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Overview of 3D Object Representations

Emil Praun

(covering for Finkelstein)

Princeton University

C0S 426, Fall 2000

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Course Syllabus

I. Image processing

II. Rendering

III. Modeling

IV. Animation

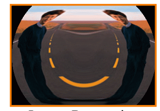
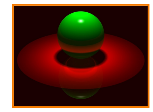
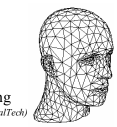


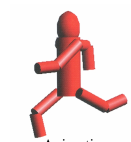
Image Processing
(Rusty Coleman, CS426, Fall99)



Rendering
(Michael Bostock, CS426, Fall99)



Modeling
(Dennis Zorin, CalTech)



Animation
(Angel, Plate 1)

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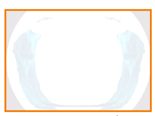

Image Processing
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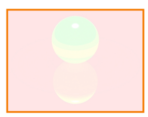
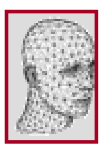
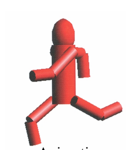


Rendering
(Michael Bostock, CS426, Fall99)



Modeling
(Dennis Zorin, CalTech)



Animation
(Angel, Plate 1)

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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

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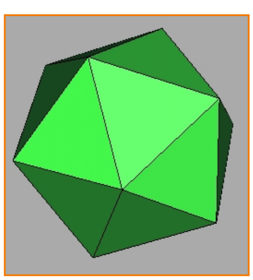
3D Objects



How can this object be represented in a computer?

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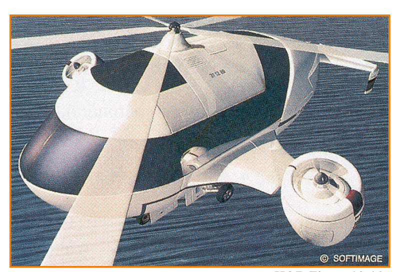
3D Objects



H&B Figure 10.46

This one?

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3D Objects

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How about this one?

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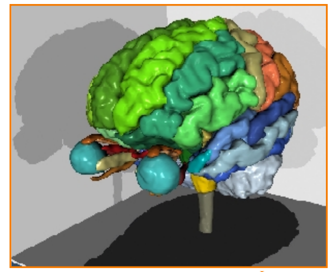
3D Objects



Lorensen

This one?

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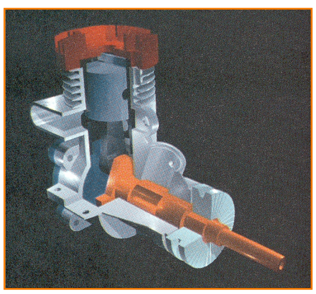
3D Objects



H&B Figure 9.9

This one?

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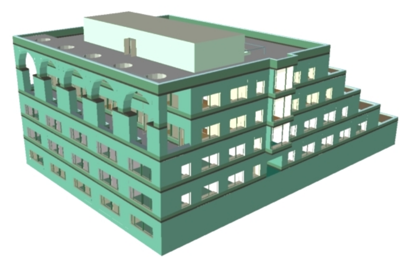
3D Objects



This one?

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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!

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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

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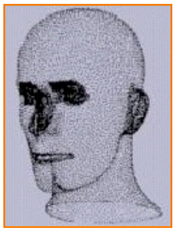
Point Cloud

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



Hoppe

Hoppe

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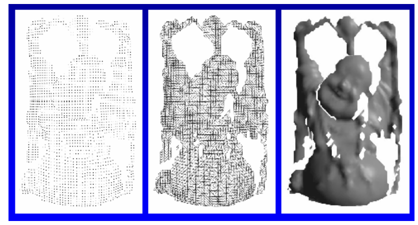
Range Image

- 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

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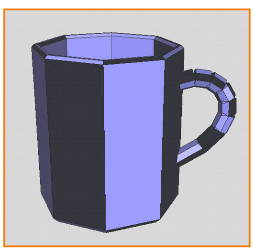
Polygon Soup

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



Larson

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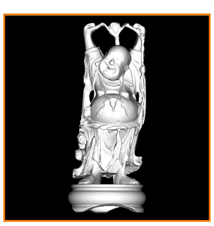
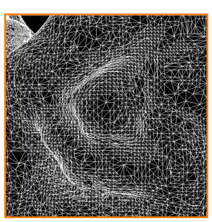
Mesh

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





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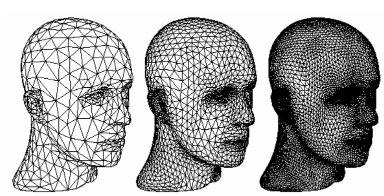
Subdivision Surface

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



Zorin & Schroeder
SIGGRAPH 99
Course Notes

Parametric Surface

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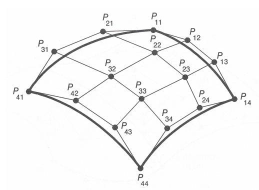
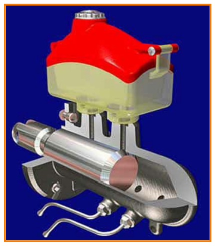
- Tensor product spline patchs
  - Careful constraints to maintain continuity



FvDFH Figure 11.44



Implicit Surface

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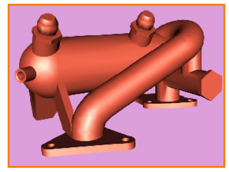
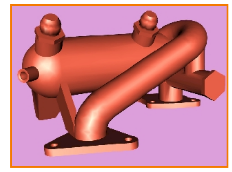
- Points satisfying: F(x,y,z) = 0



Polygonal Model



Implicit Model

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3D Object Representations

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Voxels

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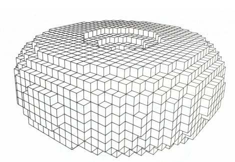
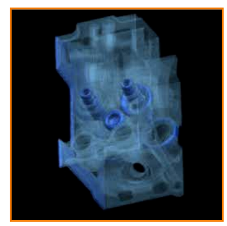
- Uniform grid of volumetric samples
  - Acquired from CAT, MRI, etc.



FvDFH Figure 12.20



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BSP Tree

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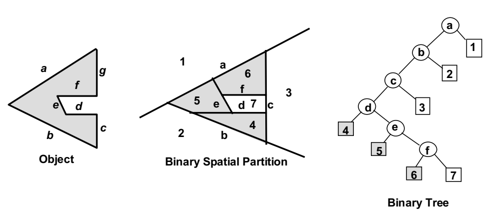
- Binary space partition with solid cells labeled
  - Constructed from polygonal representations



Naylor

CSG

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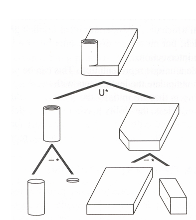
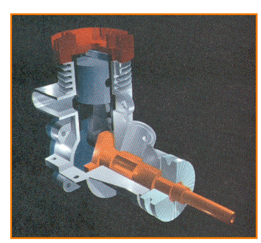
- Hierarchy of boolean set operations (union, difference, intersect) applied to simple shapes



FvDFH Figure 12.27



H&B Figure 9.9

Sweep

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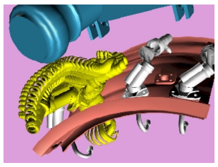
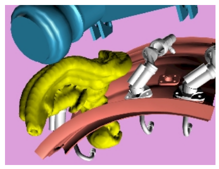
- Solid swept by curve along trajectory



Removal Path



Sweep Model

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Scene Graph

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- Union of objects at leaf nodes

Bell Laboratories

avalon.viewpoint.com

Skeleton

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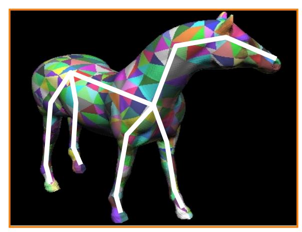
- Graph of curves with radii



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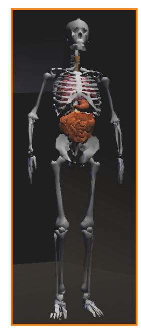

SGI

Application Specific

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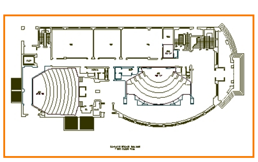
Apo A-1
(Theoretical Biophysics Group, University of Illinois at Urbana-Champaign)



Architectural Floorplan
(CS Building, Princeton University)

Taxonomy of 3D Representations

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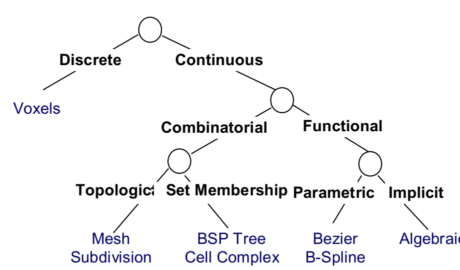

Naylor

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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

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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

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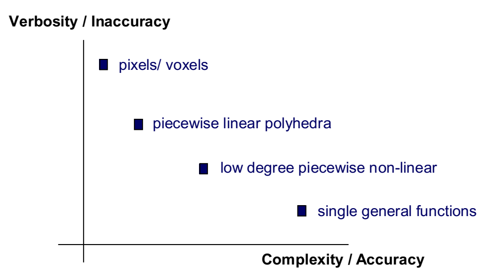
Complexity vs. Verbosity Tradeoff



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