3D Modeling

COS 426

Syllabus

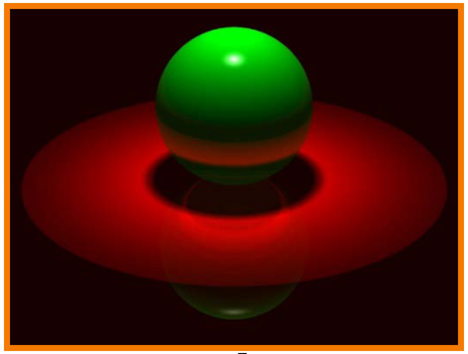
I. Image processing

II. Modeling

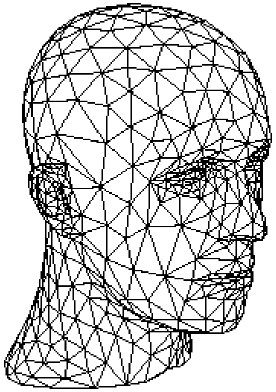
III. Rendering

IV. Animation

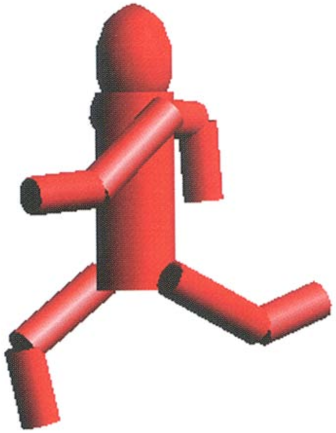
Image Processing
(Rusty Coleman, CS426, Fall99)



Rendering
(Michael Bostock, CS426, Fall99)



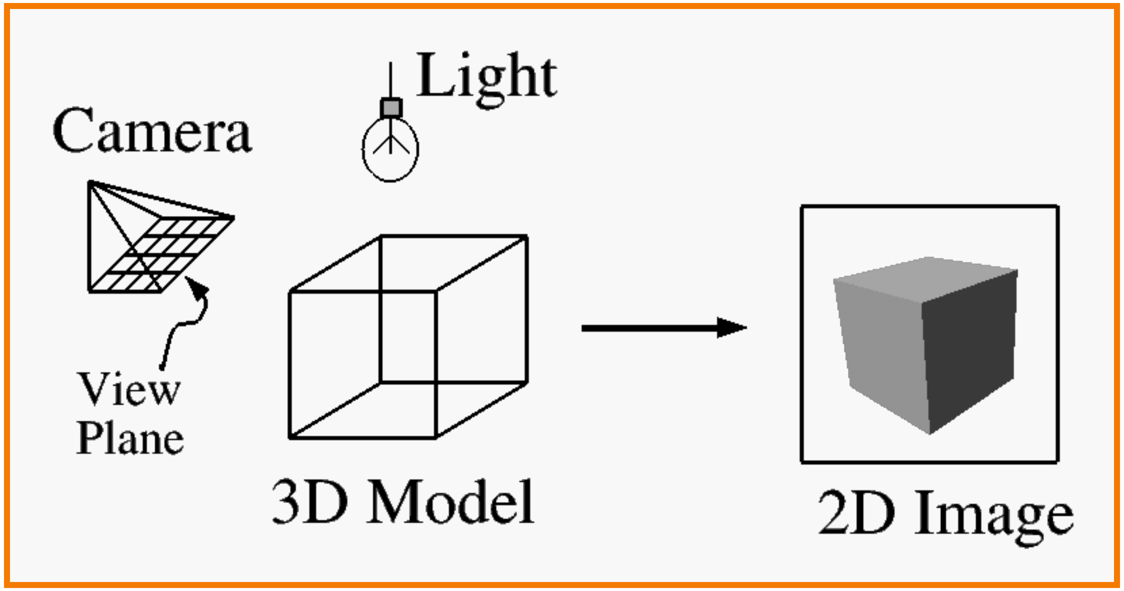
Modeling
(Dennis Zorin, CalTech)



Animation
(Angel, Plate 1)

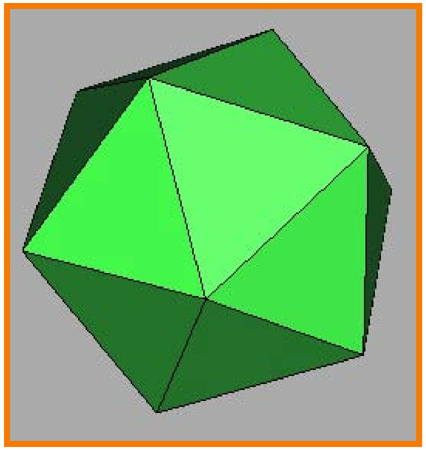
What is 3D Modeling?

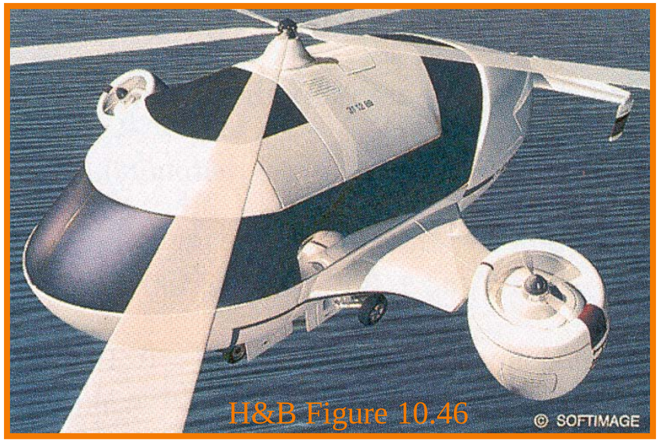
- Topics in computer graphics
    - Imaging = *representing 2D images*
    - Rendering = *constructing 2D images from 3D models*
    - Modeling = *representing 3D objects*
    - Animation = *simulating changes over time*



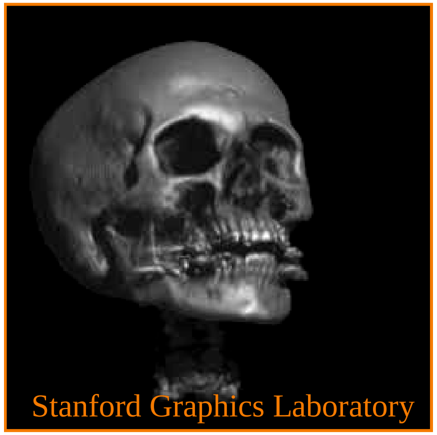
Modeling

- How do we ...
  - Represent 3D objects in a computer?
  - Acquire computer representations of 3D objects?
  - Manipulate computer representations of 3D objects?

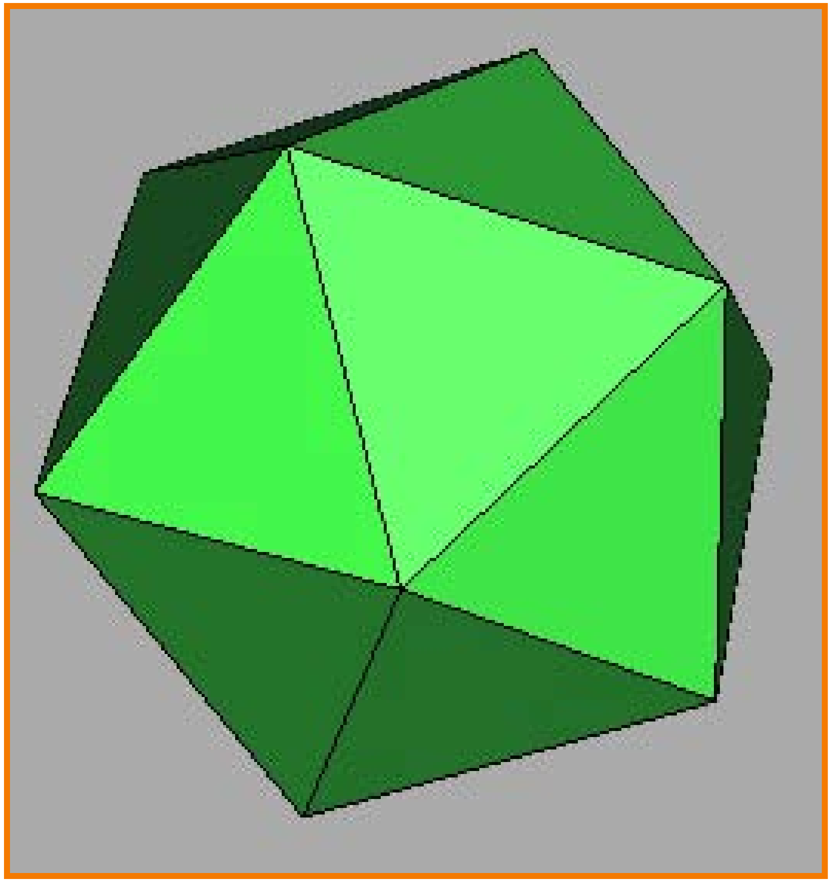




H&B Figure 10.46

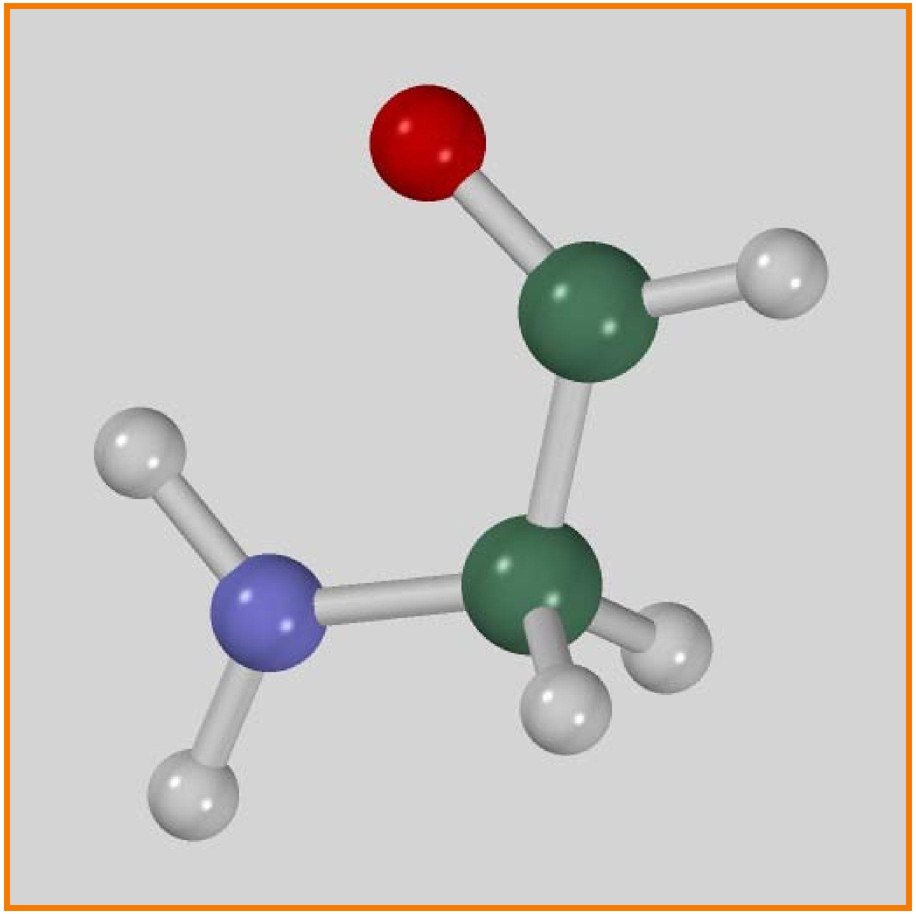

Stanford Graphics Laboratory

3D Object Representations



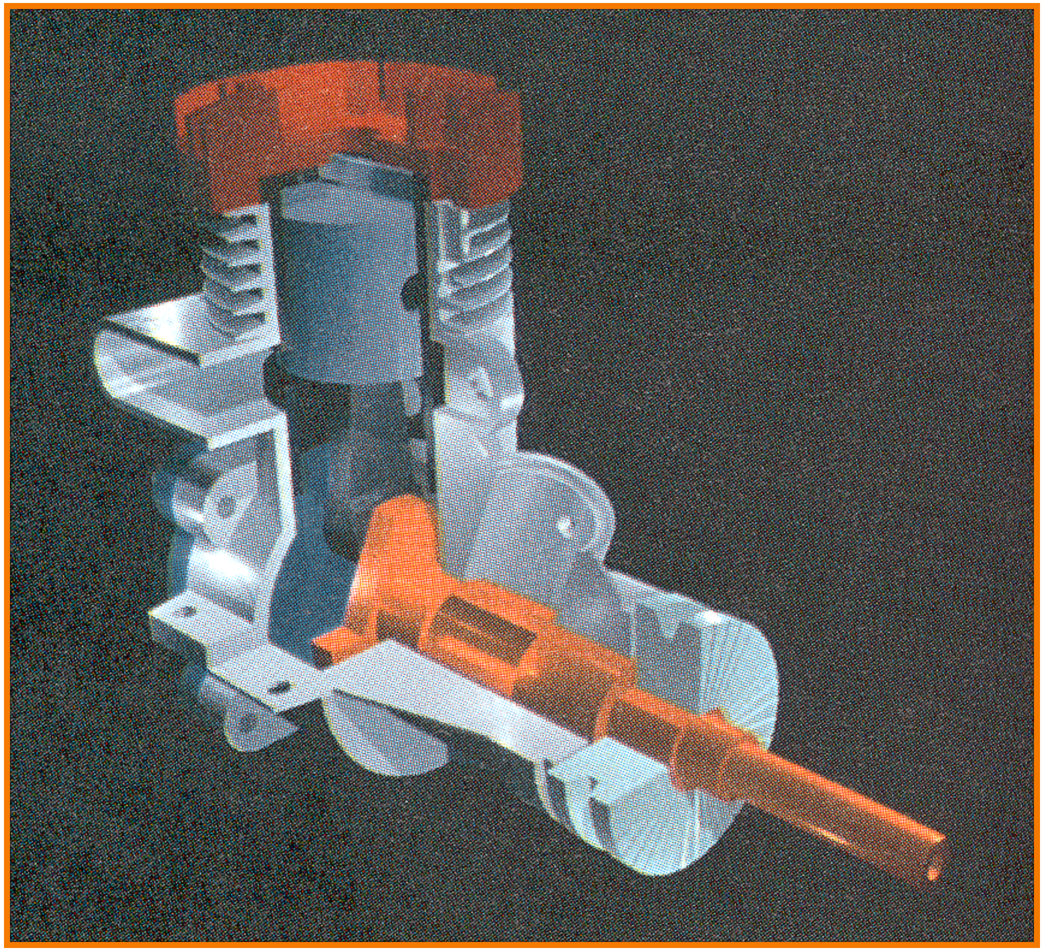
How can this object be represented in a computer?

3D Object Representations



How about this one?

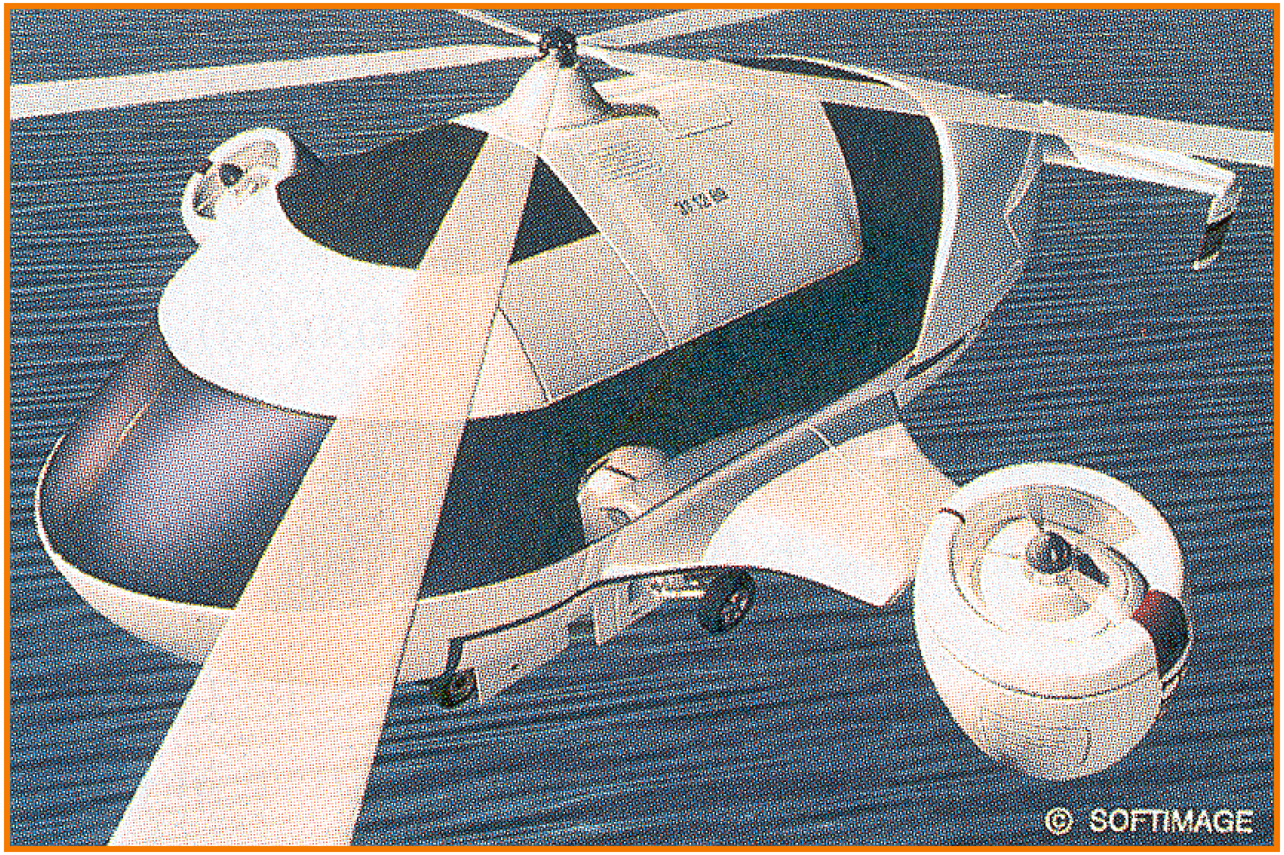
3D Object Representations



H&B Figure 9.9

This one?

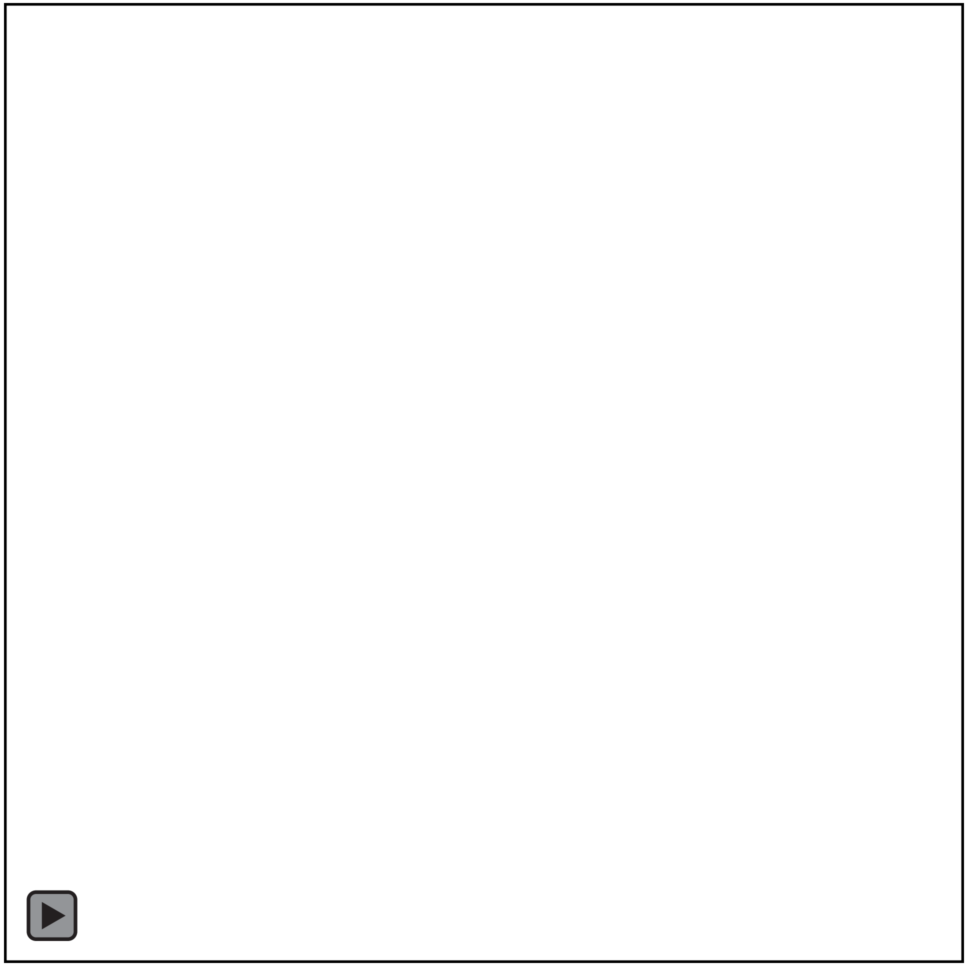
3D Object Representations



H&B Figure 10.46

This one?

3D Object Representations



This one?

Stanford Graphics Laboratory

3D Object Representations

This one?

3D Object Representations

- Points
  - Range image
  - Point cloud
- Surfaces
  - Polygonal mesh
  - Subdivision
  - Parametric
  - Implicit
- Solids
  - Voxels
  - BSP tree
  - CSG
  - Sweep
- High-level structures
  - Scene graph
  - Application specific

Equivalence of Representations

- Thesis:
  - Each 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
  - Computers and programming languages are Turing-equivalent, but each has its benefits…

Why Different Representations?

- Efficiency for different tasks
  - Acquisition
  - Rendering
  - Manipulation
  - Animation
  - Analysis

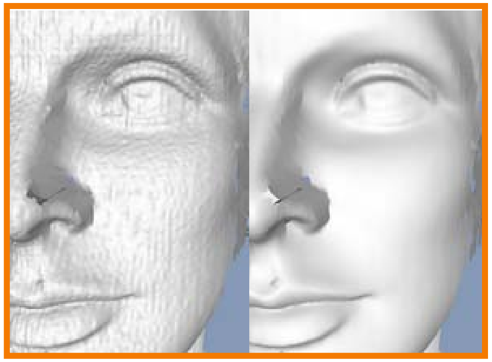
Data structures determine algorithms

Modeling Operations

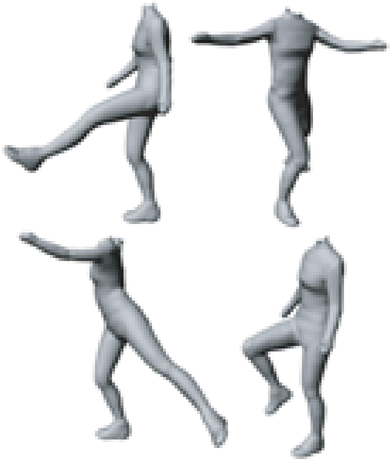
- What can we do with a 3D object representation?
  - Edit
  - Transform
  - Smooth
  - Render
  - Animate
  - Morph
  - Compress
  - Transmit
  - Analyze
  - etc.

Digital Michelangelo

Pirates of the Caribbean



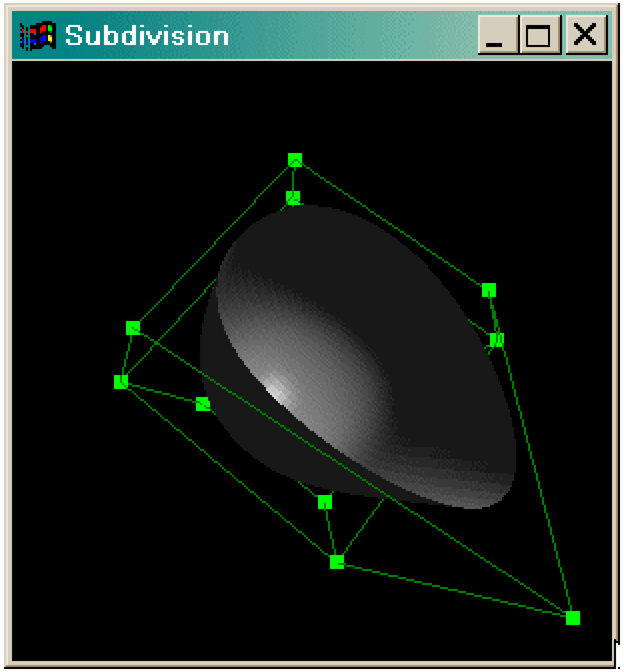
Thouis "Ray" Jones



Sand et al.

3D Object Representations

- Desirable properties depend on intended use
  - Easy to acquire
  - Accurate
  - Concise
  - Intuitive editing
  - Efficient editing
  - Efficient display
  - Efficient intersections
  - Guaranteed validity
  - Guaranteed smoothness
  - etc.

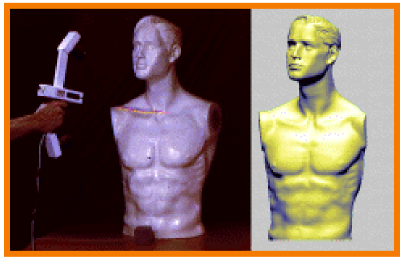


Outline

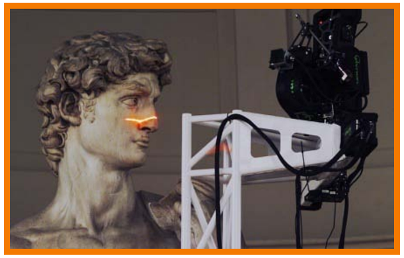
- Points
  - Range image
  - Point cloud
- Surfaces
  - Polygonal mesh
  - Subdivision
  - Parametric
  - Implicit
- Solids
  - Voxels
  - BSP tree
  - CSG
  - Sweep
- High-level structures
  - Scene graph
  - Application specific

Range Image

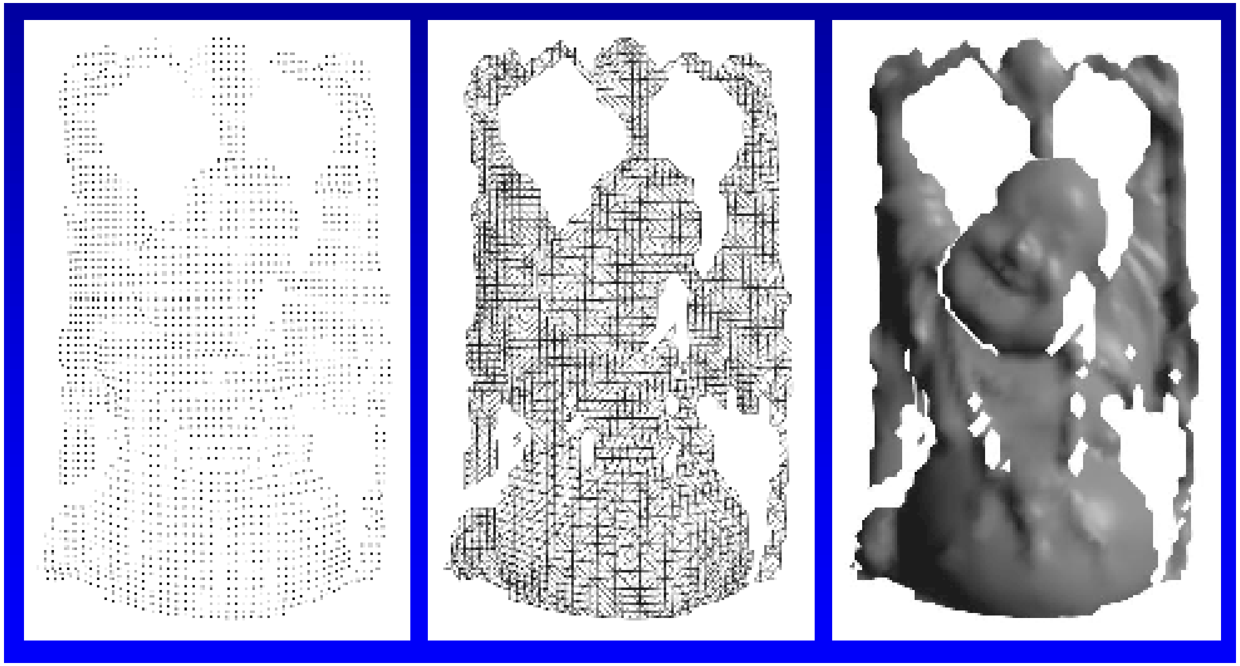
- Set of 3D points mapping to pixels of depth image
  - Acquired from range scanner



Cyberware



Stanford



Range Image Tesselation Range Surface

Brian Curless
SIGGRAPH 99
Course #4 Notes

Range Image

- Image: stores an intensity / color along each of a set of regularly-spaced rays in space
- Range image: stores a depth along each of a set of regularly-spaced rays in space
- Not a complete 3D description: does not store objects occluded (from some viewpoint)
- View-dependent scene description

Terminology

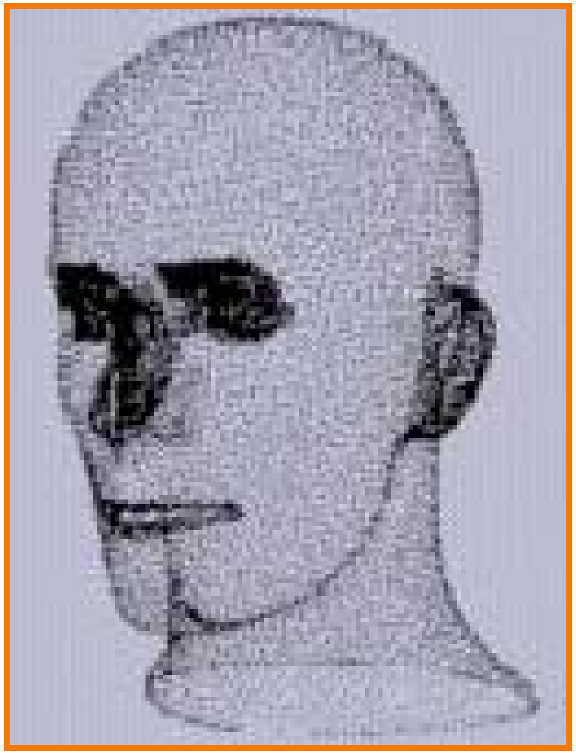
- Range images
- Range surfaces
- Depth images
- Depth maps
- Height fields
- 2½-D images
- Surface profiles
- xyz maps
- …

Point Cloud

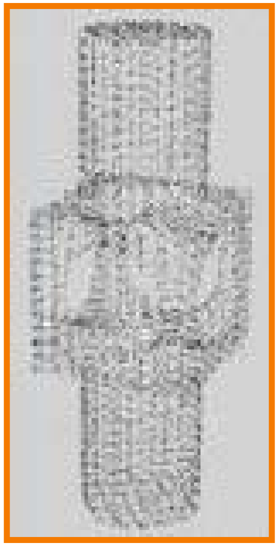
- Unstructured set of 3D point samples
  - Acquired from range finder, computer vision, etc

Polhemus

Microscribe-3D



Hoppe



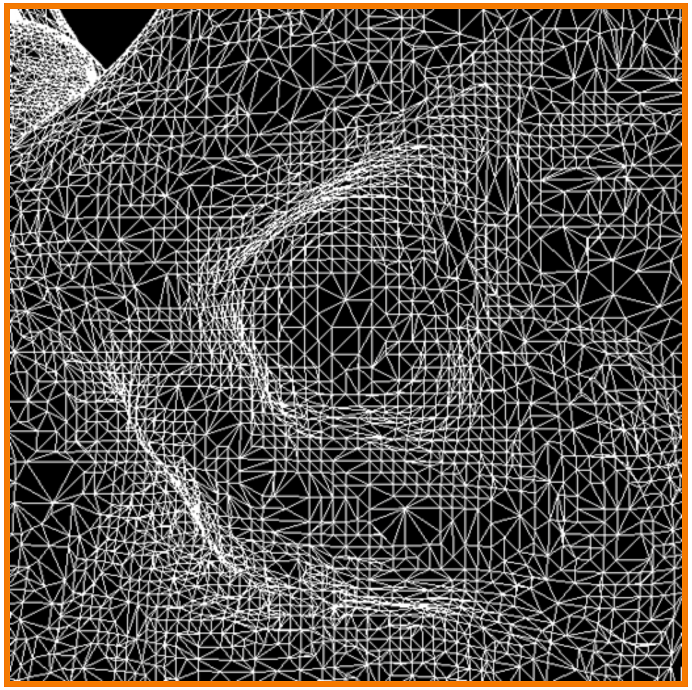
Hoppe

Outline

- Points
  - Range image
  - Point cloud
- Surfaces
  - Polygonal mesh
  - Subdivision
  - Parametric
  - Implicit
- Solids
  - Voxels
  - BSP tree
  - CSG
  - Sweep
- High-level structures
  - Scene graph
  - Application specific

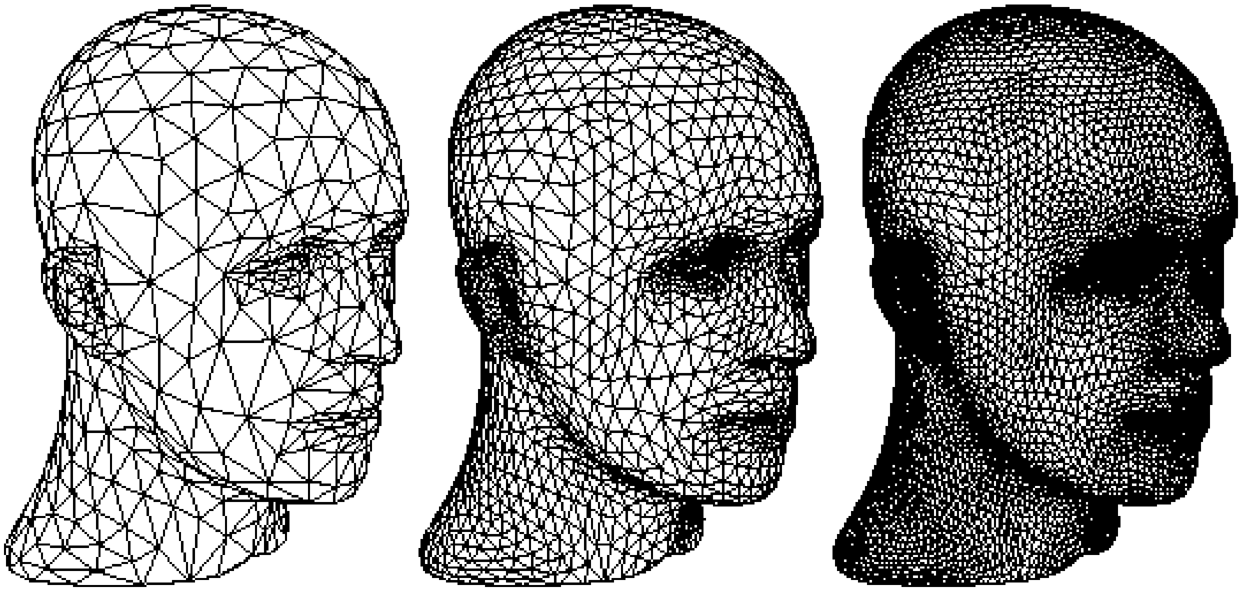
Polygonal Mesh

- Connected set of polygons (usually triangles)



Subdivision Surface

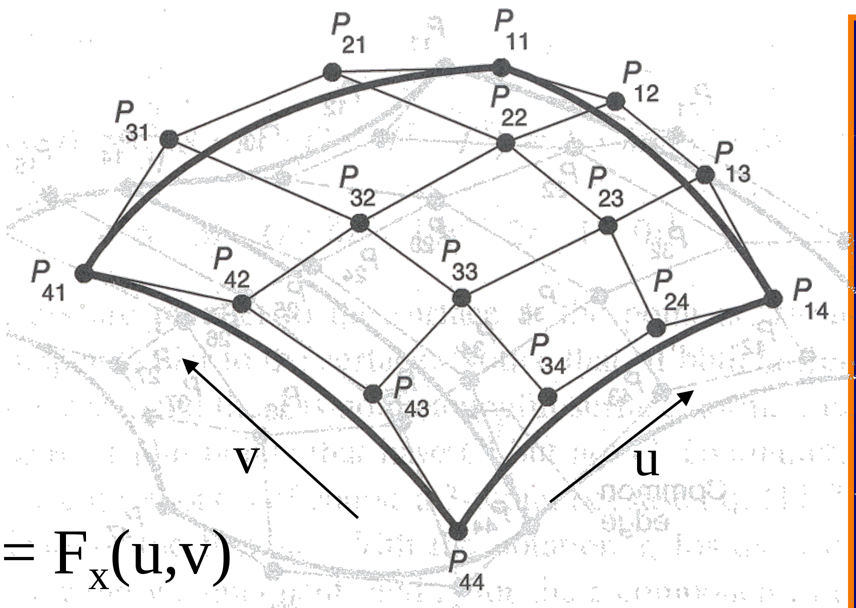
- Coarse mesh & subdivision rule
  - Define smooth surface as limit of sequence of refinements



Zorin & Schroeder
SIGGRAPH 99
Course Notes

Parametric Surface

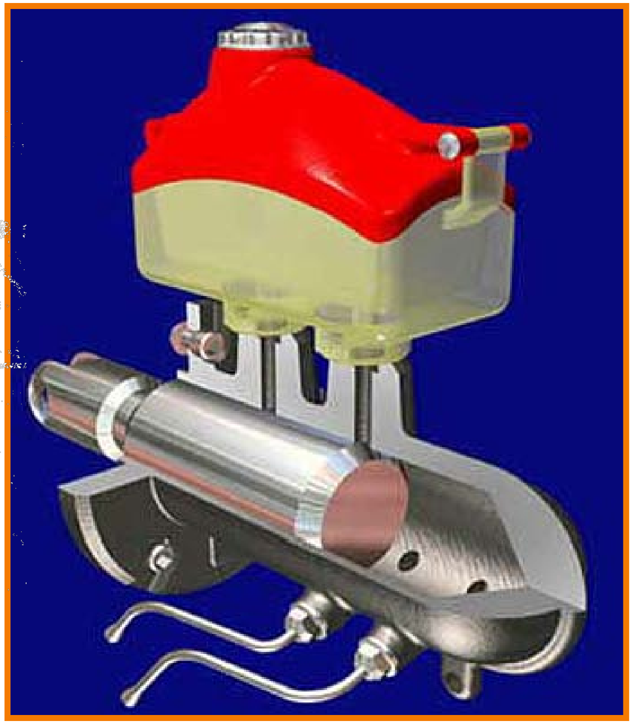
- Tensor product spline patchs
  - Each patch is parametric function
  - Careful constraints to maintain continuity



$x = F_x(u,v)$

$y = F_y(u,v)$

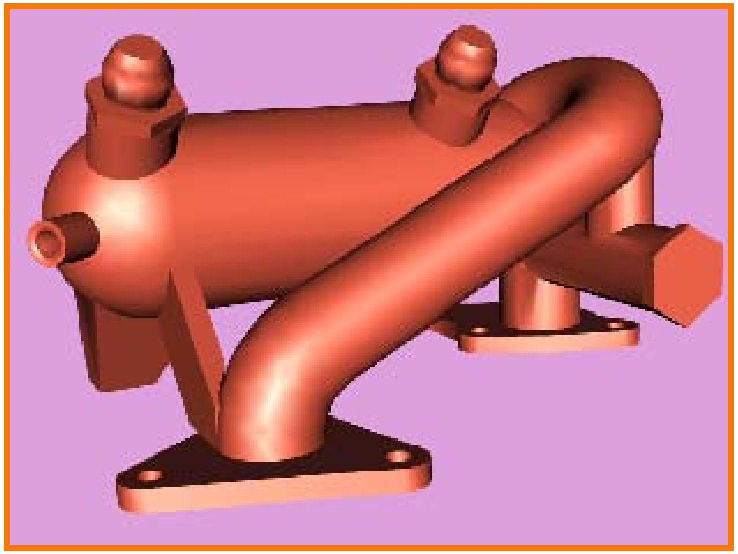
$z = F_z(u,v)$

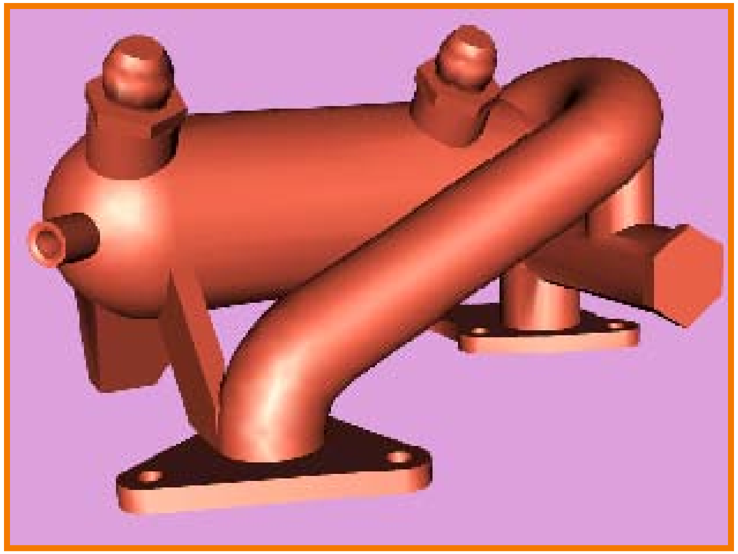


FvDFH Figure 11.44

Implicit Surface

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


Polygonal Model


Implicit Model

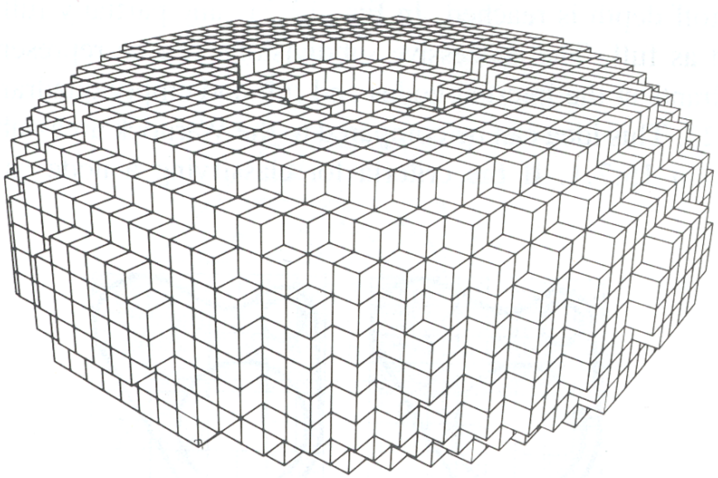
Bill Lorensen
SIGGRAPH 99
Course #4 Notes

Outline

- Points
  - Range image
  - Point cloud
- Surfaces
  - Polygonal mesh
  - Subdivision
  - Parametric
  - Implicit
- Solids
  - Voxels
  - BSP tree
  - CSG
  - Sweep
- High-level structures
  - Scene graph
  - Application specific

Voxels

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

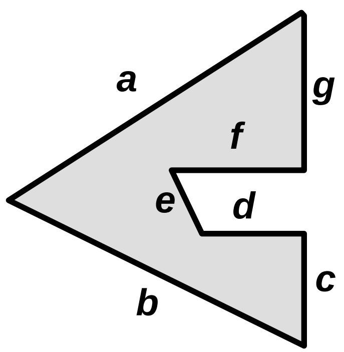


FvDFH Figure 12.20

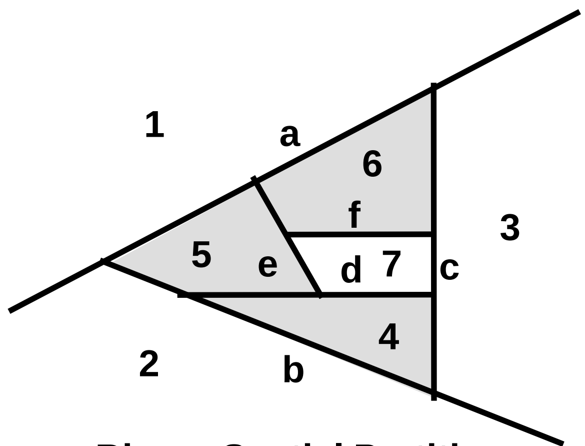
Stanford Graphics Laboratory

BSP Tree

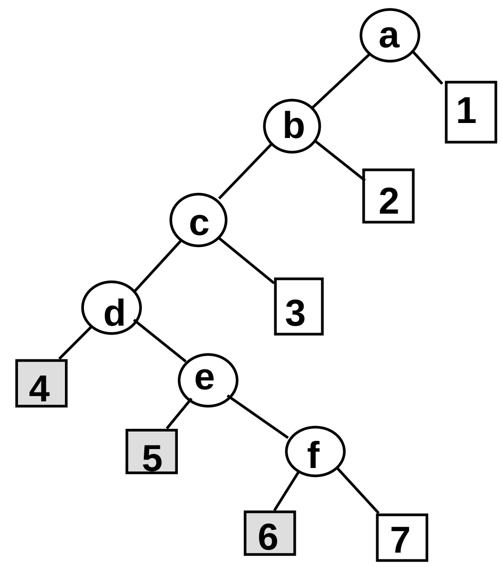
- Binary space partition with solid cells labeled
  - Constructed from polygonal representations



Object



Binary Spatial Partition

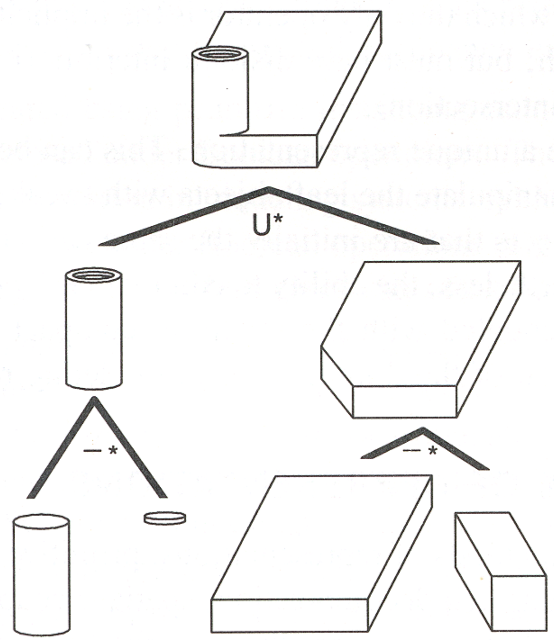


Binary Tree

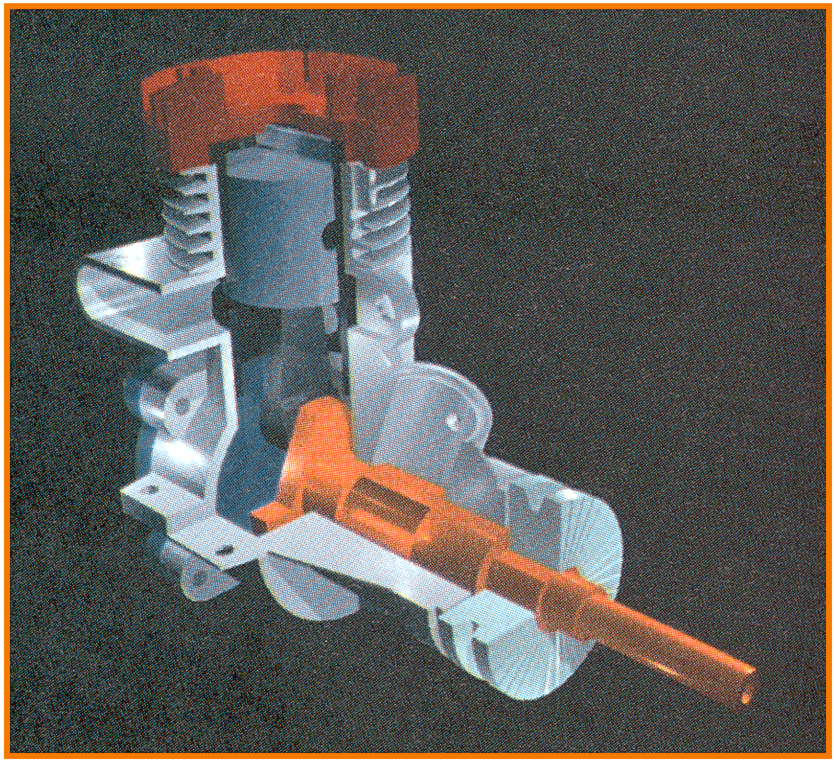
Naylor

CSG

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



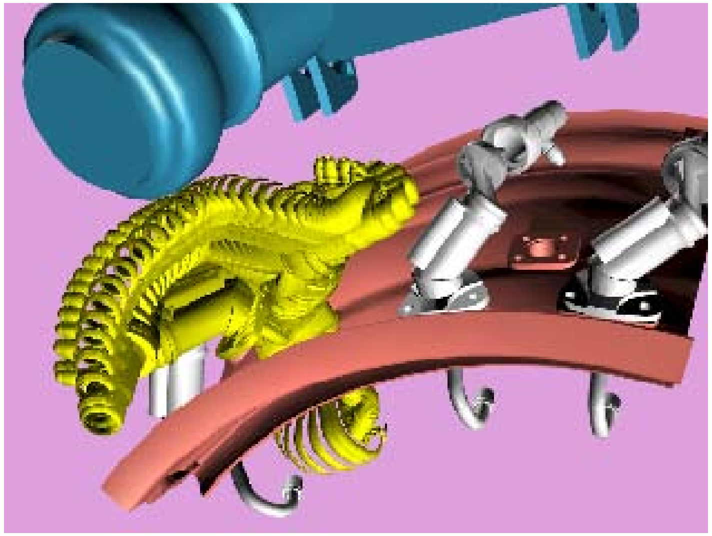
FvDFH Figure 12.27



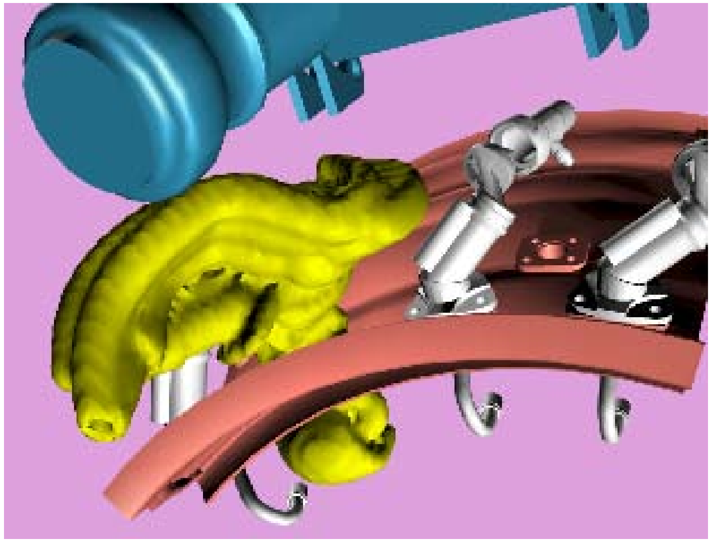
H&B Figure 9.9

Sweep

- Solid swept by curve along trajectory



Removal Path



Sweep Model

Bill Lorensen
SIGGRAPH 99
Course #4 Notes

Outline

- Points
  - Range image
  - Point cloud
- Surfaces
  - Polygonal mesh
  - Subdivision
  - Parametric
  - Implicit
- Solids
  - Voxels
  - BSP tree
  - CSG
  - Sweep
- High-level structures
  - Scene graph
  - Application specific

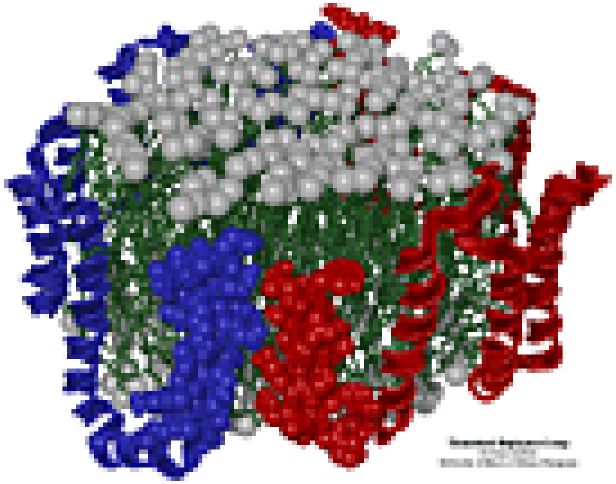
Scene Graph

- Union of objects at leaf nodes

Bell Laboratories

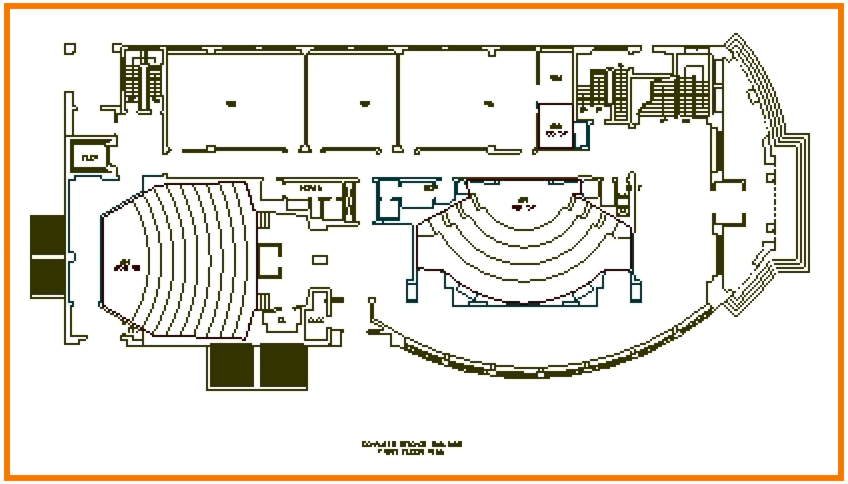
avalon.viewpoint.com

Application Specific



Apo A-1

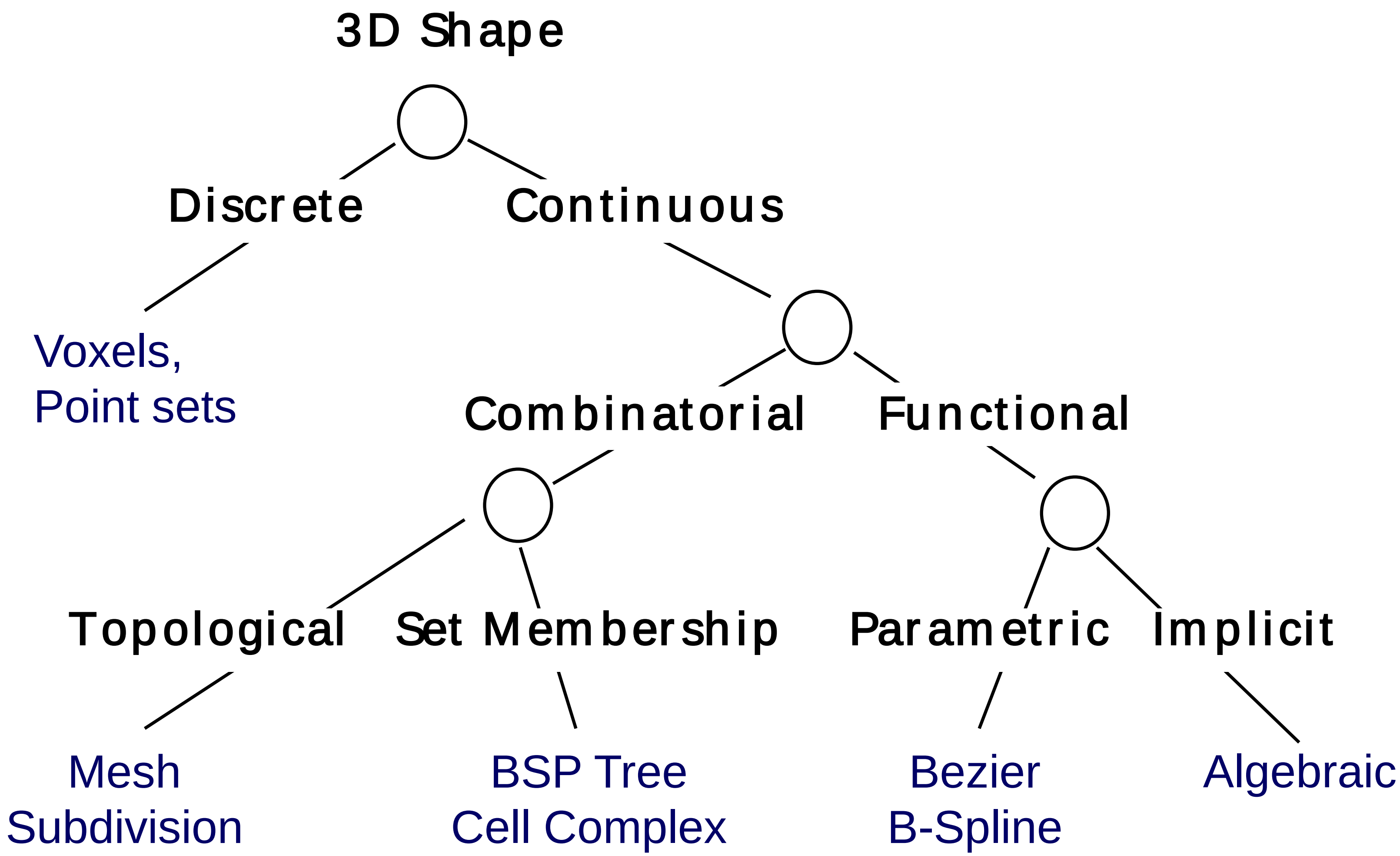
(Theoretical Biophysics Group, University of Illinois at Urbana-Champaign)



Architectural Floorplan

(CS Building, Princeton University)

Taxonomy of 3D Representations



Naylor

Equivalence of Representations

- Thesis:
  - Each fundamental representation has sufficient 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

Upcoming Lectures

- Points
  - Range image
  - Point cloud
- Surfaces
  - Polygonal mesh
  - Subdivision
  - Parametric
  - Implicit
- Solids
  - Voxels
  - BSP tree
  - CSG
  - Sweep
- High-level structures
  - Scene graph
  - Application specific