Announcements

Programming Assignment 4 is out
No Class Thursday
(Office Hrs On Request)
Procedural Modeling

Procedural Terrain
L-Systems
Procedural Animation/Behavior

COMPUTER GRAPHICS
15-462
Database Amplification

• Procedural content generation is attractive because it allows for significant database amplification
• Limited input data produces rich & varied output
  – i.e.: Perlin noise function + basic math gives fire, clouds, wood, etc.
• If it can be generated on the fly…
  – Artist doesn’t have to design it
  – Don’t need to store/transmit it
“Implicit” vs. “Explicit” Procedural Models

• Explicit:
  – Directly generate the points that make up an object
  – Good for Z-buffer/OpenGL style rendering

• Implicit:
  – Answer questions about particular points
  – Isocurve (2D) or Isosurface (3D)
  – Good for ray-tracing
Simple Explicit Procedural Model

- Begin with a regular mesh
- Perturb vertex geometry procedurally (typically pseudorandomly)
- Iterate this process until desired shape is achieved
- Very general technique that can also be used to add irregularity ("noise") to arbitrary mesh objects
Procedural Terrain

- “Subdivide and displace”
Midpoint Displacement For Terrain

- Seed corners with values
- Perturb midpoint randomly from mean
- Recurse using a smaller window
- In 2D, best to use “diamond-square” recursion (to prevent axis-aligned artifacts)
Fractal Noise Terrain

• Use fractal noise to generate terrain
• Can be made tileable over unit square:

\[ F_{tileable}(x,y) = [ \]
\[ F(x,y) \times (1-x) \times (1-y) + \]
\[ F(x-1,y) \times x \times (1-y) + \]
\[ F(x-1,y-1) \times x \times y + \]
\[ F(x,y-1) \times (1-x) \times y ] \]

F.K. Musgrave
Adding Water

- Use an elevation threshold ($z < z_{\text{water}}$)
Terrain Example

F.K. Musgrave
Terrain Example
Terragen

- Commercial product (free for personal use)
- Website: http://www.planetside.co.uk/terragen/
- This image took ~3 minutes to set up
Hypertexture

- Implicit procedural model
- Treat the isosurface of a function as the boundary of an object
- Above: fractal egg

Photo: K. Perlin
Hypertexture Example

K. Perlin
Hypertexture Example

K. Perlin
Architexture

- Sweep the path of a line drawing with a sphere
- Apply hypertexture to resulting shape
L-Systems (Background)

- Developed by A. Lindenmayer to model the development of plants
- Based on parallel string-rewriting rules
- Excellent for modeling organic objects and fractals
L-Systems (Basics)

• Begin with a set of “productions” (replacement rules) and a “seed” axiom
• In parallel, all matching productions are replaced with their right-hand sides
• Ex:
  – Rules: B->ACA
    A->B
  – Axiom: AA
  – Sequence: AA, BB, ACAACA, BCBBCB, etc.
• Strings are converted to graphic representations via interpretation as turtle graphics commands
L-Systems (Basic Example)

• Turtle Commands:
  – $F_x$: move forward one step, drawing a line
  – $f_x$: move forward one step, without drawing a line
  – $+x$: turn left by angle $\partial$
  – $-x$: turn right by angle $\partial$
L-Systems (Koch Snowflake)

- Axiom: F-F-F-F \( \partial \): 90 degrees
- \( F \rightarrow F-F+F+FF-F-F+F \)
L-Systems (Dragon Curve)

- Axiom: $F_l$  $\partial$: 90 degrees  $n$: 10 iterations
- $F_l \rightarrow F_l + F_r +$
- $F_r \rightarrow F_l - F_r -$
L-Systems (Extensions)

• Basic L-Systems have inspired a large number of variations
• Context sensitive: productions look at neighboring symbols
• Bracketed: save/restore state (for branches)
• Stochastic: choose one of n matching productions randomly
• Parametric: variables can be passed between productions
L-Systems For Plants

- L-Systems can capture a large array of plant species
- Designing rules for a specific species can be challenging
Algorithmic Botany

- [http://algorithmicbotany.org/papers/](http://algorithmicbotany.org/papers/)
- Free 200pg ebook
- Covers many variants of L-Systems, formal derivations, and exhaustive coverage of different plant types
Interactive Design With PovTree

• http://propro.ru/go/Wshop/povtree/povtree.html
• http://arbaro.sourceforge.net/
• Fast procedural foliage is important for real-time applications

http://www.speedtree.com/
L-Systems for Cities [Parish01]

- Start with a single street
- Branch & extend w/ parametric L-System
- Parameters of the string are tweaked by goals/constraints
- Goals control street direction, spacing
- Constraints allow for parks, bridges, road loops
• Once we have streets, we can form buildings with another L-System
• Building shapes are represented as CSG operations on simple shapes
Procedural Hair [Chang02]

• Generate a model with a few hundred guide hairs
• Each hair is a rigid chain w/ revolute joints
• Use breakable springs between nearby hairs to simulate hairstyles
• Create triangle strips between adjacent hairs to simulate collisions
• Interpolate between guide hairs to produce many other hairs
Procedural Hair (Examples)

Short Hair in Wind with Artistic Rendering
UIUC
MojoWorld

• Commercial application for creating photorealistic procedural planets
Procedural Planets

E. DeGuili
Texturing and Modeling: A Procedural Approach

- D.S. Ebert et al
- 3rd Ed, 2003
- Excellent reference

- http://www.mkp.com/tm3
- http://www.texturingandmodeling.com/
Procedural Animation

- Particle Systems
- Ragdoll Physics
- Fluid simulation
- Flocking/crowd simulations
Procedural Flocking (Boids)

- Simulate the movement of a flock of birds in 3-space
- Separation: move to avoid crowding local neighbors
- Alignment: steer towards average heading of neighbors
- Cohesion: steer towards average position of neighbors
- Limited Senses: only neighbors in forward-facing arc are observable
Boids Example

- Open example
Flow-Based Video Synthesis And Editing [Bhat04]

• Allows animator to easily create loops and variants of flowing natural phenomena (water, smoke, etc)
• Artist draws a set of flow lines on the original image
• Algorithm computes textures for a particle system that uses these flow lines
• Sequence of textures is transformed to prevent linear discontinuities
• Artist can then draw additional flow lines to create new variants
Flow-Based Synthesis (Example)

Input (looped)  Synthesized Result
Flow-Based Synthesis (Example)

Input (looped)  Edit
Procedural Content: Games

• Reduces cost of art assets
  – Current AAA title costs upwards of $10M
• Reduces download/storage size
• Reduces memory throughput to GPU
• Provides enhanced replayability
Games: Rogue-like

• All level layouts are procedurally generated
• Inspired games like Diablo, .hack, etc.
Games: .kkrieger

- Demoscene FPS game
- Total file size: 97,280 bytes
Games: Spore

- Multiple sub-games of creature/civilization gameplay
- Editors for creatures, buildings, vehicles
- Procedural behavior, animation, and texturing (driven by player-created models)
Spore E3 2006 Video

• Show video
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