Procedural Modeling

Last Time?
- Modern Graphics Hardware
- Cg Programming Language
- Gouraud Shading vs. Phong Normal Interpolation
- Bump, Displacement, & Environment Mapping

Reading for Today
- Chris Wyman, "An Approximate Image-Space Approach for Interactive Refraction”, SIGGRAPH 2005
Today

- Texture Mapping
- Common Texture Coordinate Mappings
- Solid Texture
- Procedural Textures
- Perlin Noise
- Procedural Modeling
- L-Systems

Texture Mapping

For each triangle in the model establish a corresponding region in the phototexture

During rasterization interpolate the coordinate indices into the texture map

Texture Mapping Difficulties

- Tedious to specify texture coordinates
- Acquiring textures is surprisingly difficult
  - Photographs have projective distortions
  - Variations in reflectance and illumination
  - Tiling problems

Can’t do this!

Common Texture Coordinate Mappings

- Orthogonal
- Cylindrical
- Spherical
- Perspective Projection
- Texture Chart
Projective Textures

- Use the texture like a slide projector
- No need to specify texture coordinates explicitly

Projective Texture Example

- Modeling from photographs
- Using input photos as textures

Texture Chart

- Pack triangles into a single image

Questions?
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Texture Map vs. Solid Texture

“Solid Texturing of Complex Surfaces”, Peachey, SIGGRAPH 1985

Procedural Textures

\[ f(x, y, z) \rightarrow \text{color} \]

Image by Turner Whitted

Procedural Textures

- Advantages:
  - easy to implement in ray tracer
  - more compact than texture maps (especially for solid textures)
  - infinite resolution

- Disadvantages
  - non-intuitive
  - difficult to match existing texture
Readings for Tuesday:

• Ken Perlin, “An Image Synthesizer”, SIGGRAPH 1985
  & “Improving Noise”, SIGGRAPH 2002

Perlin Noise

• Properties:
  – Looks “random”, but is deterministic (always returns the same answer for a specific coordinate)
  – Small memory footprint & fast to compute
  – Known amplitude & frequency
  – Smooth interpolation when zoomed in

• Can be combined/layered:
  – Add multiple noise functions w/ different frequencies and amplitudes
  – Simple arithmetic operations (thresholding, sine waves, etc.)

“Shade Trees”, Cook, SIGGRAPH 1984

• Grey: Delauney Triangulation
  – “Best” triangulation of the red dots (most equilateral)
  – A specific triangle is in the Delauney Triangle if and only if the circle defined by those 3 points does not contain any other red dot
  – Note: Well defined when points are random. If points are on a uniform grid, we have ties...

• Black: Voronoi Diagram
  – Each cell is the set of all points in the plane that claim that cell’s red dot as the closest
  – Note: The black & grey edges are perpendicular bisectors
Voronoi Diagram/Cells/Regions

- How to re-district the Netherlands into provinces so that everyone reports to the closest capital
- Cell edges are the perpendicular bisectors of nearby points
- 2D or 3D
- Supports efficient Nearest Neighbor queries

http://ccc.inaoep.mx/~rodrigo/robotica/Trigui.pdf

“Optimally” site the next Starbucks

http://findbyclick.com/coffee_s.html

Cellular Textures

www.worley.com
Procedural Displacement Mapping

Image by Justin Legakis

Ken Musgrave
www.kenmusgrave.com

Procedural Textures

Prusinkiewicz & Lindenmayer,
The Algorithmic Beauty of Plants, 1990
http://algorithmicbotany.org/

Procedural Modeling

L-Systems

alphabet: \{a,b\}
initiator: a
production rules:
a -> b
b -> ba

generations:
a
b
ba
bab
babba
babbabab
babbabababab
babbabababababab

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Questions?

Today

• Texture Mapping
• Common Texture Coordinate Mappings
• Solid Texture
• Procedural Textures
• Perlin Noise
• Procedural Modeling
• L-Systems
L-Systems

Animation of Plant Development
Prusinkiewicz et al., SIGGRAPH 1993

http://algorithmicbotany.org/

“Synthetic Topiary”, Prusinkiewicz, James, and Mech, SIGGRAPH 1994

Cellular Texturing for Architecture

“Feature-Based Cellular Texturing for Architectural Models”, Legakis, Dorsey, & Gortler, SIGGRAPH 2001

Procedural Modeling Advantages

- Small representation
- Generate detail as needed (“infinite”? resolution)
- Great for natural mathematical patterns and manmade engineering and design
- Trivial to make many duplicate objects with small variations
L-Systems for Cities

“Procedural Modeling of Cities”, Parish & Müller, SIGGRAPH 2001

Procedural Modeling of Buildings


Applications

• Entertainment – Gaming
• Education – Studying botanical variation
• Archeological reconstruction
• Realism for Training
• Predicting the future (how will things grow over time)
• Urban planning (preparing for traffic)
• Accommodate for that growth/change

Image-based Procedural Modeling of Facades

• Mueller, Zeng, Wonka, & Van Gool, SIGGRAPH 2007
Questions about Procedural Modeling

• Number of rules necessary?
• Cost in human designer time of creating procedural model?
• Re-useability of procedural model?
• Validation
• Can you build a procedural model that produces a specific target?
  – *From a photo of a specific rare wood grain, can you create a procedural model that creates texture that looks like it came from a different location of the same/similar tree?*