3D Modeling

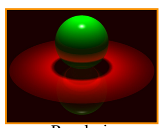
Adam Finkelstein & Tim Weyrich
Princeton University
COS 426, Spring 2008

Announcement - talks of interest

- David Stork: *"When Computers Look at Art: Computer Vision and Image Analysis in Humanistic Studies of the Visual Arts"*
  Tuesday, February 19, 4:30pm
  185 Nassau Street, James Stewart Theater
- Ian Buck *99, nVidia
  Compute Unified Device Architecture (CUDA)
  Friday, February 22, noon (lunch provided)
  Computer Science Dept, room 302

Syllabus

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


Rendering
(Michael Bostock, CS426, Fall99)

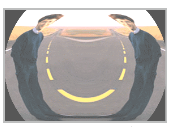
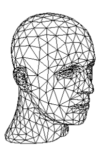
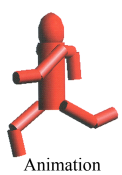


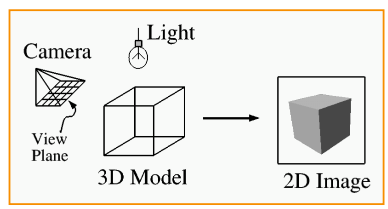
Image Processing
(Rusty Coleman, CS426, Fall99)


Modeling
(Dennis Zorin, CalTech)


Animation
(Angel, Plate 1)

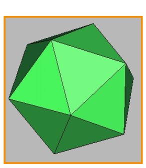
What is 3D Modeling?

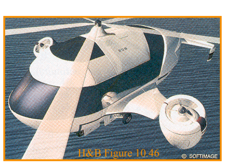
- Topics in computer graphics
  - o Imaging = *representing 2D images*
  - o Rendering = *constructing 2D images from 3D models*
  - o Modeling = *representing 3D objects*
  - o Animation = *simulating changes over time*

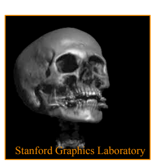


Modeling

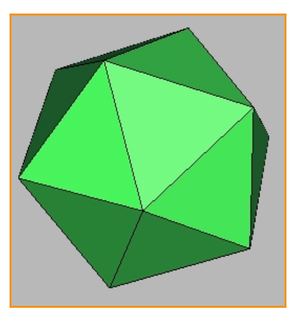
- How do we ...
  - o Represent 3D objects in a computer?
  - o Acquire computer representations of 3D objects?
  - o Manipulate computer representations of 3D objects?





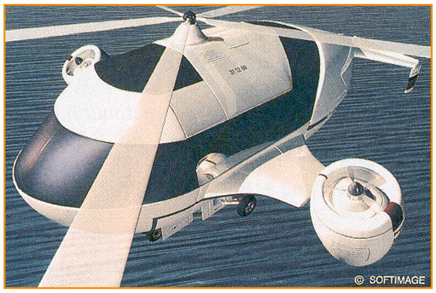


3D Object Representations



How can this object be represented in a computer?

3D Object Representations



H&B Figure 10.46

This one?

7

3D Object Representations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How about this one?

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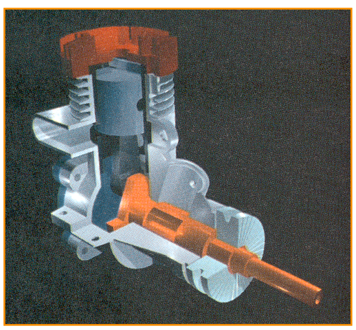
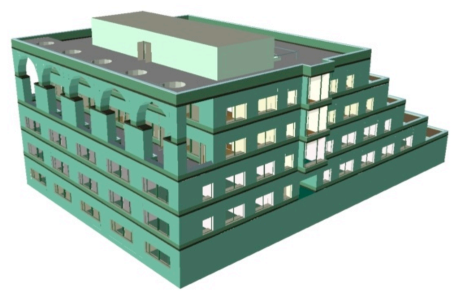
3D Object Representations


H&B Figure 9.9

This one?

9

3D Object Representations



This one?

10

3D Object Representations

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

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Equivalence of Representations

- Thesis:
  - o Each representation has enough expressive power to model the shape of any geometric object
  - o It is possible to perform all geometric operations with any fundamental representation
- Analogous to Turing-equivalence
  - o Computers and programming languages are Turing-equivalent, but each has its benefits…

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Why Different Representations?

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

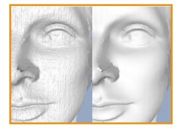
Data structures determine algorithms

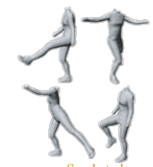
Modeling Operations

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


Digital Michelangelo

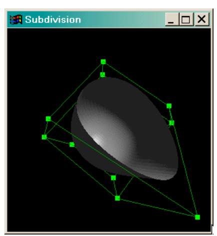

Pirates of the Caribbean


Thouis "Ray" Jones


Sand et al.

3D Object Representations

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



Outline

- Points
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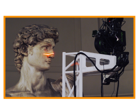
Range Image

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


Cyberware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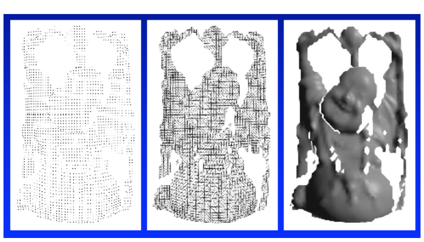

Range Image Tesselation Range Surface

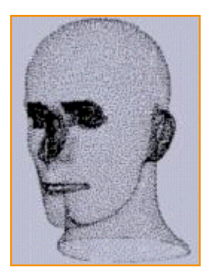
Brian Curless
SIGGRAPH 99
Course #4 Notes

Point Cloud

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


Polhemus


Microscribe-3D


Hoppe


Hoppe

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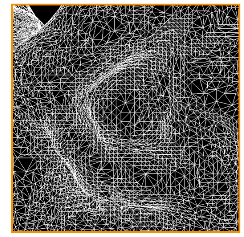
Polygonal Mesh

- Connected set of polygons (usually triangles)

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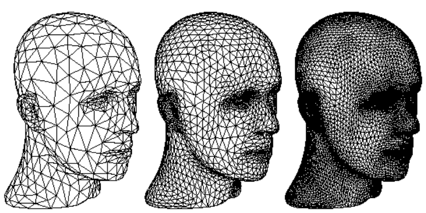
Subdivision Surface

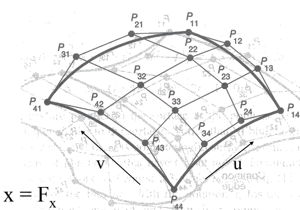
- Coarse mesh & subdivision rule
  - o Define smooth surface as limit of sequence of refinements



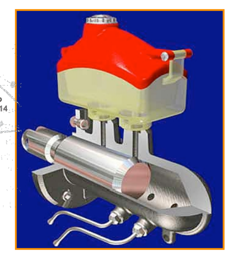
Zorin & Schroeder
SIGGRAPH 99
Course Notes

Parametric Surface

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



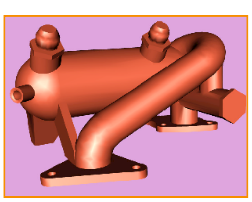
$x = F_x(u,v)$
$y = F_y(u,v)$
$z = F_z(u,v)$



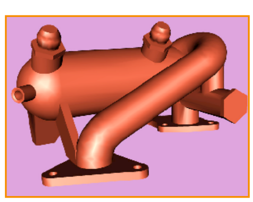
FvDFH Figure 11.44

Implicit Surface

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



Polygonal Model



Implicit Model

Bill Lorensen
SIGGRAPH 99
Course #4 Notes

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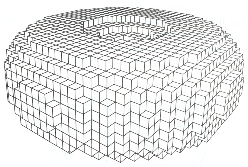
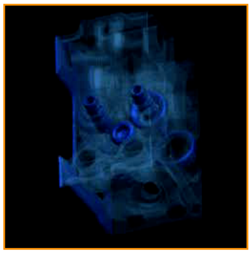
Voxels

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



FvDFH Figure 12.20



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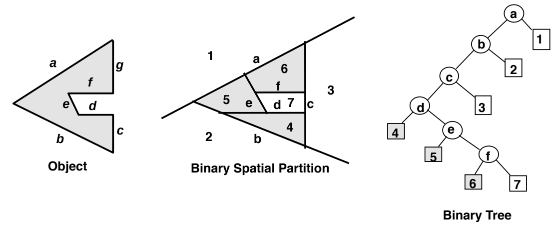
BSP Tree

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



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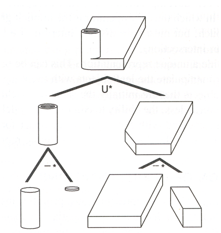
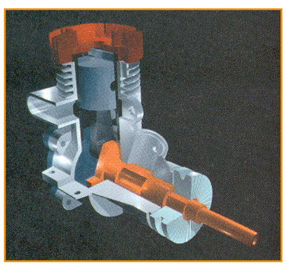
CSG

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



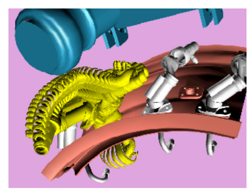
FvDFH Figure 12.27



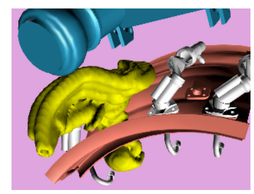
H&B Figure 9.9

Sweep

- Solid swept by curve along trajectory



Removal Path



Sweep Model

Bill Lorensen
SIGGRAPH 99
Course #4 Notes

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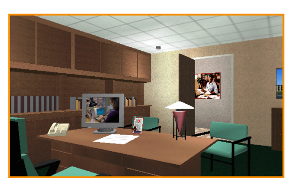
Scene Graph

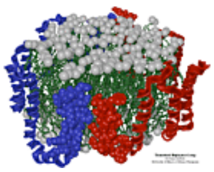
- Union of objects at leaf nodes



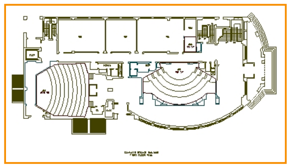
Bell Laboratories

avalon.viewpoint.com

Application Specific

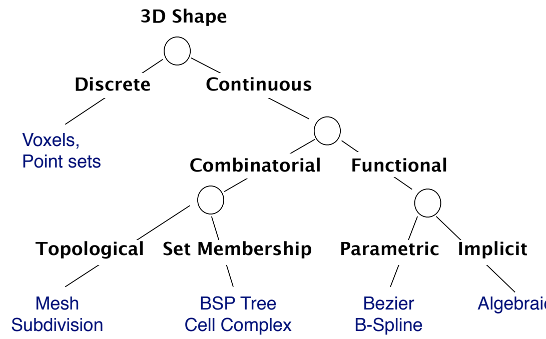


Apo A-1
(Theoretical Biophysics Group, University of Illinois at Urbana-Champaign)



Architectural Floorplan
(CS Building, Princeton University)

Taxonomy of 3D Representations



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Equivalence of Representations

- Thesis:
  - o Each fundamental representation has sufficient expressive power to model the shape of any geometric object.
  - o It is possible to perform all geometric operations with any fundamental representation!
- Analogous to Turing-Equivalence:
  - o All computers today are turing-equivalent, but we still have many different processors

Computational Differences

- Efficiency
  - o Combinatorial complexity (e.g. O(n log n))
  - o Space/time trade-offs (e.g. z-buffer)
  - o Numerical accuracy/stability (degree of polynomial)
- Simplicity
  - o Ease of acquisition
  - o Hardware acceleration
  - o Software creation and maintenance
- Usability
  - o Designer interface vs. computational engine

Upcoming Lectures

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