# Overview of 3D Object Representations

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Princeton University
C0S 426, Fall 2000

## Course Syllabus

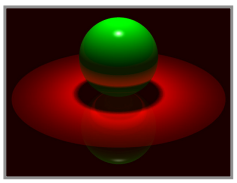
I. Image processing

II. Rendering

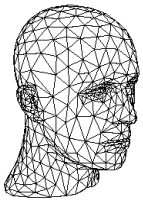
III. Modeling

IV. Animation

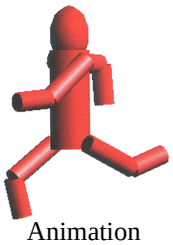
Image Processing
*(Rusty Coleman, CS426, Fall99)*



Rendering
*(Michael Bostock, CS426, Fall99)*



Modeling
*(Dennis Zorin, CalTech)*



Animation
*(Angel, Plate 1)*

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Image Processing
*(Rusty Coleman, CS426, Fall99)*

Rendering
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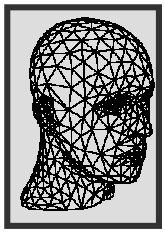
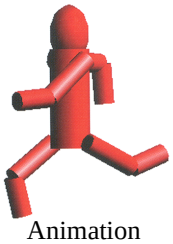


**Modeling**
*(Dennis Zorin, CalTech)*



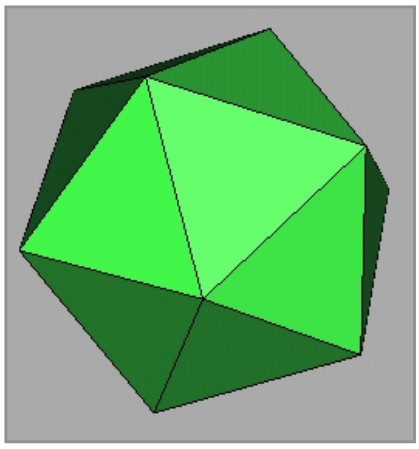
Animation
*(Angel, Plate 1)*

# 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?

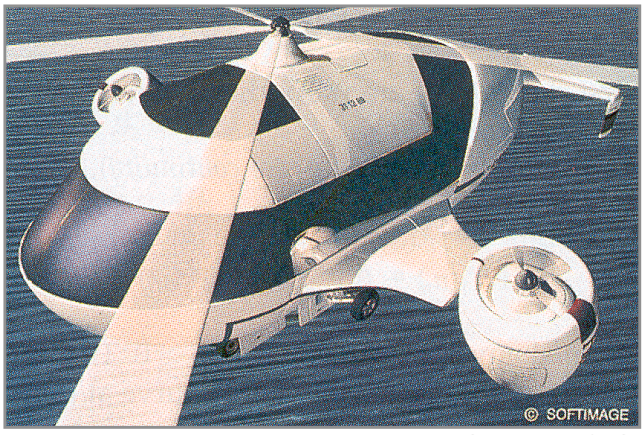
Different methods for different object representations

## 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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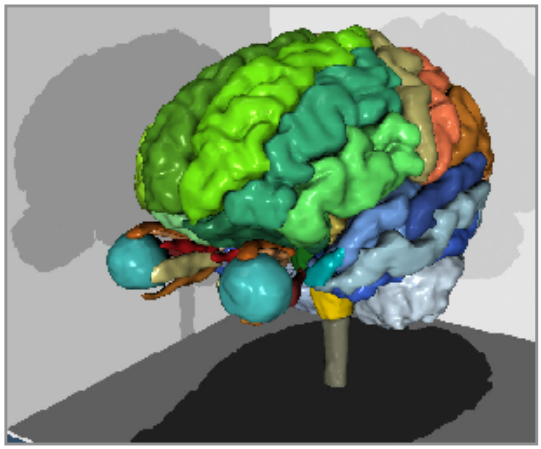
How about this one?

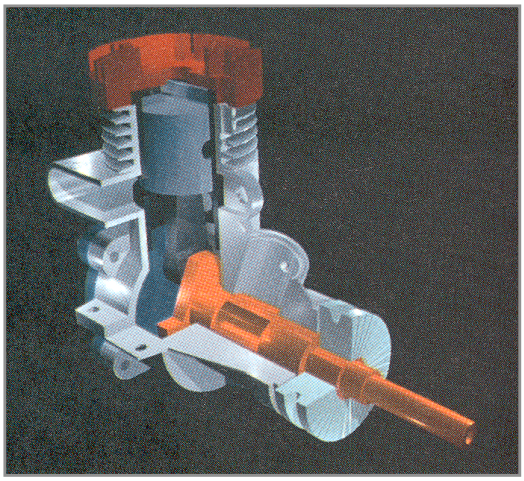
## 3D Objects



Lorensen

This one?

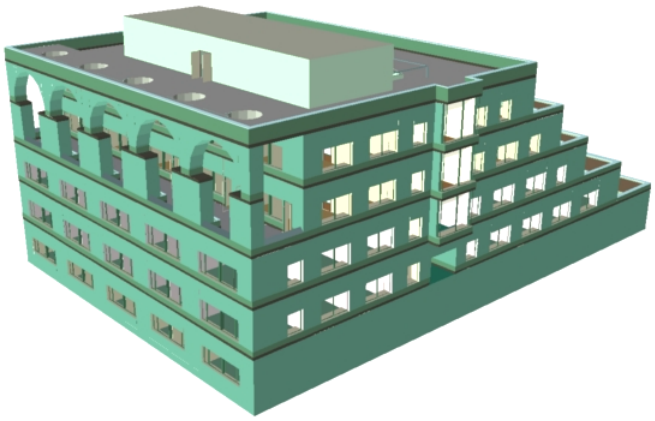
## 3D Objects



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** |

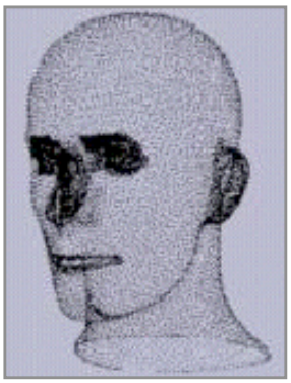
- Data structures determine algorithms!

## 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



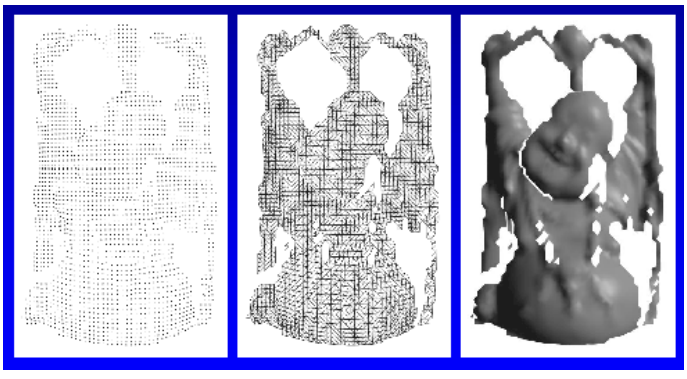
Hoppe

Hoppe

## Range Image



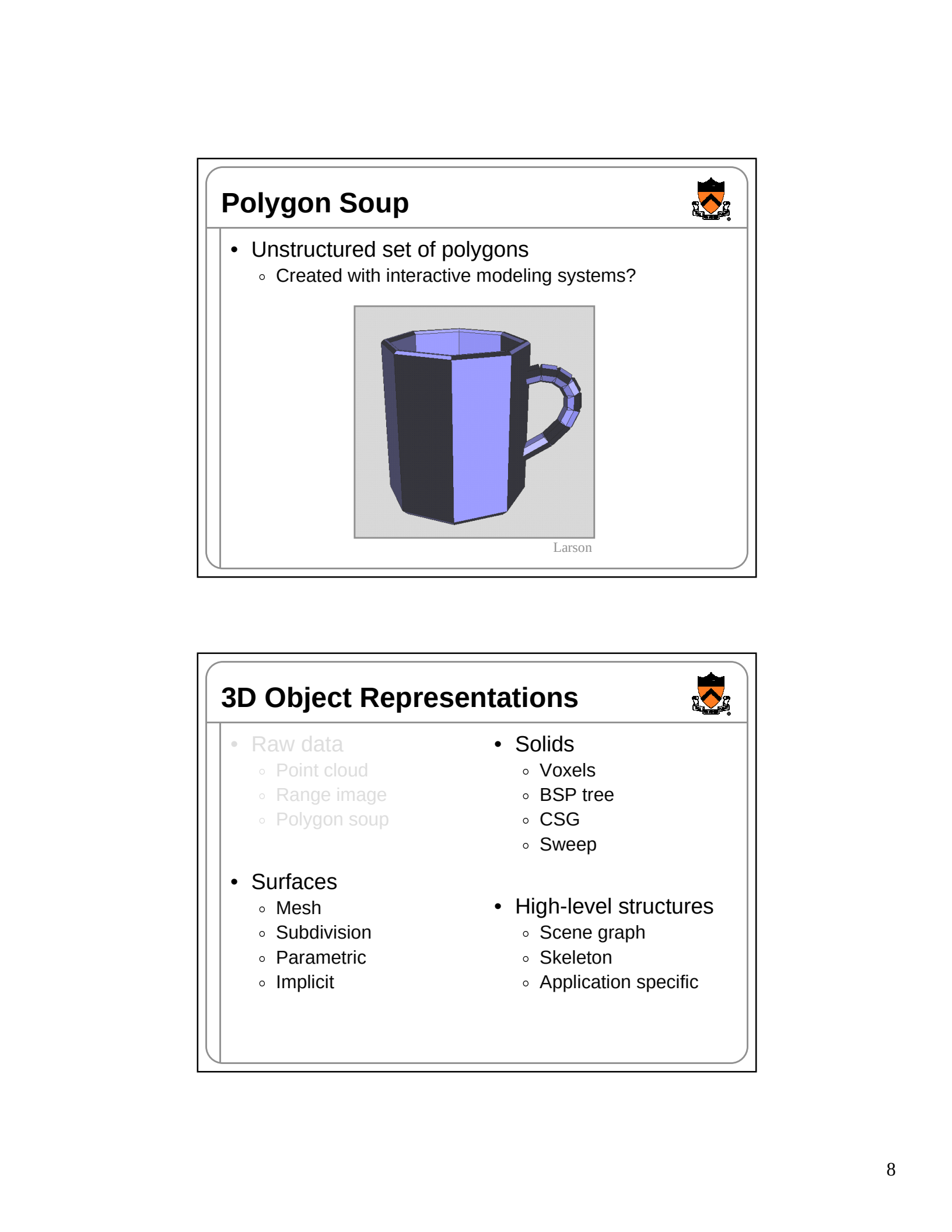
- Set of 3D points mapping to pixels of depth image
  - Acquired from range scanner



Range Image Tesselation Range Surface

Brian Curless
SIGGRAPH 99
Course #4 Notes

## Polygon Soup



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



Larson

## 3D Object Representations



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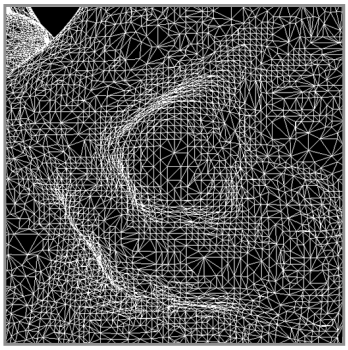
## Mesh



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



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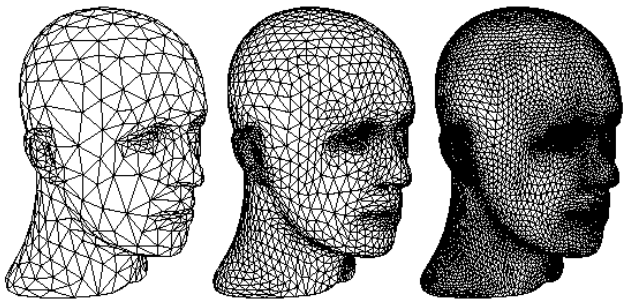
## Subdivision Surface



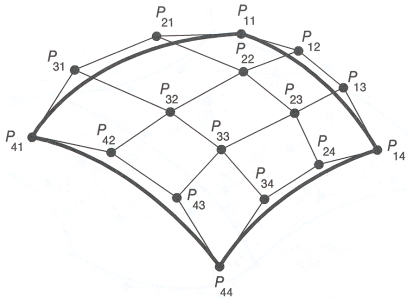
- Coarse mesh & subdivision rule
  - Define smooth surface as limit of sequence of refinements



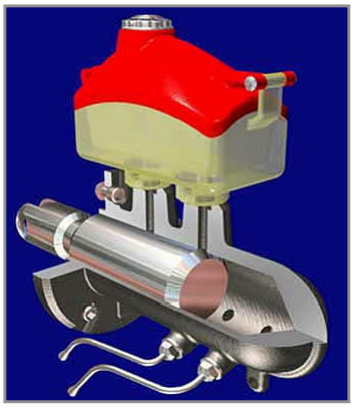
Zorin & Schroeder
SIGGRAPH 99
Course Notes

## Parametric Surface

- Tensor product spline patchs
  - Careful constraints to maintain continuity



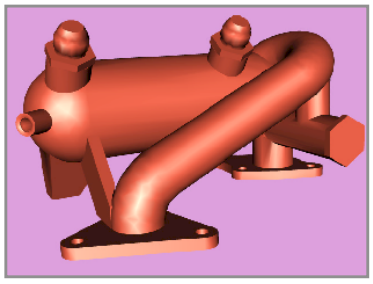

FvDFH Figure 11.44



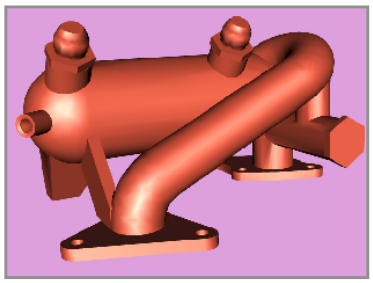
## Implicit Surface



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



Polygonal Model



Implicit Model

Bill Lorensen
SIGGRAPH 99
Course #4 Notes

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  - Skeleton
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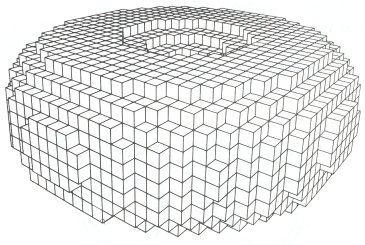
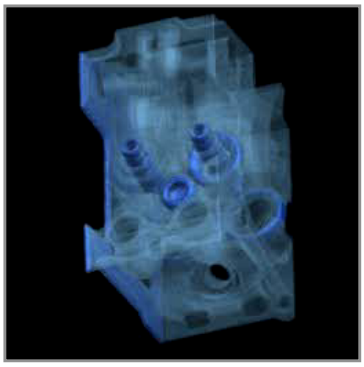
## Voxels

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



FvDFH Figure 12.20



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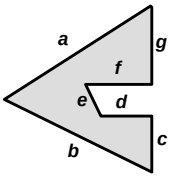
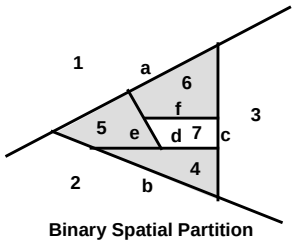
# BSP Tree



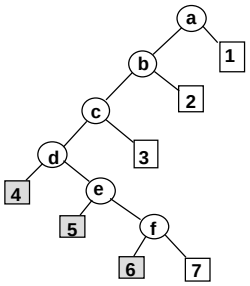
- Binary space partition with solid cells labeled
  - Constructed from polygonal representations




Object




Binary Spatial Partition



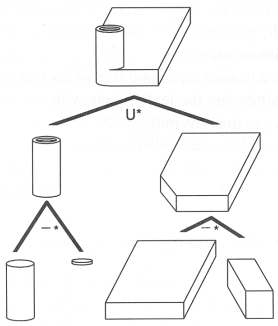

Binary Tree

Naylor

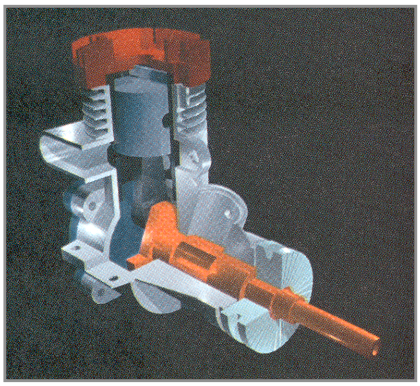
# CSG



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




FvDFH Figure 12.27

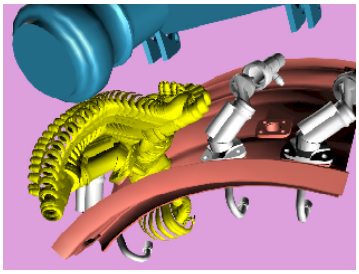


H&B Figure 9.9

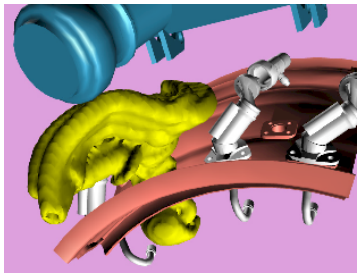
## Sweep



- Solid swept by curve along trajectory



Removal Path



Sweep Model

Bill Lorensen
SIGGRAPH 99
Course #4 Notes

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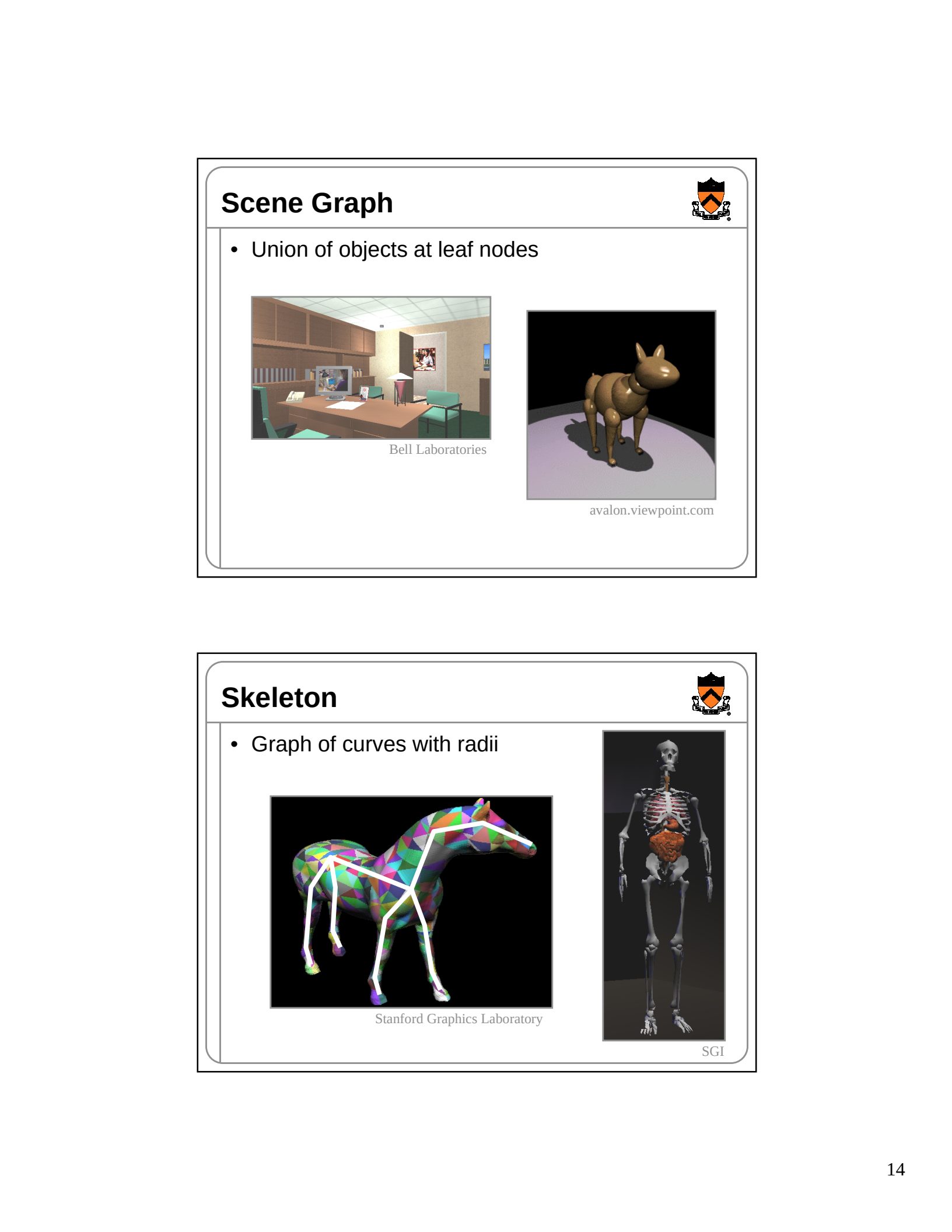
## Scene Graph



- Union of objects at leaf nodes



Bell Laboratories



avalon.viewpoint.com

## Skeleton



- Graph of curves with radii



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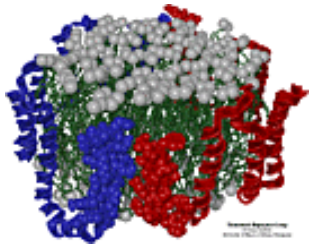
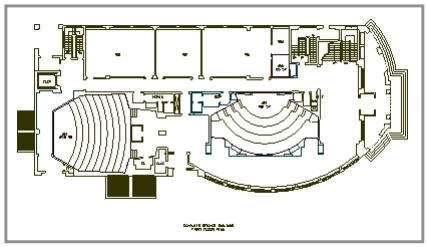
SGI

# Application Specific



Apo A-1

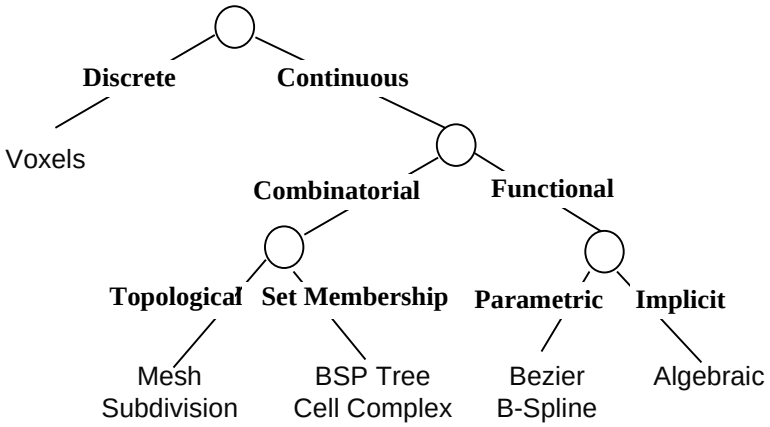
*(Theoretical Biophysics Group, University of Illinois at Urbana-Champaign)*



Architectural Floorplan

*(CS Building, Princeton University)*

# Taxonomy of 3D Representations




Naylor

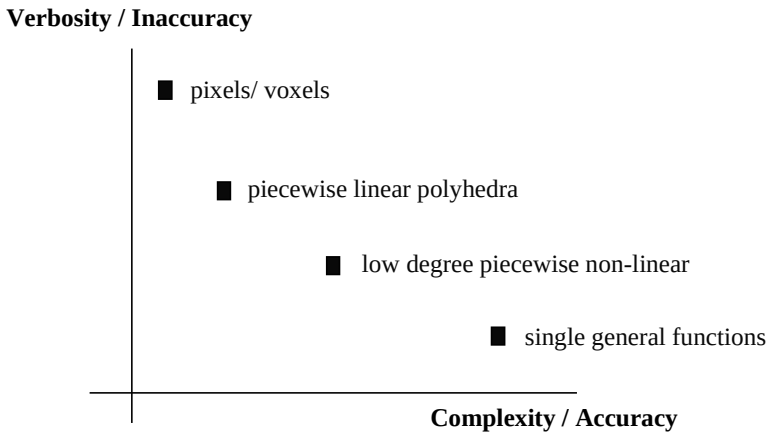
## Equivalence of Representations

- Thesis:
  - 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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