3D Modeling I

CG08b
Lior Shapira
Lecture 8

Based on:

Thomas Funkhouser,Princeton University

Course Syllabus

I. Image processing

II. Rendering

III. Modeling

IV. Animation

Rendering

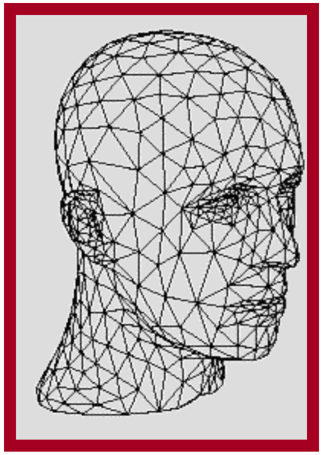
(Michael Bostock, CS426, Fall99)

Image Processing

(Rusty Coleman, CS426, Fall99)

Modeling

(Dennis Zorin, CalTech)

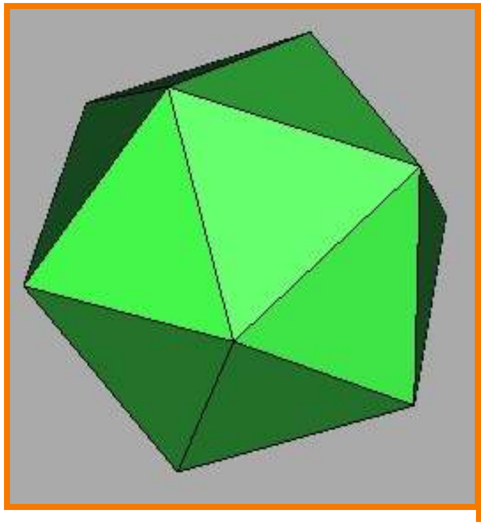


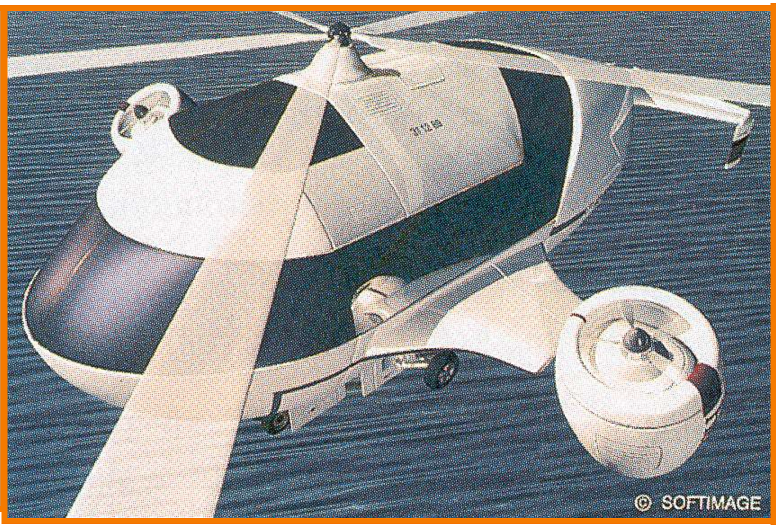
Animation

(Angel, Plate 1)

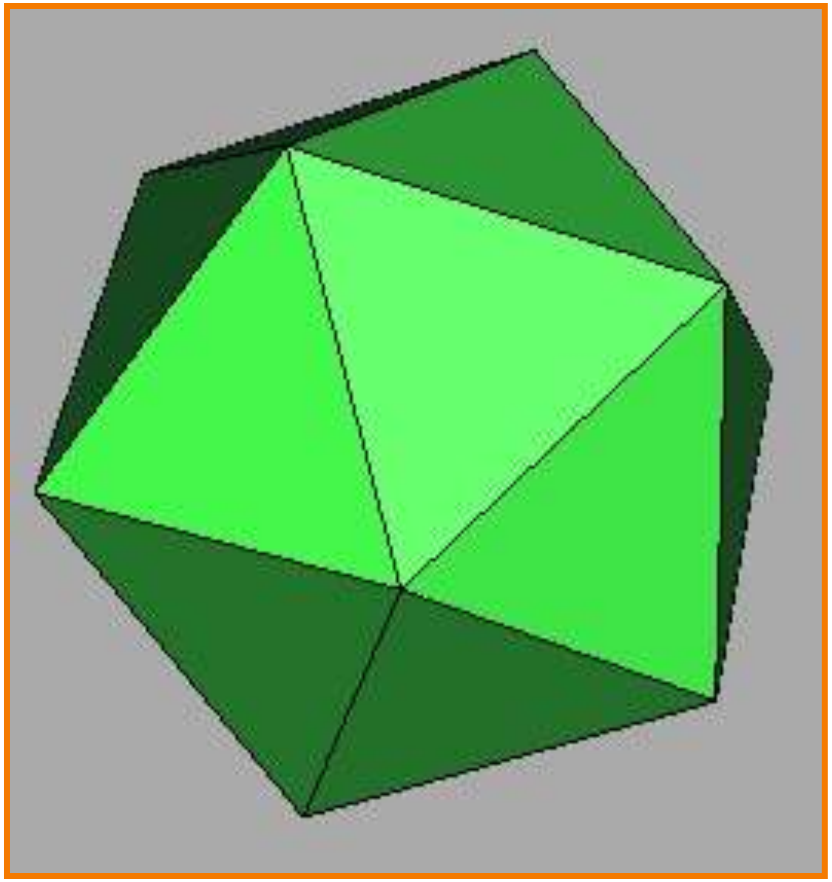
Modeling

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



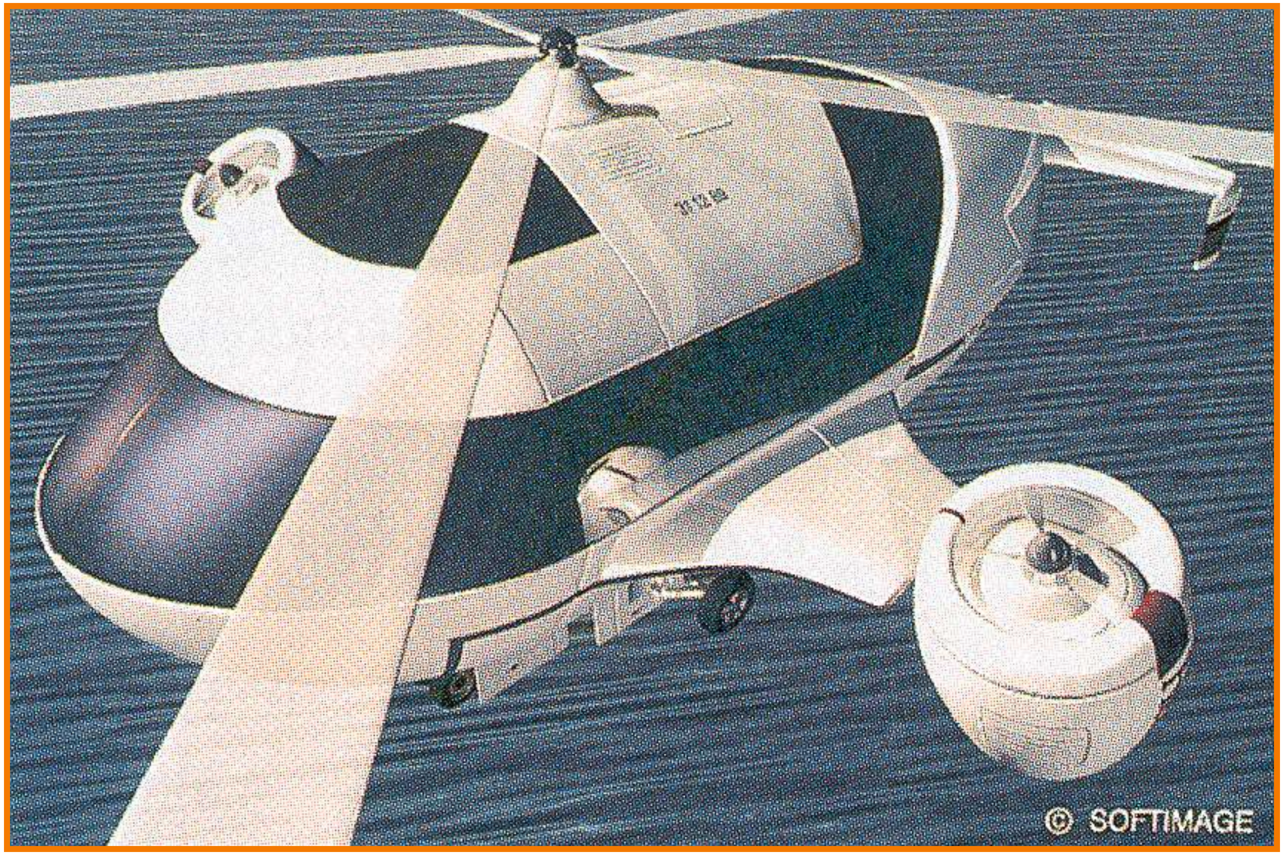


3D Objects



How can this object be represented in a computer?

3D Objects



H&B Figure 10.46

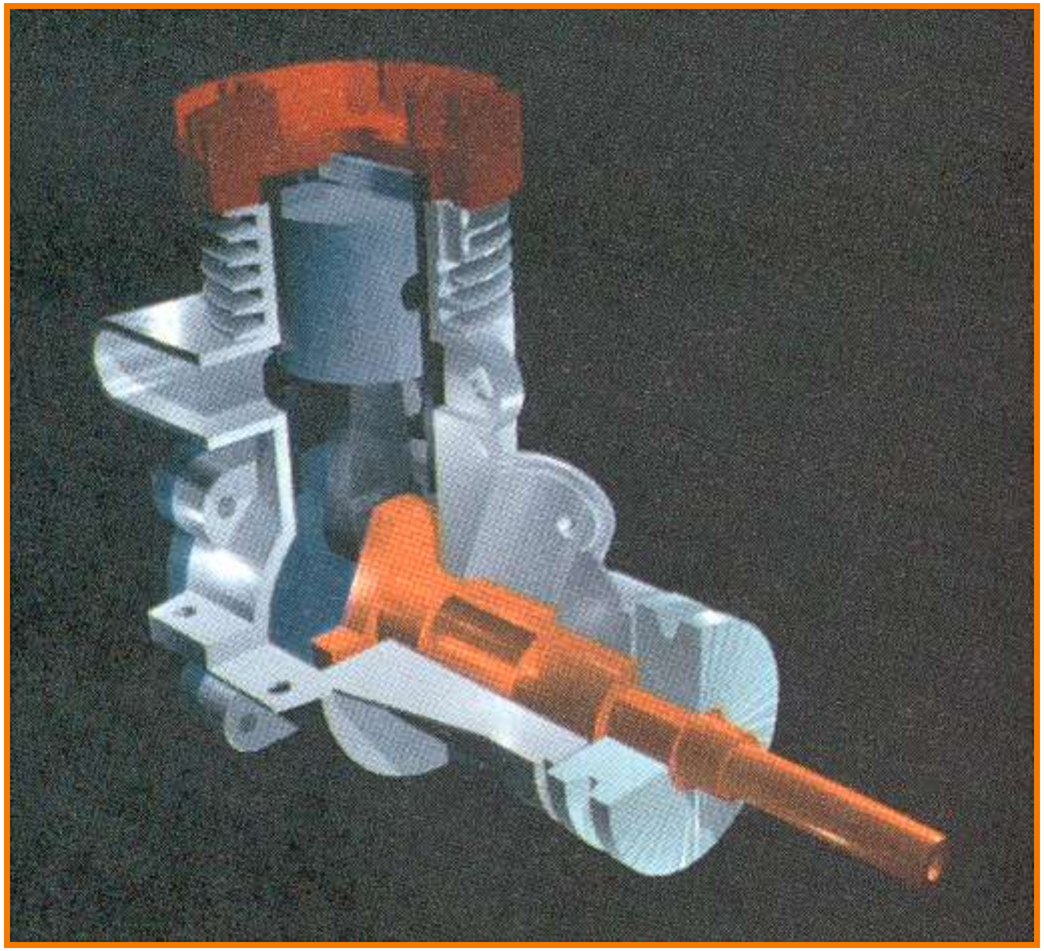
This one?

3D Objects

Stanford Graphics Laboratory

How about this one?

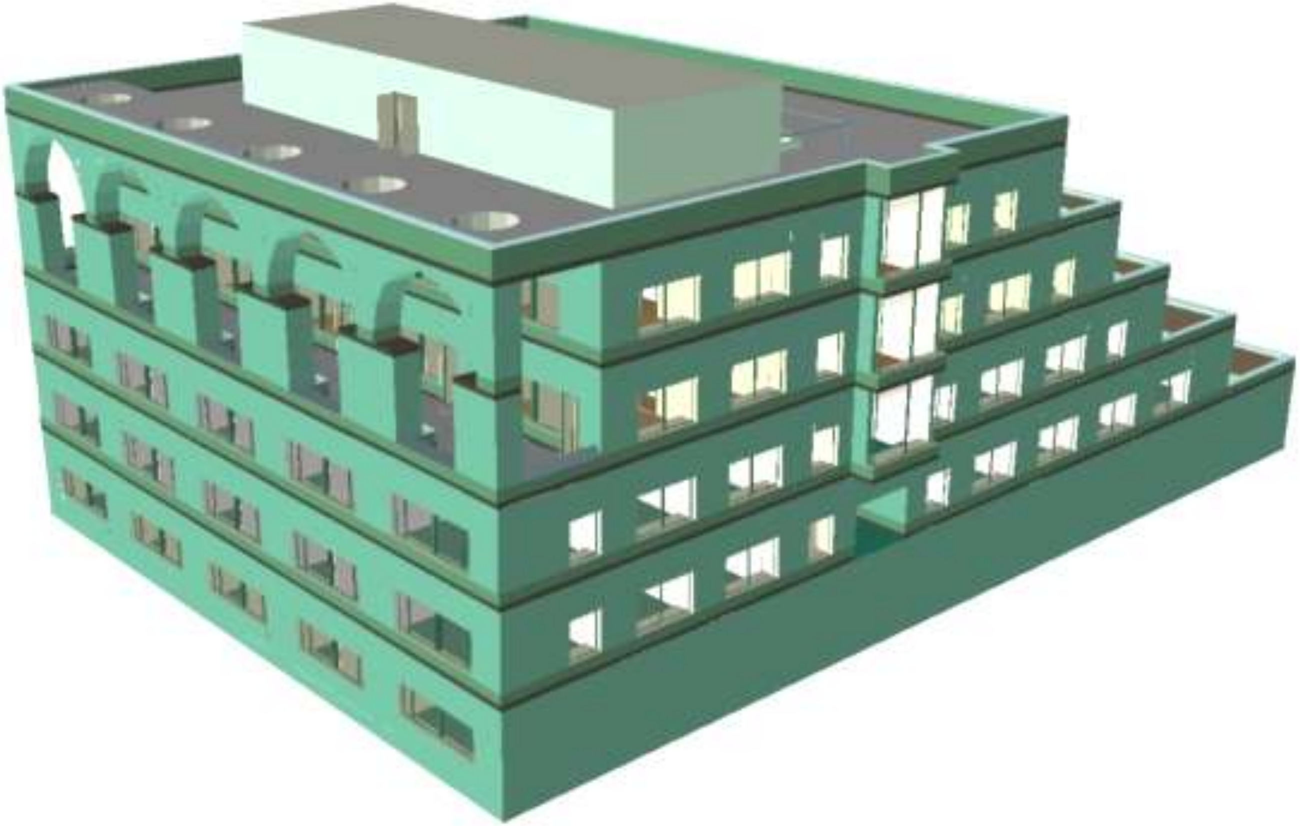
3D Objects



H&B Figure 9.9

This one?

3D Objects



This one?

3D Object Representations

- Points
  - Point cloud
  - Range image
- 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 / programming languages Turing-equivalent. But each does different things better!

Why different Representations?

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

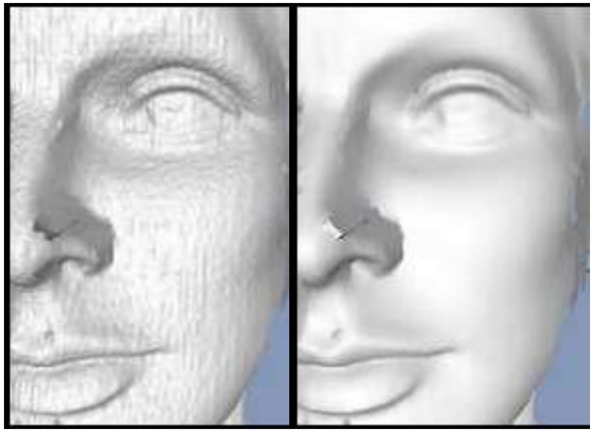
Data Structures determine algorithms!

Modeling Operations

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

Digital Michealangelo

Pirates of the carribean



Smoothing

3D Object Representations

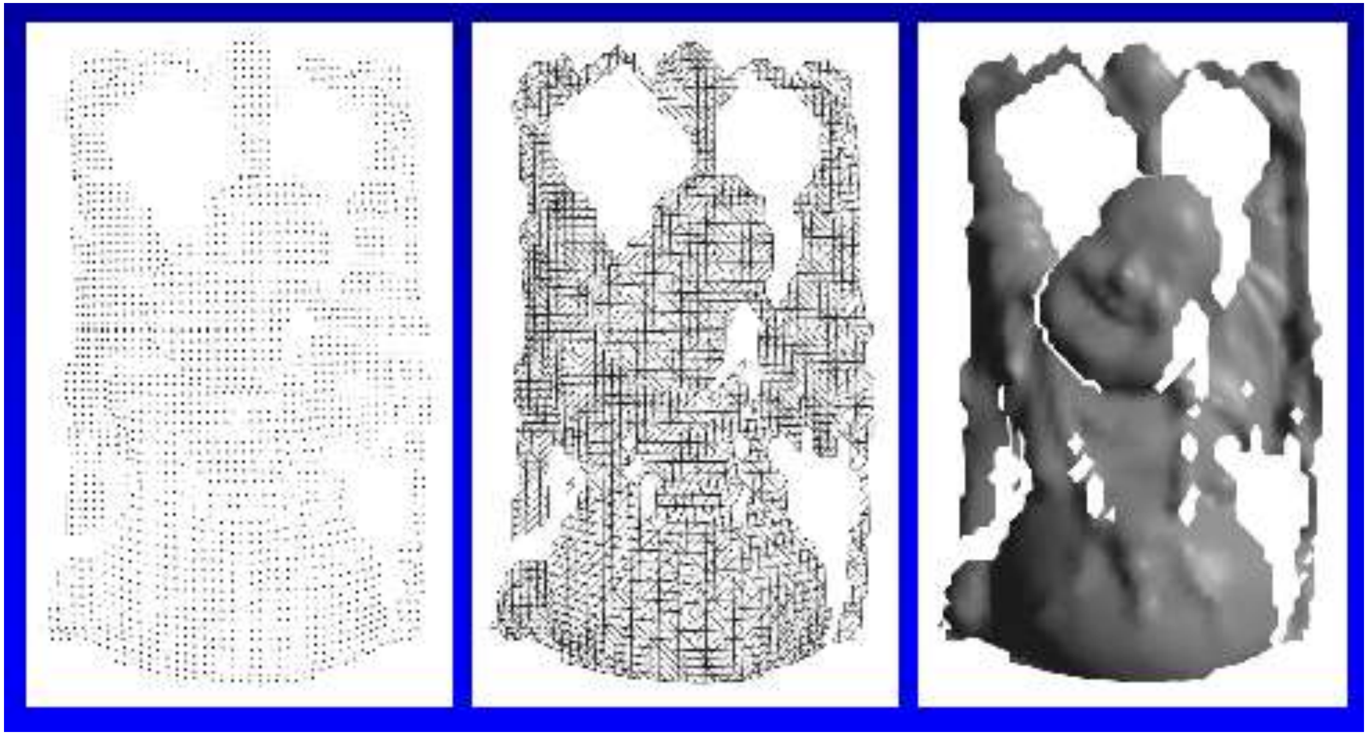
- Desirable properties depend on intended use
  - Easy to acquire
  - Accurate
  - Concise
  - Intuitive editing
  - Efficient editing
  - Efficient display
  - Efficient intersections
  - Guaranteed validity
  - Guaranteed smoothness
  - …

Outline

- Points
  - Point cloud
  - Range image
- 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

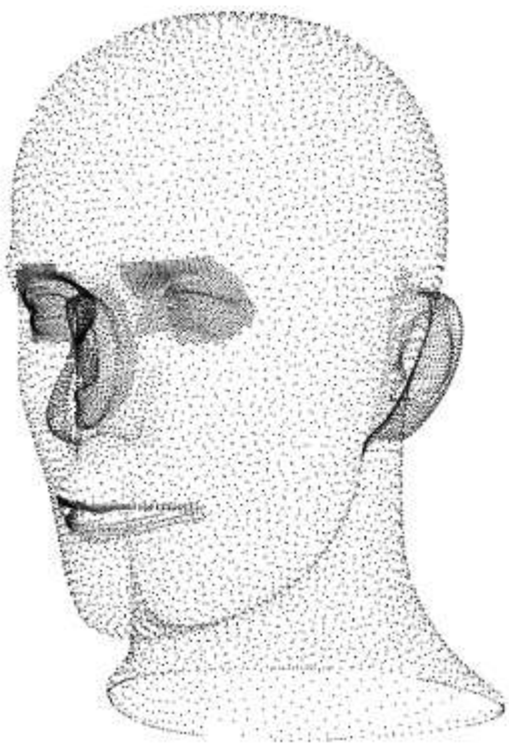


Range Image Tesselation Range Surface

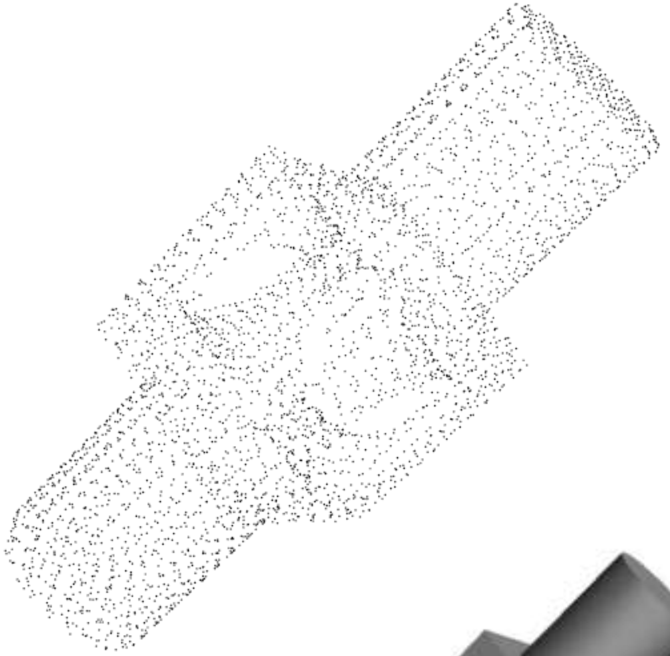
Brian Curless
SIGGRAPH 99
Course #4 Notes

Point Cloud

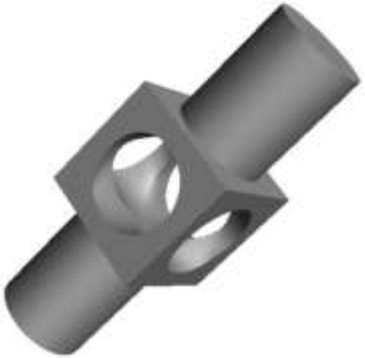
- Unstructured set of 3D point samples
  - Acquired from range finder, computer vision, etc



Hugues Hoppe



Hugues Hoppe

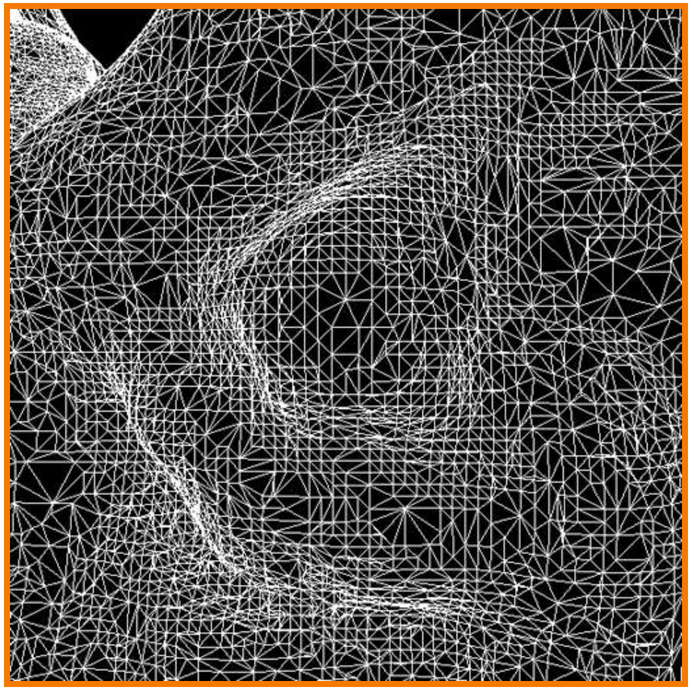


Outline

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

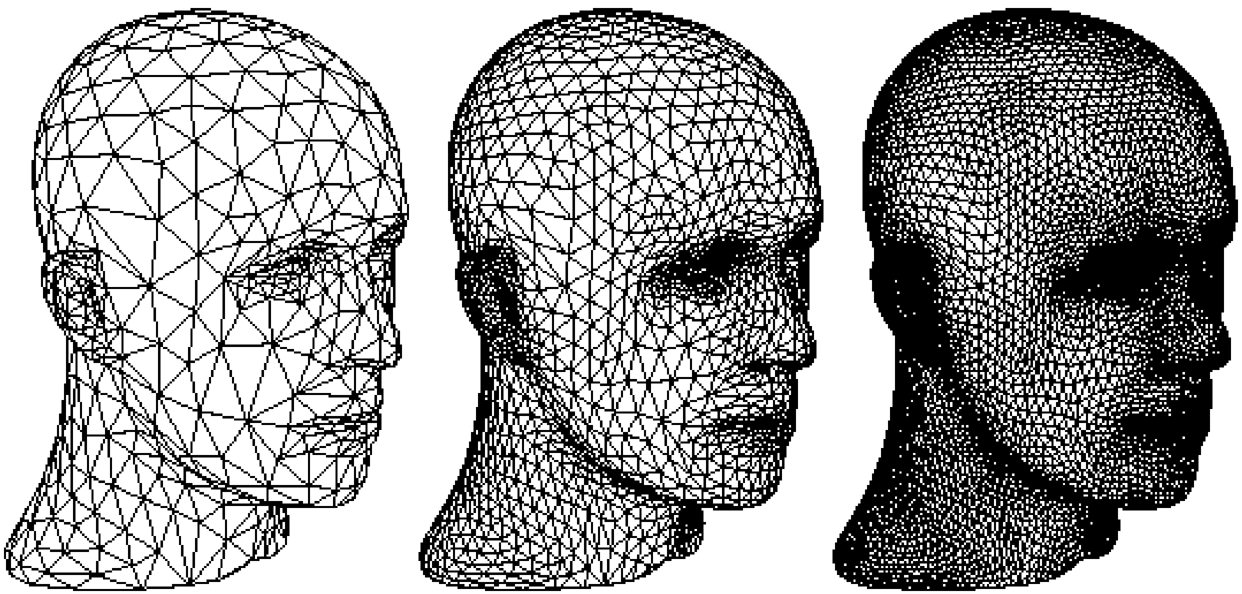
Polygonal Mesh

- Connected set of polygons (usually triangles)



Subdivision Surface

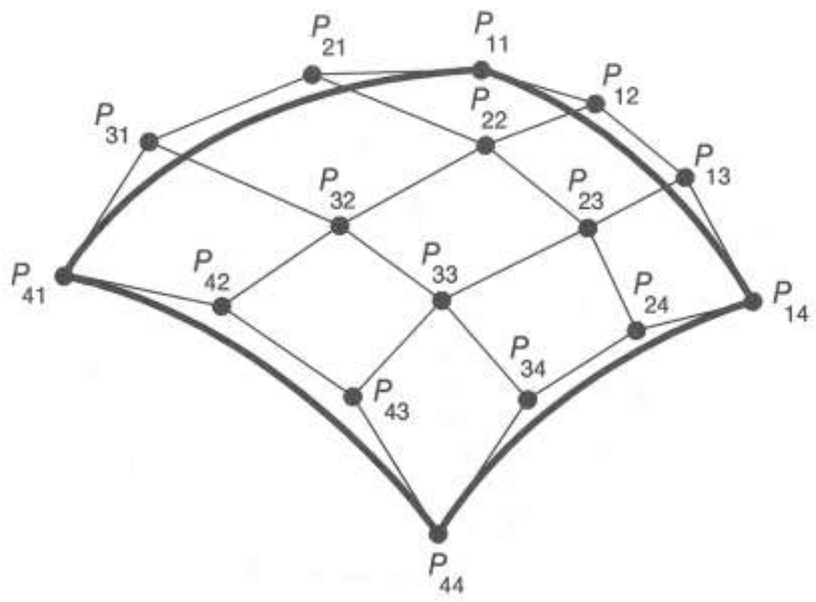
- Coarse mesh & subdivision rule
  - Define smooth surface as limit of sequence of refinements



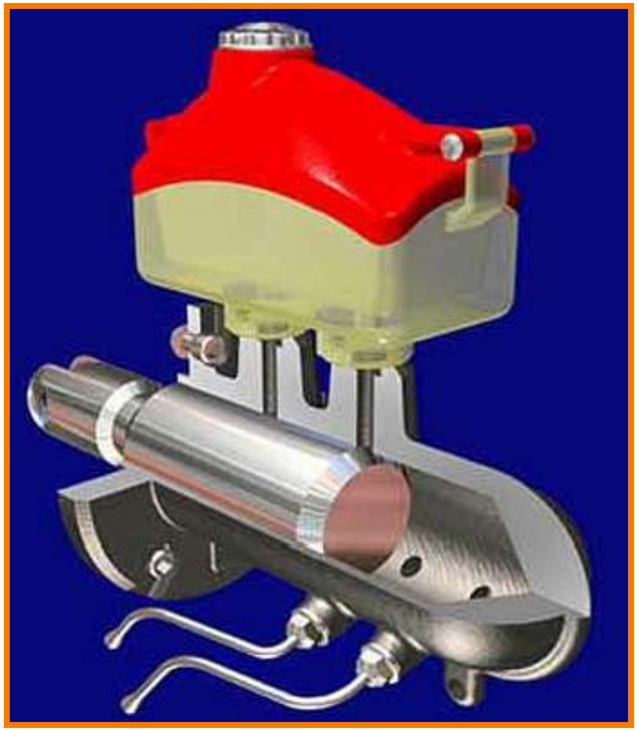
Zorin & Schroeder
SIGGRAPH 99
Course Notes

Parametric Surface

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

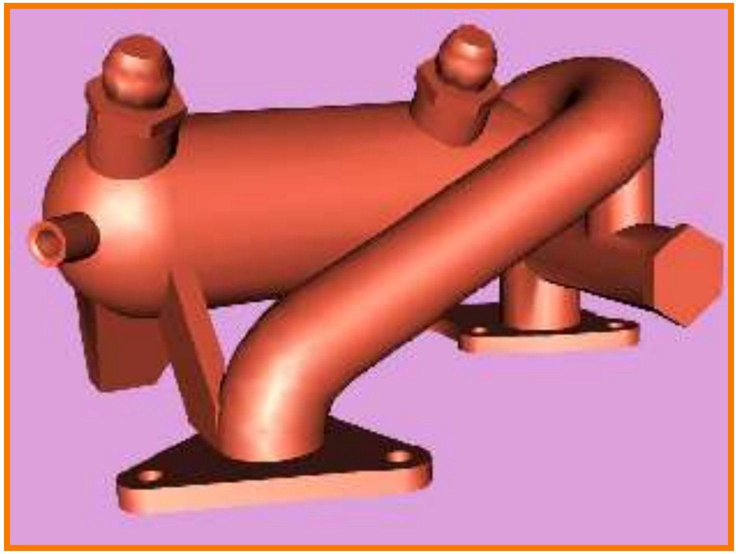


FvDFH Figure 11.44

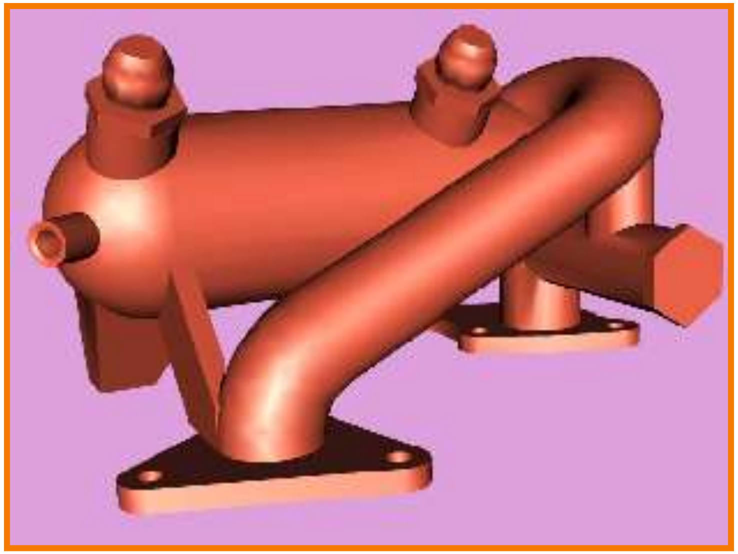


Implicit Surface

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



Polygonal Model



Implicit Model

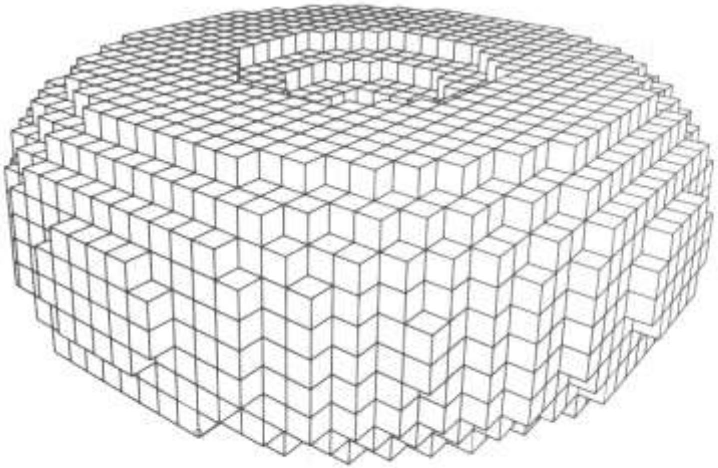
Bill Lorensen
SIGGRAPH 99
Course #4 Notes

Outline

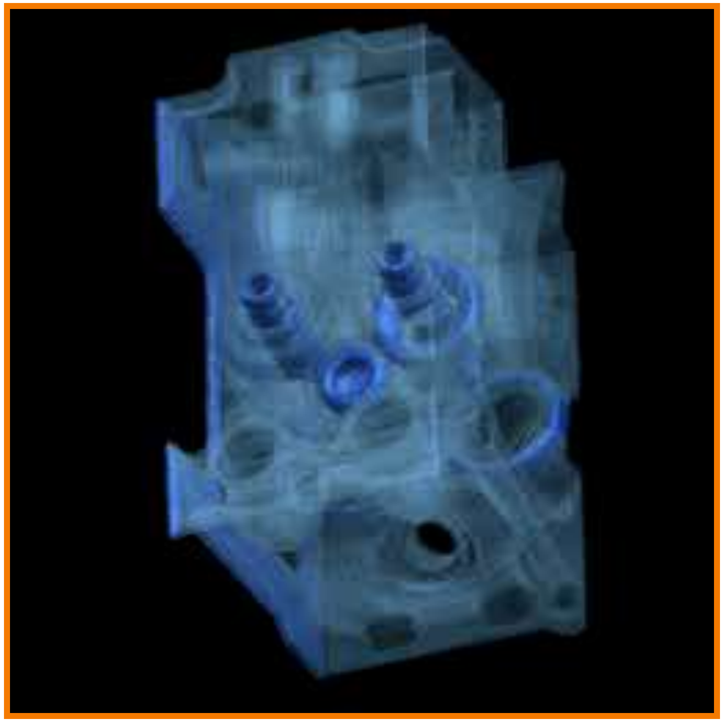
- Points
  - Point cloud
  - Range image
- Surfaces
  - Polygonal Mesh
  - Subdivision
  - Parametric
  - Implicit
- Solids
  - Voxels
  - BSP tree
  - CSG
  - Sweep
- High-level structures
  - Scene graph
  - Application specific

Voxels

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



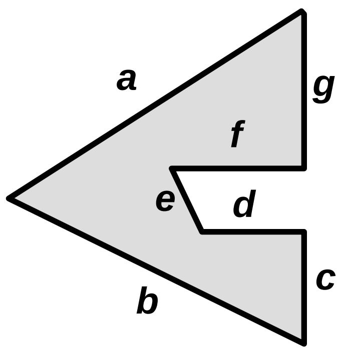
FvDFH Figure 12.20



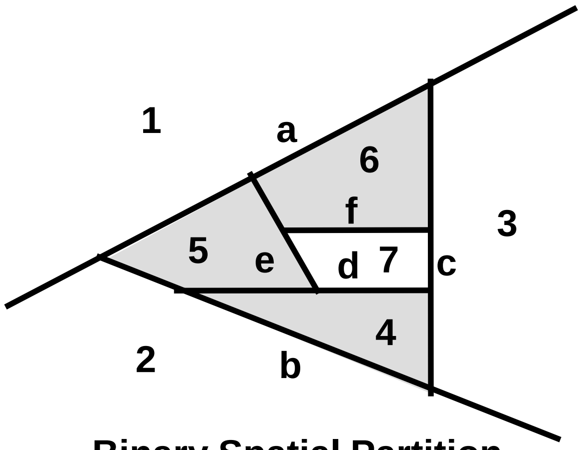
Stanford Graphics Laboratory

BSP Tree

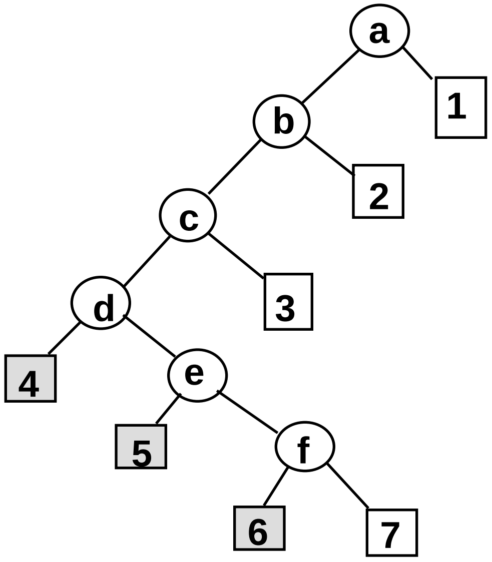
- Binary space partition with solid cells labeled
  - Constructed from polygonal representations



Object



Binary Spatial Partition



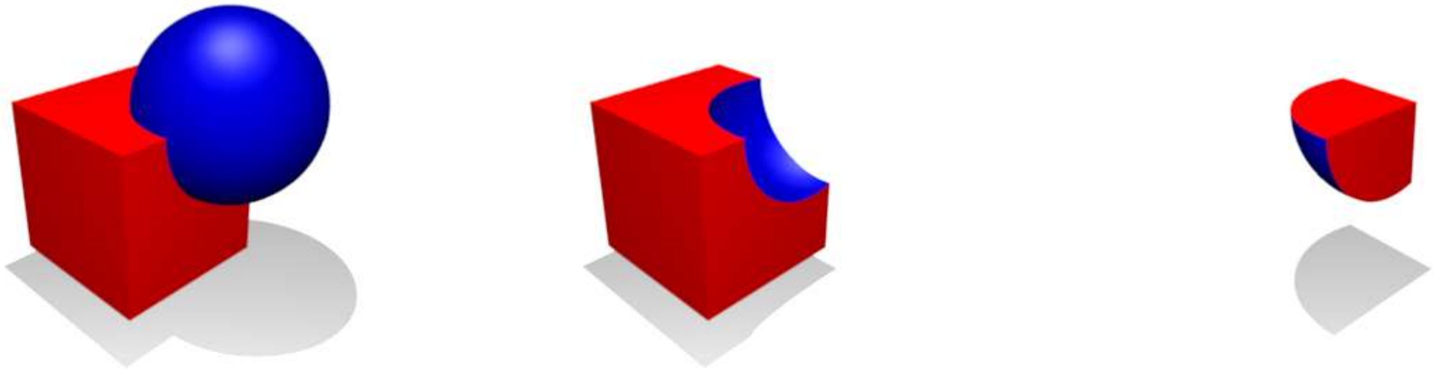
Binary Tree

Naylor

CSG (constructive solid geometry)

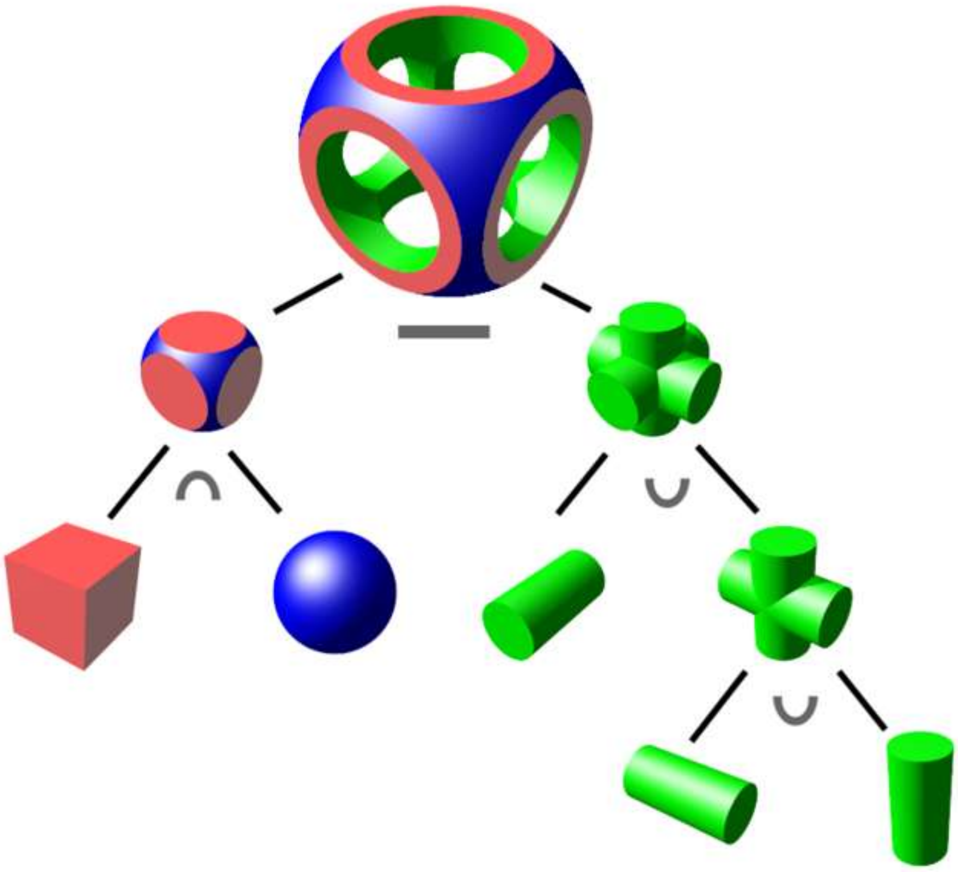
- Hierarchy of boolean set operations (union, difference, intersect) applied to simple shapes

Boolean union Boolean difference Boolean intersection



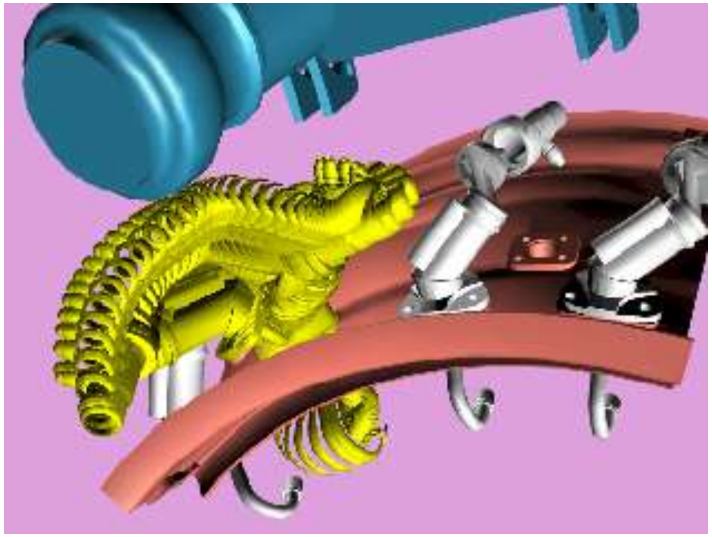
CSG (constructive solid geometry)

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

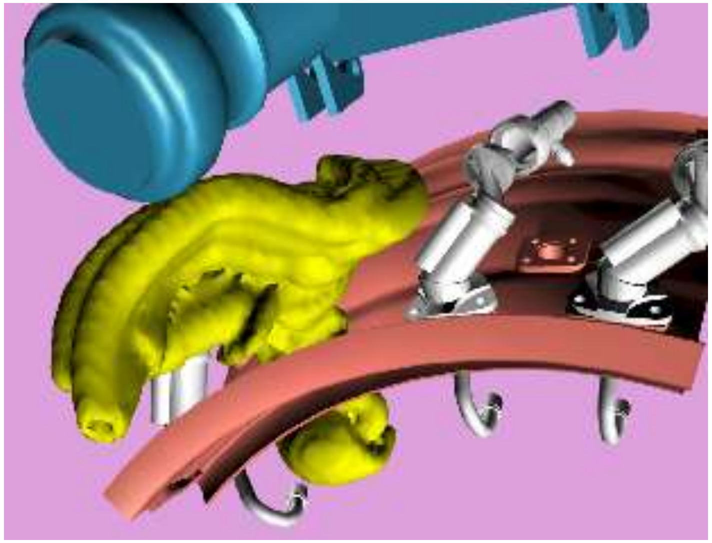


Sweep

- Solid swept by curve along trajectory



Removal Path



Sweep Model

Bill Lorensen
SIGGRAPH 99
Course #4 Notes

Outline

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

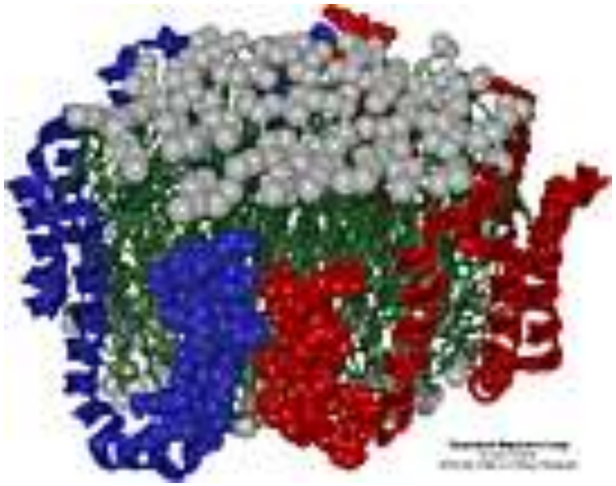
Scene Graph

- Union of objects at leaf nodes

Bell Laboratories

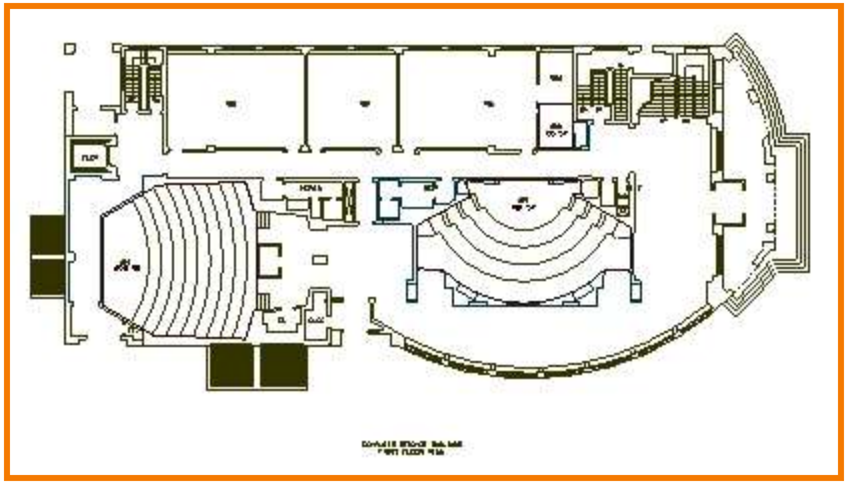
avalon.viewpoint.com

Application Specific



Apo A-1

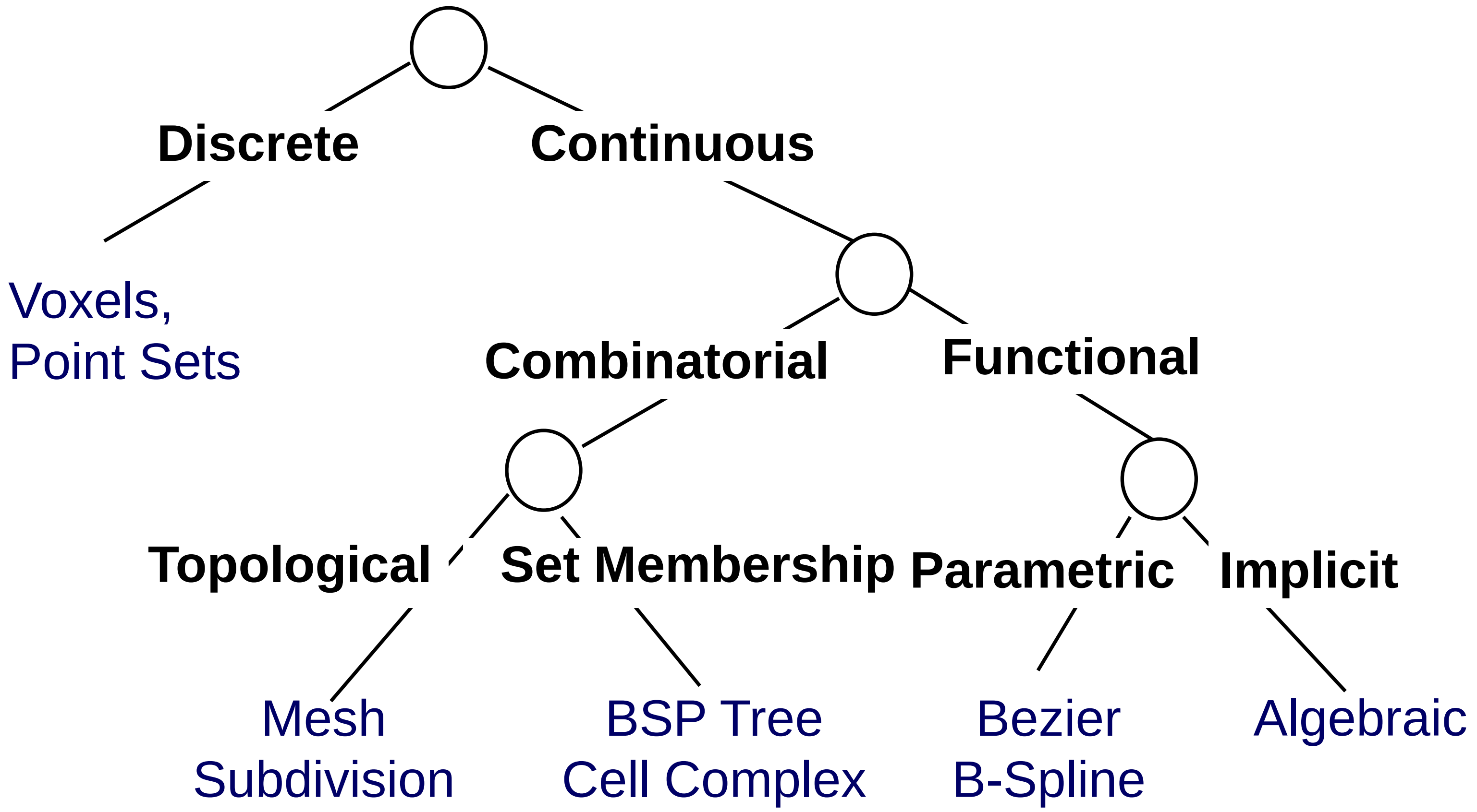
(Theoretical Biophysics Group,
University of Illinois at Urbana-Champaign)



Architectural Floorplan

(CS Building, Princeton University)

Taxonomy of 3D Representations



Naylor

Equivalence of Representations

- Thesis:
  - Each 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 / programming languages Turing-equivalent. But each does different things better!

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