Polygonal Meshes

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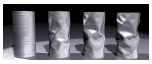
Princeton University
COS 526, Fall 2010

Digital Geometry Processing

Processing of 3D surfaces
- Creation, acquisition
- Storage, transmission
- Editing, animation, simulation
- Manufacture



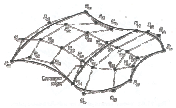
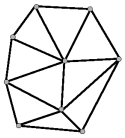
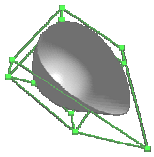
Applications
- Movies, games
- Computer-aided design
- Medicine, biology
- Art, history



Sweldens

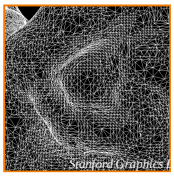
Digital Geometry Processing

Many possible surface representations
- Polygonal meshes
- Parametric surfaces
- Subdivision surfaces
- Implicit surfaces
- etc.

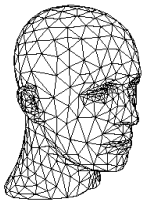
Digital Geometry Processing

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

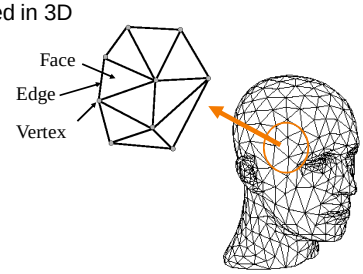
Set of polygonal faces representing a 2D surface embedded in 3D



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

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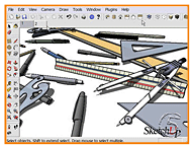
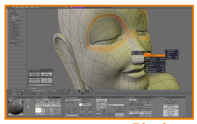


Sketchup



Blender

Polygonal Mesh Acquisition

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Princeton Shape Benchmark

Polygonal Mesh Acquisition

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Digital Michelangelo Project
Stanford

Polygonal Mesh Acquisition

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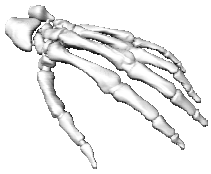

Large Geometric Model Repository
Georgia Tech

Polygonal Mesh Acquisition

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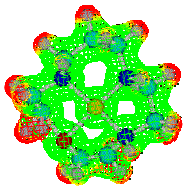

MIT

Outline

Acquisition

Processing ←

Representation

Polygonal Mesh Processing

Storage
- Compression
- Transmission

Analysis
- Parameterization
- Differential geometry
- Feature detection
- Segmentation

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

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Lossy Compression
(Simplification)

Garland

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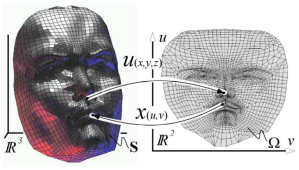

Sheffer

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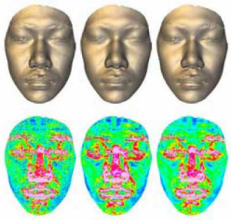

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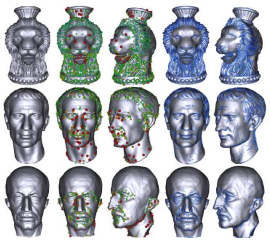

Novatnek et al.

Polygonal Mesh Processing

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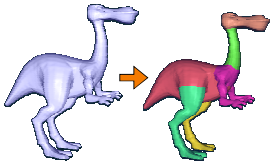

Katz & Tal

Polygonal Mesh Processing

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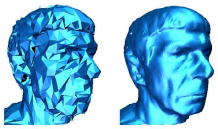
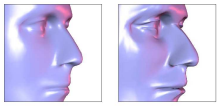


Smoothing



Sharpening

Desbrun

Polygonal Mesh Processing

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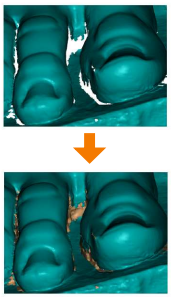


Podolak

Outline

Acquisition

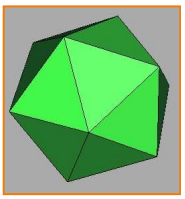
Processing

Representation ←

Polygon Mesh Representation

Data structures determine algorithms
- Data structure must support key operations of algorithm efficiently

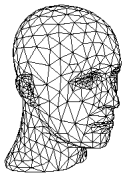
Examples:
- Drawing a mesh
- Removing a vertex
- Computing per-vertex normals

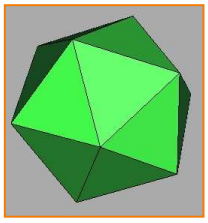


Different data structures for different algorithms

Polygon Mesh Representation

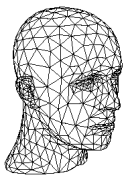
Important properties of mesh representation?

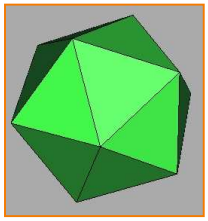




Polygon Mesh Representation

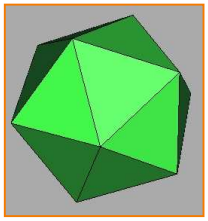
Important properties of mesh representation?
- Efficient traversal of topology
- Efficient use of memory





Polygon Mesh Representation

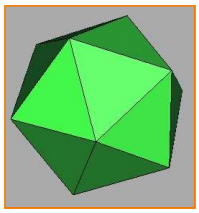
Possible data structures
- List of independent faces
- Vertex and face tables
- Adjacency lists
- Winged edge
- Half edge
- etc.

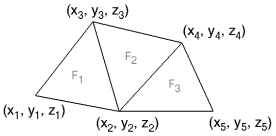


Independent Faces

Each face lists vertex coordinates

- Redundant vertices
- No topology information



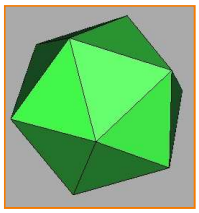


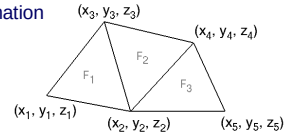
FACE TABLE	
F1	(x1, y1, z1) (x2, y2, z2) (x3, y3, z3)
F2	(x2, y2, z2) (x4, y4, z4) (x3, y3, z3)
F3	(x2, y2, z2) (x5, y5, z5) (x4, y4, z4)

Vertex and Face Tables

Each face lists vertex references

- Shared vertices
- Still no topology information





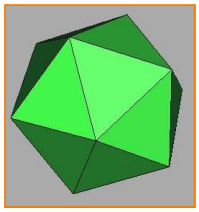
VERTEX TABLE			
V1	X1	Y1	Z1
V2	X2	Y2	Z2
V3	X3	Y3	Z3
V4	X4	Y4	Z4
V5	X5	Y5	Z5

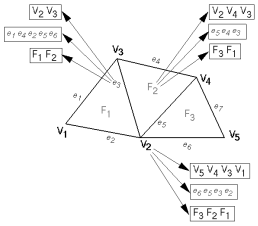
FACE TABLE			
F1	V1	V2	V3
F2	V2	V4	V3
F3	V2	V5	V4

Adjacency Lists

Store all vertex, edge, and face adjacencies

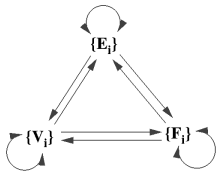
- Efficient topology traversal
- Extra storage

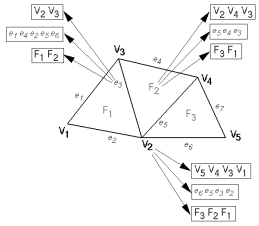




Partial Adjacency Lists

Can we store only some adjacency relationships and derive others?

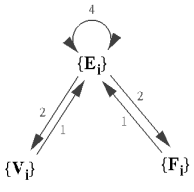


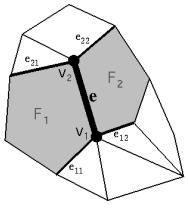


Winged Edge

Adjacency encoded in edges

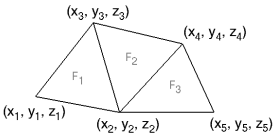
- All adjacencies in O(1) time
- Little extra storage (fixed records)
- Arbitrary polygons





Winged Edge

Example:



VERTEX TABLE			
V1	X1	Y1	Z1	e1
V2	X2	Y2	Z2	e6
V3	X3	Y3	Z3	e3
V4	X4	Y4	Z4	e5
V5	X5	Y5	Z5	e6

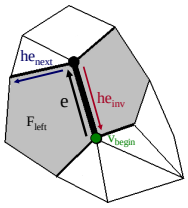
EDGE TABLE					11	12	21	22
e1	V1	V3		F1	e2	e2	e4	e3
e2	V1	V2	F1		e1	e1	e3	e6
e3	V2	V3	F1	F2	e2	e5	e1	e4
e4	V3	V4		F2	e1	e3	e7	e5
e5	V2	V4	F2	F3	e3	e6	e4	e7
e6	V2	V5	F3		e5	e2	e7	e7
e7	V4	V5		F3	e4	e5	e6	e6

FACE TABLE	
F1	e1
F2	e3
F3	e5

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

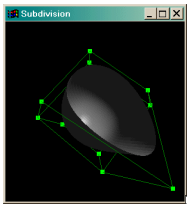


Summary

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