3D Modeling

Tom Funkhouser
Princeton University
COS 426, Spring 2007

Syllabus

I. Image processing
II. Modeling
III. Rendering
IV. Animation

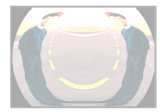
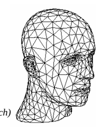


Image Processing
(Rusty Coleman, CS426, Fall99)

Rendering
(Michael Bostock, CS426, Fall99)

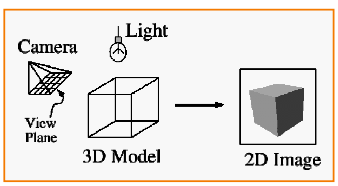


Modeling
(Dennis Zorin, CalTech)

Animation
(Angel, Plate 1)

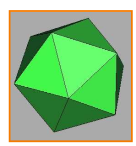
What is 3D Modeling?

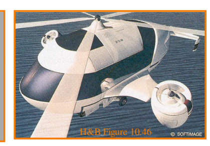
- Topics in computer graphics
  - Imaging = *representing 2D images*
  - Rendering = *constructing 2D images from 3D models*
  - Modeling = *representing 3D objects*
  - Animation = *simulating changes over time*

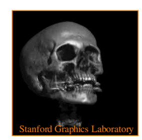


Modeling

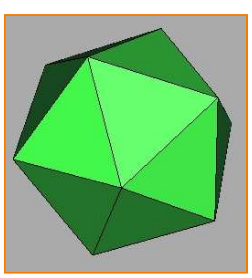
- How do we ...
  - Represent 3D objects in a computer?
  - Acquire computer representations of 3D objects?
  - Manipulate computer representations of 3D objects?





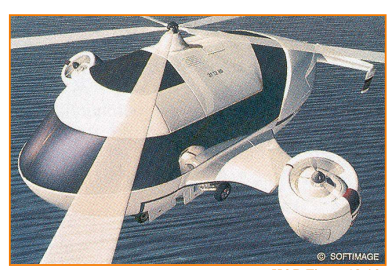


3D Object Representations



How can this object be represented in a computer?

3D Object Representations



H&B Figure 10.46

This one?

3D Object Representations

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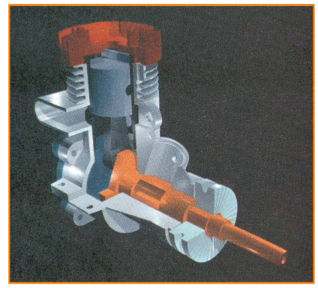
How about this one?

3D Object Representations



H&B Figure 9.9

This one?

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 / programming languages Turing-equivalent, but each does different things better

Naylor

Why Different Representations?

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

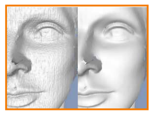
Data structures determine algorithms

Modeling Operations

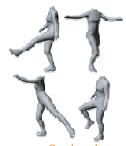
- What can we do with a 3D object representation?
  - Edit
  - Transform
  - Smooth
  - Render
  - Animate
  - Morph
  - Compress
  - Transmit
  - Analyze
  - etc.

Digital Michelangelo

Pirates of the Caribbean



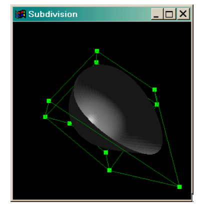
Thouis "Ray" Jones



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
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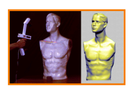
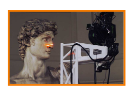
Range Image

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



Cyberware



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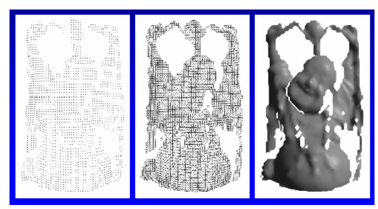


Range Image Tesselation Range Surface

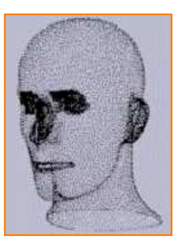
Brian Curless
SIGGRAPH 99
Course #4 Notes

Point Cloud

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

Polhemus

Microscribe-3D



Hoppe

Hoppe

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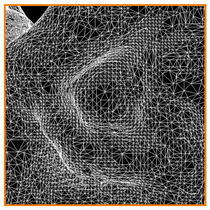
Polygonal Mesh

- Connected set of polygons (usually triangles)



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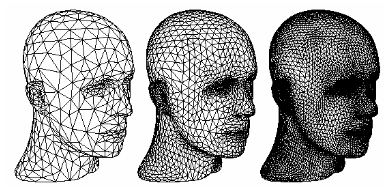
Subdivision Surface

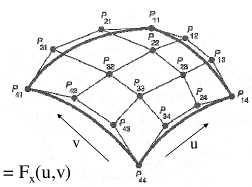
- Coarse mesh & subdivision rule
  - Define smooth surface as limit of sequence of refinements



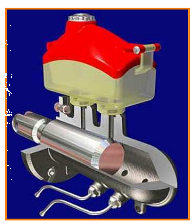
Zorin & Schroeder
SIGGRAPH 99
Course Notes

Parametric Surface

- Tensor product spline patchs
  - 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

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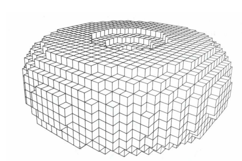
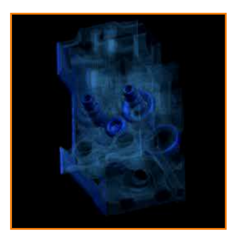
Voxels

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



FvDFH Figure 12.20



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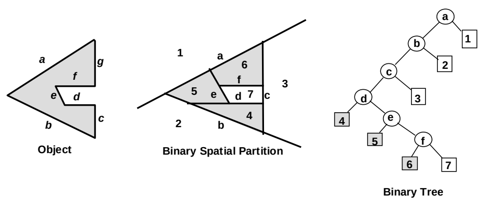
BSP Tree

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



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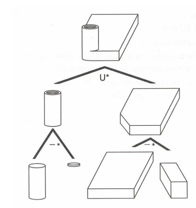
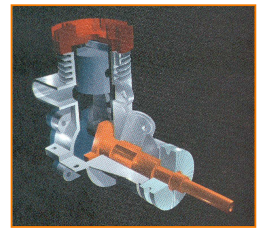
CSG

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



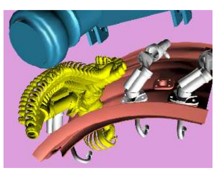
FvDFH Figure 12.27



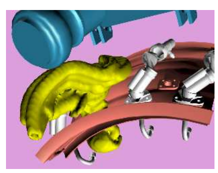
H&B Figure 9.9

Sweep

- Solid swept by curve along trajectory



Removal Path



Sweep Model

Bill Lorensen
SIGGRAPH 99
Course #4 Notes

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Scene Graph

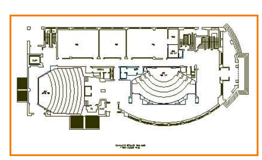
- Union of objects at leaf nodes

Bell Laboratories

avalon.viewpoint.com

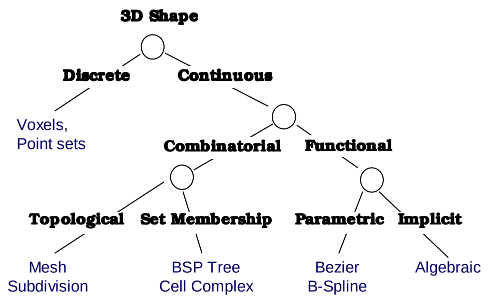
Application Specific

Apo A-1
(Theoretical Biophysics Group, University of Illinois at Urbana-Champaign)



Architectural Floorplan
(CS Building, Princeton University)

Taxonomy of 3D Representations



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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

Upcoming Lectures

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