Introduction

Elements of computer graphics:

- **Imaging**: representing 2D images
- **Modeling**: representing 3D objects
- **Rendering**: constructing 2D images from 3D objects
- **Animation**: simulating changes over time
Background

- Image Processing
  - Basic signal processing
  - Filtering, resampling, warping, etc.

- Rendering
  - Polygon rasterization pipeline
  - Ray tracing

- Modeling
  - Basic 3D object representation
  - Polygonal meshes

- Animation
  - Basic principles
Background

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Angel, Plate I
Background

- Linear algebra
- Calculus
- C/C++
- OpenGL
Syllabus

Geometric modeling
- polygonal meshes
- subdivision surfaces
- splines
- volumetric reps
- procedural techniques

Image-based modeling and rendering
- plenoptic function
- light fields
- view-dependent texture mapping

Global illumination
- lighting models
- simulating light transport
- visibility

Animation
- kinematics
- passive dynamics
- active dynamics
Syllabus

- Geometric modeling
  - polygonal meshes
  - subdivision surfaces
  - splines
  - volumetric representations
  - procedural techniques

Hoppe
Syllabus

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Zorin & Shroeder
Syllabus

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FvDFH Figure 11.43
Syllabus

- Geometric modeling
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Turk
Syllabus

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Fowler et al.
Syllabus

- Global illumination
  - lighting models
  - simulating light transport
  - visibility

Greenberg et al.
Syllabus

- Global illumination
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Syllabus

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Drettakis
Syllabus

- Image-based modeling and rendering
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Syllabus

- Animation
  - kinematics
  - passive dynamics
  - active dynamics

Gleicher et al.
Syllabus

- Animation
  - kinematics
  - passive dynamics
  - active dynamics

Losasso et al.
Syllabus

- Animation
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Losasso et al.
Syllabus

- Animation
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Gleicher et al.

Hodgins et al.
Course Mechanics

- Three written assignments (25% of your grade)
  - Triangle meshes (due 01/29)
  - Splines (due 02/21)
  - Light transport (due 03/27)

- Three programming assignments (40% of your grade)
  - Progressive meshes (due 02/12)
  - Procedural seashells (due 03/13)
  - View-dependent texture mapping (due 04/15)

- Final project (35% of your grade)
  - Proposals due (Tuesday, April 15)
  - In-class presentations + report due (Tuesday, May 6)
3D Modeling: Which Object Representation?
What’s the difference?

Represent different kinds of information
- point data
- surface data
- volumetric data
- higher-level structure
What’s the difference?

- **Efficiency for different tasks**
  - rendering (e.g., with hardware acceleration)
  - manipulation (simplification, compression, etc.)
  - acquisition
  - similarity comparisons, indexing, search

- **Other metrics**
  - compactness of representation
  - user control for creation or editing
  - simplicity
Equivalence

- 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 are Turing-equivalent, but each does different things better.

- Data structures determine algorithms!!
3D Object Representations

- **Point data**
  - point cloud
  - range image

- **Surface data**
  - polygon soup
  - mesh
  - subdivision
  - parametric

- **Volumetric data**
  - implicit functions
  - voxel grids
  - BSP tree
  - CSG

- **High-level structures**
  - scene graph
  - skeleton
  - application specific
Point Cloud

- Unstructured samples
- Advantage: simplicity
- Disadvantage: no information on adjacency / connectivity

Hoppe
Range Image

- Image: stores an intensity / color along each of a set of regularly-spaced rays in space
- Range image: stores a depth along each of a set of regularly-spaced rays in space
- Advantages:
  - uniform (?) parameterization
  - adjacency / connectivity information
Range Image

- Not a complete 3D description: does not include part of object occluded from viewpoint

Range Image  |  Tessellation  |  Range Surface
Range Image

- Adjacency in range image \(\neq\) adjacency on surface
Range Image

- Adjacency in range image ≠ adjacency on surface

- Avoid connecting across these discontinuities
  - Common heuristic: depth threshold
Range Image Terminology

- Range images
- Range surfaces
- Depth images
- Depth maps
- Height fields
- 2.5-D images
- Surface profiles
- xyz maps
- ...
Polygon “Soup”

- Unstructured set of polygons
- Often the output of interactive modeling systems
Mesh

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

- Coarse mesh + subdivision rule
- Smooth surface is limit of refinements

Zorin & Schroeder
Parametric Surface

- Tensor product spline patches
- Careful constraints to maintain continuity
Implicit Surfaces

Points satisfying: $F(x,y,z)=0$
Why Implicit Surfaces?

Function usually sampled regularly (voxel grid)

Advantages:
- Can guarantee that model is hole-free
- Easy to change topology

Disadvantages:
- Algorithms must traverse volume: slow
- More space than parametric representation
Voxels

- Uniform grid of occupancy, density, etc.
- Often acquired from CAT, MRI, etc.
BSP Tree

- Binary Space Partition with solid cells labeled
- Constructed from polygonal representations
- Other hierarchical data structures: k-d trees, octrees, ...

Object

Binary Space Partition

Tree

Naylor
Constructive Solid Geometry

Hierarchy of boolean operations (union, difference, intersect) applied to simple shapes
Scene Graph

Union of objects at leaf nodes

Bell Laboratories

avalon.viewpoint.com
Skeleton

- Graph of curves with radii

Stanford Graphics Laboratory
Application-Specific Models

- Domain-specific information + geometry

Apo A-1
(Theoretical Biophysics Group,
University of Illinois at Urbana-Champaign)
3D Objects

How would you represent this object in a computer?
3D Objects

What about this one?
3D Objects

What about this one?
3D Objects

What about this one?
3D Objects

What about this one?

H&B Figure 9.9
3D Objects

What about this one?
Complexity vs. Verbosity

Verbosity / Inaccuracy

- Pixels/ Voxels
- Piecewise linear polyhedra
- Low degree piecewise non-linear
- Single general functions

Complexity / Accuracy
Getting your $’s worth

- This is an **advanced** course
- Do all the reading prior to class
- Seek out answers on your own
- Participate in class
- Visit my office hours (W 1-5)
- Enthusiasm!!