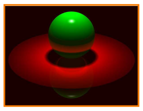
Overview of 3D Object Representations

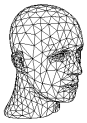
Thomas Funkhouser
Princeton University
C0S 426, Spring 2004

Course Syllabus

- I. Image processing
- II. Rendering
- III. Modeling
- IV. Animation


Image Processing
(Rusty Coleman, CS426, Fall99)


Rendering
(Michael Bostock, CS426, Fall99)


Modeling
(Dennis Zorin, CalTech)

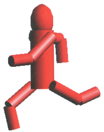

Animation
(Angel, Plate 1)

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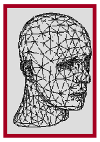
Image Processing
(Rusty Coleman, CS426, Fall99)


Rendering
(Michael Bostock, CS426, Fall99)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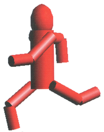
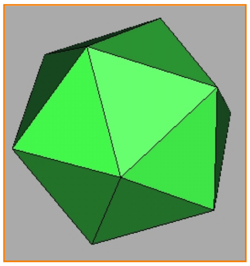

Animation
(Angel, Plate 1)

Modeling

- How do we ...
  - Represent 3D objects in a computer?
  - Construct such representations quickly and/or automatically with a computer?
  - Manipulate 3D objects with a computer?

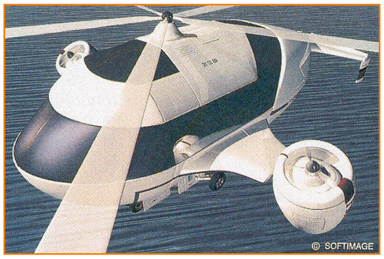
Different methods for different object representations

3D Objects



How can this object be represented in a computer?

3D Objects



H&B Figure 10.46

This one?

3D Objects

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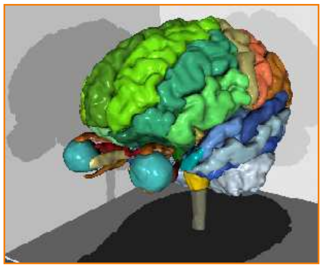
How about this one?

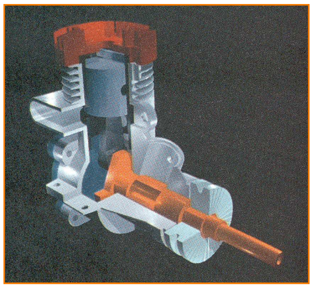
3D Objects



Lorensen

This one?

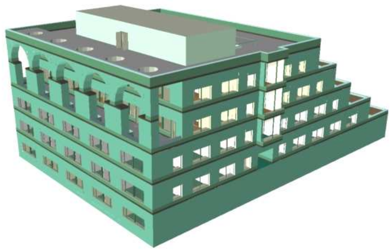
3D Objects



H&B Figure 9.9

This one?

3D Objects



This one?

Representations of Geometry

- 3D Representations provide the foundations for
  - Computer Graphics, Computer-Aided Geometric Design, Visualization, Robotics
- They are languages for describing geometry

Semantics	Syntax
values	**data structures**
operations	**algorithms**

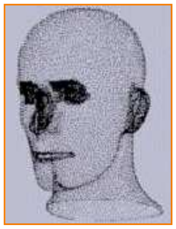
- Data structures determine algorithms!

3D Object Representations

- Raw data
  - Point cloud
  - Range image
  - Polygon soup
- Surfaces
  - Mesh
  - Subdivision
  - Parametric
  - Implicit
- Solids
  - Voxels
  - BSP tree
  - CSG
  - Sweep
- High-level structures
  - Scene graph
  - Skeleton
  - Application specific

Point Cloud

- Unstructured set of 3D point samples
  - Acquired from range finder, computer vision, etc

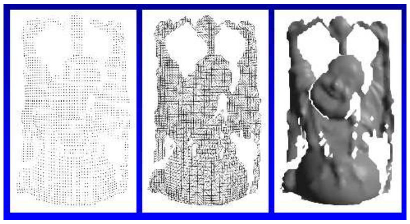


Hoppe

Hoppe

Range Image

- Set of 3D points mapping to pixels of depth image
  - Acquired from range scanner

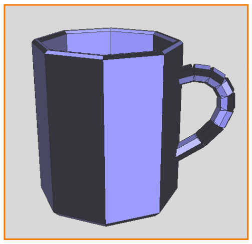


Range Image   Tesselation   Range Surface

Brian Curless
SIGGRAPH 99
Course #4 Notes

Polygon Soup

- Unstructured set of polygons
  - Created with interactive modeling systems?



Larson

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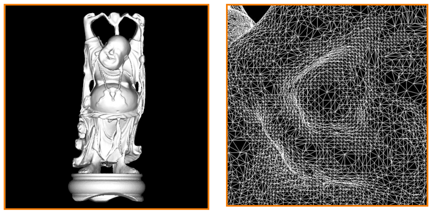
Mesh

- Connected set of polygons (usually triangles)
  - May not be closed



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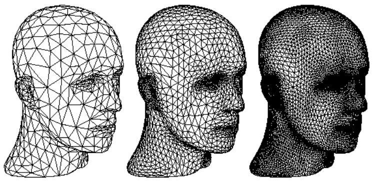
Subdivision Surface

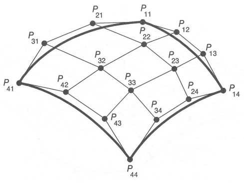
- Coarse mesh & subdivision rule
  - Define smooth surface as limit of sequence of refinements



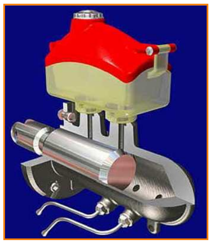
Zorin & Schroeder
SIGGRAPH 99
Course Notes

Parametric Surface

- Tensor product spline patchs
  - Careful constraints to maintain continuity

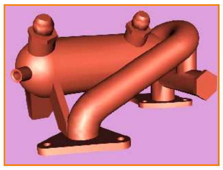


FvDFH Figure 11.44

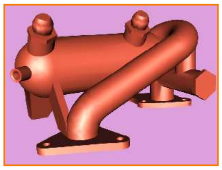


Implicit Surface

- Points satisfying: F(x,y,z) = 0



Polygonal Model



Implicit Model

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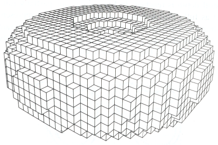
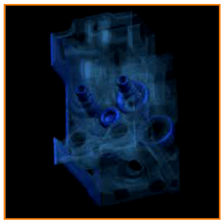
Voxels

- Uniform grid of volumetric samples
  - Acquired from CAT, MRI, etc.



FvDFH Figure 12.20



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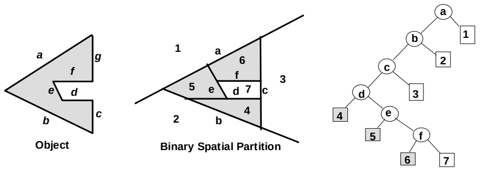
BSP Tree

- Binary space partition with solid cells labeled
  - Constructed from polygonal representations



Object

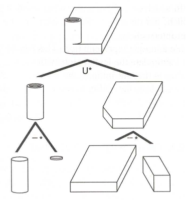
Binary Spatial Partition

Binary Tree

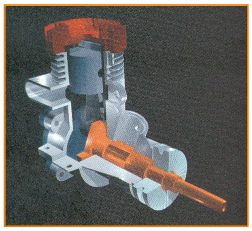
Naylor

CSG

- Hierarchy of boolean set operations (union, difference, intersect) applied to simple shapes



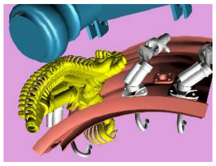
FvDFH Figure 12.27

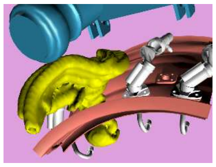


H&B Figure 9.9

Sweep

- Solid swept by curve along trajectory


Removal Path


Sweep Model

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Scene Graph

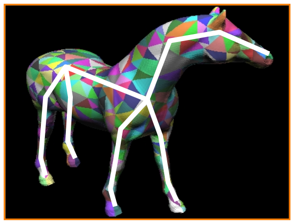
- Union of objects at leaf nodes


Bell Laboratories


avalon.viewpoint.com

Skeleton

- Graph of curves with radii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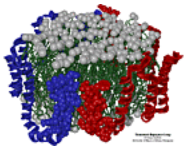
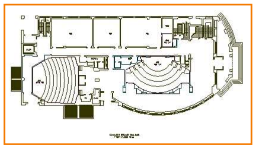
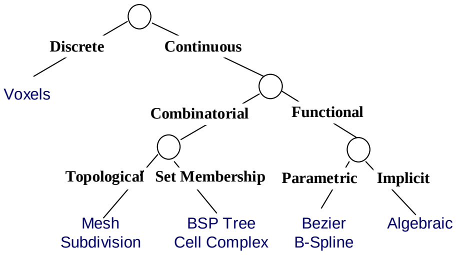
SGI

Application Specific


Apo A-1
(Theoretical Biophysics Group, University of Illinois at Urbana-Champaign)


Architectural Floorplan
(CS Building, Princeton University)

Taxonomy of 3D Representations


Discrete
Continuous
Voxels
Combinatorial
Functional
Topological
Set Membership
Parametric
Implicit
Mesh
Subdivision
BSP Tree
Cell Complex
Bezier
B-Spline
Algebraic

Naylor

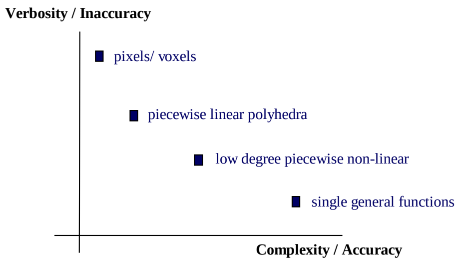
Equivalence of Representations

- Thesis:
  - Each fundamental representation has enough expressive power to model the shape of any geometric object
  - It is possible to perform all geometric operations with any fundamental representation!
- Analogous to Turing-Equivalence:
  - All computers today are turing-equivalent, but we still have many different processors

Computational Differences

- Efficiency
  - Combinatorial complexity (e.g. O(n log n))
  - Space/time trade-offs (e.g. z-buffer)
  - Numerical accuracy/stability (degree of polynomial)
- Simplicity
  - Ease of acquisition
  - Hardware acceleration
  - Software creation and maintenance
- Usability
  - Designer interface vs. computational engine

Complexity vs. Verbosity Tradeoff



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