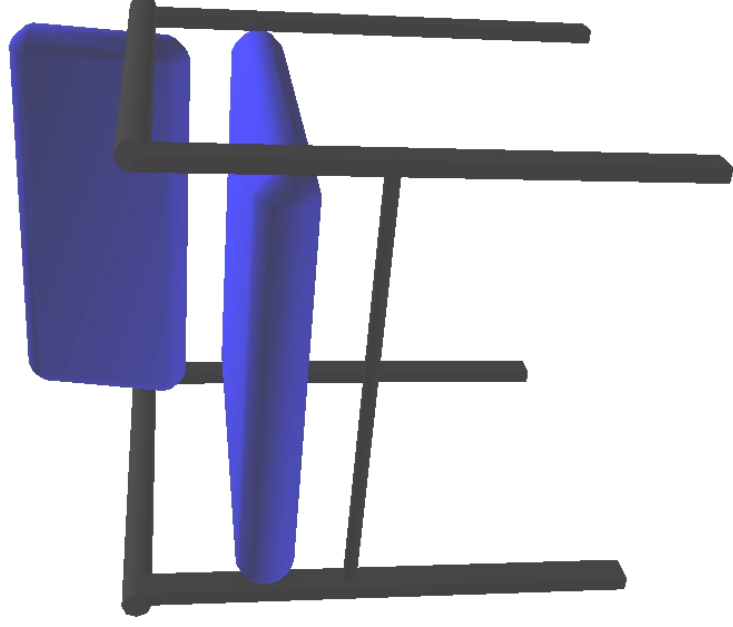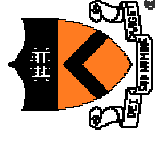# Review of
3D Object Representations

Thomas Funkhouser

Princeton University

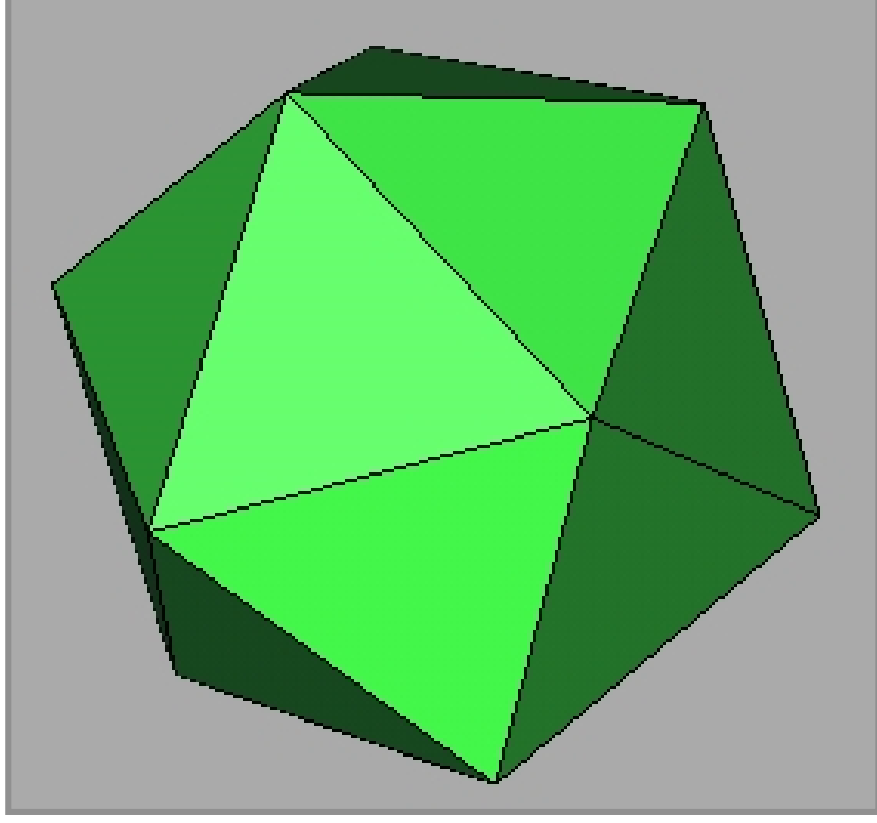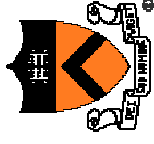COS 598B, Spring 2000

Goal

- Develop algorithms for analysis of 3D models
  - Reconstruction
  - Segmentation
  - Feature detection
  - Labeling
  - Matching
  - Classification
  - Retrieval
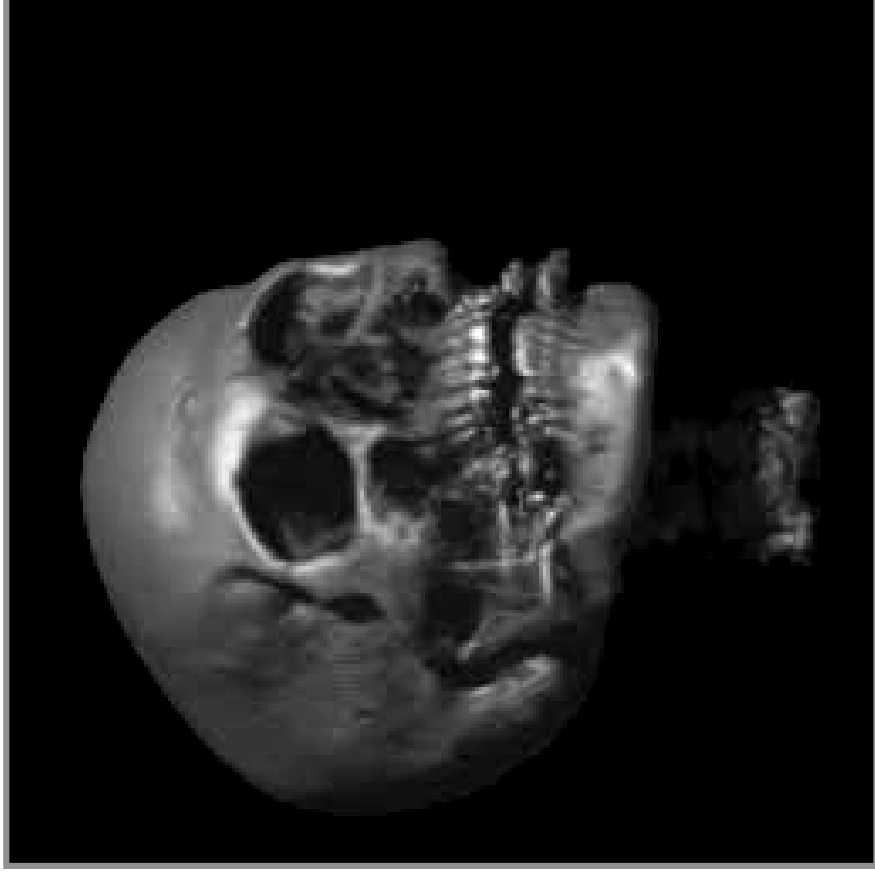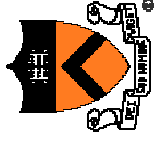 - Recognition
  - Clustering

Different methods for different object representations

3D Objects

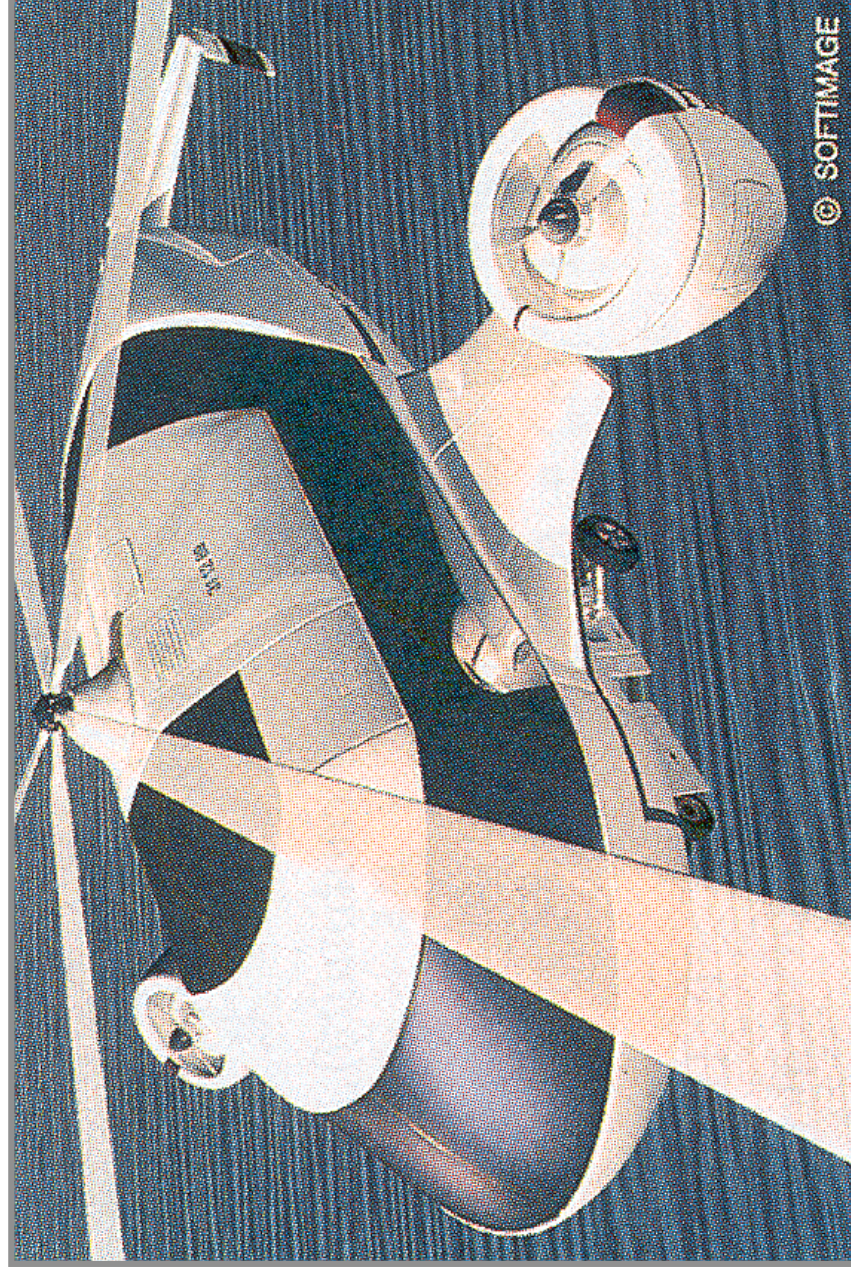How can this object be represented in a computer?

3D Objects

How about this one?
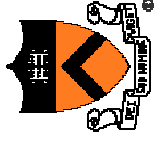
3D Objects

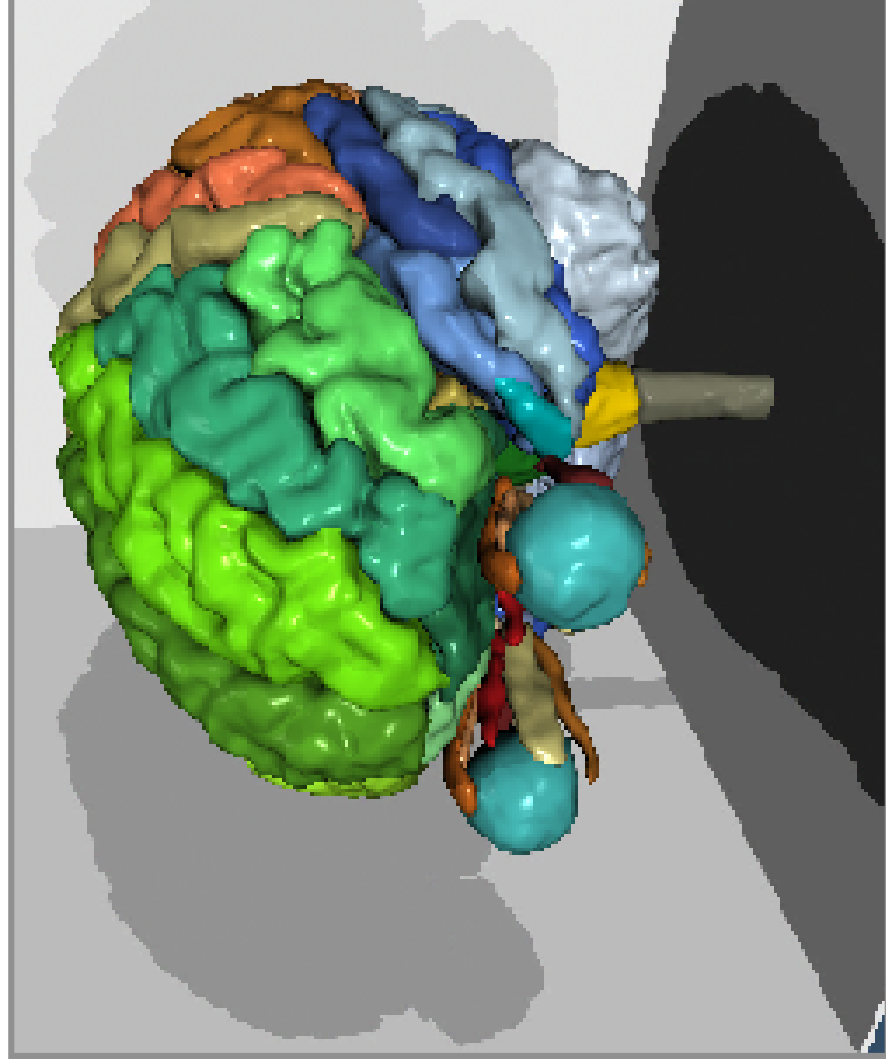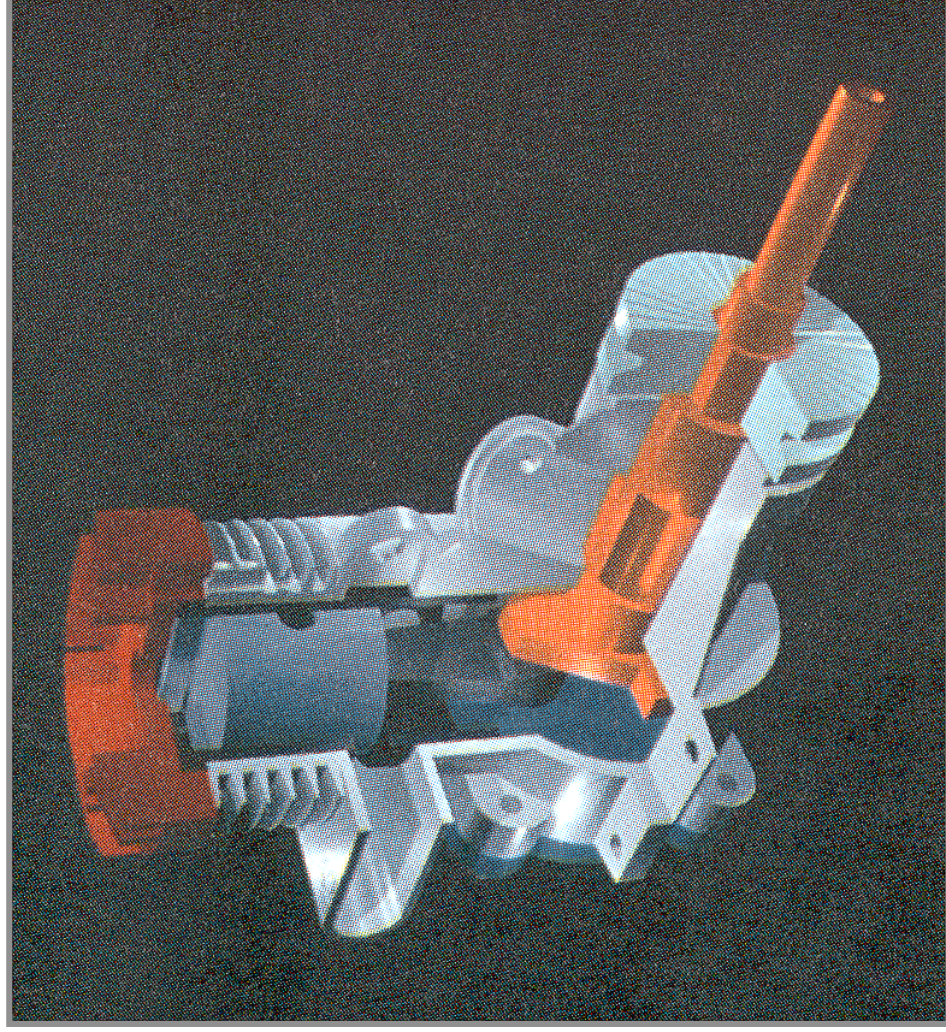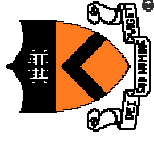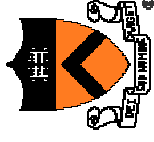H&B Figure 10.46
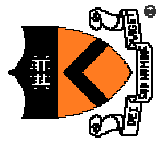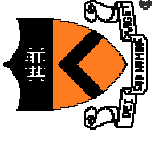
This one?

3D Objects

Lorensen

This one?

3D Objects
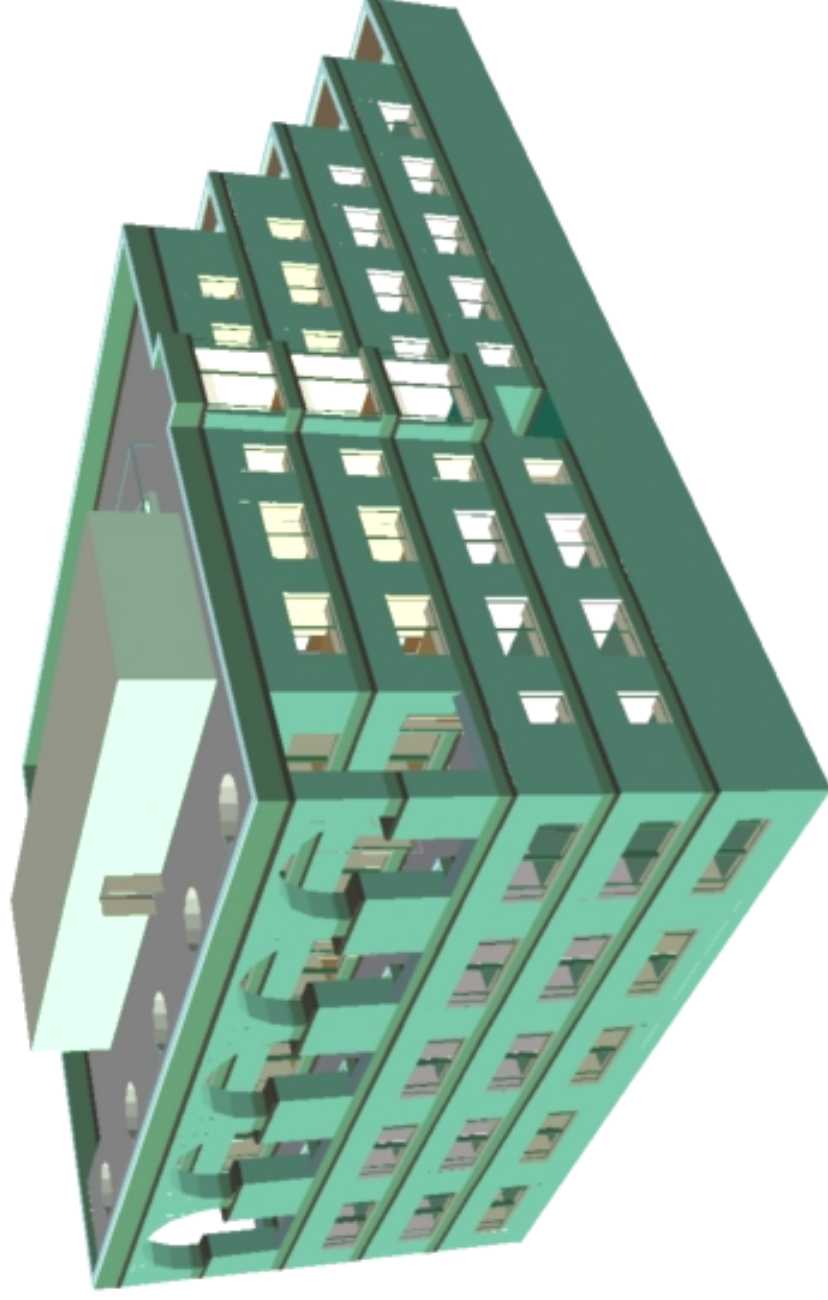
This one?

3D Objects

This one?

3D Object Representations

- Raw data
  - Point cloud
  - Range image
  - Polygon soup

- Surfaces
  - Mesh
  - Subdivision
  - Parametric
  - Implicit

- Solids
  - Voxels
  - BSP tree
  - Cell complex

- High-level structures
  - CSG
  - Constrained blocks
  - Generative model
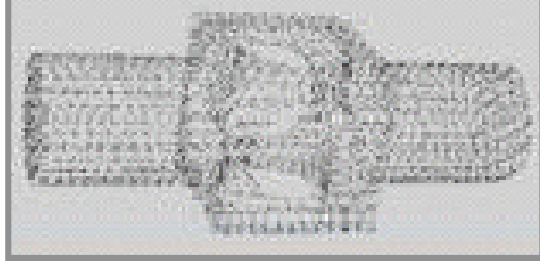 - Skeleton
  - Sweep
  - Scene graph

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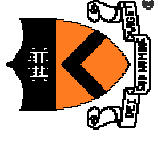
- Unstructured set of 3D point samples
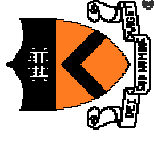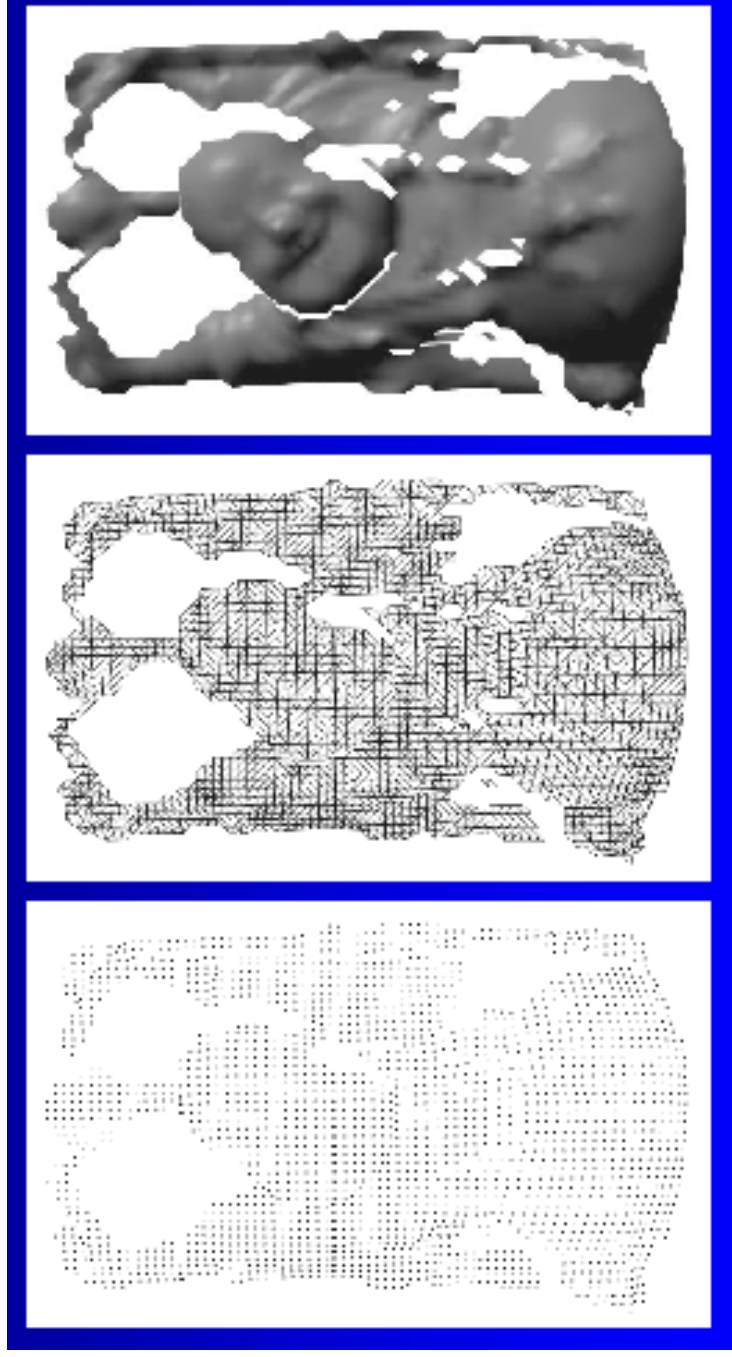 - Acquired from range finder, computer vision, etc
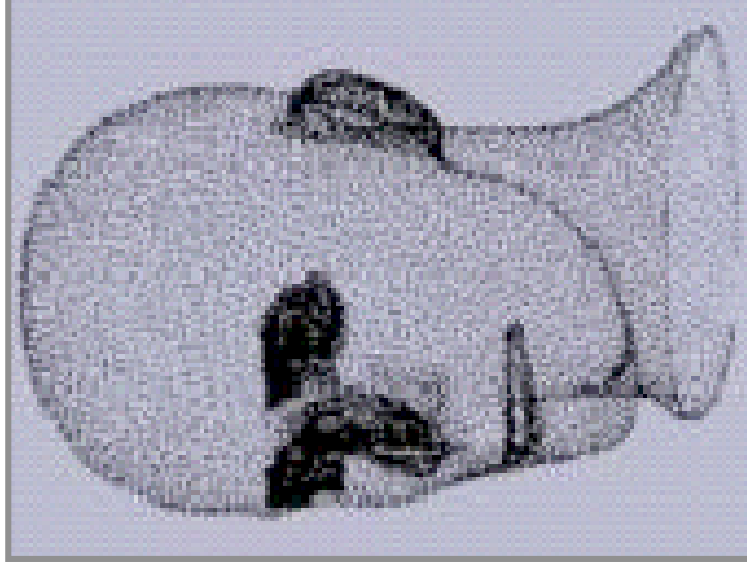
Hoppe

Hoppe

Range Image

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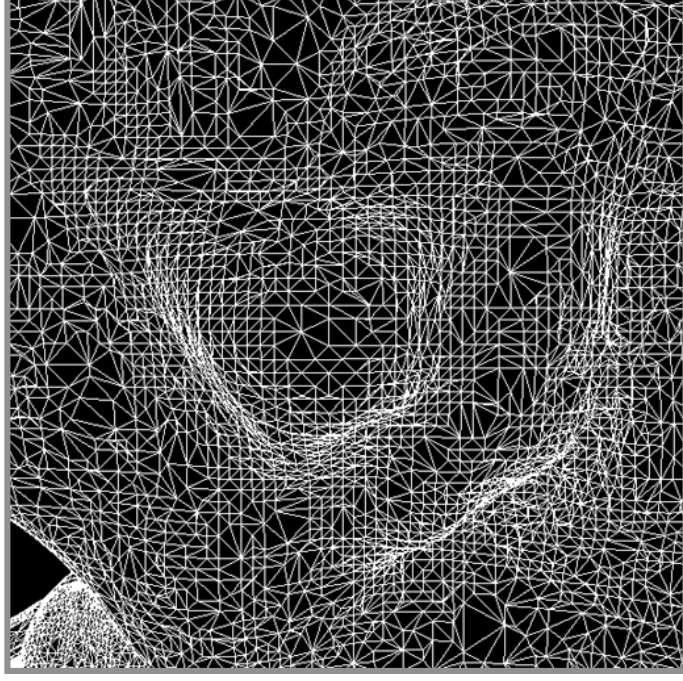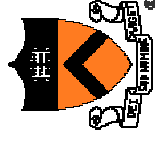 - Acquired from range scanner

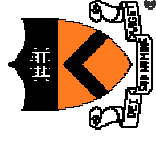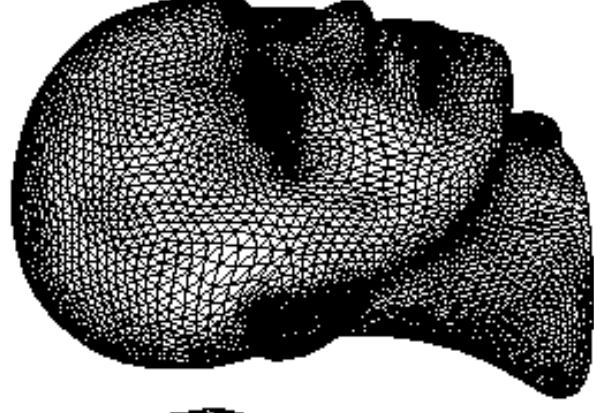
Range Image   Tesselation   Range Surface
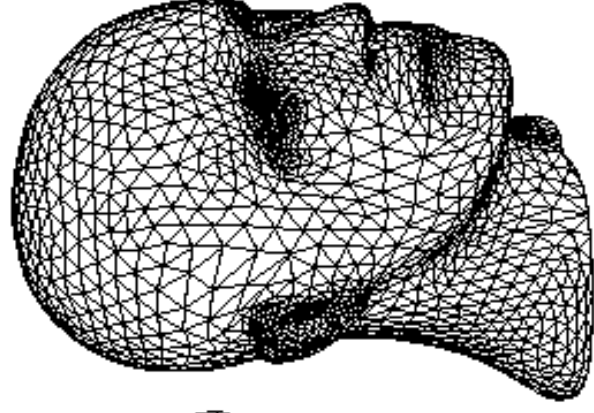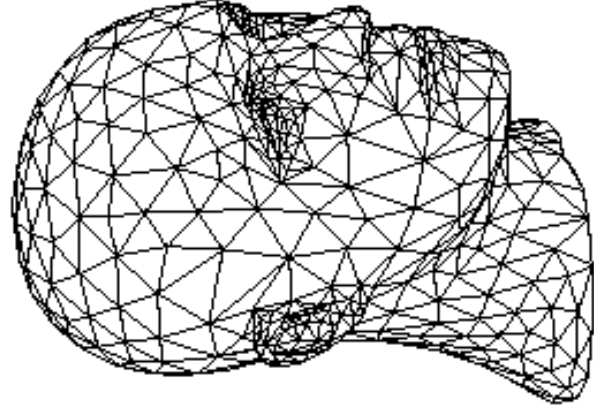
Mesh

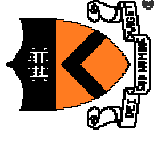- Connected set of polygons (usually triangles)
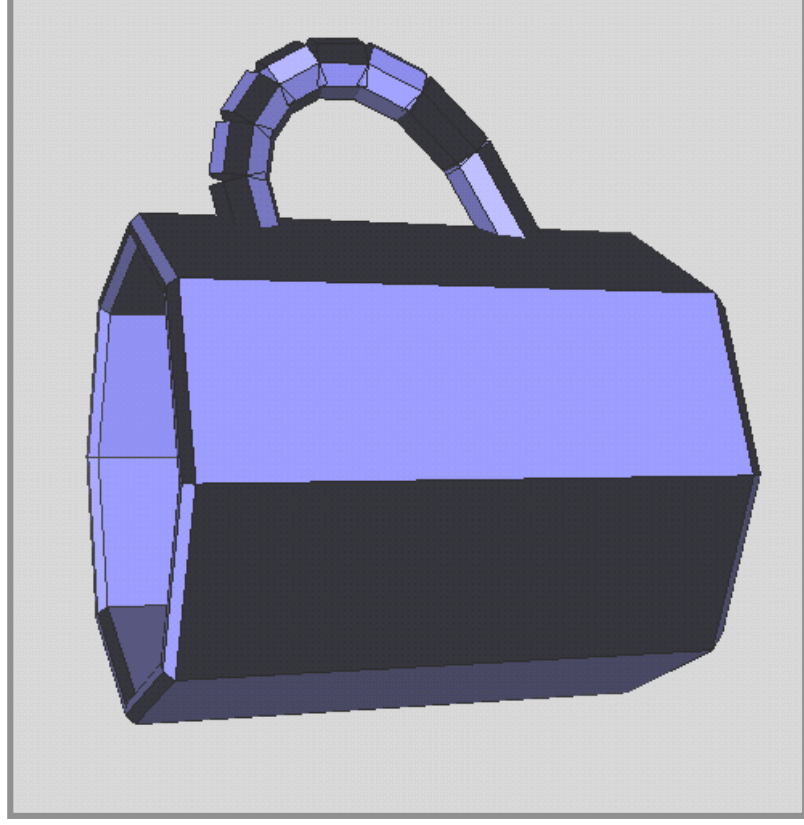 - May not be closed

Subdivision Surface

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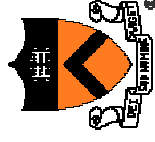
Polygon Soup

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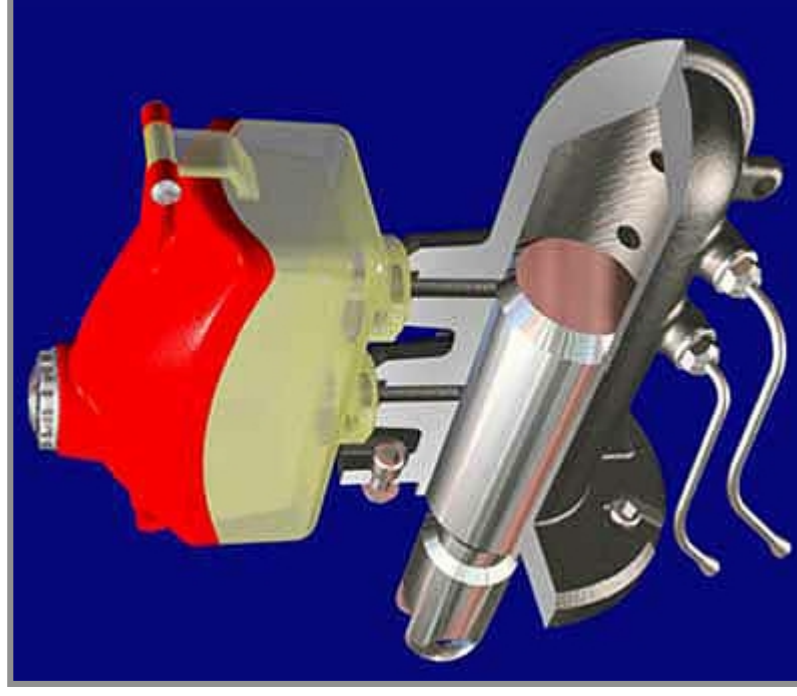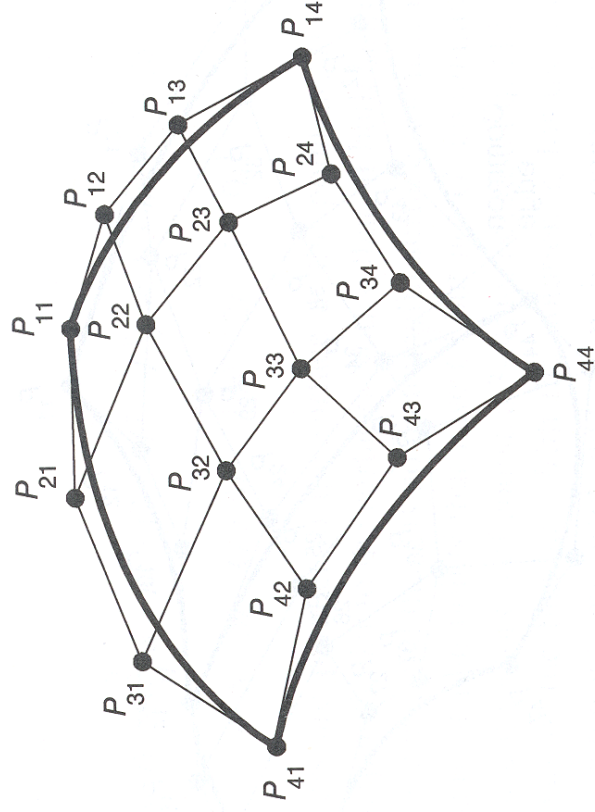 - Created with interactive modeling systems?

Larson

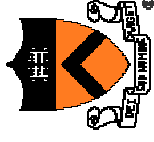# Parametric Surface

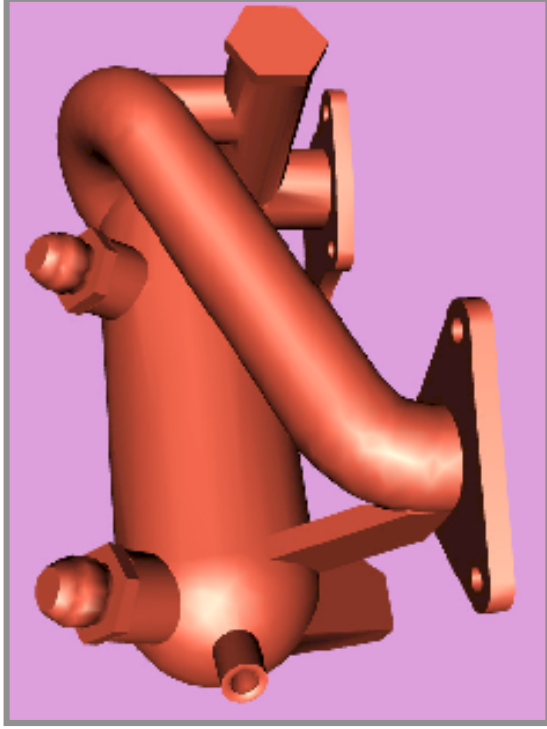- Tensor product spline patchs
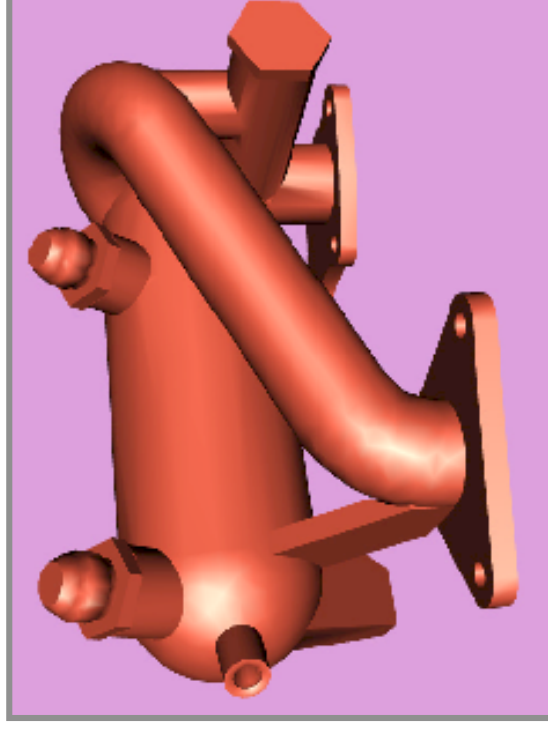 - Careful constraints to maintain continuity

FvDFH Figure 11.44

Implicit Surface

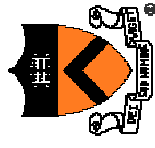- Points satisfying: $F(x,y,z) = 0$

Implicit Model

Polygonal Model

3D Object Representations

- Raw data
  - Point cloud
  - Range image
  - Polygon soup

- Surfaces
  - Mesh
  - Subdivision
  - Parametric
  - Implicit

- Solids
  - Voxels
  - BSP tree
  - Cell complex

- High-level structures
  - CSG
  - Constrained blocks
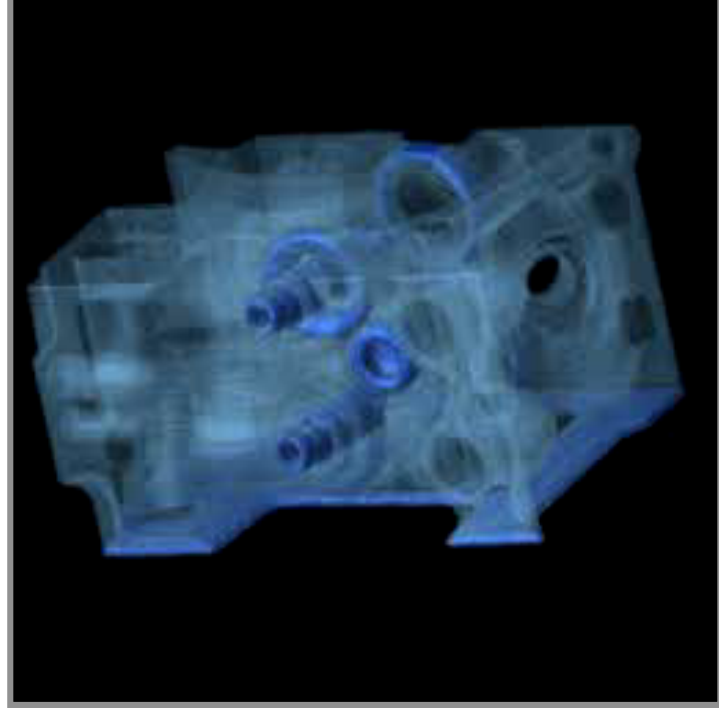 - Generative model
  - Skeleton
  - Sweep
  - Scene graph

Voxels

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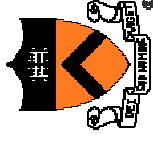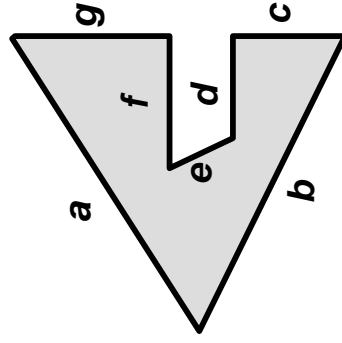 - Acquired from CAT, MRI, etc.
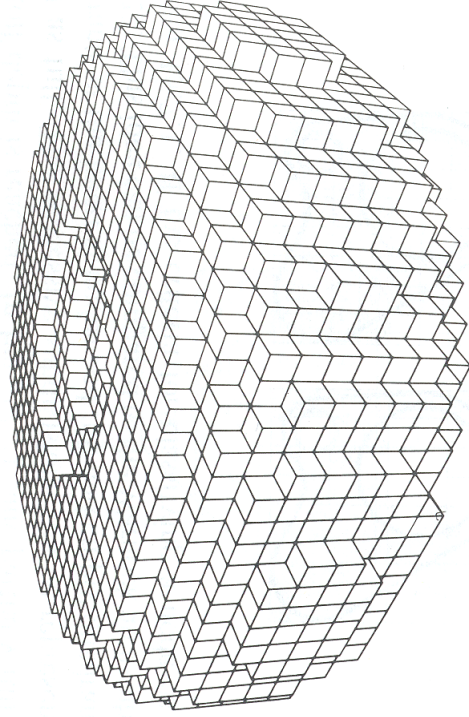
Stanford Graphics Laboratory
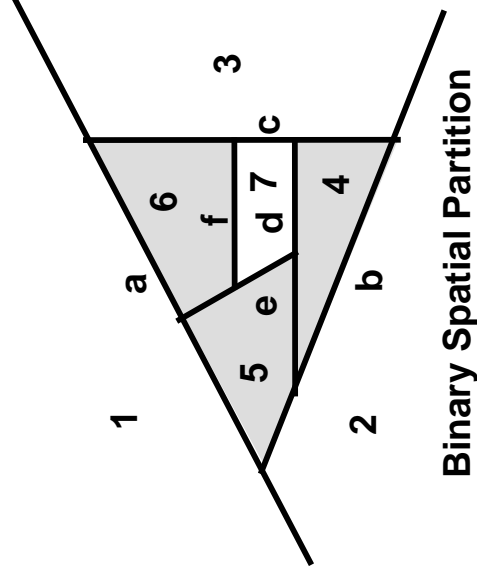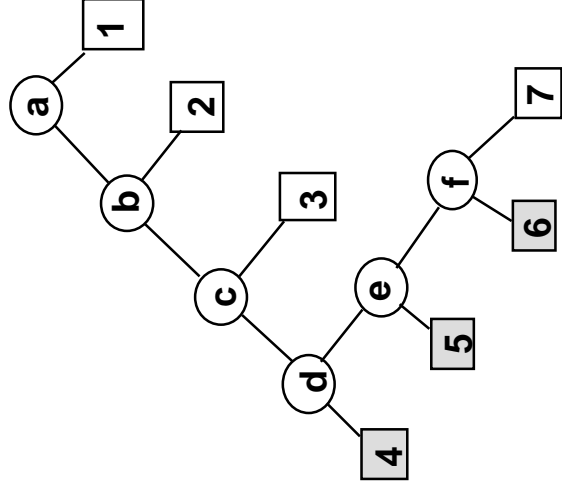

FvDFH Figure 12.20

BSP Tree

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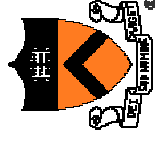
  ○ Constructed from polygonal representations
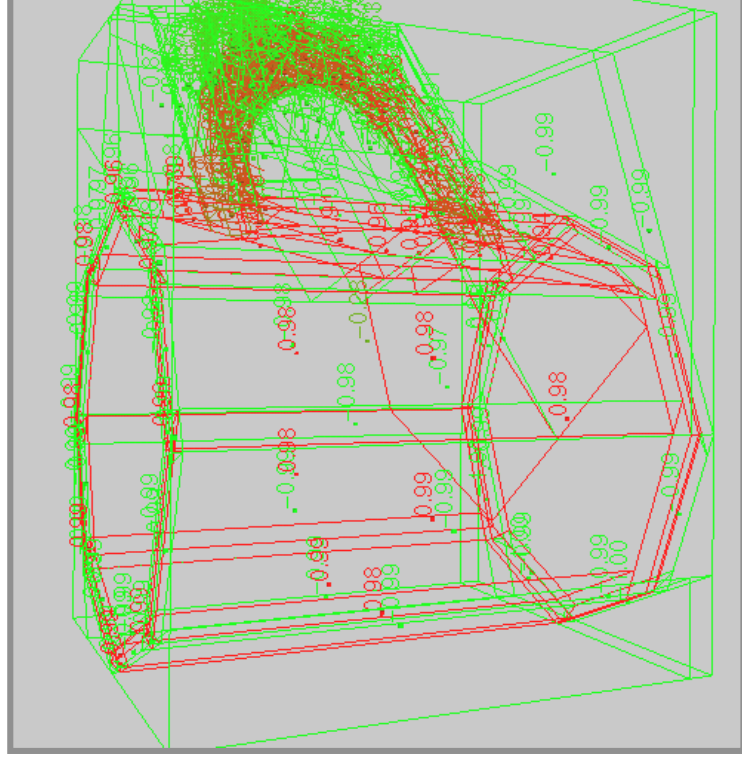

Object

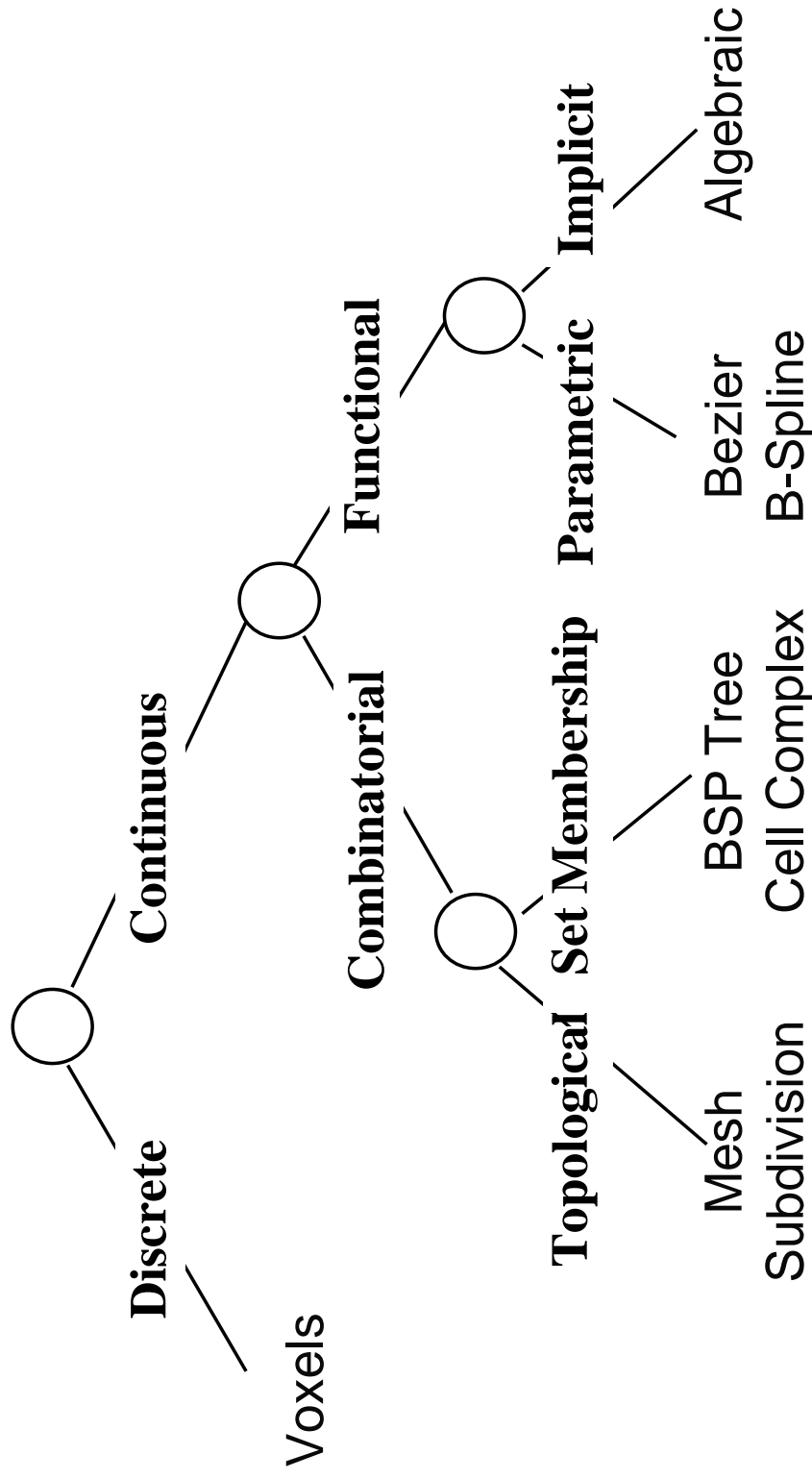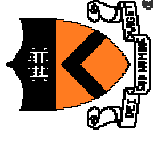Binary Spatial Partition

Binary Tree

Cell Complex

- Arrangement of polyhedral cells with adjacent cells linked and solid cells labeled
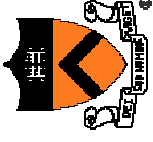 - e.g., adjacency graph of BSP leaf cells
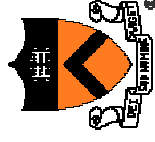

Murali

Taxonomy of 3D Representations

Discrete
- Voxels

Continuous

Combinatorial

Functional

Topological
- Mesh
- Subdivision

Set Membership
- BSP Tree
- Cell Complex

Parametric
- Bezier
- B-Spline

Implicit
- Algebraic

3D Object Representations

- Raw data
  - Point cloud
  - Range image
  - Polygon soup

- Surfaces
  - Mesh
  - Subdivision
  - Parametric
  - Implicit

- Solids
  - Voxels
  - BSP tree
  - Cell complex

- High-level structures
  - CSG
  - Constrained blocks
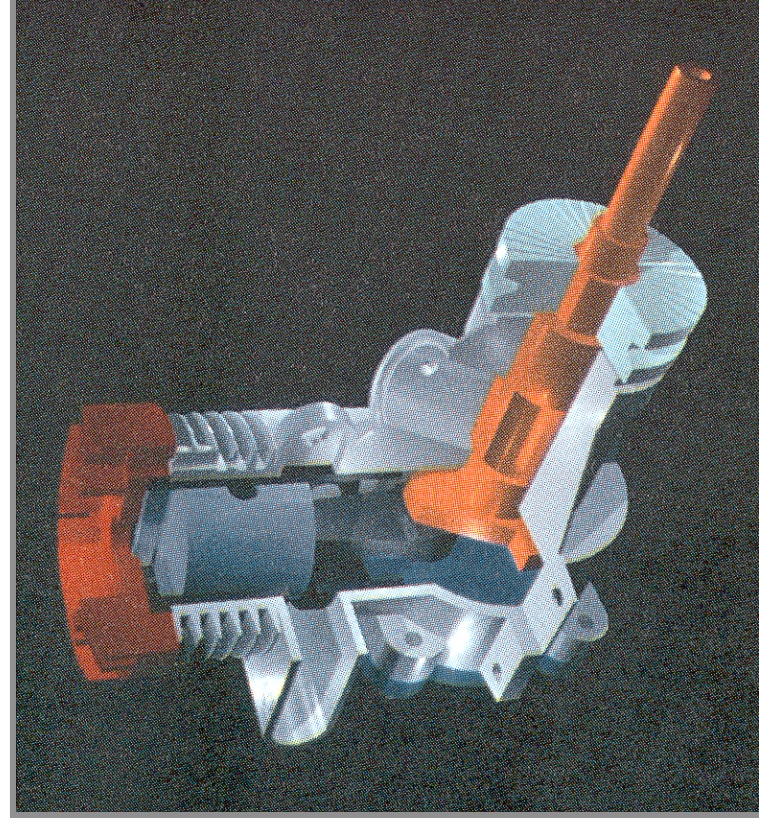 - Generative model
  - Skeleton
  - Sweep
  - Scene graph

CSG

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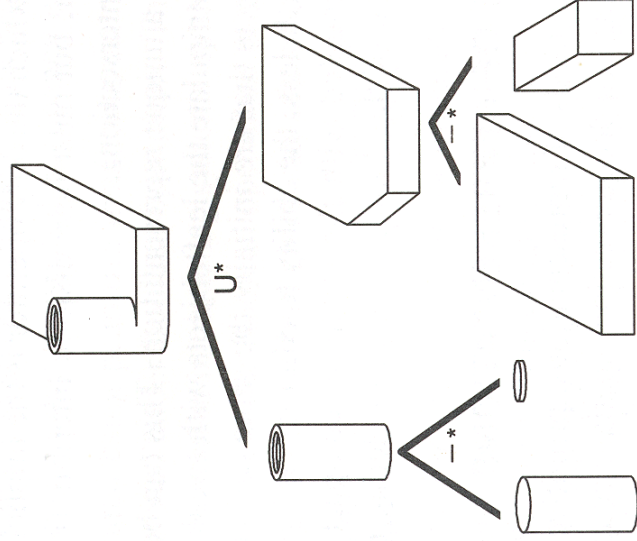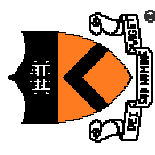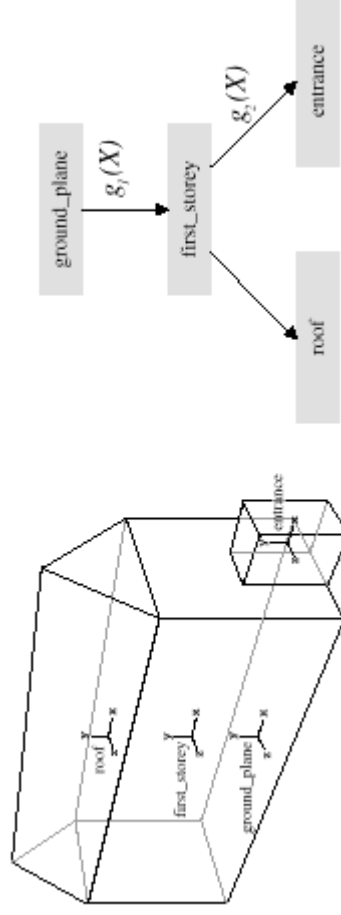

H&B Figure 9.9

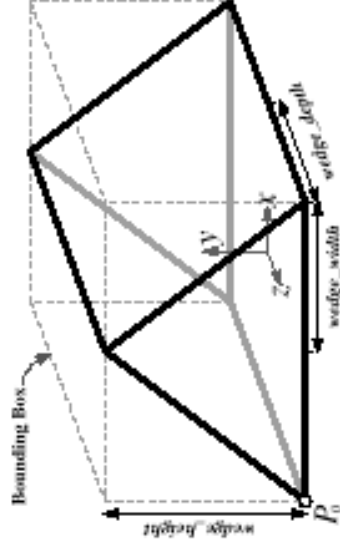FvDFH Figure 12.27

Constrained Blocks
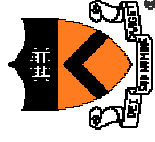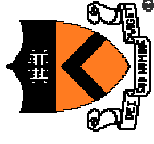
- Set of simple shapes with geometric constraints

Generative Model

- Hierarchy of modifying curves
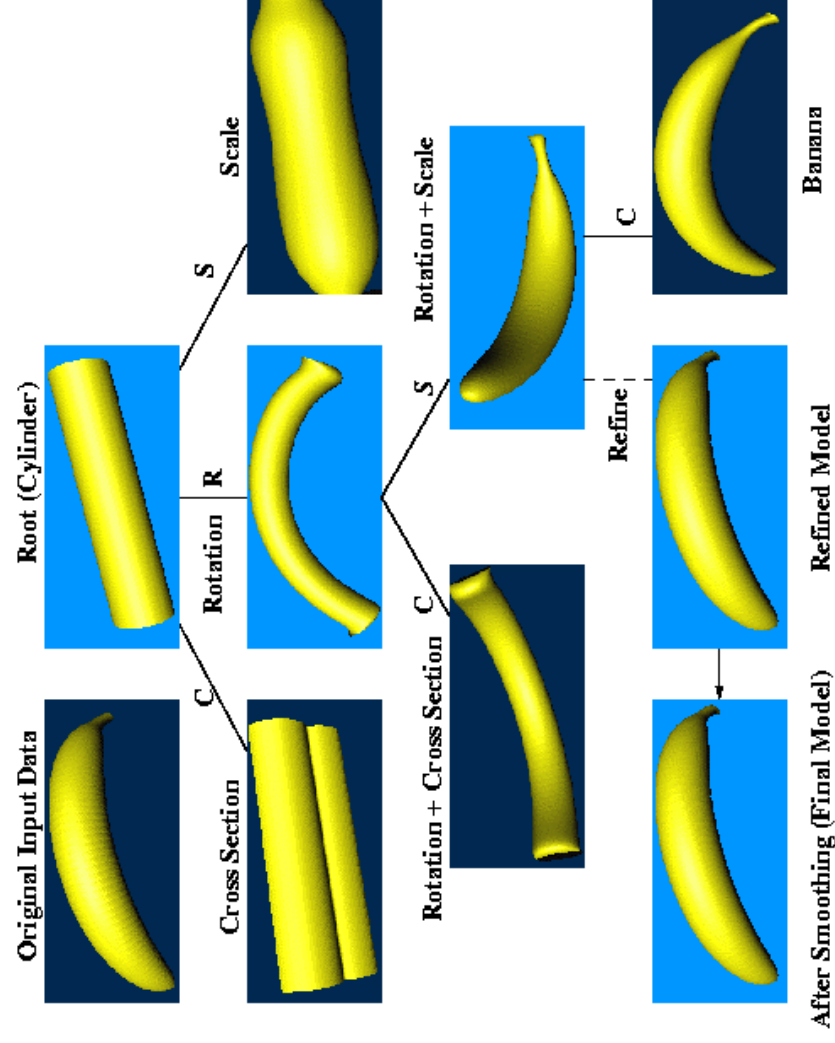
Skeleton

- Graph of curves with radii

Sweep

- Surface swept by curve along trajectory
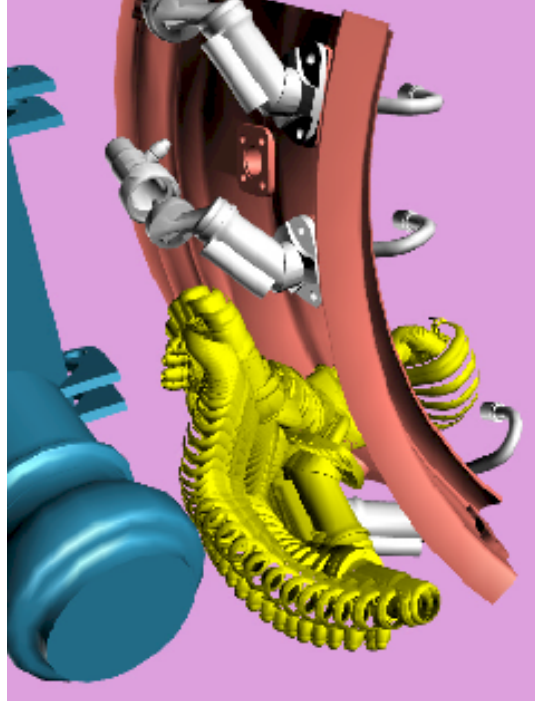
Removal Path
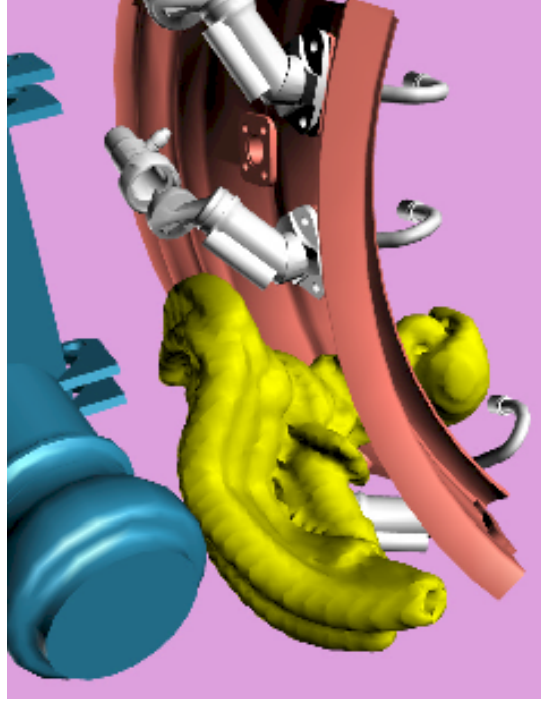
Sweep Model

Scene Graph
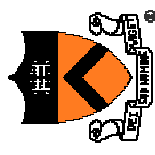
• Union of objects at leaf nodes

avalon.viewpoint.com
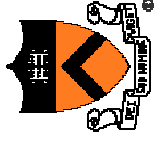

Bell Laboratories
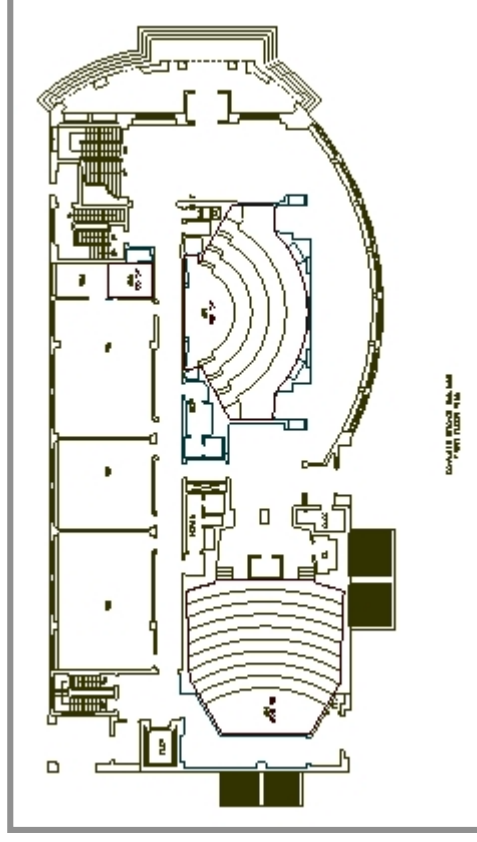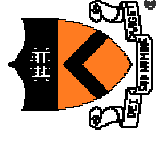
Others?
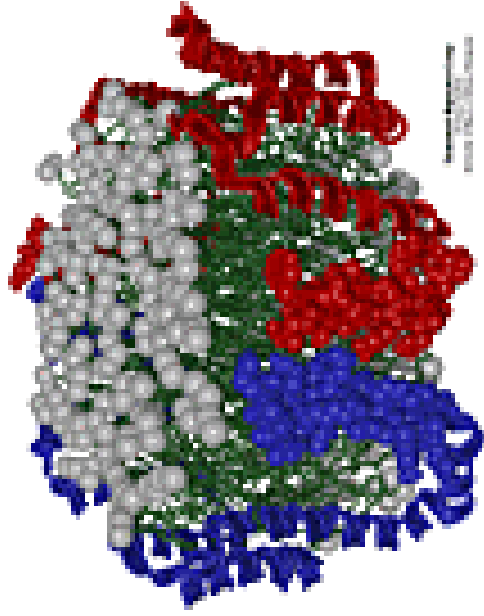
Apo A-1

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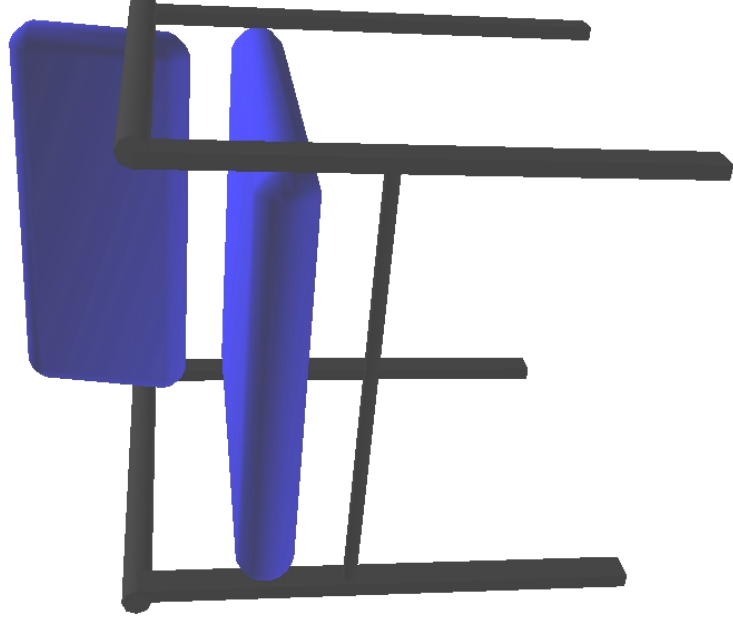*University of Illinois at Urbana-Champaign)*

Architectural Floorplan

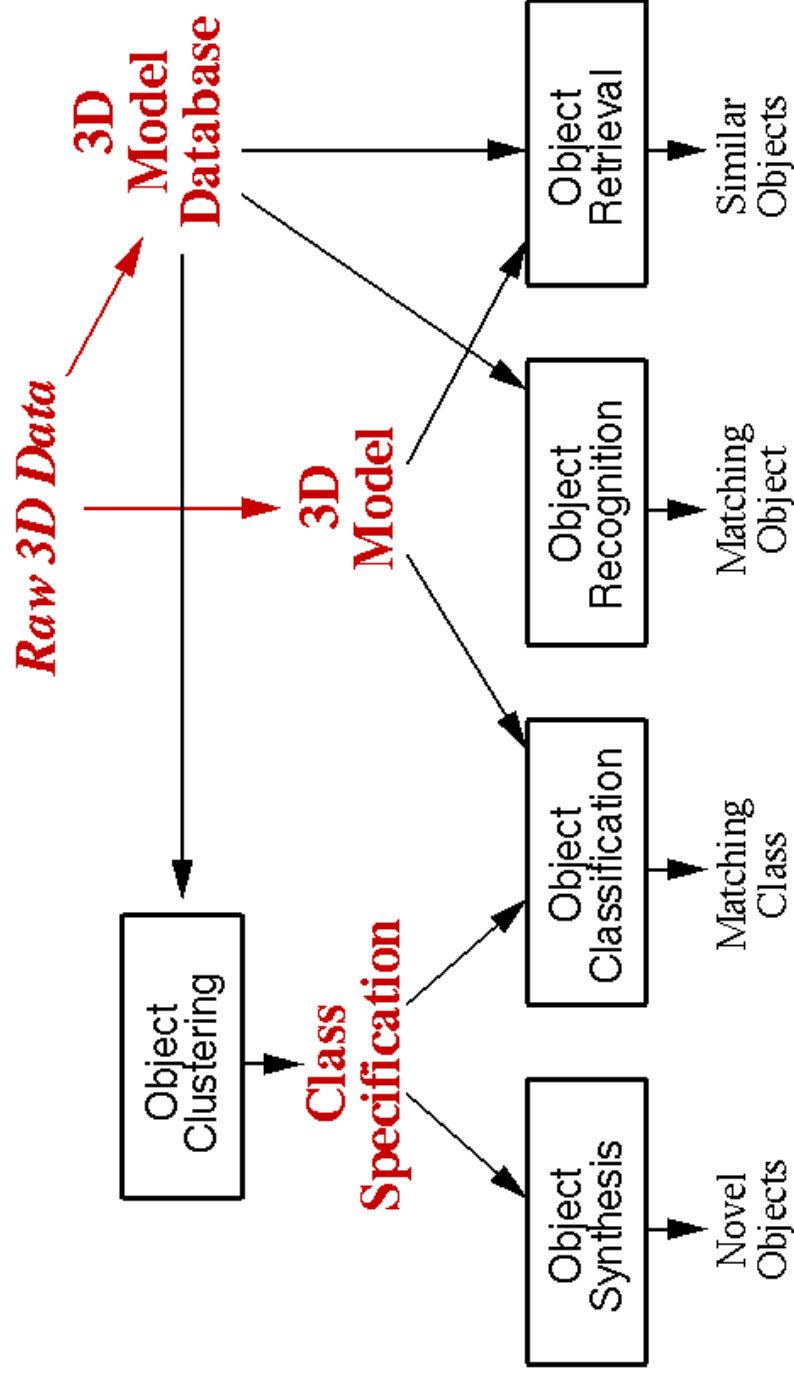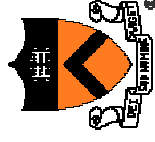*(CS Building, Princeton University)*

Summary

- Goals
  - Reconstruction
  - Segmentation
  - Feature detection
  - Labeling
  - Matching
  - Classification
  - Retrieval
  - Recognition
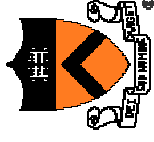 - Clustering

Summary

3D object representation is key!

Summary

- Raw data
  - Point cloud
  - Range image
  - Polygon soup

- Surfaces
  - Mesh
  - Subdivision
  - Parametric
  - Implicit

- Solids
  - Voxels
  - BSP tree
  - Cell complex

- High-level structures
  - CSG
  - Constrained blocks
  - Generative model
  - Skeleton
  - Sweep
  - Scene graph