Overview of 3D Object Representations

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Princeton University

COS 426, Spring 2005

Course Syllabus

I. Image processing

II. Rendering

III. Modeling

IV. Animation

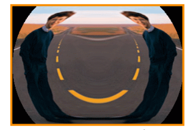
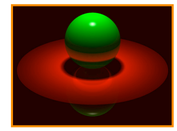
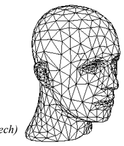


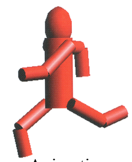
Image Processing
(Rusty Coleman, CS426, Fall99)



Rendering
(Michael Bostock, CS426, Fall99)



Modeling
(Dennis Zorin, CalTech)



Animation
(Angel, Plate 1)

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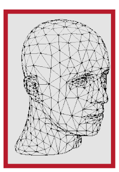

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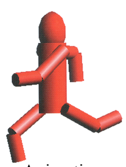


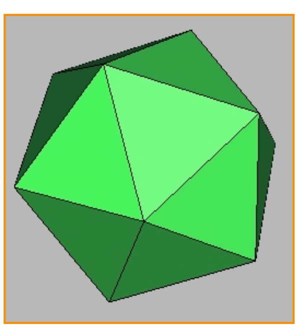
Animation
(Angel, Plate 1)

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?

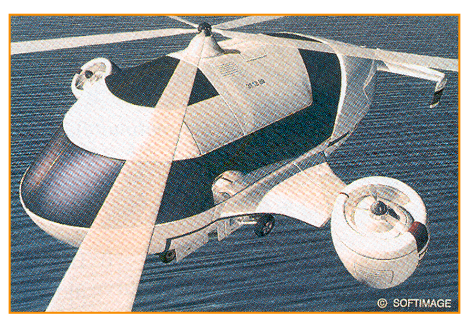
Different methods for different object representations

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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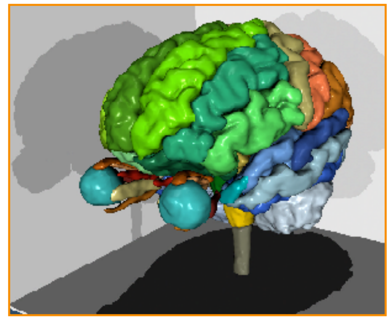
How about this one?

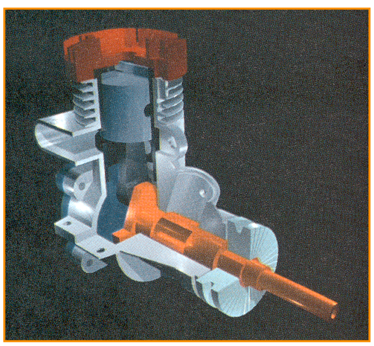
3D Objects



Lorensen

This one?

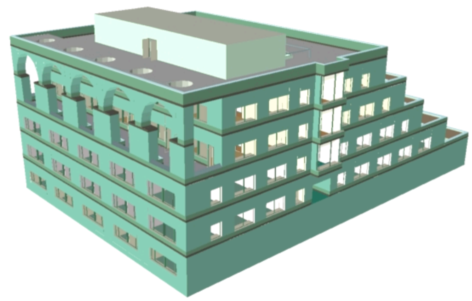
3D Objects



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**

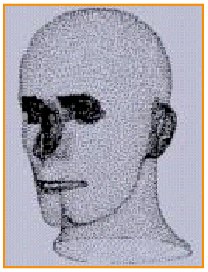
- Data structures determine algorithms!

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

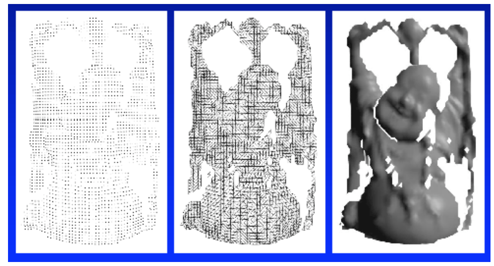


Hoppe

Hoppe

Range Image

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

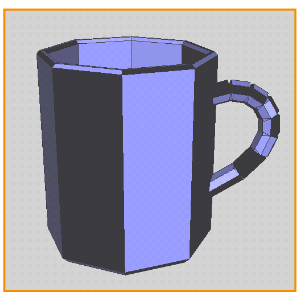


Range Image　　Tesselation　　Range Surface

Brian Curless
SIGGRAPH 99
Course #4 Notes

Polygon Soup

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



Larson

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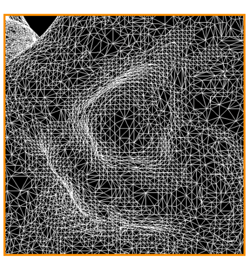
Mesh

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



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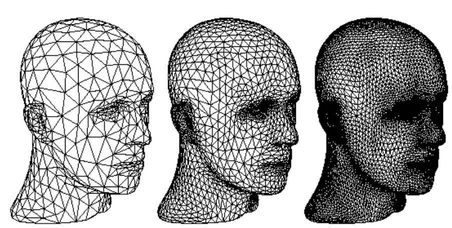
Subdivision Surface

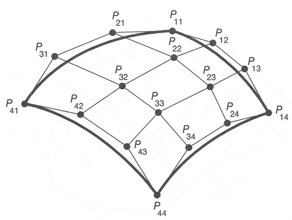
- Coarse mesh & subdivision rule
  - Define smooth surface as limit of sequence of refinements



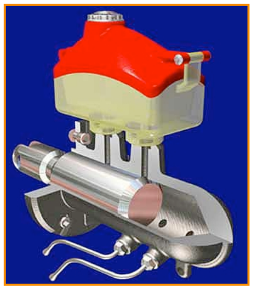
Zorin & Schroeder
SIGGRAPH 99
Course Notes

Parametric Surface

- Tensor product spline patchs
  - o Careful constraints to maintain continuity

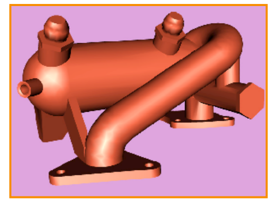


FvDFH Figure 11.44

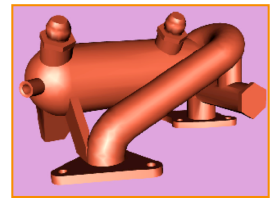


Implicit Surface

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



Polygonal Model



Implicit Model

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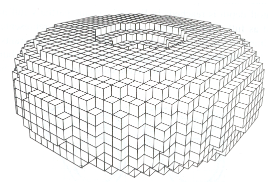
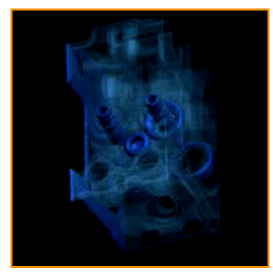
Voxels

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



FvDFH Figure 12.20



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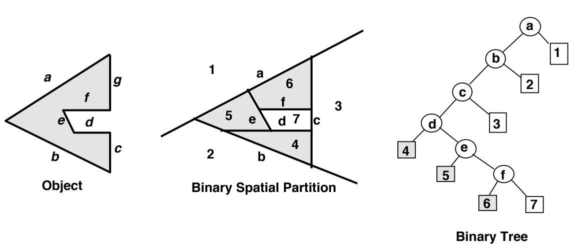
BSP Tree

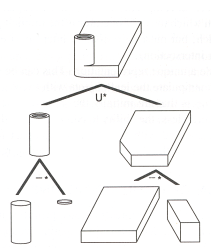
- Binary space partition with solid cells labeled
  - o Constructed from polygonal representations



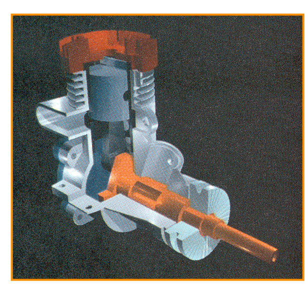
Naylor

CSG

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



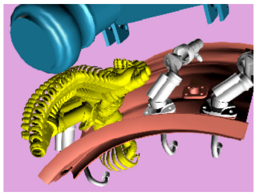
FvDFH Figure 12.27



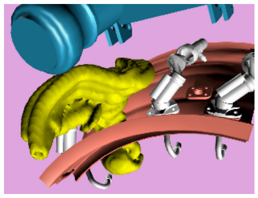
H&B Figure 9.9

Sweep

- Solid swept by curve along trajectory



Removal Path



Sweep Model

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Scene Graph

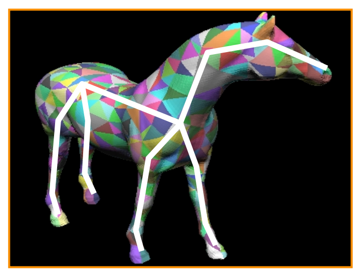
- Union of objects at leaf nodes

Bell Laboratories

avalon.viewpoint.com

Skeleton

- Graph of curves with radii



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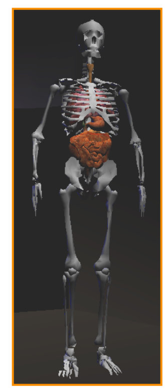
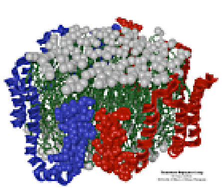
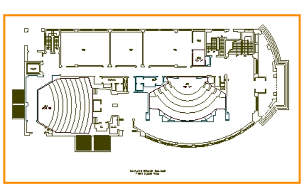


SGI

Application Specific

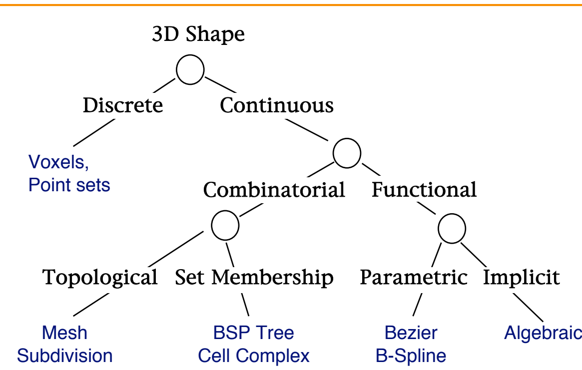


Apo A-1
(Theoretical Biophysics Group, University of Illinois at Urbana-Champaign)



Architectural Floorplan
(CS Building, Princeton University)

Taxonomy of 3D Representations



Naylor

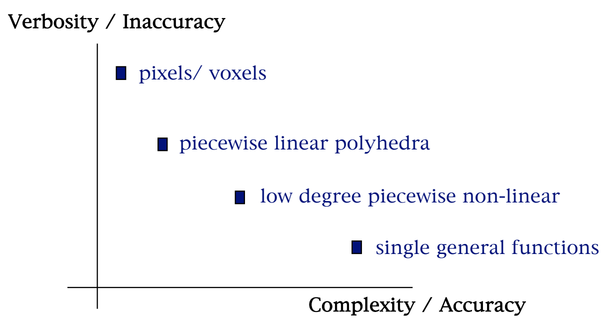
Equivalence of Representations

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

Computational Differences

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

Complexity vs. Verbosity Tradeoff



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