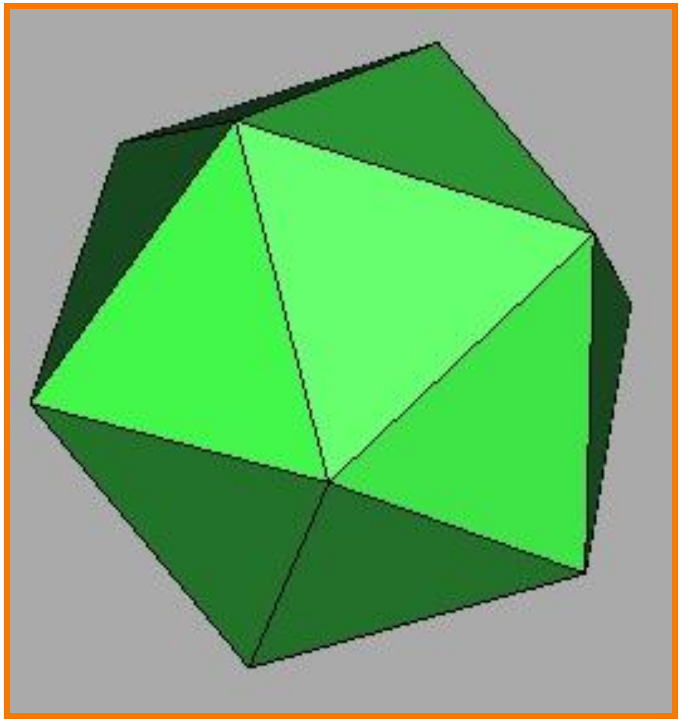


Polygon Mesh Representation

Important properties of mesh representation?

- Efficient traversal of topology
- Efficient use of memory

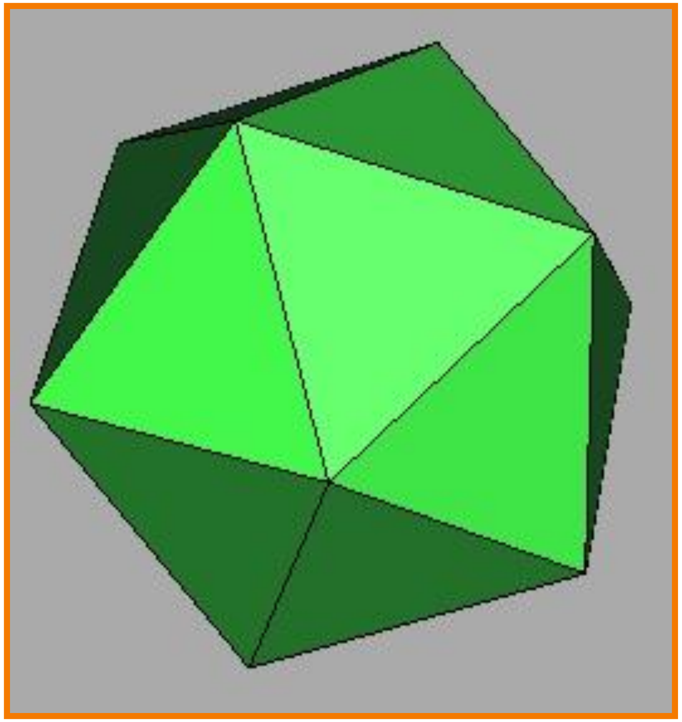




Polygon Mesh Representation

Possible data structures

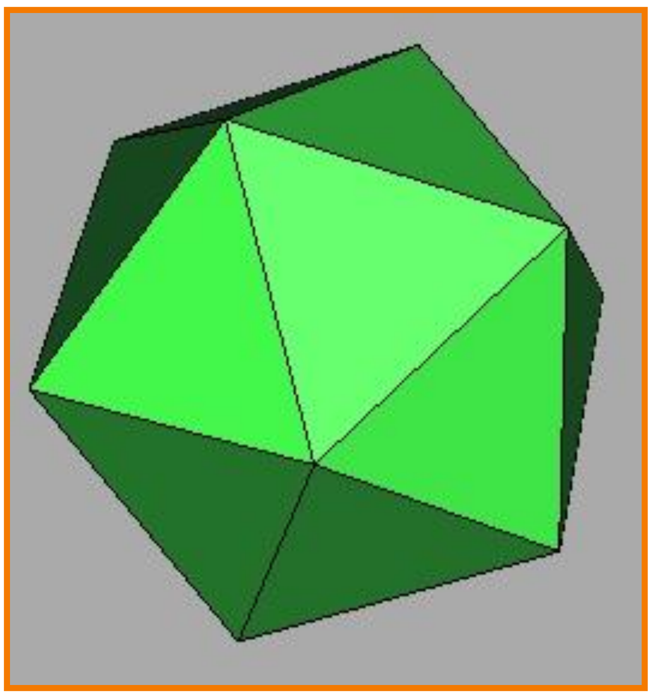
- List of independent faces
- Vertex and face tables
- Adjacency lists
- Winged edge
- Half edge
- etc.

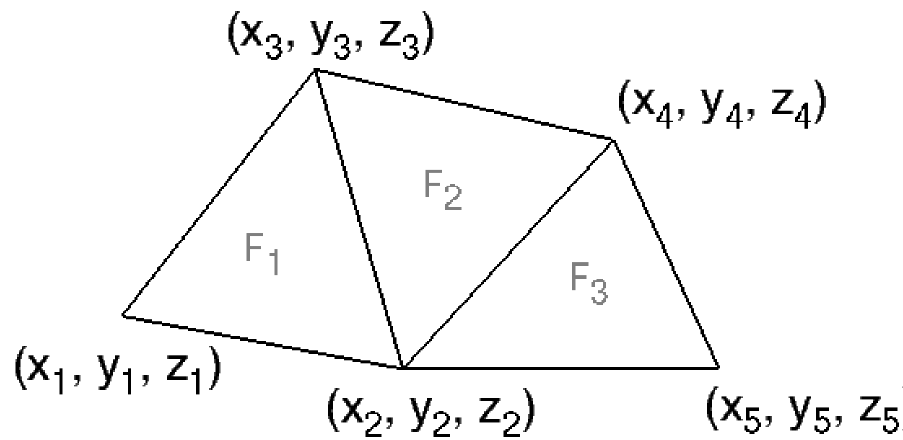


Independent Faces

Each face lists vertex coordinates

- Redundant vertices
- No topology information



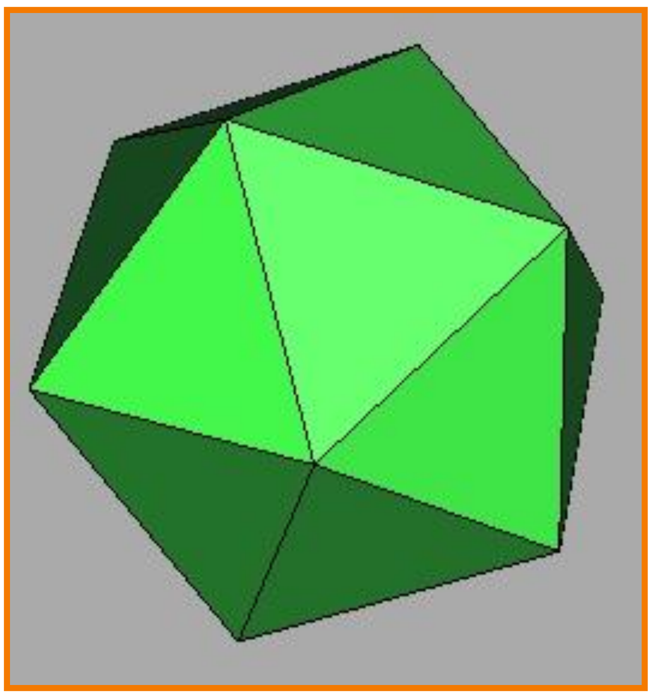


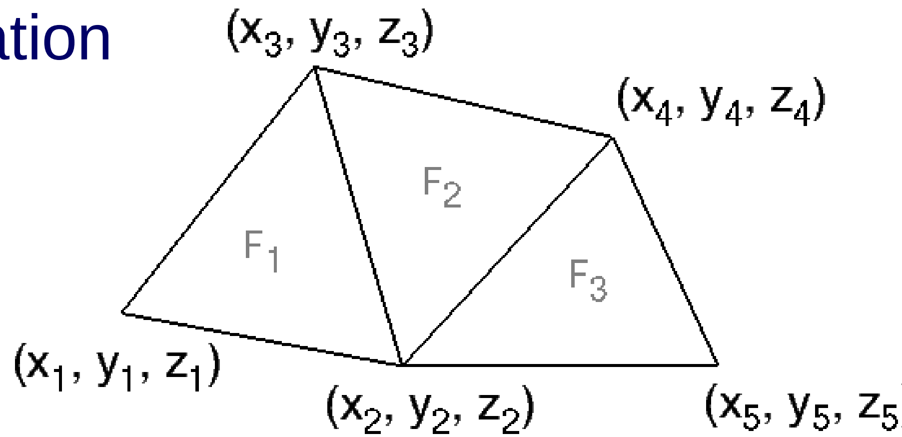
FACE TABLE	
F_1	(x_1, y_1, z_1) (x_2, y_2, z_2) (x_3, y_3, z_3)
F_2	(x_2, y_2, z_2) (x_4, y_4, z_4) (x_3, y_3, z_3)
F_3	(x_2, y_2, z_2) (x_5, y_5, z_5) (x_4, y_4, z_4)

Vertex and Face Tables

Each face lists vertex references

- Shared vertices
- Still no topology information





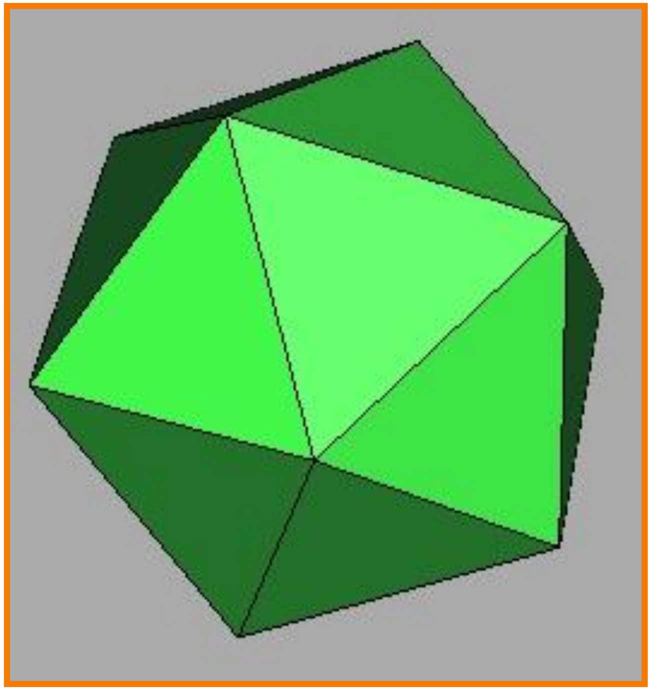
VERTEX TABLE			
V_1	X_1	Y_1	Z_1
V_2	X_2	Y_2	Z_2
V_3	X_3	Y_3	Z_3
V_4	X_4	Y_4	Z_4
V_5	X_5	Y_5	Z_5

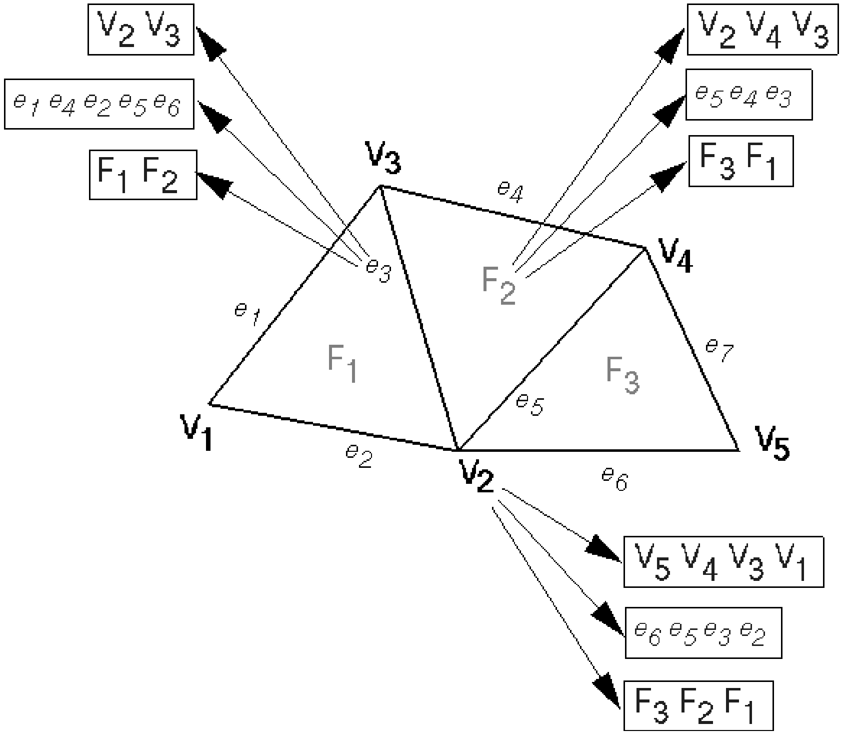
FACE TABLE			
F_1	V_1	V_2	V_3
F_2	V_2	V_4	V_3
F_3	V_2	V_5	V_4

Adjacency Lists

Store all vertex, edge, and face adjacencies

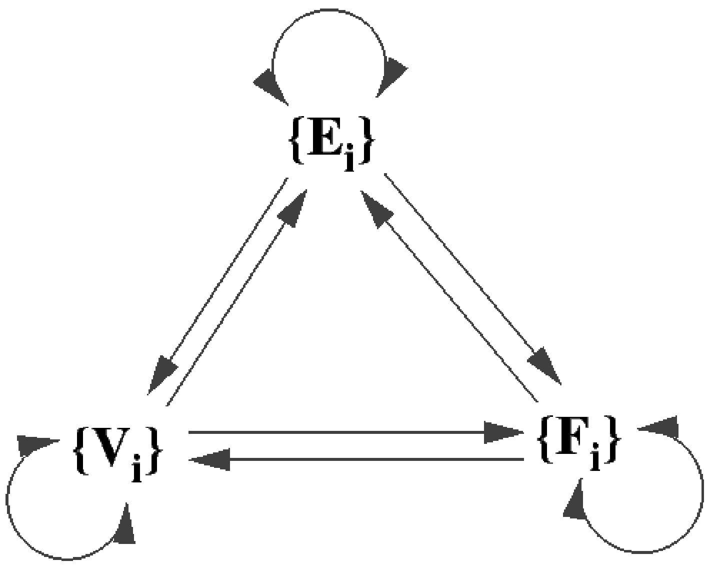
- Efficient topology traversal
- Extra storage

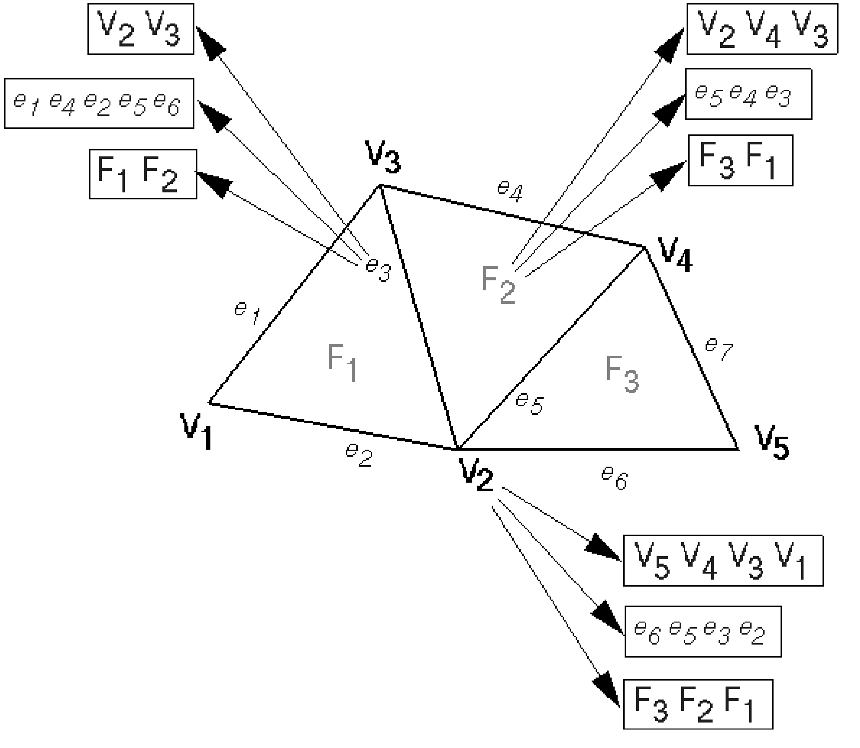




Partial Adjacency Lists

Can we store only some adjacency relationships and derive others?

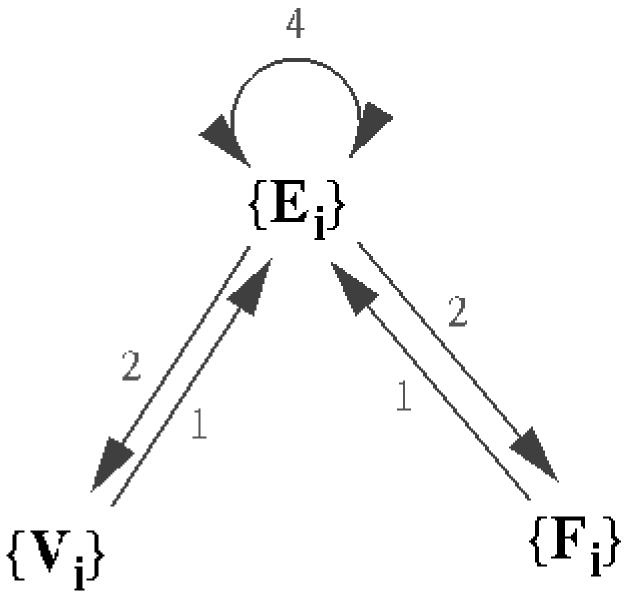


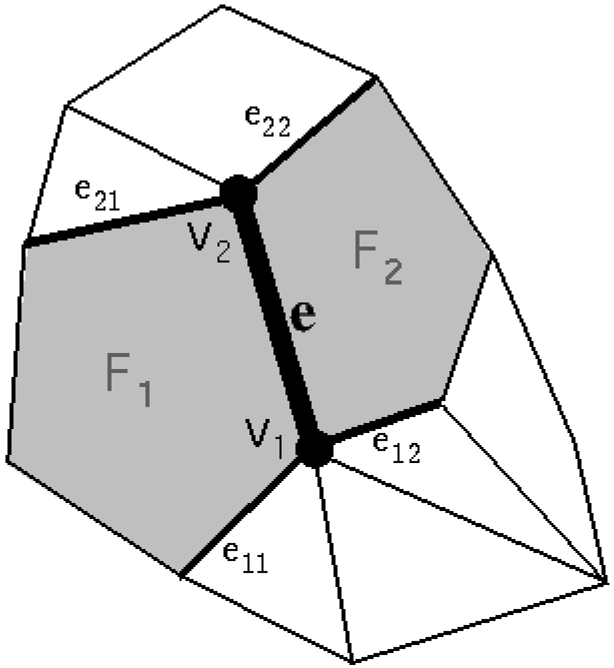


Winged Edge

Adjacency encoded in edges

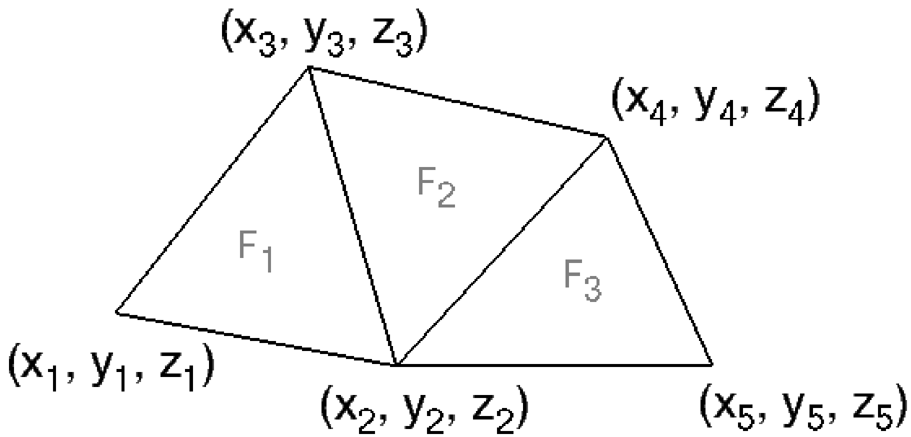
- All adjacencies in O(1) time
- Little extra storage (fixed records)
- Arbitrary polygons





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

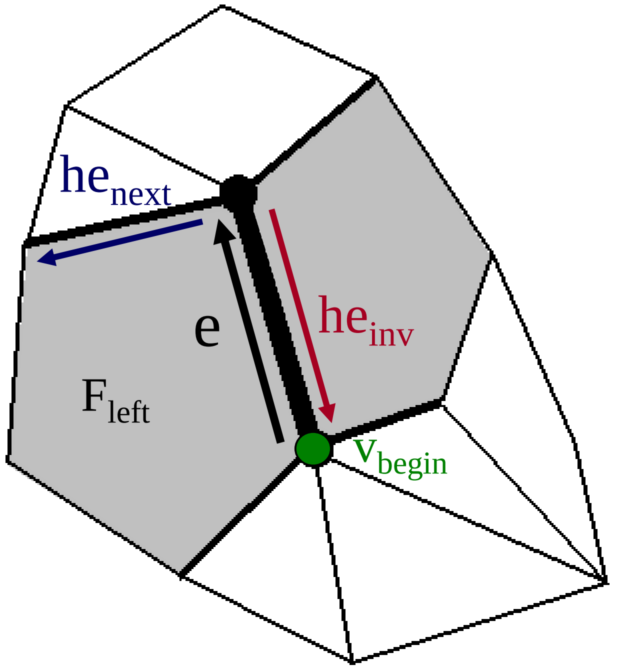
FACE TABLE	
F_1	e_1
F_2	e_3
F_3	e_5

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

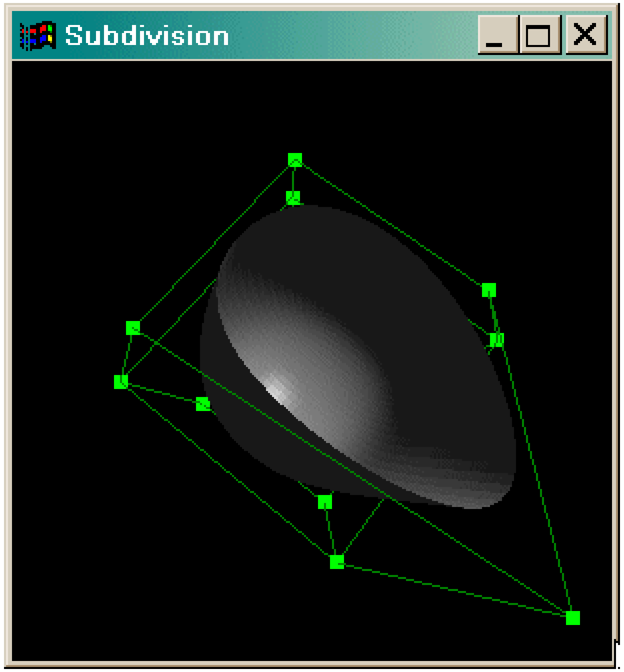
Polygonal mesh overview

- Acquisition
- Processing
- Representation

Summary

Do polygonal mesh reps have these properties?

- Easy to acquire
- Accurate
- Concise
- Efficient display
- Efficient intersections
- Efficient deformations
- Efficient topology changes
- Guaranteed validity
- Guaranteed smoothness
- Intuitive editing controls



Summary

Next time: Laplacian Surface Editing