# 3D Object Modeling

## (SENG 463 - **Game Programming)**


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# Outline

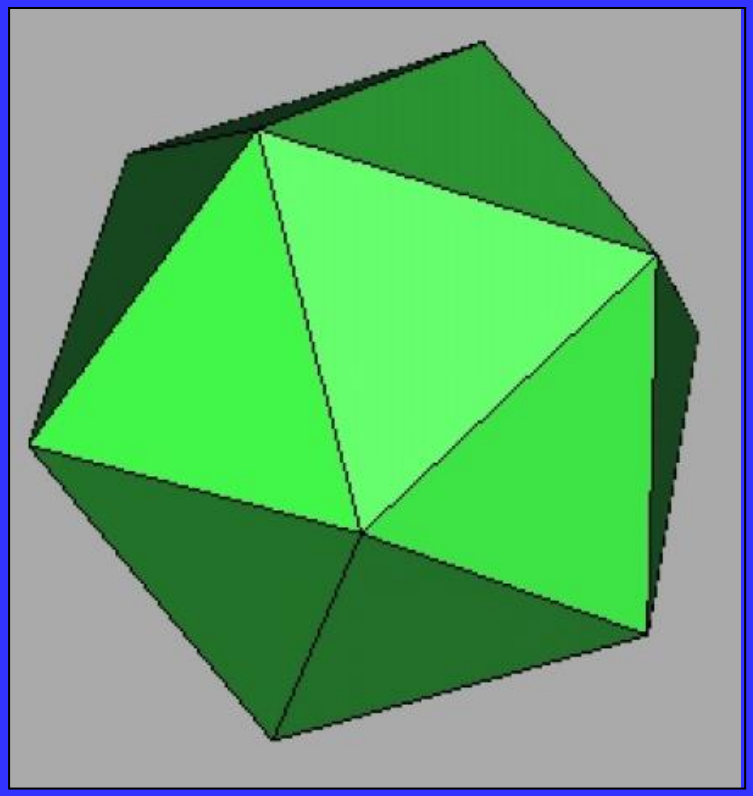
- 3D Objects
- Raw Data Types
- 3D Object Representations
  - Surface models
  - Solid models
  - High-Level Structures

# Our Goal

- To learn data structures to represent 3D objects in games and simulations
  - Surface Representations
  - Volumetric Representations

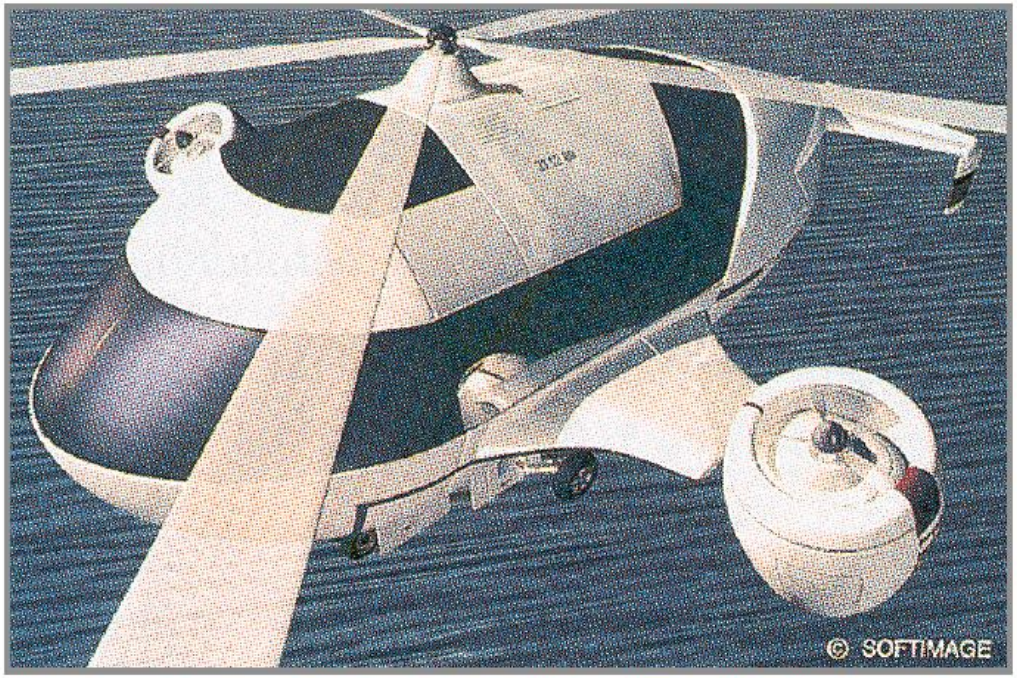

# 3D Objects

- How can this simple object be represented in a computer?



# 3D Objects

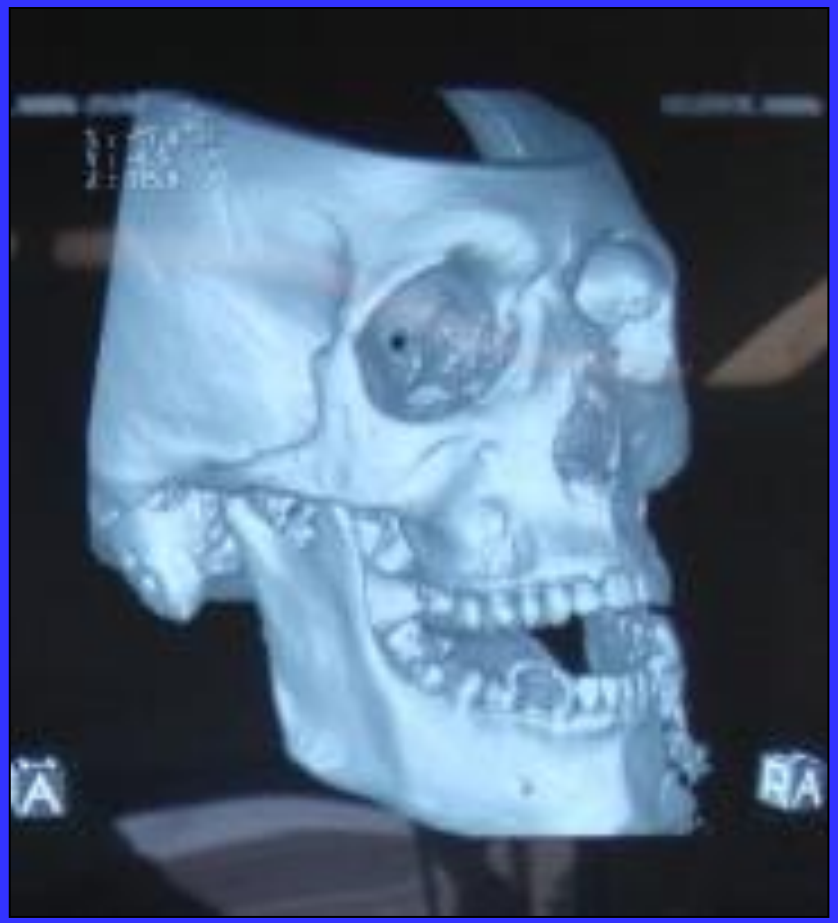
- Is representing this object similar to the previous one an effective way?
- Highly smooth curves...




H&B Figure 10.46

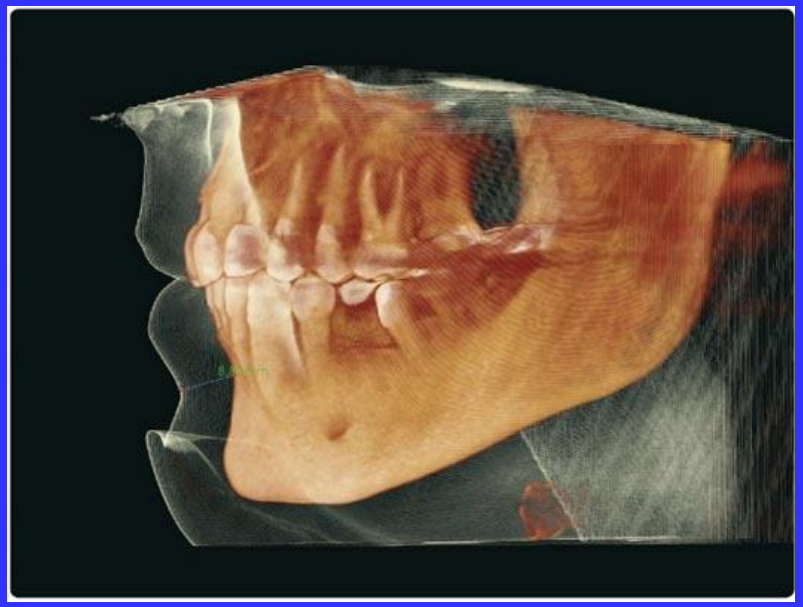
# 3D Objects

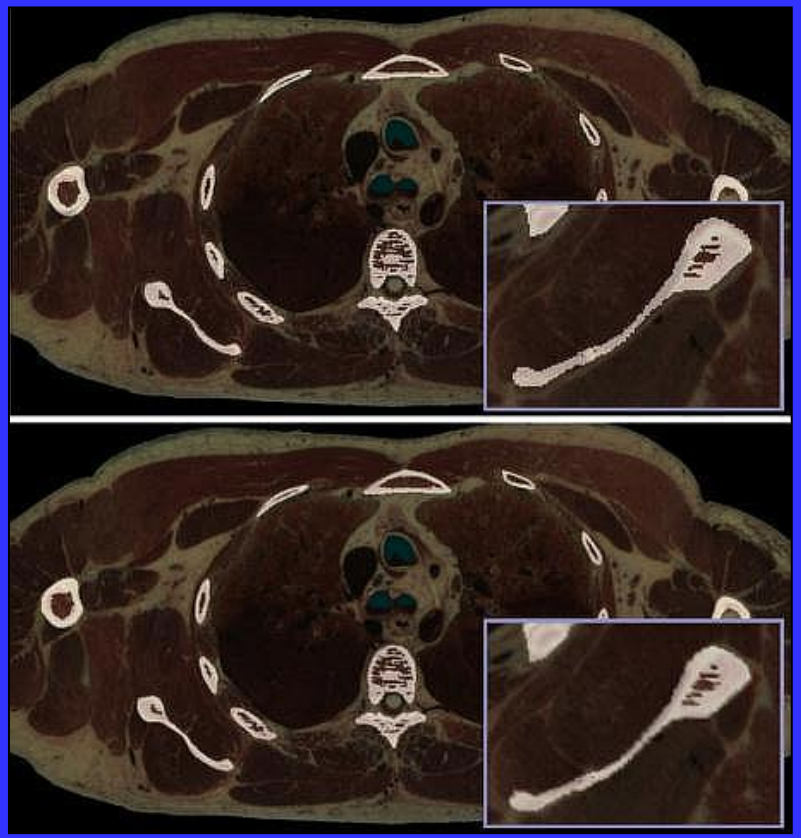
- How about this one?
- A volumetric body, but just its outer surface is shown, not interior data required…



# 3D Objects

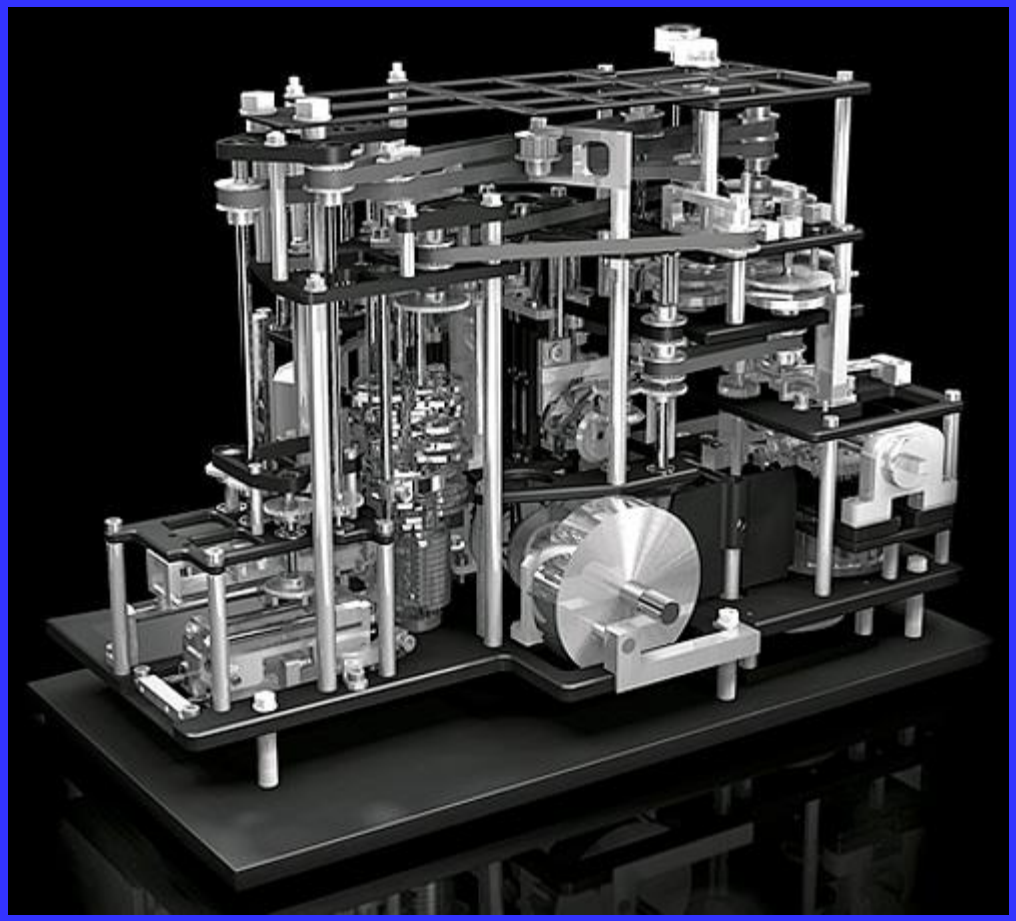
- How about these ones?
- Has soft and hard tissue...
- Has different densities...
- Has Interrior data...





# 3D Objects

- What about this one?
- Composed of different geometric parts / shapes...
- An engineering model…



# 3D Objects

- And this one?

# 3D Objects

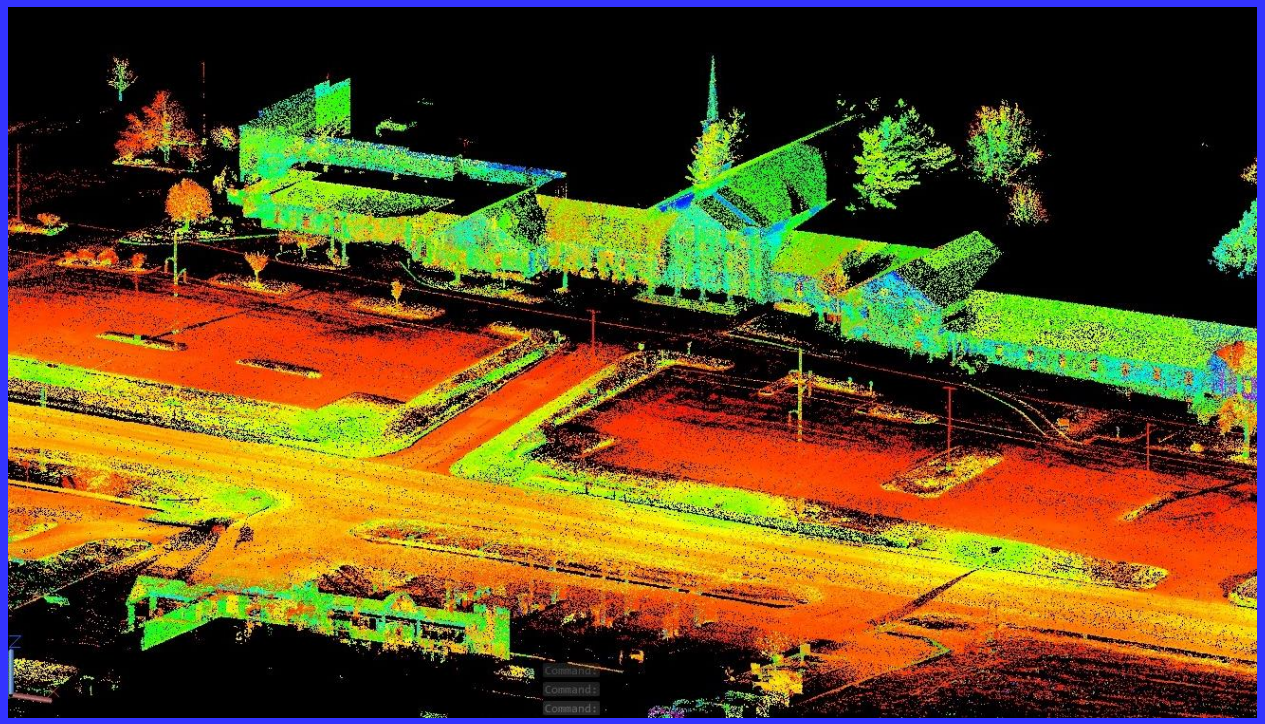
- How about these?
- A deformable body...
- Animation integration...

# 3D Object Representations

- Raw Data (Sensors)
  - Point cloud
  - Range image
  - Polygon soup
  - ...
- Surfaces
  - Mesh
  - Subdivision
  - Parametric
  - Implicit
- Solids
  - Voxels
  - BSP Tree
  - Cell Complex
- High-Level Structures
  - CSG
  - Constraint blocks
  - Generative model
  - Skeleton
  - Sweep model
  - Scene graph

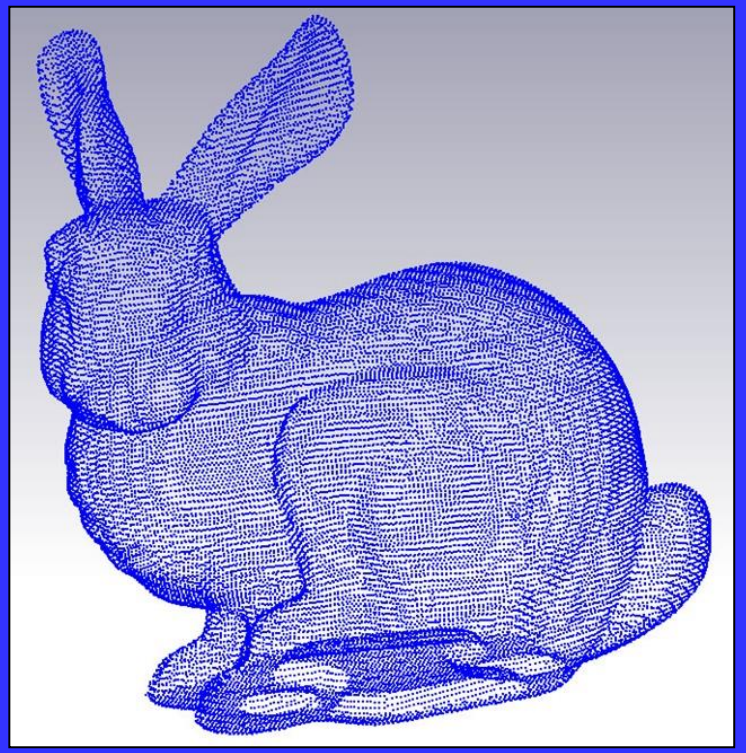
# Raw Data (Sensor Data)

- Point cloud
- Range Images
- Polygon Soup
- …



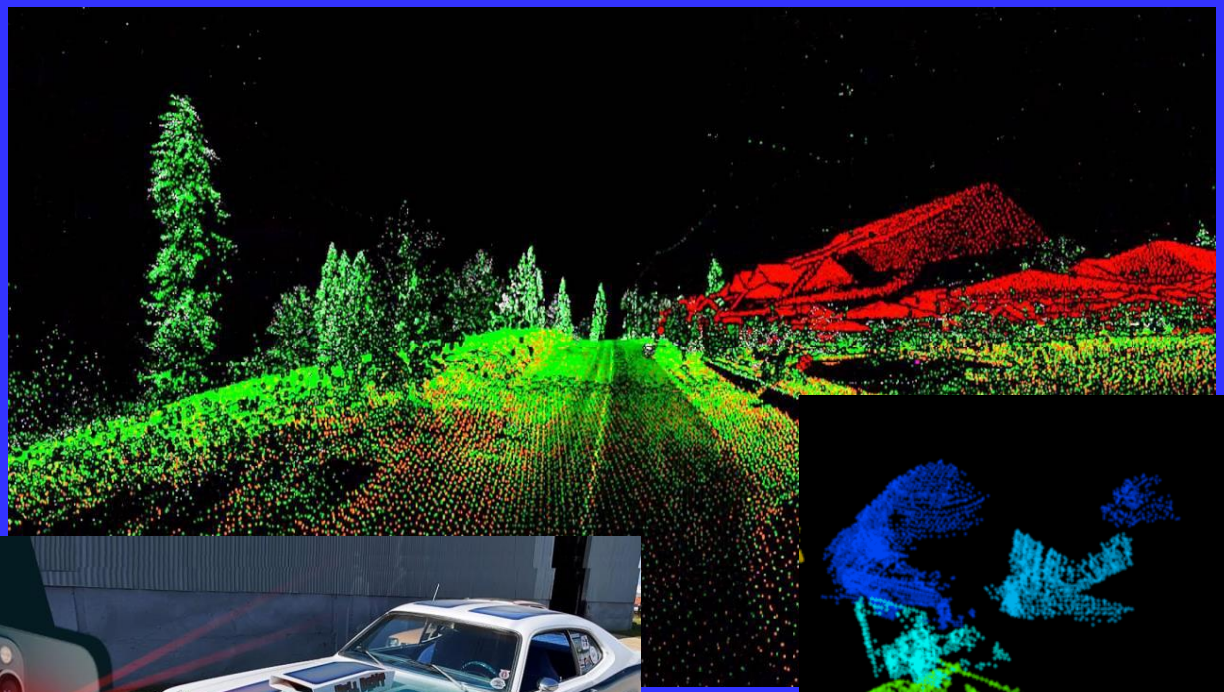
# Point Cloud

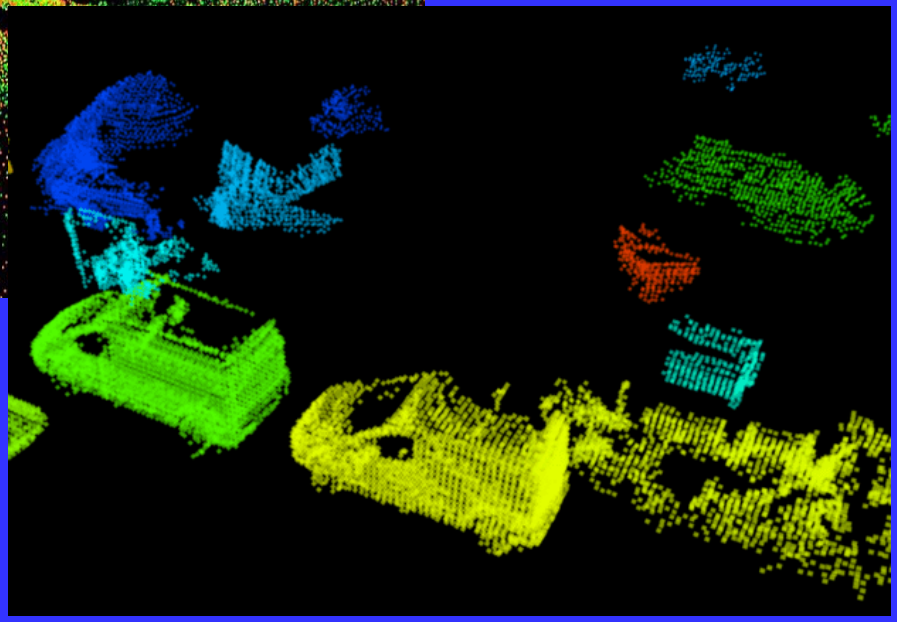
- Unstructured set of point samples
- Accuirred with range finders (Lidar, etc.), 3D scanners, computer vision (SLAM, etc.)



# Point Cloud

- Collecting lidar data



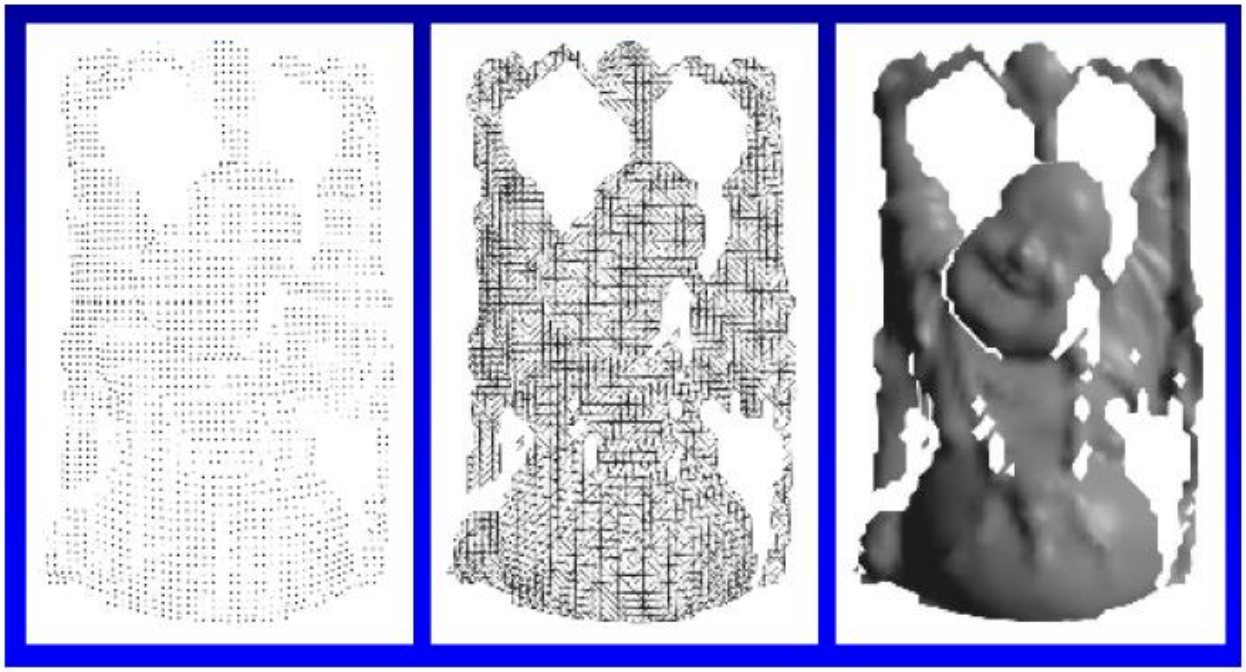
# Range Image

- Set of 3D points that maps to pixels of a depth image
- From range scanners, stereo cameras, etc.

Range (depth) image

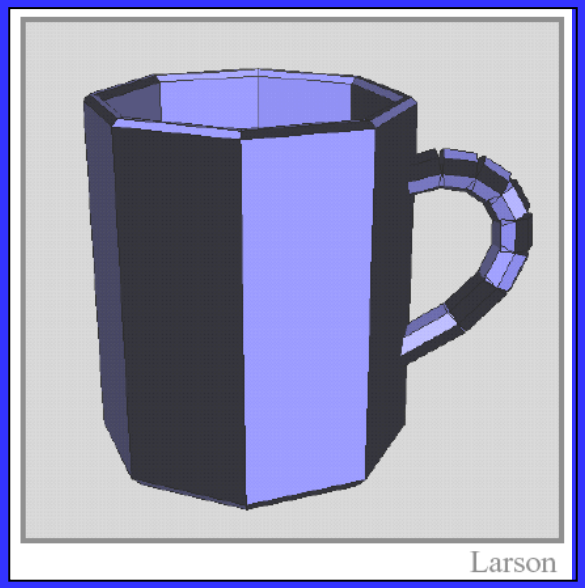
# Range Image

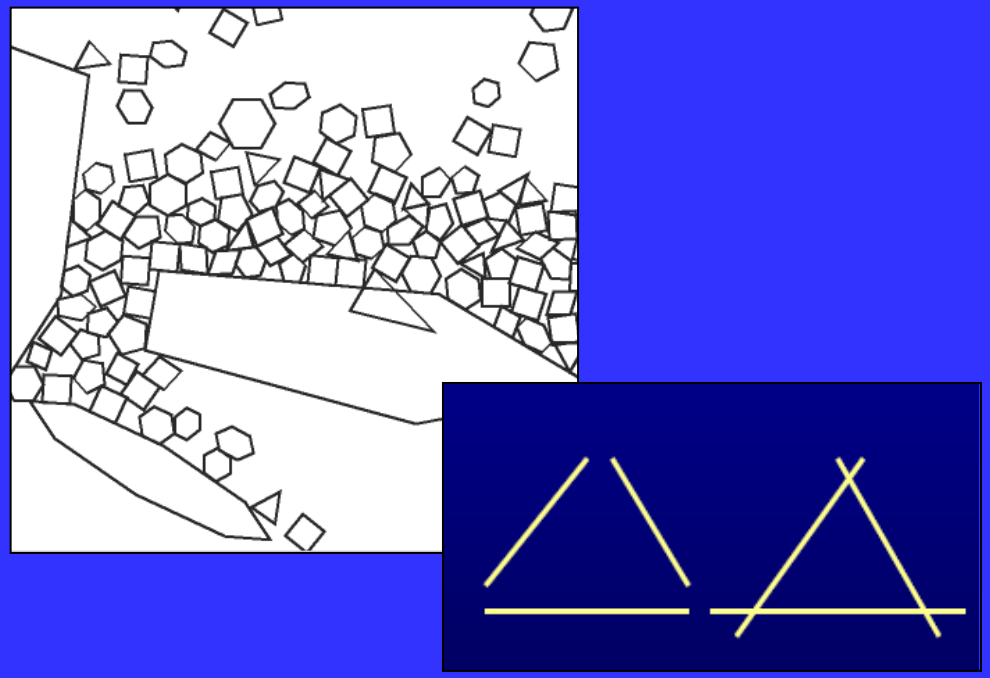
- A kind of more structured point cloud
- Generating surfaces from 3d point clouds



# Polygon Soup

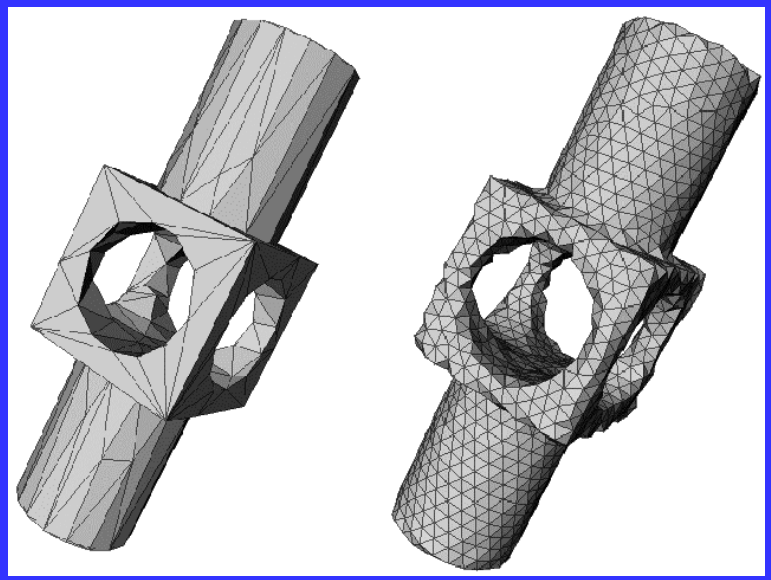
- Unstructures set of polygons or unconnected lines of polygons
- Mostly created with interactive modeling techniques so not very organized

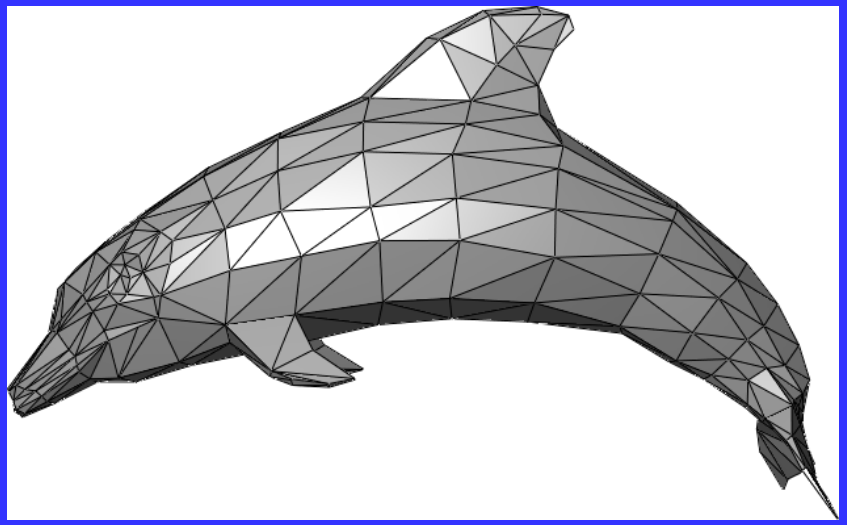


# Surface Objects

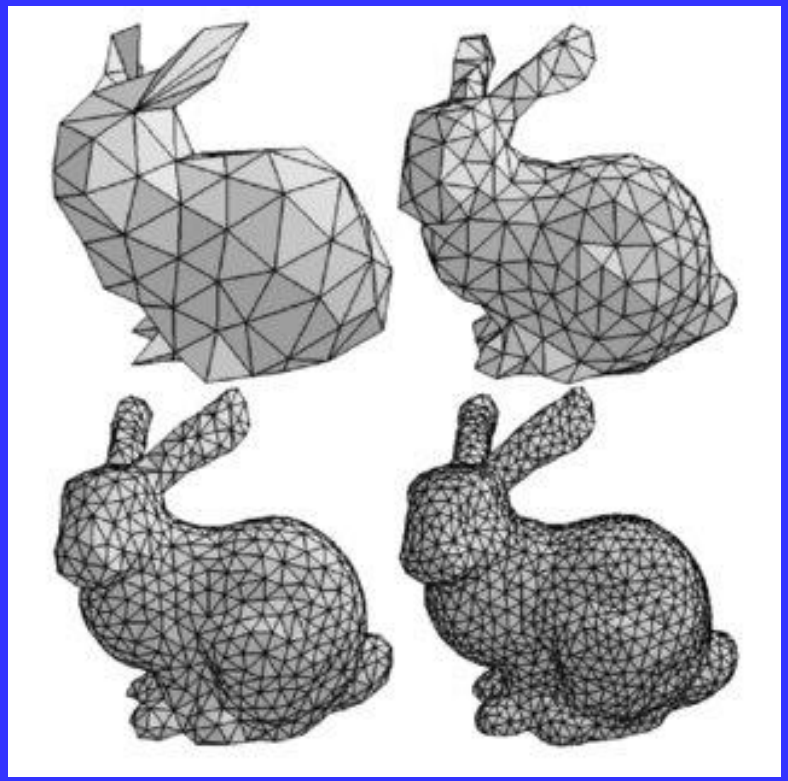
- Mesh
- Subdivision
- Parametric
- Implicit

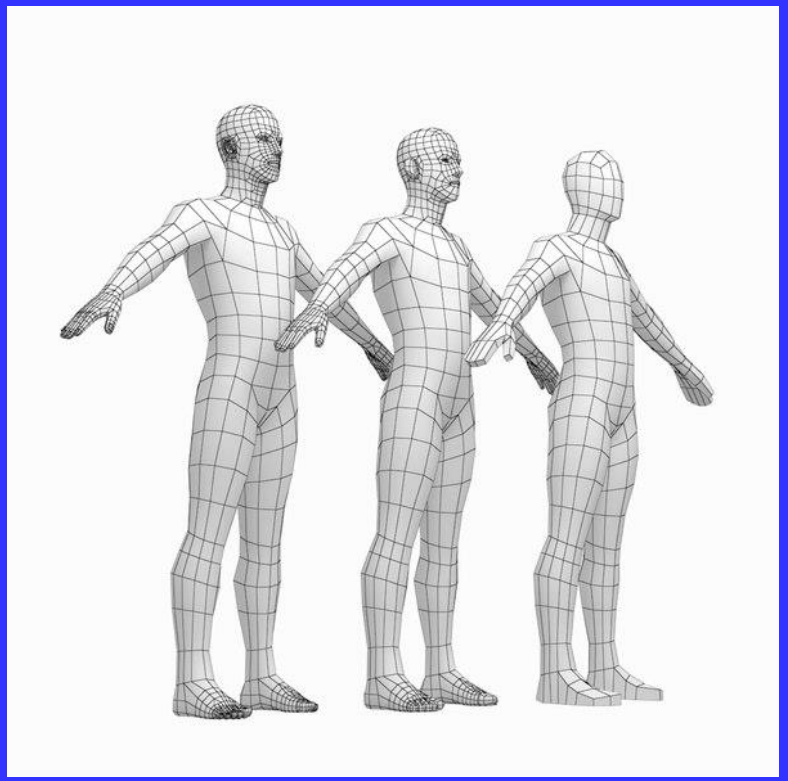




# Mesh

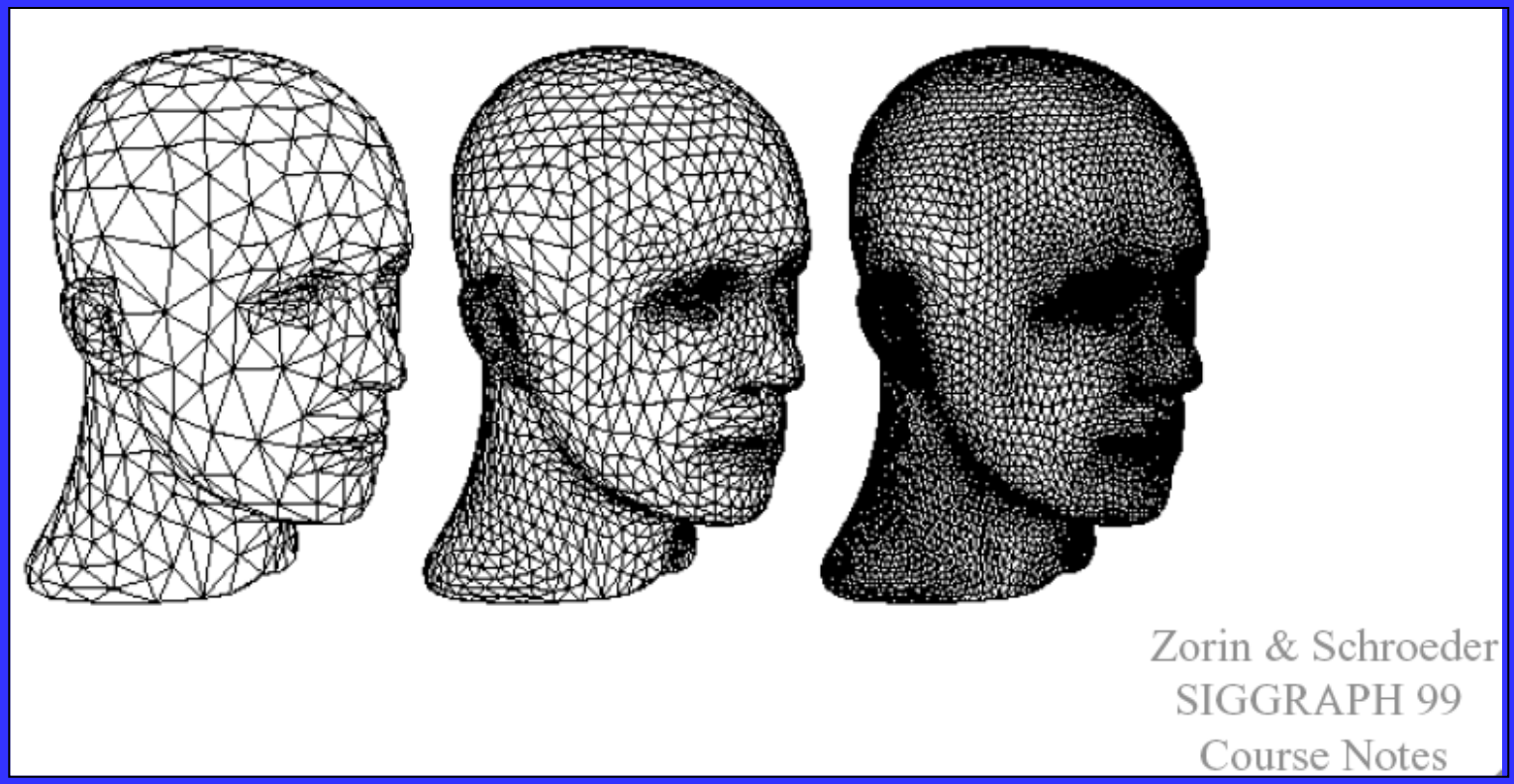
- Connected set of polygons (usually triangles)
- 3D Modellers frequently use quad surfaces
- May include multiple level of Detail (LOD)





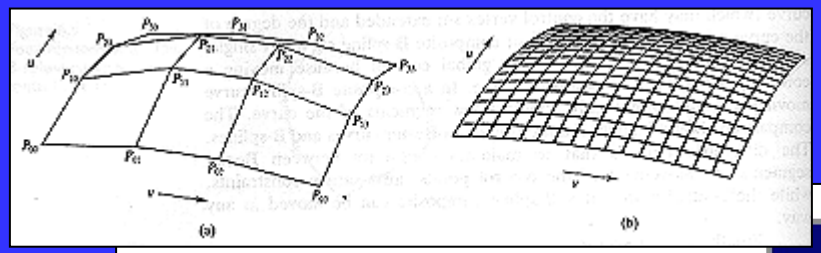
# Subdivision Surface

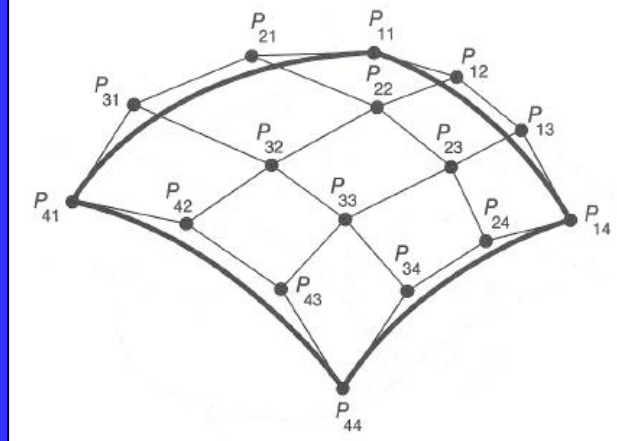
- Consists of a coarse mesh and subdivision rule
- Generates smooth surfaces with refinements



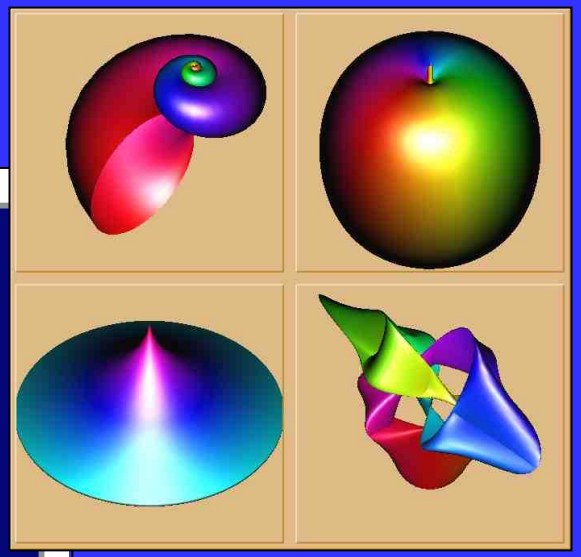
# Parametric Surface

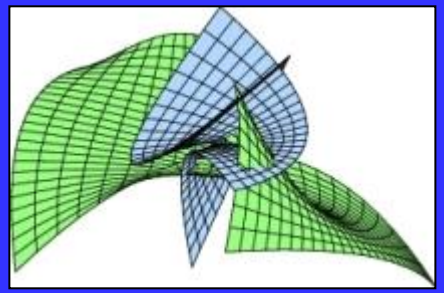
- Bezier / spline surface patches
- Defined with a parametric equation






FvDFH Figure 11.44





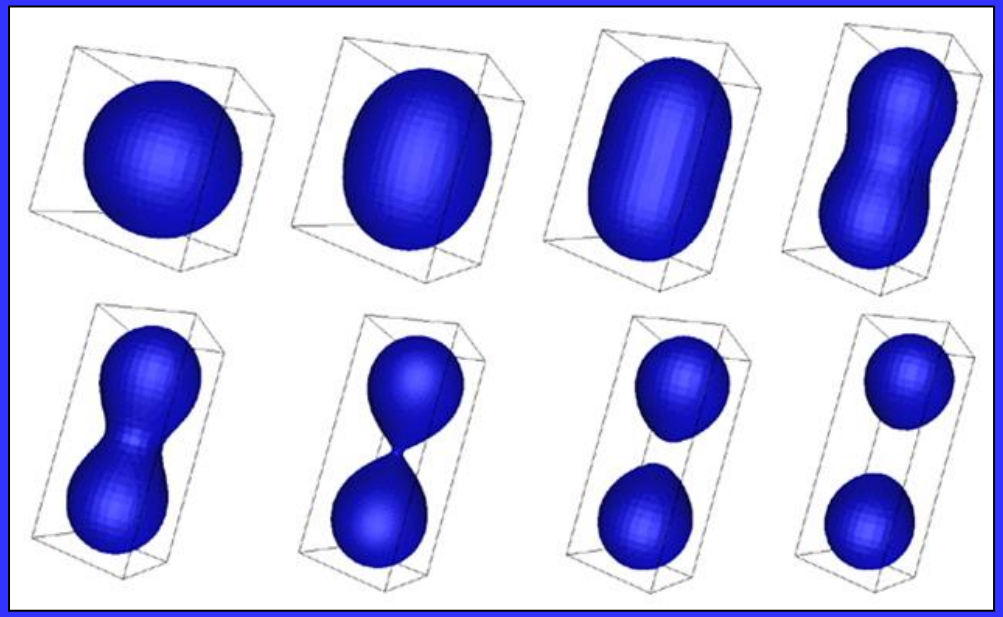
# Implicit Surface

- Many smooth and deformable objects are difficult or inefficient to represent with basic primitives, even with bezier/spline surfaces.
- Field functions with control points, line segments and/or polygonally bounded planes are used to define shapes in space.

$$D(r) = a\, e^{-b\, r^2}$$

$$D(r) = \begin{cases} a\left(1 - \frac{3\, r^2}{b^2}\right) & 0 \le r \le b/3 \\ \frac{3\, a}{2}\left(1 - \frac{r}{b}\right)^2 & b/3 \le r \le b \\ 0 & b \le r \end{cases}$$

$$D(r) = \begin{cases} a\left(1 - \frac{4\, r^6}{9\, b^6} + \frac{17\, r^4}{9\, b^4} - \frac{22\, r^2}{9\, b^2}\right) \\ 0 \end{cases}$$

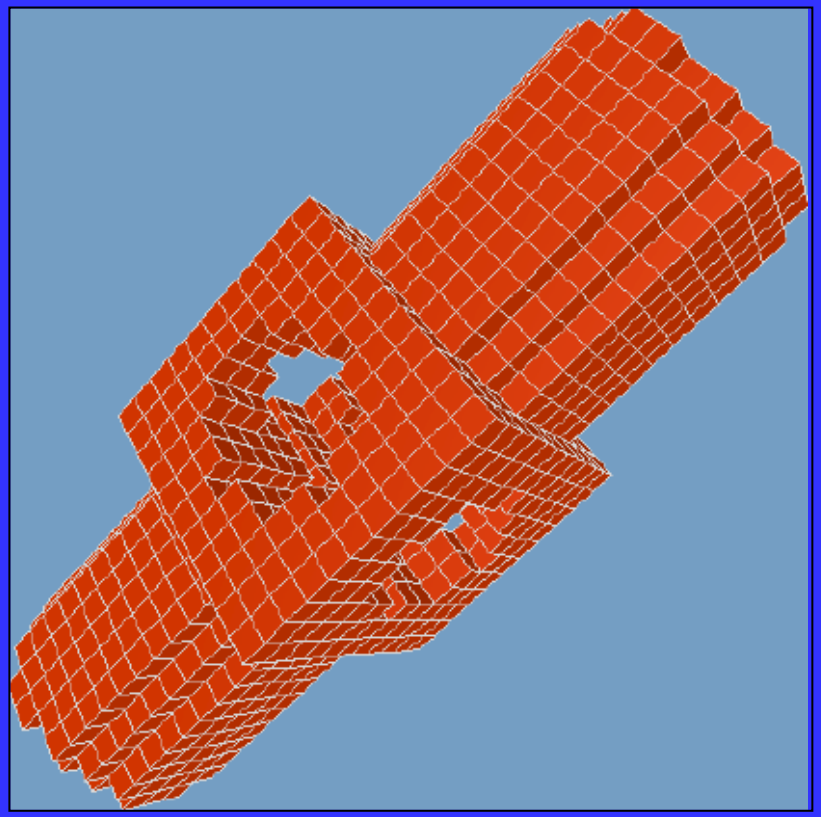


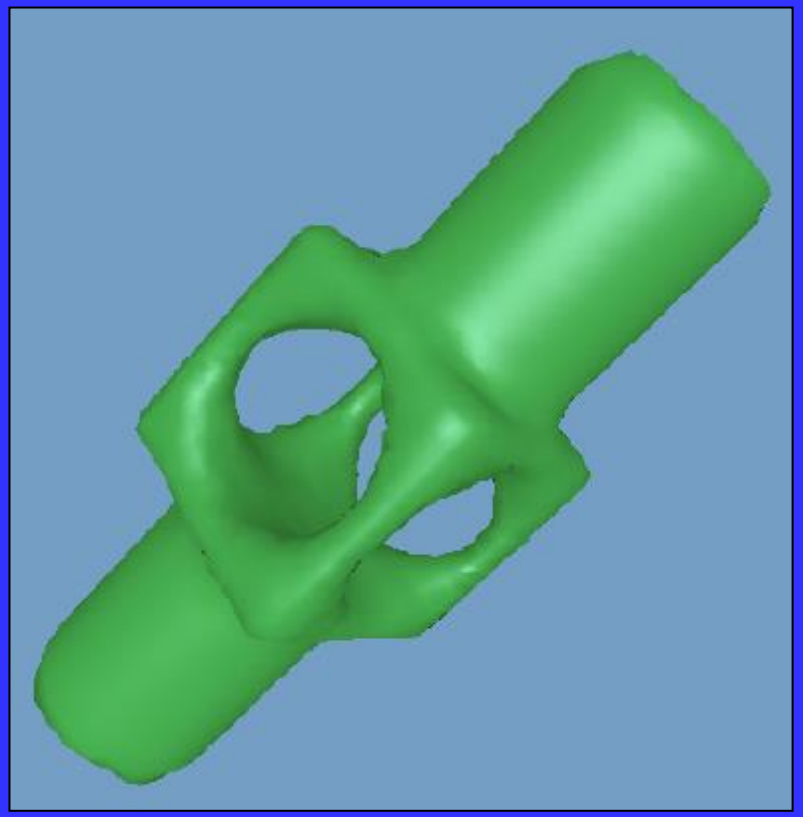
# Solid Objects

- Voxels
- BSP Tree
- Cell Complex

# Voxels

- Uniform 3D grid of volumetric samples (Voxels)
- Mostly acquired from CT, MRI, etc.



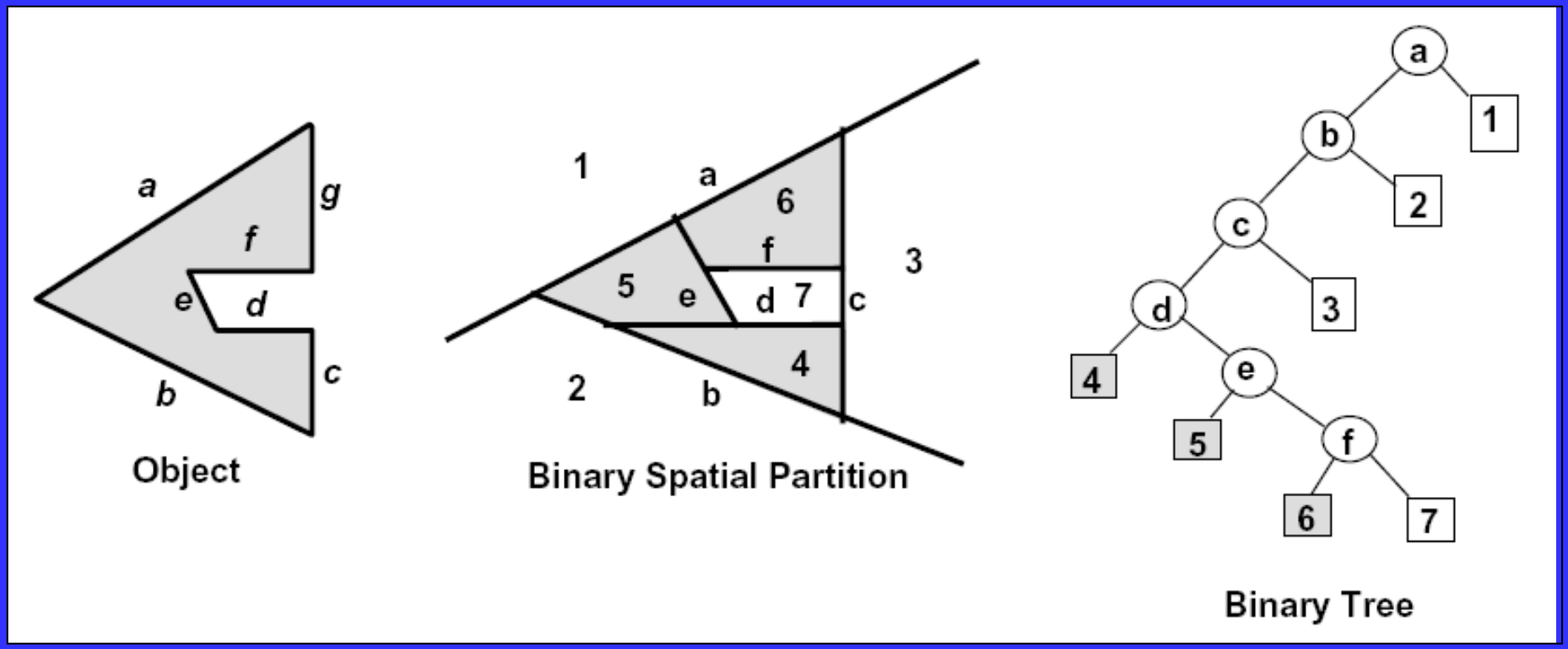


# Voxels Worlds

- 3D environments / worlds generated with voxels

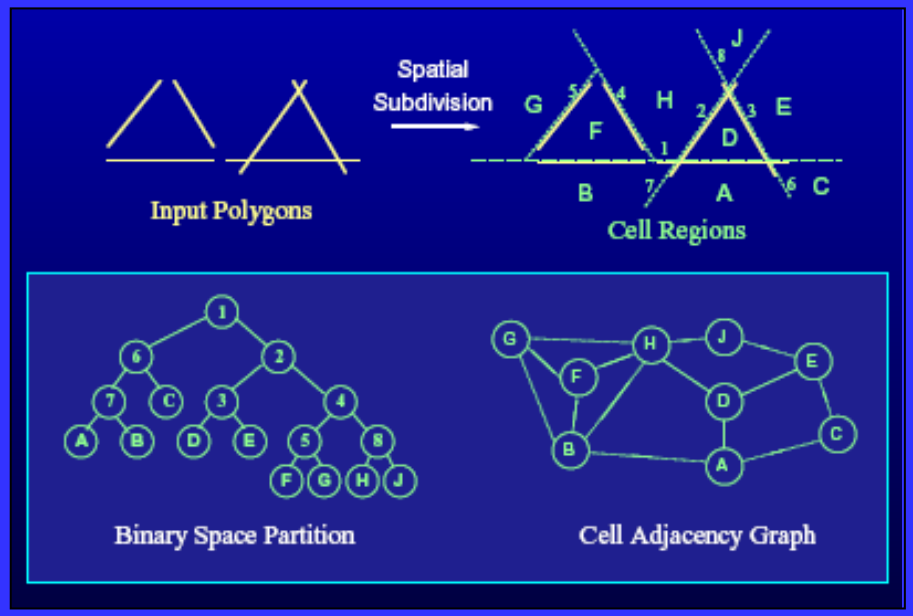
# BSP Tree

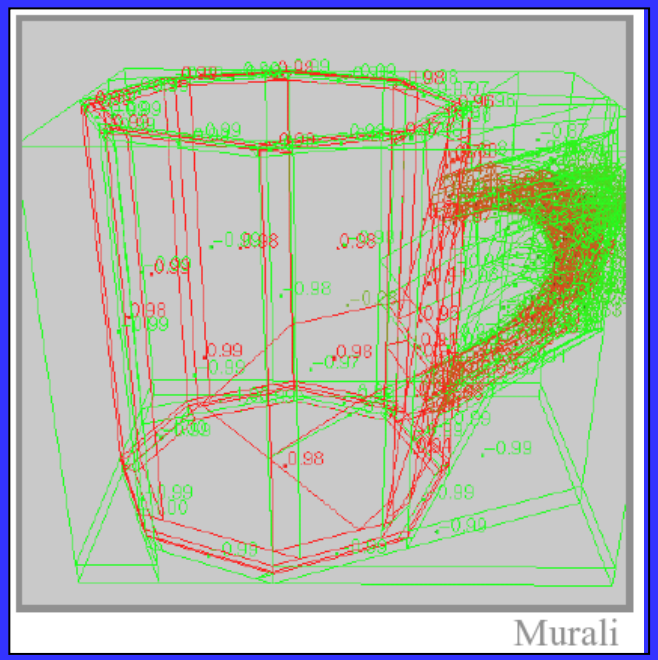
- Binary space partition with labeled solid cells
- Constructed from polygonal representations



# Cell Complex

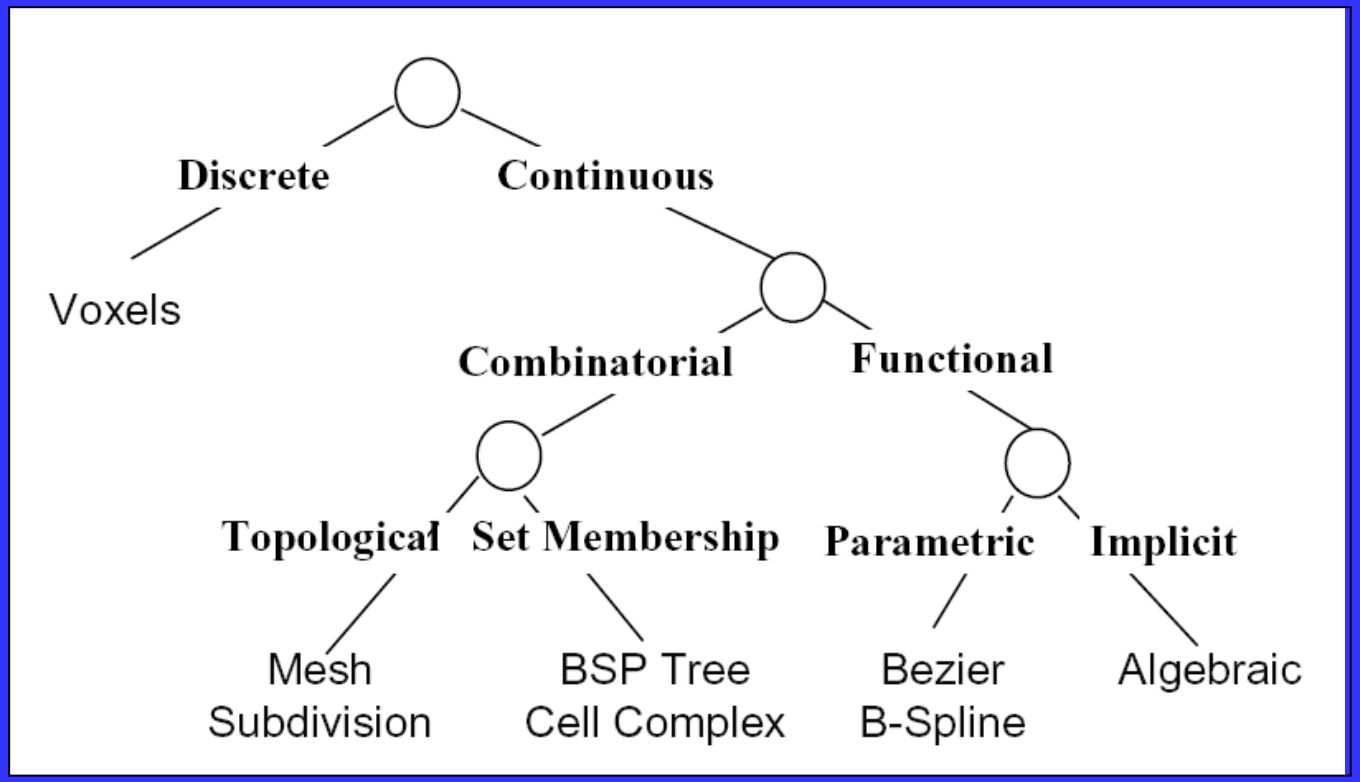
- A topological space, an arrangement of polyhedral cells with adjacent cells linked and solid cells labeled
- e.g. Adjacency graph of BSP leaf cells



# Topology of 3D Representations

- There are many different types of 3D representations
- Mesh representation is the most common one



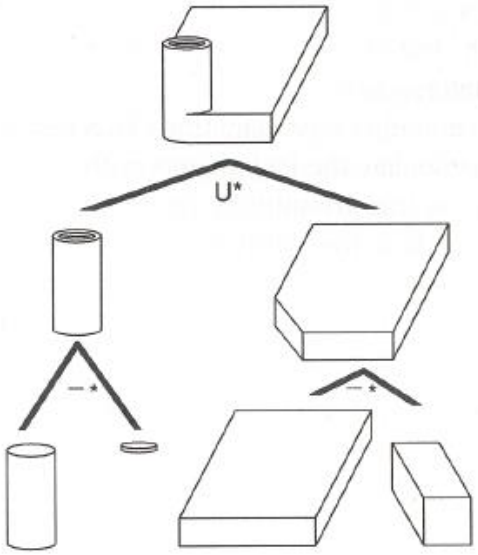
# High-Level Structures

- Using primitives we can form complex structures

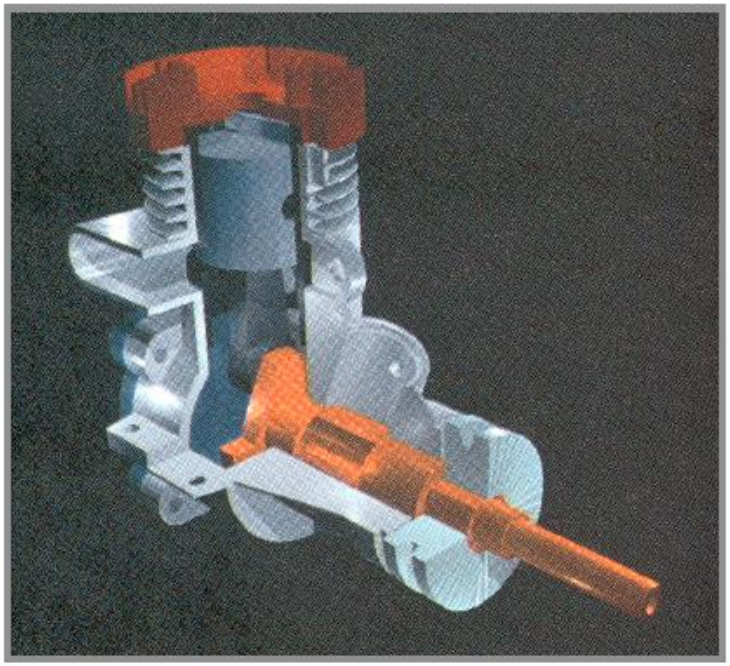
- CSG (Constructive Solid Geometry)
- Constraint blocks
- Generative model
- Skeleton
- Sweep model
- Scene graph

# CSG (Constructive Solid Geometry)

- Hierarchy of boolean set operators (union, difference, subtraction, intersection) applied to simple shapes



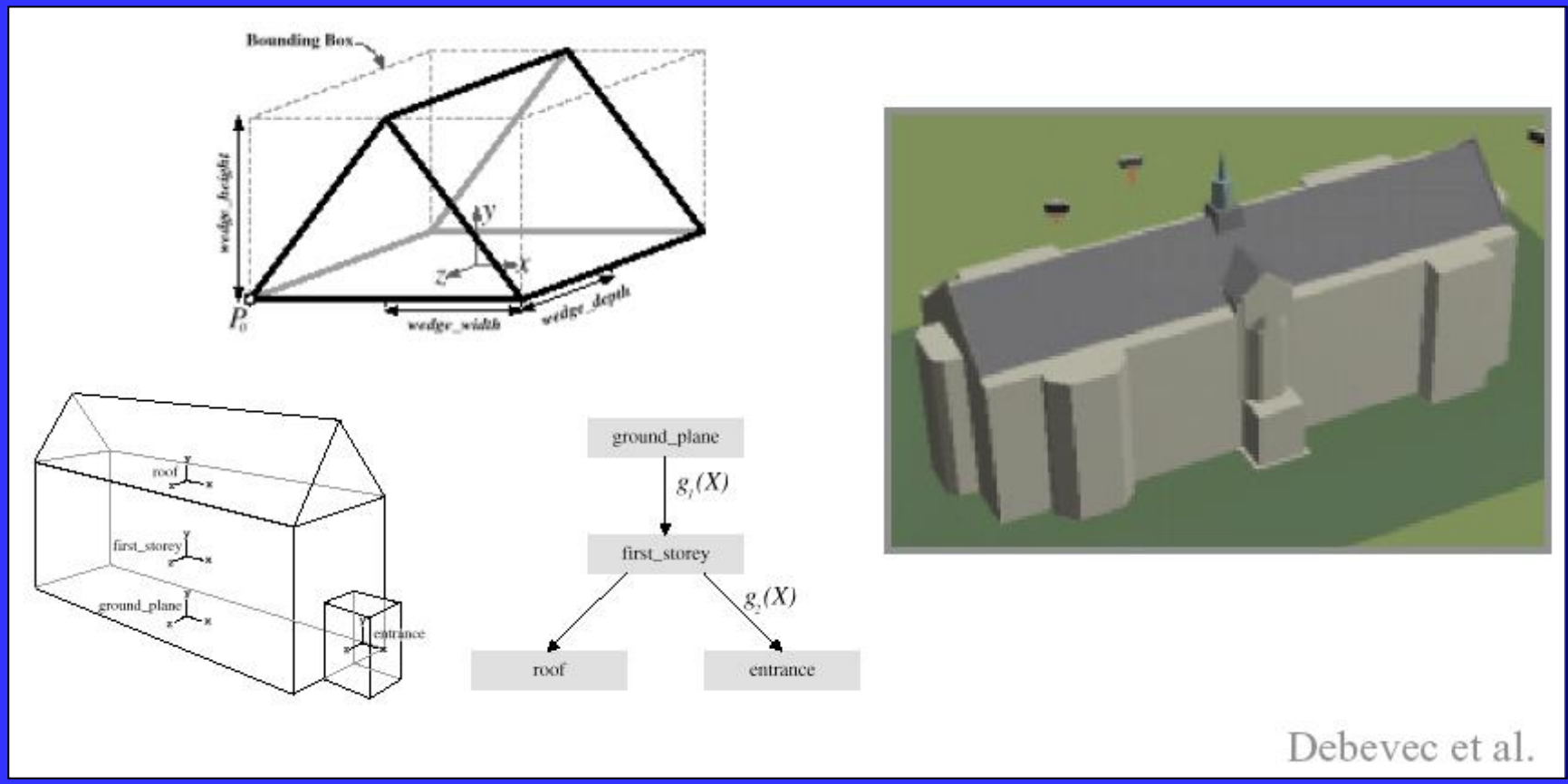

FvDFH Figure 12.27



H&B Figure 9.9

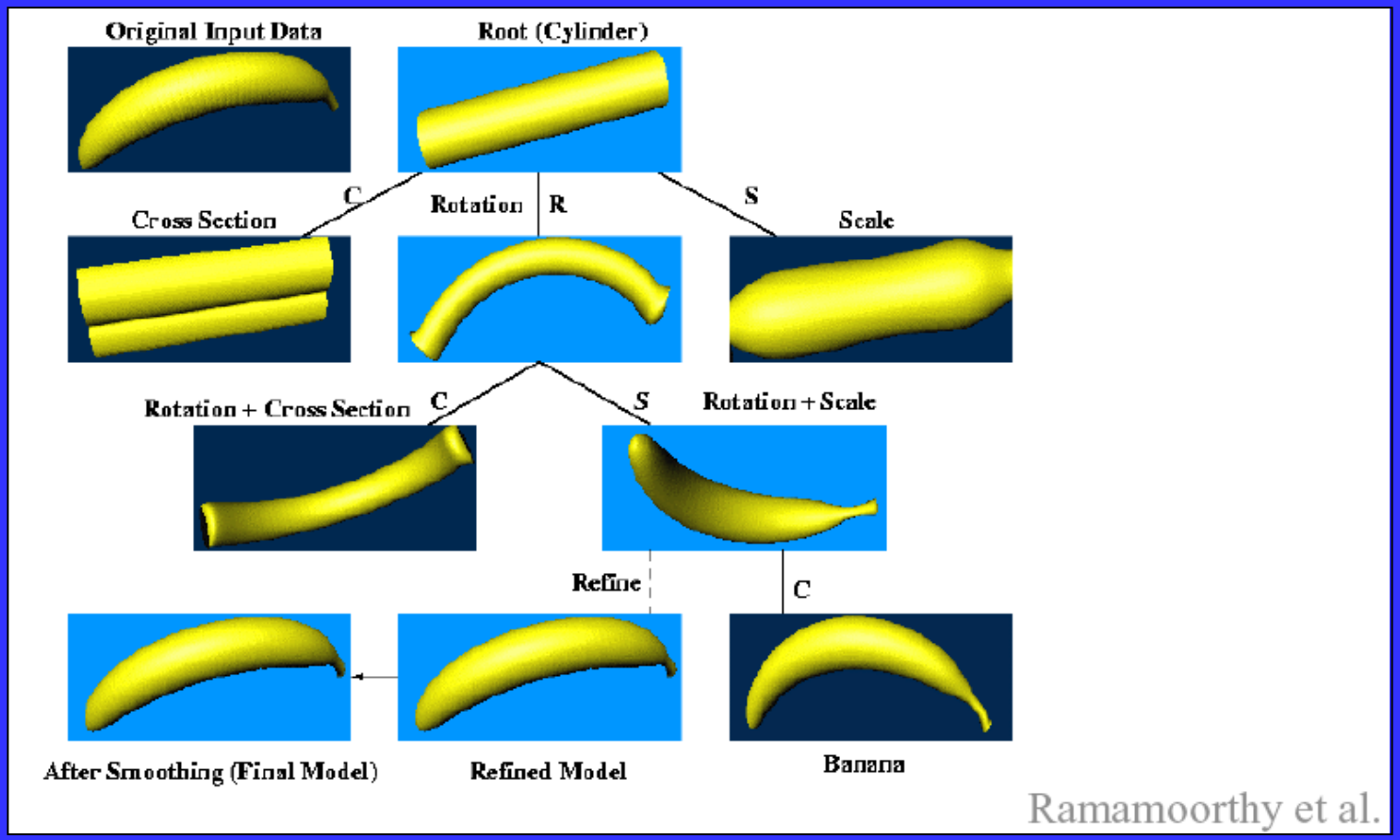
# Constraint Blocks

- Set of simple shapes with geometric constraints / parameters



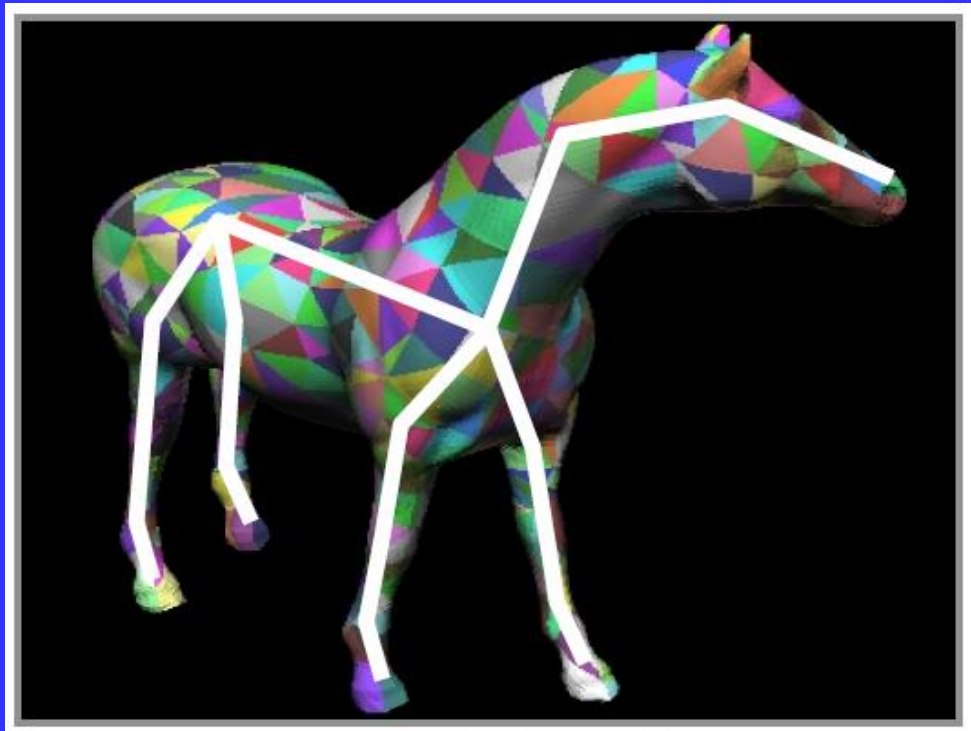
# Generative Model

- Hierarchy of modification operators on a shape



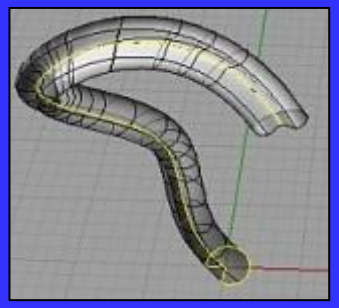
# Skeleton

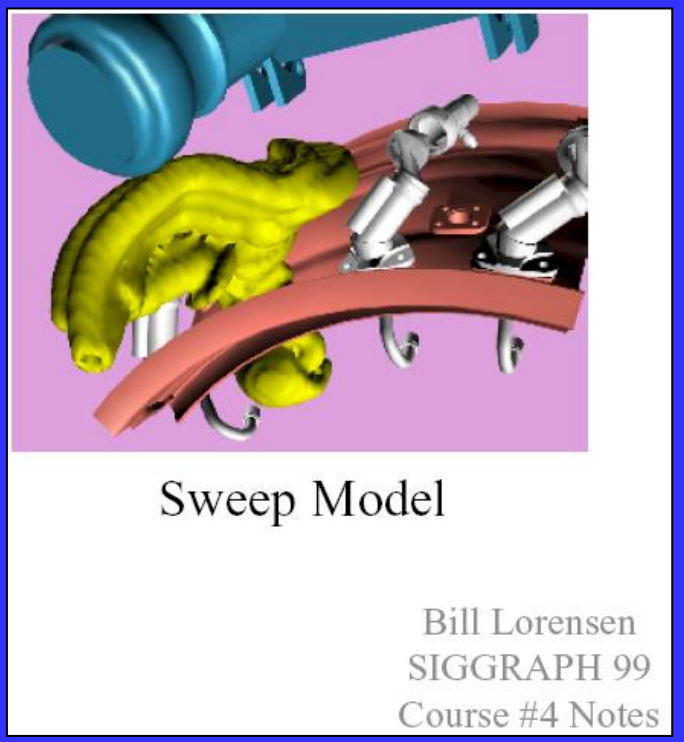
- A set of connected bone structures deforming shape of a 3D model




# Sweep Model

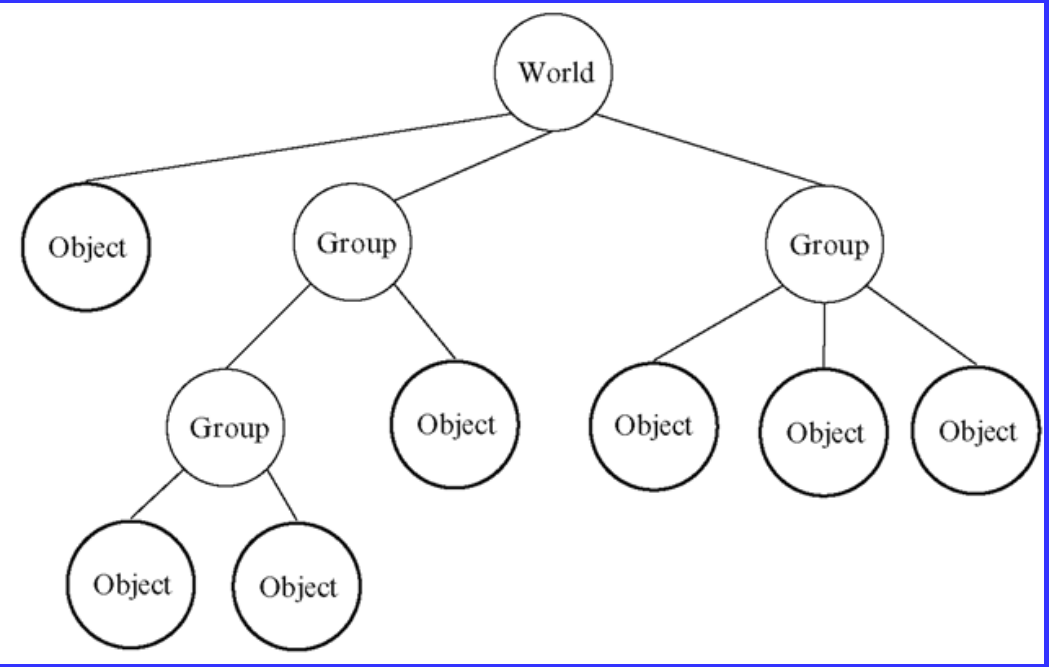
- A 3d model generated by sweeping a surface along a trajectory





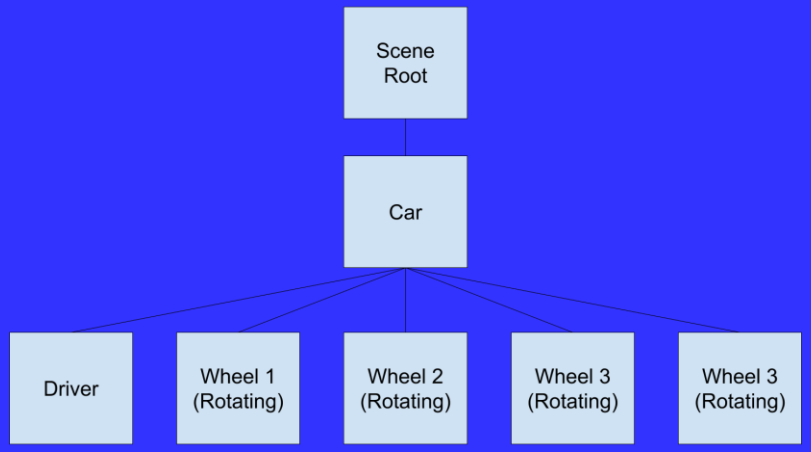
# Scene Graph

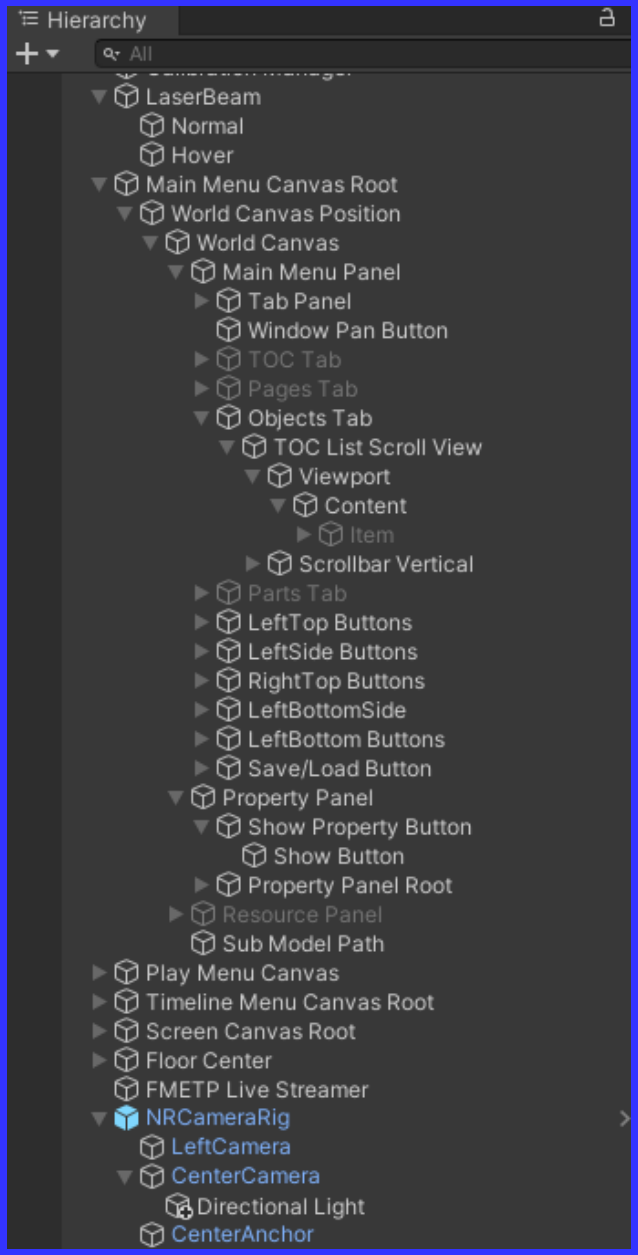
- A general data structure commonly used by computer games
- A scene graph is a tree data structure with nodes and objects usually located at leafs.



# Scene Graph

- Each node contains transformation matrices that define their position in 3D space;
- These transformation matrices are generated using:
  - local position, rotation, and scale values
  - Applying parent transformations one by one, you can reach a world transformation.






# Scene Graph

- A sample Unity scene graph