Review of Basics of 3D Object Representation

Connelly Barnes

CS 6501: Large-scale data-driven graphics and vision

Acknowledgment: slides by Jason Lawrence, Misha Kazhdan, Allison Klein, Tom Funkhouser, Adam Finkelstein and David Dobkin
3D Object Representation

- How do we ...
  - Represent 3D objects in a computer?
  - Construct such representations quickly and/or automatically with a computer?
  - Manipulate 3D objects with a computer?

Different methods for different object representations
3D Objects

How can this object be represented in a computer?
3D Objects

This one?

H&B Figure 10.46
3D Objects

How about this one?

Imaging Economics
3D Objects

This one?

H&B Figure 9.9
3D Objects

This one?
Representations of Geometry

• 3D Representations provide the foundations for
  o Computer Graphics
  o Computer-Aided Geometric Design
  o Visualization
  o Robotics

• They are languages for describing geometry
  data structures      algorithms

• Data structures determine algorithms!
3D Object Representations

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

- **Surfaces**
  - Mesh
  - Parametric
  - Implicit

- **Solids**
  - Voxels

See slides from the graphics class for more!
Point Cloud

• Unstructured set of 3D point samples
  ◦ Acquired from range finder, random sampling, particle system implementations, etc

Hoppe

Czech Academy of Sciences
Point Cloud

- Unstructured set of 3D point samples
  - Acquired from range finder, random sampling, particle system implementations, etc

Can associate colors/normals/etc. to the points

Czech Academy of Sciences
Range Image

- An image storing depth instead of color
  - Acquired from range scanners — e.g. Microsoft Kinect

Range Image  
Tesselation  
Range Surface
Polygon Soup

- Unstructured set of polygons
  - Created with interactive modeling systems, combining range images, etc.
3D Object Representations

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

- Surfaces
  - Mesh
  - Parametric
  - Implicit

- Solids
  - Voxels
Mesh

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

- Tensor product spline patches
  - Careful use of constraints to maintain continuity
Implicit Surface

- Points satisfying: $F(x,y,z) = 0$
3D Object Representations

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

- Surfaces
  - Mesh
  - Subdivision
  - Parametric
  - Implicit

- Solids
  - Voxels
Voxels

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

FvDFH Figure 12.20

Stanford Graphics Laboratory
Equivalence of Representations

• Thesis:
  o Each fundamental 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 All computers today are Turing-equivalent, but we still have many different processors
Computational Differences

• Efficiency
  o Combinatorial complexity
  o Space/time trade-offs
  o Numerical accuracy/stability

• Simplicity
  o Ease of acquisition
  o Hardware acceleration

• Usability