Modeling

CMSC 435/634
Modeling?

Modeling
Creating a *model* of an object, usually out of a collection of simpler *primitives*.

Primitive
A basic shape handled directly the rendering system.
Primitives

Some common primitives

- Triangles & Polygons
  - Most common, usually the only choice for interactive
- Patches, Spheres, Cylinders, ...
  - RenderMan has these
  - Often converted to simpler primitives within the renderer
- Volumes
  - What’s at each point in space?
  - Often with some transparent material
  - Few renderers handle both volume & surface models
Composing primitives

- Collections of large numbers of primitives
  - Sometimes called Boundary Representation (BRep)
- Constructive Solid Geometry (CSG)
  - Set operations (union, intersection, difference)
- Implicit Models & Blobs
  - Surface where \( f(x,y,z) = 0 \)
  - Sum, product, etc. of simpler functions
Composing primitives

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Images: Friedrich Lohmueller
Composing primitives

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Images: Paul Bourke
Modeling Approaches

- Manual primitive creation
- Procedural
- Scan from physical object
- From data (visualization)
- Through image capture (image-based rendering)
Modeling Approaches

Manual primitive creation

Procedural

Scan from physical object

From data (visualization)

Through image capture (image-based rendering)
Manual Creation

- Text editor
- High-level primitives
- Modeling programs
Modeling Approaches

Manual primitive creation

Procedural
- Fractals
- Implicit Functions
- Grammars
- Simulations

Scan from physical object

From data (visualization)

Through image capture (image-based rendering)
Procedural Modeling

- Describe physical attributes through some (spatial) function
  - Shape
  - Density
  - Color
  - Texture
Procedural Approaches

- Fractals
- Implicit Functions
- Grammars
- Simulations
Fractals

Complex structure through self-similarity across scales

- Iterated equations
- Iterated replacement
- Spectral Synthesis
Iterated Equations / Mandelbrot Set

\[ p' = p^2 + c \]

Image: David E. Joyce
Iterated Replacement / Koch Curve
Iterated Replacement / Mountains

Randomness in replacement
Spectral Synthesis

- Spectral energy a function of frequency
  - Higher frequency, less energy
  - Characterizes roughness of surface
  - Natural phenomena tend to be $1/f$
Noise-Based Synthesis

- Band-limited *Perlin noise* function
  - Most energy between 1/2 and 1 cycle per unit
  - Average value is 0
  - Random, but repeatable
  - 1D, 2D, 3D & 4D versions common

- Sum noise *octaves*
  - \( n(x) + \frac{1}{2} n(2 \times x) + \frac{1}{4} n(4 \times x) + ... \)
  - Stop adding “...” when frequency is too high to see
Fractal Landscape

Landscape height is a fractal function of $x,y$

- Plus whatever embellishments make it look good

Image: Ken Musgrave
Multifractal

- Change roughness across fractal
  - Scaling ($\frac{1}{2}$, $\frac{1}{4}$, ...) becomes a function
- Here, scale is a function of altitude

Image: Ken Musgrave
Implicit Functions

- Model as sum of implicit functions
- Surface at threshold

Liang, et al., PG'01
Hybrid Implicit & Polygonal

Bloomenthal, SIGGRAPH 85
Hypertexture

- Add noise or turbulence to functions

Perlin & Hoffert, SIGGRAPH 89
Grammar-Based Modeling

- Use (mostly) context-free grammars (CFG) to specify structural change over generations
- Often used to simulate a biological growth process
  - Plants
  - Seashells
- L-systems (Lindenmeyer)
Context-Free Grammar

- A CFG $G = (V, T, S, P)$ where
  - $V$ is a set of non-terminals
  - $T$ is a set of terminals
  - $S$ is the start symbol
  - $P$ is a set of productions (rules) of the form:
    - $A \rightarrow x$, where $A \in V$, $x \in (V \cup T)^*$
Applying Grammar Rules

- **Symbols**
  - $A, B$, straight line segments
  - $[ ]$, branch left $90^\circ$

- **Rules**
  - $B \rightarrow A[B]AA[B]$
  - $A \rightarrow AA$

- **Strings**
  - $B$
Applying Grammar Rules

- **Symbols**
  - $A, B$, straight line segments
  - $[ ]$, branch left $45^\circ$
  - $( )$, branch right $45^\circ$

- **Rules**
  - $B \rightarrow A[B]AA(B)$
  - $A \rightarrow AA$

- **Strings**
  - $B$
  - $A[B]AA(B)$
L-System Examples

- **Symbols**
  - 
  - 
  - 
  - 

- **Rules**
  - 
  - 
  - 
  - 

- **25.7°, 7 generations**

- **X → F[+X][−X]FX**

- **F → FF**
L-System Examples

- Rules
  - 22.5°, 5 generations
  - $F \rightarrow FF$
L-System Examples

- Rules
  - 22.5°, 4 generations
  - $F \rightarrow FF - [F + F + F] + [+F - F - F]$
Additions

- 3D structure
- Randomness
- Leaves
- Flowers

Prusinkiewicz, et al., SIGGRAPH 88
Pruning

Prusinkiewicz, et al., SIGGRAPH 94
Pruning

Prusinkiewicz, et al., SIGGRAPH 94
Simulations

- Biological
  - Simulate growth, development

- Physical
  - Simulate formation or erosion
Biological Simulations

Fowler, et al., SIGGRAPH 92

Fleischer, et al., SIGGRAPH 95
Biological Simulations

Fowler, et al., SIGGRAPH 92
Biological Simulations

Turk, SIGGRAPH 91
Physical Simulation

- Erosion, Deposition

Kenji Nagashima, Visual Computer 1997
Modeling Approaches

Manual primitive creation

Procedural

Scan from physical object

From data (visualization)

Through image capture (image-based rendering)
Scan from Objects

- General concept
  - Find points on surface
  - Connect into mesh

- Mechanical

- Triangulation
  - Laser
  - Structured Light
  - Multiple Cameras

- CAT scan / MRI
Mechanical

- Touch tip to surface
- Measure angles
Triangulation

- Point in space at intersection of ray from A and ray from B
Structured Light

- Point in space at intersection of color edge from light source/projector and ray through camera pixel

Zhang, Curless and Seitz, 3DPVT 2002
Modeling Approaches

Manual primitive creation

Procedural

Scan from physical object

From data (visualization)

Through image capture (image-based rendering)
Visualization

- Data
  - measurements
  - simulation
  - information

- Present visually
  - Increase understanding
  - Recognize patterns
Visualization

- Can be 3D Object
Visualization

- Can be 3D, but showing non-visual aspects.
Visualization

- Can be not traditionally geometric at all
Modeling Approaches

Manual primitive creation

Procedural

Scan from physical object

From data (visualization)

Through image capture (image-based rendering)
Image-based Rendering

- Pixels in one or more cameras
  - Color of point in space
  - Color of light along one ray
- IBR
  - Construct new *novel* view using only image data