3D Modeling
Solid Modeling

Shandong University
Spring 2013
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
Solid Modeling

• Represent solid interiors of objects
Motivation 1

• Some acquisition methods generate solids

Airflow Inside a Thunderstorm
(Bob Wilhelmson,
University of Illinois at Urbana-Champaign)

Visible Human
(National Library of Medicine)
Motivation 2

- Some applications require solids
  - Examples: CAD/CAM

Intergraph Corporation
Motivation 3

- Some operations are easier with solids
  - Example: union, difference, intersection
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Voxels

- Regular array of 3D samples (like image)
  - Samples are called voxels ("volume pixels")
Voxels

• Store properties of solid object with each voxel
  – Occupancy
  – Color
  – Density
  – Temperature
  – etc.

Engine Block
Stanford University

Visible Human
(National Library of Medicine)
Voxel Processing

• Signal processing (just like images)
  – Reconstruction
  – Resampling
• Typical operations
  – Blur
  – Edge detect
  – Warp
  – etc.
• Often fully analogous to image processing
Voxel Boolean Operations

- Compare objects voxel by voxel
  - Trivial
Binary Voxel Visualization

- Draw the faces between on and off voxels.
Continuous Voxel Visualization

- Slicing
- Ray-Casting
- Iso-Surface Extraction
Voxel Display

- Slicing
  - Draw 2D image resulting from intersecting voxels with a plane
Voxel Display

• Ray casting
  – Integrate density along rays through pixels
Voxel Display

• Extended ray-casting
  – Complex transfer functions
  – Map voxel densities to materials
Voxel Display

- Iso-Surface Extraction
  - Treat the voxel grid as a regular sampling of some function $F(x,y,z)$, and extract the iso-surface satisfying $F(x,y,z) = \delta$. 

  $F(x,y,z) = \delta_1$

  $F(x,y,z) = \delta_2$
Voxel Display

- **Isosurface rendering**
  - Interpolate samples stored on regular grid
  - Isosurface at $f(x,y,z) = 0$ defines surface
Voxels

• Advantages
  – Simple, intuitive, unambiguous
  – Same complexity for all objects
  – Natural acquisition for some applications
  – Trivial boolean operations

• Disadvantages
  – Approximate
  – Not affine invariant
  – Expensive display
  – Large storage requirements
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BSP Trees

- Binary space partitioning tree
- A method for recursively subdividing a space into convex sets by hyperplanes.
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Constructive Solid Geometry (CSG)

- Represent solid object as hierarchy of boolean operations
  - Union
  - Intersection
  - Difference
CSG Acquisition

• Interactive modeling programs
  – Intuitive way to design objects
CSG Acquisition

- Interactive modeling programs
  - Intuitive way to design objects
• Ray casting
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Sweeps

- Swept volume
  - Sweep one curve along path of another curve
Sweeps

- Surface of revolution
  - Take a curve and rotate it about an axis
Sweeps

• Surface of revolution
  – Take a curve and rotate it about an axis